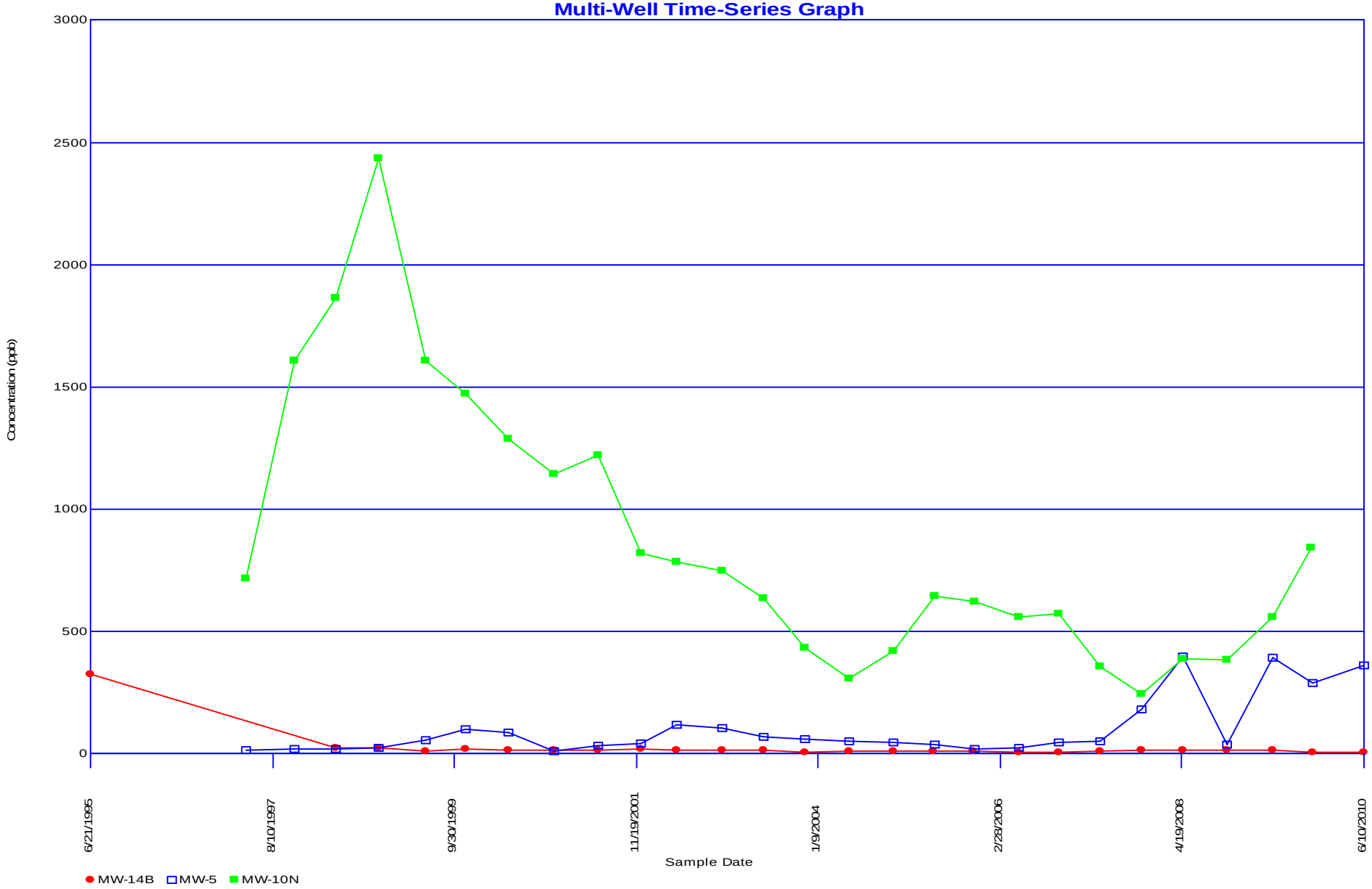
Appendix C

Time/Concentration Graphs

Central Sanitary Landfill

Total VOCs

Multi-Well Time-Series Graph



Central Sanitary Landfill

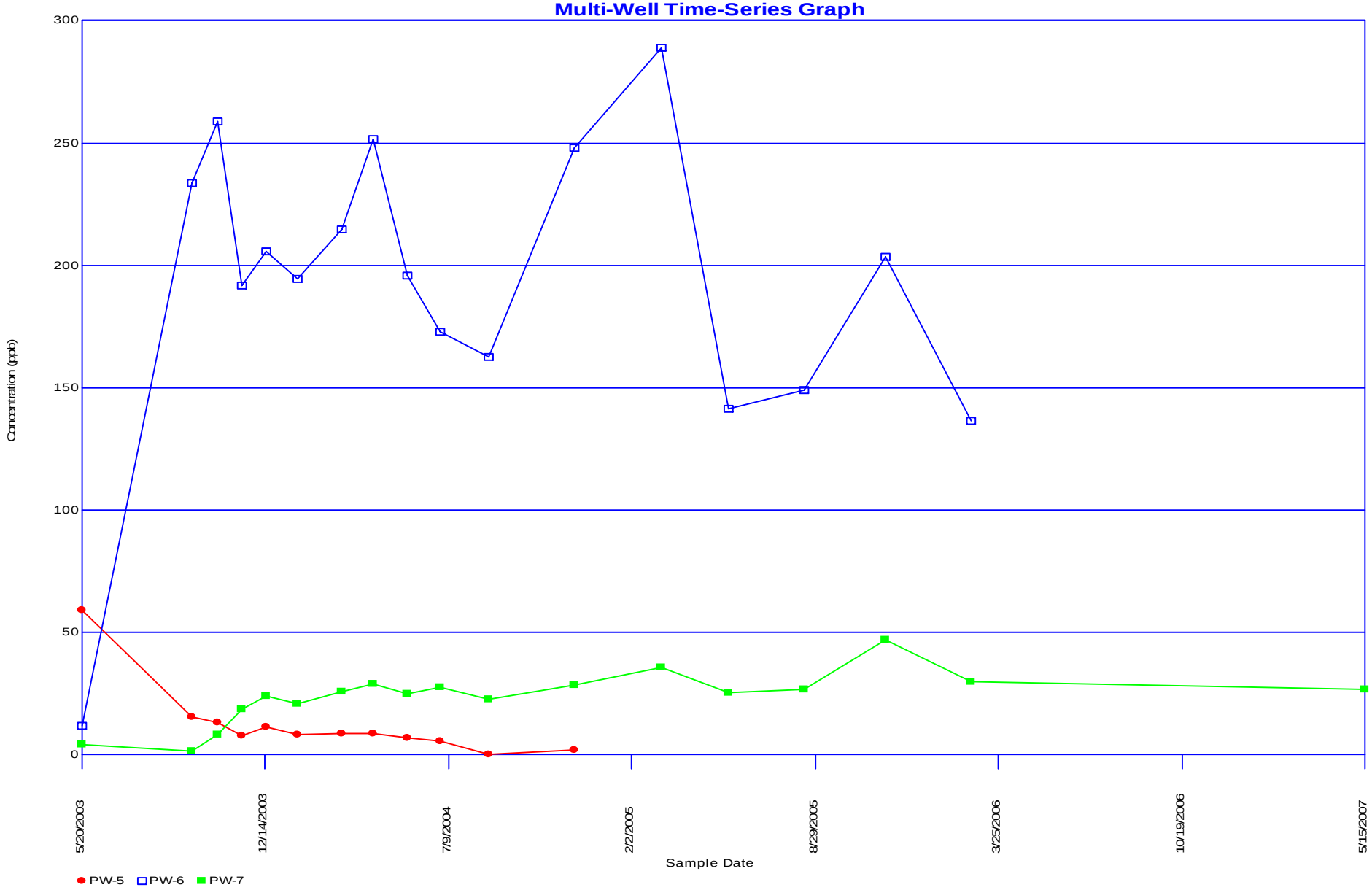
Total VOCs

Multi-Well Time-Series Graph

Central Sanitary Landfill

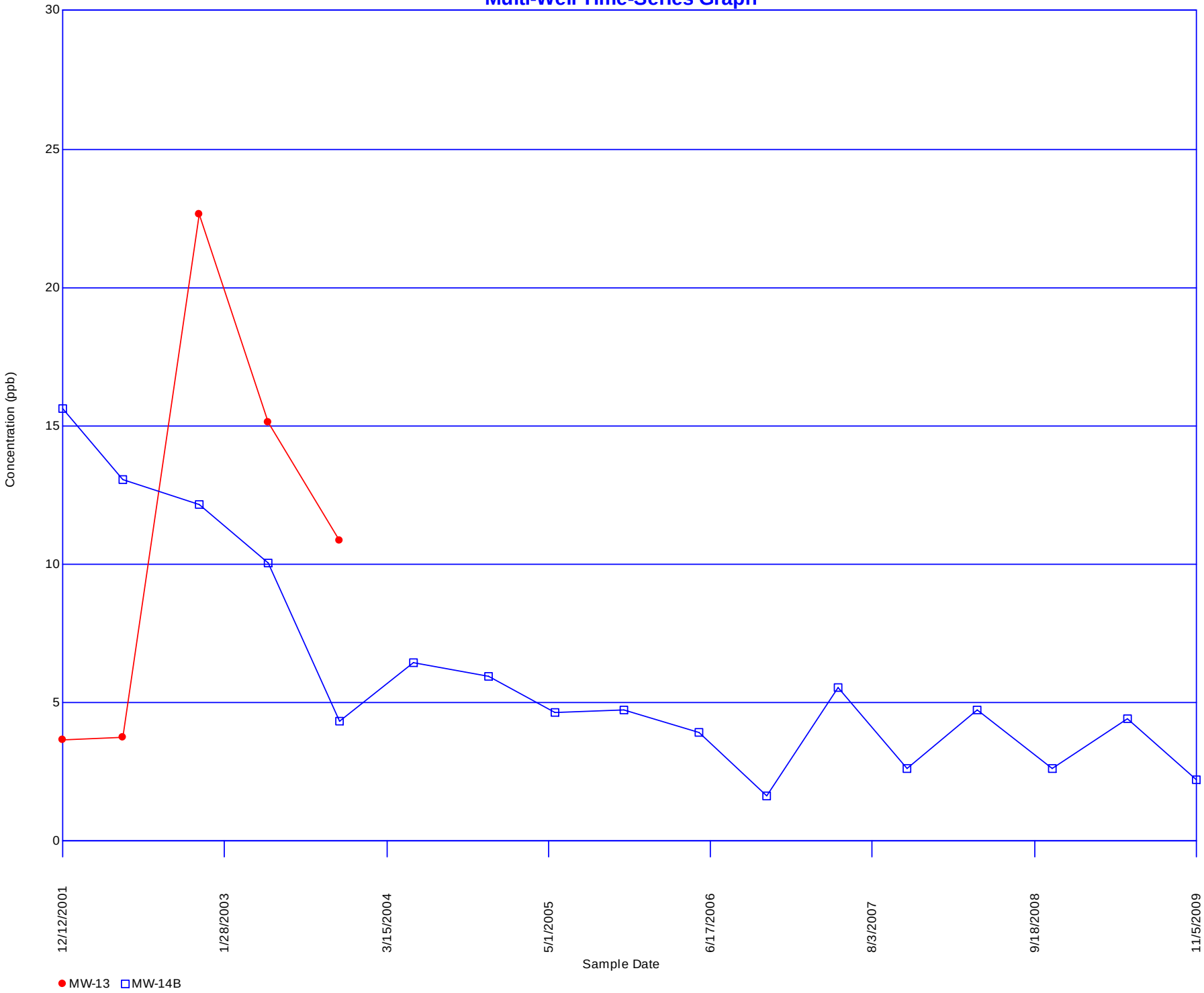
Total VOCs

Multi-Well Time-Series Graph



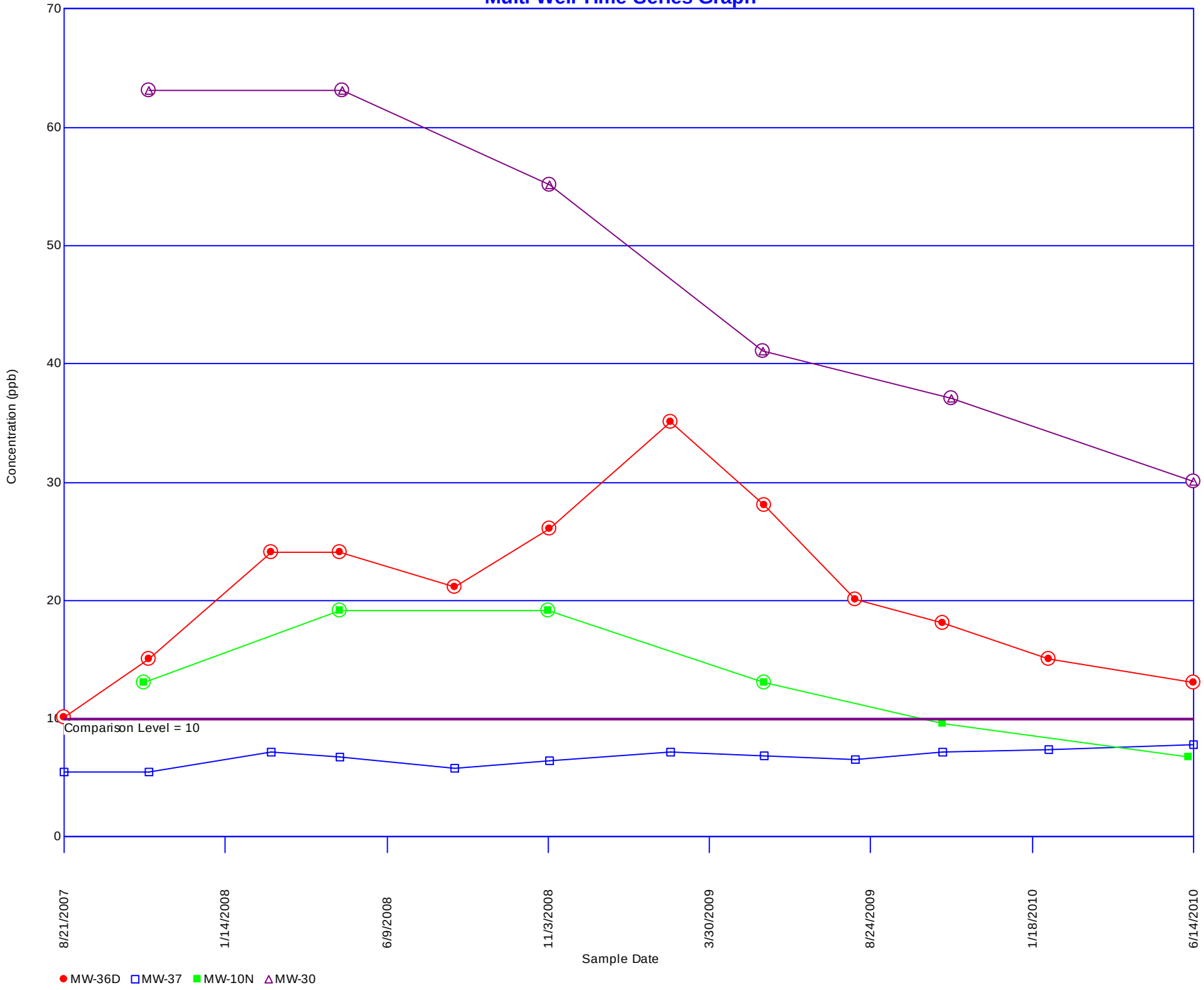
Total VOCs

Multi-Well Time-Series Graph



Diethyl Ether

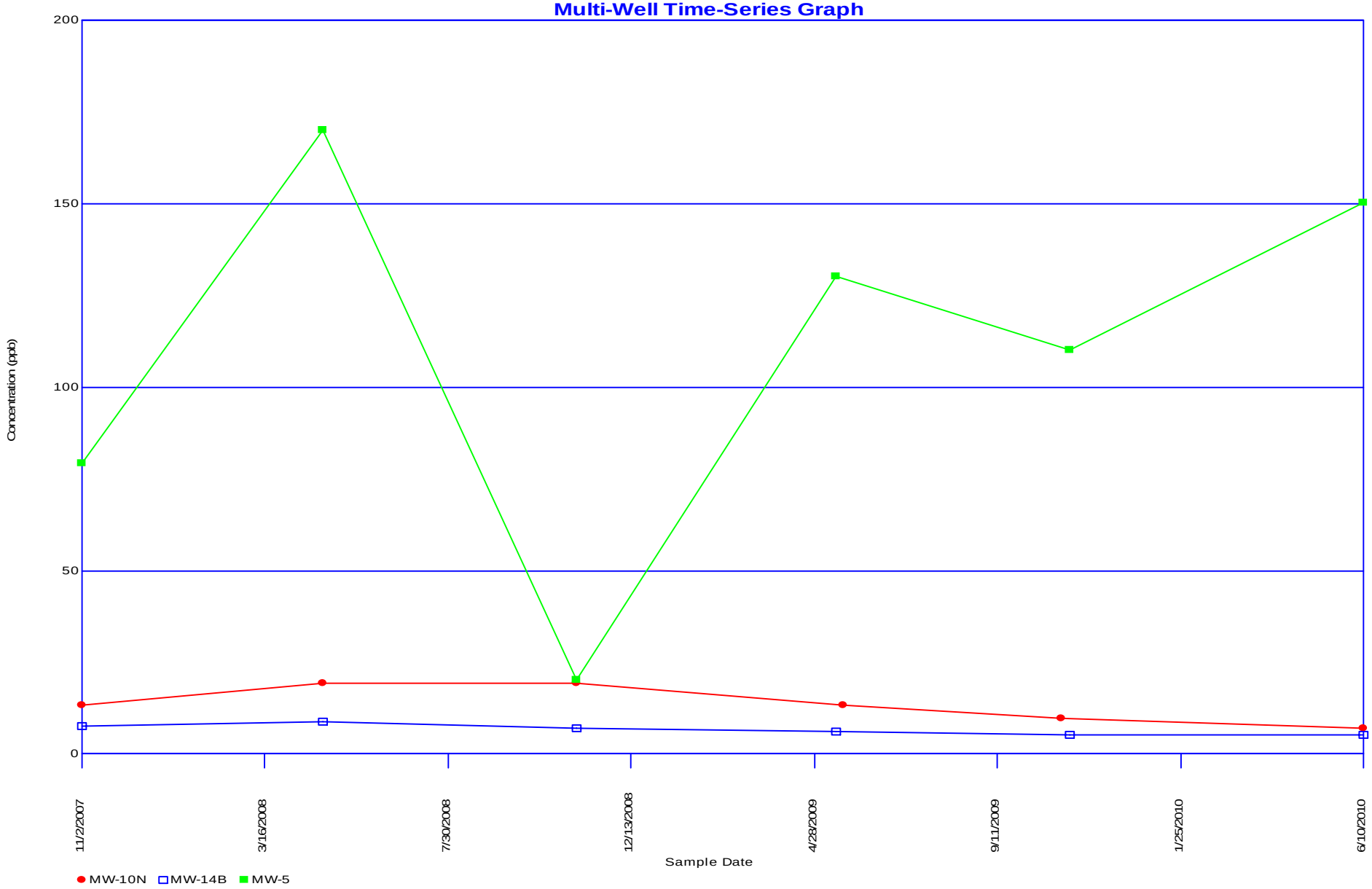
Multi-Well Time-Series Graph



Central Sanitary Landfill

Diethyl Ether

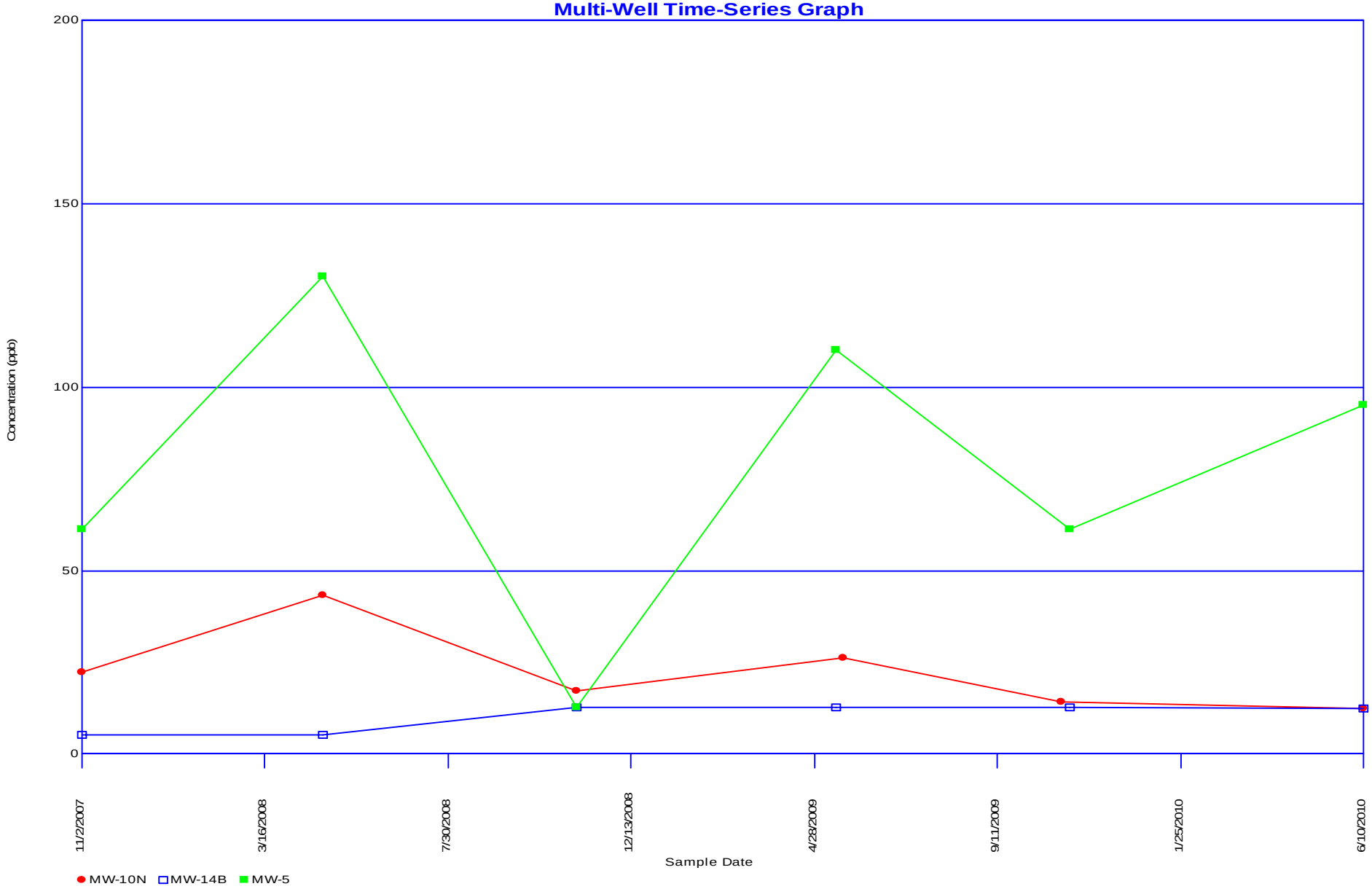
Multi-Well Time-Series Graph



Central Sanitary Landfill

Tetrahydrofuran

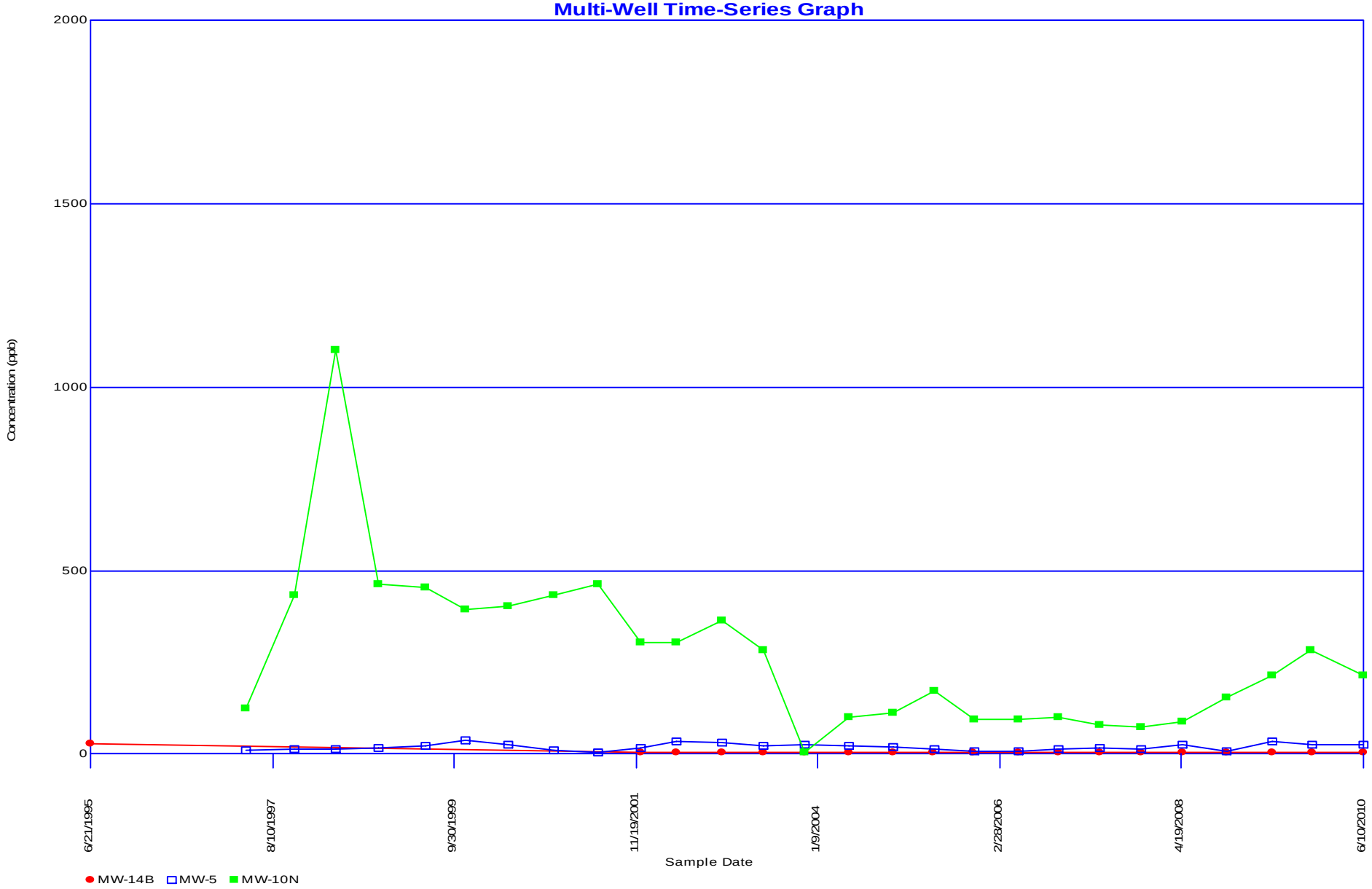
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,1-Dichloroethane

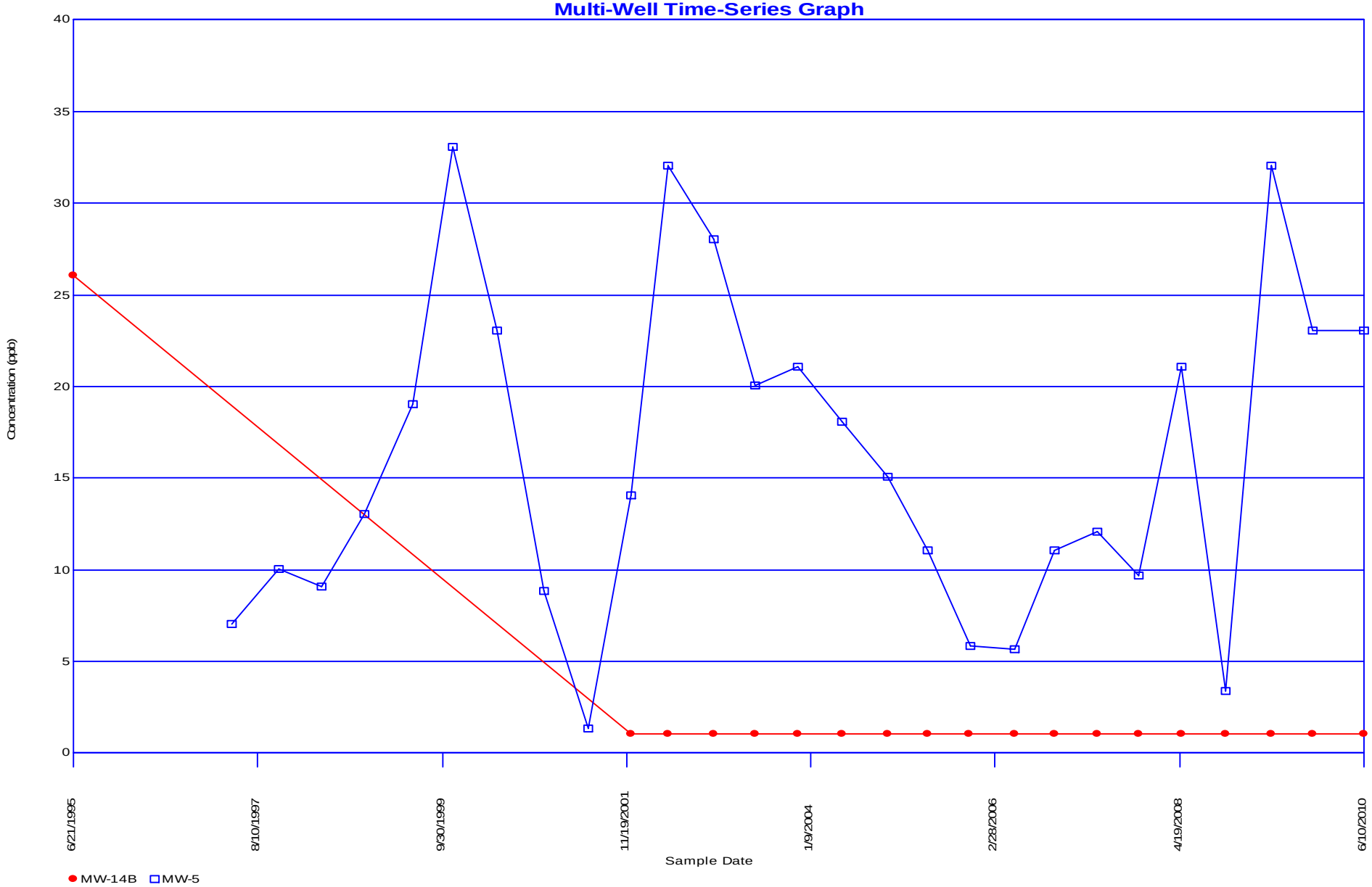
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,1-Dichloroethane

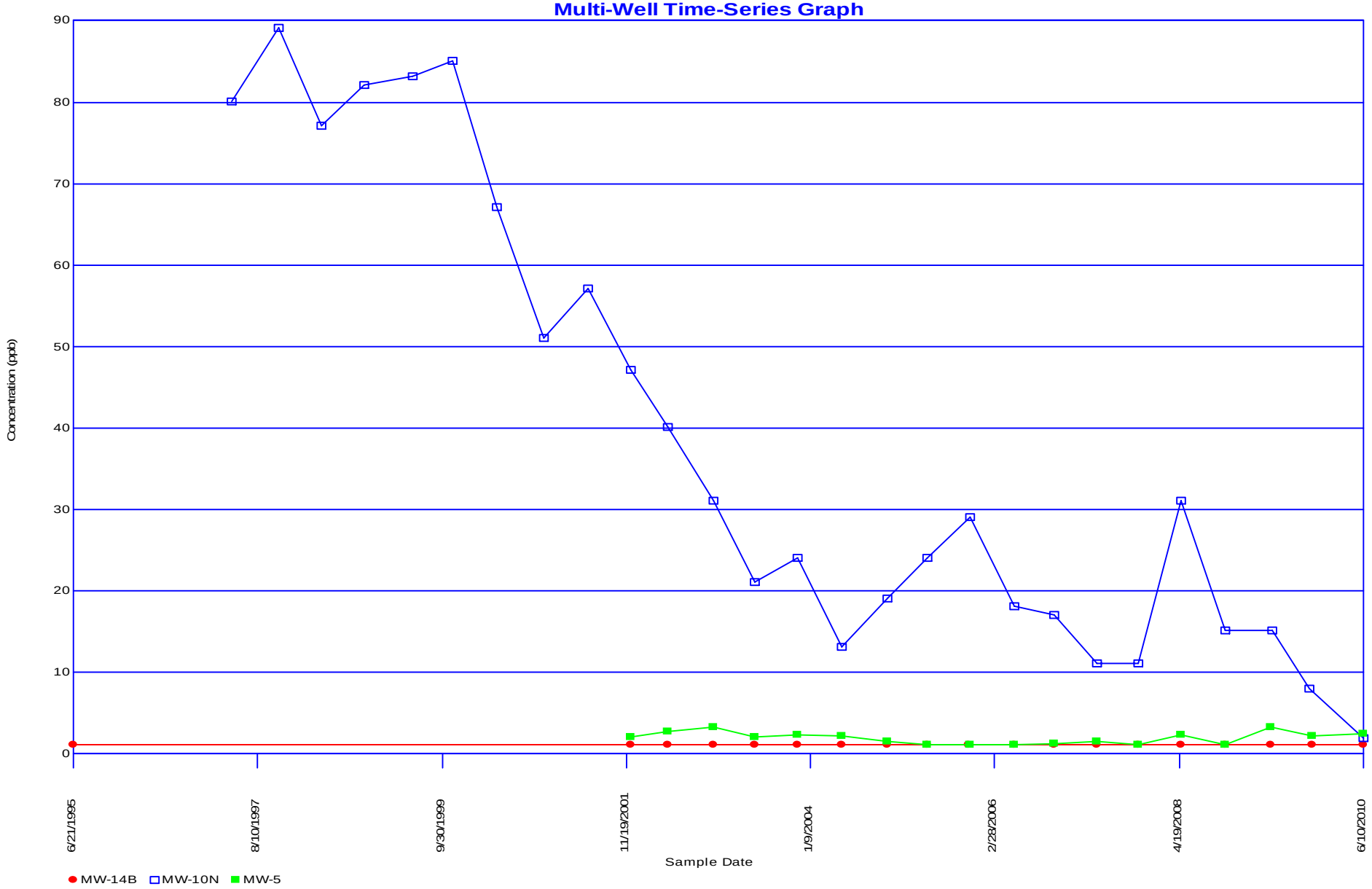
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,2-Dichloroethane

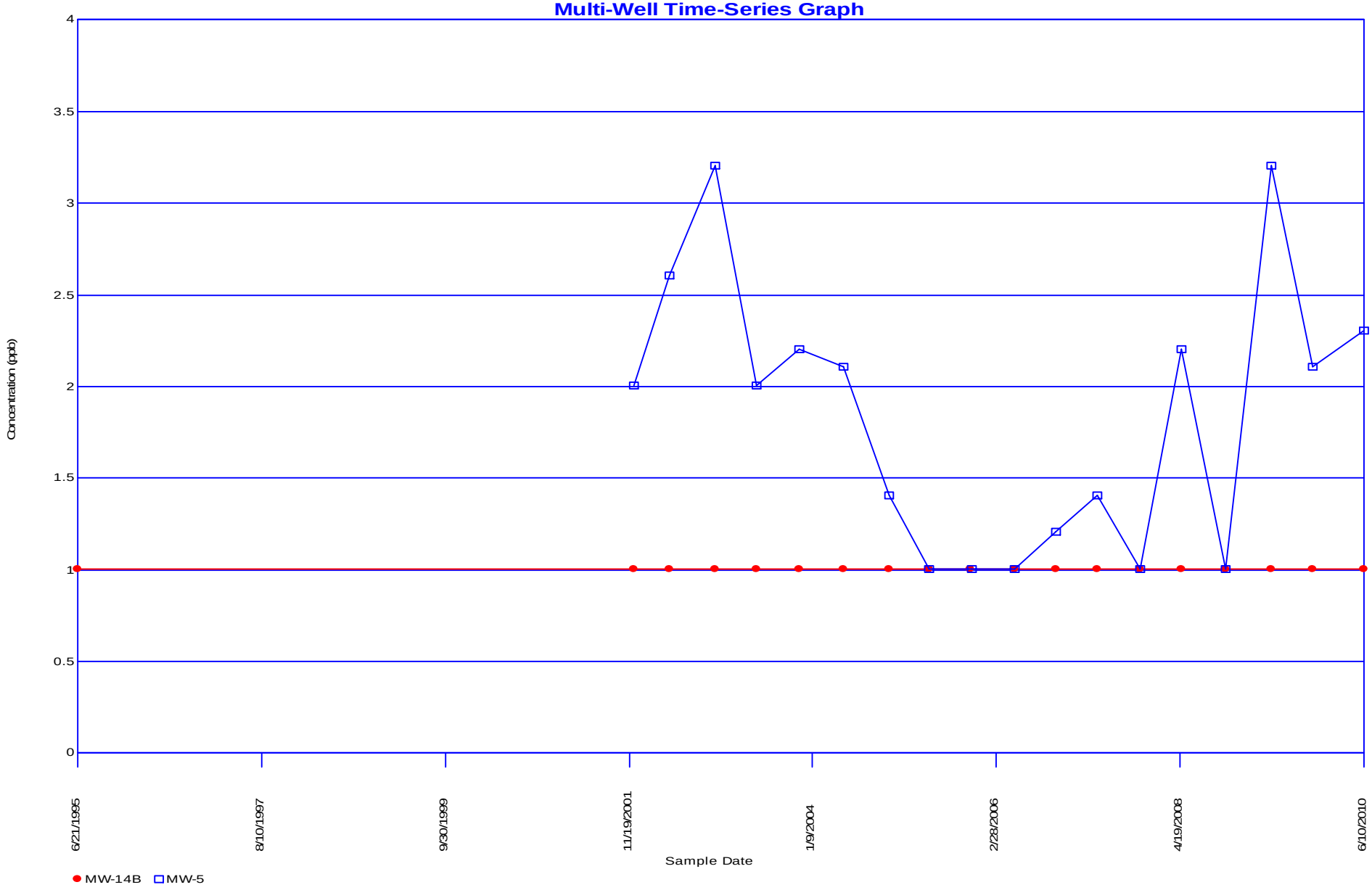
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,2-Dichloroethane

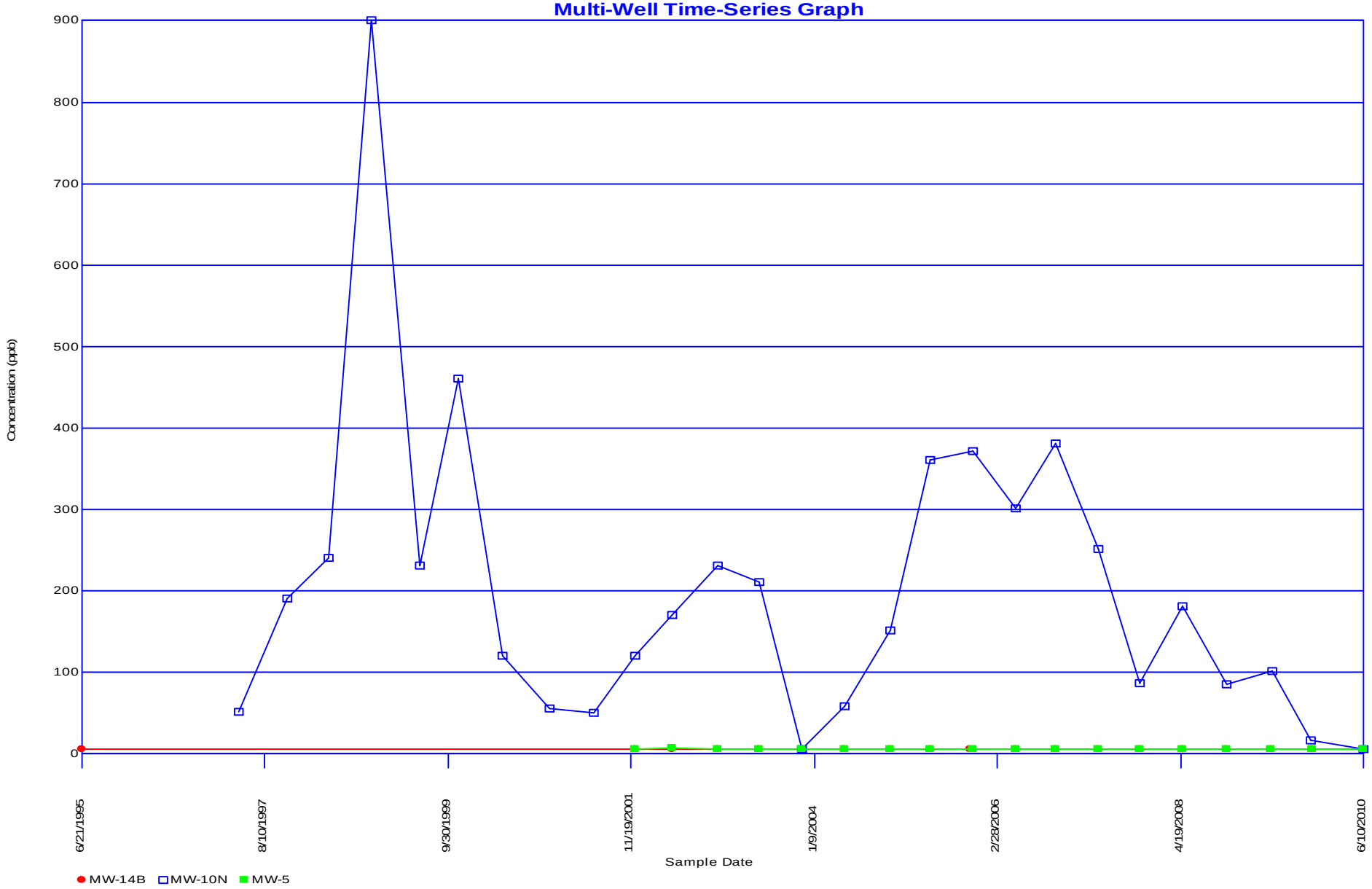
Multi-Well Time-Series Graph



Central Sanitary Landfill

Chloroethane

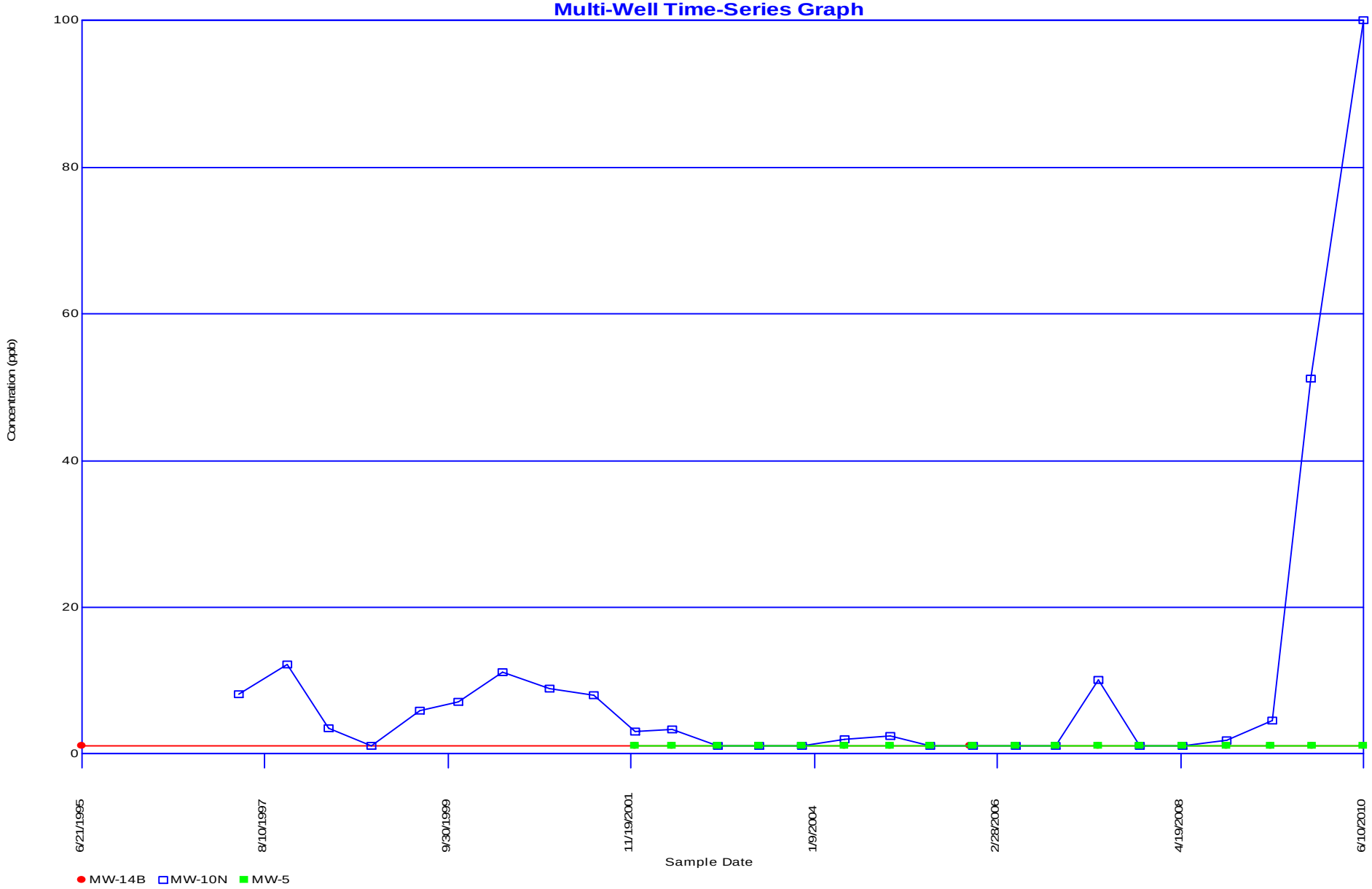
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,1-Dichloroethene

