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Lakewood Plaza Cleaners, Groundwater Monitoring Results

June and October 2011

by
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Abstract

This progress report is one in a series describing results of long-term groundwater monitoring at the former Lakewood Plaza Cleaners site south of Tacoma. The Washington State Department of Ecology (Ecology) began collecting groundwater data at the site in the early 1990s as part of its official responsibilities for operation and maintenance of the remedial actions. The goal was to evaluate the effectiveness of municipal wells H1 and H2 to contain and remove the contaminated groundwater.

This report discusses volatile organic results of samples collected from project monitoring wells and a Lakewood Water District municipal well in June and October 2011.

Tetrachloroethene (PCE) concentrations continue to not meet (exceed) the MTCA cleanup level of 5 ug/L in monitoring wells MW-20B (200 and 720 ug/L) and MW-16A (100 and 57 ug/L). Since Ecology began sampling, PCE concentrations have varied, but overall trends indicate that concentrations in well MW-20B are decreasing while concentrations in well MW-16A are increasing. The average annual PCE concentration in well MW-20B in 1991 was 657 ug/L, decreasing to 460 ug/L in 2011. The average annual PCE concentration in well MW-16A in 1991 was 19 ug/L, increasing to 79 ug/L in 2011.

Samples collected from municipal well H1 prior to treatment continue to have PCE concentrations near the MTCA cleanup level.

PCE was also detected in well LPMW-2 in June (3.2 ug/L). This well is near the former septic system of Lakewood Plaza Cleaners which was identified as a source of the contamination.

The use of municipal wells H1 and H2 to treat contaminated groundwater associated with the Lakewood Plaza Cleaners site continues since the cleanup goals have not been achieved. Early groundwater monitoring results projected that compliance with cleanup goals would be achieved throughout the contaminated plume by the mid-1990s. Project data indicate that it will take much longer than the projected timeframe to meet the cleanup goals.

Introduction

In 1981, the U.S. Environmental Protection Agency (EPA) confirmed that the Lakewood Water District production wells H1 and H2 were contaminated with tetrachloroethene (PCE), trichloroethene (TCE), and cis-1,2-dichloroethene (cis-1,2-DCE). Lakewood is south of Tacoma in Pierce County. The source of the contamination was identified as the former Lakewood Plaza Cleaners (EPA, 1983). Contamination had resulted from the dumping of PCE into on-site septic tanks and the disposal of sludge on the ground surface. The Lakewood Plaza Cleaners site was added to the National Priorities List (NPL) in 1982.

Remedial activities at the site began in 1983. They included the operation of wells H1 and H2 to pump and treat contaminated groundwater, the removal of contaminated soils and sludge from the source area, and treatment of a small portion of the contaminated septic field soils with vapor extraction. Soil remediation was completed in 1993. The soils unit of the site was removed from the NPL in 1996 (EPA, 1996a). Treatment of the contaminated groundwater with wells H1 and H2 continued. Early groundwater monitoring results projected that compliance with cleanup goals of 5 ug/L for PCE and TCE, and 70 ug/L for cis-1,2-DCE would be achieved throughout the contaminated plume by the mid-1990s.

Although the Washington State Department of Ecology's (Ecology) official responsibilities for operation and maintenance of the remedial actions did not begin until 1994, Ecology began semi-annual groundwater compliance monitoring at the site in 1991. The objective of the sampling was to collect groundwater quality data to evaluate the effectiveness of Lakewood water supply wells H1 and H2 to contain, remove, and treat the groundwater contaminated by Plaza Cleaners.

In accordance with EPA policy and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA § 121(42 U.S.C. Section 9621) and the National Contingency Plan (NCP), five-year reviews of the project are also required as long as cleanup goals have not been achieved. Four 5-year reviews have been completed: in 1992, 1997, 2002, and 2007. During the 5-year reviews the monitoring program is evaluated. Groundwater monitoring has been modified over the years to focus primarily on wells in the immediate vicinity of the former Plaza Cleaners. Currently there are 14 monitoring wells and the two production wells (H1 and H2) being monitored.

Remediation and monitoring of the groundwater is ongoing under a long-term response action as cleanup goals have not yet been achieved (EPA, 2007). Project data indicate that it will take much longer than the projected timeframe to meet the cleanup goals. EPA has recommended that if cleanup goals throughout the contaminant plume are not achieved in a reasonable time-frame, then the pump and treat system should be evaluated to determine if it is adequate to meet the cleanup goals. If it is not, then EPA and Ecology need to determine what additional actions are needed for this site to meet the cleanup goals (EPA, 2007).

Methods

Groundwater Monitoring

Ecology collected groundwater samples in June and October 2011 from two shallow and eight deep wells (Figure 1). The two shallow wells are screened in the Steilacoom Gravel (LPMW-2) and the Vashon Till (MW-20B) and are located near the source area. The Steilacoom Gravel generally contains areas of perched water above the Vashon Till and the regional water table. The Vashon Till is typically a very low permeable layer which forms an aquitard of unsaturated and saturated sediment separating the Steilacoom Gravel above and the Advance Outwash below. Well MW-20B is the only well screened in the Vashon Till where contamination had been detected. This well continues to have the highest PCE concentrations. The majority of the monitoring wells and municipal wells H1 and H2 are screened in the Advance Outwash deposits, the primary water-supply aquifer for the area.

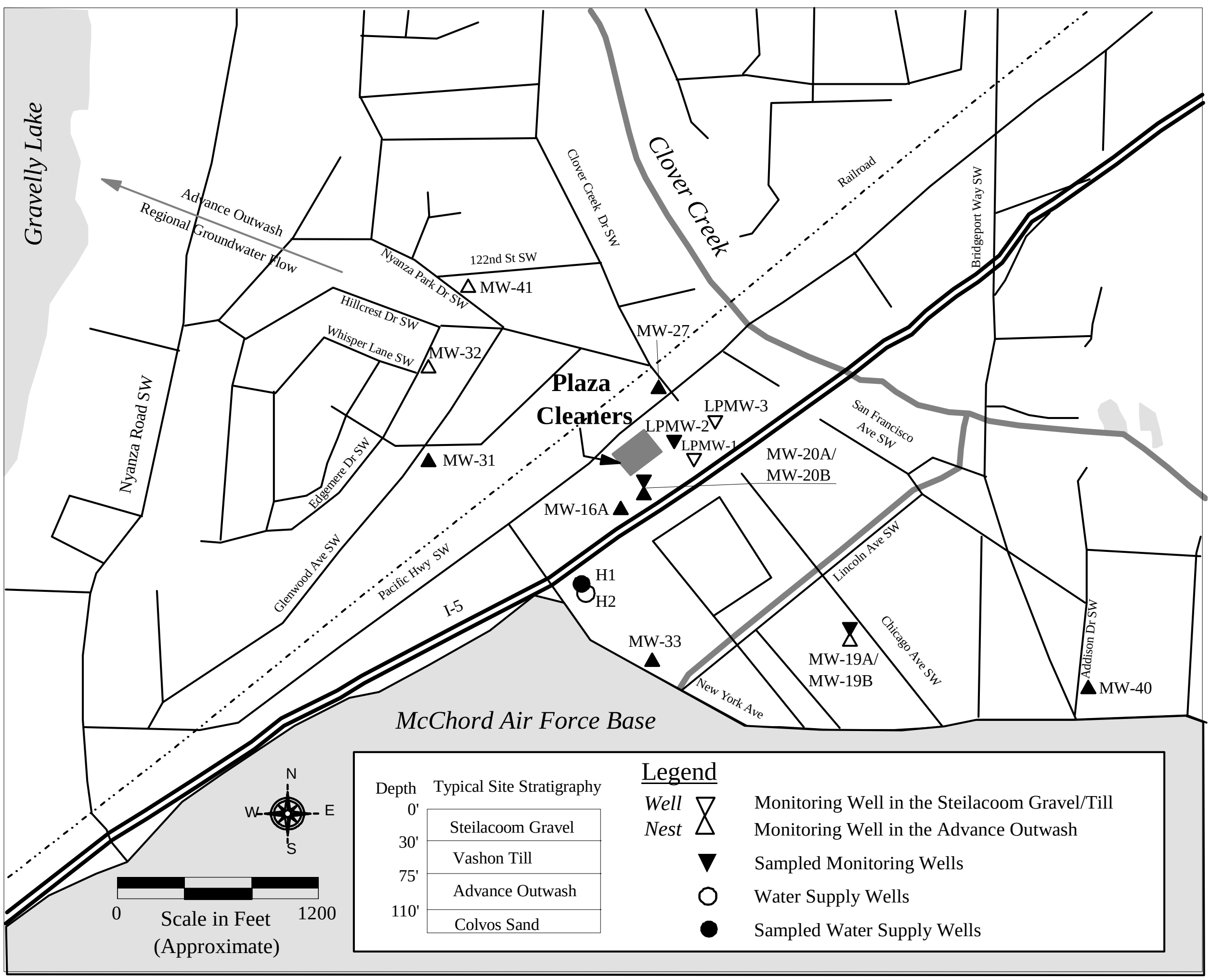

Figure 1. Lakewood Plaza Cleaners Sampling Locations.

During 2011 the following wells were sampled: LPMW-2, MW-20B, MW-16A, MW-19A, MW-20A, MW-27, MW-31, MW-33, MW-40, and municipal well H1. Samples were submitted for analysis of volatile organic compounds (VOCs) to monitor PCE concentrations.

Ecology measured static water levels in all wells prior to well purging and sampling. Measurements were collected according to procedures in standard operating procedure (SOP) EAP052 (Marti, 2009).

Monitoring wells MW-16A, MW-19A, MW-20A, and MW-40 were purged and sampled using dedicated bladder pumps.

Wells MW-20B, MW-27, MW-31, MW-33, and LPMW-2 were purged and sampled with a stainless-steel submersible pump with dedicated tubing using low-flow sampling techniques. The submersible pump was decontaminated between wells by circulating laboratory-grade detergent/water through the pump followed by a clean water rinse, with each cycle lasting five minutes.

The monitoring wells were purged until pH, specific conductance, dissolved oxygen, and temperature readings stabilized. Purge water was collected and stored in 55-gallon drums. The purge water waste was transported and disposed of in accordance with Washington State regulations (Chapter 173-340-400 WAC).

At the completion of purging, samples were collected from the monitoring wells directly from the dedicated pump discharge tubing into laboratory-supplied containers. Municipal well H1 was sampled from the tap nearest the well.

Volatile organics samples were collected free of headspace in three 40-mL glass vials with Teflon-lined septa lids and preserved with 1:1 hydrochloric acid. After labeling, all samples were stored in an ice-filled cooler. Samples were transported to Ecology's Operations Center in Lacey. Samples were kept in the walk-in cooler until taken by the courier to the Ecology/EPA Manchester Environmental Laboratory in Manchester, Washington. Chain-of-custody procedures were followed according to Manchester Laboratory protocol (Ecology, 2008).

Analysis

Table 1 lists analytes, analytical methods, and reporting limits for both field and laboratory parameters. Manchester Laboratory analyzed all groundwater samples for volatile organics.

Table 1. Field and Laboratory Methods.

Field Measurements	Instrument Type	Method	Accuracy
Water Level	Solinst Water Level Meter	SOP EAP 052	±0.03 feet
pH	YSI ProPlus with Quatro Cable	EPA 150.1 (EPA, 2001a)	±0.2 standard units
Specific Conductance	YSI ProPlus with Quatro Cable	EPA 120.1 (EPA, 2001b)	±10 umhos/cm
Dissolved Oxygen	YSI ProPlus with Quatro Cable	EPA 360.1 (EPA, 2002)	±0.2 mg/L
Temperature	YSI ProPlus with Quatro Cable	EPA Method 150.1	±0.2 ºC
Laboratory Analytes	**Method**	**Reference**	**Reporting Limit**
Volatile Organics	EPA SW-846 Method 8260B	EPA 1996b	1-5 ug/L

EAP: Environmental Assessment Program, Ecology.

Results

Data Quality Assessment

Quality control samples collected in the field consisted of blind field duplicates obtained from well MW-16A. Field duplicates were collected by splitting the pump discharge between two sets of sample bottles, which provides a measure of the overall sampling and analytical precision. Precision estimates are influenced not only by the random error introduced by collection and measurement procedures, but also by the natural variability of the concentrations in the media (e.g., groundwater) being sampled.

The numeric comparison of duplicate results is expressed as the relative percent difference (RPD). The RPD is calculated as: the difference between sample results, divided by the mean, and expressed as a percent.

Table 2 shows the results of the duplicate samples and their RPD. The RPD for the June and October data ranged from 0% to 10%. The quality of the data for this progress report is good.

Table 2. Relative Percent Difference (RPD) of Duplicate Sample Results (ug/L), June and October 2011.

Well Sample ID	Tetrachloroethylene (PCE)		Trichloroethylene (TCE)		Cis-1,2-Dichloroethylene (cis-DCE)	
	6/11	10/11	6/11	10/11	6/11	10/11
MW-16A	100	57	1.4	0.75 J	1.6	1.0
MW-16B	100	58	1.4	0.79 J	1.6	1.1
RPD[1] (%)	0%	2%	0%	--	0%	10%

MW-16B is the duplicate sample identification.

[1] RPD target ±30%.

J: Analyte was positively identified. The associated numerical result is an estimate.

A review of the data quality control and quality assurance from laboratory case narratives indicates that overall the analytical performance was good. The reviews include descriptions of analytical methods, holding times, instrument calibration checks, blank results, surrogate recoveries, and laboratory control samples. No major problems were reported that compromised the usefulness or validity of the sample results; therefore, all results are usable as qualified. Quality assurance case narratives and laboratory reporting sheets are available upon request.

Field Results

Depth-to-water measurements, as well as pH, specific conductance, dissolved oxygen, and temperature readings, at the time of sampling are listed in Table 3.

Table 3. Summary of Field Parameter Results, June and October, 2011.

Well	Total Depth (feet)[1]	Depth to Water (feet)[1]	pH (standard units)	Specific Conductance (umhos/cm)	Dissolved Oxygen (mg/L)	Temperature (°C)
June 2011						
MW-16A	109	32.93	7.1	217	6.0	12.4
MW-20A	97.3	26.18	7.8	213	4.7	12.3
MW-20B	50.4	23.39	6.6	296	5.3	13.7
MW-27	93	25.58	6.8	181	4.7	13.7
LPMW-2	29	20.07	6.6	140	9.9	13.3
H1	110	++	6.6	198	--	12.3
October 2011						
MW-16A	109	37.76	7.2	222	--	12.1
MW-19A	97.5	38.41	6.8	199	--	11.2
MW-20A	97.3	32.57	7.8	213	--	12.1
MW-20B	50.4	33.18	6.5	300	2.9	14.2
MW-27	93	31.58	6.7	183	5.2	14.3
MW-31	91.2	38.05	6.7	185	6.6	13.2
MW-33	98.4	34.83	6.9	211	6.4	12.5
MW-40	75.1	35.98	7.2	415	--	11.2
H1	110	++	6.8	188	--	10.8

[1] Measured from top of PVC casing.
++ Dedicated pump obstructed water-level measurement.
-- Not Measured.