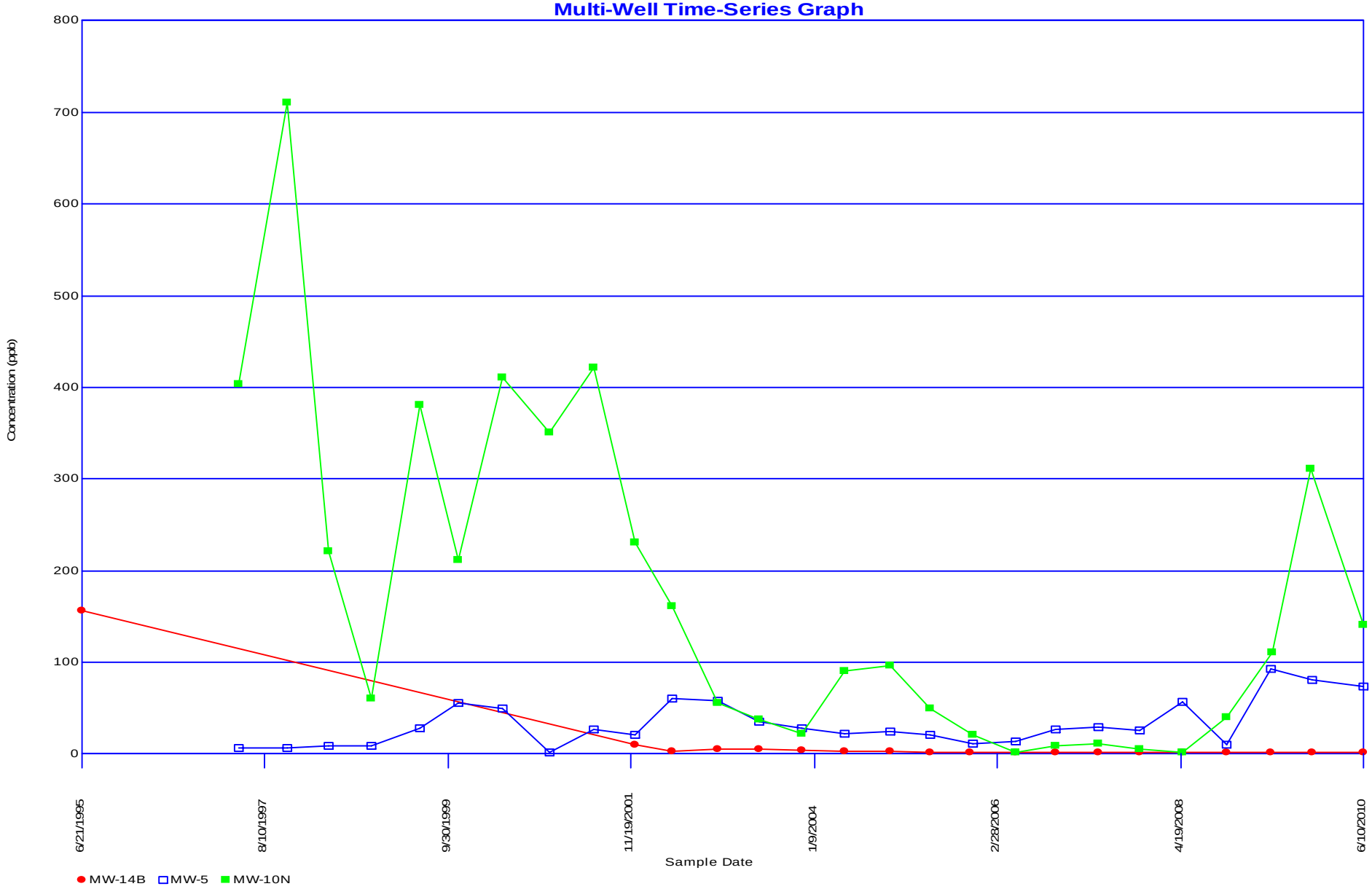
Multi-Well Time-Series Graph



Central Sanitary Landfill

cis-1,2-Dichloroethene

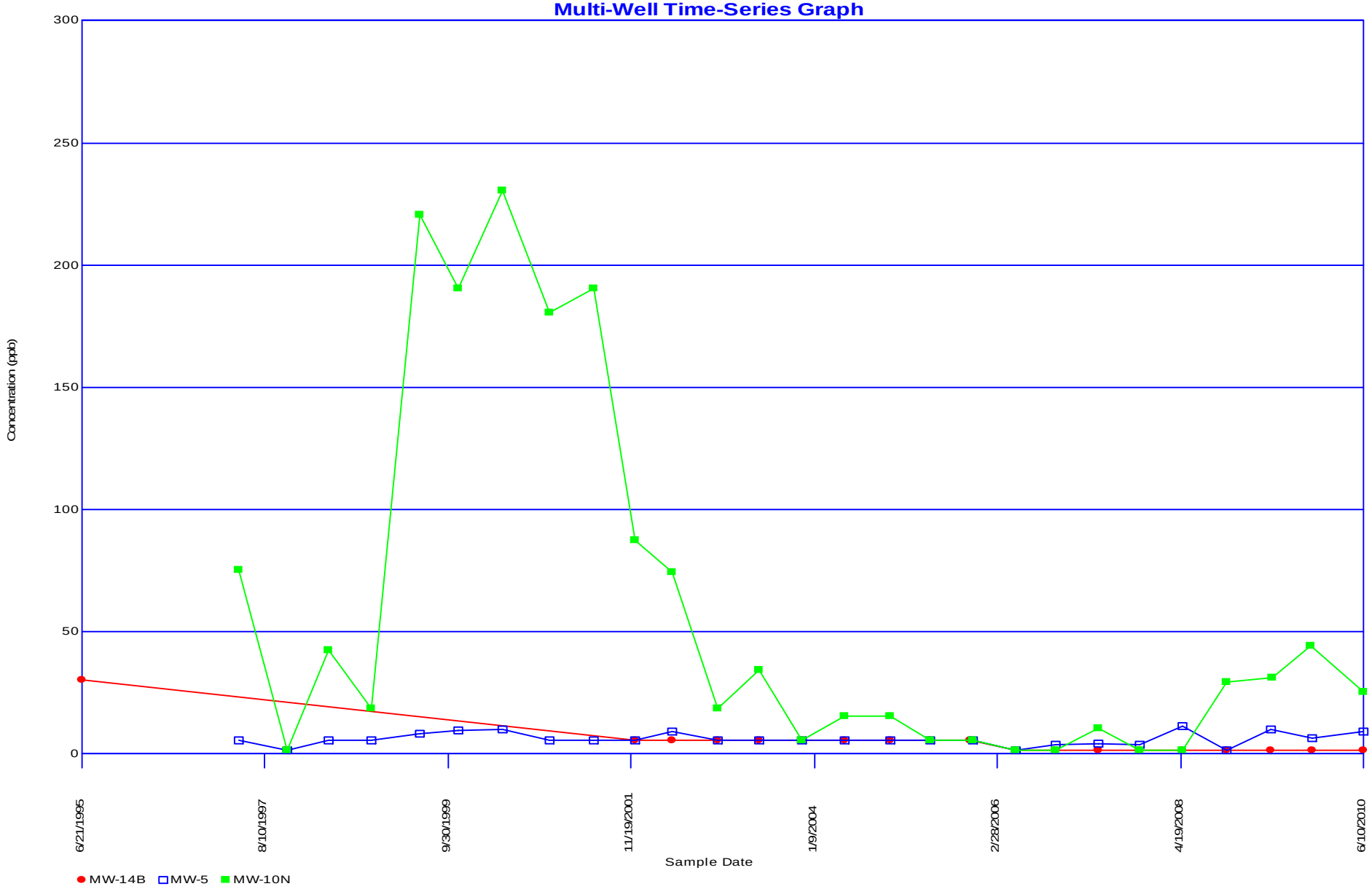
Multi-Well Time-Series Graph



Central Sanitary Landfill

Vinyl Chloride

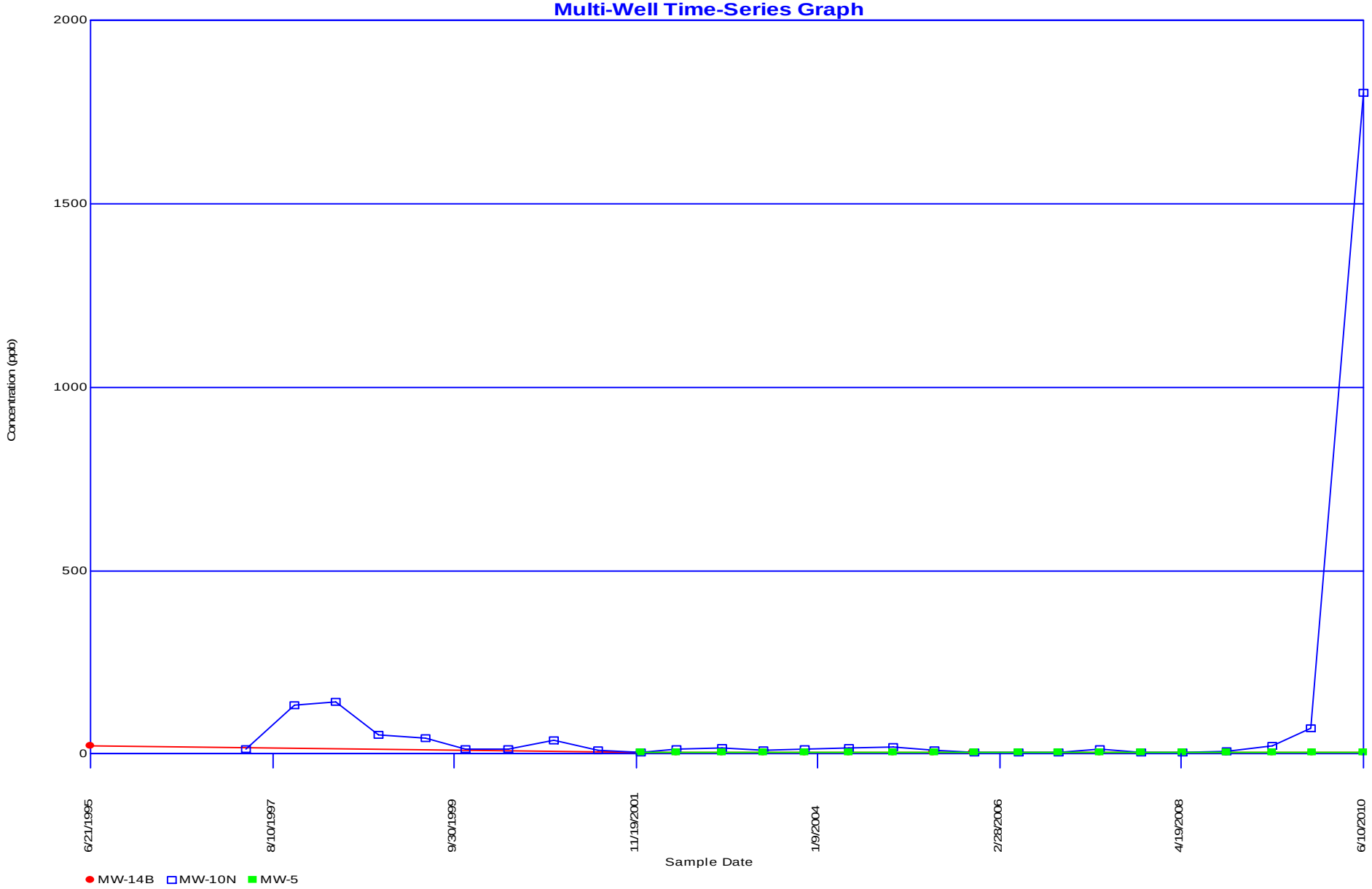
Multi-Well Time-Series Graph



Central Sanitary Landfill

Trichloroethene

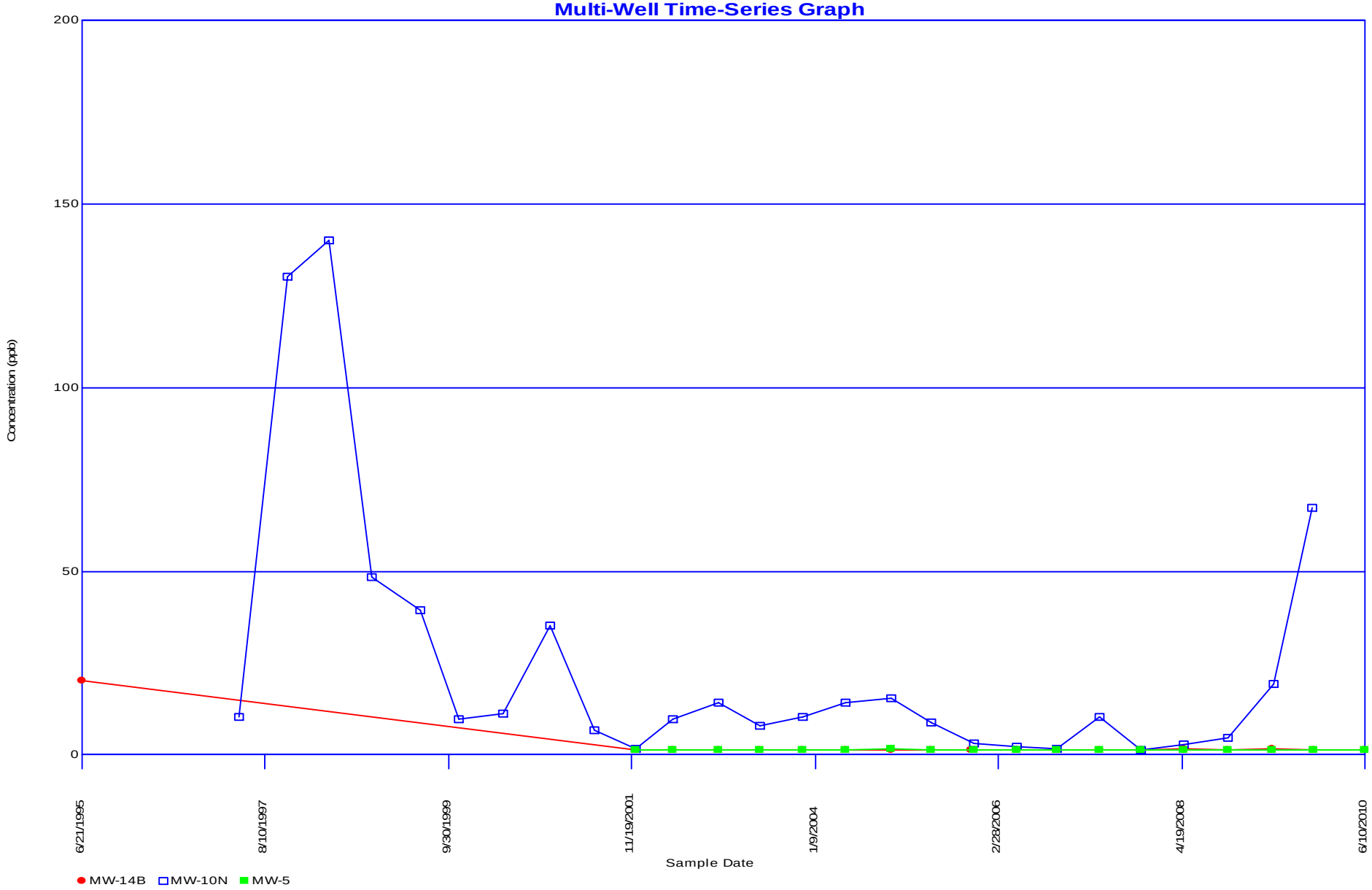
Multi-Well Time-Series Graph



Central Sanitary Landfill

Trichloroethene

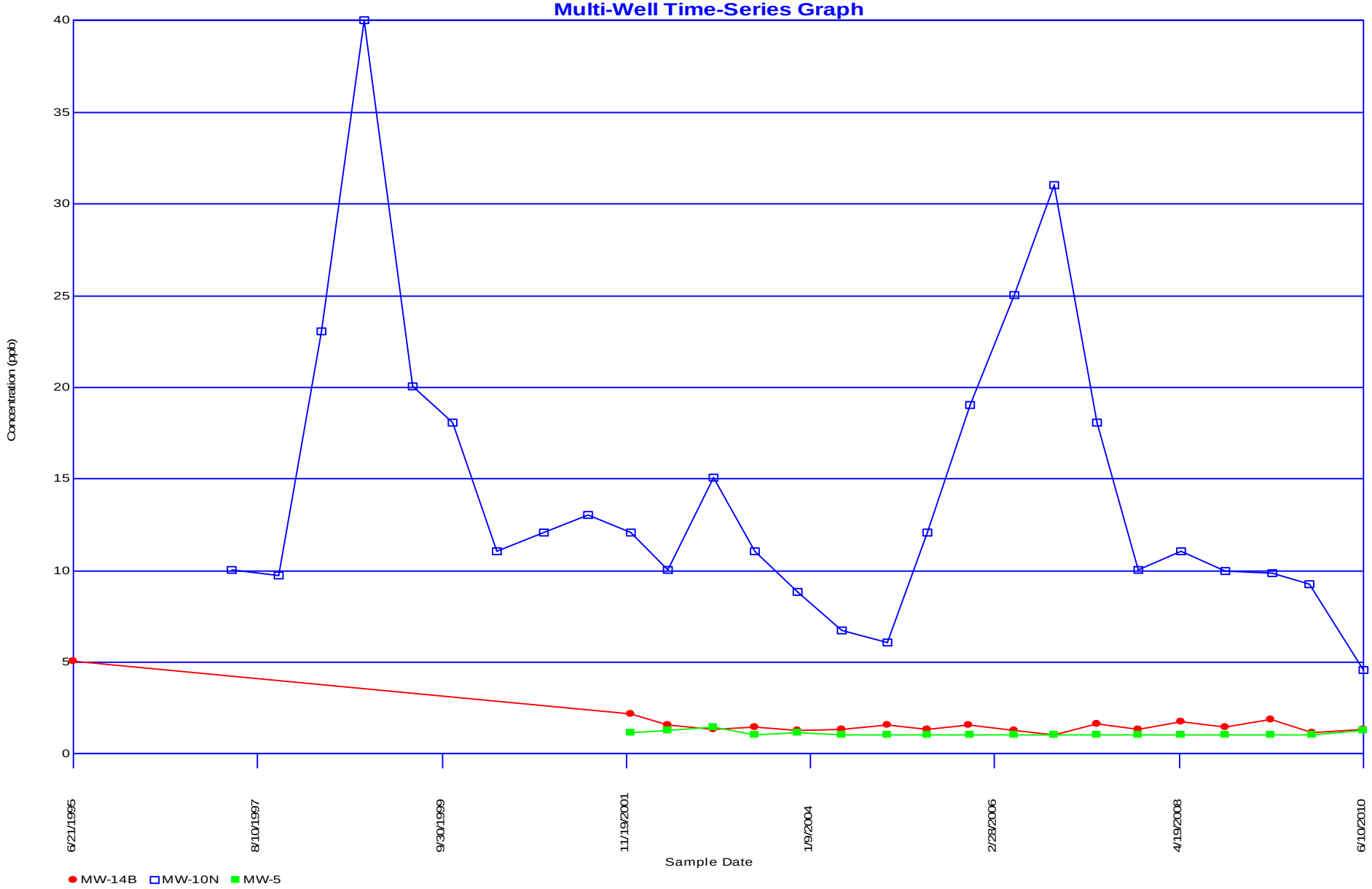
Multi-Well Time-Series Graph



Central Sanitary Landfill

Benzene

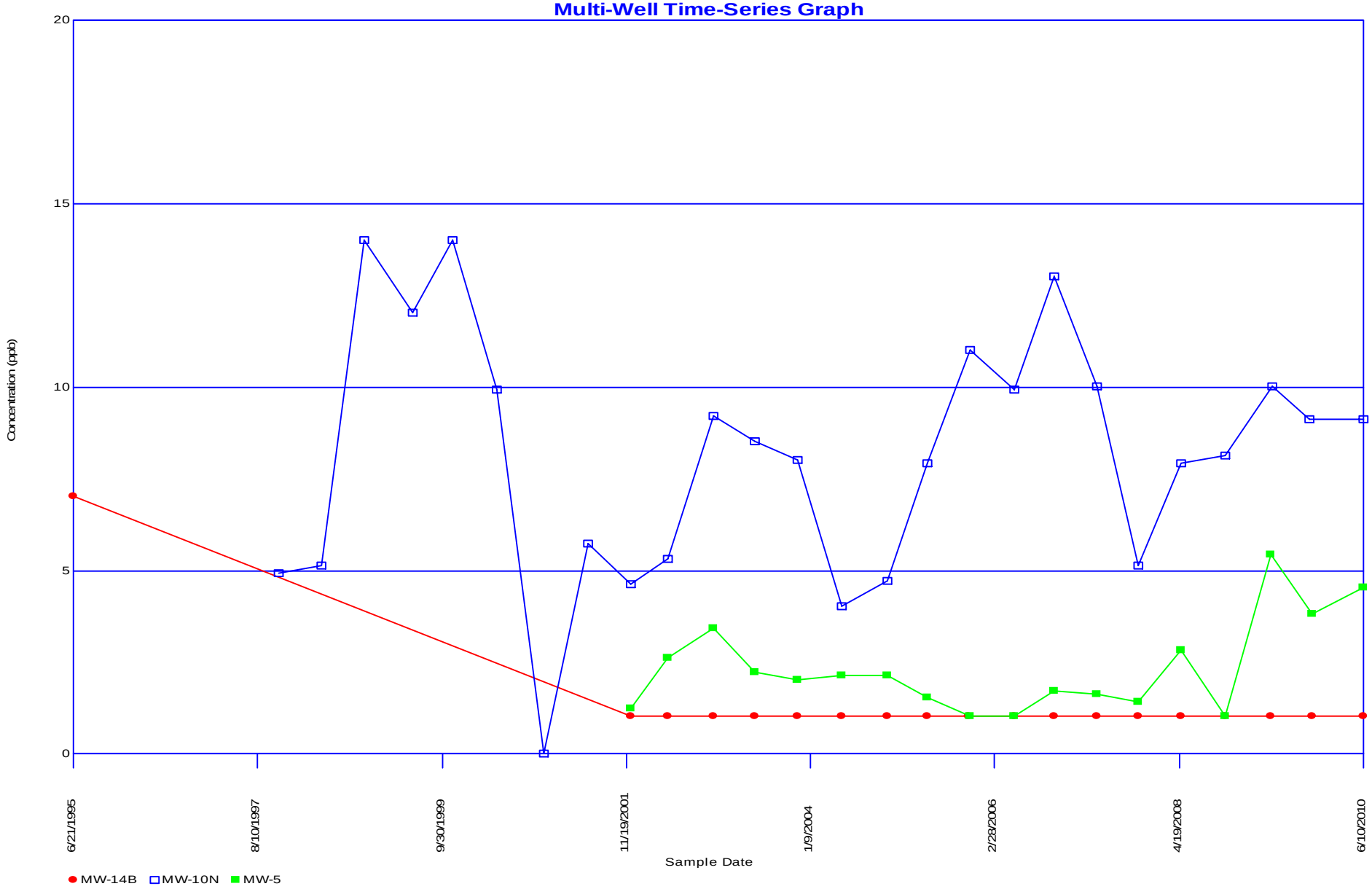
Multi-Well Time-Series Graph



Central Sanitary Landfill

trans-1,2-Dichloroethene

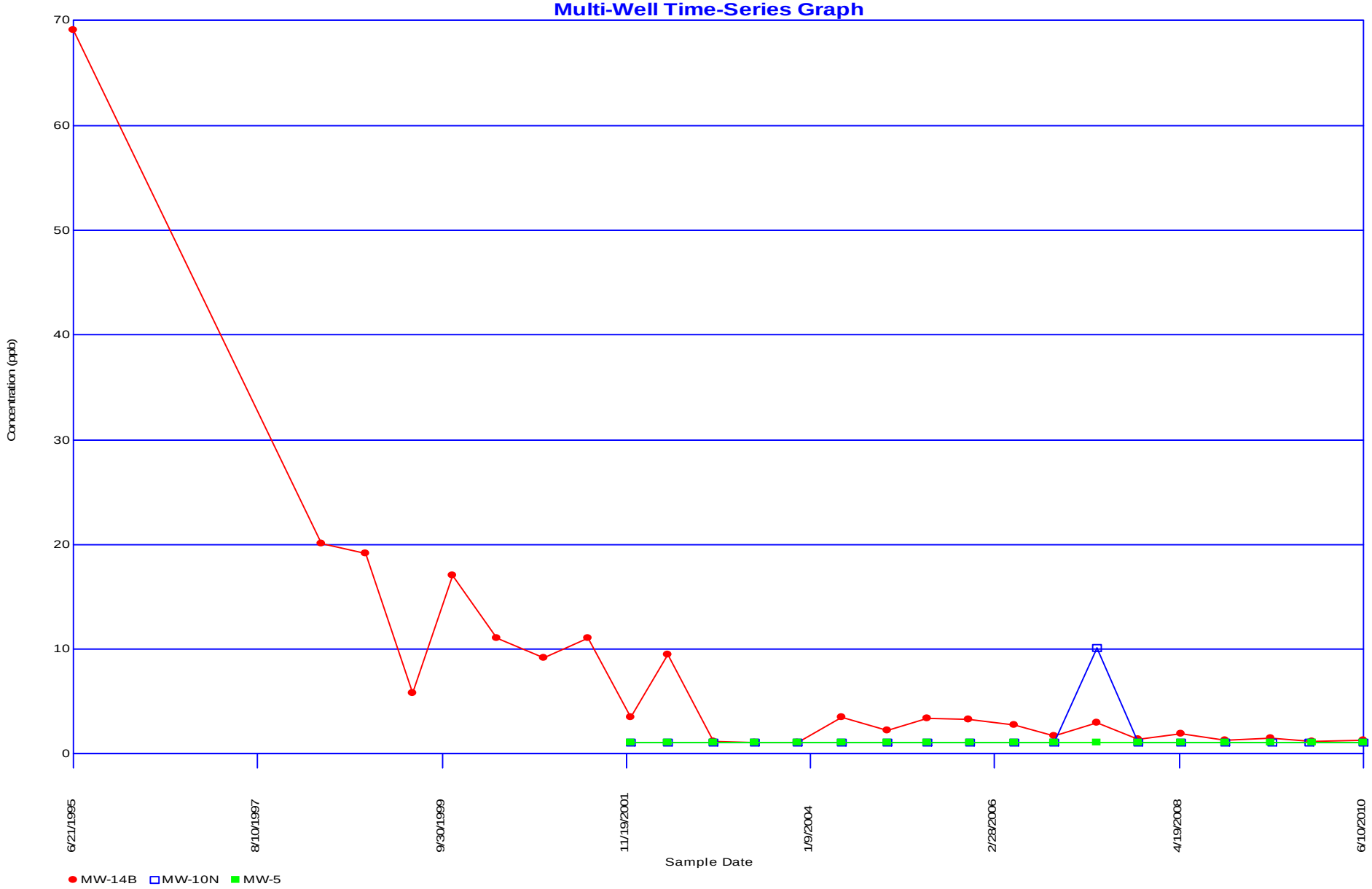
Multi-Well Time-Series Graph



Central Sanitary Landfill

Tetrachloroethene

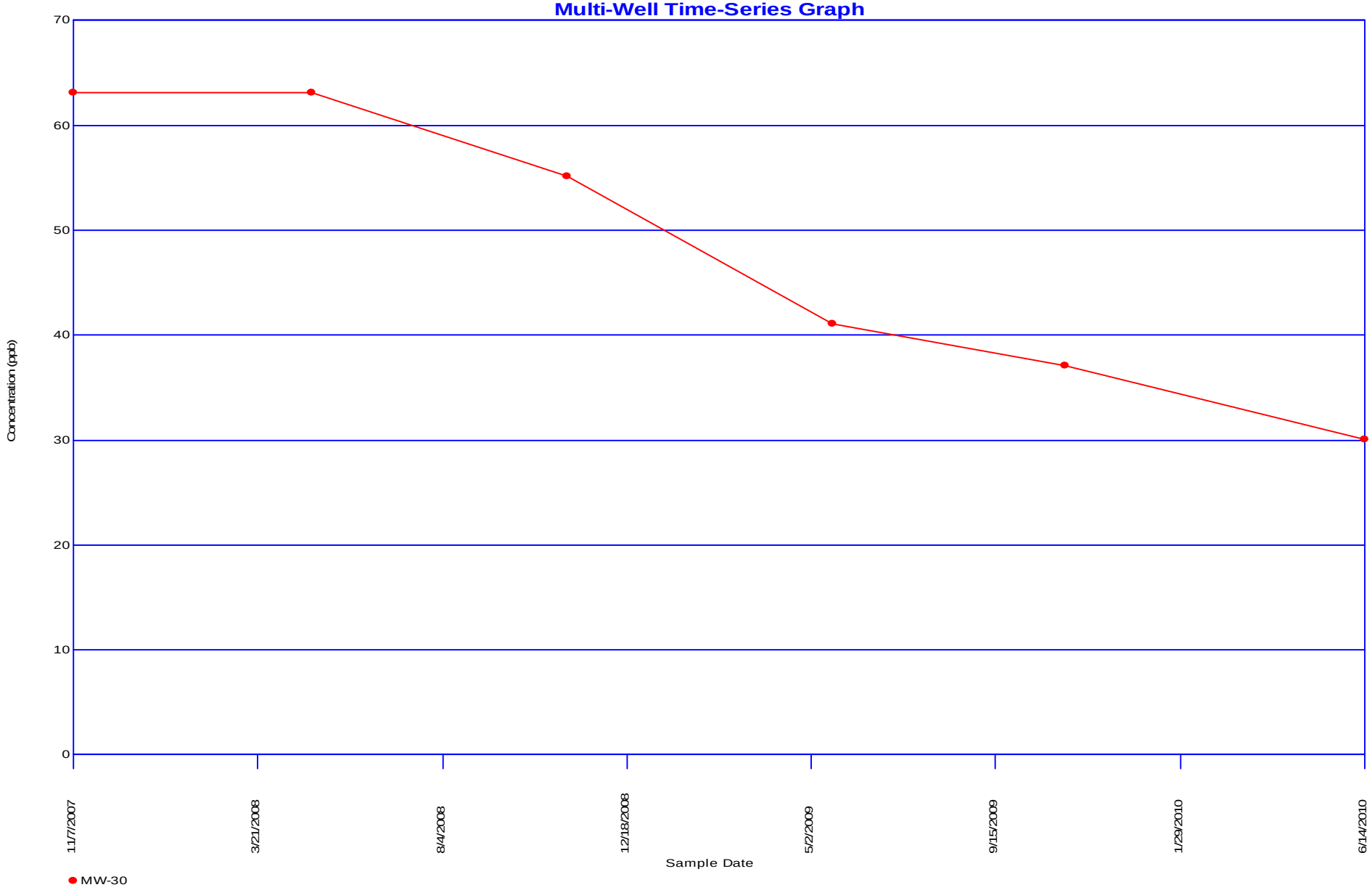
Multi-Well Time-Series Graph



Central Sanitary Landfill

Diethyl Ether

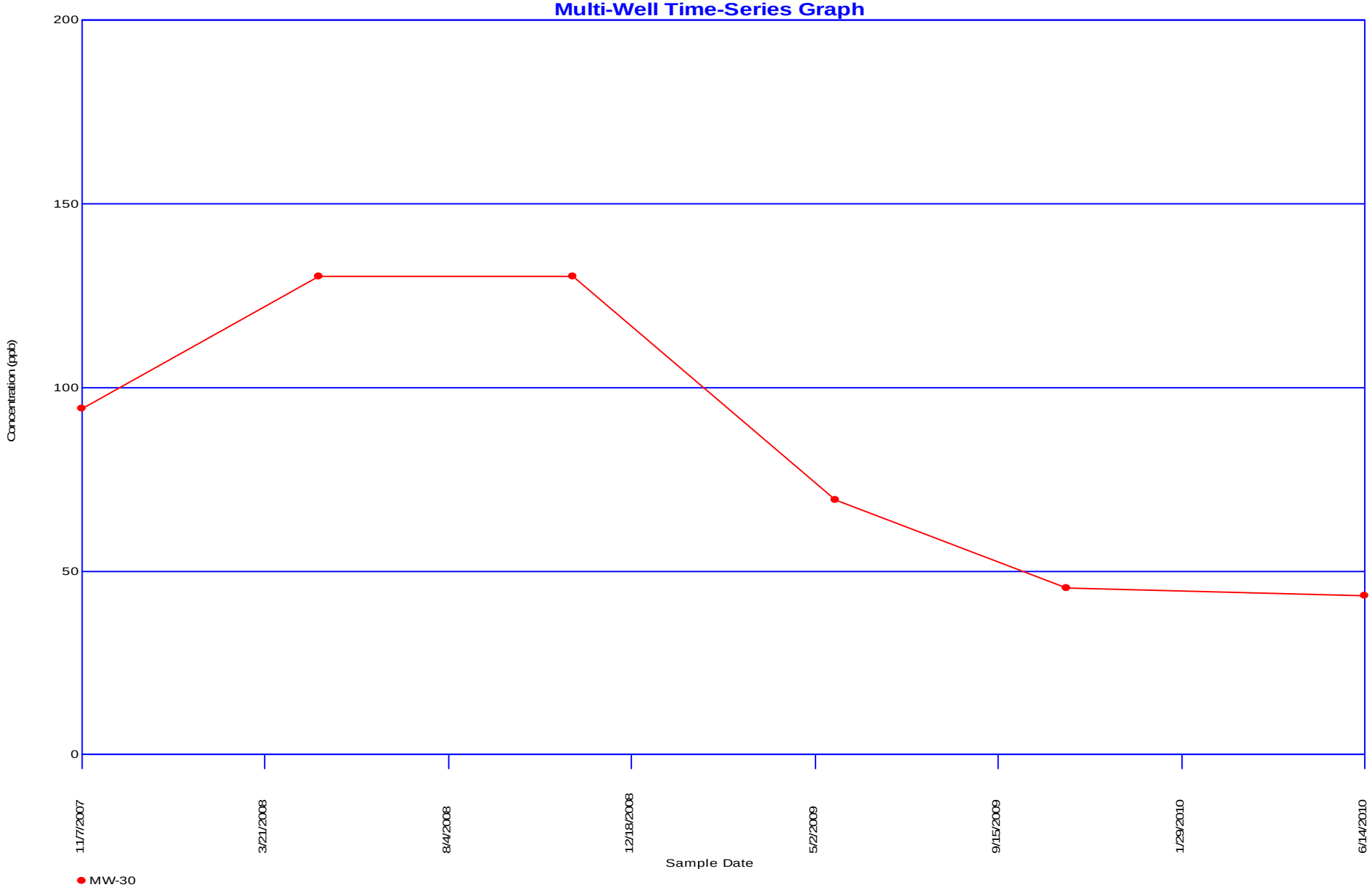
Multi-Well Time-Series Graph



Central Sanitary Landfill

Tetrahydrofuran

Multi-Well Time-Series Graph



Central Sanitary Landfill

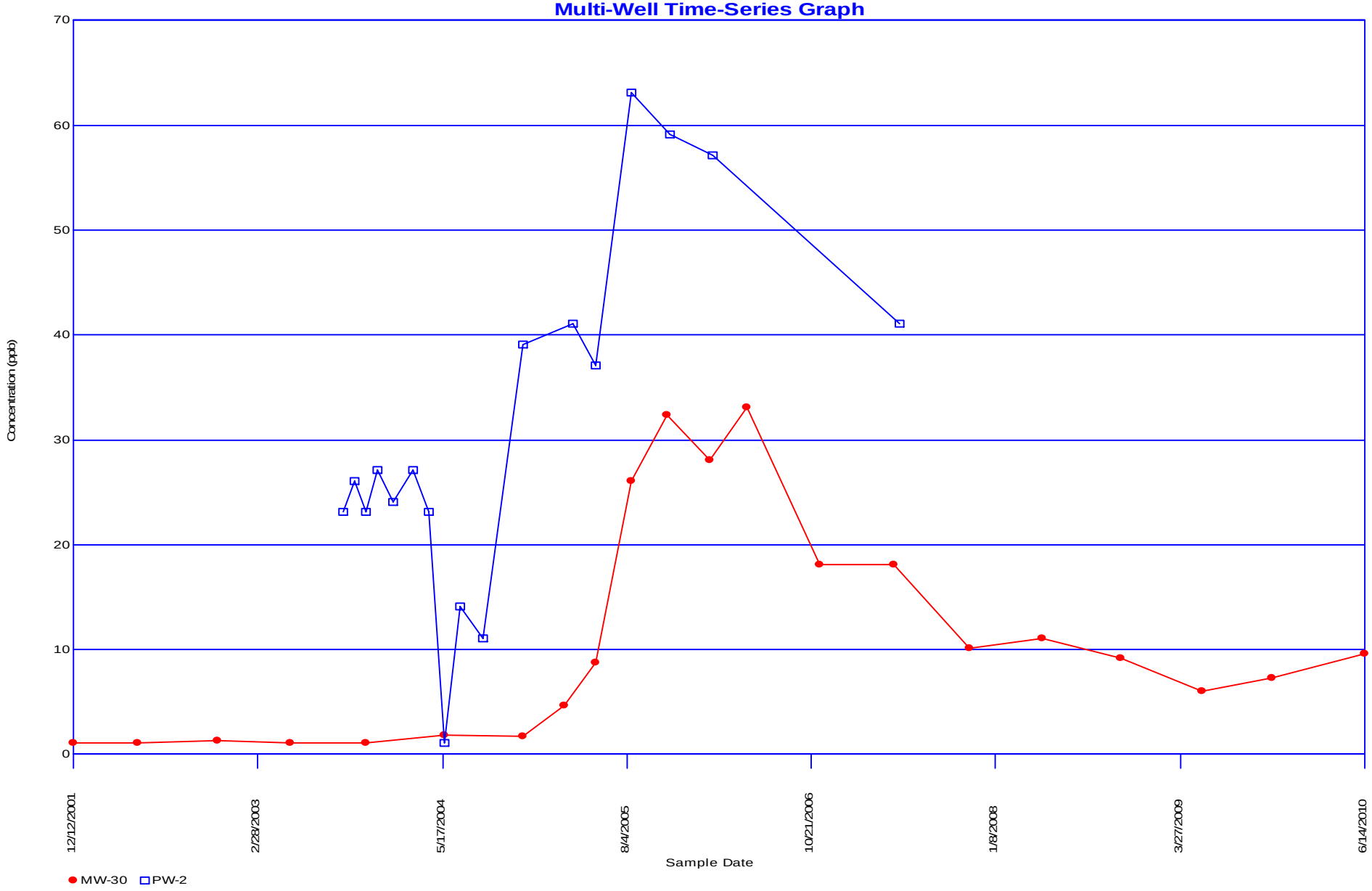
1,1-Dichloroethane

Multi-Well Time-Series Graph

Central Sanitary Landfill

1,2-Dichloroethane

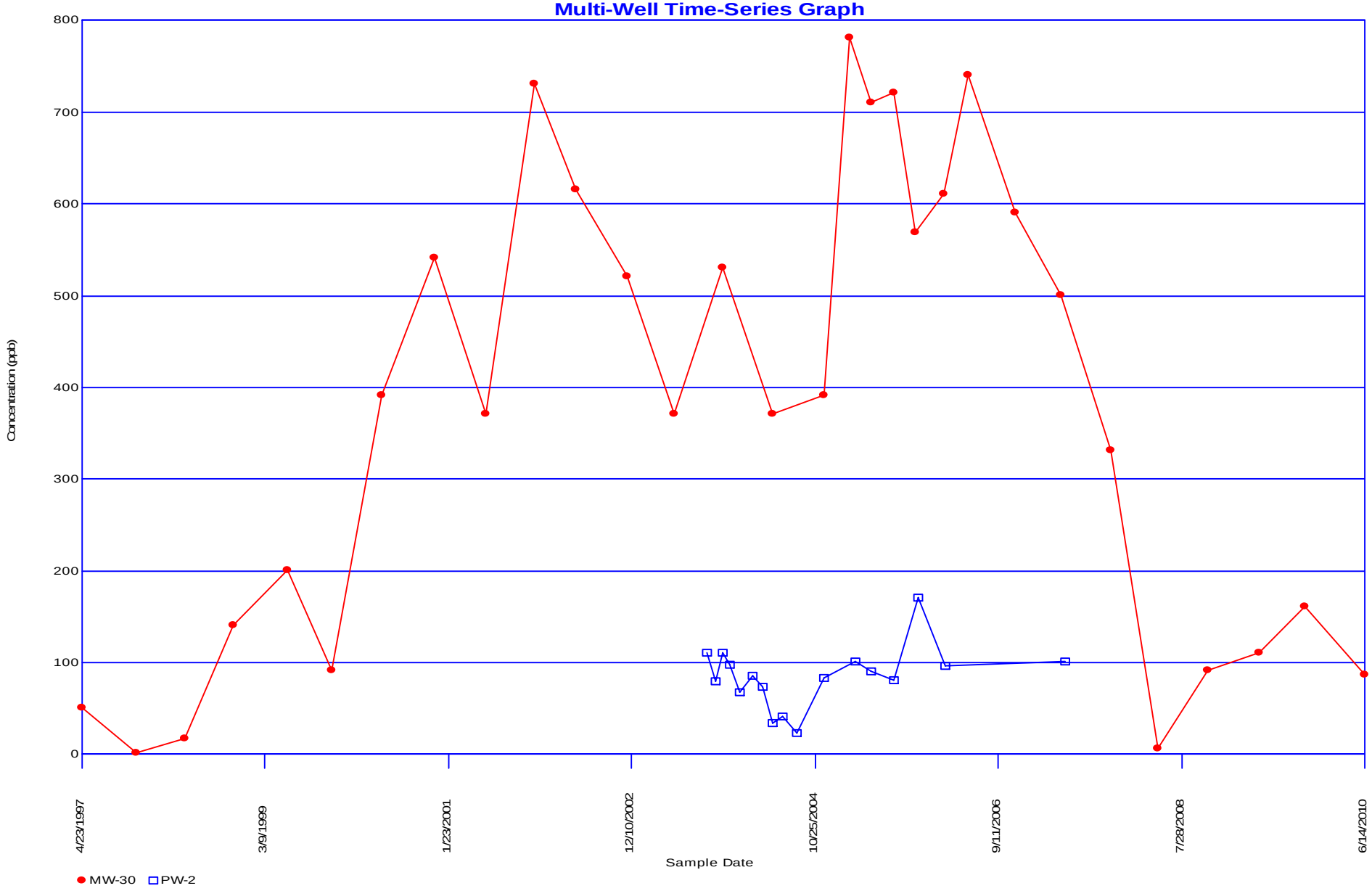
Multi-Well Time-Series Graph



Central Sanitary Landfill

Chloroethane

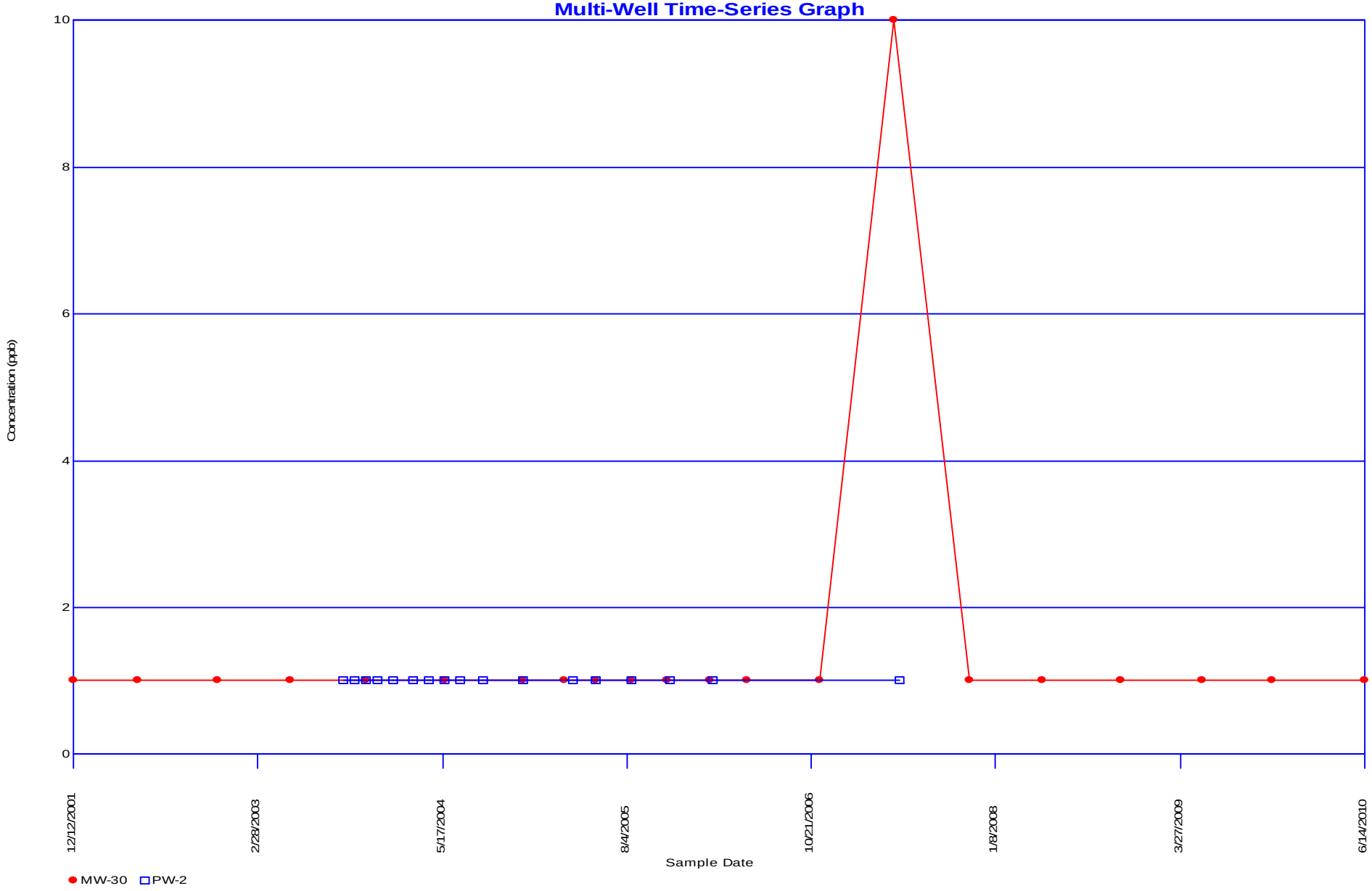
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,1-Dichloroethene