Most of the sampled wells are screened in the Advance Outwash deposits (MW-16A, MW-19A, MW-20A, MW-27, MW-31, MW-33, MW-40, and H1). Depth to water in the Advance Outwash ranged from 25.58 - 32.93 ft. in June and 31.58 - 38.41 ft. in October. An aquifer stress test conducted in 1981, when municipal wells H1/H2 were shut down, determined that the natural groundwater flow direction in the Advance Outwash is west-northwest toward Gravelly Lake. When in use, these wells create a large cone of depression which influences groundwater flow directions. Previous studies showed that drawdown occurs in shallow monitoring wells drilled in the Steilacoom gravel when H1 and H2 are pumping (EPA, 1985). This indicates possible hydraulic interconnection between the Steilacoom gravel and the Advance Outwash.

Well MW-20B is screened in the Vashon Till. Depth to water was 23.39 ft. in June and 33.18 ft. in October. The Vashon Till forms an aquitard when composed of silt and clay-rich gravels. The Vashon Till also contains thin layers of sandy gravel, one of which appears to be large in lateral extent, covering the area including Plaza Cleaners. This lens is saturated and appears to be hydraulically interconnected with the Steilacoom gravel (EPA, 1985). Well LPMW-2 is screened in the Steilacoom Gravel. Depth to water was 20.07 in June and 26.63 ft. in October.

In October well LPMW-2 did not have sufficient amount water to collect a sample with the submersible pump.

Field parameters (pH, specific conductance, dissolved oxygen, and temperature) were within expected ranges. During the monitoring period pH of the groundwater ranged from 6.5 to 7.8. Specific conductance measurements ranged from 140 to 296 umhos/cm in June and 183 to 415 umhos/cm in October. Generally, the specific conductance in well MW-20B, which is screened in the till unit, is greater than the other wells. Specific conductance readings are typically higher for water from fine-grained units such as the till. Dissolved oxygen measurements in the advanced outwash ranged from 4.7 to 6.6 mg/L, 2.9 to 5.3 mg/L in the Vashon Till, and in June was 9.9 mg/L in the Steilacoom Gravel. Groundwater temperatures over the monitoring period ranged from 10.8º to 14.3 ºC. Temperature measurements are subject to change due to ambient air conditions and therefore are not considered to be representative of in-situ groundwater conditions.

Analytical Results

June and October 2011 analytical results for volatile organics of interest are summarized in Table 4 and presented in Figure 2.

All field measurements and analytical results data are available in electronic format from Ecology's EIM data management system: www.ecy.wa.gov/eim/index.htm. Search study ID LAKEWOOD.

Table 4. Results (ug/L) of Volatile Organics of Interest, June and October, 2011.

Well	Tetrachloroethene (PCE)	Trichloroethene (TCE)	Cis-1,2-Dichloroethene (cis-1,2-DCE)
MTCA Cleanup Level	5 ug/L	5 ug/L	70 ug/L
June 2011			
MW-16A	**100**	**1.4**	**1.6**
MW-20A	1 U	1 U	1 U
MW-20B	**200**	**3.5**	**5.6**
MW-27	1 U	1 U	1 U
LPMW-2	**3.2**	1 U	1 U
H1	**5.9**	1 U	1 U
October 2011			
MW-16A	**57**	**0.75 J**	**1.0**
MW-19A	1 U	**0.42 J**	1 U
MW-20A	1 U	1 U	1 U
MW-20B	**720**	**4.8**	**7.9**
MW-27	1 U	1 U	1 U
MW-31	**0.65 J**	1 U	1 U
MW-33	1 U	1 U	1 U
MW-40	1 U	1 U	1 U
H1	**1.4**	1 U	1 U

Bold: Analyte detected.
U: Analyte was not detected at or above the reported value.
J: Analyte was positively identified. The associated numerical result is an estimate.

Chlorinated solvents continue to be detected in monitoring wells MW-20B, MW-16A, and LPMW-2 as well as in municipal well H1.

PCE also continues to be detected in well MW-31 near the reporting limit of 1 ug/L. Although this well is sampled once every other year, PCE concentrations have remained consistent since Ecology began monitoring in 1991.

Monitoring wells MW-20B and MW-16A, and municipal well H1, continue to have PCE concentrations that exceed the MTCA cleanup level of 5 ug/L.