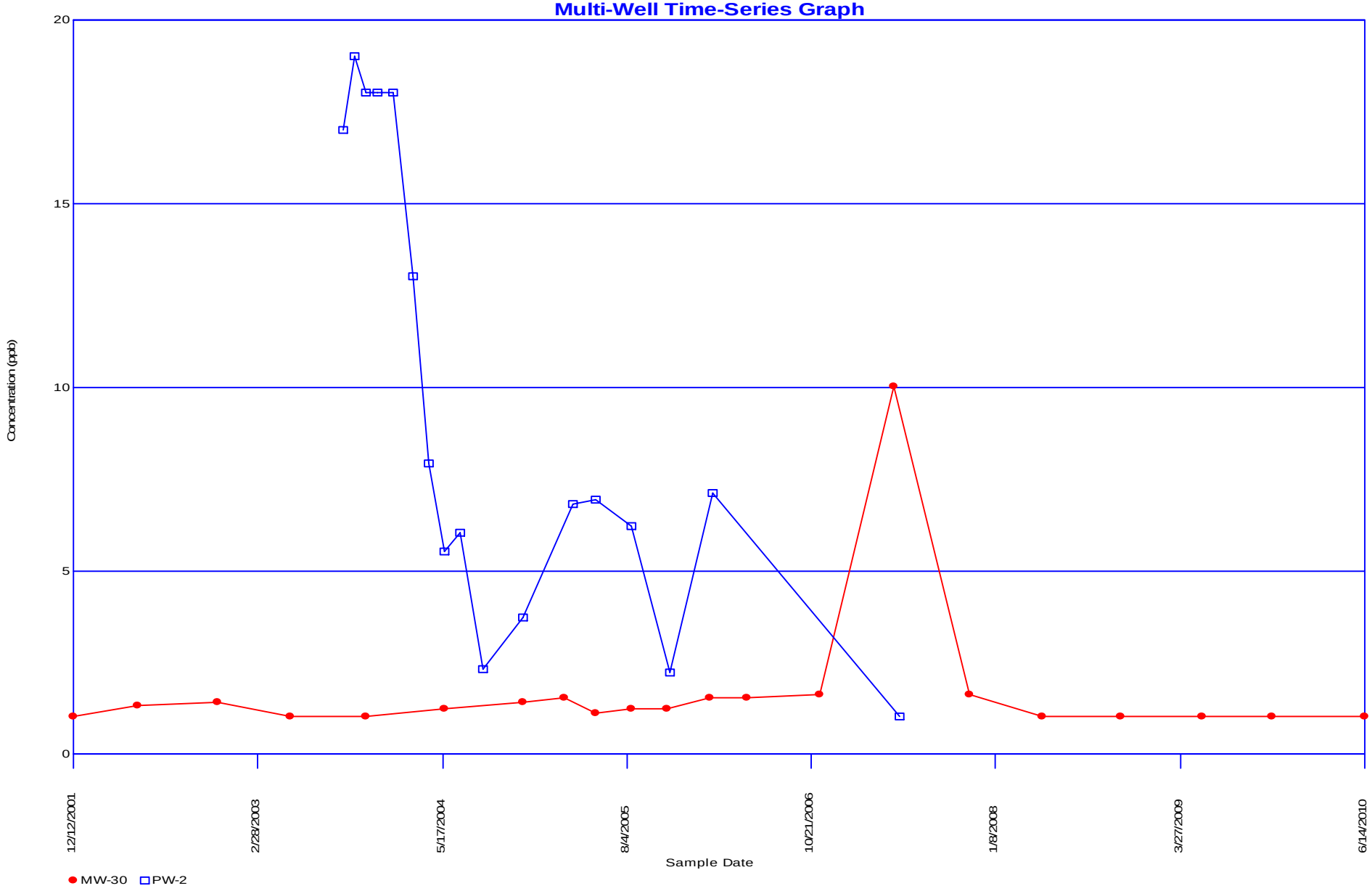
Multi-Well Time-Series Graph



Central Sanitary Landfill

cis-1,2-Dichloroethene

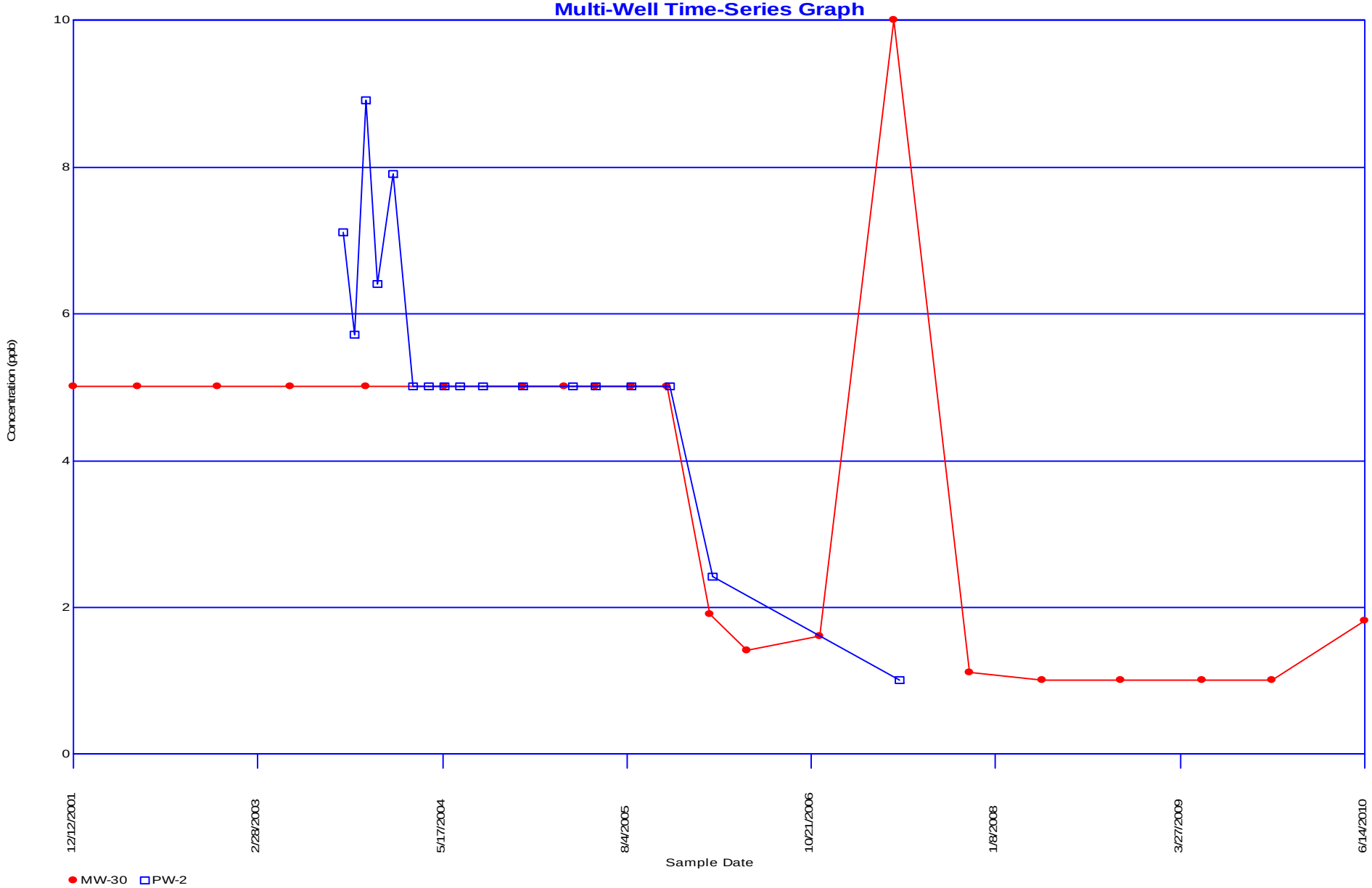
Multi-Well Time-Series Graph



Central Sanitary Landfill

Vinyl Chloride

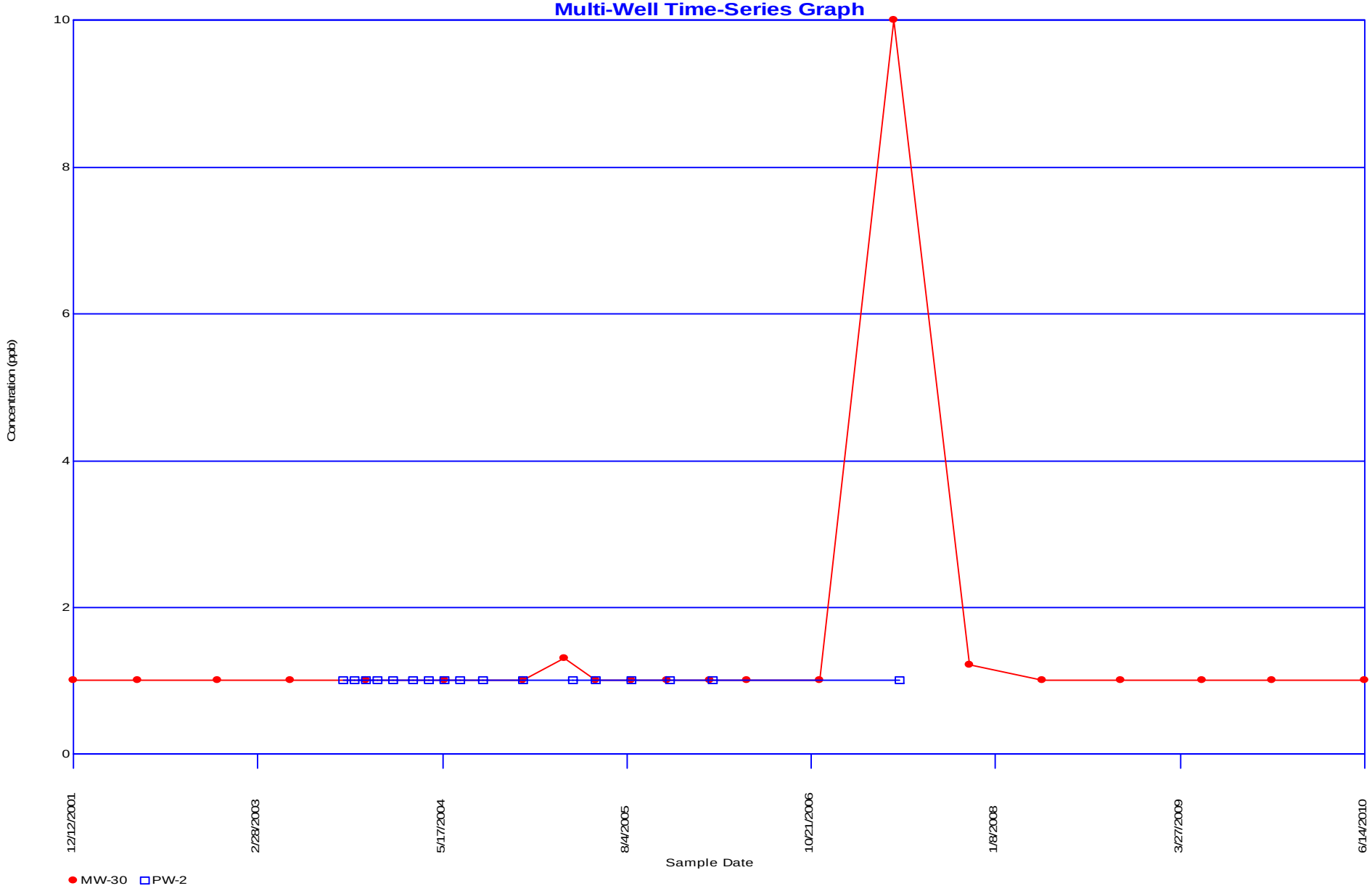
Multi-Well Time-Series Graph



Central Sanitary Landfill

Trichloroethene

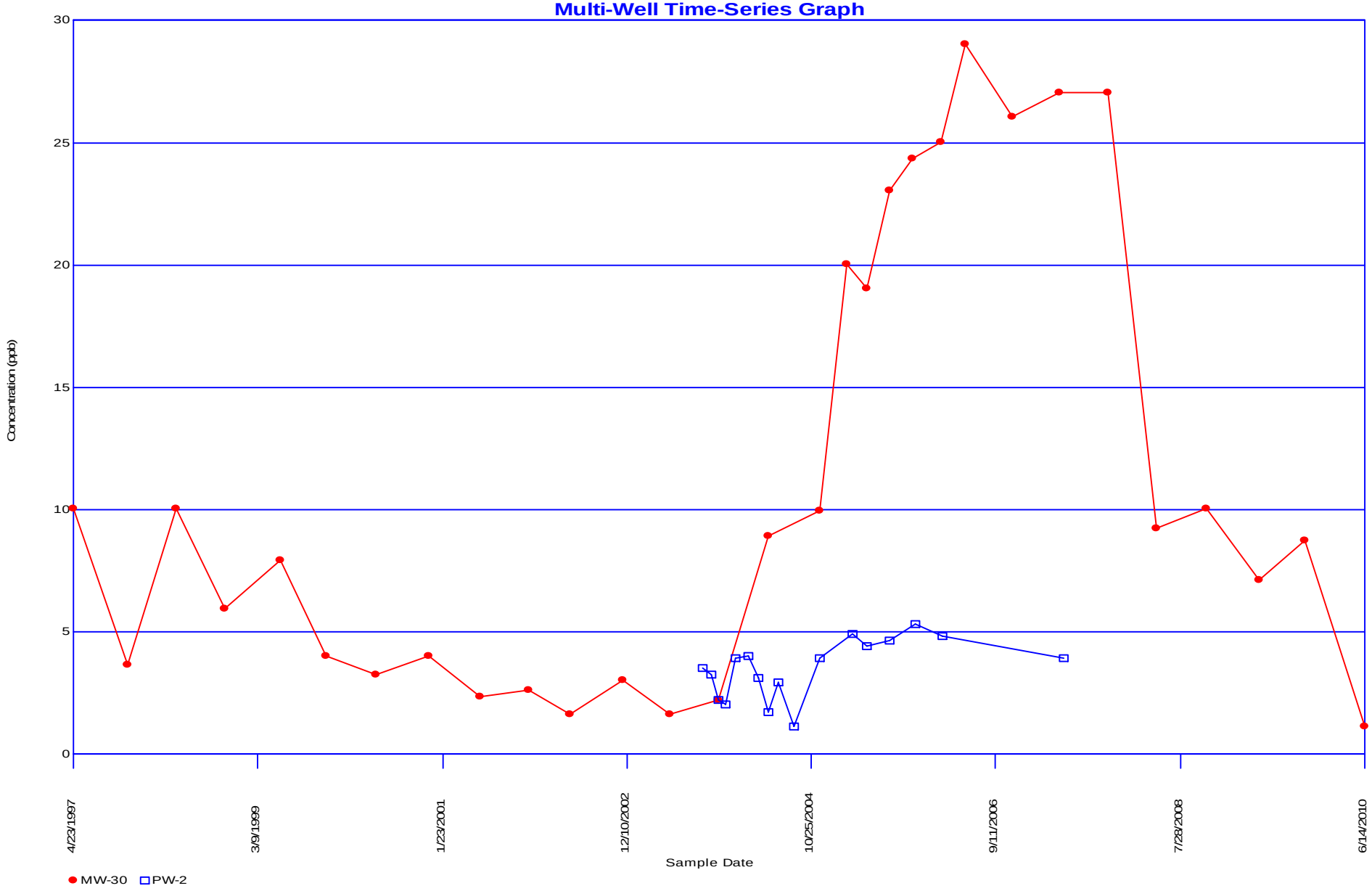
Multi-Well Time-Series Graph



Central Sanitary Landfill

Benzene

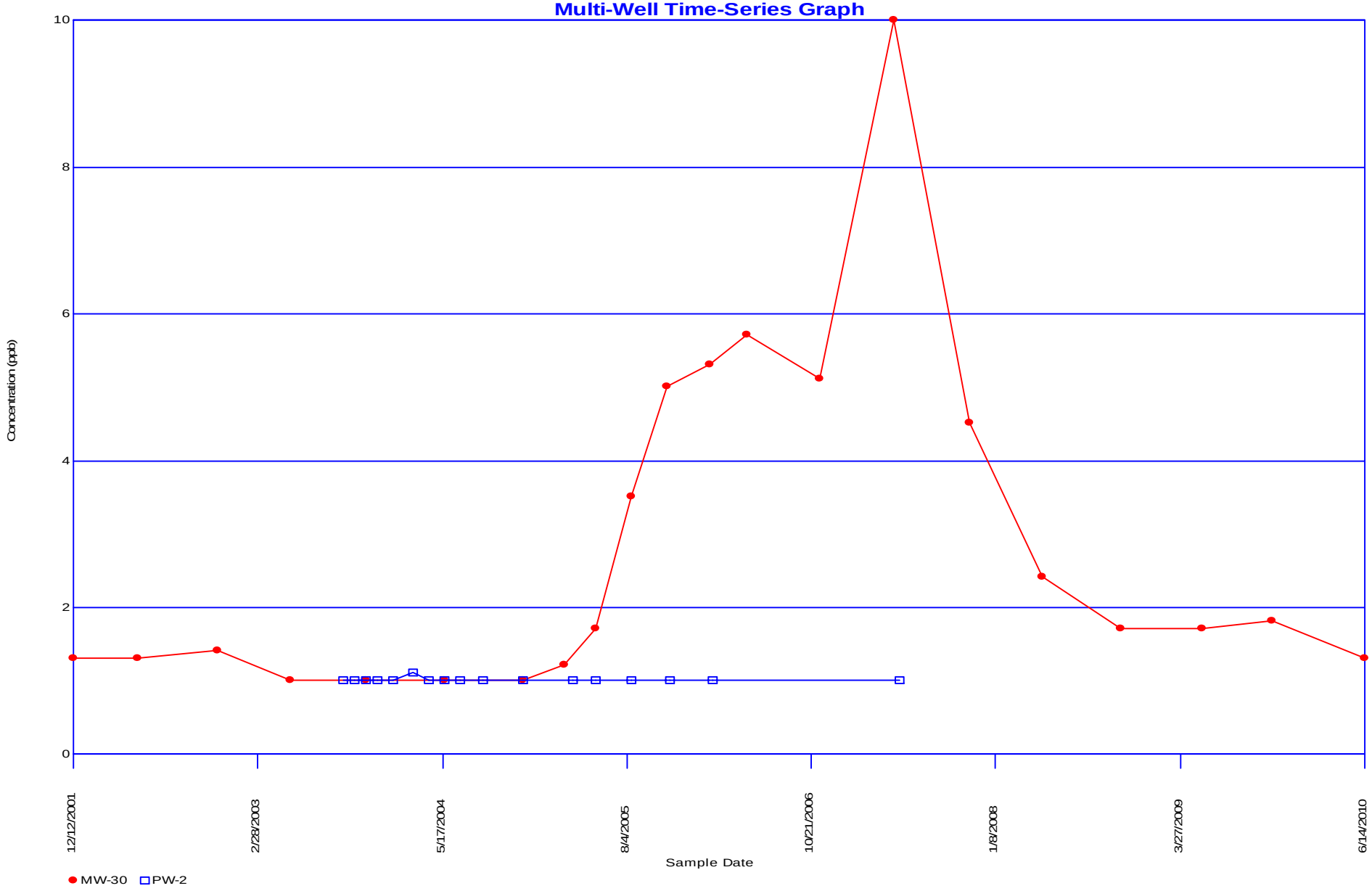
Multi-Well Time-Series Graph



Central Sanitary Landfill

trans-1,2-Dichloroethene

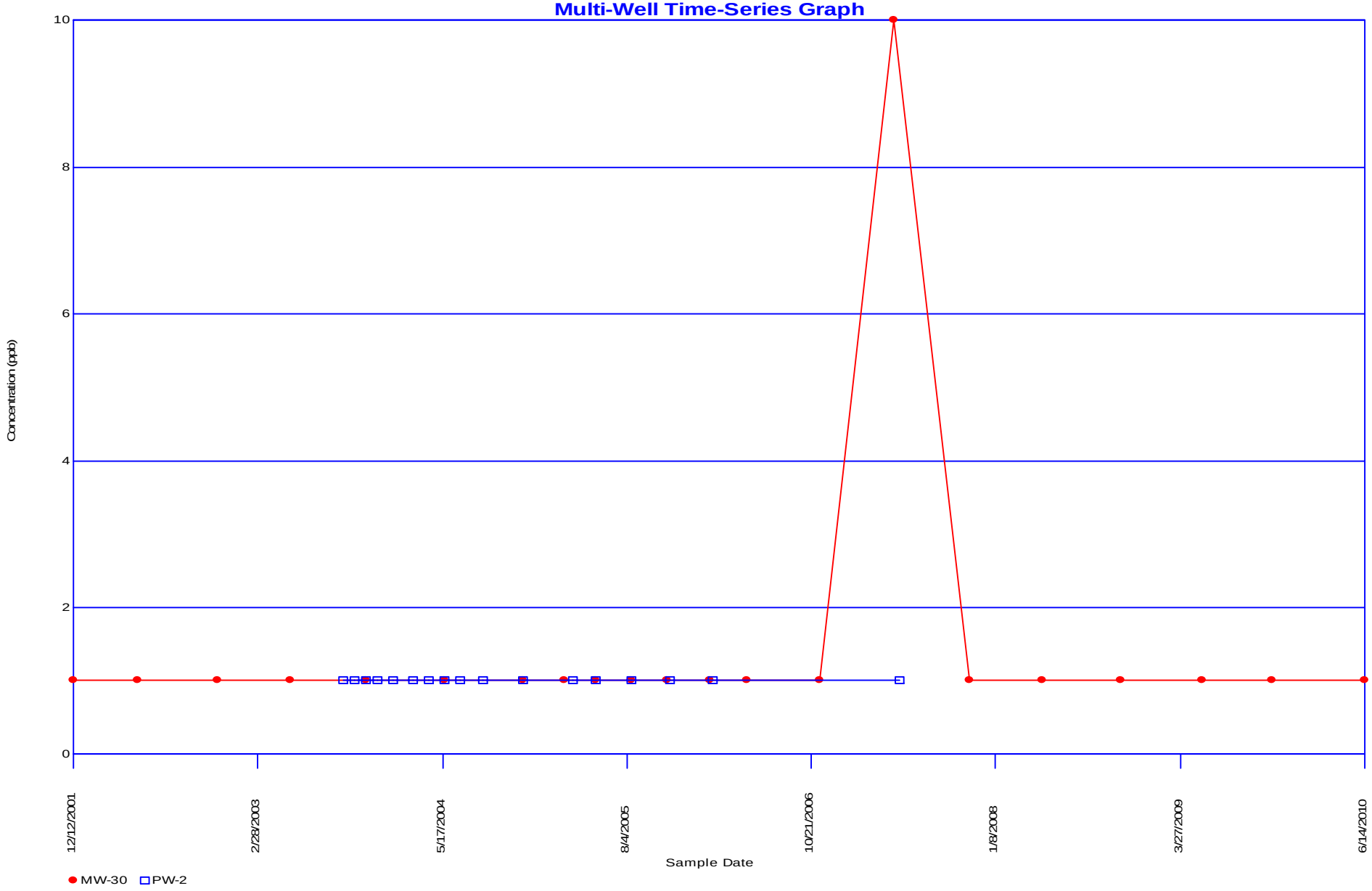
Multi-Well Time-Series Graph



Central Sanitary Landfill

Tetrachloroethene

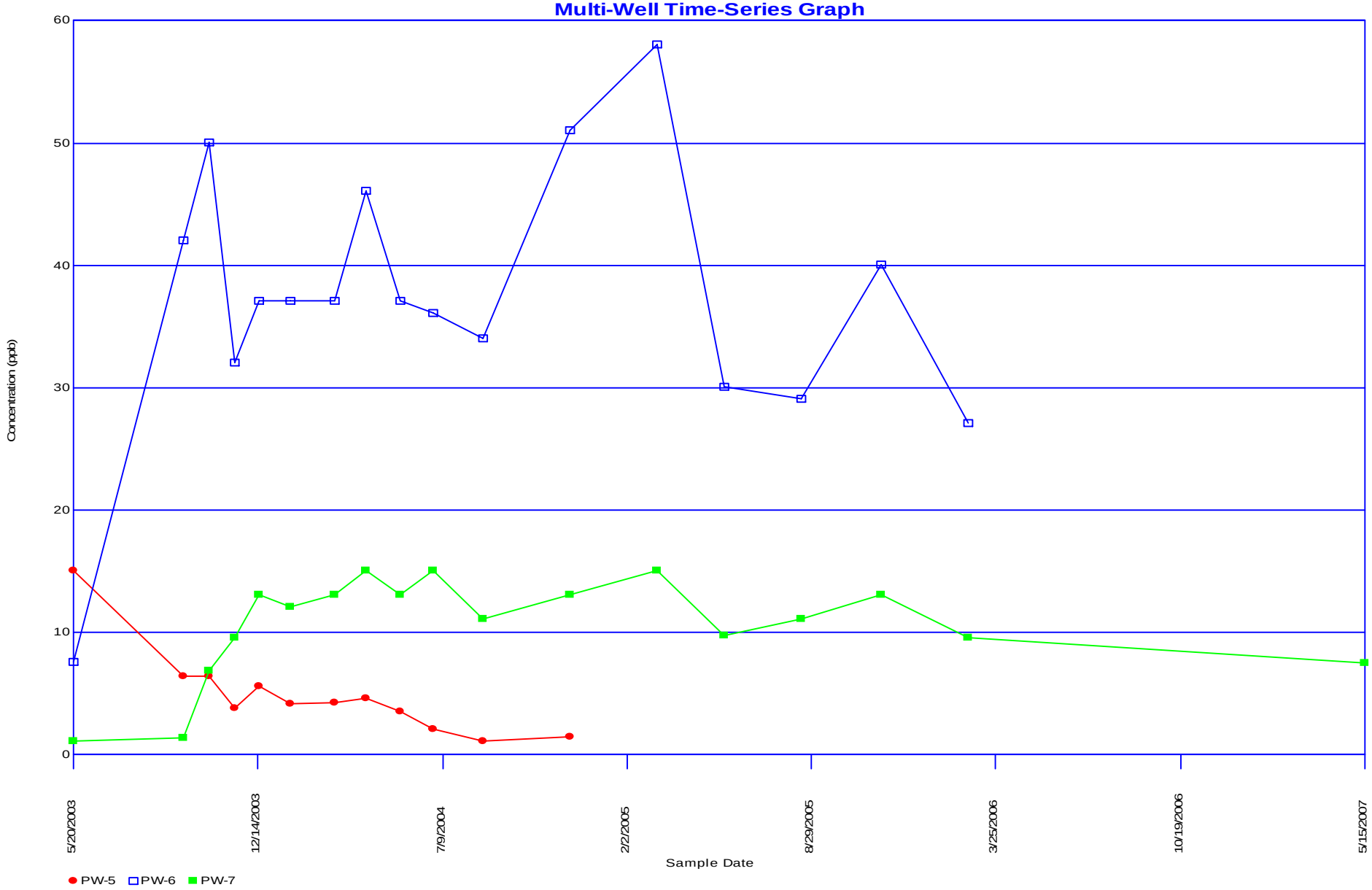
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,1-Dichloroethane

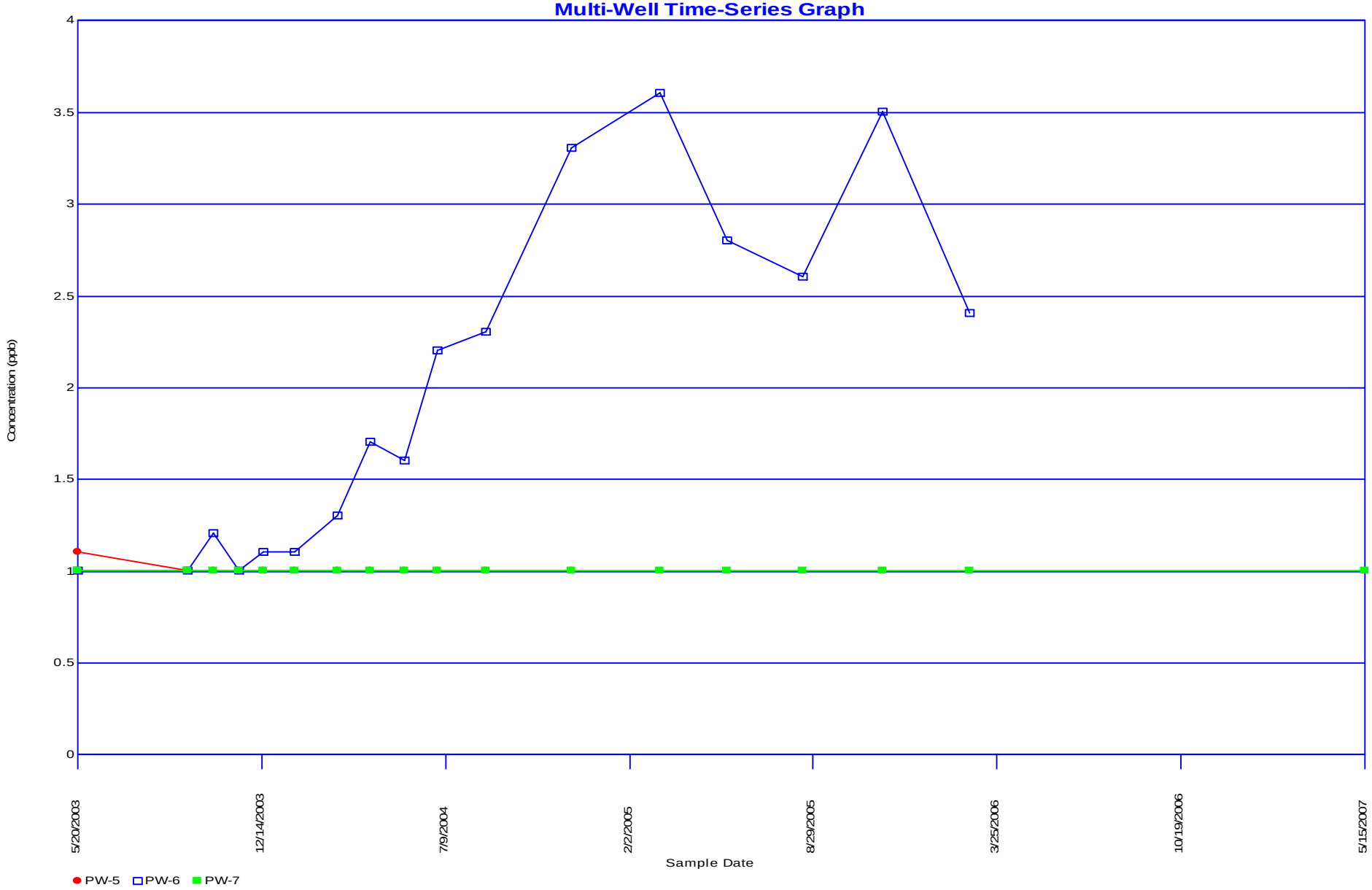
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,2-Dichloroethane

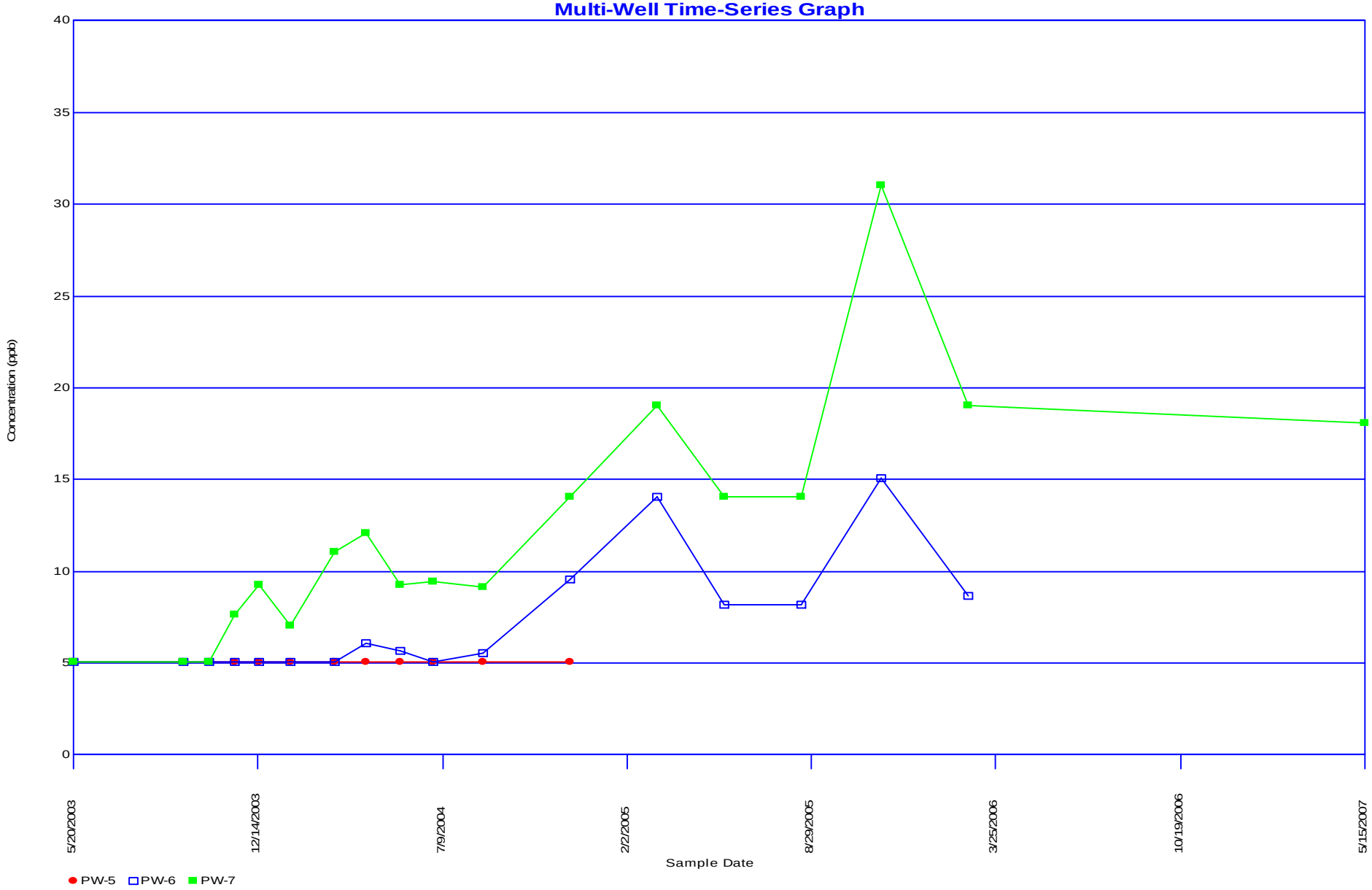
Multi-Well Time-Series Graph



Central Sanitary Landfill

Chloroethane

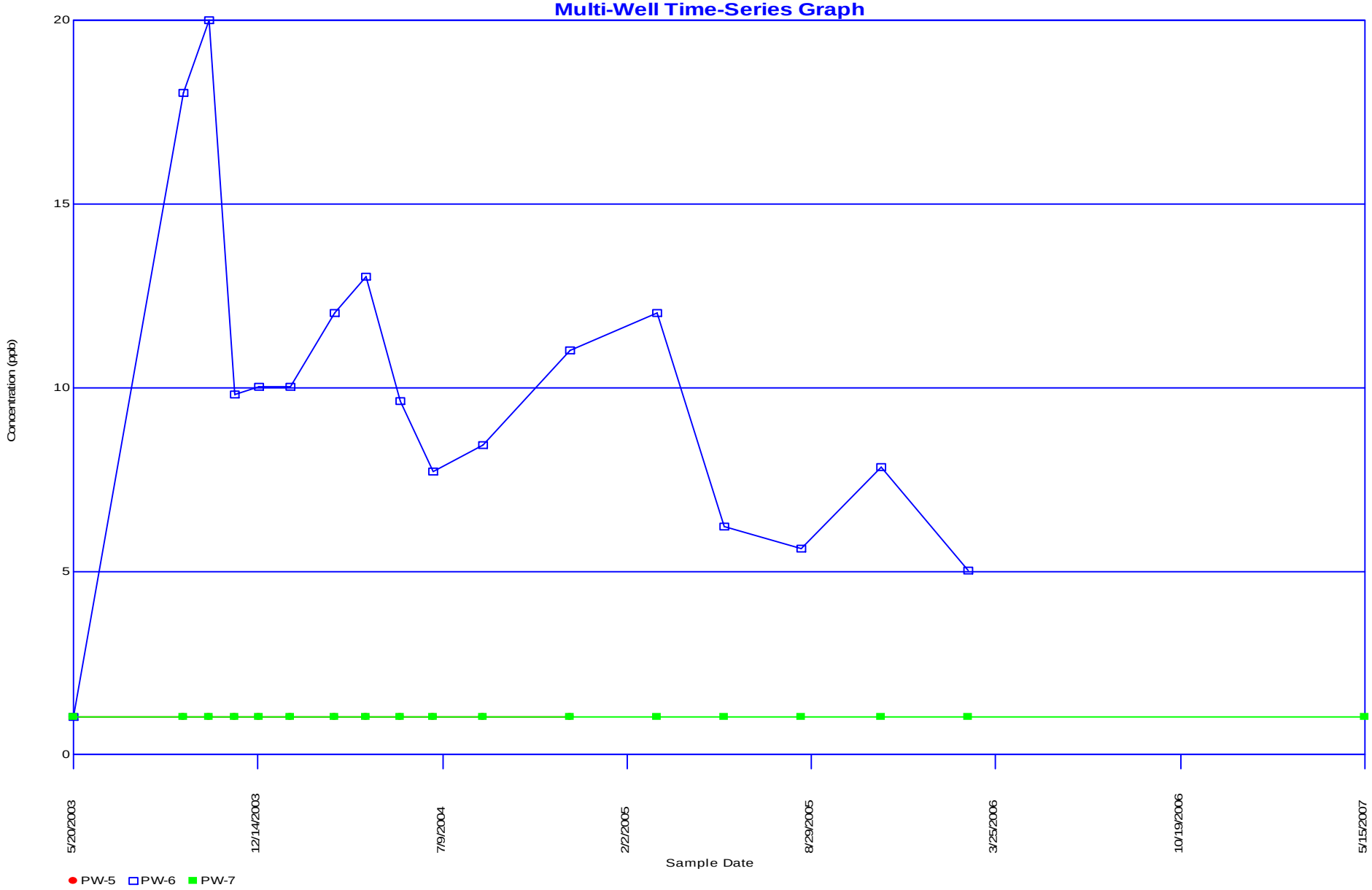
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,1-Dichloroethene