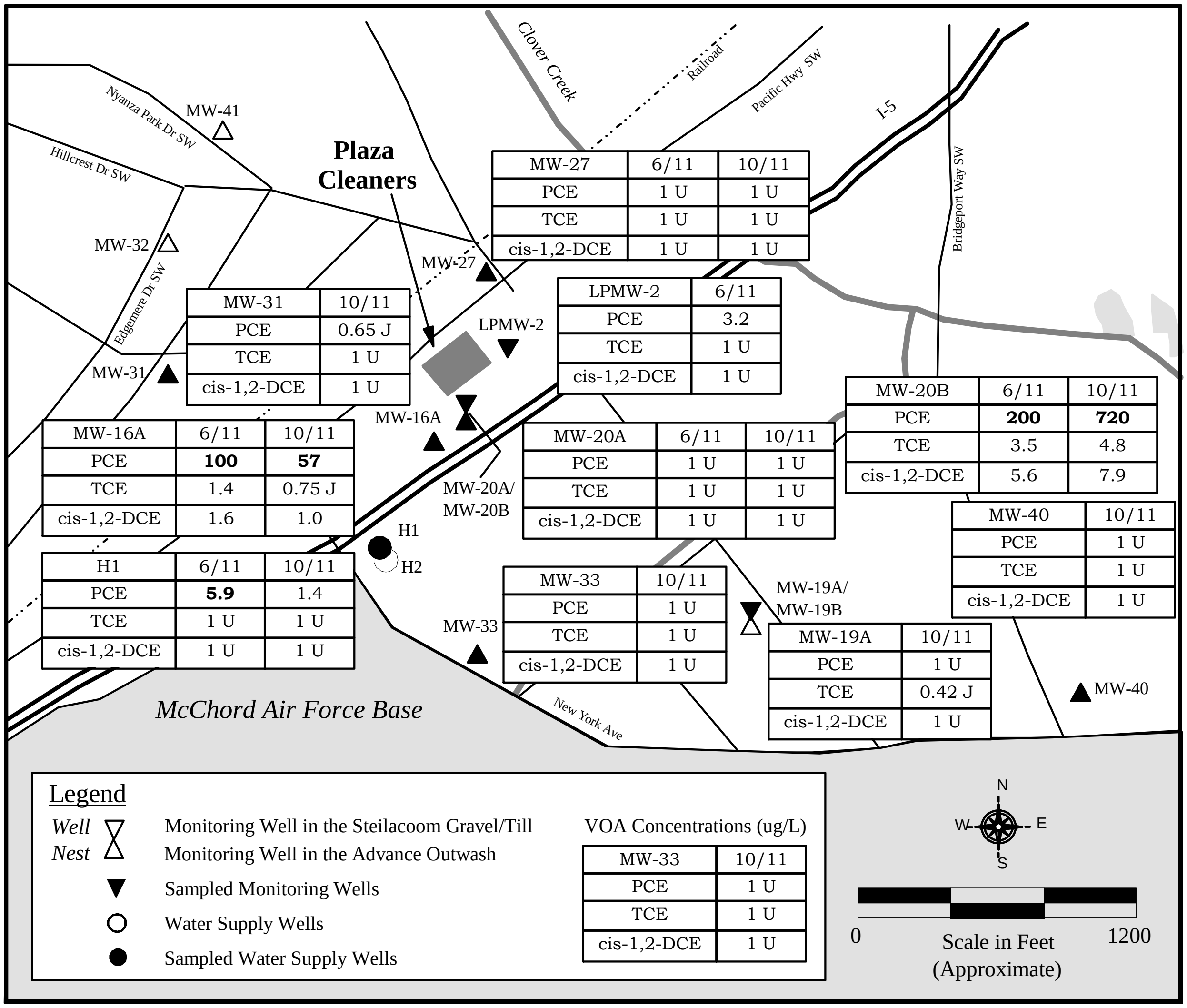

Figure 2. Lakewood Plaza Cleaners PCE, TCE, and Cis-1,2-DCE Concentrations (ug/L), June and October 2011.

Discussion

In 1991, Ecology assumed responsibility for long-term groundwater monitoring of the former Lakewood Plaza Cleaners site with the goal of collecting data to evaluate the effectiveness of municipal wells H1 and H2 to contain and remove the contaminated groundwater.

Table 5 shows average PCE and TCE concentrations for the wells that have consistently had concentrations that exceeded the MTCA cleanup level of 5 ug/L during Ecology's sample period of 1991 to 2011. All PCE, TCE, and cis-1,2-DCE concentrations from January 1991 through October 2011 are presented in Appendix A. PCE concentrations for wells MW-20B and MW-16A for the same time period are also presented as graphs in Appendix A.

Table 5. Average Annual PCE and TCE Concentrations (ug/L) for Wells that Exceed the MTCA Method A Cleanup Level for Groundwater of 5 ug/L.

Year	MW-20B		MW-16A	H1/H2	LPMW-2
	PCE	TCE	PCE	PCE	PCE
1991	657	12	19	---	---
1992	640	14	8	---	---
1993	443	12	28	---	---
1994	279	8.6	21	---	---
1995	340[a]	8.4[a]	27[a]	9[a]	---
1996	370	7	45	4	---
1997	297	4	50	13	---
1998	515	8	33	10	---
1999	715	7	22[a]	3	---
2000	416	6	31	9	---
2001	489	7	28	9	---
2002	309	8.5	34	9	---
2003	234	5.4	42	6.4	---
2004	293	6.6	39	5.3	---
2005	484	6.5	62	10.2	---
2006	367	4.9	77	6.1	9.9[a]
2007	348	6	54	4.5	4.8[a]
2008	201	5	43	7.4	2.5[a]
2009	205	4.4	48	6.8 [a]	7.6
2010	325	4.8	73	4.3 [a]	4.7
2011	460	4.2	79	3.7	3.2 [a]

-- Not tested.
a: Single annual result.

Figures 3 and 4 show the average annual PCE concentrations for MW-20B and MW-16A from 1985 through 2011. PCE concentrations in both wells have varied substantially.

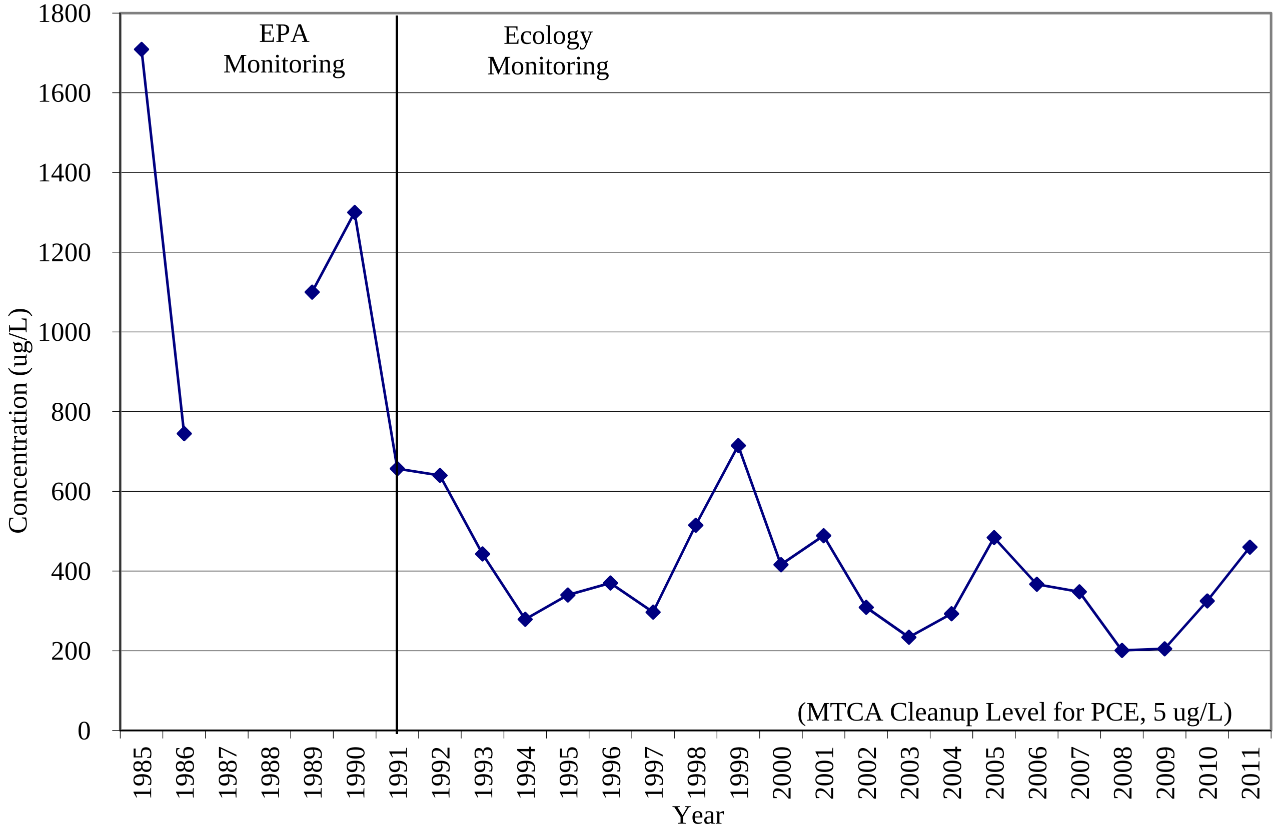

Figure 3. Average Annual PCE Concentrations for Well MW-20B, 1985 through 2011.

PCE concentrations decreased in well MW-20B during the 1980s with the implementation of remedial activities. In 1991, Ecology began semi-annual, long-term groundwater monitoring at the site. Although PCE concentrations have varied, primarily due to seasonal fluctuations, the overall trend indicates that concentrations in well MW-20B are decreasing (Figure A1). The average annual PCE concentration in 1991 was 657 ug/L, and in 2011 it was 460 ug/L.