Multi-Well Time-Series Graph



Central Sanitary Landfill

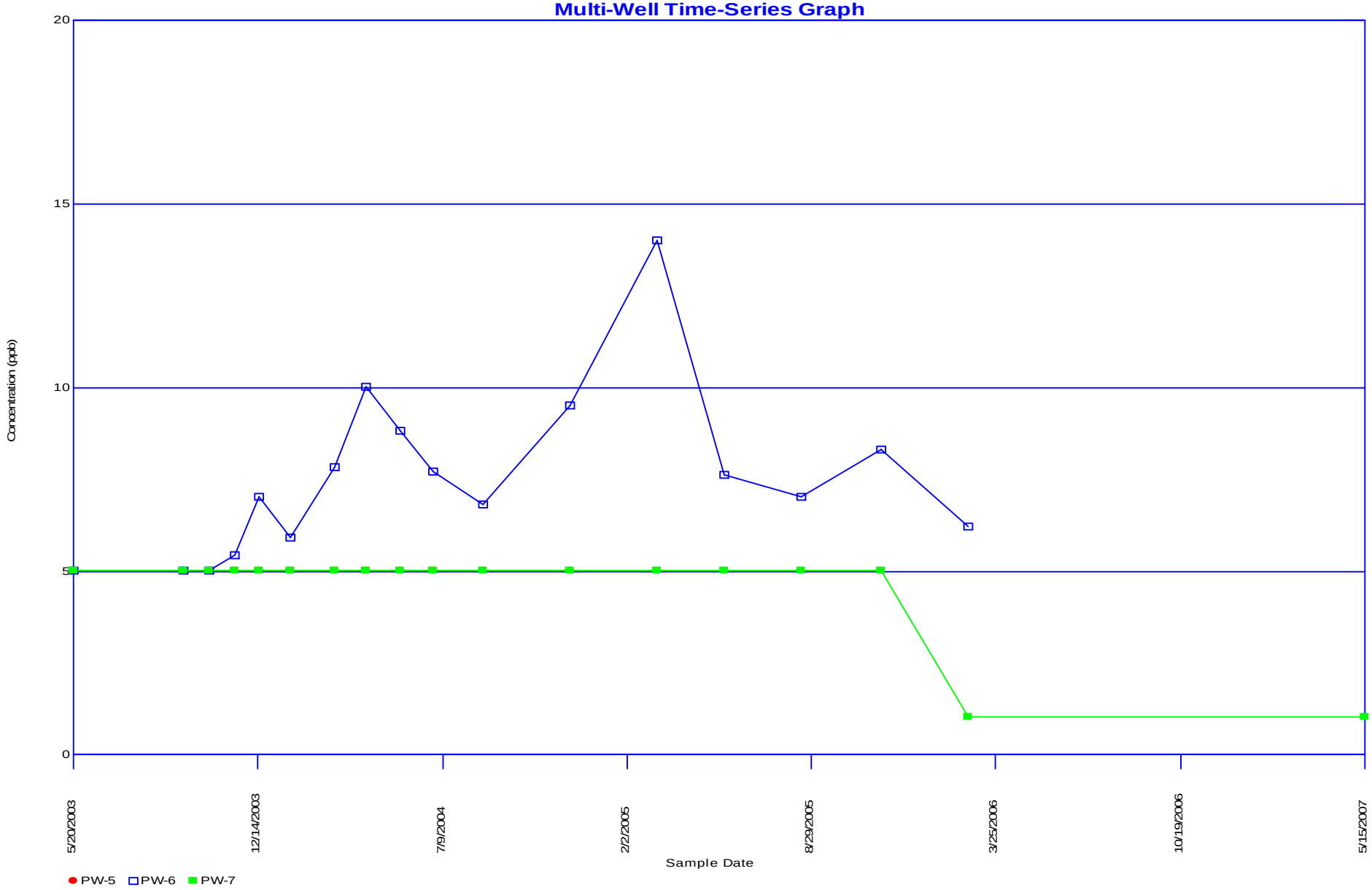
cis-1,2-Dichloroethene

Multi-Well Time-Series Graph

Central Sanitary Landfill

Vinyl Chloride

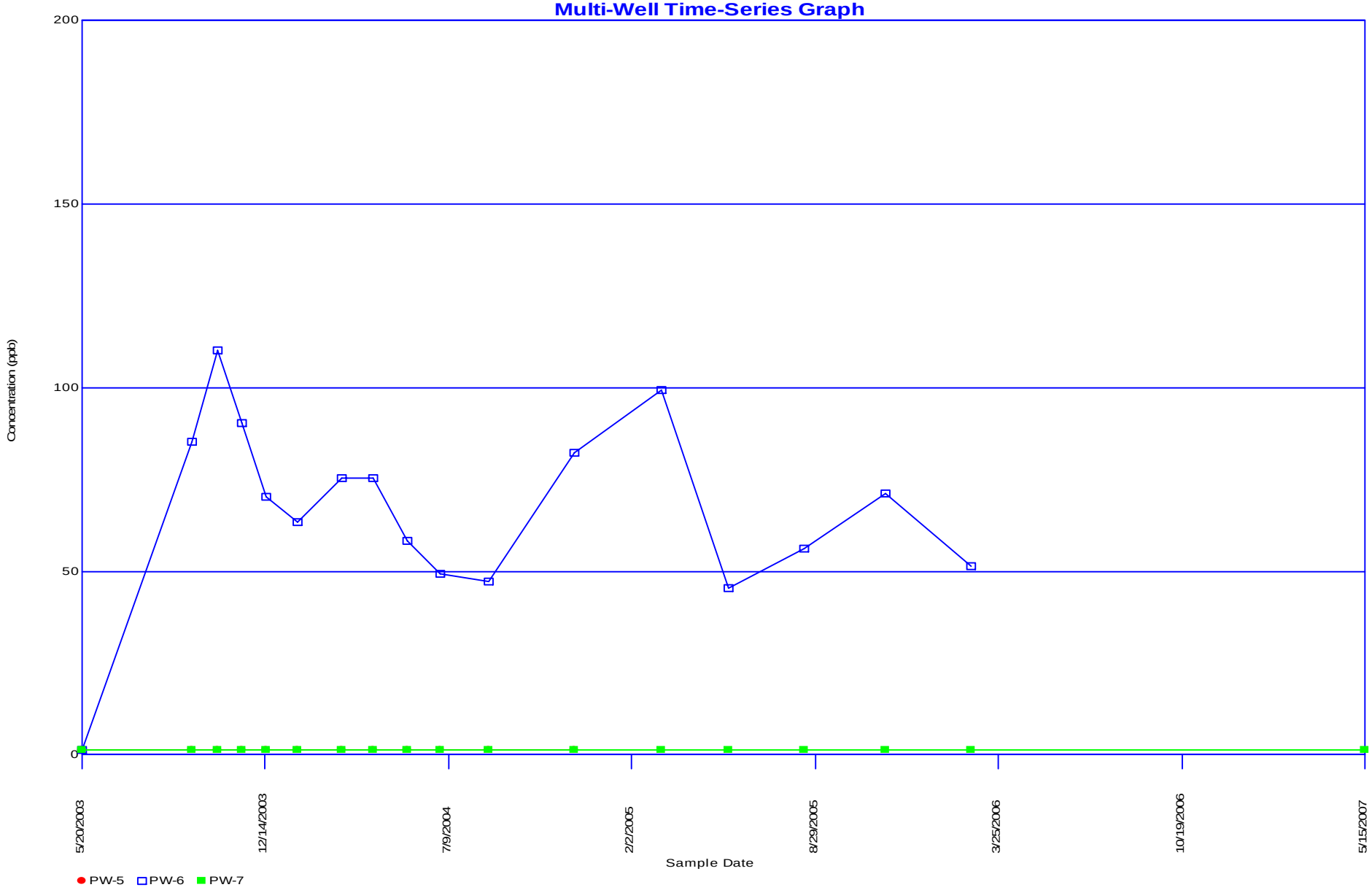
Multi-Well Time-Series Graph



Central Sanitary Landfill

Trichloroethene

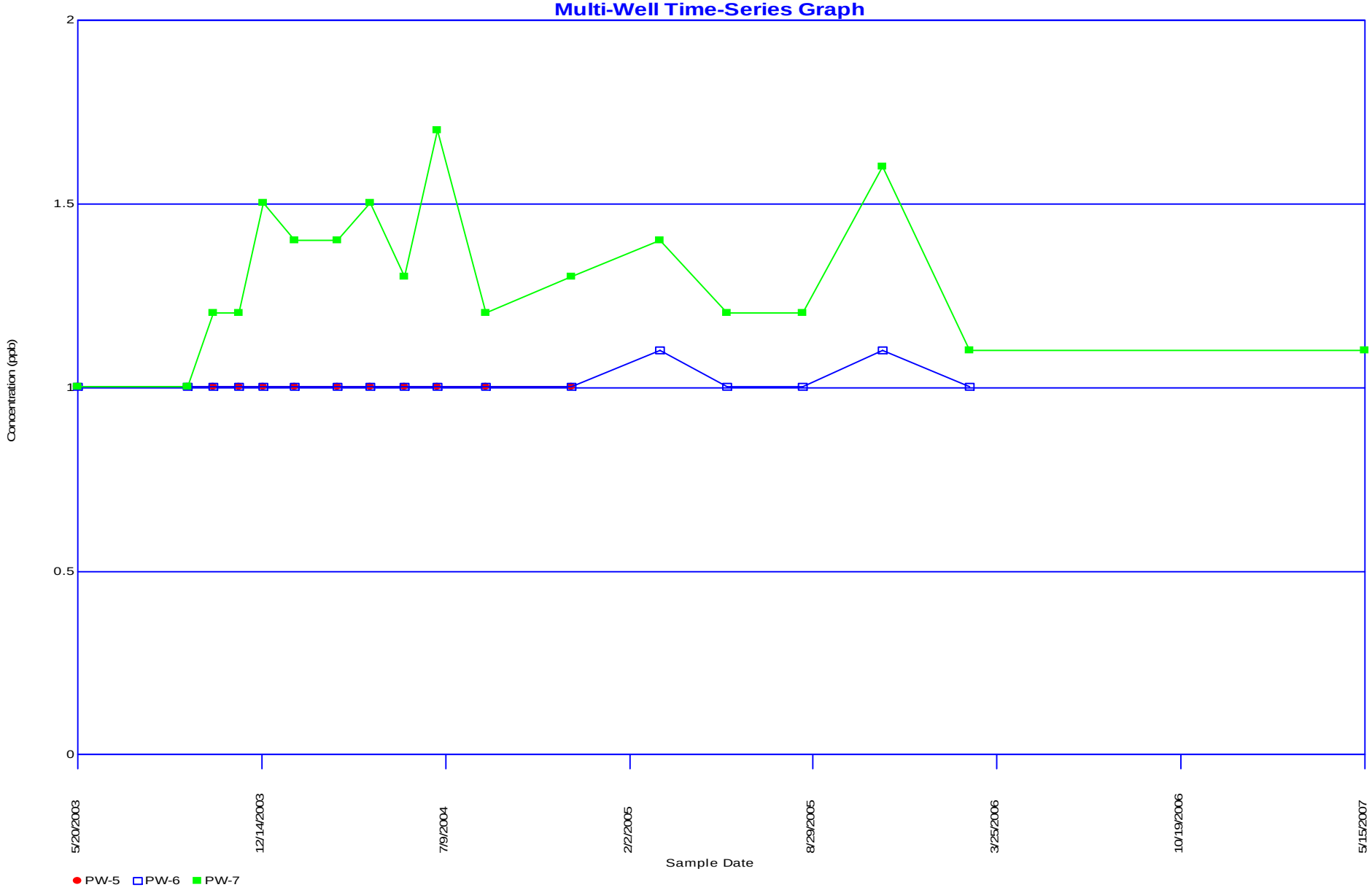
Multi-Well Time-Series Graph



Central Sanitary Landfill

Benzene

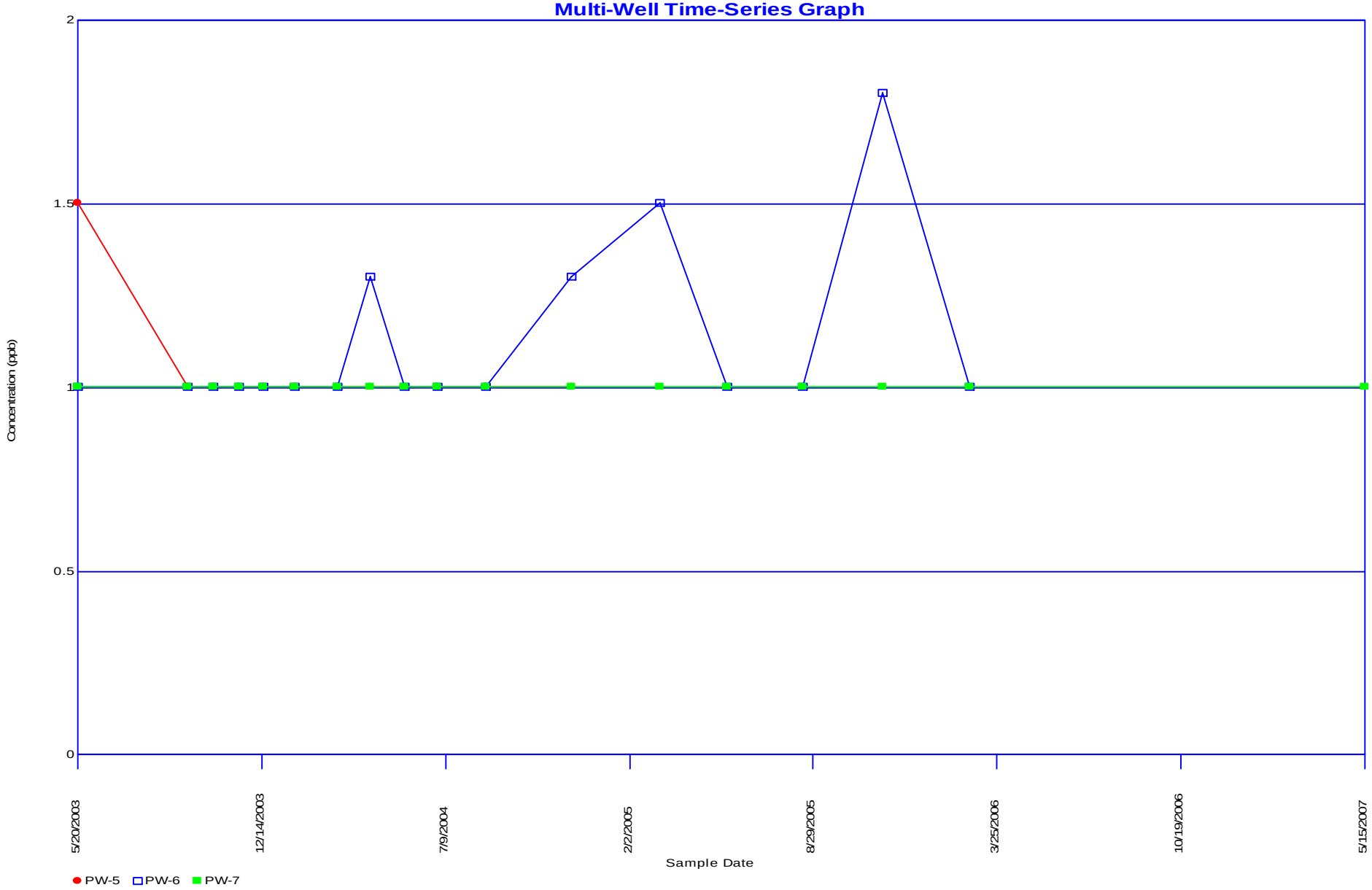
Multi-Well Time-Series Graph



Central Sanitary Landfill

trans-1,2-Dichloroethene

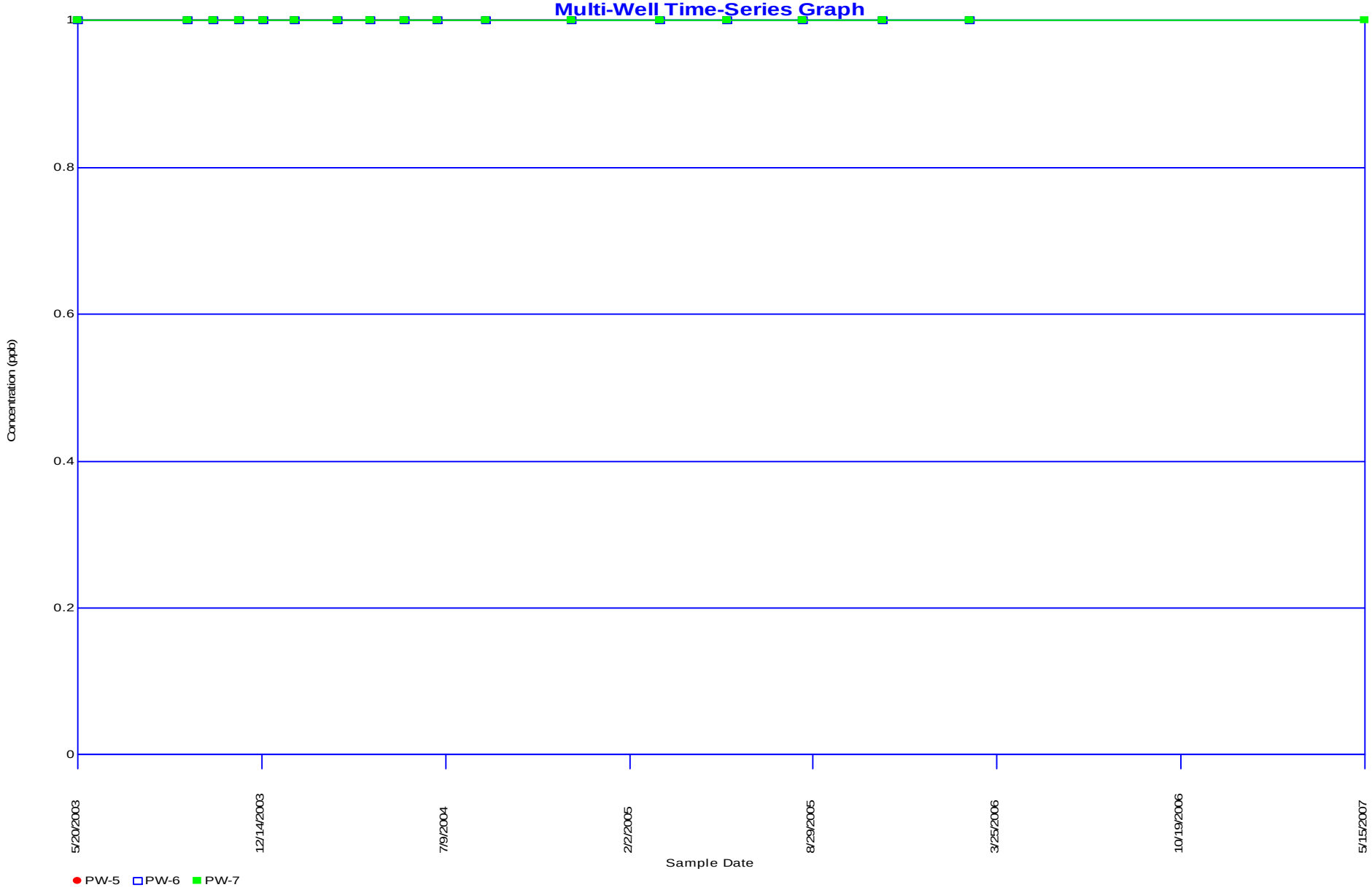
Multi-Well Time-Series Graph



Central Sanitary Landfill

Tetrachloroethene

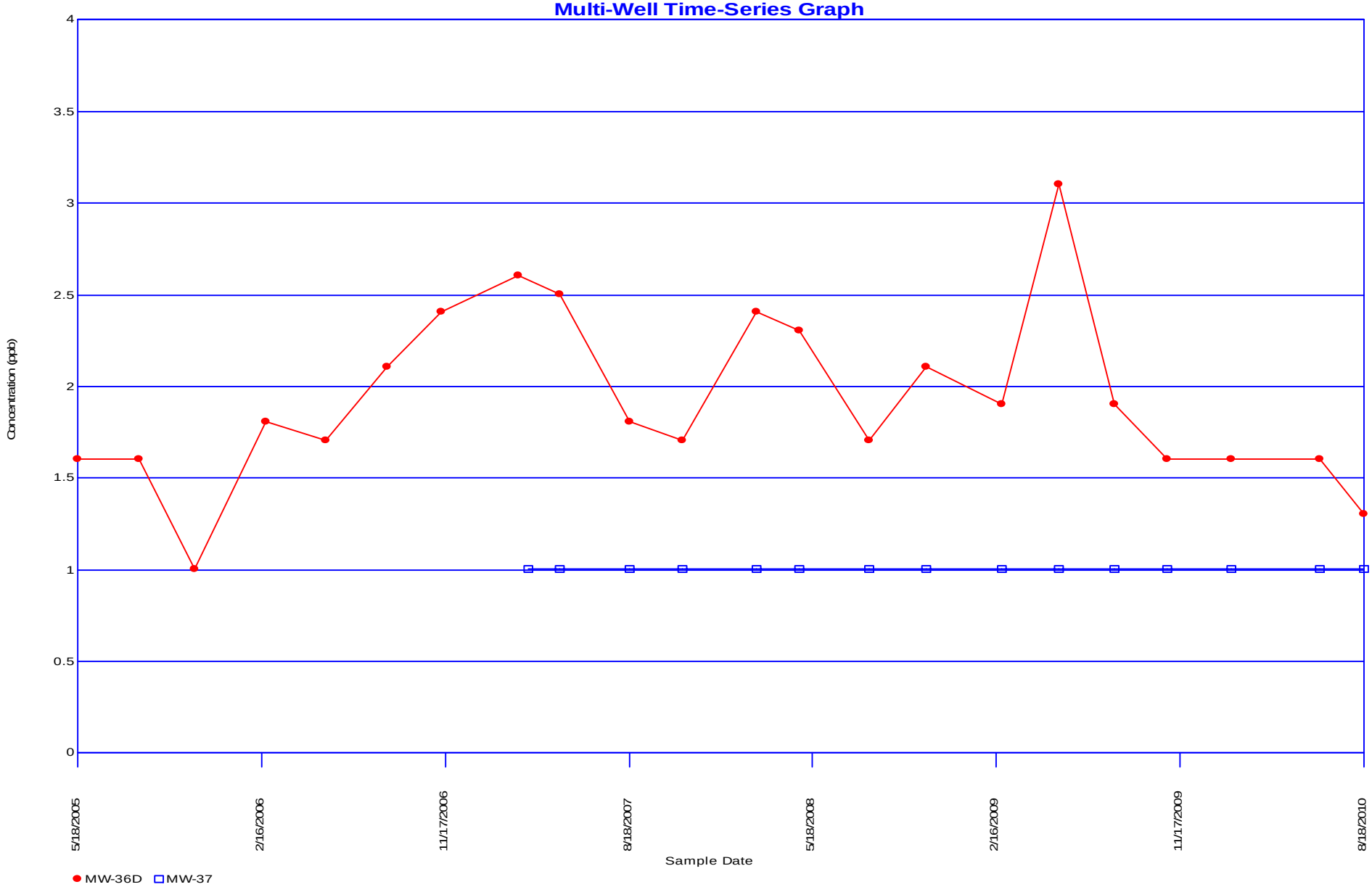
Multi-Well Time-Series Graph



Central Sanitary Landfill

1,1-Dichloroethane

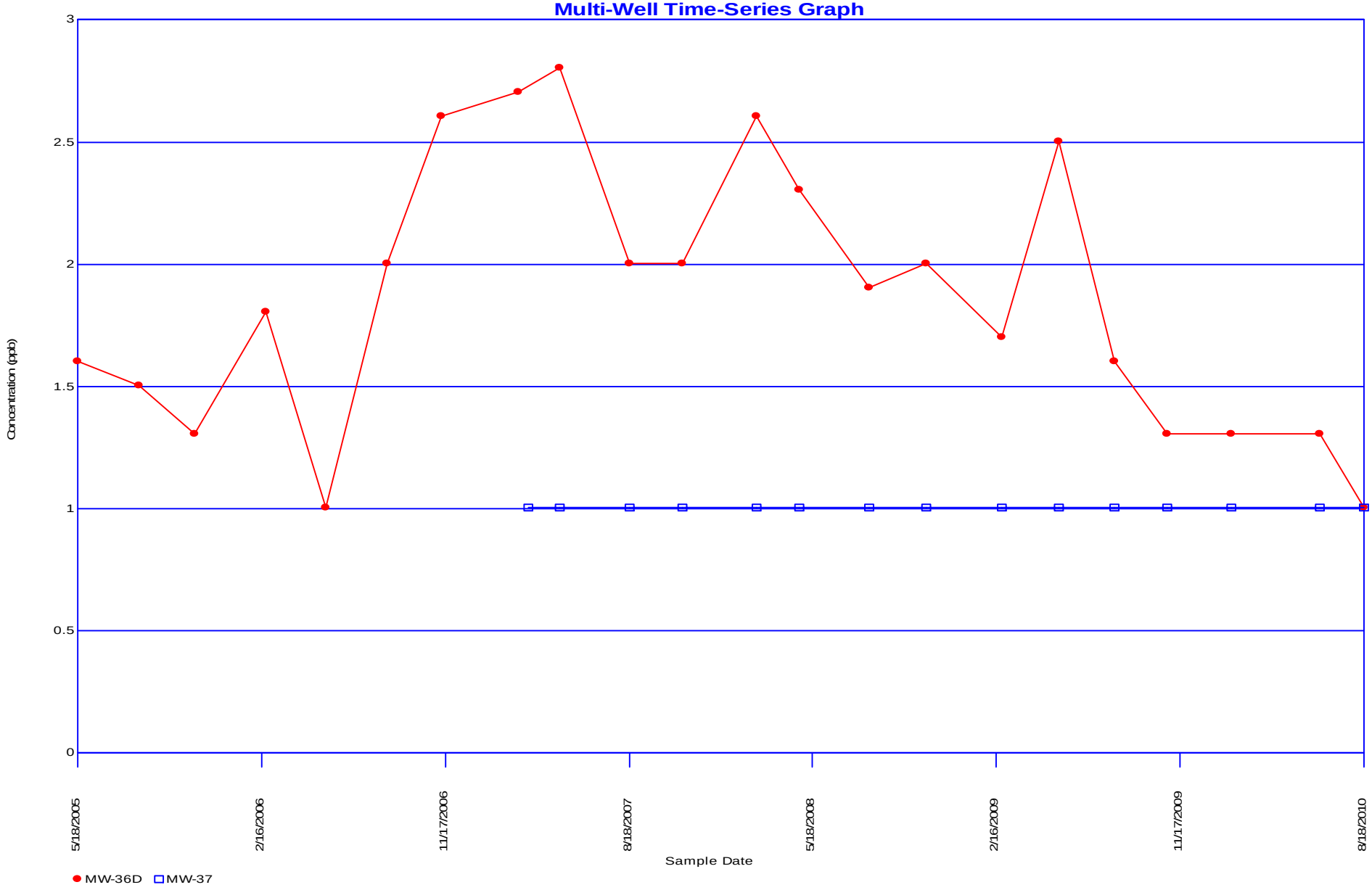
Multi-Well Time-Series Graph



Central Sanitary Landfill

cis-1,2-Dichloroethene

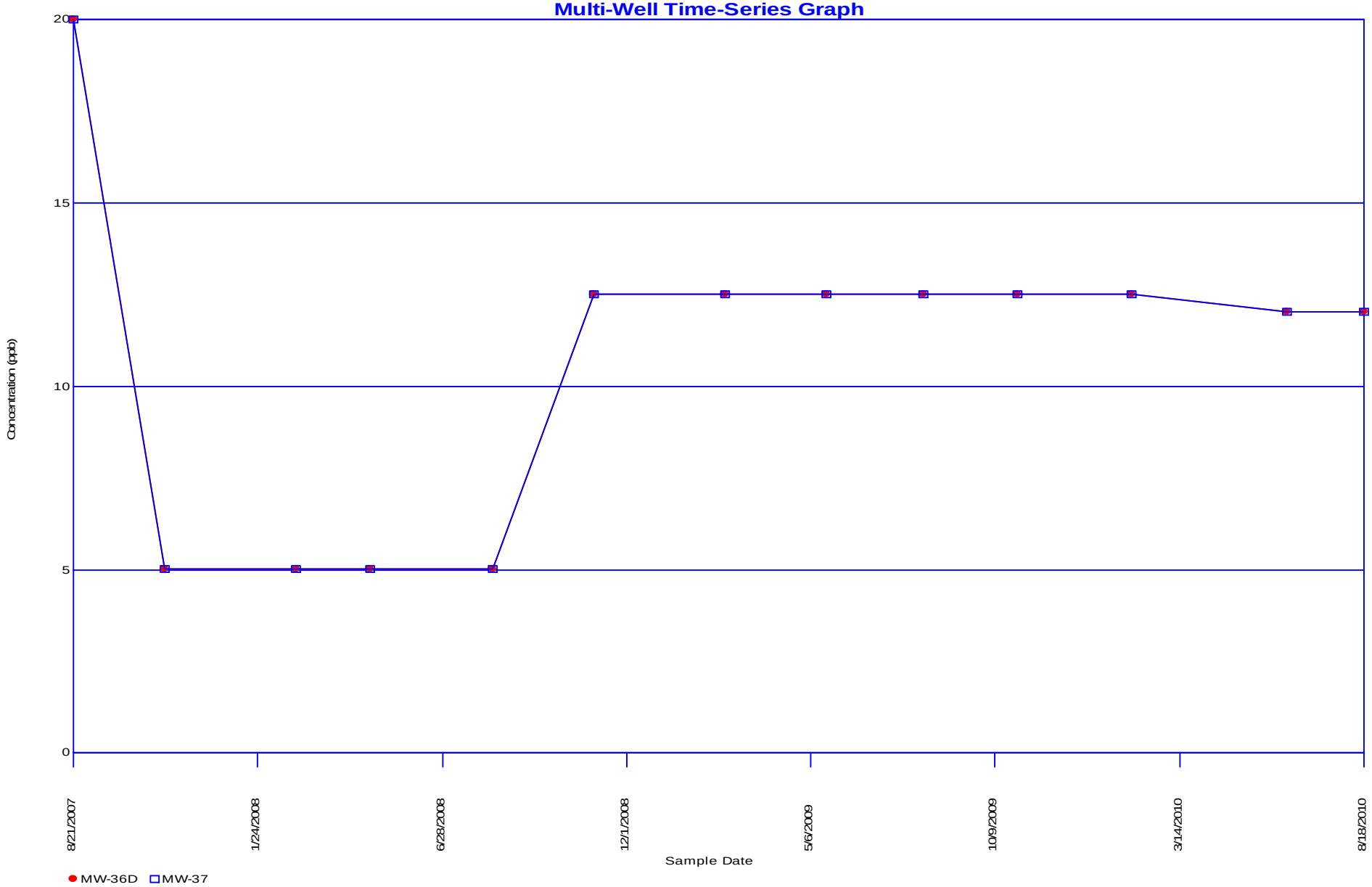
Multi-Well Time-Series Graph



Central Sanitary Landfill

Tetrahydrofuran

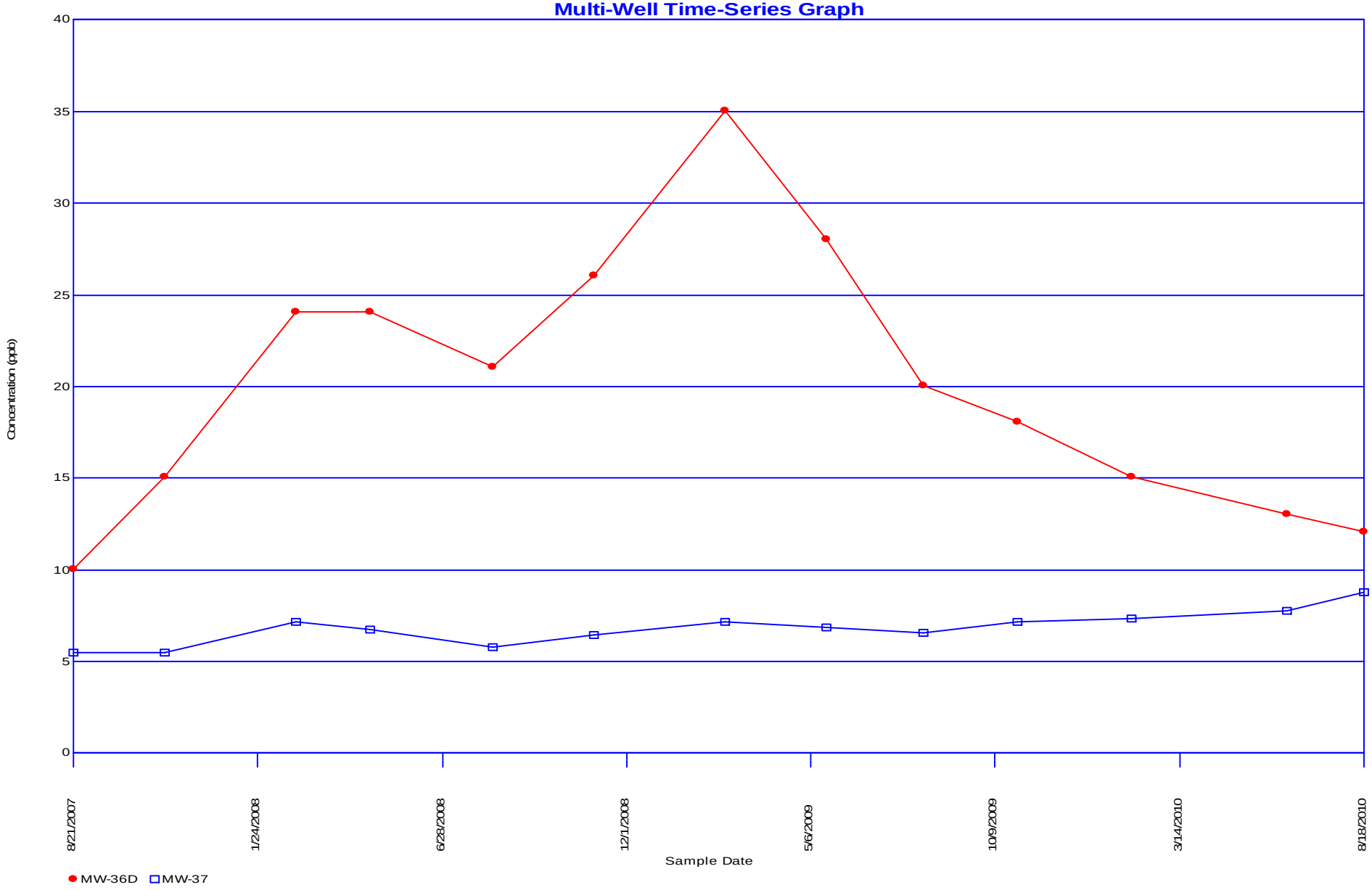
Multi-Well Time-Series Graph



Central Sanitary Landfill

Diethyl Ether

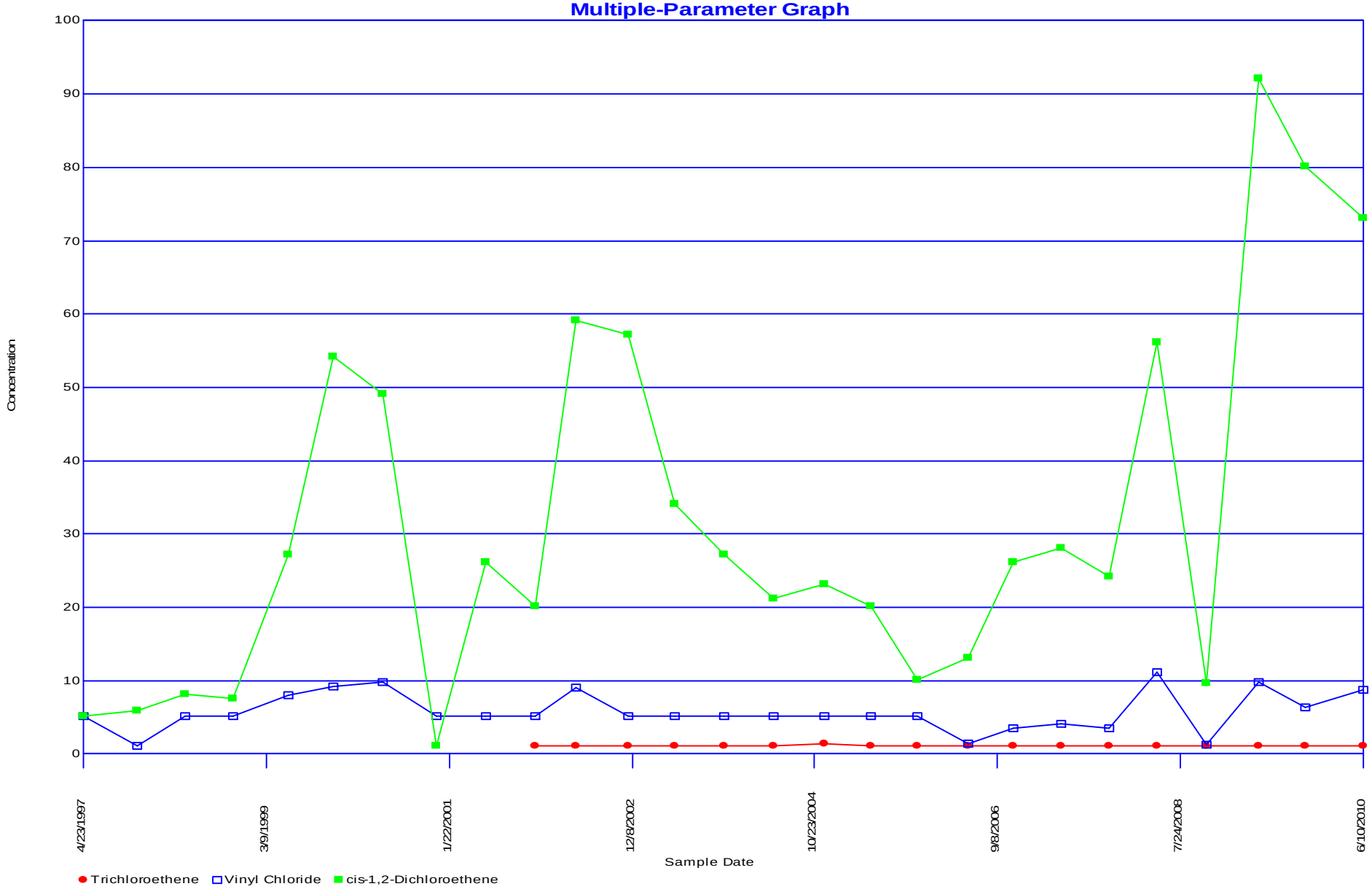
Multi-Well Time-Series Graph



Central Sanitary Landfill

MW-5

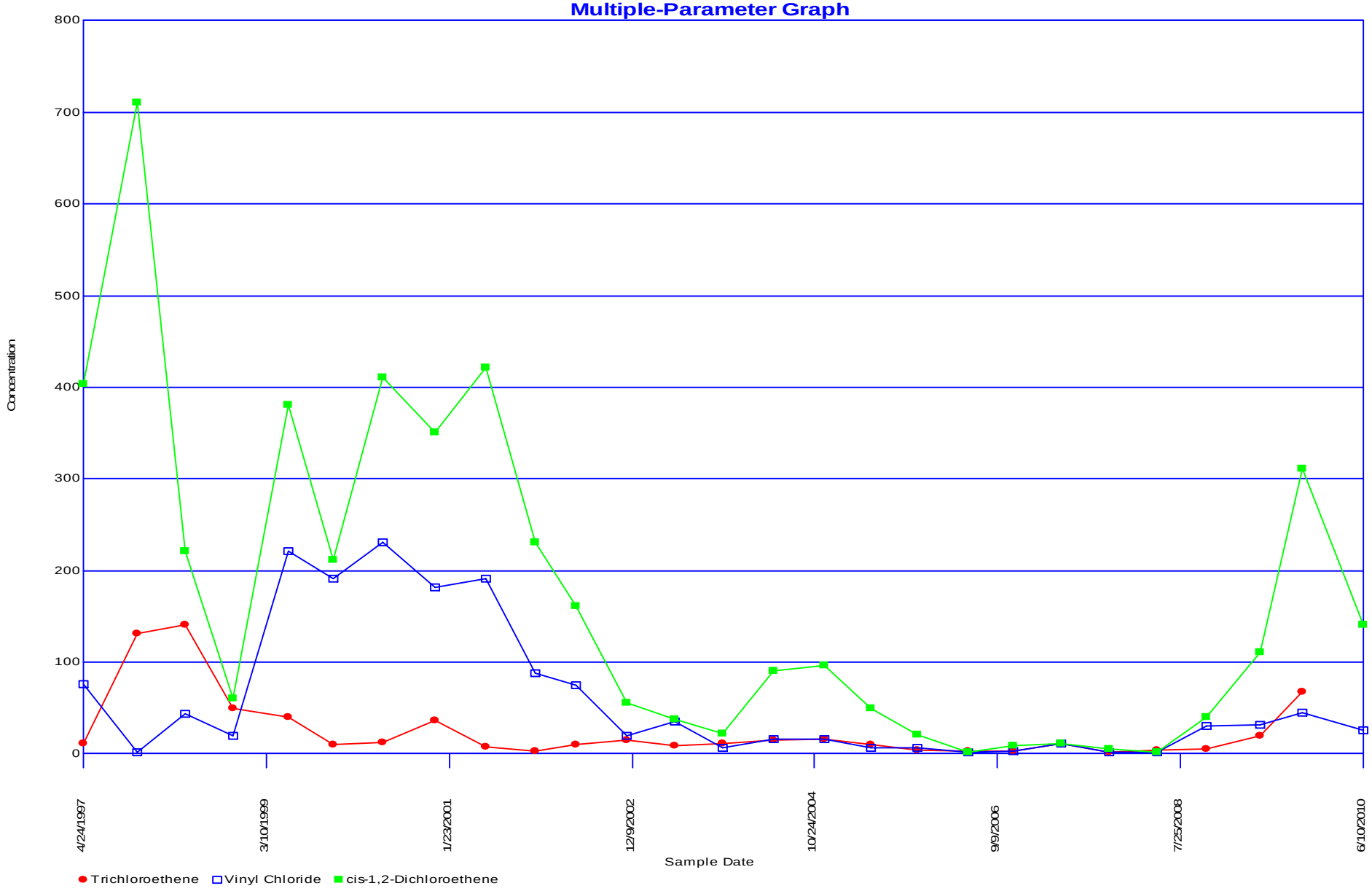
Multiple-Parameter Graph



Central Sanitary Landfill

MW-10N

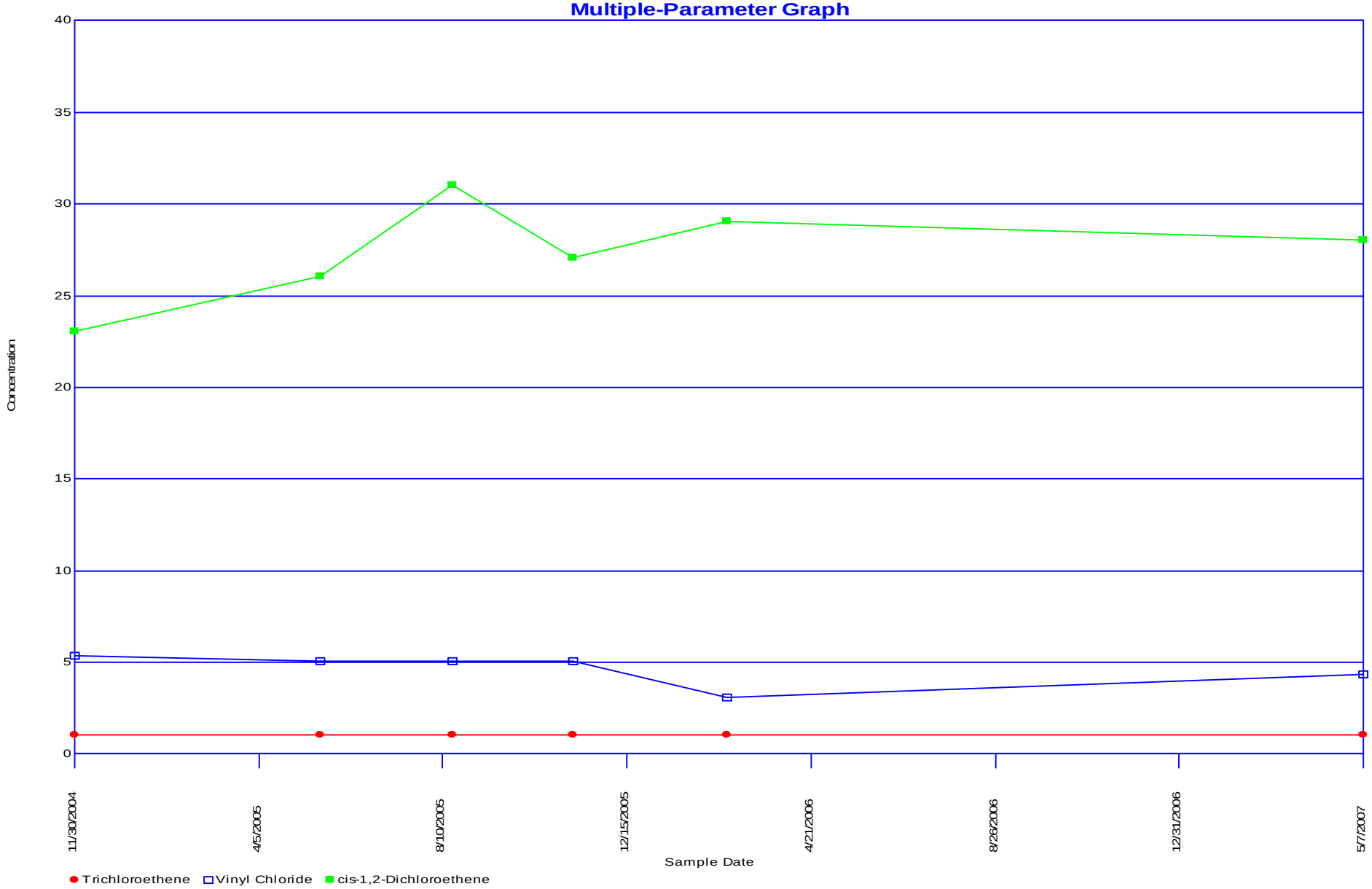
Multiple-Parameter Graph



Central Sanitary Landfill

MW-35D

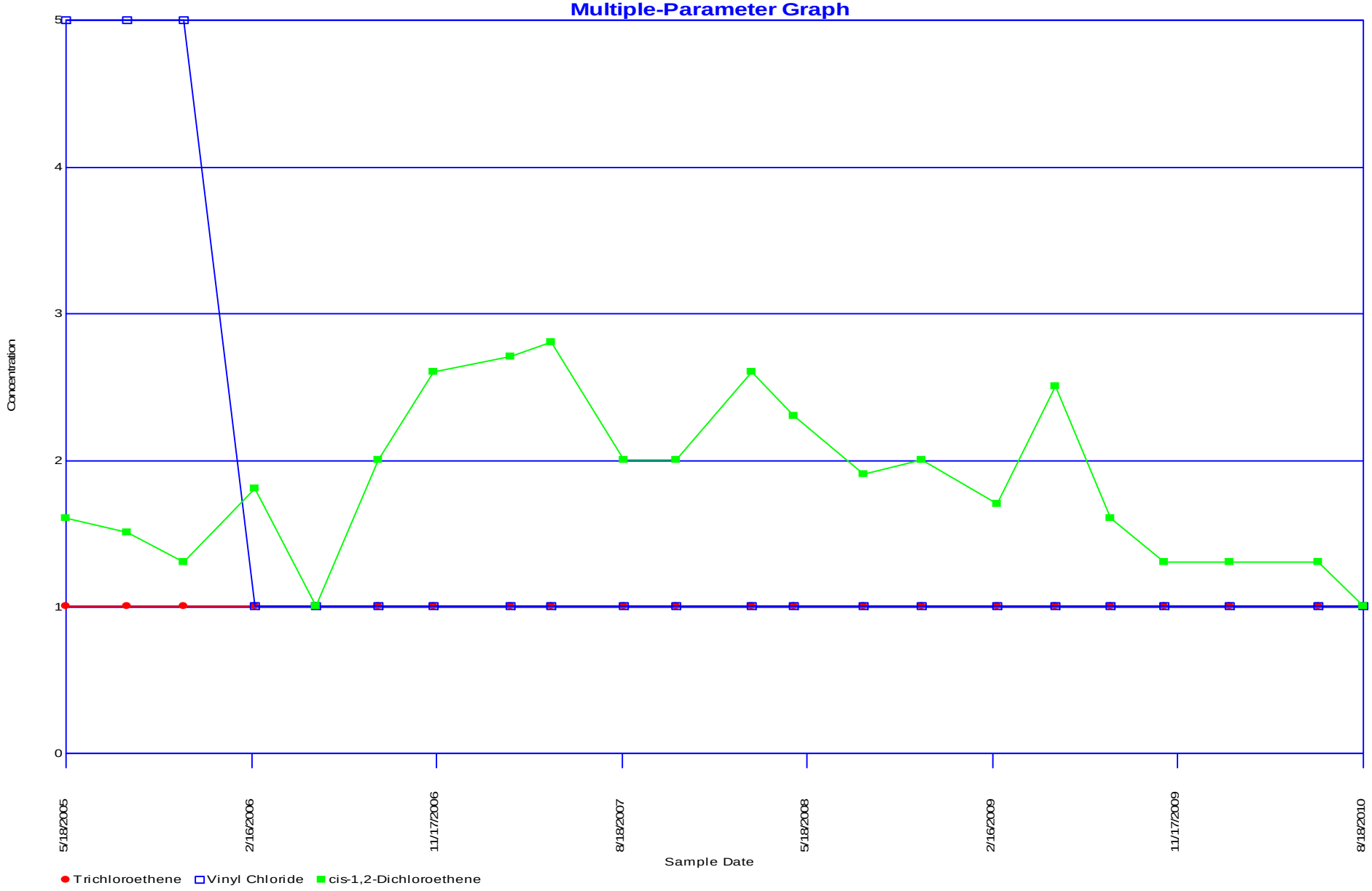
Multiple-Parameter Graph



Central Sanitary Landfill

MW-36D

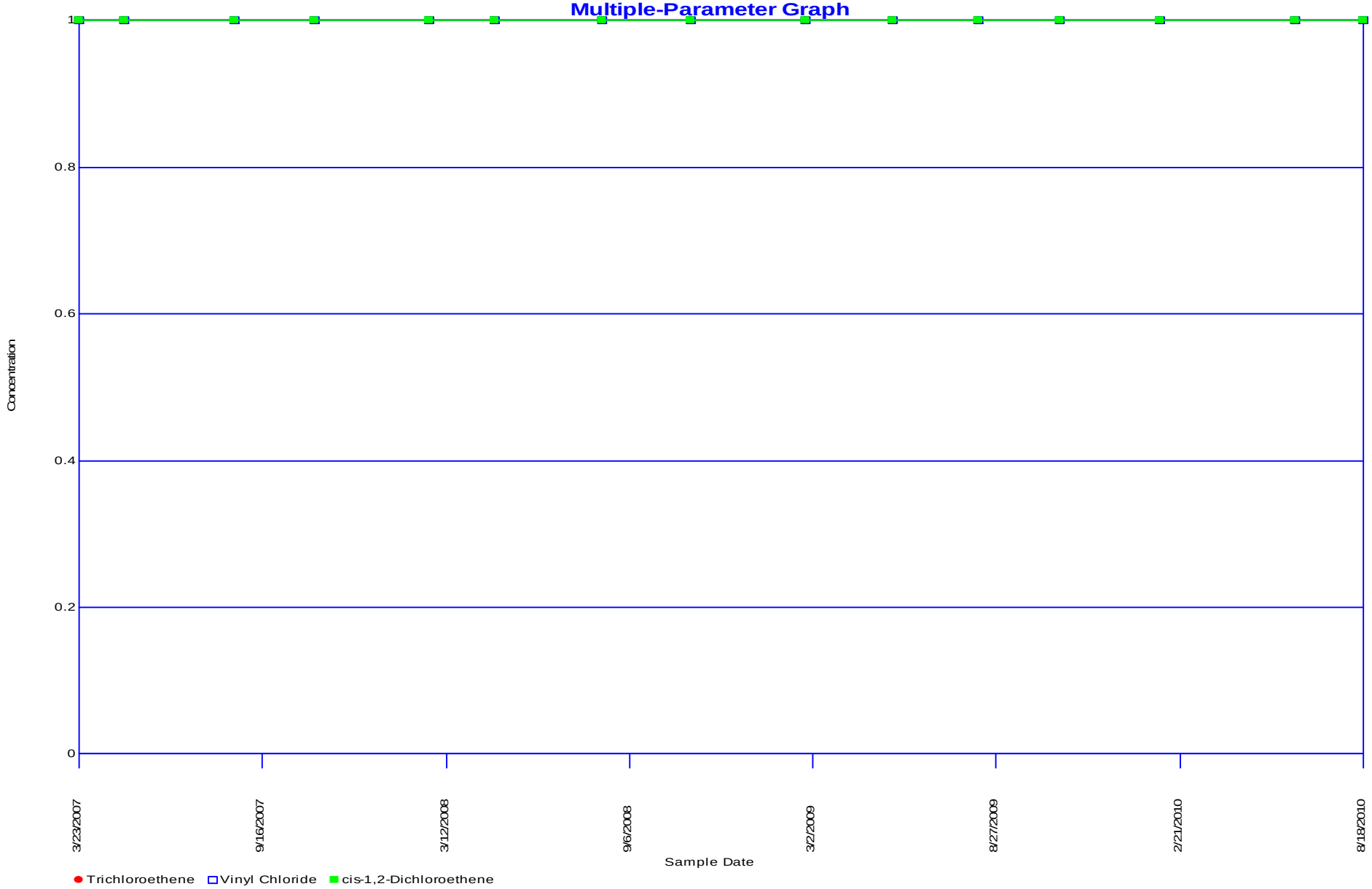
Multiple-Parameter Graph



Central Sanitary Landfill

MW-37

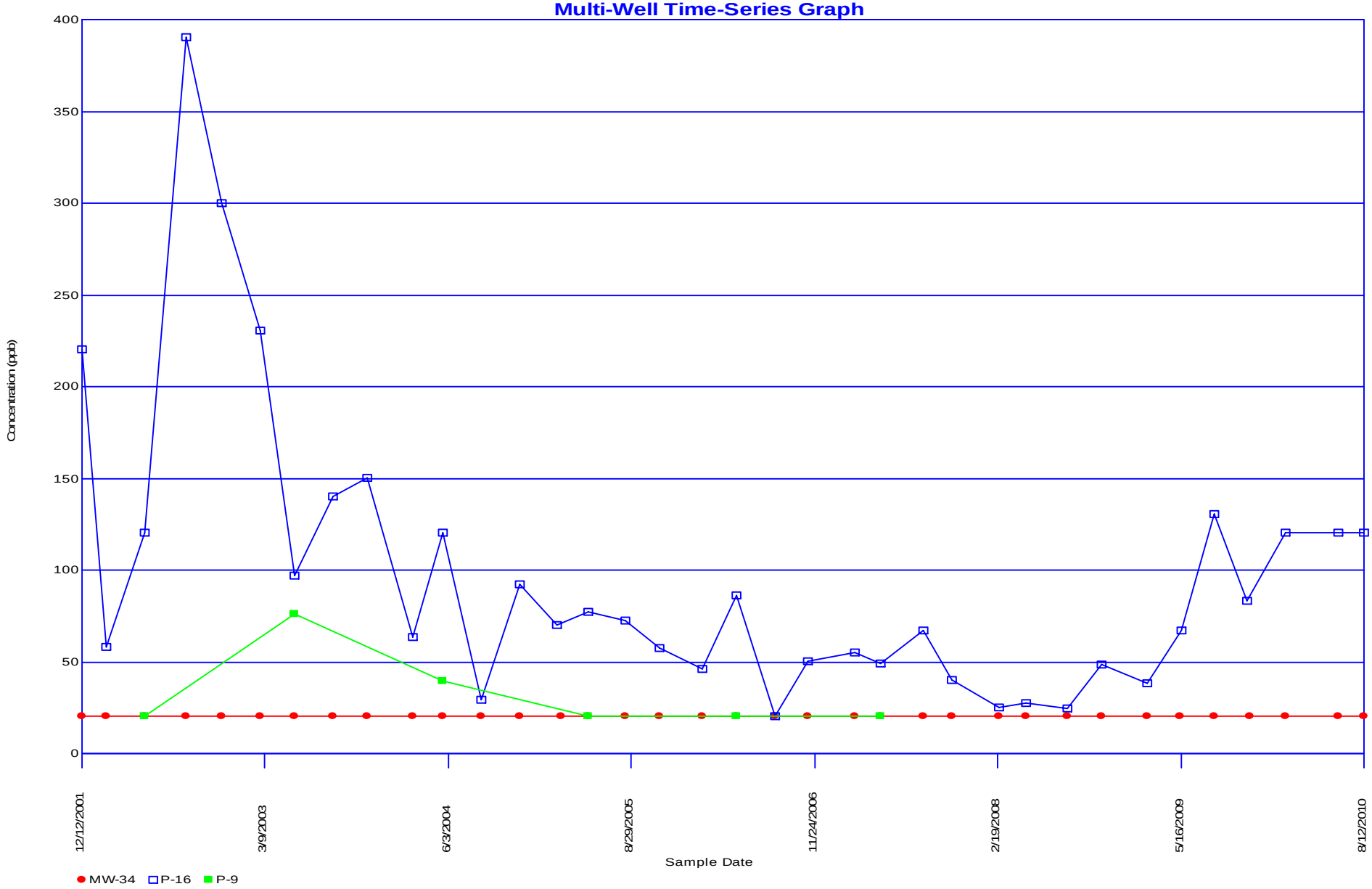
Multiple-Parameter Graph



Central Sanitary Landfill

Iron, Dissolved

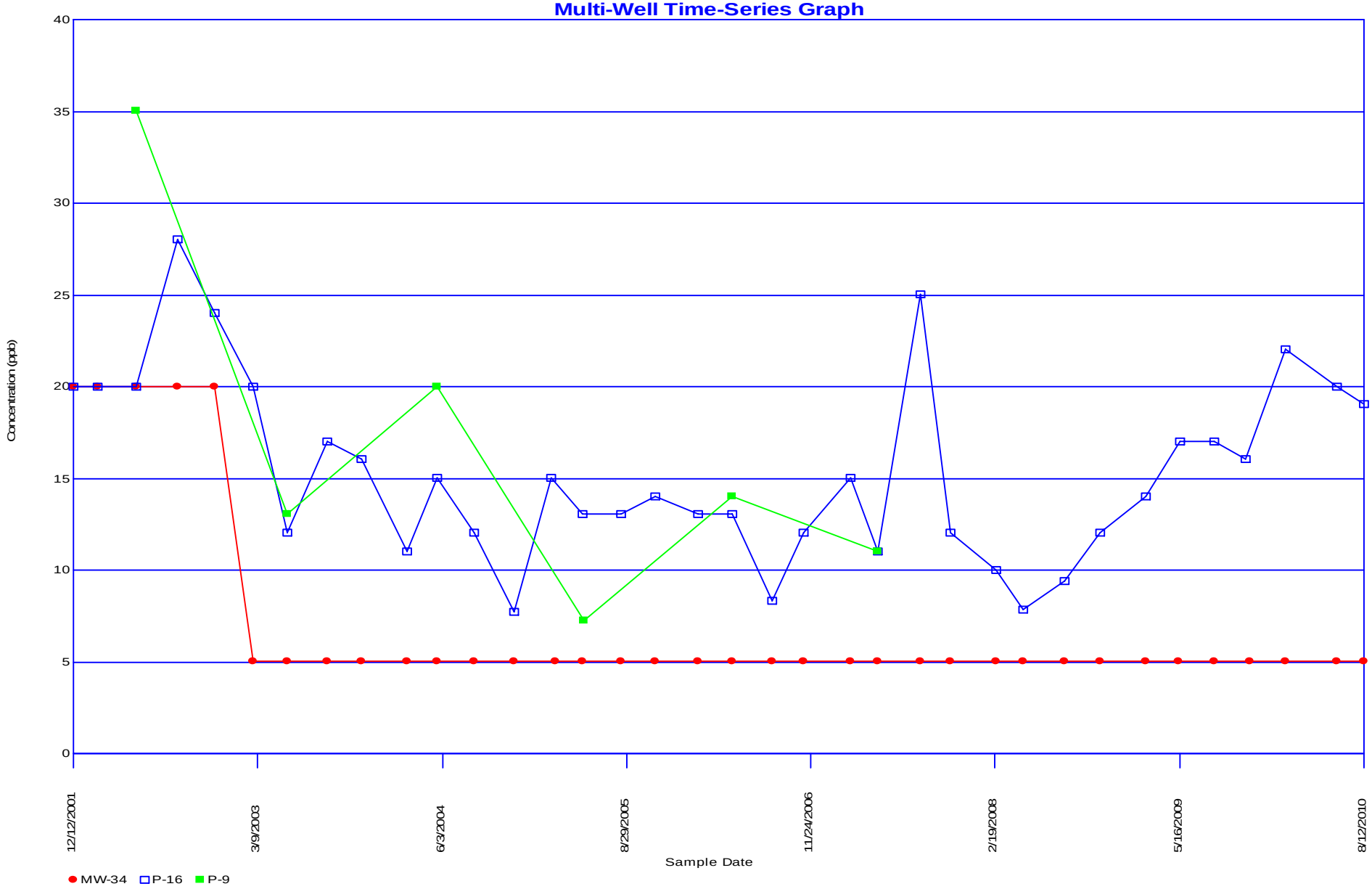
Multi-Well Time-Series Graph



Central Sanitary Landfill

Manganese, Dissolved

Multi-Well Time-Series Graph



Central Sanitary Landfill

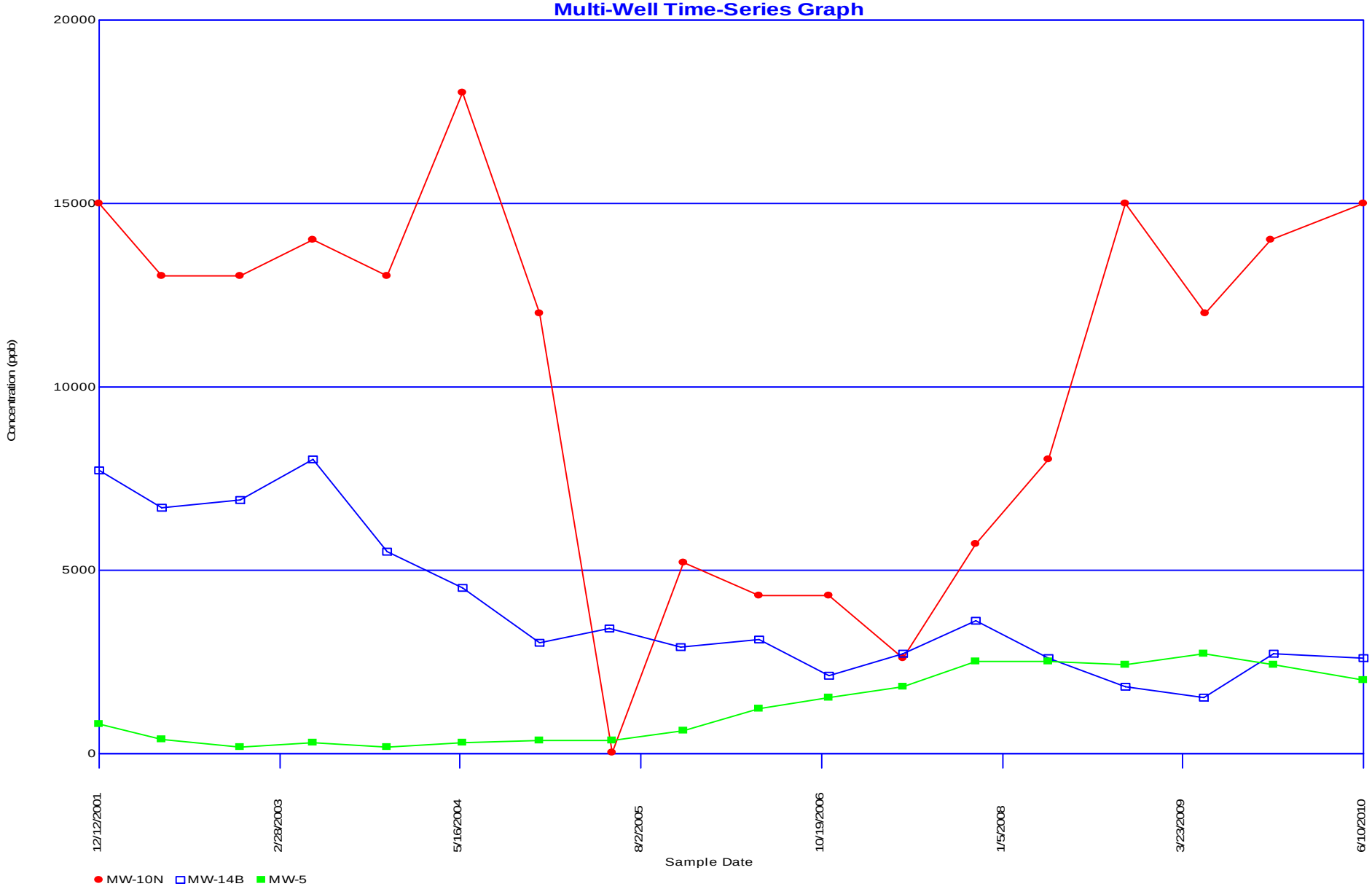
Dissolved Solids

Multi-Well Time-Series Graph

Central Sanitary Landfill

Iron, Dissolved

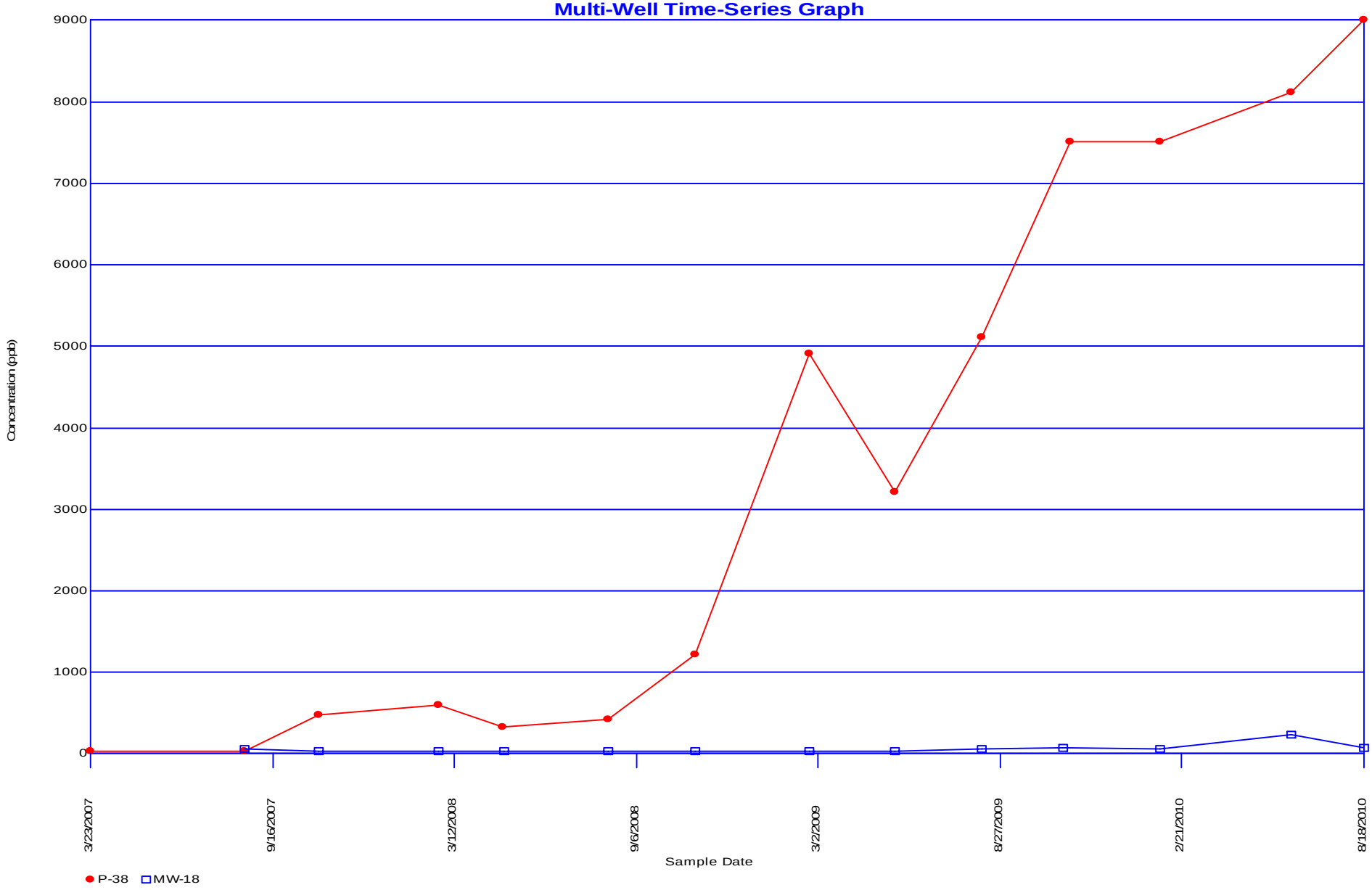
Multi-Well Time-Series Graph



Central Sanitary Landfill

Iron, Dissolved

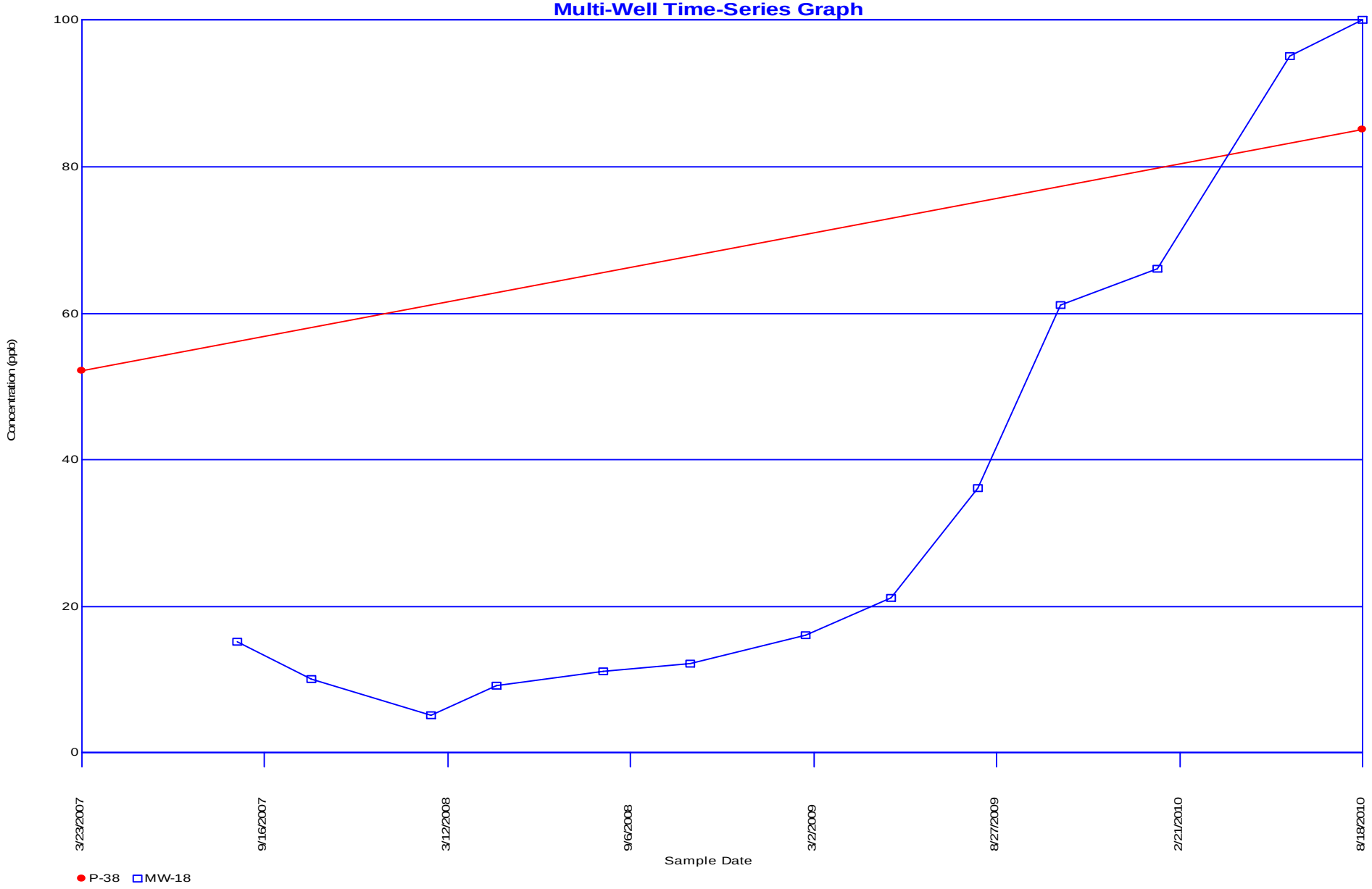
Multi-Well Time-Series Graph



Central Sanitary Landfill

Manganese, Dissolved

Multi-Well Time-Series Graph



Iron, Dissolved

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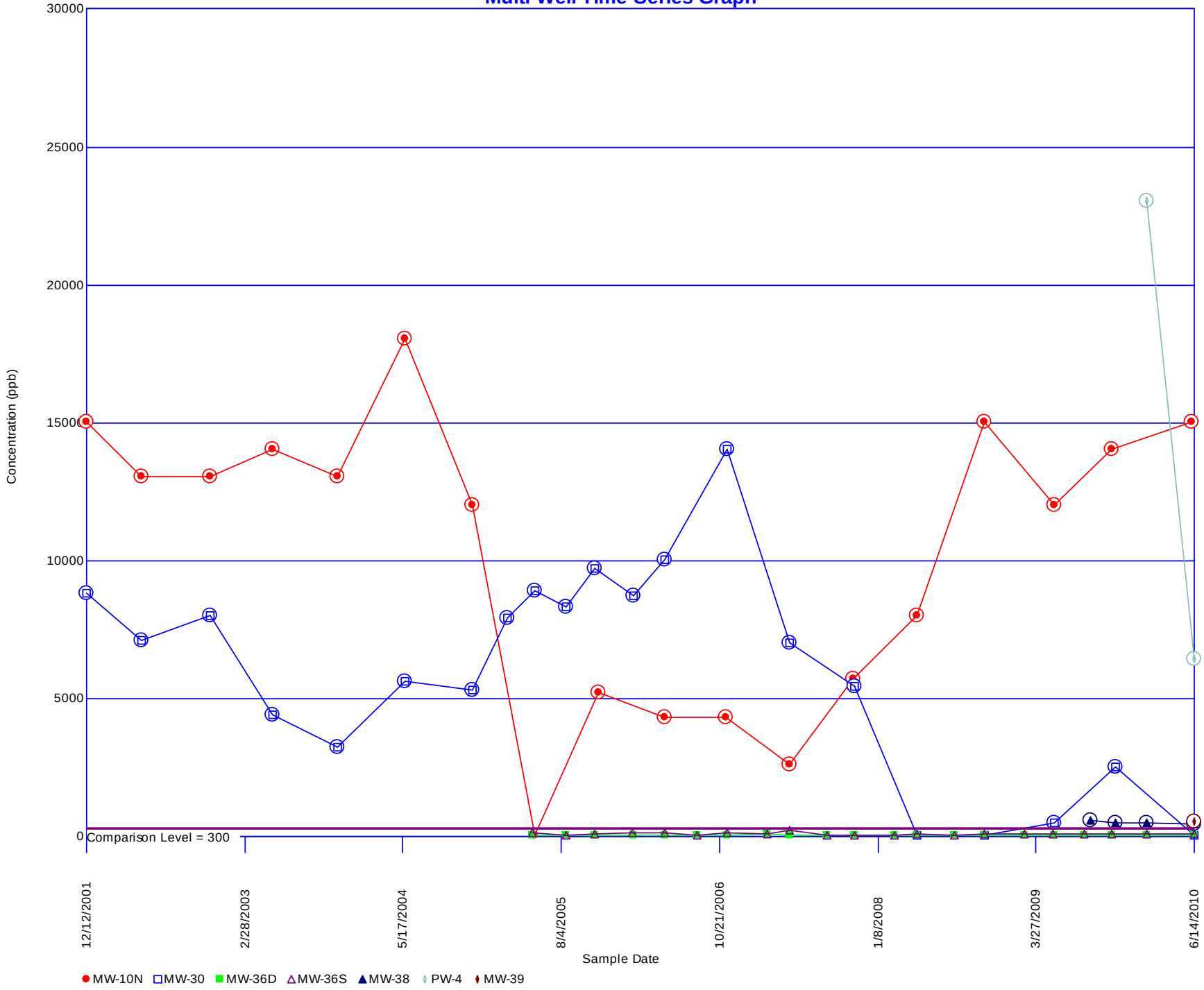
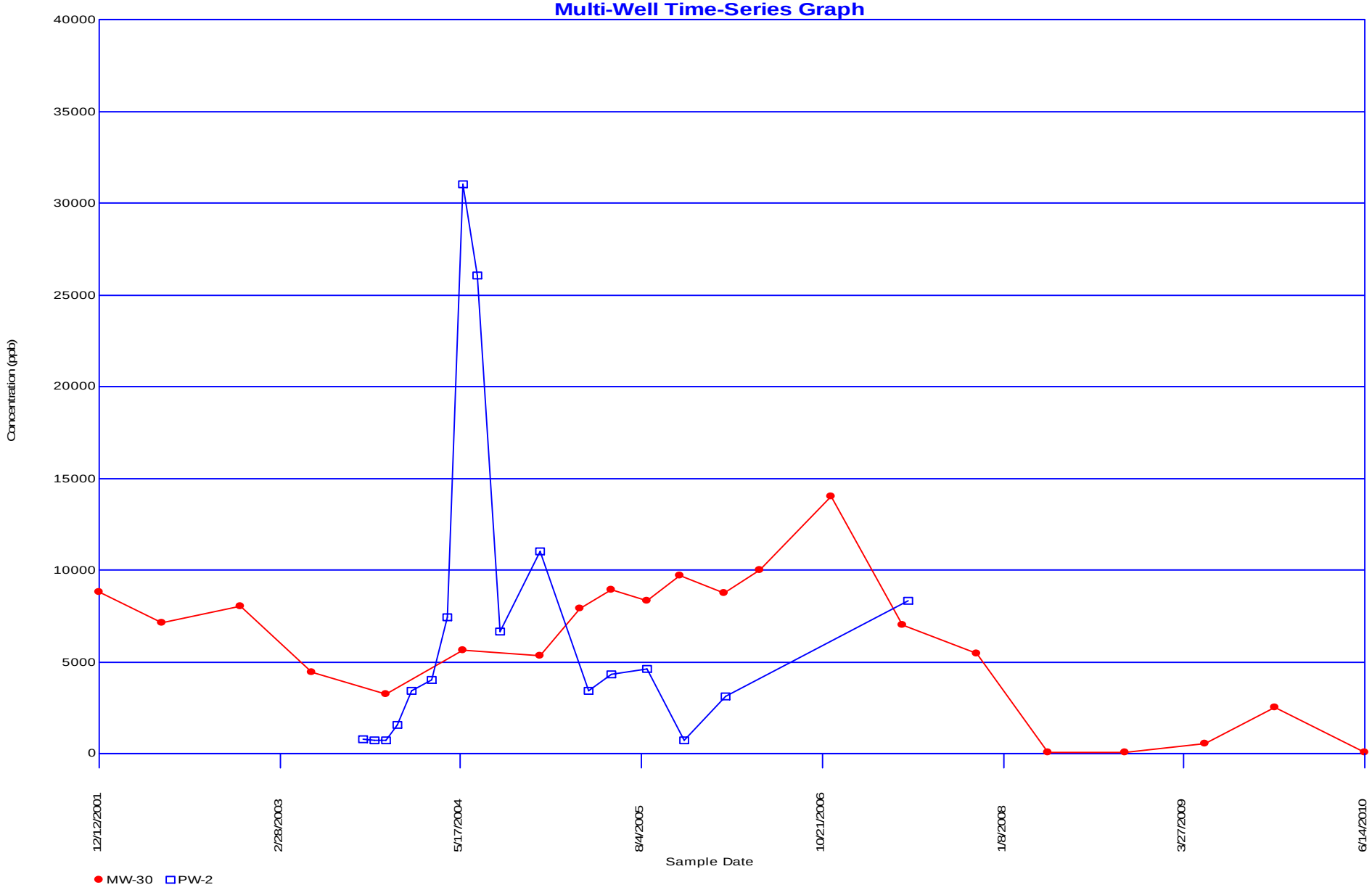


Central Sanitary Landfill

Iron, Dissolved

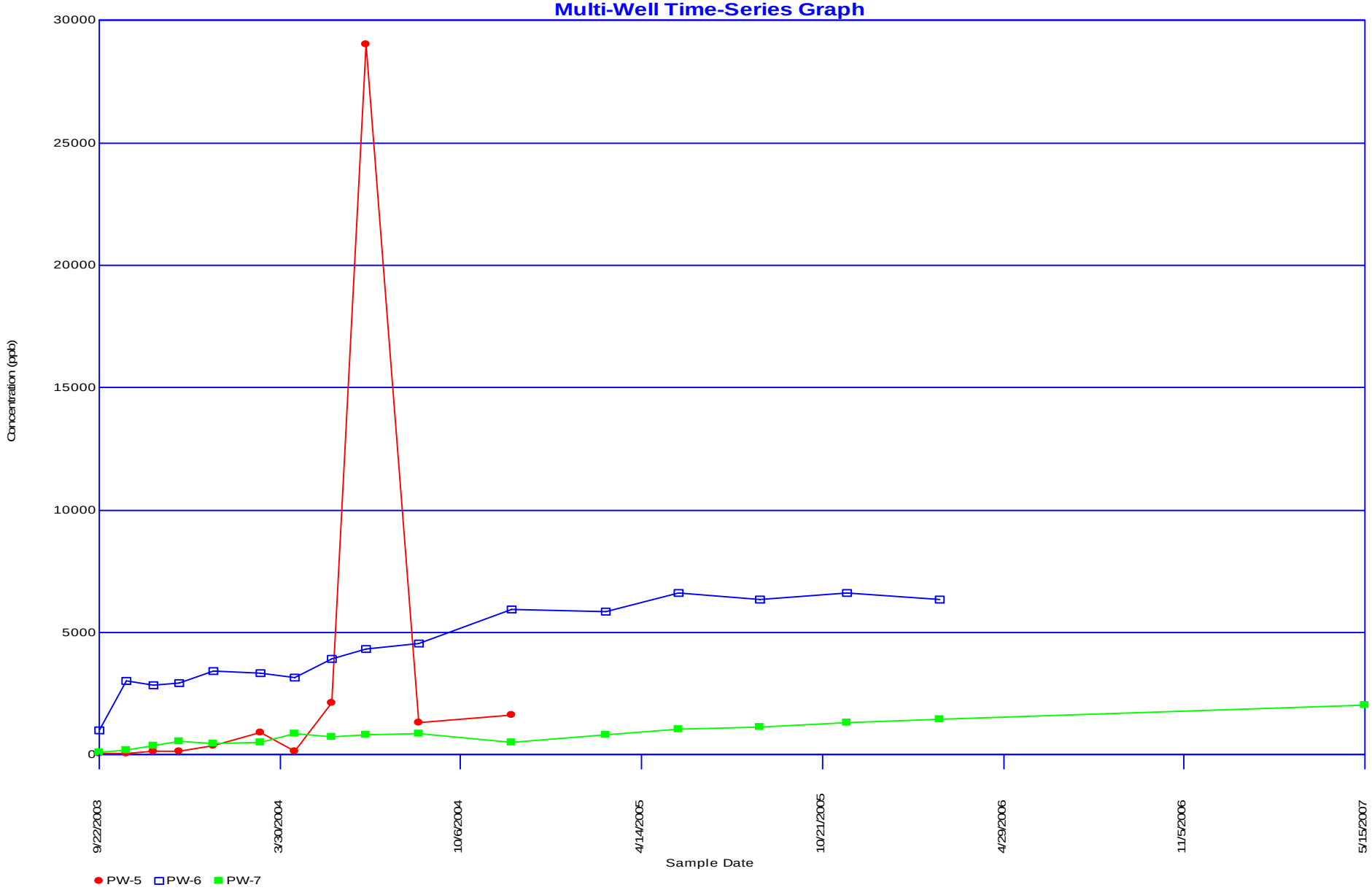
Multi-Well Time-Series Graph



Central Sanitary Landfill

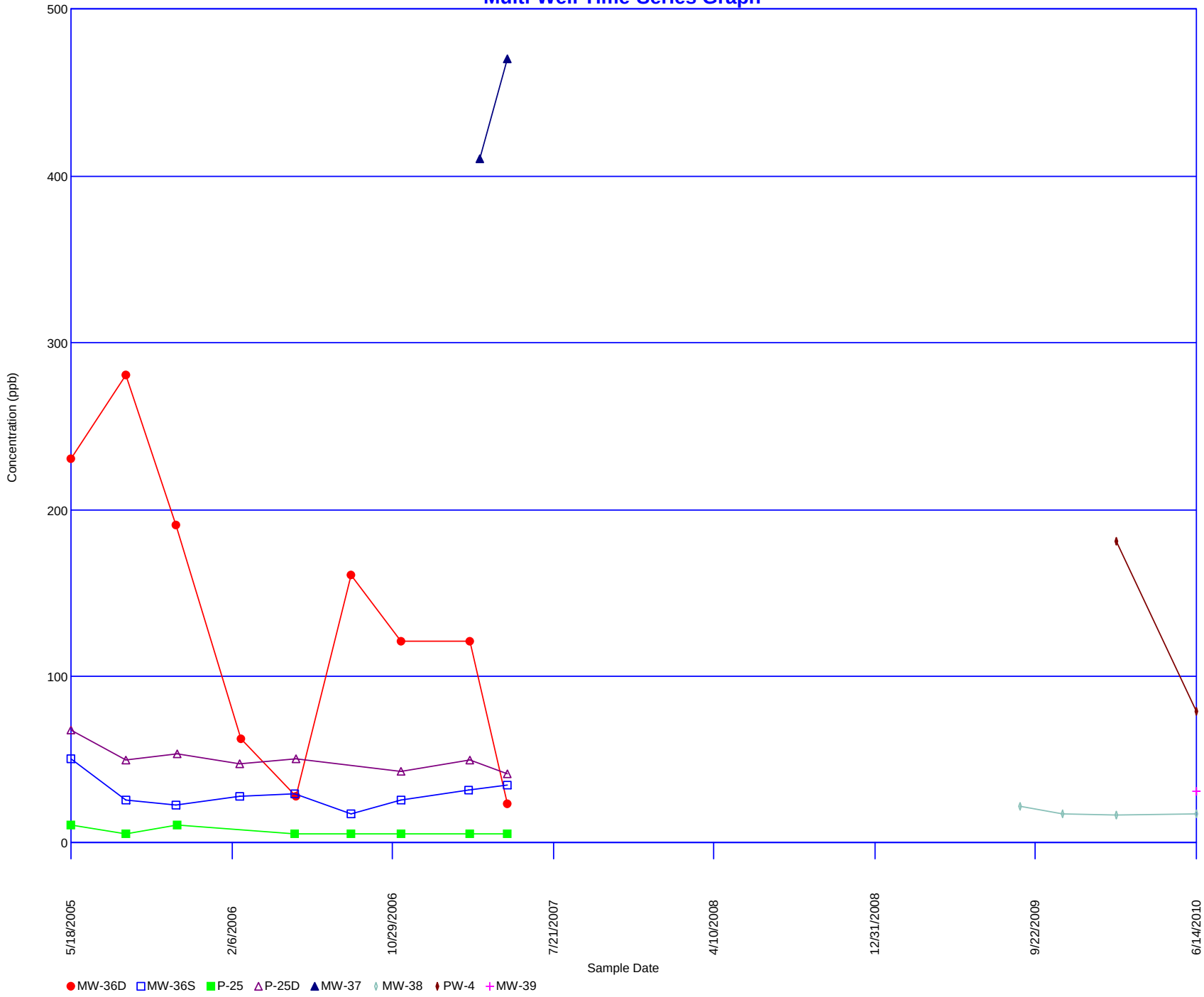
Iron, Dissolved

Multi-Well Time-Series Graph



Manganese, Dissolved

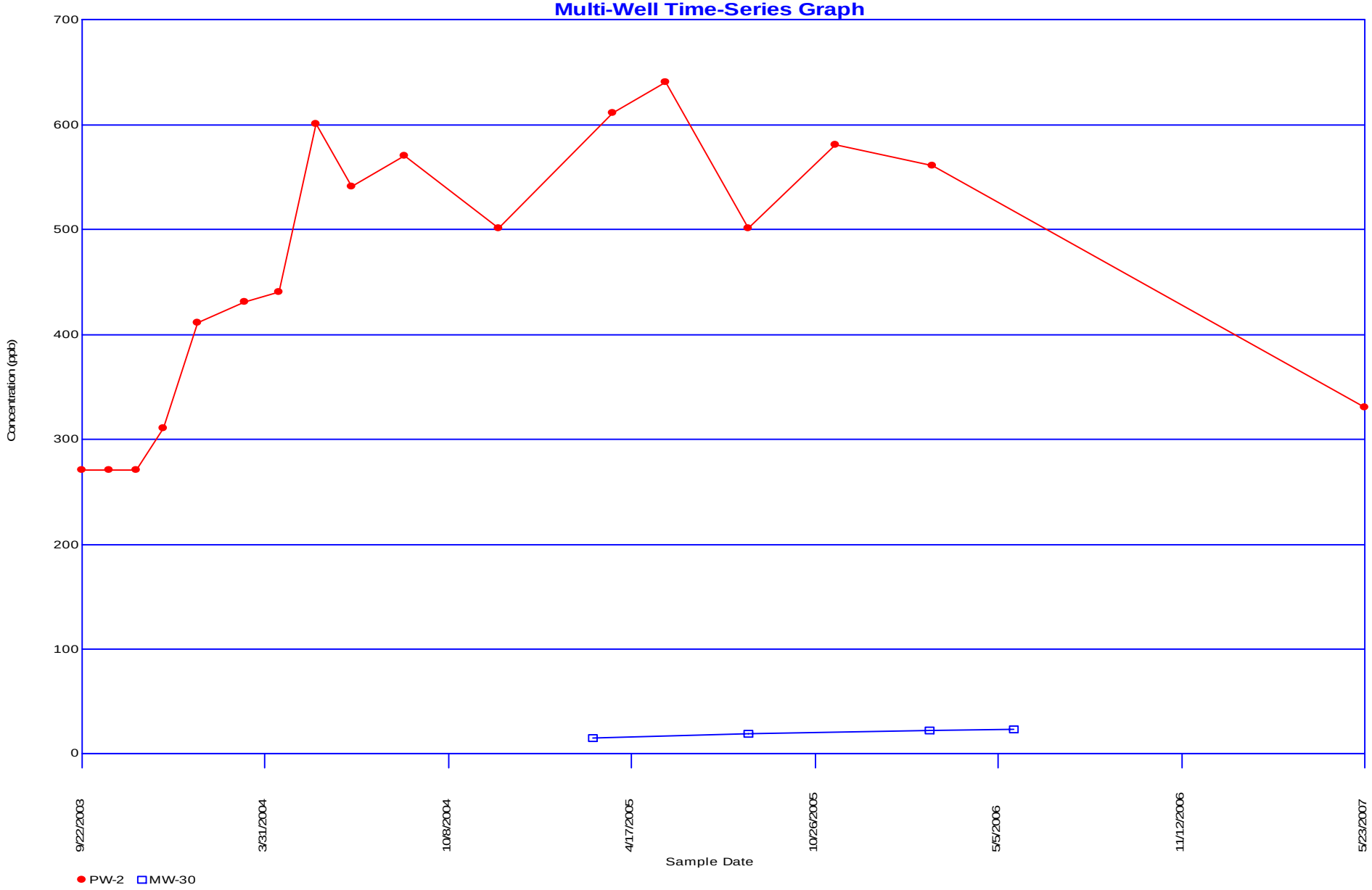
Multi-Well Time-Series Graph



Central Sanitary Landfill

Manganese, Dissolved

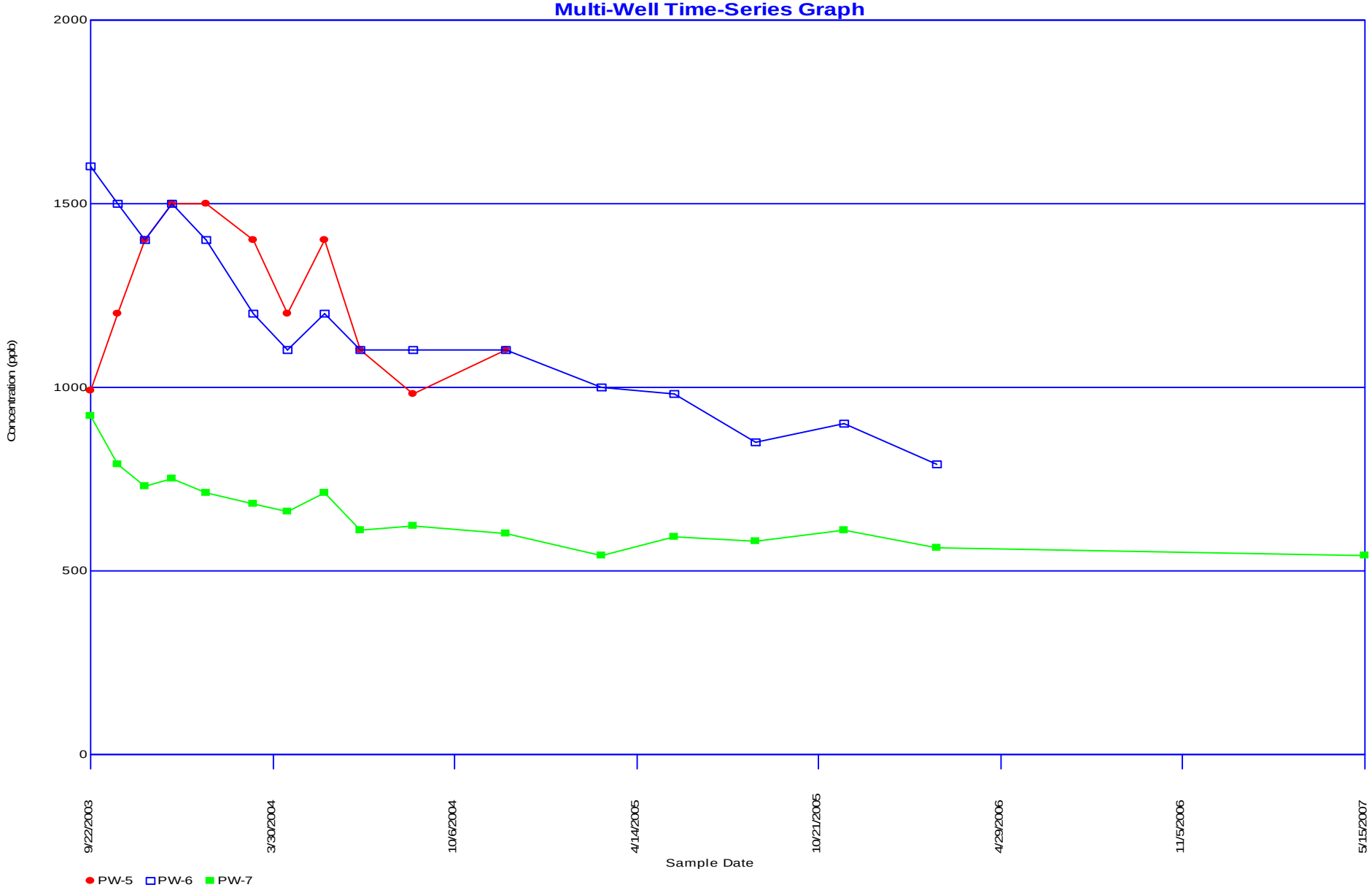
Multi-Well Time-Series Graph



Central Sanitary Landfill

Manganese, Dissolved

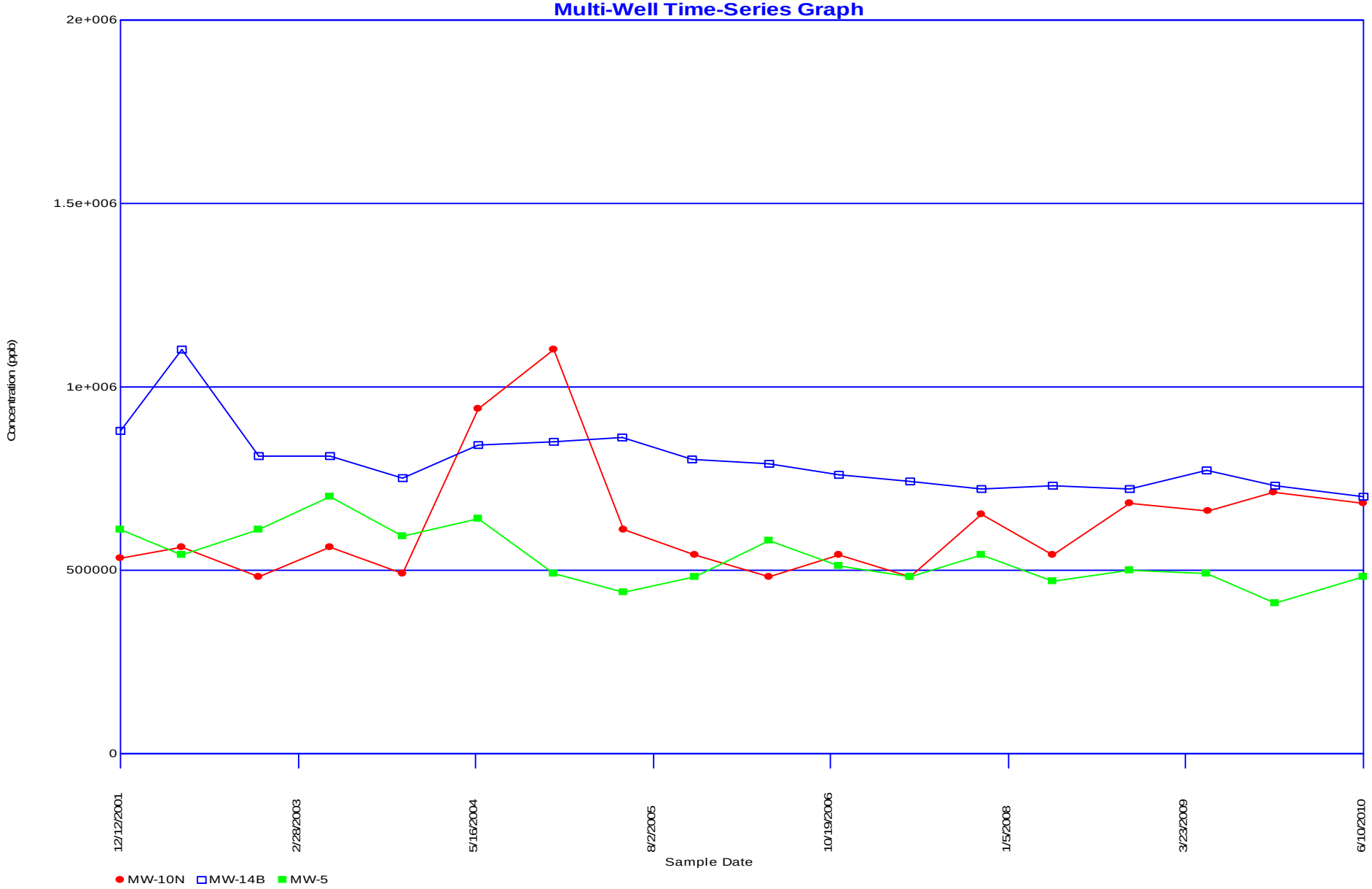
Multi-Well Time-Series Graph



Central Sanitary Landfill

Dissolved Solids

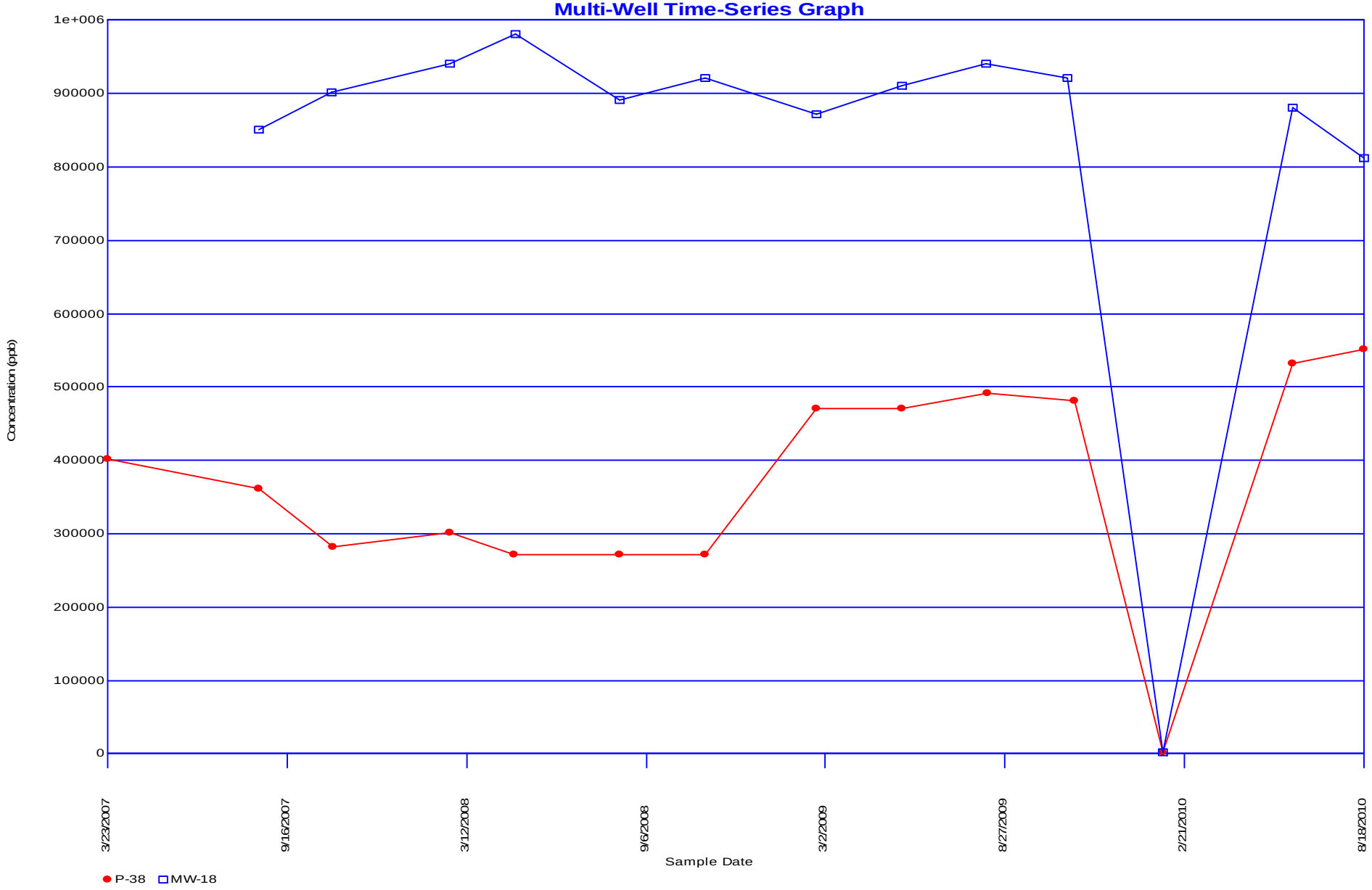
Multi-Well Time-Series Graph



Central Sanitary Landfill

Dissolved Solids

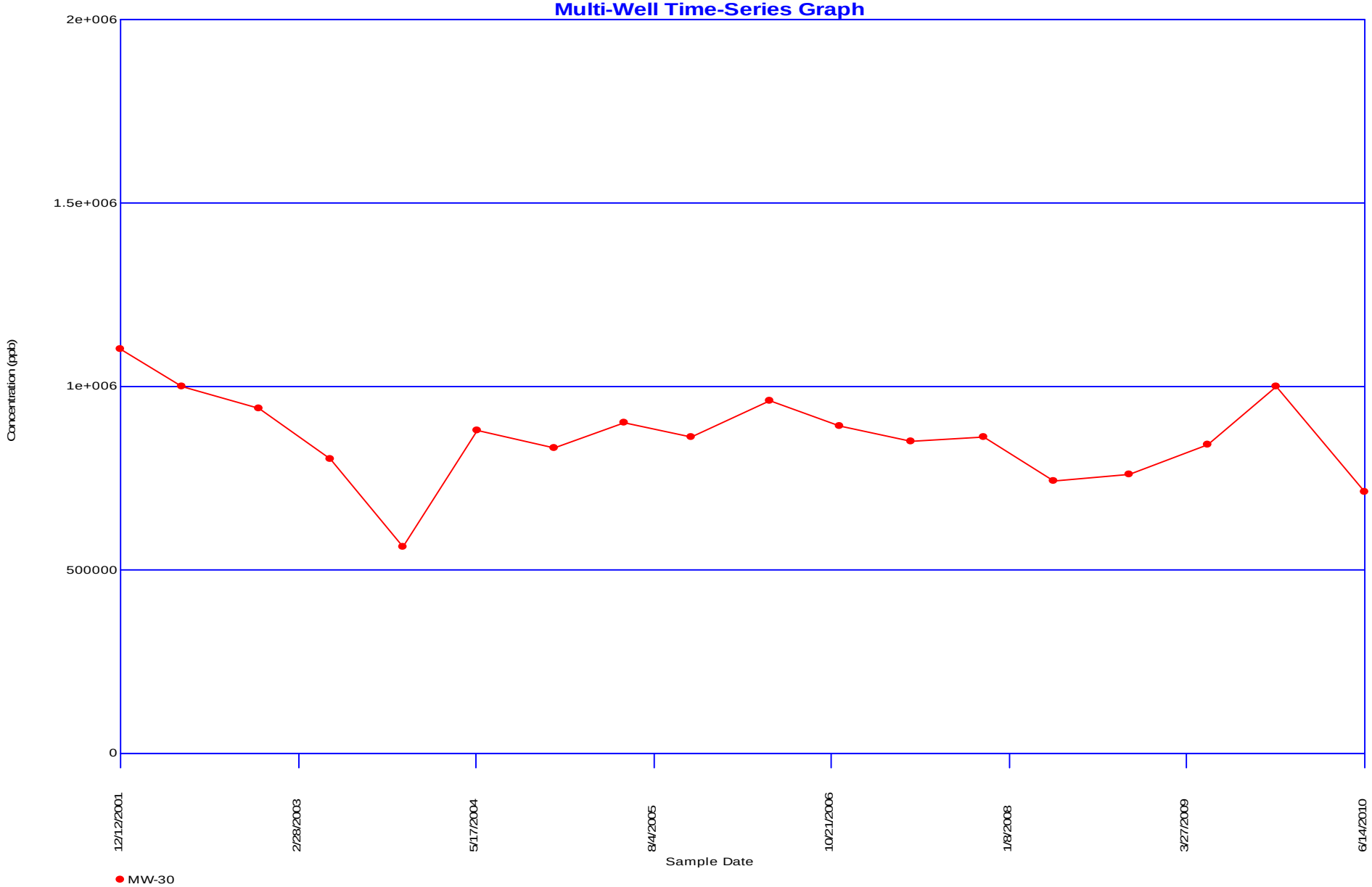
Multi-Well Time-Series Graph



Central Sanitary Landfill

Dissolved Solids

Multi-Well Time-Series Graph



Appendix D

Groundwater Modeling Report

Groundwater Model Simulations
for
Evaluation of Remedial Action Plan
at
Central Sanitary Landfill
Pierson TWP, Michigan

October 2010
(revised October 2011)

on behalf of

REPUBLIC SERVICES, INC.

Prepared by

Andrews Engineering, Inc.
7478 Shadeland Station Way
Indianapolis, Indiana 46256
Ph: 317-595-6492

Groundwater Model Simulations for Evaluation of a Remedial Action Plan for Central Sanitary Landfill; Pierson TWP, Michigan
Republic Services, Inc.

Table of Contents

	Page No.
1.0 Introduction and Background	1
2.0 Conceptual Site Model	1
2.1 Hydrostratigraphic Units	1
2.2 Recharge and Discharge Locations	1
2.3 Current Groundwater Flow Patterns	2
3.0 Model Setup	2
3.1 Model Extent and Grid Design	2
3.2 Model Boundary Conditions	2
3.3 Hydraulic Conductivity Estimates	3
4.0 Model Calibration	4
4.1 Calibration Data	4
4.2 Calibration Results	4
4.3 Sensitivity Analysis	4
5.0 Evaluation of Groundwater Pump and Treat System	5
6.0 Conclusions	6
7.0 References	6

Figures

Tables

Appendices

List of Figures and Tables

Figure #	**Title**
1	Geologic Map and Site Location
2	Groundwater Model Hydrologic Features
3	Recent Groundwater Elevation Map
4	Groundwater Model Extent and Grid
5	Groundwater Model Hydrologic Boundaries
6	Recharge Zones in Calibrated Model
7	Hydraulic Conductivity Test Results
8	Pumping Rates for PW-6 and PW-7
9	Groundwater Model Calibration Statistics
10	Modeled Groundwater Map for Calibration Date
11	Distribution of Hydraulic Conductivity in Calibrated Model
12	Relative Sensitivity of Output Results to Input Parameters
13	Estimated Capture Zones for Pre-2010 Pumping Rates
14(rev)	Estimated Capture Zone for Proposed Remedial Action

Table #	**Title**
1	Observed and Model-Calculated Groundwater Elevations for November 2004 Calibration Event
2	Input Parameter Correlation Coefficient Matrix

Appendix	**Title**
1	Pond Design Calculations and As-built Pond Coordinates

Groundwater Model Simulations for Evaluation of a Remedial Action Plan for Central Sanitary Landfill; Pierson TWP, Michigan Republic Services, Inc.

1.0 Introduction and Background

E&E Solutions on behalf of Central Sanitary Landfill submitted an updated Remedial Action Plan (RAP) to Michigan Department of Environmental Quality (MDEQ) in 2007. In that report, the primary remedial action was determined to be natural biodegradation supplemented by the site's existing groundwater pump and treat system.

Central Sanitary Landfill contracted with Andrews Engineering, Inc. to utilize a groundwater simulation model to evaluate the site's groundwater pump and treat system and determine if changes could be made to increase the system's capture efficiency.

This report provides the results of the model simulations conducted for the evaluation of the groundwater pump and treat system and is part of the revised RAP. Preliminary model results were presented in a meeting with MDEQ on November 9, 2009.

2.0 Conceptual Site Model

The conceptual site model is based on data presented in earlier reports, more specifically the Interim Remedial Action Plan submitted to MDEQ in 2004 and the Updated Remedial Action Plan submitted to MDEQ in 2007. A summary of the conceptual site model derived from these earlier reports is presented below.

2.1 Hydrostratigraphic Units

Figure 1 shows a geologic map of Montcalm County and the approximate site location. The site is situated at the approximate boundary between end moraine and glacial outwash units. As is typical at the boundary of different glacial units, there are locations on the site where the soil textures vary considerably. The uppermost aquifer consists of uniform, fine to medium sands that are within glacial end moraine or outwash deposits. There are areas on site where the finer texture of soils result in much lower hydraulic conductivity (see **Section 3.3** below).

The uppermost aquifer is unconfined and its base elevation ranges between approximately elevations 815 and 860 feet. Groundwater elevations beneath the site are generally between 890 and 894 feet. A silty clay unit underlies the aquifer.

2.2 Recharge and Discharge Locations

Locations of the model area's primary hydrologic features are shown in **Figure 2.** Recharge to the site and vicinity occurs primarily from rainfall precipitation. A groundwater divide lies just to the west of the site and generally follows the orientation of US Highway 131, which is also coincident with a topographic divide. Groundwater flow beneath the site is predominantly to the

east. Within the facility boundaries, recharge also occurs through several storm water ponds and the discharge pond for treated groundwater from the remediation wells.

Groundwater discharge locations include the many lakes in the site vicinity, Heron Drain east of the site, and the groundwater remediation wells on site.

2.3 Current Groundwater Flow Patterns

The most recent groundwater elevation map is shown on **Figure 3**. The influence of pumping at PW-6 and PW-7R can be seen in the deflection of the contours just down gradient from these wells. The recharge influence of one of the storm water ponds is indicated by the closed contour surrounding MW-27, MW-28, and MW-29. These patterns of flow observed at the site have been generally consistent since groundwater extraction was initiated at PW-6 and PW-7.

3.0 Model Setup

3.*1 Model Extent and Grid Design*

The USGS software code MODFLOW was utilized for this analysis: in particular, Version 1.15.01 of MODFLOW-2000, dated 04/05/2005. References that describe the model software and its calculation algorithms are provided in Section 7 and include USGS Open-File Report 00-92 and Waterloo Hydrologic, Inc., Feb 2005 - Visual MODFLOW Pro User's Manual.

The model extent and grid spacing is shown on **Figure 4**. The model is extended to include major surface drainage features surrounding the site. Grid spacing varies between 14 and 38 feet within the facility boundaries and expands to 180 feet near the model boundary extent.

Based on earlier models of the site and evaluation of vertical hydraulic gradients, a two-dimensional areal representation of the uppermost aquifer was judged to be sufficient to simulate site features, groundwater flow patterns, and extraction well capture zones. Therefore, the model has one layer with the top represented by the ground surface and the bottom represented by the base of the uppermost aquifer or top of the basal clay.

3.2 Model Boundary Conditions

Model boundary conditions refer to those model features that establish head levels or flow rates that are used in conjunction with other input data to calculate groundwater elevations throughout the modeled area. Model boundaries do not necessarily coincide with the actual model limits – that is, they can be anywhere within the model extent. Precipitation recharge is also referred to as a model boundary, for example.

<u>Hydrologic Features</u>

The model representations of the site's hydrologic features are shown on **Figure 5**. Each feature is assigned a head elevation based on data obtained from the State of Michigan's Lake Inventory

or USGS digital elevation maps. The lakes are modeled as specified constant heads, while the Heron Drain is simulated with MODFLOW's drain feature.

Precipitation Recharge

Recharge rates depend on many factors: surface soils, vegetation, drainage, rainfall amount and intensity, antecedent moisture conditions, temperature and humidity. Therefore, this input parameter is obtained primarily through calibration. Earlier model efforts estimated that recharge rates for the model area were between 4 and 12 inches per year and varied spatially based on surficial soil characteristics. The same approach was utilized for this model. Zero recharge was assumed within the waste boundaries based on the final cover, liner, and leachate collection features.
The final calibrated recharge values and their distributions (shown as color-coded zones) are shown on **Figure 6**. The range of recharge is slightly greater than earlier model estimates, with the lowest value equal to 2 inches per year and the highest, 13 inches per year. The basis for these values is detailed below in **Section 4.0**, Model Calibration.

As a result of MDEQ review of model results (Dale Bridgford, MDEQ, personal communication, August 2011), the effect of utilizing USDA soils distribution maps for assigning precipitation recharge distributions was examined. USDA "shape" files of soil types across the model area were imported into MODFLOW and recharge assigned according to each soil's estimated capacity to allow infiltration. The wells' capture zones utilizing precipitation recharge based on USDA soils were compared to the results based on the recharge distribution shown in **Figure 6** and were found to be essentially the same. Documentation of this comparison was provided via E-mail to MDEQ for informational purposes and is not included in this report.

3.3 Hydraulic Conductivity Estimates

Hydraulic conductivities were initially estimated based on single-well tests, aquifer tests with observation wells, and for off-site areas, driller's specific capacity tests. Specific capacity data were obtained from water well records obtained from the Michigan Department of Health (Conceptual Model Report, Water Well Logs; by G.R. Kunkel and Associates). Utilizing a specific capacity well formula (Walton, 1962), hydraulic conductivities were calculated for those wells with sufficient pumping and drawdown data. The on-site and off-site hydraulic conductivity test results are shown on **Figure 7**.

Final model calibrated values of horizontal conductivities differed from the initial estimates from test results and are discussed further in **Section 4.0**.

4.0 Model Calibration

4.1 Calibration Data

The computer model for this project assumes that, for practical purposes, groundwater flow is in a steady state condition; that is, recharge and discharge rates are constant and groundwater elevations are not changing. Previous evaluations of pumping rates and groundwater elevations indicate that approximate steady state conditions are established within 2 weeks following a significant change in recharge or discharge conditions. Therefore, the model was calibrated for a date when the groundwater extraction well pumping rates were fairly stable. **Figure 8** shows plots of PW-6 and PW-7 since 2004. Based on this chart, the date chosen for model calibration to groundwater elevations was November 30, 2004. During this time, PW-6 was pumping approximately 31.3 gpm and PW-7, 13.4 gpm. In addition, rainfall for the month of November was approximately 2.5 inches, which is close to normal precipitation for November.

4.2 Calibration Results

Observed groundwater elevations and calibrated model values are provided in **Table 1**. **Figure 9** shows calibration statistics, which indicate a good match with observed data (correlation coefficient close to 1.0 and low % RMS error). Some error between observed and modeled values is expected and can be caused by numerous factors, both with the observations themselves and with the model.

The modeled groundwater map for the calibration date is shown in **Figure 10**. The modeled results replicate the primary features of the observed groundwater elevation maps: a flow divide along US Highway 131 , and an easterly hydraulic gradient across the site. Variations in the steepness of the hydraulic gradient are caused primarily by variations in hydraulic conductivity and aquifer thickness, and secondarily by variations in precipitation recharge. The distribution of hydraulic conductivity in the calibrated model is shown in **Figure 11**. Although the distributions of low and high zones of hydraulic conductivity in the model are similar to the hydraulic conductivity test results (compare **Figure 7** with **Figure 11**), the values in the model are generally much higher than test results. This is not surprising, since single-well tests are often skewed low due to wellbore damage from drilling. Also, aquifer tests, whether single-well or with observation wells, represent a small fraction of aquifer material, while the computer model zones represent much larger areas.

4.3 Sensitivity Analysis

During the calibration process for the current model, an automated parameter estimation software code termed PEST (Parameter ESTimation) was utilized (Doherty, 2001). In addition to being able to make hundreds of runs efficiently to aid in arriving at an optimal match with observations, PEST analysis also determines the relative sensitivity of model-calculated groundwater elevations to variations of input parameters.

Seven input parameters were varied utilizing PEST to determine sensitivity of model-calculated groundwater elevations to the input parameters. The seven input parameters included four hydraulic conductivity zones and three precipitation recharge zones (see **Figures 6** and **7**).

The relative sensitivities of model output results to the seven input parameters are graphically shown in **Figure 12**. The model is most sensitive to hydraulic conductivity zone Kx2, which is the majority and highest hydraulic conductivity soils beneath the site. The model is generally less sensitive to precipitation recharge than hydraulic conductivity. Although precipitation recharge is very difficult to determine independently of calibration, the uncertainty in this input parameter has less effect on model-calculated groundwater elevations than other parameters.

Another output of the sensitivity analysis is an evaluation of the correlation of input parameters. When parameters are highly correlated with each other, different combinations of parameter values can produce essentially the same model output results. In most groundwater models this is the case to some degree. **Table 2** is a correlation coefficient matrix for the seven input parameters tested. A perfect correlation between parameter groups is represented by a value of 1.0. The absolute values of the correlation coefficients for the seven parameters ranged between 0 and 0.99. There is a particularly strong positive correlation between recharge zone 1 (Rech1) and hydraulic conductivity zone Kx1.

5.0 Evaluation of Groundwater Pump and Treat System

After a good calibration of the model was achieved, the model was utilized to calculate groundwater elevations, and by extension, capture zones, under a number of different scenarios of corrective action pumping and recharge of treated water. The goals of the modeling effort were to evaluate the existing capture zone and to evaluate potential changes in the groundwater pump and treat system that would increase the efficiency of the system. The estimated capture zones for PW-6 and PW-7 under recent (pre-2010) average pumping conditions is shown in **Figure 13**. In order to evaluate changes that would increase the capture zones shown in Figure 13, different combinations of pumping rates among the existing extraction wells and different locations of treated recharge basins were considered.

The optimum corrective action pumping scenario of the ones evaluated is shown in **Figure 14 (rev)**. This scenario maximizes the capture of the existing contaminant plume while minimizing the potential for drawing contamination further from the site. This scenario includes re-activating PW-5 at the northeast corner of the oldest waste cells and relocating the treated water infiltration pond further to the east from its present location immediately adjacent to PW-6. The proposed infiltration pond re-location is shown on **Figure 14 (rev)** and is positioned: 1) to serve as a hydraulic barrier to eastward contaminant movement from the site, and 2) to be within the outermost edge of the contaminant plume. This location is also revised from an earlier proposal submitted to MDEQ in April 2011. MDEQ suggested that a location further west and south of the original proposal would close the minor capture zone gap shown on previous model runs between pumping wells PW-6 and PW-7R. After further model runs were made with various alternative locations, the location shown on Figure 14 (rev) was submitted for review by MDEQ, approved, and finalized.

Included in the review of pond locations was an evaluation that demonstrated the capacity of shallow soils to allow recharge of treated water at the proposed pumping well discharge rate. The soils at the proposed pond location, design capacity calcuations, and dimensions were presented to MDEQ for review via E-mail on August 19, 2011. This documentation is provided in Appendix 1 along with the as-built coordinates of the new pond location, which was installed in August-September 2011 following MDEQ approval.
The proposed pumping rates for the three extraction wells are estimates that will necessarily have to be refined based on future water quality and groundwater elevation monitoring.

6.0 Conclusions

The following conclusions are presented based on the results of the current modeling work:

1. An areal, two-dimensional groundwater flow model was constructed utilizing MODFLOW and available site and off-site data for input to the model.

2. The model was calibrated successfully to groundwater elevations obtained on November 30, 2004. The model replicates typical site groundwater flow directions and calibration statistics indicate a good match between observed and model-calculated groundwater elevations.

3. Sensitivity analysis indicates that model-calculated groundwater elevations are most sensitive to high hydraulic conductivity zones beneath the site and least sensitive to recharge zones distant from the site.

4. An evaluation of capture zones for pre-2010 pumping conditions and a range of other potential remediation pumping scenarios indicate that much greater capture efficiency can be gained by including PW-5 in the remediation pumping plan and by re-locating the treated water infiltration pond to its new site shown on **Figure 14 (rev)**.

7.0 References

Davis, S.N., 1969; “Porosity and permeability in natural materials”. In *Flow through Porous Media*, ed R.J. DeWiest. 53-59. New York: Academic Press.

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G.R. Kunkel and Associates, August 4, 1994; Conceptual Model Report, Water Well Logs.

Montcalm County, Michigan; Montcalm County Maps, www.montcalm.org, Sep. 2009.

USGS, 2000; Arlen W. Harbaugh, Edward Banta, Mary Hill and Michael G. McDonald; “The USGS Modular Ground-Water Model”; Open-File Report 00-92.

Walton, William C., 1962; "Selected Analytical Methods for Well and Aquifer Evaluation"; p. 12; Illinois State Water Survey Bulletin 49.

Waterloo Hydrologic Inc., February 2005; "Visual MODFLOW Pro User's Manual, v. 4.1".

Tables

Table 1 - Observed and Model-Calculated Groundwater Elevations for November 2004 Calibration Event

			Groundwater Elevations, ft above MSL		
Well/Point Name	**X-Coordinate, Ft**	**Y-Coordinate, Ft**	**Observed (Measured)**	**Model Calculated**	**Calculated - Observed**
MW-13/A	1770126	1014984	893.58	893.39	-0.19
MW-18/A	1771170	1013600	892.67	892.62	-0.05
MW-20/A	1770746	1015229	893.25	893.32	0.07
MW-21/A	1770336	1015141	893.54	893.40	-0.14
MW-27/A	1771830	1015092	892.91	892.60	-0.31
MW-28/A	1771682	1014984	893.20	892.87	-0.33
MW-29/A	1771654	1015253	892.85	892.80	-0.05
MW-30/A	1771486	1013969	892.57	892.54	-0.03
MW-31/A	1768420	1014100	892.93	892.87	-0.06
MW-34/A	1770933	1016116	893.62	893.48	-0.14
MW-5/A	1771071	1014799	892.97	893.06	0.09
MW-6A/A	1769822	1014017	893.31	893.26	-0.05
P-1/A	1770439	1015252	893.52	893.41	-0.11
P-10/A	1771768	1015924	892.70	892.73	0.03
P-11/A	1772066	1015484	891.89	892.12	0.23
P-12/A	1772184	1015657	891.77	891.94	0.17
P-13/A	1772309	1016026	891.43	891.75	0.32
P-14/A	1772311	1011650	890.21	890.02	-0.19
P-16/A	1769515	1012544	893.34	893.54	0.20
P-18/A	1770464	1012379	893.67	893.67	0.00
P-19/A	1770019	1012379	893.28	893.60	0.32
P-2/A	1770414	1015193	893.53	893.40	-0.13
P-20/A	1771367	1012854	891.05	891.17	0.12
P-22/A	1771436	1013435	892.42	892.06	-0.36
P-23/A	1771371	1012385	891.11	890.85	-0.26
P-24/A	1771156	1014351	892.86	892.82	-0.04
P-25/A	1772314	1013662	890.63	890.87	0.24
P-26/A	1772352	1012539	890.31	890.22	-0.09
P-27/A	1772321	1012539	890.30	890.24	-0.06
P-28/A	1769748	1013684	893.45	893.27	-0.18
P-29/A	1769505	1012521	893.34	893.54	0.20
P-3/A	1771730	1014171	892.29	892.32	0.03
P-30/A	1772277	1014187	891.16	891.46	0.30
P-32/A	1771137	1014711	893.00	893.00	0.00
P-33/A	1771269	1014816	892.93	893.00	0.07
P-4/A	1771707	1014091	892.32	892.33	0.01
P-6/A	1772299	1012954	890.25	890.38	0.13
P-8/A	1771964	1015331	892.10	892.29	0.19
P-9/A	1770733	1015680	893.42	893.45	0.03

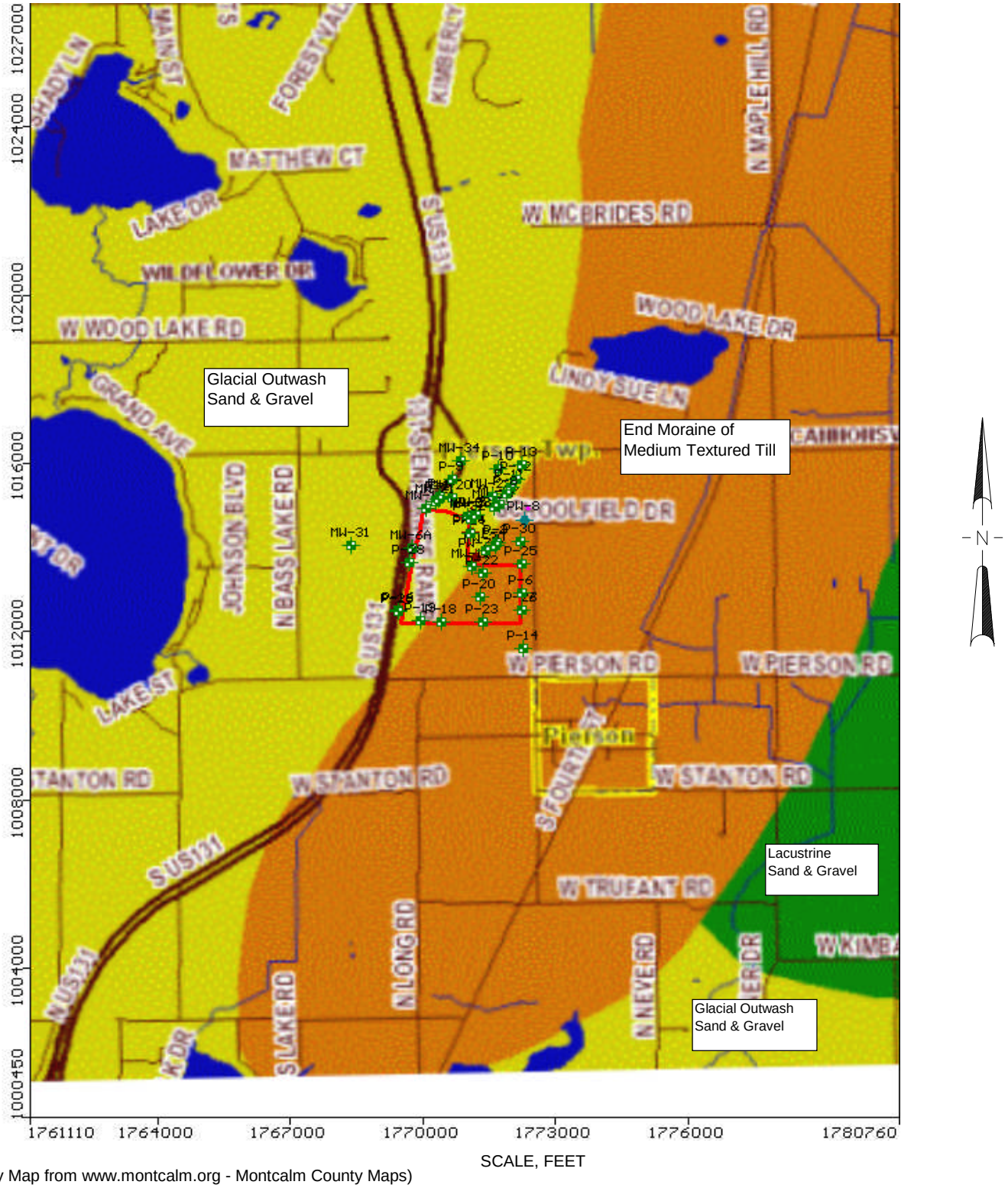
AEI, 10/21/2010

Table 2
Input Parameter Correlation Coefficient Matrix

	Kx1	Kx2	Kx3	Kx4	Rech1	Rech2	Rech3
Kx1	1.00	0.40	0.45	0.33	0.99	0.15	0.11
Kx2	0.40	1.00	-0.04	-0.06	0.52	0.75	-0.27
Kx3	0.45	-0.04	1.00	-0.12	0.43	-0.38	0.91
Kx4	0.33	-0.06	-0.12	1.00	0.32	0.00	-0.26
Rech1	0.99	0.52	0.43	0.32	1.00	0.23	0.08
Rech2	0.15	0.75	-0.38	0.00	0.23	1.00	-0.65
Rech3	0.11	-0.27	0.91	-0.26	0.08	-0.65	1.00

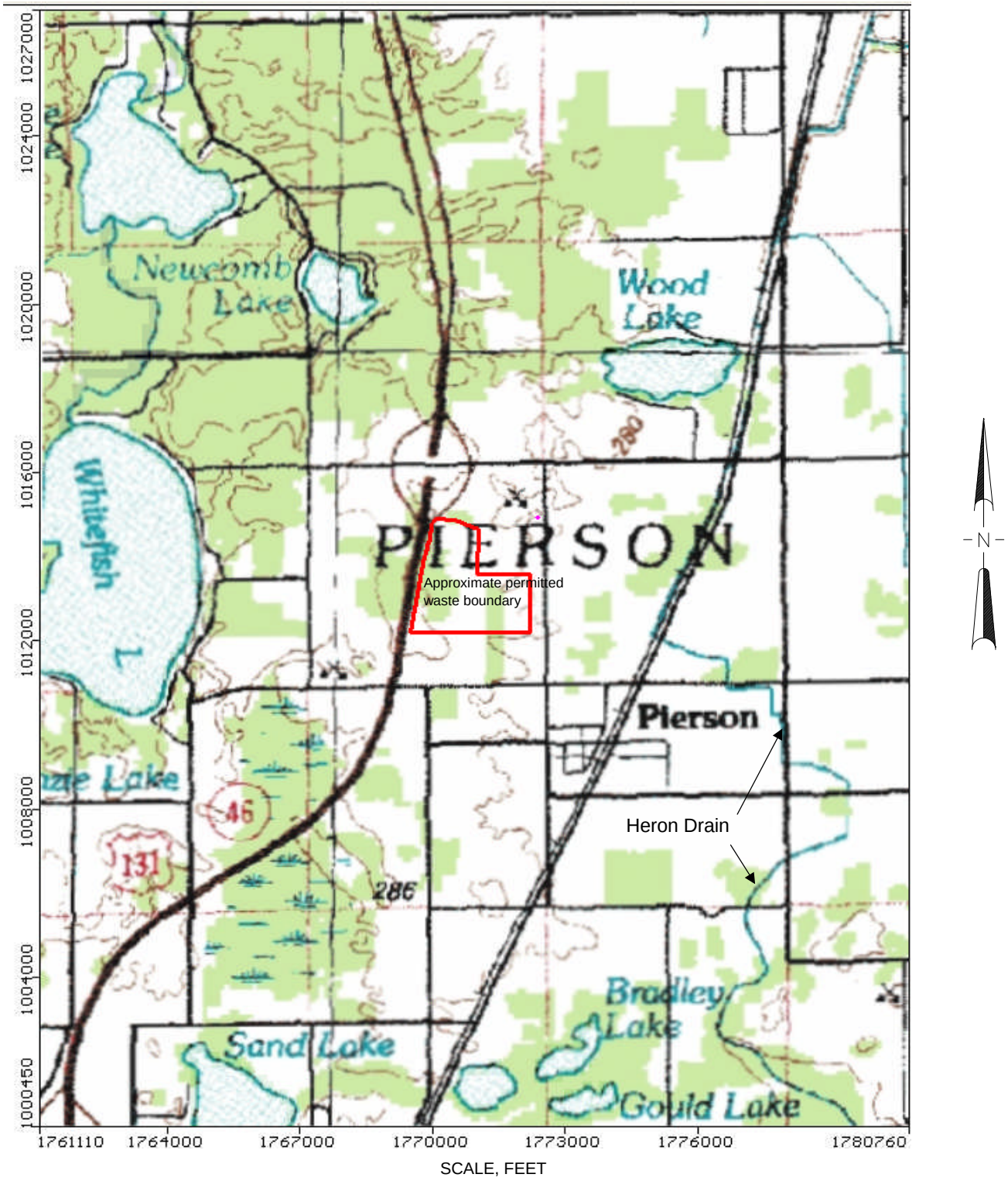
AEI, 10/21/2010

Figures

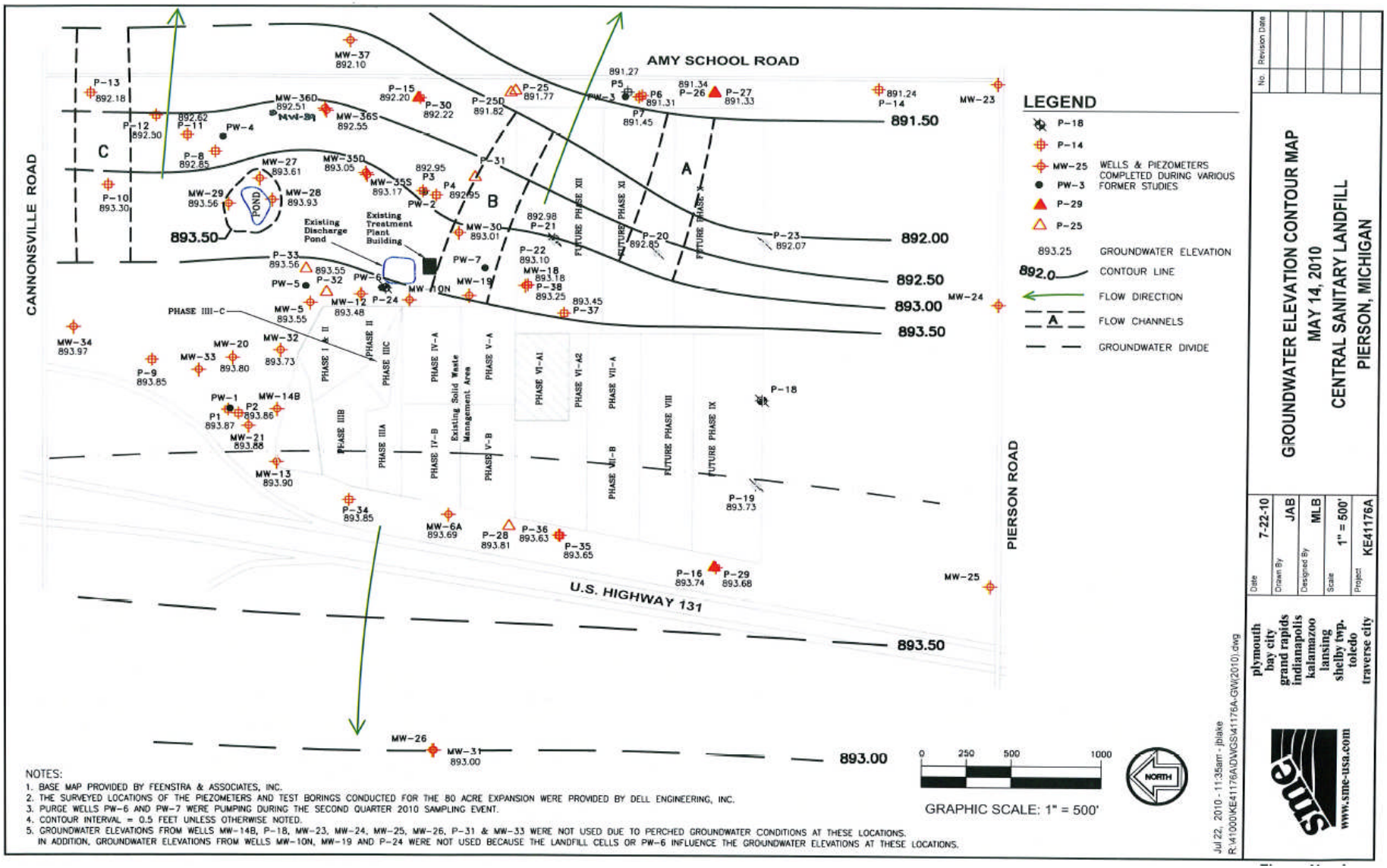


(Quaternary Map from www.montcalm.org - Montcalm County Maps)

Andrews Engineering, Inc.	Central Sanitary Landfill Pearson, Michigan	*Figure 1*
8/20/2010	Republic Services, Inc.	Geologic Map and Site Location



Andrews Engineering, Inc.	Central Sanitary Landfill Pearson, Michigan	*Figure 2*
10/20/2010	Republic Services, Inc.	Groundwater Model Hydrologic Features



NOTES:
1. BASE MAP PROVIDED BY FEENSTRA & ASSOCIATES, INC.
2. THE SURVEYED LOCATIONS OF THE PIEZOMETERS AND TEST BORINGS CONDUCTED FOR THE 80 ACRE EXPANSION WERE PROVIDED BY DELL ENGINEERING, INC.
3. PURGE WELLS PW-6 AND PW-7 WERE PUMPING DURING THE SECOND QUARTER 2010 SAMPLING EVENT.
4. CONTOUR INTERVAL = 0.5 FEET UNLESS OTHERWISE NOTED.
5. GROUNDWATER ELEVATIONS FROM WELLS MW-14B, P-18, MW-23, MW-24, MW-25, MW-26, P-31 & MW-33 WERE NOT USED DUE TO PERCHED GROUNDWATER CONDITIONS AT THESE LOCATIONS. IN ADDITION, GROUNDWATER ELEVATIONS FROM WELLS MW-10N, MW-19 AND P-24 WERE NOT USED BECAUSE THE LANDFILL CELLS OR PW-6 INFLUENCE THE GROUNDWATER ELEVATIONS AT THESE LOCATIONS.

Andrews Engineering, Inc.

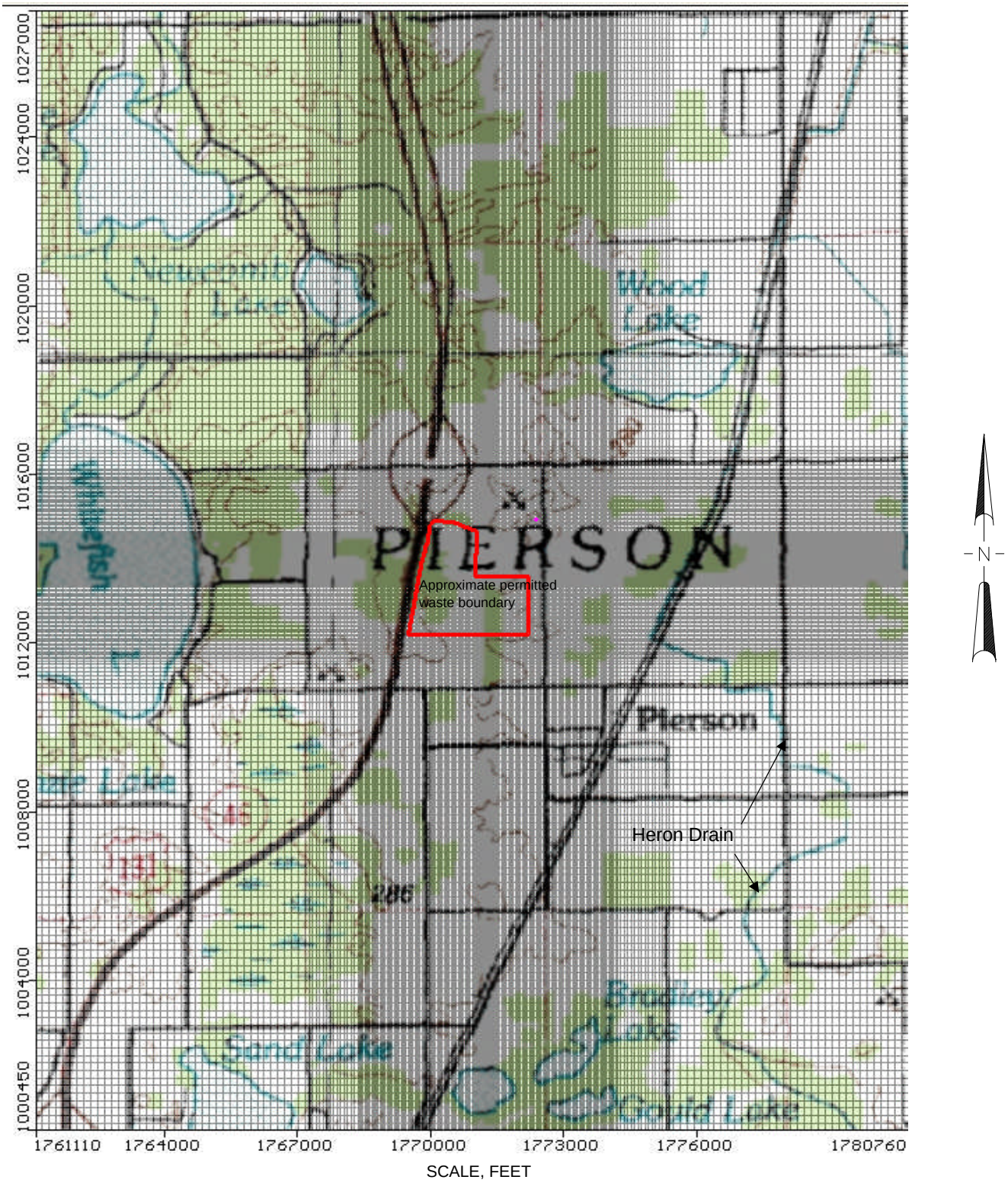
10/20/2010

Central Sanitary Landfill
Pearson, Michigan

Republic Services, Inc.

Figure 3

Recent Groundwater Elevation Map



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10/20/2010

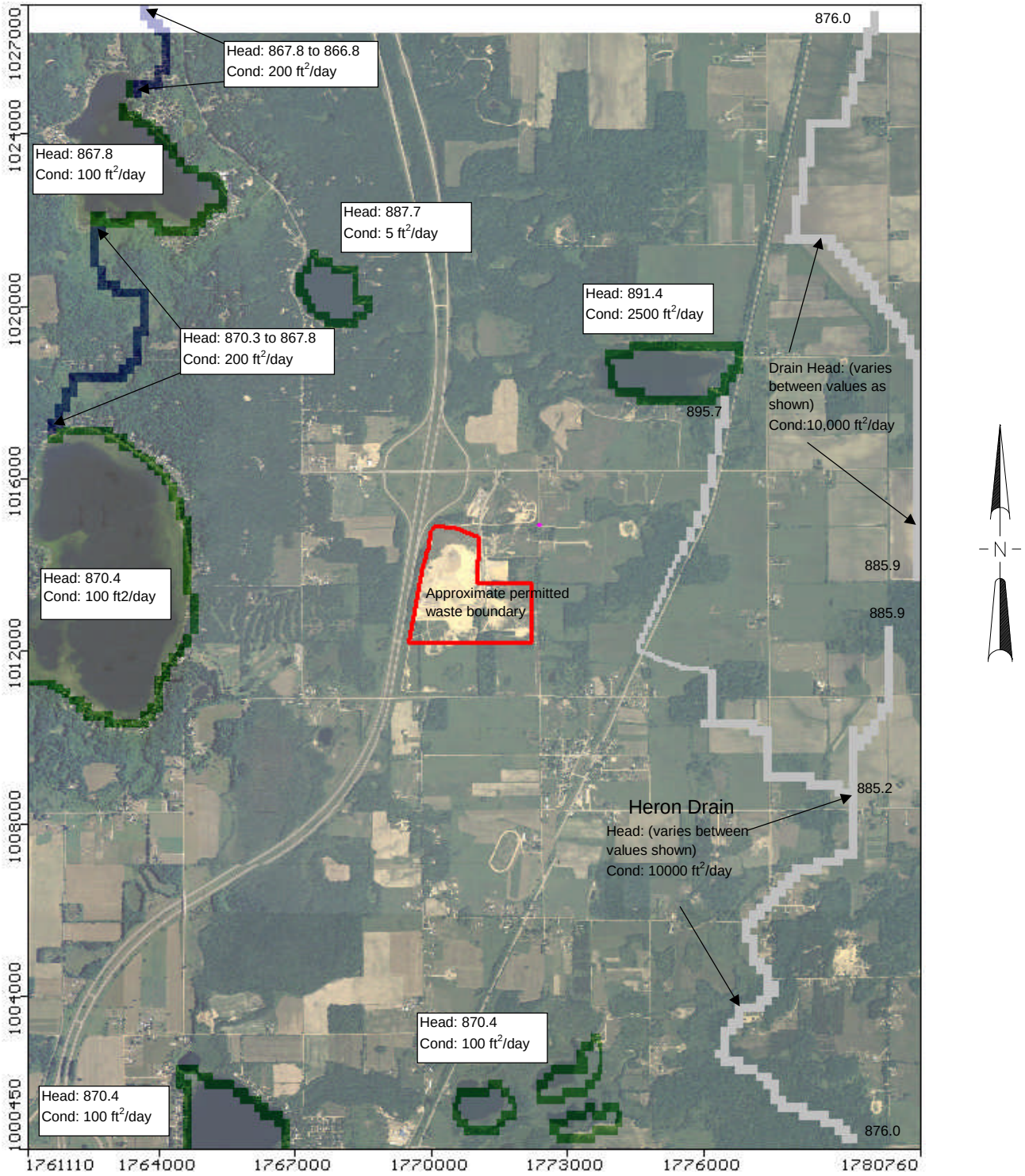
Central Sanitary Landfill

Pearson, Michigan

Republic Services, Inc.

Figure 4

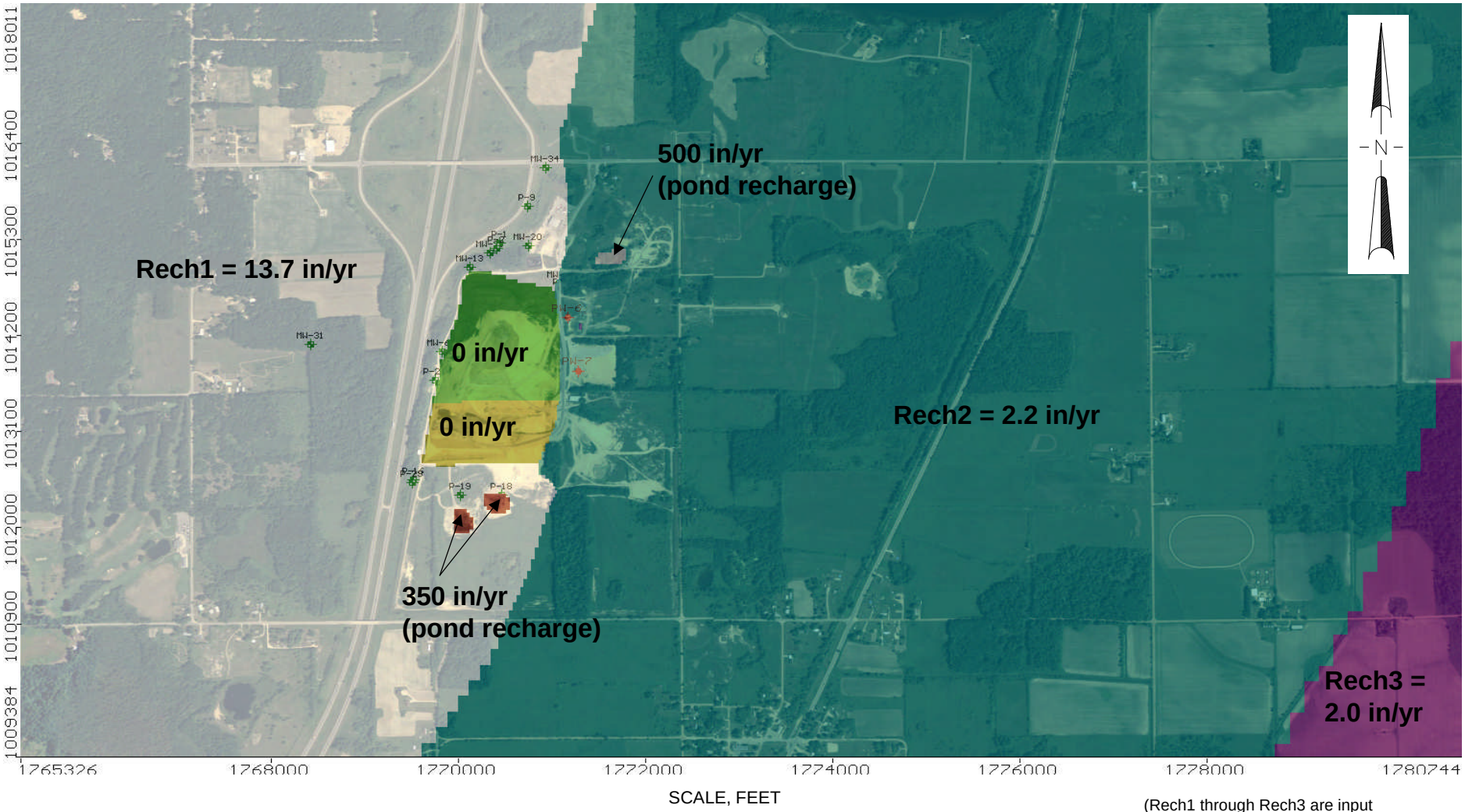
Groundwater Model Extent and Grid



(All head values in feet above MSL)

SCALE, FEET

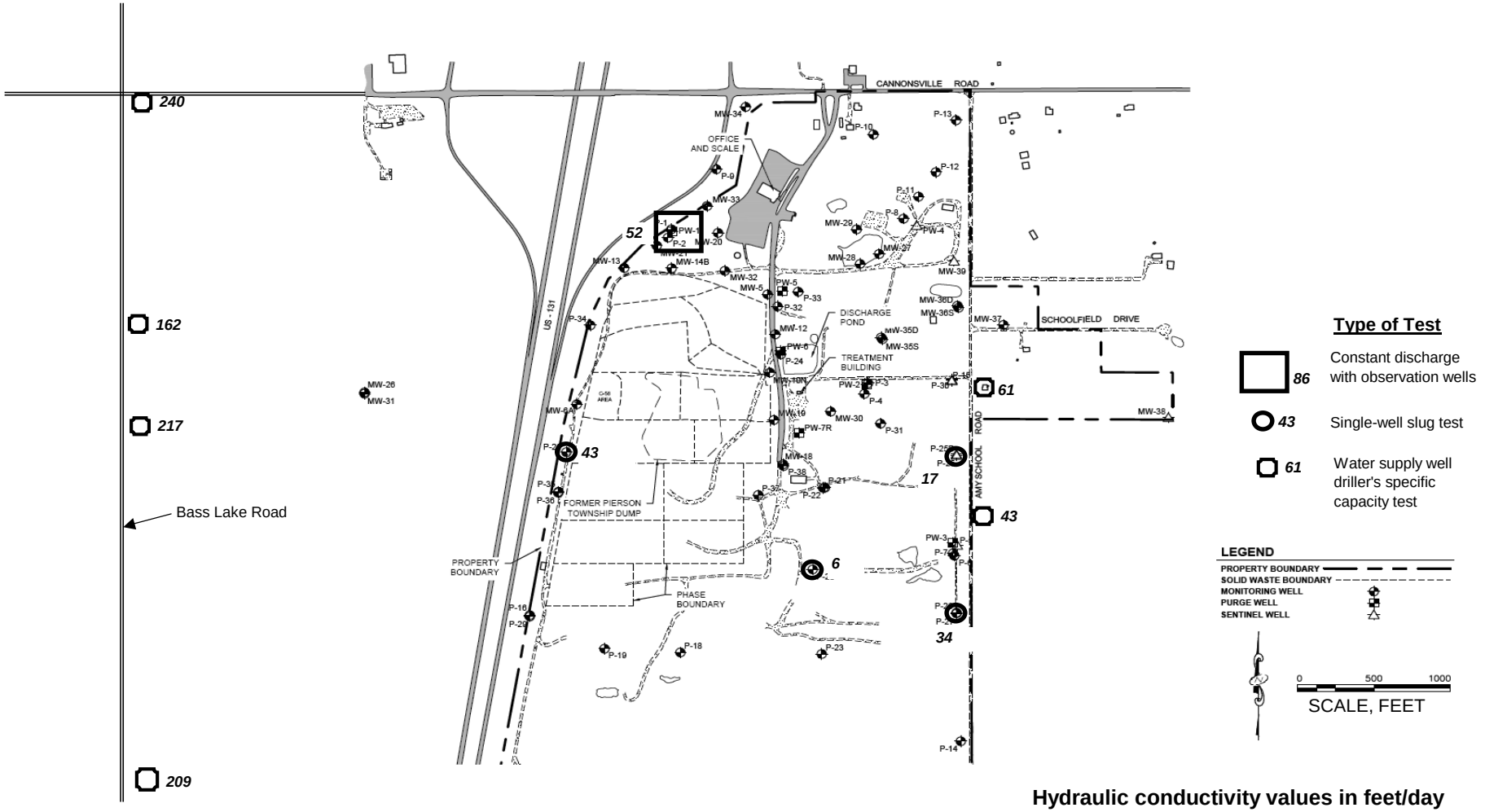
Andrews Engineering, Inc.	Central Sanitary Landfill Pearson, Michigan	*Figure 5*
10/20/2010	Republic Services, Inc.	Groundwater Model Hydrologic Boundaries



Recharge values represent conditions on Nov. 30, 2004

(Rech1 through Rech3 are input parameter ID numbers for sensitivity analysis - see also Figure 12)

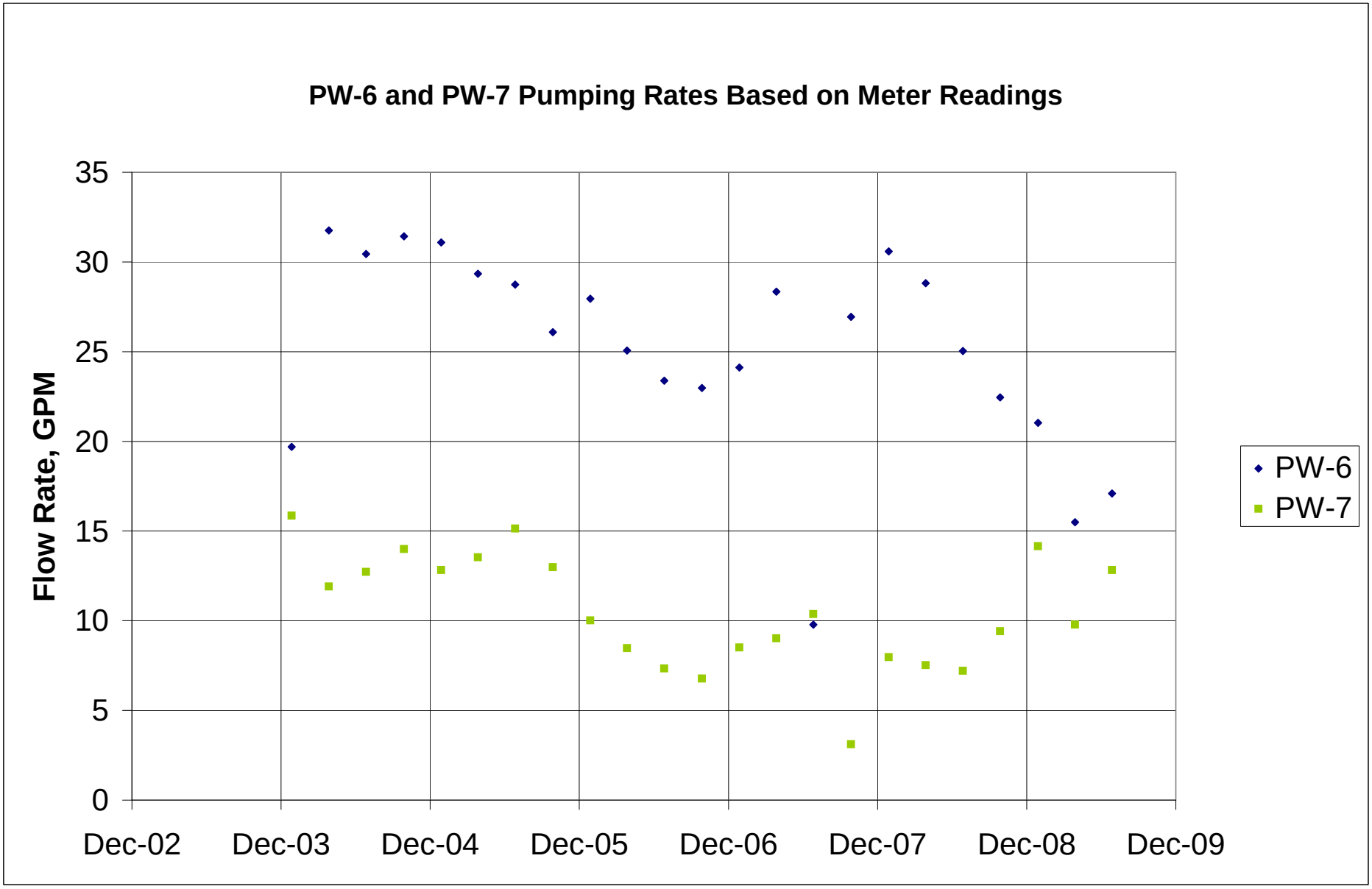
Andrews Engineering, Inc. 10/20/2010	Central Sanitary Landfill Pearson, Michigan Republic Services, Inc.	*Figure 6* Recharge Zones in Calibrated Model



Hydraulic conductivity values in feet/day

Facility base map from Engineering and Environmental Solutions, LLC

Andrews Engineering, Inc. 10/20/2010	Central Sanitary Landfill Pearson, Michigan Republic Services, Inc.	*Figure 7* Hydraulic Conductivity Test Results



Andrews Engineering, Inc.

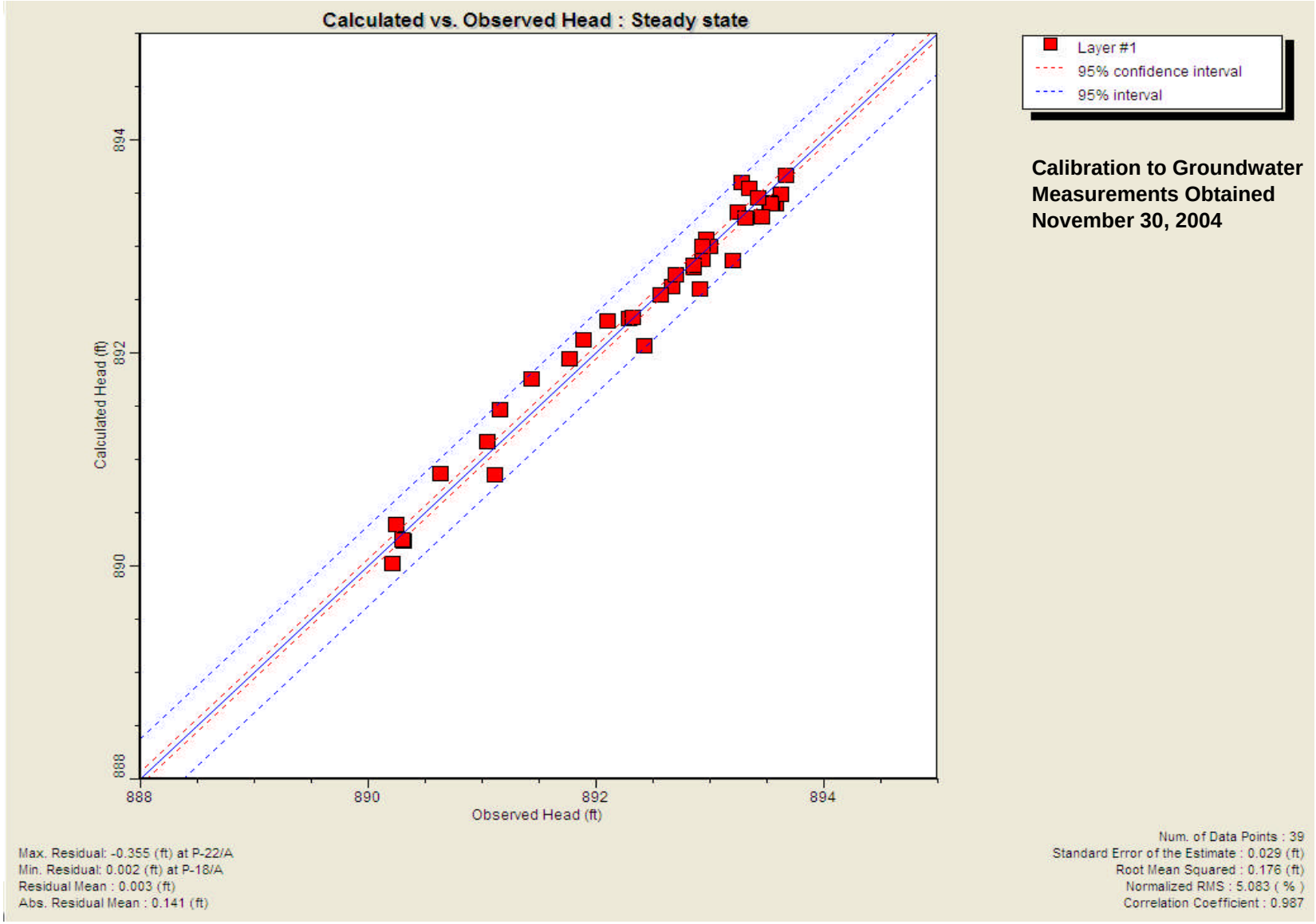
10/21/2010

Central Sanitary Landfill
Pearson, Michigan

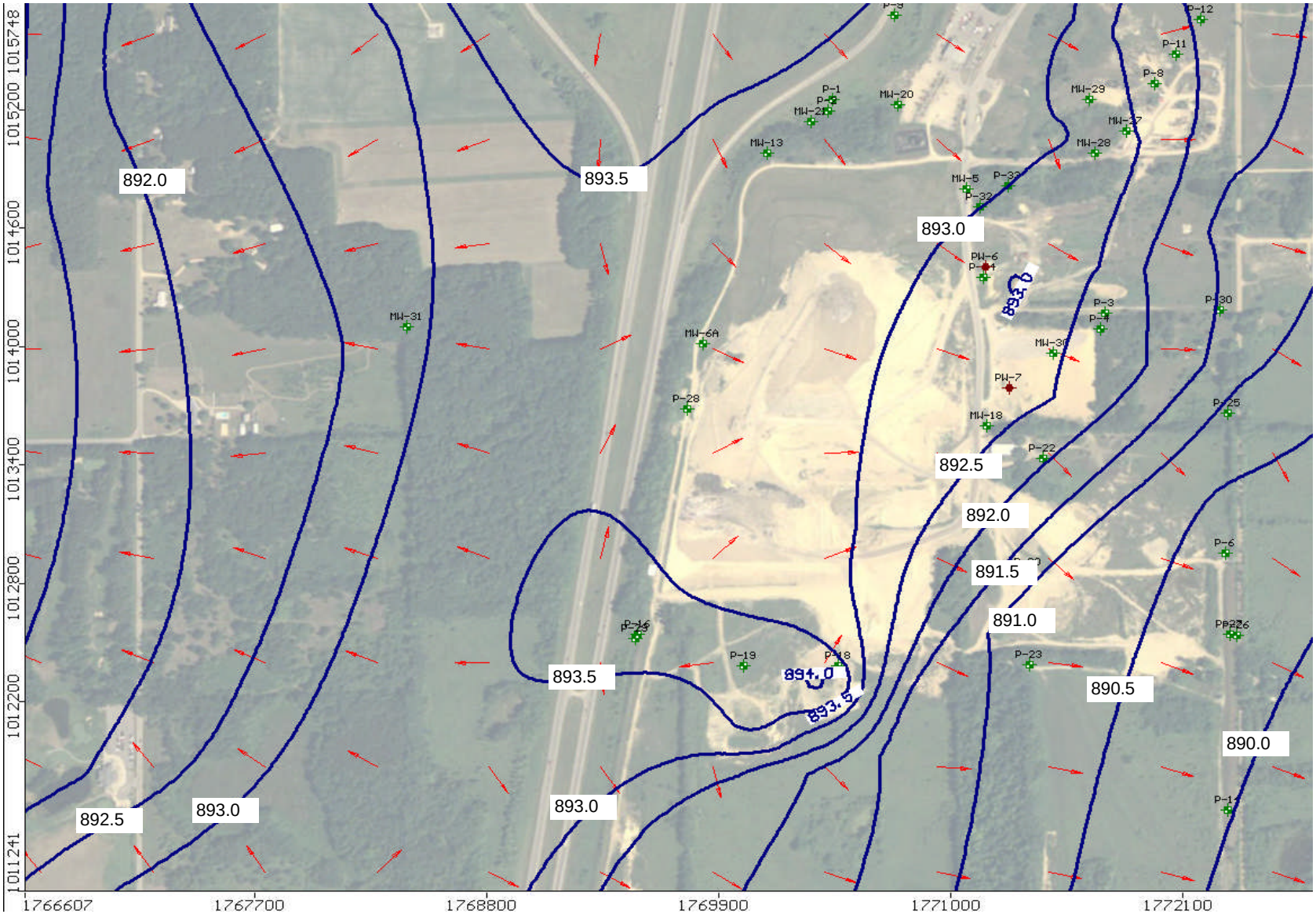
Republic Services, Inc.

Figure 8

Pumping Rates for PW-6 and PW-7

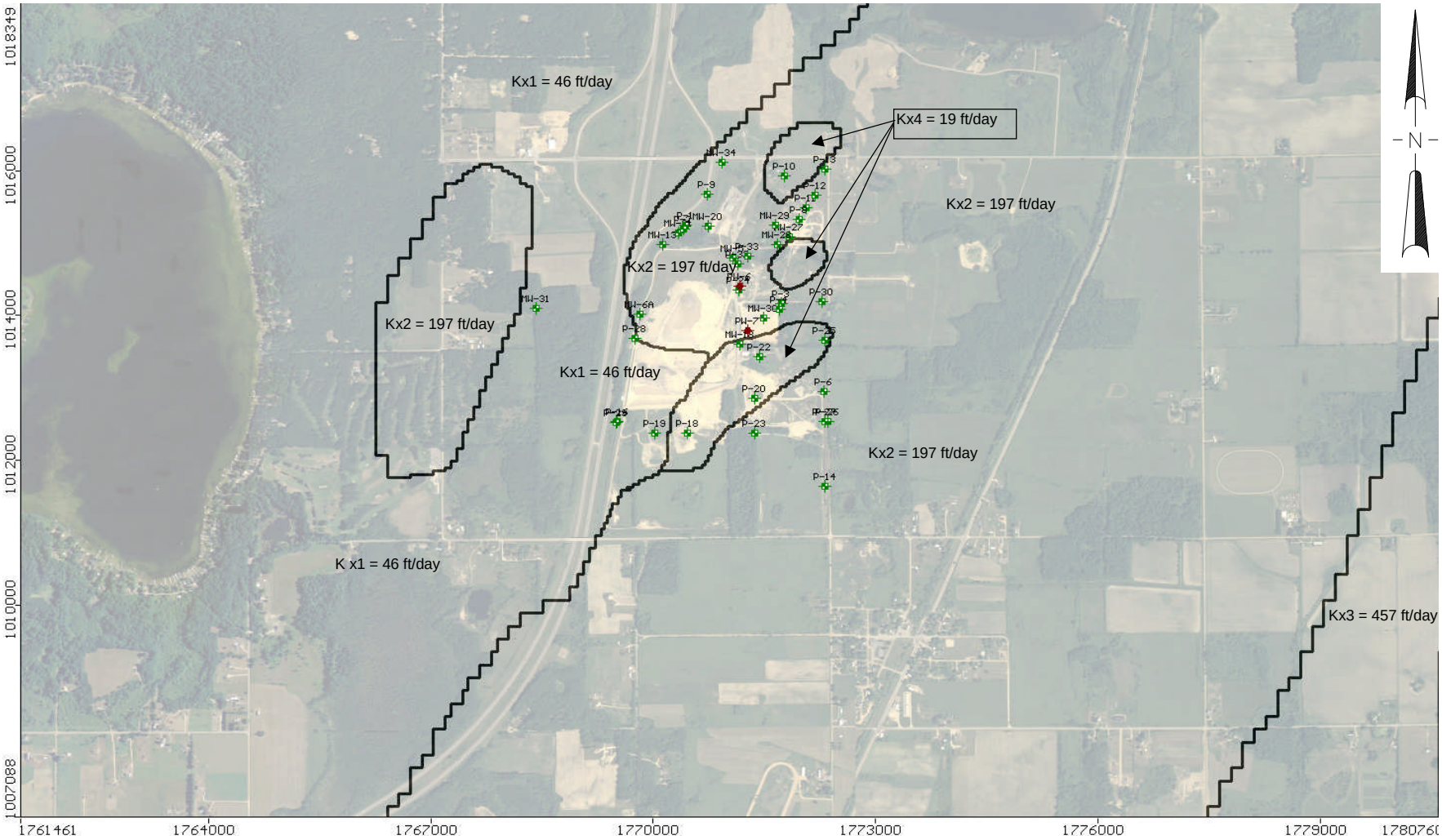


Andrews Engineering, Inc. 10/21/2010	Central Sanitary Landfill Pearson, Michigan Republic Services, Inc.	*Figure 9* Groundwater Model Calibration Statistics



Contour Values are Elevation, Feet Above MSL

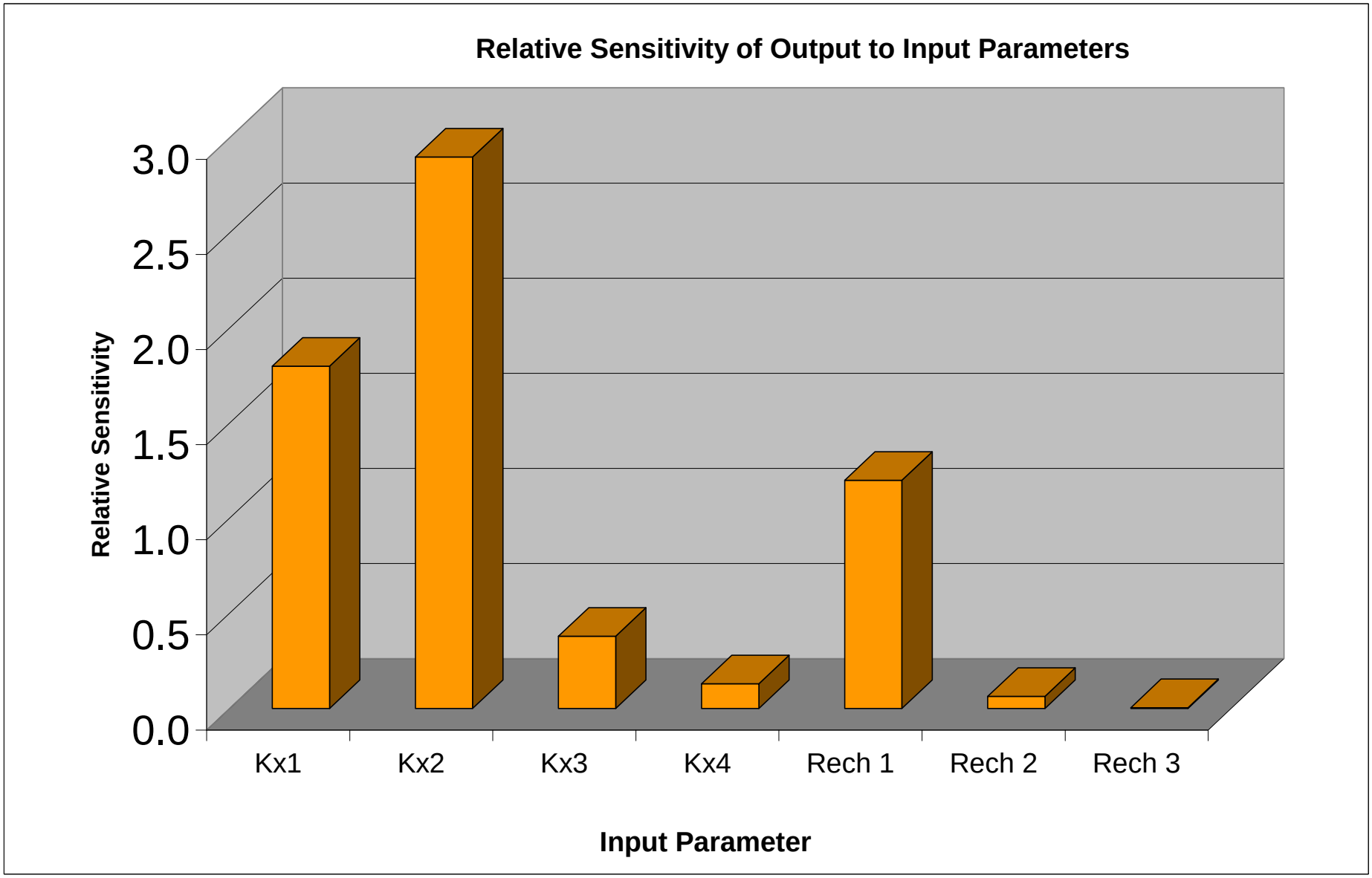
Andrews Engineering, Inc. 10/21/2010	**Central Sanitary Landfill** **Pearson, Michigan** **Republic Services, Inc.**	***Figure 10*** **Modeled Groundwater Map for Calibration Date**



SCALE, FEET

(Kx1 through Kx4 are input parameter ID numbers for sensitivity analysis - see also Figure 12)

Andrews Engineering, Inc. 10/20/2010	**Central Sanitary Landfill** **Pearson, Michigan** **Republic Services, Inc.**	***Figure 11*** **Distribution of Hydraulic Conductivity in Calibrated Model**



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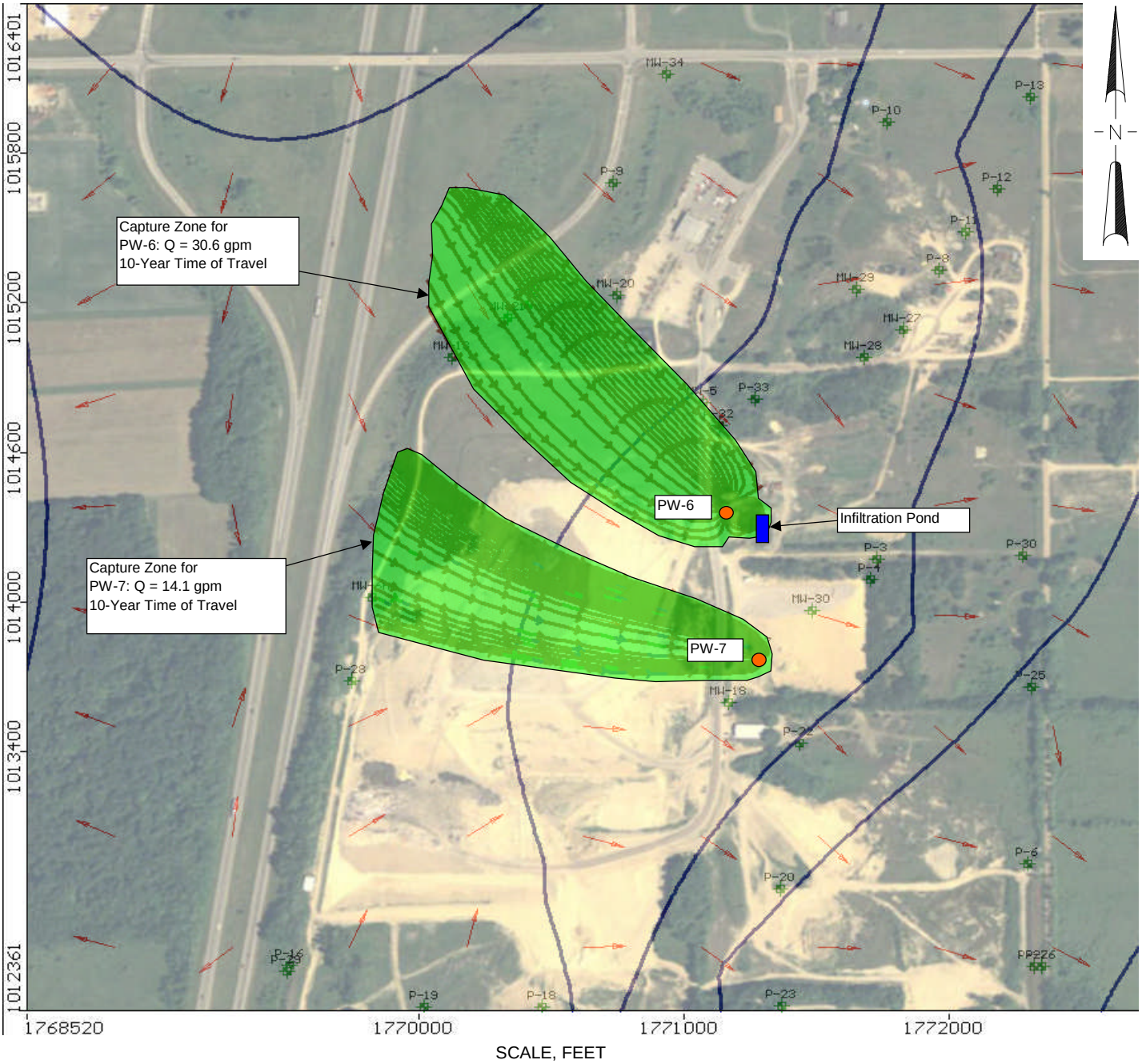
Pearson, Michigan

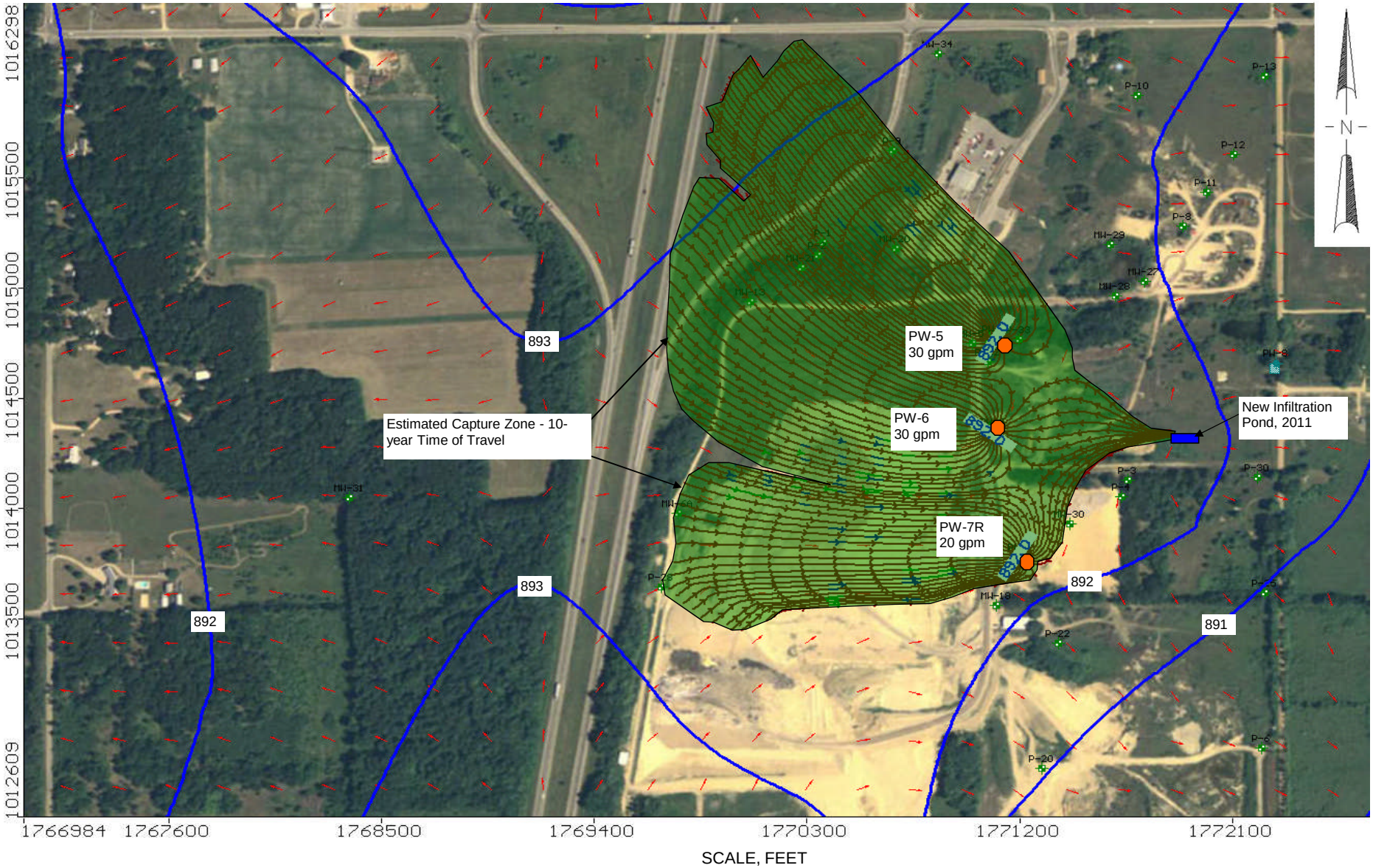
Republic Services, Inc.

Figure 12

Relative Sensitivity of Output Results to Input Parameters



Andrews Engineering, Inc. 10/21/2010	Central Sanitary Landfill Pearson, Michigan Republic Services, Inc.	*Figure 13* Estimated Capture Zones for Pre-2010 Pumping Rates



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Pearson, Michigan

Republic Services, Inc.

Figure 14 (revised 10/20/2011)

Estimated Capture Zone for Proposed Remedial Action

Appendix 1

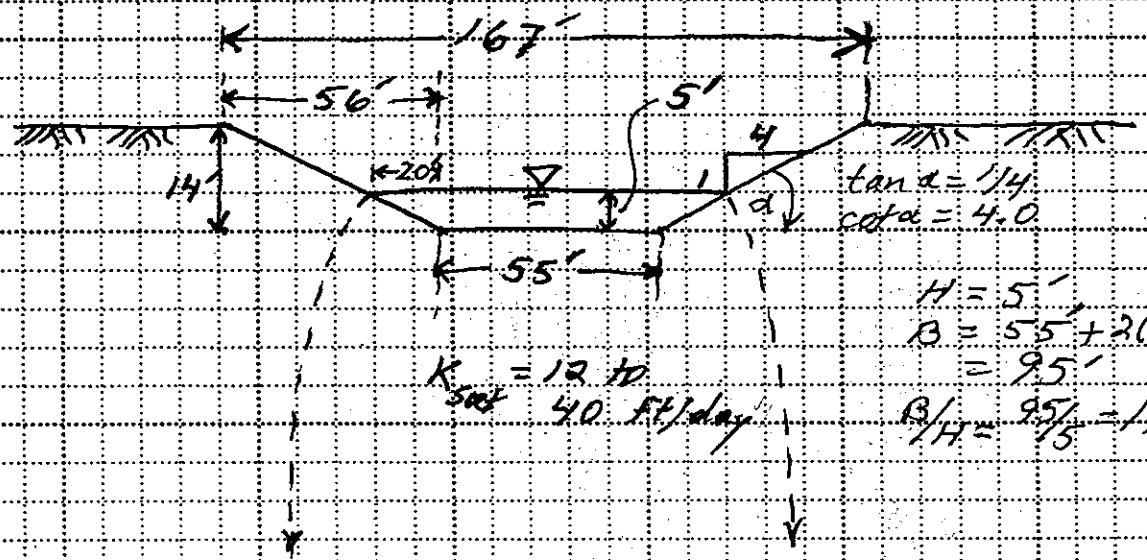
Pond Design Calculations and As-built Pond Coordinates

ANDREWS ENVIRONMENTAL ENGINEERING, INC.
7172 Graham Road Indianapolis, IN 46250
Ph (317) 595-6492 Fx (317) 598-9929

Sheet 1 of 1
By TAB Date 7/28/2011
Ckd SPR Date 8-1-2011

Project Central Sanitary LF - Discharge Pond Project No. 2009-403GMS 1101

Given: Pond cross-sectional dimensions below, pond fill depth of 5 feet, soil properties as indicated, and assuming an infinite depth to impermeable soils;
Find: Average seepage flow rate per length of pond, q.



$H = 5'$
$B = 55' + 2(20') = 95'$
$B/H = 95/5 = 19$

$K_{sat} = 12$ to 40 ft/day

- K_{sat} based on USDA soil Report - soil is Mancelona loamy sand

- utilizing method presented by Harr, 1962, pages 235-240 (see attached):

Seepage Quantity Per Foot of Pond Length

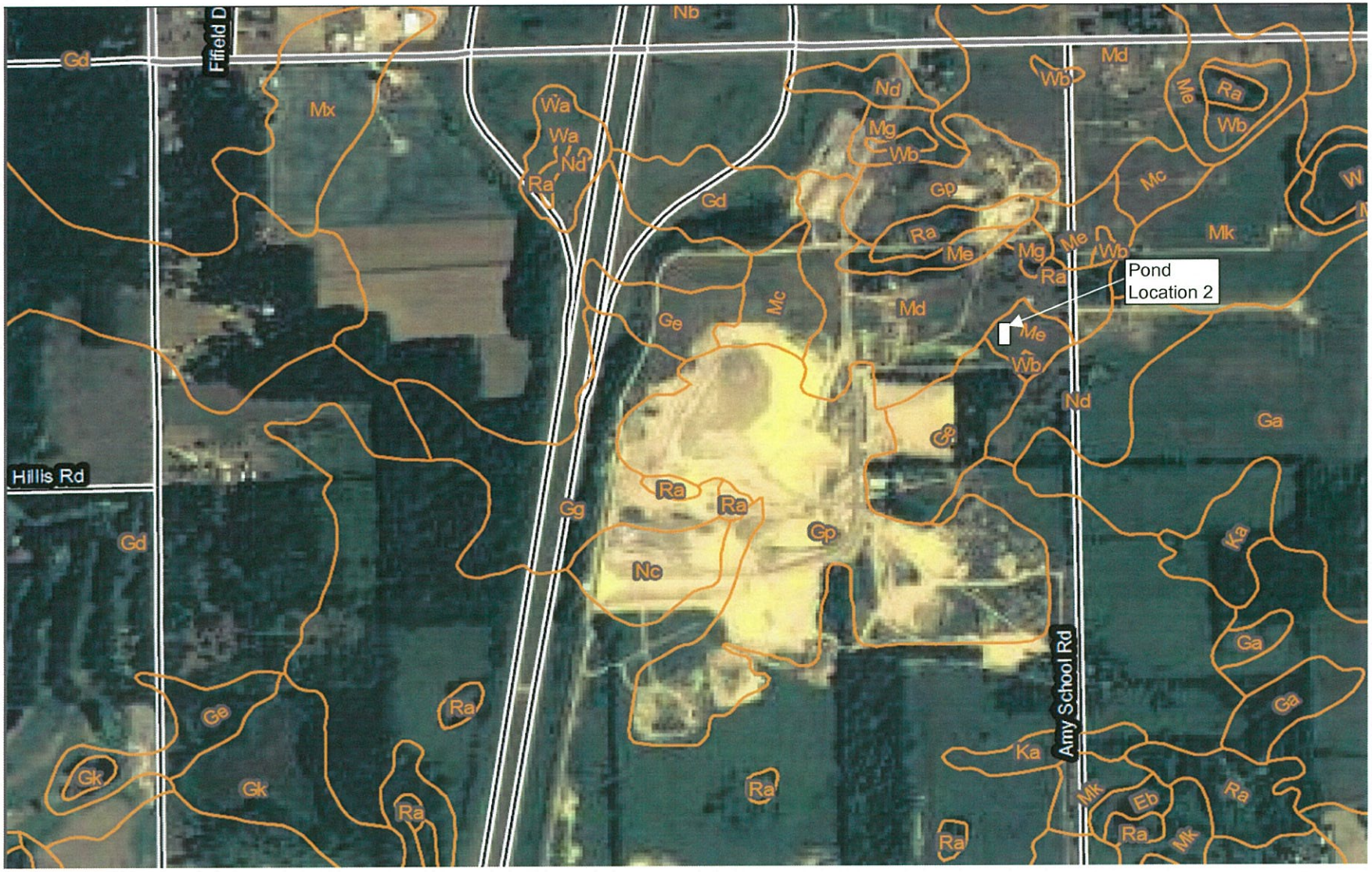
$q_1 = K_{sat}(B + AH)$

$= 12\,ft/d\,(95 + 2.8(5)) = 1{,}308\ ft^3/day/ft$
$= 6.8\ gpm/ft$

$q_2 = 40\,ft/d\,(95 + 2.8(5)) = 4{,}360\ ft^3/day/ft$
$= 22.6\ gpm/ft$

- For a wetted pond length of 130', Q is between about 900 and 3000 gpm

USDA Soils Map for Site and Surrounding Areas - Pond Location 2 in Me, Mancelona Loamy Sand



Me—Mancelona loamy sand, 10 to 18 percent slopes

Map Unit Setting

Elevation: 800 to 1,200 feet
Mean annual precipitation: 30 to 36 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 140 to 150 days

Map Unit Composition

Mancelona and similar soils: 100 percent

Description of Mancelona

Setting

Landform: Outwash plains
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Sandy and/or loamy supraglacial meltout till

Properties and qualities

Slope: 10 to 18 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 25 percent
Available water capacity: Low (about 4.2 inches)

Interpretive groups

Land capability (nonirrigated): 7s

Typical profile

0 to 13 inches: Loamy sand
13 to 37 inches: Loamy sand
37 to 41 inches: Gravelly loamy sand
41 to 60 inches: Gravelly sand

Groundwater and Seepage

M. E. Harr

Professor of Soil Mechanics
School of Civil Engineering, Purdue University

McGRAW-HILL BOOK COMPANY

New York
San Francisco
Toronto
London

9-3. Seepage from Ditches of Trapezoidal Shape

A much more direct method of solution for the seepage from ditches, canals, etc., was given by Vedernikov [151], using the method of inversion. The section to be investigated is shown in Fig. 9-5*a*. The hodograph is given in Fig. 9-5*b*, and the inversion of the hodograph $[dz/dw = 1/(u - iv)]$ in Fig. 9-5*c*.

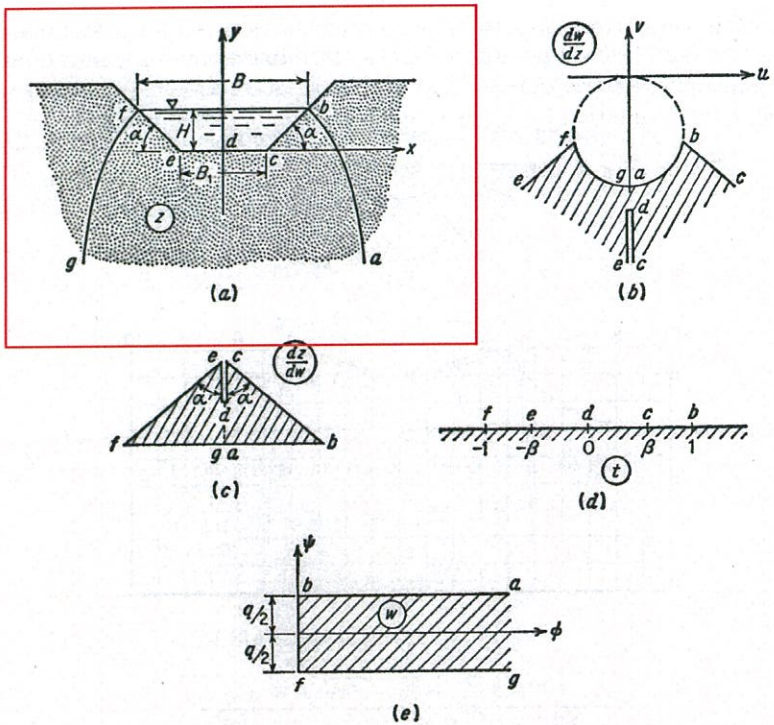


FIG. 9-5

Taking an auxiliary t plane as shown in Fig. 9-5d, we obtain for the mapping of the dz/dw plane onto the lower half plane of t

$$\frac{dz}{dw} = M \int_0^t \frac{t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(\beta^2-t^2)^{1-\sigma}} + N = M\Phi(t) + N \tag{1}$$

where $\sigma = \alpha/\pi$, and $\Phi(t)$ is the indicated integral. In particular, we shall define

$$\begin{aligned} J_1 &= \Phi(\beta) = \int_0^\beta \frac{t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(\beta^2-t^2)^{1-\sigma}} \\ J_2 &= \int_\beta^1 \frac{t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}} \end{aligned} \tag{2}$$

Substituting $(t^2-\beta^2)/(1-\beta^2) = x$ into the second of Eqs. (2), we find that (cf. Sec. B-7)

$$J_2 = \frac{1}{2\beta'}\int_0^1 x^{\sigma-1}(1-x)^{-\frac{1}{2}-\sigma}\,dx = \frac{1}{2\beta'}B(\sigma, \tfrac{1}{2}-\sigma) = \frac{\Gamma(\sigma)\Gamma(\frac{1}{2}-\sigma)}{2\beta'\sqrt{\pi}} \tag{3}$$

where $\beta' = (1-\beta^2)^{\frac{1}{2}}$.

To eliminate the constant N in Eq. (1), we note that at points $t = \beta$, and the velocity is infinite ($dz/dw = 0$); hence

$$MJ_1 + N = 0$$

and

$$\frac{dz}{dw} = M[\Phi(t) - J_1] \qquad (\cdot$$

To evaluate the constant M in Eq. (4) we note that at points b, whe $u = k \sin \pi\sigma \cos \pi\sigma$, $v = -k \cos^2 \pi\sigma$, $dw/dz = u - iv = kie^{-\pi i\sigma} \cos \pi$ and $t = 1$,

$$\frac{1}{ki}e^{\pi i\sigma} = M[\Phi(1) - J_1]\cos \pi\sigma$$

Now, noting in the second of Eqs. (2) that

$$(\beta^2 - t^2)^{1-\sigma} = -e^{-i\pi\sigma}(t^2-\beta^2)^{1-\sigma}$$

we have

$$\Phi(t) = J_1 - e^{i\pi\sigma}\int_\beta^t \frac{t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}}$$

$$\Phi(1) = J_1 - e^{\pi i\sigma}J_2 \qquad (\cdot$$

hence

$$M = \frac{i}{kJ_2 \cos \pi\sigma} \qquad ($$

and

$$\frac{dz}{dw} = \frac{i}{kJ_2 \cos \pi\sigma}[\Phi(t) - J_1] \qquad ($$

The mapping of the w plane (Fig. 9-5e) onto the lower half of tl t plane is given by (cf. Sec. 4-7)

$$w = \frac{iq}{\pi}\sin^{-1} t \qquad ($$

Now multiplying Eq. (7) by the derivative of Eq. (8) with respect to we find that

$$\frac{dz}{dt} = \frac{dz}{dw}\frac{dw}{dt} = -\frac{q[\Phi(t) - J_1]}{k\pi J_2 \cos \pi\sigma\sqrt{1-t^2}}$$

which, after integration with respect to t, yields

$$z = -\frac{q}{k\pi J_2 \cos \pi\sigma}\left[\int_0^t \frac{\Phi(t)\,dt}{\sqrt{1-t^2}} - J_1 \sin^{-1} t\right] \qquad (9$$

For the integral in Eq. (9a) we integrate by parts.

$$\int_0^t \frac{\Phi(t)\,dt}{\sqrt{1-t^2}} = \Phi(t)\sin^{-1} t - \int_0^t \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(\beta^2-t^2)^{1-\sigma}} \qquad (9$$

We shall now consider Eqs. (9) for the various parts of the flow regio

Along the bottom of the ditch, where $0 < t < \beta$,

$$= -\frac{q}{k\pi J_2 \cos \pi\sigma}\left\{\sin^{-1} t\left[\int_0^t \frac{t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(\beta^2-t^2)^{1-\sigma}} - J_1\right] - \int_0^t \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(\beta^2-t^2)^{1-\sigma}}\right\} \tag{10a}$$

t points c, where $t = \beta$ and $z = B_1/2$, we find

$$\frac{B_1}{2} = \frac{q}{\pi k J_2 \cos \pi\sigma}\int_0^\beta \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(\beta^2-t^2)^{1-\sigma}} \tag{10b}$$

Along the side of the ditch bc, where $\beta < t < 1$,

$$= \frac{B_1}{2} + \frac{q}{k\pi J_2 \cos \pi\sigma} e^{\pi\sigma i}\left[\sin^{-1} t \int_\beta^t \frac{t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}} - \int_\beta^t \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}}\right] \tag{11a}$$

; points b, where $t = 1$ and $z = B/2 + iH$, we obtain

$$\frac{B-B_1}{2} = \frac{q}{k\pi J_2}\left[\frac{\pi}{2}J_2 - \int_\beta^1 \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}}\right] \tag{11b}$$

$$H = \frac{q}{k\pi J_2}\tan \pi\sigma\left[\frac{\pi}{2}J_2 - \int_\beta^1 \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}}\right] \tag{11c}$$

Along the free surface ba, where $1 < t < \infty$, from Eq. (11*a*) we find

$$= \frac{B}{2} + Hi + \frac{q}{k\pi J_2 \cos \pi\sigma}\left[-\cosh^{-1} t \int_1^t \frac{t\,dt}{(t^2-1)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}} - iJ_2 e^{\pi\sigma i}\cosh^{-1} t + \int_1^t \frac{t \cosh^{-1} t\,dt}{(t^2-1)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}}\right] \tag{12a}*$$

Separating this equation into real and imaginary parts, we obtain for e equation of the free surface *ba*,

$$-\frac{B}{2} = \frac{q}{k\pi J_2 \cos \pi\sigma}\left[\int_1^t \frac{t \cosh^{-1} t\,dt}{(t^2-1)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}} + J_2 \sin \pi\sigma \cosh^{-1} t - \cosh^{-1} t \int_1^t \frac{t\,dt}{(t^2-1)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}}\right] \tag{12b}$$

We shall now derive the expression for the discharge from the ditch. efining

$$\int_0^\beta \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}} = f_1(\sigma,\beta)$$
$$\int_\beta^1 \frac{t \sin^{-1} t\,dt}{(1-t^2)^{\frac{1}{2}+\sigma}(t^2-\beta^2)^{1-\sigma}} = f_2(\sigma,\beta) \tag{13}$$

* We note that $(1-t^2)^{\frac{1}{2}+\sigma} = ie^{\pi\sigma i}(t^2-1)^{\frac{1}{2}+\sigma}$. Also for real values of $t > 1$, $\sin^{-1} t = \pi/2 - i \cosh^{-1} t$.

we have, in place of Eq. (10*b*),

$$B_1 = \frac{2q}{k\pi J_2 \cos \pi\sigma} f_1(\sigma,\beta) \tag{14a}$$

and in place of Eqs. (11*b*) and (11*c*),

$$\frac{B-B_1}{2} = \left[\frac{\pi}{2}J_2 - f_2(\sigma,\beta)\right]\frac{q}{\pi k J_2}$$
$$H = \frac{q}{\pi k J_2}\tan \pi\sigma\left[\frac{\pi}{2}J_2 - f_2(\sigma,\beta)\right] \tag{14b}$$

whence

$$B = B_1 + \frac{q}{k}\left[1 - \frac{2f_2(\sigma,\beta)}{\pi J_2}\right]$$
$$H = \frac{q}{2k}\tan \sigma\pi\left[1 - \frac{2f_2(\sigma,\beta)}{\pi J_2}\right] \tag{14c}$$

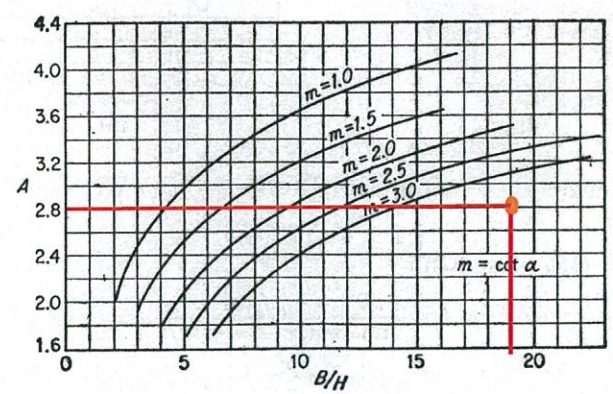
We note in Eqs. (14*c*) that the quantity of seepage is dependent upon the parameters σ and β and one of the dimensions B, B_1, or H, which are related by $B - B_1 = 2H \cot \sigma\pi$. As was done in the previous sections, Vedernikov takes the quantity of seepage in the form

$$q = k(B + AH) \tag{15a}$$

where, from Eqs. (14*c*), A is given by

$$A = \frac{2}{\tan \sigma\pi}\,\frac{f_2(\sigma,\beta) - f_1(\sigma,\beta)/\cos \sigma\pi}{J_2\pi/2 - f_2(\sigma,\beta)} \tag{15b}$$

Taking a series of values for α and β, Vedernikov obtained the correspondence between A and B/H as given in Fig. 9-6. In this figure $m = \cot \alpha$ is the side slope of the ditch.



for B/H = 19, and m = 4.0, A = 2.8

FIG. 9-6. (*After Vedernikov* [151].)

Comparing Eq. (15*a*) with the expression for the quantity of seepage obtained in Sec. 9-1 for ditches with a curved perimeter [$q = k(B + 2H)$], we see that the latter solution implied $A = 2$, whereas in Fig. 9-6, for the trapezoidal section, A is seen to vary from 2 to 4 for typical values of B/H. Noting that the velocity at infinity equals the coefficient of permeability, we find that the width of the flow at infinity (Fig. 9-7) is

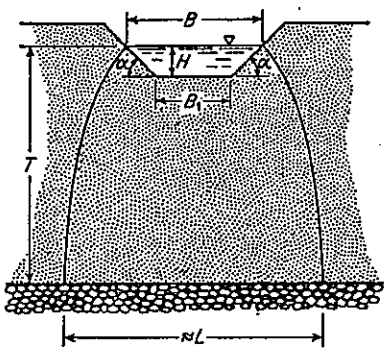
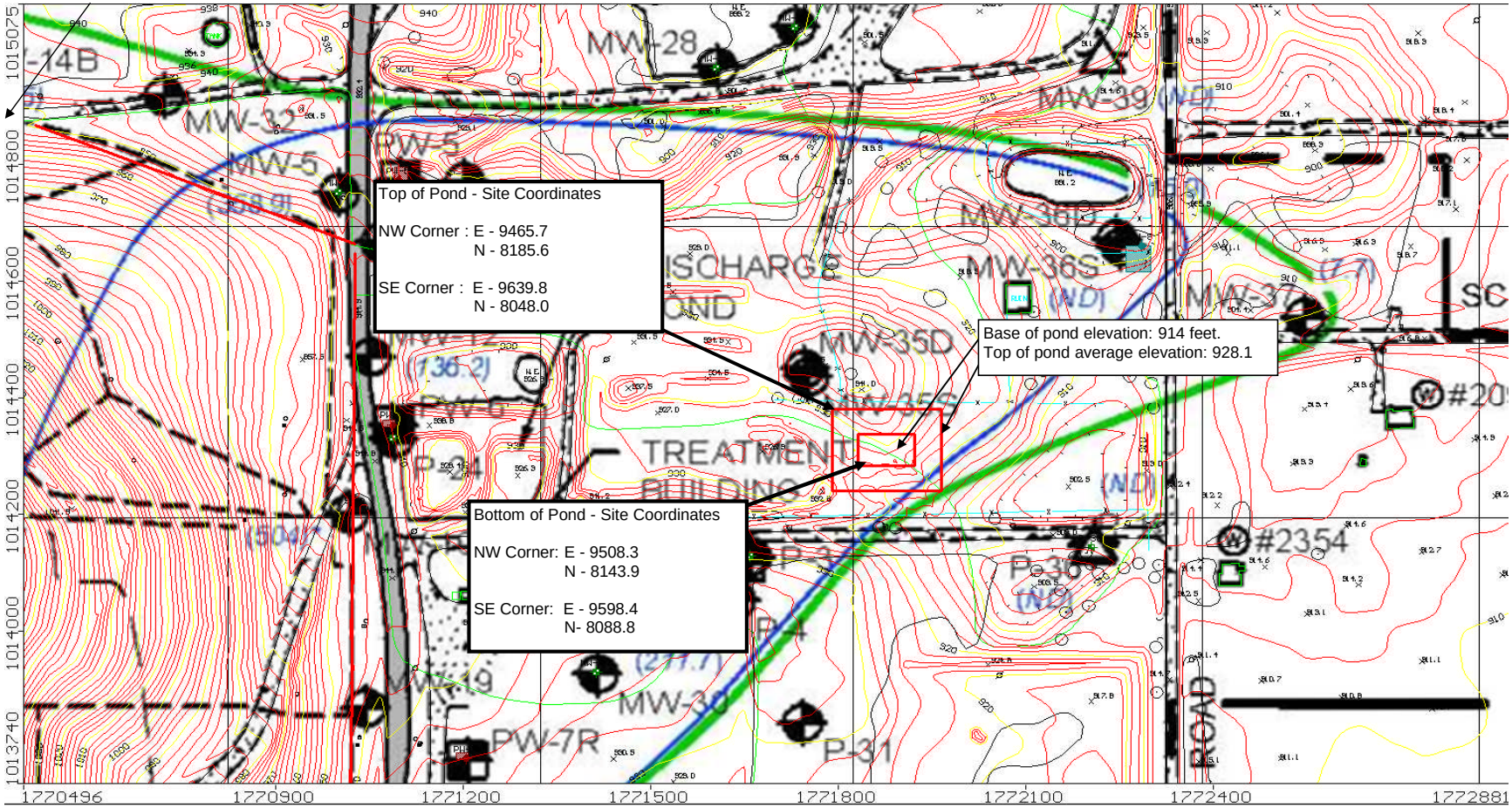


Fig. 9-7

$$L = B + AH \tag{16}$$

Thus we see that for a trapezoidal section, as was also shown to be the case for the curved perimeter, the equipotential lines rapidly approach the horizontal. Hence the solution of this section may also be considered to provide a sufficiently valid approximation for seepage into deep horizontal filters, as shown in Fig. 9-7.

As-Built Discharge Pond Coordinates and Elevations



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AEI 10/20/2011

Appendix E

Iron & Manganese Investigations

Engineering & Environmental Solutions, LLC
200 N. Franklin Street, Suite 202, Zeeland, MI 49464 - Phone (616) 931-3960

June 21, 2011
File Number: 001.03-11-002

Ms. Emily Freeman
Michigan Department of Environmental Quality
State Office Building
350 Ottawa, N.W.
Grand Rapids, Michigan 49503

Re: Results for Additional Iron Sampling at Central Sanitary Landfill

Dear Ms. Freeman:

On behalf of Central Sanitary Landfill, Engineering & Environmental Solutions is providing additional groundwater sampling results for the Remedial Action Plan (RAP). Additional iron sampling at Central Sanitary Landfill was conducted during the second quarter 2011 sampling event. Below is a summary of why we conducted additional iron sampling for the RAP and the results of that sampling.

During our meeting on March 29, 2011, and conference call on May 2, 2011, you had concerns regarding the high iron levels observed at monitoring well PW-4 and a possible connection with the high iron levels associated with the VOC plume beneath the landfill. Additional iron sampling at wells PW-4, MW-27, MW-28, and P-33 (Figure 1) was completed on May 5, 2011, and is intended to show that the high iron levels observed at monitoring well PW-4 are not associated with landfill operations or the VOC plume beneath the landfill. A revised iron isoconcentration map with the results of the second quarter iron sampling is shown on Figure 1. Analytical data used for the iron isoconcentration map were collected from shallow wells adjacent to the landfill and shallow/deep sentinel well pairs at the perimeter of the site.

As we discussed during our conference call, the exceptionally high iron levels initially detected at monitoring well PW-4 (up to 23,000 µg/L) are believed to be from the old purge well casing and not representative of the iron levels in the surrounding aquifer. Similar conditions are observed at purge well PW-2 where very high iron levels (up to 31,000 µg/L) were historically detected in the purge well and low levels of iron were detected in the surrounding aquifer at monitoring well P-3. For reference, historical groundwater analytical data collected at site wells is provided in Appendix B of the March 2011 RAP.

Monitoring well PW-4 was purged for 24 hours on May 4 through May 5, 2011, to pull in groundwater from the surrounding aquifer allowing us to collect a more representative sample. The iron levels at purge well PW-4 dropped to 2,400 to 2,600 µg/L during this sampling event. Groundwater analytical results are attached. This supports that the old steel well construction led to the very high iron levels observed shortly after the purge well was converted to a PVC monitoring well.

Although the iron level at monitoring well PW-4 has decreased by an order of magnitude since the initial sampling event, recent sampling results from deep monitoring well MW-39 and historical data from shallow well P-8 indicate that the aquifer surrounding well PW-4 has higher iron levels than site background (up to 4,000 µg/L at well P-8). Currently, the site's background tolerance limit is 390 µg/L. Well P-8 is approximately 100 feet upgradient from monitoring well PW-4 and well MW-39 is approximately 350 feet downgradient from well PW-4. Groundwater beneath the site flows from the northwest towards the southeast (blue arrows on Figure 1).

We believe that ponds and natural wetland conditions in the area around well PW-4 are producing elevated iron in the aquifer by natural processes. The MDEQ references this type of condition in their October 26, 2010, Remediation Advisory Team Briefing Paper for iron exceedance of Part 201 criteria. At the site, there are two shallow wells (MW-29 and P-8) downgradient from Pond 1 (Figure 1) and two shallow wells (MW-27 and MW-28) downgradient and adjacent to Pond 2 (Figure 1). Surface water in the ponds is an expression of the water table. Shallow groundwater in this area is approximately 5 to 10 feet below ground surface and the upper aquifer is very likely influenced by anaerobic conditions at the bottom of the ponds. Monitoring well PW-4 is approximately 450 downgradient from Pond 1 and approximately 250 feet downgradient from Pond 2 (Figure 1). The old purge well (PW-4) operated at this location for over 10 years capturing groundwater from beneath the ponds and wetlands. The purge well was screened across the shallow and deep portions of the aquifer.

On May 5, 2011, groundwater samples were collected from wells MW-27 and MW-28 to measure iron levels in the shallow aquifer adjacent to the larger pond (Pond 2, Figure 1). Sampling results from well MW-28 indicate that shallow groundwater adjacent to Pond 2 has iron levels above site background (up to 2,500 µg/L, Attachment). Well P-33 was sampled to measure iron levels between the pond and the area of high iron levels at the landfill. Well P-33 is a shallow well located near the northeast edge of the landfill at the edge of the VOC plume (Figure 1). The plume beneath the landfill would have to migrate past well P-33 to impact the area around the pond and well PW-4. The

iron level detected at well P-33 was very low (29 µg/L) and is consistent with historical data (72 µg/L, December 2000). The low levels of iron detected at well P-33 show that there is not a connection between the high iron levels beneath the landfill and the naturally occurring iron levels around the ponds and well PW-4.

Iron levels detected in the shallow aquifer at wells MW-28 and P-8 show that the ponds and wetlands are a natural source for elevated iron in this area. Iron levels above site background detected at deep well PW-4 do not appear to be related to the VOC plume at the landfill but are likely the result of naturally high iron associated with the ponds.

The additional iron data collected during this investigation supports our original conclusion that there are portions of the aquifer with naturally high iron above site background. Iron has been detected above its background tolerance limit in areas that have not been impacted by landfill operations. The site's background tolerance limit of 390 µg/l is based on a small number of monitoring wells located upgradient from the landfill. Monitoring wells in the vicinity of well PW-4 and MW-38 are recommended to be evaluated for developing a revised site background tolerance limit for iron. We will contact you to discuss this recommendation.

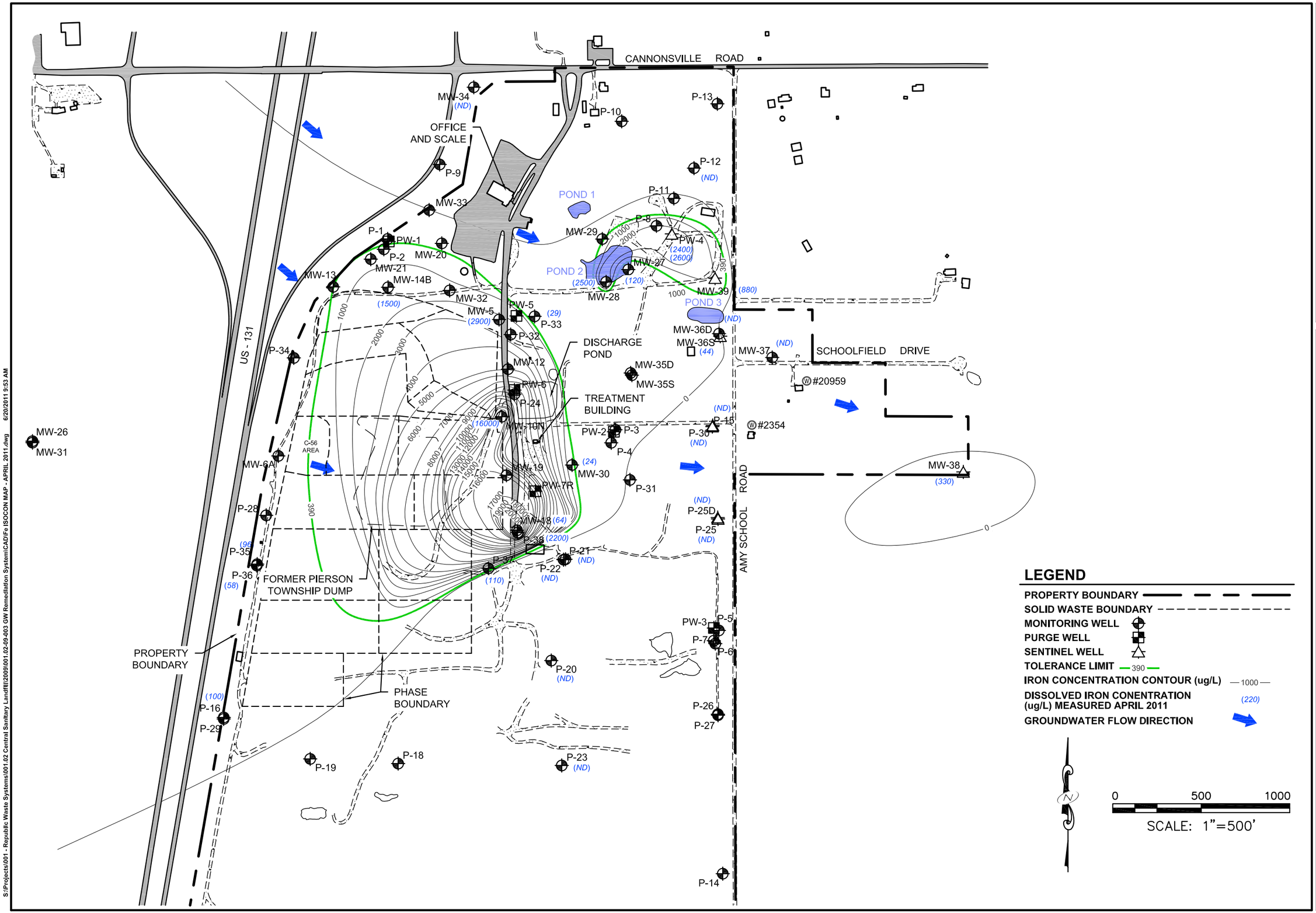
If you have questions or need additional information please contact me at (616) 566-4596.

Sincerely,

Dean B. Vander Meulen, P.G.
Managing Partner

Attachments

cc: Debbie Nurmi – Republic Services, Inc.
Joe Montello – Republic Services, Inc.
Roger Rockburn – Central Sanitary Landfill
File



LEGEND

- PROPERTY BOUNDARY
- SOLID WASTE BOUNDARY
- MONITORING WELL
- PURGE WELL
- SENTINEL WELL
- TOLERANCE LIMIT — 390 —
- IRON CONCENTRATION CONTOUR (ug/L) — 1000 —
- DISSOLVED IRON CONENTRATION (ug/L) MEASURED APRIL 2011 (220)
- GROUNDWATER FLOW DIRECTION

N

0 500 1000

SCALE: 1"=500'

S:\Projects\001 - Republic Waste Systems\001.02 Central Sanitary Landfill\2009\001.02-09-003 GW Remediation System\CAD\Fe ISOCON MAP - APRIL 2011.dwg 6/20/2011 9:53 AM

Engineering & Environmental Solutions, LLC
200 North Franklin Street, Suite 202, Zeeland, Michigan 49464
Phone: (616) 931-3960 Fax: (616) 931-3970
www.GetEESolutions.com

CENTRAL SANITARY LANDFILL
GROUND WATER REMEDIATION SYSTEM
SECTION 21, T. 11 N., R. 10 W., PIERSON TOWNSHIP, MONTCALM COUNTY
REPUBLIC SERVICES, INC.
21545 CANNONSVILLE ROAD, PIERSON, MI 49339

MARK	DATE	DESCRIPTION

DESIGNED BY: KJV
DRAWN BY: ALB
CHECKED BY:
PROJECT NO: 001.02-09-003
SHEET TITLE

IRON ISOCON-CENTRATION MAP APRIL 2011

FIGURE 1

HERITAGE ENVIRONMENTAL SERVICES

CERTIFICATE OF ANALYSIS

Service Location	Received	Lab ID
HERITAGE ENVIRONMENTAL SERVICES, LLC COMMERCIAL LABORATORY OPERATIONS 7901 W. MORRIS ST. INDIANAPOLIS, IN 46231 (317)243-8304	15-APR-11	A913780
	Completed	**PO Number**
	12-MAY-11	2198264 (2011)
	Printed	**Sampled**
	23-MAY-11	14-APR-11 12:40

Report To	Bill To
MYNDI BACON SOIL AND MATERIALS ENGINEERS, INC. 4460 COMMERCIAL AVENUE, SUITE B KALAMAZOO, MI 49002	MARK SCHNEIDER ALLIED WASTE SYSTEMS, INC. 21545 WEST CANNONSVILLE ROAD PIERSON, MI 49339

Sample Description

CLIENT ID: PW-4
MATRIX TYPE: NON-SPECIFIC WATER
SUBMITTER: 9403 - MI-ALLIED-CENTRAL SANITARY
DATA PACKAGE #: 61404
LOCATION: CENTRAL SANITARY LANDFILL
DESCRIPTION: TABLE D-3A

FIELD TEMPERATURE SM 2550 B, 19TH ED. NELAC:N

Analysis Date: 14-APR-11 12:40 Instrument: FIELD Test: G603.1.0

Parameter	Result	Det. Limit	Units
TEMPERATURE	10.2		Degrees C

FIELD SPECIFIC CONDUCTANCE SW846-9050A NELAC:Y

Analysis Date: 14-APR-11 12:40 Instrument: FIELD Test: G604.0.0

Parameter	Result	Det. Limit	Units
CONDUCTIVITY	1313	1.0	umHOS/cm

FIELD PH (AQUEOUS) SW846-9040C NELAC:Y

Analysis Date: 14-APR-11 12:40 Instrument: FIELD Test: G607.0.0

Parameter	Result	Det. Limit	Units
PH	7.16	0.1	Std. Units

FIELD FILTRATION SAS

Analysis Date: Instrument: FIELD Test: P110.0.0

Parameter	Result	Det. Limit	Units

IRON ICP SW846-6010B NELAC:Y

Analyst: J. KRAMER Analysis Date: 19-APR-11 09:02 Instrument: ICP Test: M115.3.1

Prep: FIELD FILTRATION SAS P110.0.0

Parameter	Result	Det. Limit	Units
IRON	2400	20	ug/L

HERITAGE ENVIRONMENTAL SERVICES

Sample ID: A913780 PW-4

MANGANESE ICP SW846-6010B NELAC:Y

Analyst: J. KRAMER Analysis Date: 19-APR-11 09:02 Instrument: ICP Test: M119.3.1

Prep: FIELD FILTRATION SAS P110.0.0

Parameter	Result	Det. Limit	Units
MANGANESE	83	5.0	ug/L

TOTAL DISSOLVED SOLIDS SM2540C 18TH ED NELAC:Y

Analyst: S. BOXUM Analysis Date: 18-APR-11 14:40 Test: G402.9.0

Parameter	Result	Det. Limit	Units
DISSOLVED SOLIDS	650	20	mg/L

VOLATILE ORGANICS (CAPILLARY COLUMN) SW846-8260B NELAC:Y

Analyst: R. SHAMP Analysis Date: 25-APR-11 13:20 Instrument: GC/MS VOA Test: O510.6.0

Parameter	Result	Det. Limit	Units
CHLOROETHANE	BDL	5.0	ug/L
CHLOROMETHANE	BDL	5.0	ug/L
1,1,1-TRICHLOROETHANE	BDL	1.0	ug/L
1,1-DICHLOROETHANE	BDL	1.0	ug/L
1,2-DICHLOROETHANE	BDL	1.0	ug/L
1,1-DICHLOROETHENE	BDL	1.0	ug/L
CIS-1,2-DICHLOROETHENE	BDL	1.0	ug/L
1,2-DICHLOROPROPANE	BDL	1.0	ug/L
TRANS-1,2-DICHLOROETHENE	BDL	1.0	ug/L
ACETONE (2-PROPANONE)	BDL	20	ug/L
DIETHYL ETHER	BDL	5.0	ug/L
DICHLOROMETHANE (METHYLENE CHLORIDE)	BDL	5.0	ug/L
TETRACHLOROETHENE	BDL	1.0	ug/L
TRICHLOROETHENE	BDL	1.0	ug/L
VINYL CHLORIDE	BDL	1.0	ug/L
BENZENE	BDL	1.0	ug/L
ETHYL BENZENE	BDL	1.0	ug/L
TOLUENE	BDL	1.0	ug/L
XYLENES (O/M/P-XYLENE)	BDL	2.0	ug/L
METHYL ETHYL KETONE	BDL	5.0	ug/L
4-METHYL-2-PENTANONE	BDL	5.0	ug/L
TETRAHYDROFURAN	BDL	12	ug/L
...			
SURROGATE RECOVERY			

DICHLOROETHANE-D4	120		% Rec
TOLUENE-D8	93		% Rec
4-BROMOFLUOROBENZENE	80		% Rec
DIBROMOFLUOROMETHANE	110		

			% Rec

Prep Method SW846-5030B Purge and Trap

Sample Comments

BDL Below Detection Limit

Sample was received on ice at temperature 4.5 C.
Sample chain of custody number 083752.

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KS ELAP / NELAP Accreditation # E-10177 Indiana SDWA C-49-01

Approved by: CHRISTINE SARKAN 12-MAY-11

HERITAGE ENVIRONMENTAL SERVICES

CERTIFICATE OF ANALYSIS

Service Location	Received	Lab ID
HERITAGE ENVIRONMENTAL SERVICES, LLC COMMERCIAL LABORATORY OPERATIONS 7901 W. MORRIS ST. INDIANAPOLIS, IN 46231 (317)243-8304	06-MAY-11	A916128
	Completed	**PO Number**
	12-MAY-11	2198264 (2011)
	Printed	**Sampled**
	23-MAY-11	05-MAY-11 15:50

Report To	Bill To
MYNDI BACON SOIL AND MATERIALS ENGINEERS, INC. 4460 COMMERCIAL AVENUE, SUITE B KALAMAZOO, MI 49002	MARK SCHNEIDER ALLIED WASTE SYSTEMS, INC. 21545 WEST CANNONSVILLE ROAD PIERSON, MI 49339

Sample Description

CLIENT ID: PW-4
MATRIX TYPE: NON-SPECIFIC WATER
SUBMITTER: 9403 - MI-ALLIED-CENTRAL SANITARY
DATA PACKAGE #: 61404
LOCATION: CENTRAL SANITARY LANDFILL
DESCRIPTION: TABLE D-3A

FIELD FILTRATION SAS

Analysis Date: Instrument: FIELD Test: P110.0.0

Parameter	Result	Det. Limit	Units

IRON ICP SW846-6010B NELAC:Y

Analyst: J. KRAMER Analysis Date: 09-MAY-11 05:26 Instrument: ICP Test: M115.3.1
Prep: FIELD FILTRATION SAS P110.0.0

Parameter	Result	Det. Limit	Units
IRON	2600	20	ug/L

Sample Comments

Sample was received on ice at temperature 1.3 C.
Sample chain of custody number 76506.

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KS ELAP / NELAP Accreditation # E-10177 Indiana SDWA C-49-01

Approved by: CHRISTINE SARKAN 12-MAY-11

HERITAGE ENVIRONMENTAL SERVICES

CERTIFICATE OF ANALYSIS

Service Location	Received	Lab ID
HERITAGE ENVIRONMENTAL SERVICES, LLC COMMERCIAL LABORATORY OPERATIONS 7901 W. MORRIS ST. INDIANAPOLIS, IN 46231 (317)243-8304	06-MAY-11	A916129
	Completed	**PO Number**
	20-MAY-11	2198264 (2011)
	Printed	**Sampled**
	23-MAY-11	05-MAY-11 16:05

Report To	Bill To
MYNDI BACON SOIL AND MATERIALS ENGINEERS, INC. 4460 COMMERCIAL AVENUE, SUITE B KALAMAZOO, MI 49002	MARK SCHNEIDER ALLIED WASTE SYSTEMS, INC. 21545 WEST CANNONSVILLE ROAD PIERSON, MI 49339

Sample Description

CLIENT ID: MW-28
MATRIX TYPE: NON-SPECIFIC WATER
SUBMITTER: 9403 - MI-ALLIED-CENTRAL SANITARY
DATA PACKAGE #: 61404
LOCATION: CENTRAL SANITARY LANDFILL
DESCRIPTION: TABLE D-3A

FIELD FILTRATION SAS

Analysis Date: Instrument: FIELD Test: P110.0.0

Parameter	Result	Det. Limit	Units

ICP ACID DIGESTION (DISSOLVED METALS) AQUEOUS SAMPLES SW846-3005A

Analyst: K. KAMARA Analysis Date: 19-MAY-11 09:00 Instrument: PREP Test: P132.4.0
Prep: FIELD FILTRATION SAS P110.0.0

Parameter	Result	Det. Limit	Units
INITIAL WEIGHT OR VOLUME	50		mL
FINAL VOLUME	50		mL

IRON ICP SW846-6010B NELAC:Y

Analyst: J. KRAMER Analysis Date: 20-MAY-11 10:03 Instrument: ICP Test: M115.3.1
Prep: ICP ACID DIGESTION (DISSOLVED METALS) AQUEOUS SAMPLES SW846-3005A P132.4.0

Parameter	Result	Det. Limit	Units
IRON	2500	20	ug/L

Sample Comments

Sample was received on ice at temperature 1.3 C.
Sample chain of custody number 76506.

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KS ELAP / NELAP Accreditation # E-10177 Indiana SDWA C-49-01

Approved by: CHRISTINE SARKAN 23-MAY-11

HERITAGE ENVIRONMENTAL SERVICES

CERTIFICATE OF ANALYSIS

Service Location	Received	Lab ID
HERITAGE ENVIRONMENTAL SERVICES, LLC COMMERCIAL LABORATORY OPERATIONS 7901 W. MORRIS ST. INDIANAPOLIS, IN 46231 (317)243-8304	06-MAY-11	A916130
	Completed	**PO Number**
	20-MAY-11	2198264 (2011)
	Printed	**Sampled**
	23-MAY-11	05-MAY-11 17:00

Report To	Bill To
MYNDI BACON SOIL AND MATERIALS ENGINEERS, INC. 4460 COMMERCIAL AVENUE, SUITE B KALAMAZOO, MI 49002	MARK SCHNEIDER ALLIED WASTE SYSTEMS, INC. 21545 WEST CANNONSVILLE ROAD PIERSON, MI 49339

Sample Description

CLIENT ID: MW-27
MATRIX TYPE: NON-SPECIFIC WATER
SUBMITTER: 9403 - MI-ALLIED-CENTRAL SANITARY
DATA PACKAGE #: 61404
LOCATION: CENTRAL SANITARY LANDFILL
DESCRIPTION: TABLE D-3A

FIELD FILTRATION SAS

Analysis Date: Instrument: FIELD Test: P110.0.0

Parameter	Result	Det. Limit	Units

ICP ACID DIGESTION (DISSOLVED METALS) AQUEOUS SAMPLES SW846-3005A

Analyst: K. KAMARA Analysis Date: 19-MAY-11 09:00 Instrument: PREP Test: P132.4.0
Prep: FIELD FILTRATION SAS P110.0.0

Parameter	Result	Det. Limit	Units
INITIAL WEIGHT OR VOLUME	50		mL
FINAL VOLUME	50		mL

IRON ICP SW846-6010B NELAC:Y

Analyst: J. KRAMER Analysis Date: 20-MAY-11 10:06 Instrument: ICP Test: M115.3.1
Prep: ICP ACID DIGESTION (DISSOLVED METALS) AQUEOUS SAMPLES SW846-3005A P132.4.0

Parameter	Result	Det. Limit	Units
IRON	120	20	ug/L

Sample Comments

Sample was received on ice at temperature 1.3 C.
Sample chain of custody number 76506.

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KS ELAP / NELAP Accreditation # E-10177 Indiana SDWA C-49-01

Approved by: CHRISTINE SARKAN 23-MAY-11

HERITAGE
ENVIRONMENTAL SERVICES

CERTIFICATE OF ANALYSIS

Service Location	Received	Lab ID
HERITAGE ENVIRONMENTAL SERVICES, LLC COMMERCIAL LABORATORY OPERATIONS 7901 W. MORRIS ST. INDIANAPOLIS, IN 46231 (317)243-8304	06-MAY-11	A916131
	Completed	**PO Number**
	16-MAY-11	2198264 (2011)
	Printed	**Sampled**
	23-MAY-11	05-MAY-11 16:45

Report To	Bill To
MYNDI BACON SOIL AND MATERIALS ENGINEERS, INC. 4460 COMMERCIAL AVENUE, SUITE B KALAMAZOO, MI 49002	MARK SCHNEIDER ALLIED WASTE SYSTEMS, INC. 21545 WEST CANNONSVILLE ROAD PIERSON, MI 49339

Sample Description

CLIENT ID: P-33
MATRIX TYPE: NON-SPECIFIC WATER
SUBMITTER: 9403 - MI-ALLIED-CENTRAL SANITARY
DATA PACKAGE #: 61404
LOCATION: CENTRAL SANITARY LANDFILL
DESCRIPTION: TABLE D-3A

FIELD FILTRATION SAS

Analysis Date: Instrument: FIELD Test: P110.0.0

Parameter	Result	Det. Limit	Units

IRON ICP SW846-6010B NELAC:Y

Analyst: J. KRAMER Analysis Date: 14-MAY-11 07:02 Instrument: ICP Test: M115.3.1
Prep: FIELD FILTRATION SAS P110.0.0

Parameter	Result	Det. Limit	Units
IRON	29	20	ug/L

Sample Comments

Sample was received on ice at temperature 1.3 C.
Sample chain of custody number 76506.

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KS ELAP / NELAP Accreditation # E-10177 Indiana SDWA C-49-01

Approved by: CHRISTINE SARKAN 18-MAY-11

Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, MI 49424

September 4, 2012
File Number: 001.02-12-004

Ms. Emily Freeman
Michigan Department of Environmental Quality
State Office Building
350 Ottawa, N.W.
Grand Rapids, Michigan 49503

Re: Manganese Background, Central Sanitary Landfill, Pierson, Michigan

Dear Ms. Freeman:

On behalf of Central Sanitary Landfill (CSL), Engineering & Environmental Solutions is providing this letter in response to the Michigan Department of Environmental Quality (MDEQ) Resource Management Division letters dated May 22, 2012, and July 3, 2012, regarding updating the site-specific background level for manganese.

In response to the MDEQ review of the March 2011 Remedial Action Plan (RAP), CSL agreed to modify the site-specific tolerance limit for manganese from CSL's previous proposed value of 550 µg/L to the Part 201 aesthetic criteria of 50 µg/L. CSL agreed to this request because of limited manganese background data. In response to the MDEQ review of the October 2011 RAP, CSL proposed additional manganese background sampling with the intention of updating the site-specific tolerance limit.

During the first quarter 2012, additional groundwater samples were collected and analyzed for manganese from areas that are believed to represent background conditions at the site. Results of the background sampling identified manganese levels ranging from 800 to 820 µg/L at wells upgradient from the landfill. These values exceed the aesthetic criteria of 50 µg/L and are below the residential health-based drinking water value of 860 µg/L. The additional background sampling confirmed that manganese levels can vary greatly across relatively short distances forming isolated pockets of high manganese similar to the naturally occurring high iron levels identified at the site in a 2011 investigation.

During the third quarter 2012, additional groundwater samples were collected from the same wells as proposed in our June 20, 2012 work plan. These wells are believed to represent background conditions at the site. Results of the third quarter 2012 background sampling event confirmed the first quarter results, identifying manganese levels above the aesthetic criteria and below the residential health-based drinking water

value. A detailed discussion of the proposed background wells and sampling results is provided in the following sections.

Per your request, information provided in this report is intended to show that the proposed background wells represent site-specific background conditions, past and present. Additional information has been provided supporting an updated site-specific groundwater protection standard in place of the generic Part 201 standard. The items requested in your letter dated May 22, 2012, are shown in *italic text* followed by our discussion and demonstration.

Proposed Background Wells

1. *Data must be representative of the background groundwater quality as a whole, including the two wells designated as upgradient monitoring wells in CSL's Hydrogeologic Monitoring Plan (i.e., MW-34 and P-16). A discussion of the groundwater divide located to the west of the landfill, as well as the influence of current and previous supply and purge well configurations must be included with this demonstration.*

A total of ten groundwater wells were proposed in our June 20, 2012, Work Plan for establishing an alternate background level for manganese. These wells include; P-12, P-16, MW-34, MW-27, MW-28, PW-4, MW-20, MW-33, P-34, and P-29 (Site Map, Attachment A). As requested in your letter dated May 22, 2012, upgradient monitoring wells for the Hydrogeologic Monitoring Plan have been included with the proposed background wells. Wells P-12, P-16, and MW-34 are part of the detection monitoring program and represent background conditions at the site. Deep well P-29 is part of a well pair with background well P-16.

Three of the wells selected for this demonstration are located northeast of the landfill (MW-27, MW-28, and PW-4; Attachment A). A 2011 investigation of iron levels at the site confirmed that the area around these wells has not been impacted by the landfill (*Results of Additional Iron Sampling at Central Sanitary Landfill, June 21, 2011*). The MDEQ approved the results of the iron background investigation in their RAP review letter dated July 12, 2011. Groundwater data collected at wells MW-27, MW-28, and PW-4 represents background conditions at the site.

Wells MW-20, MW-33, and P-34 are located northwest of the landfill and are east of the regional north-south trending groundwater divide. As requested in your letter dated May 22, 2012, additional information has been provided to show that these wells are not in the landfill flow path and have not been influenced by landfill activities, past or present.

Water Supply Wells

The site utilizes two water supply wells. One of the wells is located adjacent to the landfill equipment maintenance garage east of the landfill (Attachment A) and the second well is location approximately 15 feet north of the landfill office building. The water supply well east of the landfill pumps an average of 70 gallons per day and the supply well north of the landfill pumps an average of 260 gallons per day. Based on the volume of groundwater pumped from these supply wells, they do not influence flow patterns beneath the site.

Groundwater Divide and Purge Well Configuration

This section describes the regional groundwater divide west of the landfill and the influence of past and present purge well configurations.

A Remedial Action Feasibility Study conducted by GR Kunkle and Associates provided a generalized groundwater contour map that shows regional flow direction at the site (Attachment B). Groundwater contours were developed based on surface topography and visible expressions of the water table such as lakes, streams, and wetlands as presented on a 1985 U.S. Geological Survey Quadrangle map. Regionally, the groundwater elevation data suggests that the axis of the north-south trending groundwater divide is west of the site corresponding to a topographic high. The groundwater divide is characteristic of a regional recharge area. Groundwater east of the divide, flows east beneath the site towards Heron Drains 1 and 2. Groundwater west of the divide (west of US-131) flows towards Whitefish and Newcomb Lakes. The 1985 regional contour map represents groundwater flow conditions before the site's groundwater purge system began operation.

The site's groundwater remediation system began operation in April 1992. The system consisted of four purge wells (PW-1 through PW-4) and a temporary purge well (TPW-1). Purge well PW-1 is located north of the landfill and purge well PW-2 is located approximately 600 feet east of the landfill (Attachment A). Purge wells PW-1 and PW-2 were used to purge groundwater impacted with VOCs. Purge wells PW-3 and PW-4 are located near the eastern perimeter of the site and were intended to create a barrier to groundwater flow by pumping clean groundwater relatively far from the source. Purge well PW-3 was operated intermittently and was shut-down prior to 2003. Temporary purge well TPW-1 was located east of the former Pierson Township Dump and was abandoned prior to 1995 for construction of Phase V-A.

Historical groundwater contour maps provided in Attachment B illustrate groundwater flow beneath the site under various purge well pumping configurations.

A report prepared by GR Kunkle and Associates in October 1995 (*Groundwater Flow Modeling Report*) provided a site groundwater contour map generated from static groundwater elevations measured at 45 site wells (Attachment B). At that time, purge well PW-2 was pumping 54 gallons per minute (gpm) and discharging to a former infiltration pond located south of the landfill near well P-17. Groundwater recharge from the retention pond produced an area of groundwater mounding south of the landfill. In this area, the groundwater divide shifted east creating a northern component to flow beneath the southern portion of the landfill. To the north, the groundwater divide followed the US-131 corridor west of the landfill. At that time, purge well PW-1 and wells MW-33 and MW-20 were upgradient from the landfill.

A report prepared by SME in December 2000 (*Monitoring Result/Interim Measure Plan*) provided a site groundwater contour map generated from static groundwater elevations measured at over 60 site wells (Attachment B). At that time, purge wells PW-1 and PW-2 were operating and discharging to the infiltration pond located south of the landfill. Similar to the 1995 contour map, groundwater recharge from the former retention pond produced an area of groundwater mounding south of the landfill. In this area, the groundwater divide shifted east creating a northern component to flow beneath the southern portion of the landfill. Please note that during operation of purge well PW-1, groundwater levels were lowered north of the landfill to allow capture of impacted groundwater in the area of wells MW-13 and MW-14B. By lowering groundwater in this area, the groundwater divide moved further west and created a southern and western component to flow north of the capture zone at wells MW-33 and MW-20. By design, the capture zone prevented impacted groundwater from migrating north and east of the purge well. At that time, the area around wells MW-33 and MW-20 was upgradient from purge well PW-1 and the landfill. The 1995 and 2000 groundwater contour maps show that the area around wells MW-33 and MW-20 remained upgradient from the landfill during pumping and non-pumping conditions.

Purge wells PW-5, PW-6, and PW-7 were installed in 1997 to replace purge wells PW-1, PW-2, and PW-4. The new purge wells were turned-on in 2003, and with MDEQ approval, the old purge wells (PW-1, PW-2, and PW-4) were turned-off by November 2003. Following permanent shut-down of purge well PW-1, in 2003, the area around wells MW-33 and MW-20 remained upgradient from the landfill under natural groundwater flow conditions.

In 2007, at the request of the MDEQ, well P-34 was installed west of the landfill to help verify the location of the groundwater divided. Groundwater contour maps from the third quarter 2008 monitoring report, fourth quarter 2011 monitoring report, and the pre-2010 estimated capture zone for purge wells PW-6 and PW-7 have been included in this report to show the location of the groundwater divide west of the site along the US-131 corridor (Attachment B). The groundwater contour maps and capture zone created

by the existing purge wells show that the area around wells P-34, MW-33, and MW-20 have remained upgradient from the landfill under the current purge well configuration and pumping conditions.

Wells P-34, MW-33, and MW-20 are proposed as background wells because they have not been in the flow path of the landfill. A discussion of organic and inorganic parameters detected at these wells and a statistical determination of an alternate background level is provided in the following sections.

Organic and Inorganic Parameters at Background Wells

2 *Data may not include groundwater influenced by landfill operations, past or present. To demonstrate this, both inorganic and organic water quality parameters should be examined. Absence of volatile organic compounds alone will not be considered sufficient evidence. Current and previous groundwater data from the designated upgradient monitoring wells should be included in this evaluation.*

Proposed background wells P-34, MW-33, and MW-20 are the focus of this evaluation because of their proximity to impacted groundwater along the northern edge of the landfill. These wells have remained upgradient from the landfill during past and present purge well configurations as discussed in the previous section. All other proposed background wells are either part of the site's detection monitoring program or are in areas that have been shown not to be influenced by landfill activities.

Both organic and inorganic groundwater analytical data were evaluated at upgradient wells P-34, MW-33, and MW-20 to show that the groundwater adjacent to these wells has not been influenced by past or present landfill activities.

Upgradient well MW-20 was sampled for volatile organic compounds (VOCs) a total of three times during the time that purge well PW-1 was in operation. The well was sampled in June 1995, December 2000, and May 2003. There have been no confirmed VOCs at this upgradient well. Well MW-33 was sampled for VOCs in June 1995, and well P-34 was sampled for VOCs when it was installed in March 2007. VOCs have never been confirmed at these upgradient wells. Total VOC isoconcentration maps were generated during site investigations conducted in June 1995, December 2000, and May 2003 (Attachment C). The isoconcentration maps show the VOC plume located south and east of wells P-34, MW-34, and MW-20. Based on VOC analyses and the historic flow patterns beneath the landfill, groundwater samples collected at these wells represent background conditions at the site.

The inorganic database for CSL includes groundwater sampling results from 1997 to the present. The database was evaluated to help identify a potential signature that would

distinguish impacted groundwater (plume wells) from background groundwater (background wells). Plume wells are identified as wells screened in the eastern plume (MW-5, MW-10N, and MW-30) and wells screened in northern plume (MW-13 and MW-14B). Background wells are identified as the site's detection monitoring wells (MW-34, P-16, P-12) and proposed background wells (P-34, MW-33, MW-20, PW-4) located upgradient and cross-gradient from the landfill. Inorganic parameters evaluated for this report include total alkalinity bicarbonate, total dissolved solids, potassium, magnesium, sodium, chemical oxygen demand, total organic carbon, sulfate, chloride, and total inorganic nitrogen. Statistical comparisons were made for these parameters using "box and whisker plots"(Attachment D).

High concentrations of chemical oxygen demand, total organic carbon, and total inorganic nitrogen have been identified in leachate. The high concentrations observed in leachate were not observed in the plume wells compared to the background wells (Attachment D). No distinctive signature was identified with the "box and whisker plots" plots that would distinguish impacted plume wells from background wells using magnesium, chemical oxygen demand, total organic carbon, sulfate, and total inorganic nitrogen even though some of these parameters have high levels in leachate. High concentrations of chloride and total dissolved solids were identified in leachate (Attachment D). However, we believe that natural background levels of chloride, sodium, and total dissolved solids have been affected by the annual application of deicing salts along the US-131 corridor upgradient from the site. Therefore, these parameters are not considered diagnostic indicators of leachate impact in groundwater.

A groundwater signature was identified using "box and whisker plots" that distinguishes northern plume wells (wells MW-13 and MW-14B) from background wells using alkalinity bicarbonate and potassium (Attachment D). The plume wells are grouped together by high concentrations of alkalinity bicarbonate and potassium which is similar to the higher concentrations observed in leachate. The proposed background wells are grouped together by low levels of alkalinity bicarbonate and potassium which represents natural groundwater chemistry.

Based on the evaluation of organic and inorganic parameters, wells P-34, MW-33, and MW-20 have not been impacted by landfill. These wells represent background conditions at the site, and are appropriate for characterizing background manganese.

Manganese Background Sampling Results

The site tolerance limit for manganese was initially set at 550 µg/L in the March 2011 CSL RAP. This value represented a one-time sampling event at upgradient well P-34. Well P-34 was initially sampled during for the first quarter 2007 and was resampled during the first quarter 2012 and the third quarter 2012 to confirm background levels.

Results of the background sampling confirmed the earlier value of 550 µg /L, identifying naturally occurring manganese levels of 730 µg/L and 800 µg/L. These levels exceed the aesthetic criteria of 50 µg/L, however they are below the residential health-based drinking water value of 860 µg/L.

Wells MW-33 and MW-20 were also sampled during the first and third quarters 2012 to identify background manganese levels at these upgradient wells. Similar to upgradient well P-34, naturally occurring manganese levels at well MW-20 (820 µg/L and 830 µg/L) exceed the aesthetic criteria and are below the residential health-based drinking water value.

Wells MW-27 and MW-28 were sampled for manganese during the 2012 quarterly events to measure background levels northeast of the landfill (Attachment A). A 2011 investigation of high iron levels at the site confirmed that the area around wells MW-27 and MW-28 has not been influenced by the landfill (*Results of Additional Iron Sampling at Central Sanitary Landfill, June 21, 2011*). Groundwater in the area around wells MW-27 and MW-28 represents background conditions at the site. Naturally occurring manganese levels in this area range from 310 to 470 µg/L at well MW-27, and from non-detect to 610 µg/L at well MW-28. The manganese database for CSL is provided in Attachment E.

Statistical Determination of an Alternate Background Level

3 *Data must be of acceptable quantity and quality to allow for statistical determination of an alternate background level. The statistical methodology must be appropriate for the data set and the purpose.*

Manganese groundwater analytical data collected from background wells P-12, P-16, MW-34, MW-27, MW-28, PW-4, MW-20, MW-33, P-34, and P-29 were used to establish a site-specific background tolerance limit for the site. The groundwater data were collected during the first and third quarters of 2012 and imported into ChemStat for statistical analysis (Attachment F). Distribution analyses were completed to check for outliers and determine the normality of the data using the entire manganese database of ten background wells. The Dixon's test for outliers concluded that there were no outliers and the Shapiro-Wilks Test for Normality concluded that the data were non-normal at both 95 and 99 percent level of significance (Attachment F). Based on the distribution test results, all data are appropriate to use and a non-parametric test is the appropriate method for establishing a tolerance limit.

A non-parametric tolerance limit is equivalent to the highest value in the background database. The highest manganese value for the site was observed in monitoring well MW-20 at a level of 830 µg/L. Therefore, the non-parametric tolerance limit for

manganese at the site is set at 830 µg/L (Attachment F). Background sampling at well MW-20 indicates that the third quarter value of 830 µg/L is similar to first quarter value of 820 µg/L. Other background values for manganese range from non-detect to 800 µg/L.

If the data were normally distributed, a parametric tolerance limit would have been appropriate to use. The parametric tolerance limit uses the calculated mean and standard deviation along with a one-sided normal tolerance factor to determine a limit. The parametric tolerance limit for manganese was calculated using the background wells to compare to the non-parametric tolerance limit. This statistical calculation used all of the manganese values from all of the background wells (non-detect to 830 µg/L). The parametric tolerance limit was calculated to be 826 µg/L using the USEPA 1992 Guidance Tolerance Limit Formula (Attachment F). The results support the use of 830 µg/L as the manganese tolerance limit for site.

Conclusions

A total of ten groundwater wells were proposed for establishing an alternate background level for manganese. Groundwater contour maps selected from previous site investigations show that the area around the proposed background wells remained upgradient from the landfill during various purge well pumping configurations, past and present. Based on the volume of groundwater pumped from the site's supply wells, they do not influence flow patterns beneath the site.

The proposed background wells represent background conditions at the site because they have been shown not to be in the flow path of the landfill, past and present. An evaluation of the historical groundwater analytical data (organic and inorganic parameters) indicates that the proposed background wells have not been impacted by landfill activities and represent background conditions.

Additional manganese data collected during this investigation supports our original conclusion that portions of the aquifer have naturally occurring manganese values that greatly exceed the aesthetic criteria. Background levels of manganese are greater than the aesthetic criteria, although they are below the health-based drinking water value of 860 µg/L. The background sampling conducted during 2012 confirmed that manganese levels can vary greatly across relatively short distances forming isolated pockets of high manganese similar to the naturally occurring isolated pockets of high iron previously documented at the site. A total of ten background wells were selected from across the site to develop a revised site-specific tolerance limit for manganese. A statistical analysis of the data collected from these wells gives a non-parametric site-specific tolerance limit of 830 µg/L and the parametric tolerance limit of 826 µg/L.

Results of this investigation have been submitted consistent with the criteria requested in the MDEQ response letters data May 22, 2012, and July 3, 2012. Central Sanitary Landfill considers the 830 µg/L site-specific tolerance limit for manganese as appropriate and protective and intends to use this value in future evaluations/submittals, subject to MDEQ concurrence. Please feel free to contact Joe Montello (330) 348-0376 or me at (616) 566-4596 if you have questions.

Sincerely,

Dean B. Vander Meulen, P.G.
Managing Partner

Attachments

cc: Debbie Nurmi – Republic Services, Inc.
Joe Montello – Republic Services, Inc.
Roger Rockburn – Central Sanitary Landfill
Amy LaChance - MDEQ
Tim Unseld - MDEQ
File