PCE concentrations also initially decreased in well MW-16A. As with well MW-20B, concentrations have varied over the monitoring period. However, the overall trend indicates that PCE concentrations in well MW-16A are increasing (Figure A2). The average annual PCE concentration in 1991 was 19 ug/L, and in 2011 it was 79 ug/L.

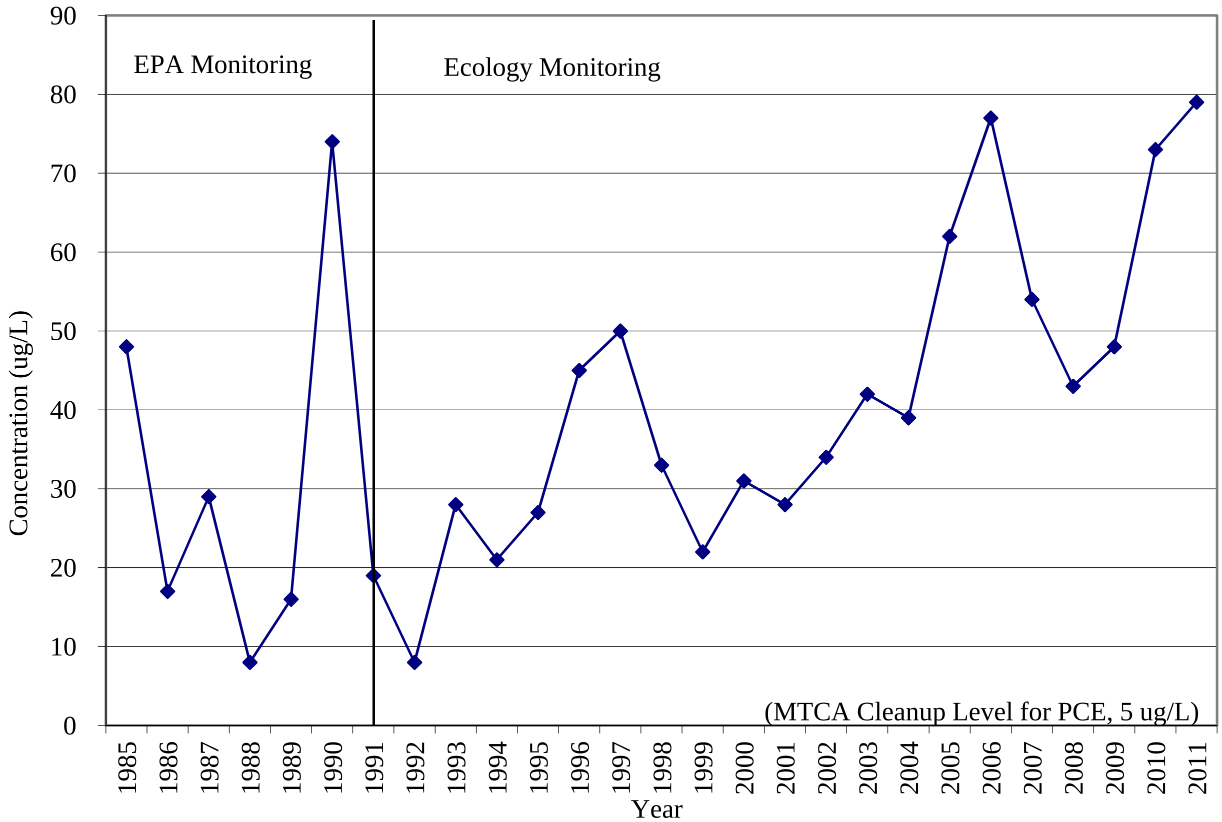

Figure 4. Average Annual PCE Concentrations for Well MW-16A, 1985 through 2011.

As shown in Figures 3 and 4, PCE concentrations continue to exceed the MTCA cleanup level of 5 ug/L in monitoring wells MW-20B and MW-16A. In addition, contaminant concentrations in well MW-16A appear to be gradually increasing over time.

Samples collected from municipal wells H1 and H2 prior to treatment continue to have PCE concentrations near the MTCA cleanup level (Table 5).

PCE also continues to be detected near the MTCA cleanup level of 5 ug/L in well LPMW-2. This well is located near the former septic system of Plaza Cleaners which was identified as a source of the contamination.

Compliance with the groundwater cleanup goals have not been met for this project. Site specific cleanup levels were established in 1992 in an Explanation of Significant Difference at 5 ug/L for PCE and TCE, and 70 ug/L for cis-1,2-DCE (EPA, 1992). Compliance with these cleanup goals is required throughout the contaminated groundwater plume in order to consider the site remediated. Project data indicate that it will take much longer than the projected timeframe to meet the cleanup goals.

Conclusions

Ecology conducted groundwater monitoring in June 2011 at 5 monitoring wells and 1 municipal well, and in October 2011 at 8 monitoring wells and 1 municipal well, to evaluate volatile organics in groundwater at the former Lakewood Plaza Cleaners site.

- Monitoring wells MW-20B and MW-16A continue to have PCE concentrations that do not meet the MTCA cleanup level of 5 ug/L.
- Samples collected from municipal wells H1 and H2 prior to treatment continue to have PCE concentrations near the MTCA cleanup level.
- PCE concentrations in well LPMW-2 continue to be detected near the cleanup level of 5 ug/L.

Concentrations of PCE have decreased from their 1980s levels, but still do not meet the project cleanup goals of 5 ug/L. Since Ecology began sampling in 1991, PCE concentrations have varied, but overall trends indicate that concentrations in well MW-20B are decreasing while concentrations in well MW-16A are increasing. The average annual PCE concentration in well MW-20B in 1991 was 657 ug/L, decreasing to 460 ug/L in 2011. The average annual PCE concentration in well MW-16A in 1991 was 19 ug/L, increasing to 79 ug/L in 2011.

The use of municipal wells H1 and H2 to contain, remove, and treat contaminated groundwater associated with the Lakewood Plaza Cleaners site continues since the cleanup goals have not yet been achieved. Project data indicates that it will take much longer than the projected timeframe to meet the cleanup goals. EPA has recommended that if cleanup goals throughout the contaminant plume are not achieved in a reasonable timeframe, then the pump and treat system should be evaluated to determine if it is adequate to meet the cleanup goals. If it is not, then EPA and Ecology need to determine what additional actions are needed for this site to meet the cleanup goals (EPA, 2007).

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Appendices

Appendix A. Summary of Results

Table A-1. Summary of Sample Results (ug/L), January 1991 to October 2011.

Well Number	January 1991			May 1991			November 1991			May 1992			December 1992		
	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	28	1 J	2.4 J	26	0.6 J	2	2.7 J	1 U	0.6 J	7	1 U	1	9 J	0.3 J	0.8 J
MW-20A	1 U	1 U	1 U	0.4 J	1 U	1 U	0.4 J	1 U	1 U	0.5 J	1 U	1 U	0.8 J	1 UJ	1 UJ
MW-20B	1100 D	18	33	752	16	30	120	2.6 J	6.7	940	13	32	340 J	14 J	20 J
MW-21	2.1 J	1 U	1 J	2	1 U	0.7 J	2.2 J	1 U	1.0 J	2	1 U	0.6 J	2	0.2 J	0.3 J
MW-27	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 UJ	1 UJ
MW-28A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-31	1 J	1 U	1.9 J	0.6 J	1 U	2	0.9 J	1 U	2.2 J	0.8 J	1 U	1	0.5 J	1 UJ	0.9 J
MW-32	1 J	1 U	1.1 J	1	1 U	2	0.6 J	1 U	0.6 J	0.7 J	1 U	1	0.7 J	1 UJ	0.5 J
MW-41	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 UJ	1 UJ
MW-19A	--	--	--	--	--	--	1 U	0.5 J	1 U	--	--	--	1 UJ	1 UJ	1 UJ
MW-33	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-40	1 U	1 U	1 U	--	--	--	1 U	1 U	1 U	--	--	--	1 UJ	1 UJ	1 UJ
H1/H2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Well Number	May 1993			December 1993			April 1994			November 1994			July 1995		
	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	44	10 U	2 J	13	0.3 J	0.7 J	33	0.6	1.4	9.7	0.3 J	0.5 J	27	0.5 J	0.8 J
MW-20A	10 U	10 U	10 U	0.3 J	1 U	1 U	0.4	0.2 U	0.2 U	0.3 J	1 U	1 U	0.4 J	1 U	1 U
MW-20B	700 D	12	21	187	50 U	8.2 J	472	8.6 J	12.6	86	50 U	3 J	340 D	8.4	17
MW-21	1 J	10 U	10 U	1.6	1 U	0.4 J	1.5	0.2 J	0.3	1.8	0.2 J	0.3 J	--	--	--
MW-27	10 U	10 U	10 U	1 U	1 U	1 U	0.2 U	0.2 U	0.2 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-28A	--	--	--	--	--	--	--	--	--	--	--	--	1 U	1 U	1 U
MW-31	10 U	10 U	10 U	0.8 J	1 U	1.2 J	0.7	0.2 U	1.0	0.8 J	1 U	1	0.6 J	1 U	0.5 J
MW-32	10 U	10 U	10 U	0.7 J	1 U	0.6 J	0.7	0.2 U	0.6	0.6 J	1 U	0.5 J	0.7 J	1 U	0.5 J
MW-41	10 U	10 U	10 U	1 U	1 U	1 U	0.2 U	0.2 U	0.2 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-19A	--	--	--	1 U	0.4	1 U	0.2 U	0.5	0.2 U	--	--	--	1 U	0.4 J	1 U
MW-33	--	--	--	--	--	--	--	--	--	--	--	--	1 U	1 U	1 U
MW-40	--	--	--	1 U	1 U	1 U	0.2 U	0.2 U	0.2 U	--	--	--	1 U	1 U	1 U
H1/H2	--	--	--	--	--	--	--	--	--	--	--	--	9	0.3 J	1 U

Table A-1 (cont.). Summary of Sample Results (ug/L) from January 1991 to October 2011.

Well Number	January 1996			July 1996			January 1997			July 1997			February 1998		
	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	47 E	0.8 J	1.5	43	0.7 J	1.9	54	1.1	3.1	47	0.7 J	2.5	36	0.7 J	2 J
MW-20A	0.2 J	1 U	1 U	0.4 J	1 U	1 U	0.4 J	1 U	1 U	0.3 J	1 U	2 U	0.4 J	1 U	1 U
MW-20B	353	7.2	15	387	7.6	15	373	100 U	6.4 J	222	4	6.4	456	7 J	12
MW-21	--	--	--	Well Decommissioned											
MW-27	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U	1 U
MW-28A	1 U	1 U	1 U	Well Decommissioned											
MW-31	0.6 J	1 U	0.7 J	--	--	--	--	--	--	0.9 J	1 U	0.9 J	--	--	--
MW-32	0.8 J	1 U	0.6 J	--	--	--	--	--	--	--	--	--	--	--	--
MW-41	1 U	1 U	1 U	--	--	--	--	--	--	--	--	--	--	--	--
MW-19A	--	--	--	--	--	--	--	--	--	1 U	0.3 J	2 U	--	--	--
MW-33	--	--	--	1 U	1 U	1 U	--	--	--	1 U	1 U	2 U	--	--	--
MW-40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
H1/H2	8.4	0.2 J	0.2 J	0.1 J	1 U	1 U	18	0.4 J	0.4 J	8.8	0.3 J	0.6 J	11	0.4 J	0.3 J

Well Number	July 1998			January 1999			August 1999			January 2000			August 2000		
	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	30	1 U	1.5 J	--	--	--	22	0.4 J	1.1	40	0.7 J	1.9	22	0.3 J	0.7
MW-20A	0.6 J	1 U	1 U	1 U	2 U	1 U	0.8 J	2 U	1 U	0.2 J	2 U	1 U	0.1 J	2 U	1 U
MW-20B	575 D	10	23	708	5.2	12	722	8.4 J	16 J	184	6	13	648	200 U	100 U
MW-27	0.05 J	1 U	1 U	1 U	2 U	1 U	1 U	2 U	1 U	1 U	2 U	1 U	1 U	2 U	1 U
MW-31	--	--	--	--	--	--	0.9 J	2 U	0.4 J	--	--	--	--	--	--
MW-32	--	--	--	--	--	--	--	--	--	--	--	--	0.8 J	2 U	1 U
MW-41	--	--	--	--	--	--	--	--	--	--	--	--	1 U	2 U	1 U
MW-19A	--	--	--	--	--	--	1 U	0.4 J	1 U	--	--	--	--	--	--
MW-33	1 U	1 U	1 U	--	--	--	1 U	2 U	1 U	--	--	--	1 U	2 U	1 U
MW-40	--	--	--	--	--	--	--	--	--	--	--	--	1 U	2 U	1 U
H1/H2	10	1 U	0.1 J	1.5	1 U	1 U	5.2	0.2 J	1 U	10	1 U	1 U	8.7	0.03 J	1 U

Table A-1 (cont.). Summary of Sample Results (ug/L) from January 1991 to October 2011.

Well Number	January 2001			August 2001			February 2002			August 2002			February 2003		
	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	**31**	**0.4 J**	**1**	**25**	**0.3 J**	**0.7 J**	**47**	**0.8 J**	**2.3**	**22**	**0.3 J**	**0.8 J**	**59 J**	**0.2 J**	**2.4**
MW-20A	**0.2 J**	1 U	1 U	1 U	2 U	1 U	--	--	--	--	--	--	1 U	1 U	1 U
MW-20B	**493**	**6.6 J**	**12**	**486**	**8.2**	**18**	**248**	200 U	100 U	**371**	**8.5**	**16**	**230**	100 U	100 U
MW-27	1 U	1 U	1 U	1 U	2 U	1 U	1 U	2 U	1 U	1 U	2 U	1 U	1 U	1 U	1 U
MW-31	--	--	--	**0.4 J**	2 U	**0.3 J**	--	--	--	--	--	--	--	--	--
MW-32	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-41	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-19A	--	--	--	1 U	**0.3 J**	1 U	--	--	--	--	--	--	--	--	--
MW-33	--	--	--	1 U	2 U	1 U	--	--	--	1 U	1 U	1 U	--	--	--
MW-40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
H1/H2	**11**	**0.2 J**	1 U	**6.8**	**0.2 J**	1 U	**12**	**0.2 J**	**0.2 J**	**6.1**	1 U	1 U	**1.3**	1 U	1 U

Well Number	September 2003			June 2004			November 2004			June 2005			November 2005		
	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	**26**	**0.3 J**	**0.5 J**	**30**	**0.4 J**	**0.8 J**	**48**	1 U	**1.4**	**80**	**1.3**	**2.8**	**43**	**0.7 J**	**1.0 J**
MW-20A	**0.1 J**	1 U	1 U	**0.2 J**	1 U	1 U	**0.3 J**	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-20B	**239**	**5.4 J**	**12**	**344**	**6.5 J**	**15**	**241**	**6.7**	**13**	**413**	**6.6**	**12**	**555**	**6.4**	**11**
MW-27	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
MW-31	**0.5 J**	1 U	**0.1 NJ**	--	--	--	--	--	--	**0.5 J**	1 U	1 U	--	--	--
MW-32	--	--	--	--	--	--	--	--	--	**1.4**	1 U	1 U	--	--	--
MW-41	--	--	--	--	--	--	--	--	--	1 U	1 U	1 U	--	--	--
MW-19A	1 U	**0.4 NJ**	1 U	--	--	--	--	--	--	1 U	**0.6 J**	1 U	--	--	--
MW-33	1 U	1 U	1 U	--	--	--	--	--	--	1 U	1 U	1 U	--	--	--
MW-40	--	--	--	--	--	--	--	--	--	1 U	1 U	1 U	--	--	--
H1/H2	**6.4**	**0.2 NJ**	1 U	**7.9**	**0.2 J**	**0.1 J**	**2.6**	1 U	1 U	**14**	**0.3 J**	1 U	**6.4**	1 U	1 U

Table A-1 (cont.). Summary of Sample Results (ug/L) from January 1991 to October 2011.

Well	May 2006			September 2006			June 2007			October 2007			May 2008		
Number	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	**124**	**1.8**	**4.6**	**29**	**0.3 J**	**0.48 J**	**83**	**1.2**	**2.5**	**24**	1 U	**0.64 J**	**55**	**1.2**	**2.8**
MW-20A	1 U	1 U	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	1 U	1 U	1 U	1 U	1 U
MW-20B	**216**	**4.2**	**6.6**	**518**	**5.6**	**11**	**204**	**4.4**	**7.8**	**491**	**7.5**	**15**	**143**	**5.5**	**12**
MW-27	1 U	1 U	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	1 U	1 U	1 U	1 U	1 U
MW-31	--	--	--	--	--	--	**1.6 J**	2 U	2 U	--	--	--	--	--	--
MW-32	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-41	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-19A	--	--	--	--	--	--	2 U	**1.2 J**	2 U	--	--	--	--	--	--
MW-33	1 U	1 U	1 U	--	--	--	2 U	2 U	2 U	--	--	--	1 U	1 U	1 U
MW-40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LPMW-2	**9.9**	1 U	1 U	--	--	--	**4.8**	1 U	1 U	--	--	--	**2.5**	1 U	1 U
LPMW-3	1 U	1 U	1 U	--	--	--	2 U	1 U	1 U	--	--	--	--	--	--
H1/H2	**7.3**	**0.2 J**	1 U	**4.8**	1 U	1 U	**5.2**	2 U	2 U	**3.8**	1 U	1 U	**9.6**	1 U	1 U

Well	October 2008			June 2009			November 2009			June 2010			October 2010		
Number	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE
MW-16A	**31**	**0.45 J**	**0.6 J**	**67**	**0.94 J**	**2.2**	**28**	**0.52 J**	**0.83 J**	**85**	**1.3**	**1.6**	**61**	**0.86 J**	**1.2**
MW-20A	1 U	1 U	1 U	1 U	1 U	1 U	**0.64 J**	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U
MW-20B	**258**	**4.5**	**9**	**160**	**4.1**	**7.4**	**250**	**4.7**	**9.6**	**130**	**3.7**	**6.3**	**520**	**5.8**	**10**
MW-27	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	--	--	--
MW-31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-32	--	--	--	--	--	--	--	--	--	**1.8**	1 U	1 U	--	--	--
MW-41	--	--	--	--	--	--	--	--	--	1 U	1 U	1 U	--	--	--
MW-19A	--	--	--	1 U	1 U	1 U	--	--	--	--	--	--	--	--	--
MW-33	--	--	--	1 U	1 U	1 U	--	--	--	1 U	1 U	1 U	--	--	--
MW-40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LPMW-2	--	--	--	**4.1**	1 U	1 U	**11**	1 U	1 U	**4.4**	1 U	1 U	**5**	1 U	1 U
H1/H2	**5.1**	1 U	1 U	**6.8**	1 U	1 U	--	--	--	**4.3**	1 U	1 U	--	--	--

Table A-1 (cont.). Summary of Sample Results (ug/L) from January 1991 to October 2011.

Well	June 2011			October 2011					
Number	PCE	TCE	cis-1,2-DCE	PCE	TCE	cis-1,2-DCE			
MW-16A	**100**	**1.4**	**1.6**	**57**	**0.75 J**	**1**			
MW-20A	1 U	1 U	1 U	1 U	1 U	1 U			
MW-20B	**200**	**3.5**	**5.6**	**720**	**4.8**	**7.9**			
MW-27	1 U	1 U	1 U	1 U	1 U	1 U			
MW-31	--	--	--	**0.65 J**	1 U	1 U			
MW-32	--	--	--	--	--	--			
MW-41	--	--	--	--	--	--			
MW-19A	--	--	--	1 U	**0.42 J**	1 U			
MW-33	--	--	--	1 U	1 U	1 U			
MW-40	--	--	--	1 U	1 U	1 U			
LPMW-2	**3.2**	1 U	1 U	--	--	--			
H1/H2	**5.9**	1 U	1 U	**1.4**	1 U	1 U			

U: The analyte was not detected at or above the reported result.
J: The analyte was positively identified. The associated numerical result is an estimate.
UJ: The analyte was not detected at or above the reported estimated result.
D: Analysis performed at secondary dilution.
E: The concentration of the associated value exceeds the known calibration range.
-- Not tested
Bold: The analyte was positively identified.

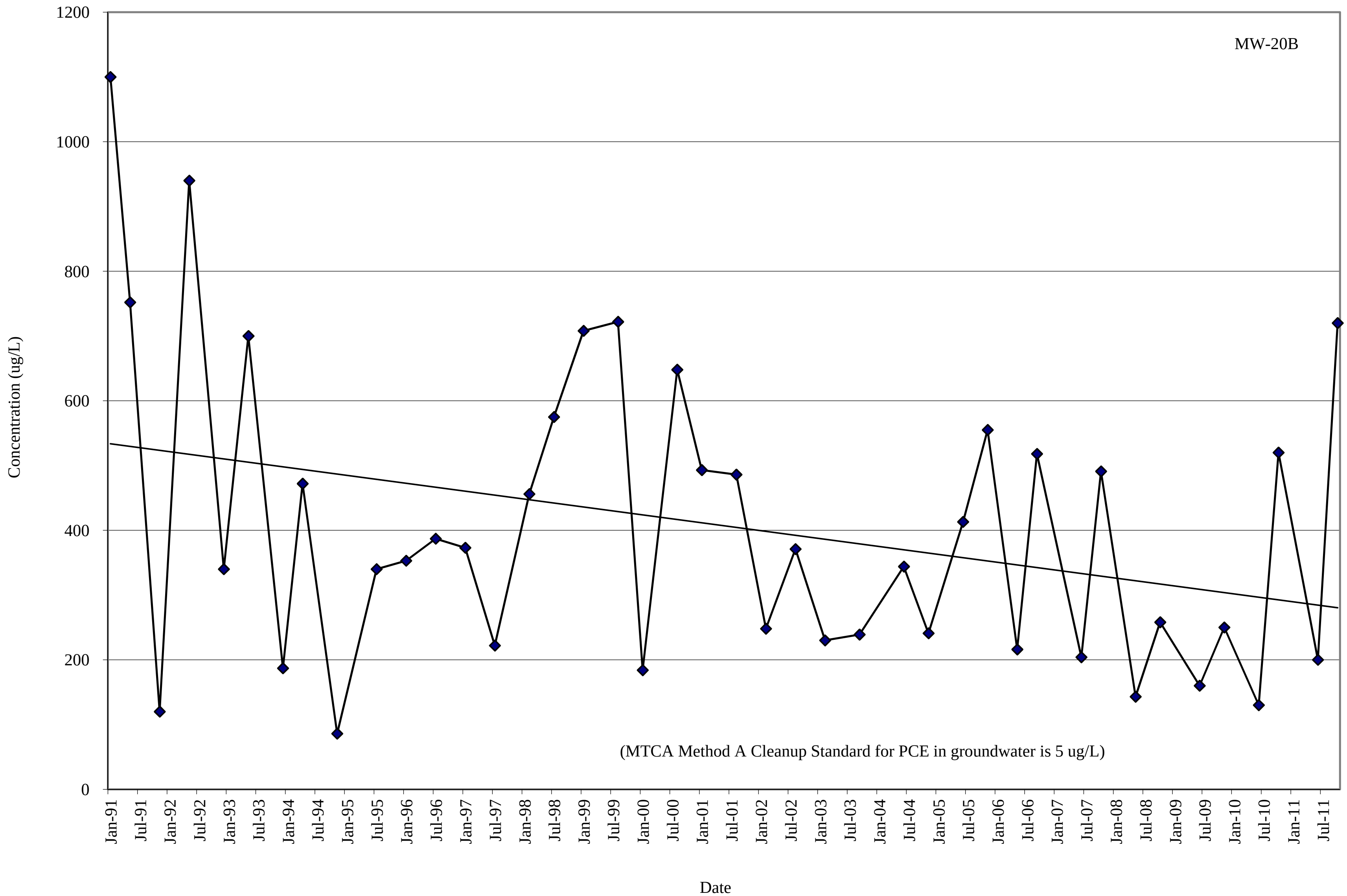

Figure A-1. PCE Concentrations for Well MW-20B, January 1991 to October 2011.

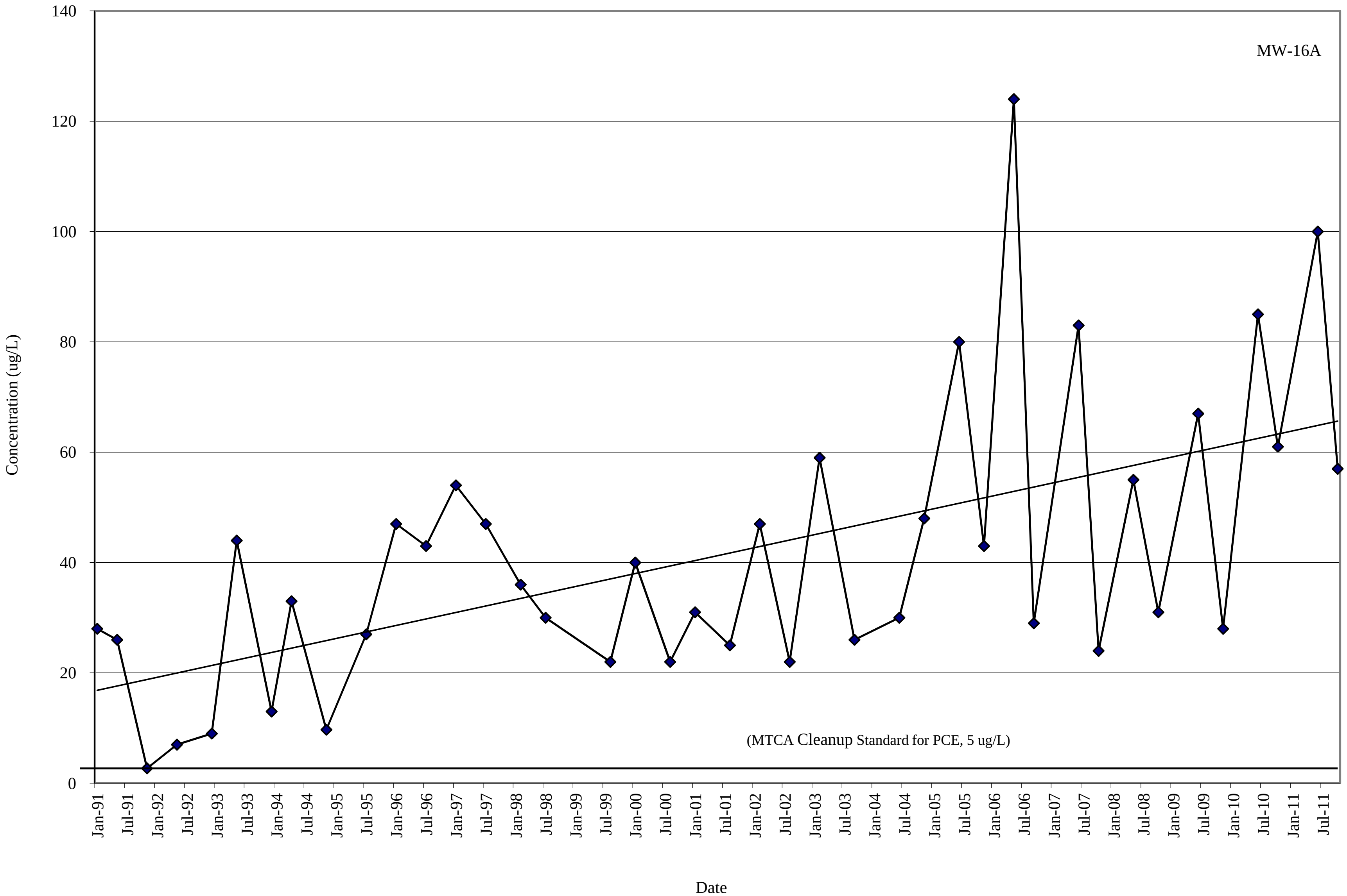

Figure A-2. PCE Concentrations for Well MW-16A, January 1991 to October 2011.

Appendix B. Glossary, Acronyms, and Abbreviations

Glossary

Aquifer: An underground geological formation, or group of formations, containing water.

Aquitard: Geologic formation that may contain groundwater but is not capable of transmitting significant quantities of it under normal hydraulic gradients. May function as a confining bed.

Depth-to-water: A measure of depth to the water (i.e., water level) in a well.

Groundwater: Water in the subsurface that saturates the rocks and sediment in which it occurs. The upper surface of groundwater saturation is commonly termed *water table*.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Purge water: Water removed from the sampling zone in a well prior to sample collection.

Specific conductance: A measure of water's ability to conduct an electrical current. Specific conductance is related to the concentration and charge of dissolved ions in water.

Volatile organics: Organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the earth's atmosphere.

Acronyms and Abbreviations

Cis-1,2-DCE	Cis-1,2-dichloroethene
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	Environmental Protection Agency
MTCA	Model Toxic Control Act
PCE	Tetrachloroethene
PVC	Polyvinyl chloride
RPD	Relative Percent Difference
TCE	Trichloroethene
VOA	Volatile Organics Analysis
WAC	Washington Administrative Code

Units of Measurement

°C	degrees centigrade
ug/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter