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Palermo Wellfield Superfund Site Subdrain System and Treatment Lagoon Status Report

October 2007 and June and November 2008

by
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Table of Contents

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List of Figures

List of Tables

Abstract

In the late 1980s, groundwater contaminated with trichloroethene (TCE) and tetrachloroethene (PCE) migrated from an upland commercial area to the City of Tumwater's Palermo Wellfield in the Deschutes River valley. The contaminated groundwater also surfaced at the base of Palermo bluff and ponded in the yards and crawlspaces of area homes. In 2000, the U.S. Environmental Protection Agency (EPA) constructed a subdrain system to lower the groundwater table and reduce the human health risk from the contaminated water.

In December 2002, the Department of Ecology assumed the lead for monitoring the subdrain system. The monitoring goal was to collect water-level and PCE/TCE data to determine if the subdrain system is operating within the remediation goals set for the project.

Ecology conducted its most recent monitoring in October 2007 and June and November 2008. Groundwater levels met the remediation goal of three feet below ground surface for the central homes and were near the remediation goal for the northern homes. As in the past, depths to groundwater were less than three feet near the two southern homes.

Overall, total depths measured in the eight subdrain cleanouts were close to the 2001 original depths. Sediment is present in some cleanouts located in the central and southern end of the perforated pipe. It does not appear that sediment deposition or scouring is occurring in the catch basins and lagoon. However, vegetation growth is occurring at the south end of the lagoon but does not appear to be adversely affecting the lagoon's performance.

PCE and TCE concentrations continue to be highest in water samples from the southern and central portion of the perforated pipe, with average concentrations of 15 µg/L for PCE and 24 µg/L for TCE. PCE and TCE concentrations detected at station 364 (treated water discharge to the Deschutes River) were below the remediation goals of 0.8 µg/L for PCE and 2.7 µg/L for TCE.

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Introduction

Background

In the late 1980s, the City of Tumwater, Washington, discovered trichloroethene (TCE) contamination in some of the water supply wells at their Palermo Wellfield. Groundwater contaminated with TCE and tetrachloroethene (PCE) migrated from an upland commercial area to the Deschutes River valley where the Palermo Wellfield is located (Figure 1). The contaminant sources are a dry cleaners and two Washington Department of Transportation (WDOT) facilities (Parametrix, 2008).

In the spring of 1999, the U.S. Environmental Protection Agency (EPA) began operating an air-stripping treatment system at the Palermo Wellfield Superfund Site to remove TCE contamination from the water supply.

In addition to the wellfield, contaminated groundwater was found to surface at the base of the Palermo bluff where it ponded in the yards and crawlspaces of area homes. This ponded water posed an inhalation risk to human health since PCE and TCE can volatilize from the water into the homes. To alleviate this situation, EPA constructed a subdrain system and treatment lagoon in 2000 to lower the local groundwater table at the base of the bluff and remove the contaminants from the collected water.

The subdrain system includes a subgrade perforated piping network installed around seven houses along Rainier Avenue (Figure 2). The main perforated pipe or "trunk drain" is aligned through the backyards of the houses. Water collected by the perforated pipes is routed to an unperforated "tightline" pipe beneath Rainier Avenue and M Street. The tightline pipe drains to a treatment lagoon located at the City of Tumwater Municipal Golf Course. PCE and TCE are removed from the water by surface aeration before it is discharged to the Deschutes River by way of an existing water course. The volatilized PCE and TCE disperse to the air and degrade naturally.

The remediation goals for this project are (1) to lower the static groundwater elevation beneath the homes along the west side of Rainier Avenue to at least three feet below ground surface, and (2) for contaminant concentrations of the treated water that discharges to the Deschutes River to be below 0.8 µg/L for PCE and 2.7 µg/L for TCE (Appendix A).

Site Monitoring

In December 2002, the Washington State Department of Ecology (Ecology) assumed the lead for monitoring the subdrain system from the EPA (Marti, 2003b). Results since December 2002 indicate that groundwater elevations have been lowered three or more feet below the ground surface for the homes in the central and northern portion of the trunk drain. However, the performance criteria do not appear to have been met for the two homes at the southern end of the trunk drain.

Total depths measured in the cleanouts indicated that sediment was accumulating in the perforated portion of the drain system. In the fall of 2006, the City of Tumwater removed sediment from several of the cleanouts.

Overall, total depths of the lagoon have not been significantly different from the original depths. However, thick vegetation growth is occurring in the south end of the treatment lagoon. It does not appear that the vegetation growth is adversely affecting the lagoons performance. PCE and TCE concentrations in the treated surface water samples have been below the remediation goals.

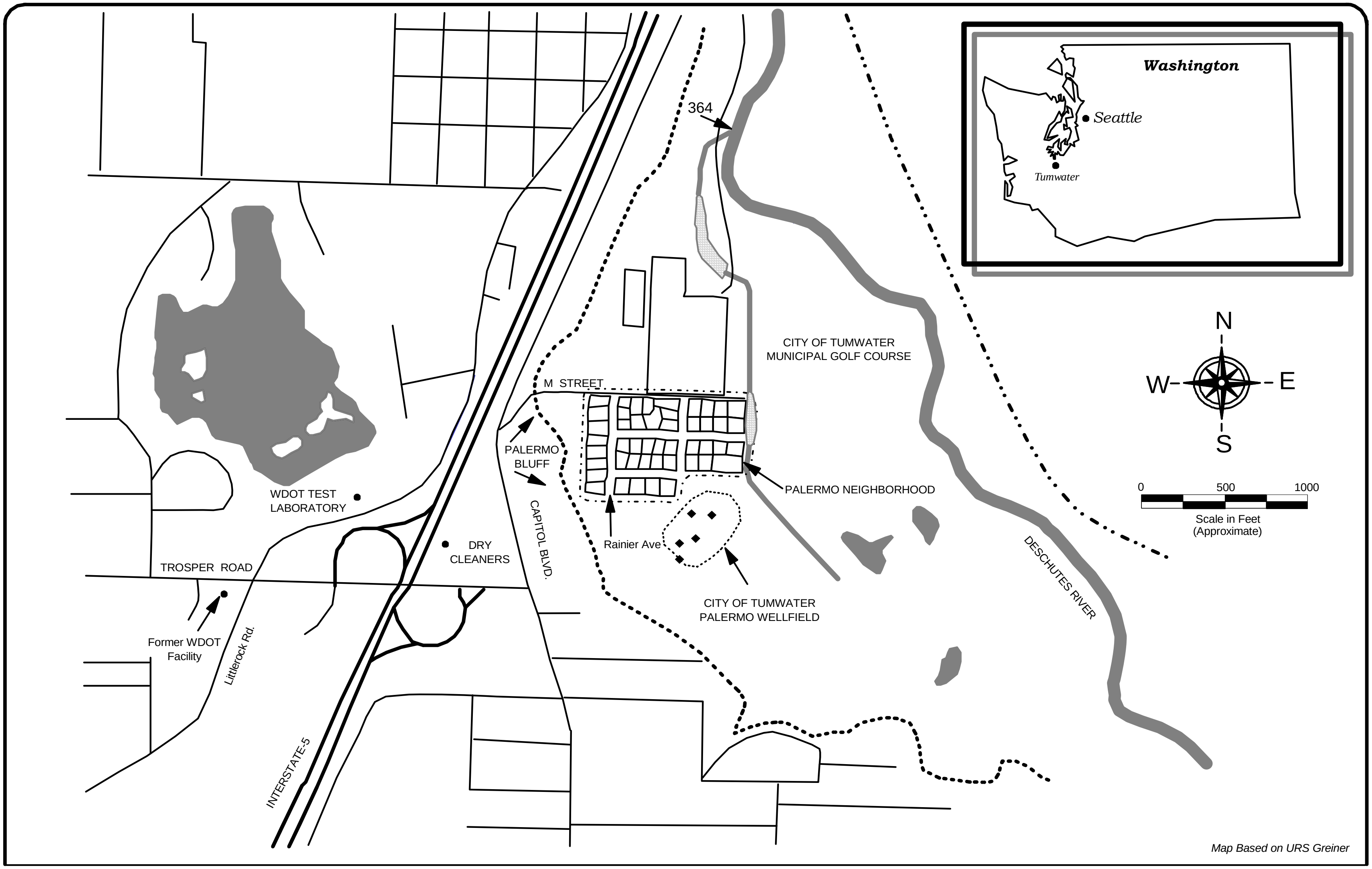

Figure 1 Palermo Wellfield and Neighborhood Site Location

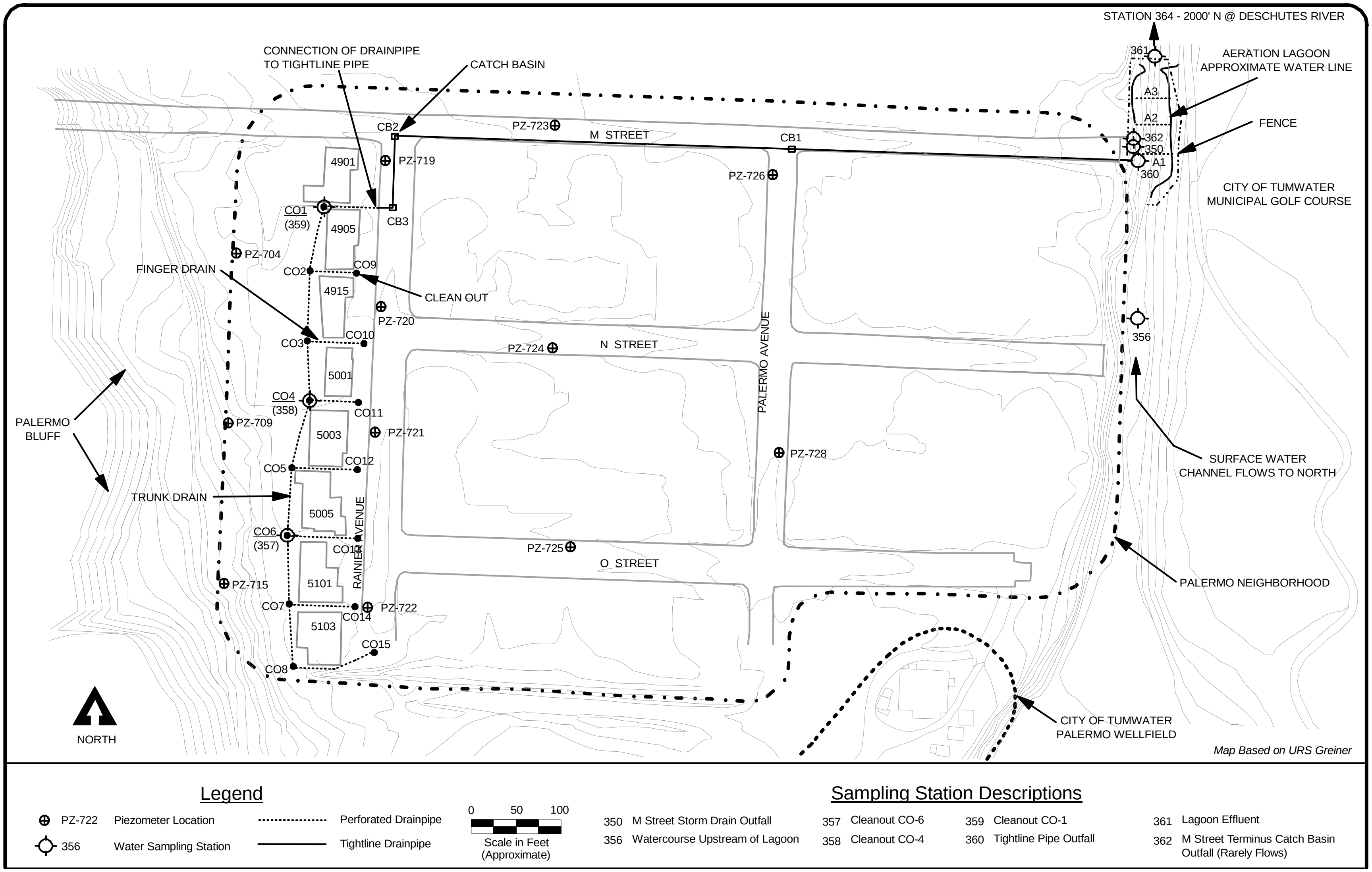

Figure 2 Palermo Wellfield Subdrain System and Treatment Lagoon Monitoring Stations

Methods

The goal of this project is to provide Ecology's Toxics Cleanup Program with water level data and PCE/TCE concentrations on a semi-annual basis to determine if the subdrain system and treatment lagoon are operating within the remediation goals. Monitoring and sampling of the system (Figure 2) were conducted by Ecology's Environmental Assessment Program on October 9, 2007 and on June 3–5 and November 3, 2008. Monitoring included the following activities:

- Measure depth-to-groundwater in 12 piezometers (PZ-704 through PZ-728) and eight trunk drain cleanouts (CO-1 through CO-8) to determine if the subdrain system has lowered the static groundwater elevation beneath the homes at the base of Palermo bluff to at least three feet below the ground surface.
- Measure total depth in CO-1 through CO-8 and three catch basins (CB-1, CB-2, CB-3) to determine if sedimentation has occurred in the trunk drain or tightline pipe. Measure total depth of the treatment lagoon along three cross-sections (A1, A2, A3) to determine if sedimentation or scouring has occurred in the lagoon.
- Measure flow rates and collect water samples for chemical analysis from three drain cleanouts (357, 358, 359), three outfalls to the treatment lagoon (360, 350, 362), and three surface water stations (356, 361, 364) to assess the contaminant removal performance of the system and compliance with remediation goals. Water samples collected from station 361 (lagoon effluent) must be collected while the lagoon aerators are operating. Station 364, where the lagoon watercourse discharges to the Deschutes River, was added to the monitoring program in October 2003 to allow better comparison of contaminant concentrations to the remediation goals. Locations of the sample stations as well as the sample identification numbers are described in Table 1 and shown in Figures 1 and 2.

Table 1: Sample Station Identification and Descriptions, Palermo Subdrain System.

Sample Identification	Sample Station Description
Flow in Subdrain System – South to North	
357	Cleanout CO-6 (southernmost station within trunk drain).
358	Cleanout CO-4 (central station within trunk drain).
359	Cleanout CO-1 (northernmost station within trunk drain).
360	Tightline pipe outfall (influent from subdrain system to treatment lagoon).
361	Lagoon effluent.
364	Lagoon watercourse discharge to the Deschutes River.
Inflows to Treatment Lagoon Other Than the Subdrain System.	
350	M Street storm drain outfall.
356	Watercourse flow upstream of the treatment lagoon.
362	M Street terminus catch basin outfall (rarely flows).

Depth-to-Groundwater

Static water levels were measured in the piezometers (PZ-704 through PZ-728) using a ¼-inch diameter Solinst water level meter. Depth-to-groundwater was also measured in the trunk drain cleanouts (CO-1 through CO-8). Measurements were recorded to 0.01 feet and are accurate to ±0.03 feet. Measurements were made from a surveyed mark at the top of the piezometer casing or cleanout frame. The water level probe was rinsed with deionized water and wiped clean between measurements.

Static water levels were not measured in the piezometers in October 2007 because the small diameter water level meter was malfunctioning. Static water levels were not measured in piezometer PZ-715 in June 2008 and PZ-704 in November 2008. These piezometers are located on the wooded Palermo bluff and are difficult to locate because of the thick vegetation.

Total Depth

The total depth of the trunk drain cleanouts (CO-1 through CO-8) and catch basins (CB-1 through CB-3) were measured from a surveyed mark near the top of the structure. These measurements were taken using a weighted tape measure marked in increments of 0.01 foot, and measurements were accurate to ±0.03 feet. The tape measure was rinsed with deionized water and wiped clean between measurements.

Depth of the aeration lagoon was measured in June 2008 along three cross-sections (A3-north, A2-central, and A1-south). A 100-foot measuring tape was secured between survey hubs located near the mooring posts for the three lagoon aerators. The measuring tape provides the reference elevation for the depth measurements. The lagoon depth was measured from the east to the west bank at two-foot increments with a survey rod.

Water Flow Rate

In October 2007 and June and November 2008, depth and velocity of water flow were measured at six of the nine stations within the subdrain system (357, 358, 359, 360, 361, and 350). Water velocity was measured with a Marsh-McBirney velocity meter. Depending on the station, flow depth was measured using either a flow wading rod (for lagoon effluent) or a graduated steel tape (for pipe outfalls). For stations within the trunk drain pipe, flow depth was calculated from depth-to-water measurements collected with a water level meter [(northerly rim elevation – depth-to-water = groundwater elevation) – pipe invert elevation = flow depth]. Flow in open channels was measured in accordance with the standard area-velocity method of measuring streamflows as described in the Operation and Maintenance Plan (URS Greiner, 2002).

As in previous monitoring rounds, flow rates at station 356 were not measured. Since the installation of the lagoon, the watercourse at this point has become wide and slow, which makes an accurate flow measurement difficult. No flow was observed from station 362 (M St. terminus catch basin) in October 2007 or November 2008, but a trace of flow was present in June 2008. Flow rates were not measured at station 364 (Figure 1) because of the difficulty of reaching either end of the culvert through which the lagoon watercourse flows before discharging to the Deschutes River.

Water Quality Sampling

Water samples were collected from seven of the nine sampling stations (357, 358, 359, 360, 361, 356, and 364) in October 2007. Stations 350 and 362 were not sampled in October. Station 350 is the storm drain outfall which discharges to the lagoon and was underwater. Sample station 362 (M St. terminus catch basin) was dry, which is usually the case. Water samples were collected from all nine stations (357, 358, 359, 360, 361, 350, 356, 362, and 364) in June 2008. Water samples were collected from eight of the stations (357, 358, 359, 360, 361,350, 356, and 364) in November 2008. Sample station 362 was dry.

Samples were collected using pre-cleaned glass beakers. The glass beakers were pre-cleaned with a Liquinox® wash and sequential rinses of hot tap water, deionized water, and pesticide-grade acetone. After cleaning, the beakers were air-dried and wrapped in aluminum foil.

Samples were transferred from the beaker into three 40-mL glass vials with Teflon-lined septa lids for volatile organic analysis. Samples were free of headspace and preserved with 1:1 hydrochloric acid. After sample collection and proper labeling, all samples were stored in an ice-filled cooler. Samples were transported to Ecology's Operation Center in Lacey. Samples were kept in the walk-in cooler until picked up by the courier to the Ecology/EPA Manchester Environmental Laboratory in Manchester. Chain-of-custody procedures were followed according to Manchester Environmental Laboratory protocol (Ecology, 2008).

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Results

Analysis

Analytes, methods, and reporting limits for both field and laboratory parameters are listed in Table 2. All water samples were analyzed for volatile organics, including the target analytes of PCE, TCE, cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride (VC).

Table 2: Field and Laboratory Measurements for October 2007, June 2008, and November 2008 Samples.

Field Measurements	Instrument Type	Method	Accuracy
Water Level	Solinst Water Level Meter	SOP EAP052	±0.03 feet
Total Depth	Weighted Tape Measure Survey Rod	SOP EAP052	±0.03 feet ±0.01 feet
Flow Velocity	Marsh-McBirney Current Meter	SOP EAP024	± 0.1 ft/s
Laboratory Analytes	**Method**	**Reference**	**Reporting Limit**
VOCs	EPA SW-846 Method 8260B	EPA 1996	0.5-5 µg/L

SOP = Standard Operating Procedure.
EPA = Environmental Protection Agency.

Field quality control samples consisted of blind field duplicates obtained from the tightline pipe outfall (station 360). Field duplicates were collected by splitting the water collected in a pre-cleaned glass beaker between two sets of sample bottles. This 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 being sampled.

Table 3 shows the results of the duplicate samples and the relative percent difference (RPD). RPD is calculated as the difference between sample results, divided by the mean and expressed as a percent.

Table 3. Relative Percent Difference (RPD) of PCE and TCE Duplicate Sample Results (ug/L) for October 2007, June 2008, and November 2008.

Well Sample ID	October 2007				June 2008				November 2008			
	PCE	TCE	Cis-1,2-DCE	VC	PCE	TCE	Cis-1,2-DCE	VC	PCE	TCE	Cis-1,2-DCE	VC
360	9.5	19	1 U	2 U	5.9	19	1 U	2 U	8.5	19	1 U	1 U
360D	9.6	20	1 U	2 U	6.1	20	1 U	2 U	8.6	19	1 U	1 U
RPD (%)	1%	5%	--	--	3%	5%	--	--	1 %	0%	--	--

In October 2007 and June and November 2008, the RPD for duplicate samples from station 360 ranged from 0% to 5%. All data met the measurement quality objectives established in the Quality Assurance Project Plan (Marti, 2003b).

A review of the data quality control and quality assurance from laboratory case narratives indicates 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 problems were reported that compromised the usefulness or validity of the sample results. No data were rejected, and all results were usable as qualified. Quality assurance case narratives and laboratory reporting sheets are available upon request.

All field measurements and analytical result data are available in electronic format from Ecology's Environmental Information Management (EIM) data management system: www.ecy.wa.gov/eim/index.htm. Click on "Search by user study ID "and enter "PALERMO".

Depth-to-Groundwater

Depth-to-groundwater data measured in the piezometers in the Palermo neighborhood are listed in Table 4, along with calculated groundwater elevations and depth below the ground surface (bgs). Groundwater elevations and depth bgs are also shown in Figure 3. Historical depth-to-groundwater data, including data collected prior to the drain installation, are presented in Appendix B.

Table 4: Depth-to-Groundwater, Groundwater Elevations, and Groundwater Depth Below Ground Surface in Piezometers for June and November 2008 (measured in feet).

Piezometer	Inner PVC Elevation	Concrete/ Ground Elevation	June 2008			November 2008		
			Measured Depth to Groundwater[1]	Groundwater Elevation	Groundwater Depth Below Ground Surface	Measured Depth to Groundwater[1]	Groundwater Elevation	Groundwater Depth Below Ground Surface
Piezometers Influenced by the Subdrain System								
PZ-704	110.61	108.43	4.84	105.77	**-2.66**	--	--	--
PZ-709	114.27	112.01	3.30	110.97	**-1.04**	3.80	110.47	**-1.54**
PZ-715	117.79	115.51	--	--	--	5.10	112.69	**-2.82**
PZ-720	107.75	108.22	3.76	103.99	-4.23	3.68	104.07	-4.15
PZ-721	108.32	108.57	3.00	105.32	-3.25	3.04	105.28	-3.29
PZ-722	108.82	109.21	-0.84	109.66	**0.45**	-0.55	109.37	**0.16**
Piezometers Beyond the Influence of the Subdrain System								
PZ-719	107.13	107.37	2.29	104.84	-2.53	2.24	104.89	-2.48
PZ-723	106.34	106.80	2.44	103.90	-2.90	2.28	104.06	-2.74
PZ-724	106.45	106.88	1.44	105.01	-1.87	1.20	105.25	-1.63
PZ-725	108.22	108.58	2.62	105.60	-2.98	--	--	--
PZ-726	105.39	105.61	3.05	102.34	-3.27	2.88	102.51	-3.10
PZ-728	105.27	105.84	2.90	102.37	-3.47	2.65	102.62	-3.22

[1] = Measured from top of PVC -- = Not measured

Bold = Did not meet performance criteria of lowering the water table to 3 feet below the ground surface.

Depth-to-groundwater ranged from 1.04 to 4.23 feet bgs in June 2008 and from 1.54 to 4.15 feet bgs in November 2008. PZ-722 is the exception, water depths in this piezometer are typically at or near ground surface. As in the past, lowering of the water table to the remediation goal of three feet bgs was not achieved in wells PZ-704, PZ-709, PZ-715, and PZ-722. Water levels in PZ-719, PZ-723, PZ-724, and PZ-725 were also near ground surface, but these piezometers are located beyond the influence of the subdrain system. October 2007 measurements were not collected.

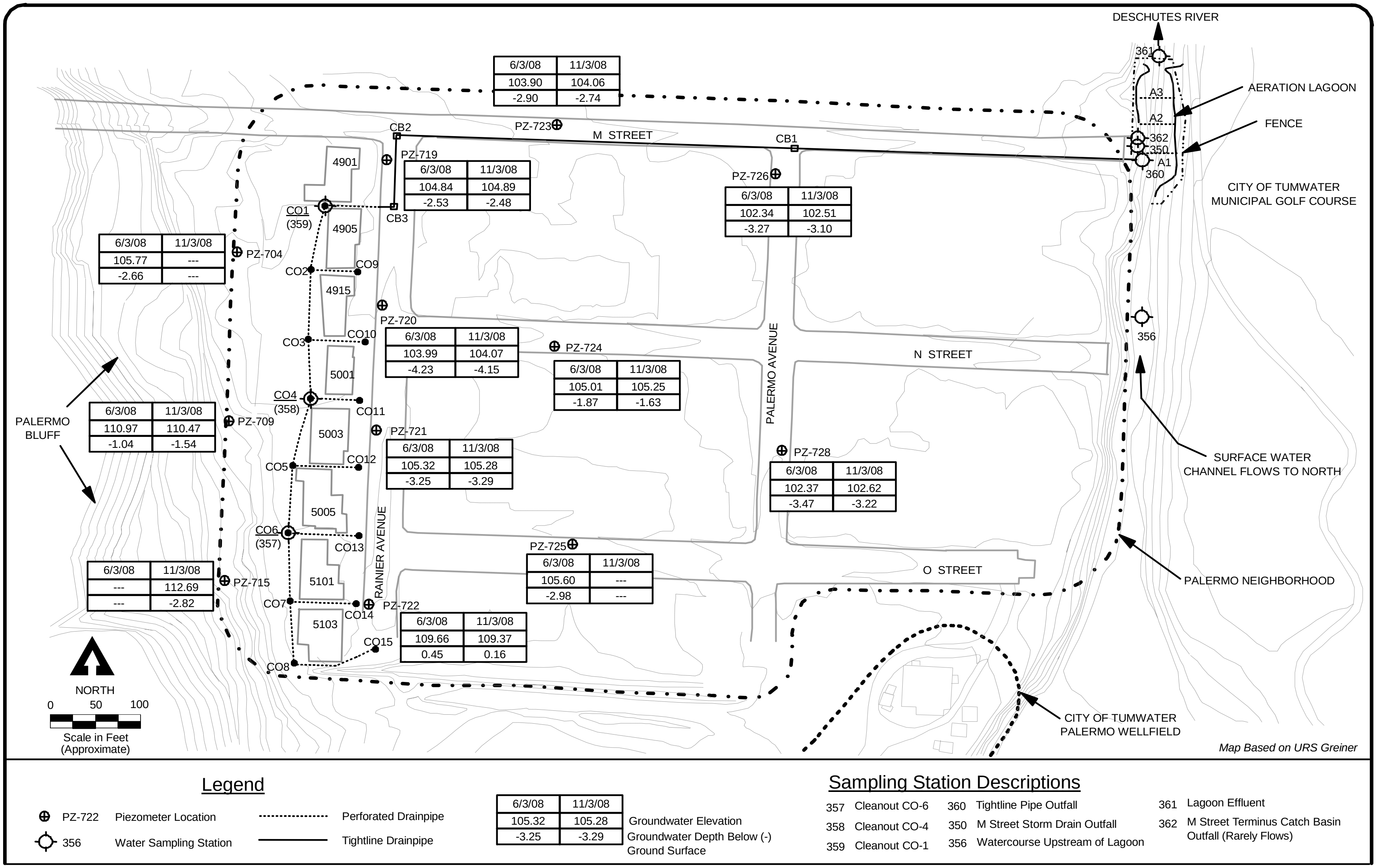


Figure 3 Palermo Wellfield Subdrain System and Treatment Lagoon Groundwater Depth

The remediation goal of lowering the groundwater elevation to three feet bgs for the residences along the west side of Rainier Avenue appears to have been met for the central homes. Groundwater levels measured in piezometers near this portion of the subdrain were approximately three to four feet bgs. Water levels near the northern homes were approximately two-and-one-half feet bgs. The remediation goal is usually met for these homes. These homes appear to be beyond the contaminant plume. The water level was at ground surface at PZ-722, therefore, it is assumed that the performance criterion was not met for the two most southern homes. Groundwater levels routinely continue to be the highest for these two homes.

Total Depth

In October 2007 and June and November 2008, total depth was measured in the cleanouts and catch basins. Total depths are measured to determine if sedimentation or erosion is occurring within the subdrain system. Previous total depth measurements for the cleanouts, catch basins, and lagoon are presented in Appendix C.

Table 5: Total Depth of Cleanouts and Catch Basins for October 2007, June 2008, and November 2008 (feet).

Location	February 2001	October 2007		June 2008		November 2008	
	Original Depth	Total Depth	Change from Original	Total Depth	Change from Original	Total Depth	Change from Original
CB-1	7.78	--	--	7.84	-0.06	7.86	-0.08
CB-2	8.78	8.71	0.07	8.71	0.07	8.79	-0.01
CB-3	8.81	8.87	-0.06	8.93	-0.12	8.91	-0.10
CO-1	7.82	7.81	0.01	7.81	0.01	7.81	0.01
CO-2	7.1	7.09	0.01	7.09	0.01	7.09	0.01
CO-3	6.84	6.83	0.01	6.81	0.03	6.81	0.03
CO-4	7.84	7.33	0.51	7.29	0.55	7.28	0.56
CO-5	7.84	7.57	0.27	7.53	0.31	7.64	0.20
CO-6	7.7	7.70	0.00	7.70	0.00	7.7	0.00
CO-7	7.89	7.75	0.14	7.67	0.22	7.57	0.32
CO-8	8.1	7.23	0.87	7.04	1.06	7.04	1.06

As shown in Table 5, the average catch basin and cleanout depths in October 2007, June 2008, and November 2008 ranged from 6.82 to 8.9 feet. In the three catch basins, the total depth measurements were not significantly different (less than ±0.12 feet) from the original depths measured in February 2001.

From September 2004 through June 2006, total depth measurements indicated that sediment had accumulated in cleanouts CO-3 through CO-8 (Appendix C). In fall 2006, the City of Tumwater removed the sediment from this portion of the trunk drain. In October 2007, June 2008, and November 2008, total depths of five of the cleanouts (CO-1, CO-2, CO-3, CO-5, and CO-6) were ±0.31 feet from the original depths. Total depths measured in CO-4, CO-7, and CO-8 indicate that sediment is still present or accumulating in these cleanouts. The average change in depths from the original depths were +0.54 feet in CO-4, +0.23 feet in CO-7, and +1.0 feet in CO-8.

Each cleanout has a sump below where the trunk drain enters the cleanout (pipe invert). The sump depths in these cleanouts are approximately 0.8 feet.

Since construction, cleanout CO-4 has consistently been about +0.4 feet less than the original reported depth. This may suggest that sediment is still present in the sump or that the original depth measurement was not correct. It has also been observed during field sampling that long strands of plant material are growing in the portion of the subdrain at cleanout CO-4.

Depth measurements were also recorded along three cross-sections of the treatment lagoon in June 2008. The lagoon depths for the north and central cross-sections were similar to the original depth measurements (February 2001) with a margin of error of ±0.5 feet (Appendix C). Depth measurements at the south end of the lagoon (cross-section A-1) were more variable. Thick vegetation growth along the lagoon banks and in the water made accurate depth measurements difficult to obtain. Changes in depth measurements were as much as one-to-three feet. The thick vegetation growth at the south end of the lagoon does not appear to be adversely affecting the lagoons function.

Many factors affect the lagoon depth measurements, such as how the measuring tape is secured to the survey hubs which can cause slight variations in the reference elevation. Small changes in the placement of the survey rod can also affect the measured depth due to the steepness of the lagoon walls, the presence of riprap at the lagoon edges, and occasional cobbles on the lagoon bottom. Vegetation along the lagoon banks also makes it difficult to measure near the bank edges. Overall, it appears that no measurable sediment deposition or scouring of the lagoon has occurred.

Water Flow Rate

Water flow depth and velocity data were used to calculate flow rates at each sample station, as shown in Table 6. Flow rates measured since February 2001 are presented in Appendix D.

Table 6: Flow Rates (gallons per minute) for October 2007, June 2008, and November 2008.

Sample Station	Location	October 2007	June 2008	November 2008
Flow in Subdrain System Through Discharge to Deschutes River				
357	Cleanout CO-6	58	69	46
358	Cleanout CO-4	88	147	101
359	Cleanout CO-1	203	205	189
360	Tightline pipe outfall	101	109	118
361	Lagoon effluent	486	873	902
364	Lagoon watercourse discharge to Deschutes River	--	--	--
Inflows to Treatment Lagoon Other Than the Subdrain System				
350	M Street storm drain outfall	--	21	30
356	Watercourse flow upstream of lagoon	--	--	--
362	M Street catch basin outfall	No Flow	Trace	No Flow

-- Not measured.

Flow rates from the south end of the trunk drain (station 357) to the north end (station 359) represent the cumulative groundwater inflow to the perforated pipe. In October 2007, June 2008, and November 2008, flow rates in these stations increased from an average of 58 gallons per minute (gpm) at station 357 to 199 gpm at station 359.

Flow rates at station 360 (tightline pipe outfall), which represents the total flow of the subdrain system, did not compare well with flow rates from station 359 (north end of the perforated pipe). From October 2007 to November 2008, the average flow rate at station 360 was 109 gpm, as compared to the average flow of 199 gpm at station 359.

Since Ecology began monitoring in December 2002, flow values from station 360 have been approximately 50% lower than flow values from station 359. This is probably the result of imprecise velocity measurements between the two stations. Velocity measurements at station 359 are measured below ground from subdrain cleanout CO-1. Velocity measurements at station 360 are measured from the end of the tightline pipe that drains into the lagoon. At times it has been difficult to completely submerge the velocity probe head in the shallow flow from the drain pipe. The difference in flow rates does not appear to be affecting the function of the subdrain system.

The flow rate from station 350 (M St. storm drain outfall) was not measured in October 2007 because the end of the storm drain was under water. The flow rate from station 350 in June 2008 was 21 gpm, and in November 2008 was 30 gpm. Station 362, which is usually dry, had no flow in October 2007 or November 2008, but a trace of flow in June 2008. As mentioned previously, the flow rates were not measured at stations 356 (upstream of lagoon) and 364 (Deschutes River discharge).

In October 2007, the flow rate at station 361 (lagoon outfall) was 486 gpm, in June 2008 it was 873 gpm, and in November 2008 it was 902 gpm. Thick pond vegetation and riprap at the lagoon outfall continues to make accurate depth and flow velocity measurements difficult. Conditions as the lagoon outfall do not appear to be adversely affecting the lagoon's performance.

Water Quality

Analytical results for PCE, TCE, cis-1,2-DCE and vinyl chloride (VC) are summarized in Table 7. PCE and TCE results for October 2007 and June and November 2008 are shown in Figure 4. Figures 5 and 6 show PCE and TCE concentrations in samples collected from the subdrain system and the lagoon effluent since February 2001. PCE and TCE results for each station, as well as calculated flow rates, are presented in Appendix D. Cis-1,2-DCE and vinyl chloride were not detected at any of the sample stations during this 2007-08 monitoring period.

Table 7: Summary of Target Analyte Results (µg/L) for October 2007, June 2008, and November 2008.

Sample Station	October 2007				June 2008				November 2008			
	PCE	TCE	Cis-1,2-DCE	VC	PCE	TCE	Cis-1,2-DCE	VC	PCE	TCE	Cis-1,2-DCE	VC
Flow in Subdrain System – South to North												
357	21	12	1 U	2 U	9.7	31	1 U	1 U	20	13	1 U	1 U
358	16	30	1 U	2 U	8.9	28	1 U	1 U	15	28	1 U	1 U
359	10	20	1 U	2 U	6.0	20	1 U	1 U	8.6	19	1 U	1 U
360	9.5	19	1 U	2 U	5.9	19	1 U	1 U	8.5	19	1 U	1 U
361	0.71	1.3	1 U	2 U	0.6 NJ	1.4	1 U	1 U	0.63	1.5	1 U	1 U
Inflows to Treatment Lagoon Other Than the Subdrain System												
350	--	--	--	--	0.5 U	1.4	1 U	1 U	0.5 U	1.8	1 U	1 U
356	0.5 U	0.5 U	1 U	2 U	0.5 U	0.5 U	1 U	1 U	0.5 U	0.5 U	1 U	1 U
362	NF	NF	NF	NF	0.5 U	0.5 U	1 U	1 U	NF	NF	NF	NF
Lagoon Watercourse Discharge to Deschutes River												
364	0.5 U	0.5 U	1 U	2 U	0.5 U	1.0	1 U	1 U	0.45 J	0.98	1 U	1 U
Remediation Goals												
	0.8	2.7	--	--	0.8	2.7	--	--	0.8	2.7	--	--

U : Analyte was not detected at or above the reported value.
J : Analyte was positively identified. The associated numerical result is an estimate.
NJ: Analysis indicates the presence of an analyte that has been tentatively identified, and the associated numerical value represents its approximate concentration.
NF: No flow.

PCE and TCE concentrations continue to be highest in groundwater samples from stations 357 and 358, located in the mapped area of the shallow groundwater plume. Average PCE concentrations for October 2007, June 2008, and November 2008 were 17 μg/L at station 357 and 13 μg/L at station 358. TCE concentrations varied more during the same monitoring period, with average concentrations of 19 μg/L at station 357, increasing to an average concentration of 29 μg/L at station 358. TCE concentrations are typically higher in samples from station 358, at the center of the trunk drain. PCE and TCE concentrations decreased at station 359 as less contaminated groundwater was collected at the northern end of the perforated pipe, with average concentrations of 8 μg/L and 20 μg/L, respectively.

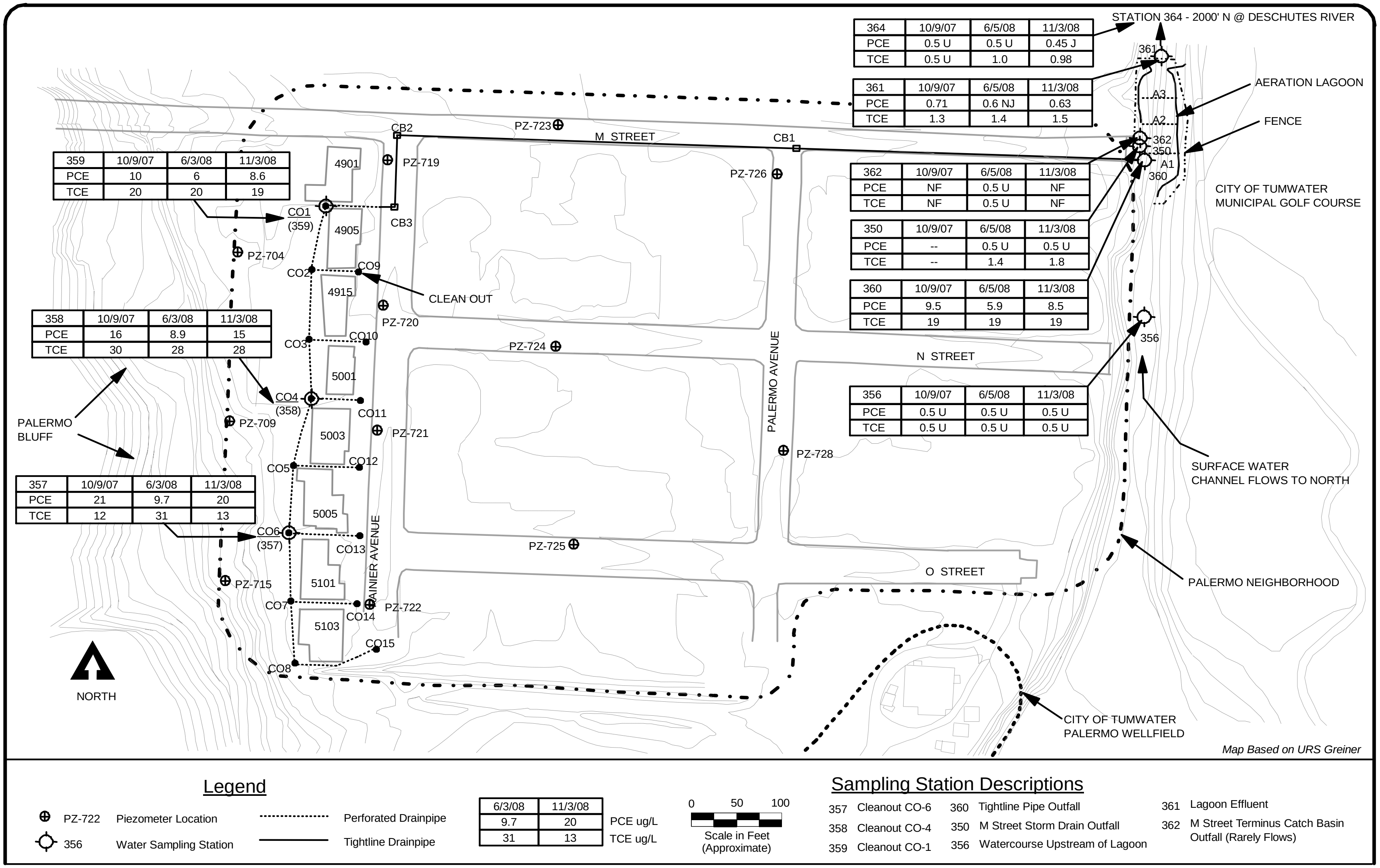
PCE and TCE concentrations at stations 359 (CO-1) and 360 (tightline pipe outfall) were similar, with average concentrations for both stations during this 2007-08 monitoring period of 8 μg/L for PCE and 19 μg/L for TCE. The similar concentration implies that little contaminant loss or degradation occurs within the tightline pipe, and that there is no substantial gain of water between the connection with the drain pipe and the outfall.

In addition to the subdrain outfall, three other stations (350, 356, and 362) contribute flow to the treatment lagoon. PCE and TCE were not detected at station 356, upstream of the lagoon. Station 350 was not sampled in October 2007 because the storm drain outfall was underwater. In June and November 2008, TCE was detected at station 350 at concentrations near the practical quantitation limit of 0.5 μg/L. Station 362 (M St. terminus catch basin outfall) was not sampled in October 2007 or November 2008 because there was no flowing water. However this station was sampled in June 2008. PCE and TCE were not detected, but toluene (1 μg/L) and acetone (4 μg/L) were detected at low concentrations.

PCE and TCE concentrations in samples from station 361 (lagoon effluent) during October 2007, June 2008, and November 2008, averaged 0.65 μg/L for PCE and 1.4 μg/L for TCE. Concentrations at the lagoon outfall were below the remediation goals of 0.8 μg/L for PCE and 2.7 μg/L for TCE for water discharging to the Deschutes River. Samples from station 361 (lagoon effluent) collected between December 2002 and May 2004, as shown in Figures 5 and 6, were collected while the treatment lagoon aerators were turned off. PCE and TCE results for this period are higher than during the 2001-2002 validation monitoring or for later samples collected after May 2004 while the aerators were operating.

Station 364 was added to the monitoring network in 2003 to allow further evaluation of the remediation goals. This station is located where the treated water discharges to the Deschutes River, approximately 2,000 feet downstream from the lagoon. PCE was not detected at this station in October 2007 or June 2008, but was detected at an estimated concentration of 0.45 μg/L in November 2008. TCE was detected at this station in June and November 2008 with an average concentration of 0.99 μg/L. PCE and TCE concentrations at station 364 were below the remediation goals.

Based on the lagoon effluent concentrations for PCE and TCE, the lagoon achieved a contaminant reduction of about 93% in October 2007, 92% in June 2008, and 93% in November 2008 (Appendix E). The residence time of the water in the lagoon was approximately four hours for October, and two hours in June and November.



364	10/9/07	6/5/08	11/3/08
PCE	0.5 U	0.5 U	0.45 J
TCE	0.5 U	1.0	0.98

361	10/9/07	6/5/08	11/3/08
PCE	0.71	0.6 NJ	0.63
TCE	1.3	1.4	1.5

359	10/9/07	6/3/08	11/3/08
PCE	10	6	8.6
TCE	20	20	19

362	10/9/07	6/5/08	11/3/08
PCE	NF	0.5 U	NF
TCE	NF	0.5 U	NF

350	10/9/07	6/5/08	11/3/08
PCE	--	0.5 U	0.5 U
TCE	--	1.4	1.8

360	10/9/07	6/5/08	11/3/08
PCE	9.5	5.9	8.5
TCE	19	19	19

358	10/9/07	6/3/08	11/3/08
PCE	16	8.9	15
TCE	30	28	28

356	10/9/07	6/5/08	11/3/08
PCE	0.5 U	0.5 U	0.5 U
TCE	0.5 U	0.5 U	0.5 U

357	10/9/07	6/3/08	11/3/08
PCE	21	9.7	20
TCE	12	31	13

6/3/08	11/3/08	
9.7	20	PCE ug/L
31	13	TCE ug/L

Figure 4 Palermo Wellfield Subdrain System and Treatment Lagoon PCE/TCE Concentrations

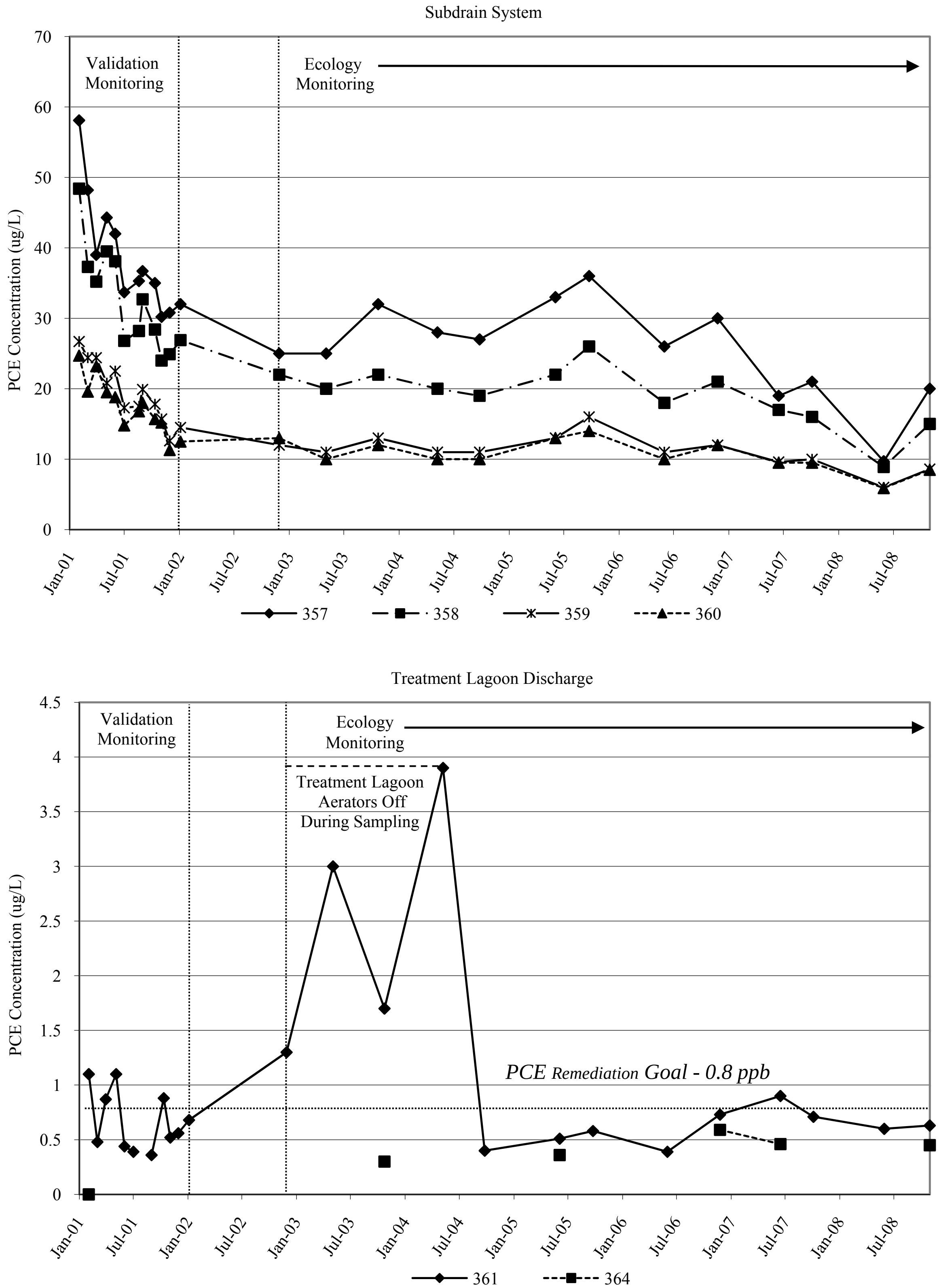
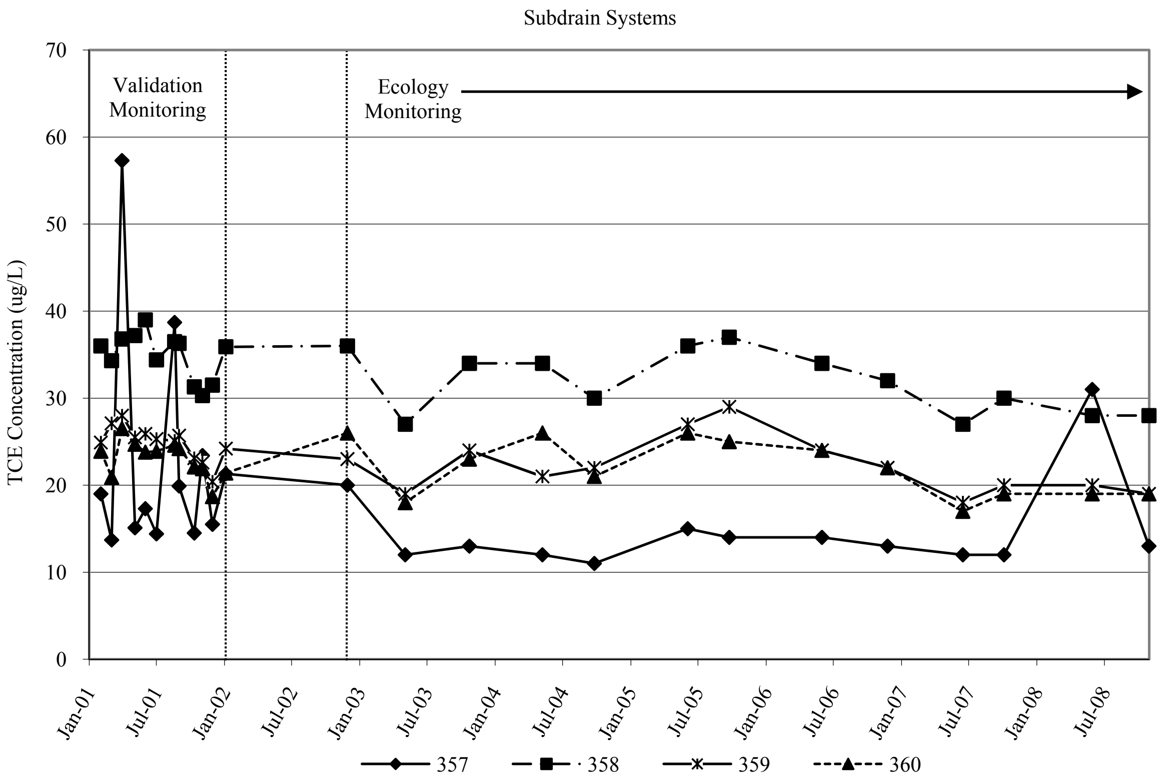


Figure 5: PCE Concentrations (µg/L) for Palermo Subdrain System and Treatment Lagoon, February 2001 through November 2008.



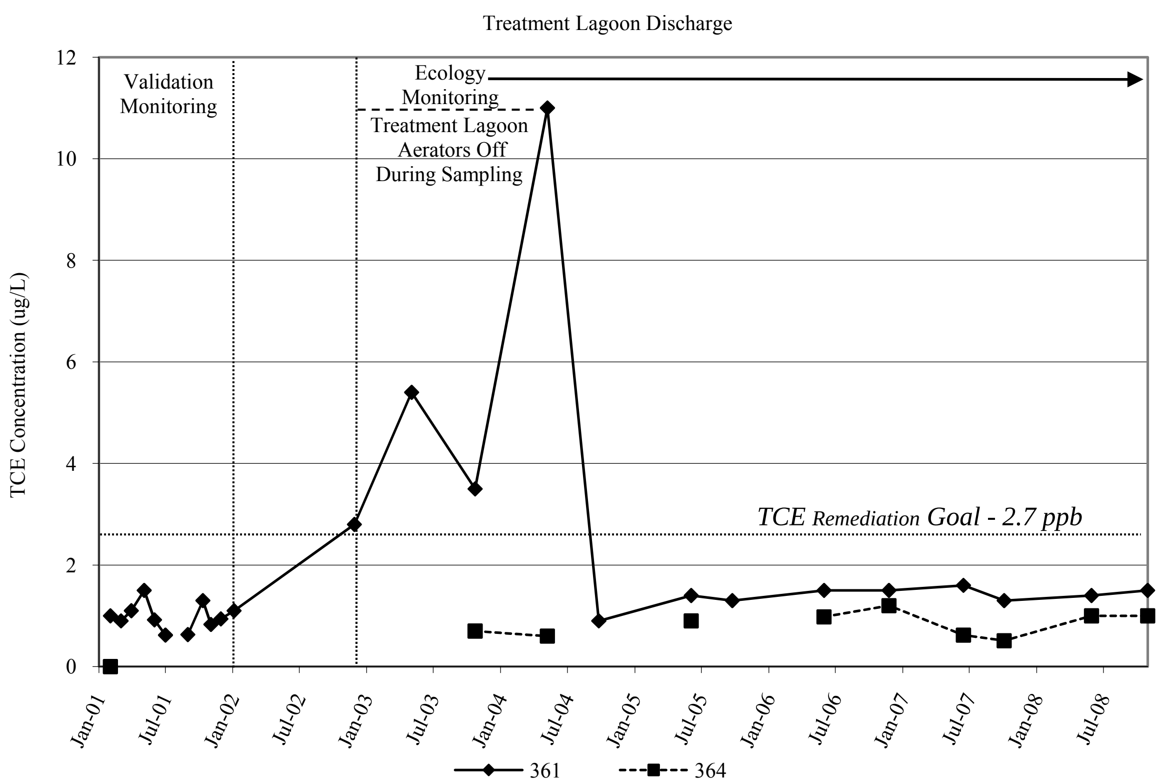


Figure 6: TCE Concentrations (µg/L) for Palermo Subdrain System and Treatment Lagoon, February 2001 through November 2008.

Conclusions and Recommendations

Conclusions

Depth-to-Groundwater

- Reduction of groundwater elevations to the remediation goal of three feet below the ground surface (bgs) was met for the central homes along the west side of Rainier Avenue in June and November 2008. Groundwater measured in piezometers near this portion of the trunk drain ranged from three to four feet below ground. Water levels near the northern homes did not meet the remediation goal and were approximately two-and-one-half feet bgs. In past sampling events, the remediation goal was usually met for these northern homes.
- Reduction of groundwater elevations to the remediation goal was not met for the two southern-most homes along the west side of Rainier Avenue. In June and November 2008, the water level in PZ-722 was at the ground surface. Groundwater levels continue to be the highest at these two homes.

Total Depth

- Total depths measured in most of the cleanouts were close to the original depths measured in February 2001. Cleaning performed by the City of Tumwater in the fall of 2006 appears to have successfully removed sediments that accumulated in most of the trunk drain cleanouts. However, total depths measured in October 2007, June 2008 and November 2008 indicate that sediment is still present or accumulating in cleanouts CO-7 and CO-8 which are located at the south end of the trunk drain.
- Total depths measured in the catch basins were not significantly different from the original depths measured in February 2001.
- Total depths measured in the lagoon indicate that no measurable sediment deposition or scouring has occurred. The lagoon depths for the north and central cross-sections were similar to the original depth measurements in February 2001. Depths at the south end of the lagoon were more variable. Vegetation growth along the lagoon banks and in the water made accurate depth measurements difficult to obtain. However, vegetation growth does not appear to be adversely affecting the lagoons function.

Water Quality

- Cis-1,2-DCE and vinyl chloride have not been detected at any of the sample stations since Ecology began monitoring in 2002.
- Overall, PCE concentrations from subdrain samples appear to show a decreasing trend. The average PCE concentration from station 357 in the 2006 sample season was 31 µg/L: the average concentration was 17 µg/L in 2008.

- Overall, TCE concentrations have remained stable and do not indicate significant loss through degradation.
- PCE and TCE were detected in samples collected from station 364, where the treatment lagoon watercourse enters the Deschutes River (approximately 2,000 feet downstream from the lagoon). Concentrations were below the remediation goals of 0.8 µg/L (PCE) and 2.7 µg/L (TCE) set for surface water that discharges to the Deschutes River.
- Reduction in contaminant concentrations after the treatment lagoon ranged from 90% to 93% in October 2007, June 2008, and November 2008.

Recommendations

- Vegetation growth along the Palermo bluff makes access to piezometers PZ-704, PZ-709, and PZ-715 difficult. If these piezometers are to continue being part of the monitoring program, regular vegetation removal is needed.
- Because of past sediment accumulation in the perforated pipe, total depths of cleanouts CO-3, CO-4, CO-5, CO-6, CO-7, and CO-8 should be closely monitored to ensure that the subdrain system continues to operate within the parameters established during the 2001 validation monitoring.
- Vegetation growth around the lagoon needs to be managed on a regular basis to allow access to the survey markers used for lagoon depth measurements.
- The west survey marker for cross-section A3 at the north end of the lagoon is gone. This needs to be replaced so that accurate depth measurements can be recorded.

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Appendices

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Appendix A. Subdrain System Operating Parameters

Table A-1: System Operating Parameters as Established During Validation Monitoring, February 2001 to April 2002.

Parameter	Representative Value	Comments
Flow rate from drain to lagoon	110 to 215 gpm	Average of 158 gpm; some low seasonal variation.
Flow rate in watercourse through lagoon	130 to 1470 gpm	High seasonal variation.
Chemicals of concern in water from drain to lagoon	PCE: 11.3 to 24.7 µg/L TCE: 18.7 to 26.5 µg/L	Overall decrease over performance validation period.
Chemicals of concern in water leaving lagoon	PCE: 0.5U to 1.1 µg/L TCE: 0.5U to 1.5 µg/L	With at least two aerators running.
Influence of drain on groundwater	*Predicted*: 3 feet of drawdown 35 feet away. *Actual*: 0.5 to 5.5 feet of drawdown, influence at 150 to 250 feet.	"Influence" refers to downgradient of drain. Actual is greater than predicted; however, near southern end of drain, effect is small (less than 1 foot of drawdown).

U – Analyte was not detected at or above the reported value.

Appendix B. Groundwater Elevation Data

Table B-1: Groundwater Elevation Changes Over Time, December 1999 through November 2008.

Date	PZ-704			PZ-709			PZ-715		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	107.15	--	--	111.60	--	--	114.79	--	--
1/31/00	107.49	0.34	--	111.83	0.23	--	114.70	-0.09	--
2/23/00	103.89	-3.60	--	111.75	-0.08	--	114.19	-0.51	--
3/28/00	107.20	3.31	--	111.82	0.07	--	114.54	0.35	--
5/9/00	107.38	0.18	--	111.77	-0.05	--	114.42	-0.12	--
5/26/00	107.07	-0.31	--	111.75	-0.02	--	114.44	0.02	--
6/22/00	106.81	-0.26	--	111.61	-0.14	--	113.90	-0.54	--
7/26/00	106.61	-0.20	--	111.30	-0.31	--	113.90	0.00	--
8/21/00	106.28	-0.33	--	111.02	-0.28	--	112.66	-1.24	--
10/2/00	106.21	-0.07	--	111.03	0.01	--	112.17	-0.49	--
11/21/00	102.61	-3.60	--	111.10	0.07	--	112.75	0.58	--
2/7/01	104.26	1.65	0.37	110.99	-0.11	-0.76	111.85	-0.90	-2.34
3/6/01	104.21	-0.05	-2.99	110.96	-0.03	-0.86	112.52	0.67	-2.02
4/3/01	104.30	0.09	-3.08	110.95	-0.01	-0.82	112.23	-0.29	-2.19
5/8/01	104.21	-0.09	-2.86	111.01	0.06	-0.74	112.01	-0.22	-2.43
6/6/01	104.11	-0.10	-2.70	110.33	-0.68	-1.28	111.82	-0.19	-2.08
7/5/01	103.86	-0.25	-2.75	110.23	-0.10	-1.07	111.40	-0.42	-2.50
8/24/01	103.92	0.06	-2.36	110.64	0.41	-0.38	111.07	-0.33	-1.59
9/4/01	103.73	-0.19	-2.48	110.24	-0.40	-0.79	110.58	-0.49	-1.59
10/17/01	103.86	0.13	-2.35	109.70	-0.54	-1.40	110.89	0.31	-1.28
11/6/01	103.56	-0.30	0.95	109.97	0.27	-1.13	110.95	0.06	-1.80
12/5/01	104.99	1.43	2.38	111.10	1.13	0.00	112.03	1.08	-0.72
1/8/02	105.44	0.45	1.18	111.00	-0.10	0.01	112.43	0.40	0.58
2/7/02	105.06	-0.38	0.80	111.05	0.05	0.06	112.18	-0.25	0.33
3/7/02	104.87	-0.19	0.66	111.04	-0.01	0.08	112.35	0.17	-0.17
4/1/02	104.97	0.10	0.67	111.07	0.03	0.12	112.28	-0.07	0.05
12/3/02	104.46	-0.51	-0.53	109.46	-1.61	-1.64	111.91	-0.37	-0.12
5/7/03	104.77	0.31	-0.20	109.87	0.41	-1.20	112.14	0.23	-0.14
10/27/03	104.74	-0.03	0.28	110.58	0.71	1.12	111.92	-0.22	0.01
5/12/04	104.93	0.19	0.16	NM	--	--	112.07	0.15	-0.07
9/29/04	104.54	-0.39	-0.20	109.87	--	-0.71	111.74	-0.33	-0.18
6/8/05	NM	--	--	NM	--	--	112.08	0.34	0.01
9/27/05	104.44	--	-0.10	NM	--	--	111.46	-0.62	-0.28
6/5/06	105.38	0.94	--	110.86	--	--	NM	--	--
11/29/06	NM	--	--	110.96	0.10	--	NM	--	--
6/20/07	NM	--	--	110.61	-0.35	-0.25	NM	--	--
6/13/08	105.77	--	--	110.97	0.36	0.36	NM	--	--
11/3/08	NM	--	--	110.47	-0.50	-0.49	112.69	--	--
Average:	105.09	0.64	--	110.87	0.29	--	112.50	0.38	--
Maximum:	107.49	--	--	111.83	--	--	114.79	--	--
3' BGS Elev.	105.43	--	--	109.01	--	--	112.51	--	--

Table B-1: Continued.

Date	PZ-719			PZ-720			PZ-721		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	103.90	--	--	106.59	--	--	107.37	--	--
1/31/00	104.85	0.95	--	106.45	-0.14	--	107.36	-0.01	--
2/23/00	104.88	0.03	--	106.50	0.05	--	107.32	-0.04	--
3/28/00	104.92	0.04	--	106.49	-0.01	--	107.33	0.01	--
5/9/00	104.93	0.01	--	106.57	0.08	--	107.44	0.11	--
5/26/00	104.82	-0.11	--	106.48	-0.09	--	107.22	-0.22	--
6/22/00	104.57	-0.25	--	106.60	0.12	--	106.94	-0.28	--
7/26/00	104.31	-0.26	--	105.89	-0.71	--	106.83	-0.11	--
8/21/00	103.73	-0.58	--	105.38	-0.51	--	106.19	-0.64	--
10/2/00	103.33	-0.40	--	105.41	0.03	--	105.77	-0.42	--
11/21/00	<97	--	--	<97	--	--	NM	--	--
2/7/01	103.50	--	-1.38	103.73	--	-2.77	104.26	--	-3.06
3/6/01	103.19	-0.31	-1.73	102.65	-1.08	-3.84	103.94	-0.32	-3.39
4/3/01	103.48	0.29	-1.45	102.73	0.08	-3.84	104.32	0.38	-3.12
5/8/01	103.65	0.17	-1.17	102.91	0.18	-3.57	104.43	0.11	-2.79
6/6/01	103.58	-0.07	-0.99	102.81	-0.10	-3.79	104.05	-0.38	-2.89
7/5/01	102.78	-0.80	-1.53	102.42	-0.39	-3.47	103.61	-0.44	-3.22
8/24/01	103.47	0.69	-0.26	102.61	0.19	-2.77	103.80	0.19	-2.39
9/4/01	102.62	-0.85	-0.71	102.38	-0.23	-3.03	103.45	-0.35	-2.32
10/17/01	102.99	0.37	-0.34	102.52	0.14	-2.89	103.72	0.27	-2.05
11/6/01	103.49	0.50	--	102.68	0.16	--	104.15	0.43	--
12/5/01	104.65	1.16	1.32	103.24	0.56	-2.17	104.98	0.83	-0.79
1/8/02	105.02	0.37	1.52	103.85	0.61	0.12	105.44	0.46	1.18
2/7/02	104.32	-0.70	0.82	103.12	-0.73	-0.61	104.92	-0.52	0.66
3/7/02	104.12	-0.20	0.93	103.07	-0.05	0.42	104.74	-0.18	0.80
4/1/02	104.21	0.09	0.73	103.12	0.05	0.39	104.85	0.11	0.53
12/3/02	103.76	-0.45	-0.89	102.91	-0.21	-0.33	104.60	-0.25	-0.38
5/7/03	104.04	0.28	-0.17	103.05	0.14	-0.07	104.60	0.00	-0.25
10/27/03	104.19	0.15	0.43	103.19	0.14	0.28	104.72	0.12	0.12
5/12/04	104.28	0.09	0.24	103.26	0.07	0.21	104.67	-0.05	0.07
9/29/04	103.75	-0.53	-0.44	103.00	-0.26	-0.19	104.28	-0.39	-0.44
6/8/05	104.23	0.48	-0.05	--	--	--	104.59	0.31	-0.08
9/27/05	103.59	-0.64	-0.16	102.95	--	-0.05	104.17	-0.42	-0.11
6/5/06	104.42	0.83	0.19	--	--	--	105.04	0.87	0.45
11/29/06	104.62	0.20	1.03	104.36	--	1.41	105.44	0.40	1.27
6/20/07	104.28	-0.34	-0.14	103.53	-0.83	--	104.96	-0.48	-0.08
6/13/08	104.84	0.56	0.56	103.99	0.46	0.46	105.32	0.36	0.36
11/3/08	104.89	0.05	0.27	104.07	0.08	-0.29	105.28	-0.04	-0.16
Average:	104.06	0.39	--	104.01	0.27	--	105.19	0.30	--
Maximum:	105.02	--	--	106.60	--	--	107.44	--	--
3' BGS Elev.	104.37	--	--	105.22	--	--	105.57	--	--

Table B-1: Continued.

Date	PZ-722			PZ-723			PZ-724		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	109.91	--	--	99.47	--	--		--	--
1/31/00	109.87	-0.04	--	103.57	4.10	--	104.89	--	--
2/23/00	110.06	0.19	--	103.71	0.14	--	104.85	-0.04	--
3/28/00	110.08	0.02	--	103.65	-0.06	--	105.01	0.16	--
5/9/00	110.10	0.02	--	103.89	0.24	--	105.01	0.00	--
5/26/00	109.97	-0.13	--	104.52	0.63	--	104.73	-0.28	--
6/22/00	109.88	-0.09	--	103.36	-1.16	--	104.50	-0.23	--
7/26/00	109.65	-0.23	--	103.01	-0.35	--	104.02	-0.48	--
8/21/00	109.43	-0.22	--	101.82	-1.19	--	102.63	-1.39	--
10/2/00	108.42	-1.01	--	100.85	-0.97	--	101.66	-0.97	--
11/21/00	109.47	1.05	--	102.85	2.00	--	104.06	2.40	--
2/7/01	108.42	-1.05	-1.64	102.89	0.04	-0.82	103.31	-0.75	-1.54
3/6/01	108.12	-0.30	-1.96	102.62	-0.27	-1.03	103.17	-0.14	-1.84
4/3/01	108.47	0.35	-1.63	102.91	0.29	-0.98	103.46	0.29	-1.55
5/8/01	107.88	-0.59	-2.09	102.91	0.00	-1.61	103.57	0.11	-1.16
6/6/01	108.52	0.64	-1.36	102.42	-0.49	-0.94	103.10	-0.47	-1.40
7/5/01	108.73	0.21	-0.92	101.60	-0.82	-1.41	102.14	-0.96	-1.88
8/24/01	107.65	-1.08	-1.78	102.70	1.10	0.88	102.36	0.22	-0.27
9/4/01	107.24	-0.41	-1.18	101.69	-1.01	0.84	NM	--	--
10/17/01	107.64	0.40	-0.78	101.97	0.28	1.12	NM	--	--
11/6/01	108.18	0.54	-1.29	102.68	0.71	-0.17	NM	--	--
12/5/01	109.00	0.82	-0.47	104.26	1.58	1.41	NM	--	--
1/8/02	109.49	0.49	1.07	105.24	0.98	2.35	105.97	--	2.66
2/7/02	109.14	-0.35	0.72	103.71	-1.53	0.82	104.43	-1.54	1.12
3/7/02	109.03	-0.11	0.91	103.36	-0.35	0.74	104.20	-0.23	1.03
4/1/02	109.32	0.29	0.85	103.44	0.08	0.53	104.31	0.11	0.85
12/3/02	108.67	-0.65	-0.33	102.84	-0.60	-1.42	104.07	-0.24	--
5/7/03	108.67	0.00	-0.65	103.02	0.18	-0.42	103.77	-0.30	-0.54
10/27/03	108.65	-0.02	-0.02	103.48	0.46	0.64	104.53	0.76	0.46
5/12/04	108.75	0.10	0.08	103.38	-0.10	0.36	104.21	-0.32	0.44
9/29/04	108.48	-0.27	-0.17	99.72	-3.66	-3.76	103.37	-0.84	-1.16
6/8/05	108.76	0.28	0.01	99.71	-0.01	-3.67	104.17	0.80	-0.04
9/27/05	108.61	-0.15	0.13	102.52	2.81	2.80	103.27	-0.90	-0.10
6/5/06	108.80	0.19	0.04	99.98	-2.54	0.27	104.44	1.17	0.27
11/29/06	109.25	0.45	0.64	104.01	4.03	1.49	105.37	0.93	2.10
6/20/07	109.28	0.03	0.48	103.30	-0.71	3.32	104.18	-1.19	-0.26
6/13/08	109.66	0.38	0.38	103.90	0.60	0.60	105.01	0.83	0.83
11/3/08	109.37	-0.29	0.12	104.06	0.16	0.05	105.25	0.24	-0.12
Average:	108.96	0.36	--	102.76	0.98	--	104.03	0.62	--
Maximum:	110.10	--	--	105.24	--	--	105.97	--	--
3' BGS Elev.	106.21	--	--	103.8	--	--	103.88	--	--

Table B-1: Continued.

Date	PZ-725			PZ-726			PZ-728		
	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year	GW Elev.	Delta Month	Delta Year
12/20/99	105.79	--	--	98.30	--	--	98.49	--	--
1/31/00	105.45	-0.34	--	101.59	3.29	--	101.72	3.23	--
2/23/00	100.99	-4.46	--	101.52	-0.07	--	98.56	-3.16	--
3/28/00	105.56	4.57	--	101.79	0.27	--	101.86	3.30	--
5/9/00	105.32	-0.24	--	101.64	-0.15	--	101.49	-0.37	--
5/26/00	105.20	-0.12	--	101.47	-0.17	--	101.96	0.47	--
6/22/00	105.00	-0.20	--	101.35	-0.12	--	101.14	-0.82	--
7/26/00	--	--	--	100.83	-0.52	--	100.54	-0.60	--
8/21/00	103.17	-1.83	--	100.76	-0.07	--	97.68	-2.86	--
10/2/00	102.81	-0.36	--	98.35	-2.41	--	97.23	-0.45	--
11/21/00	105.30	2.49	--	100.99	2.64	--	101.63	4.40	--
2/7/01	104.22	-1.08	3.23	100.74	-0.25	-0.78	100.26	-1.37	1.70
3/6/01	104.08	-0.14	-1.48	100.55	-0.19	-1.24	100.00	-0.26	-1.86
4/3/01	NM	--	--	100.85	0.30	-0.79	100.74	0.74	-0.75
5/8/01	104.68	--	-0.52	100.88	0.03	-0.59	100.87	0.13	-1.09
6/6/01	104.34	-0.34	-0.66	100.03	-0.85	-1.32	100.31	-0.56	-0.83
7/5/01	103.26	-1.08	--	97.76	-2.27	-3.07	98.90	-1.41	-1.64
8/24/01	103.19	-0.07	0.02	100.07	2.31	-0.69	98.49	-0.41	0.81
9/4/01	102.68	-0.51	-0.13	98.64	-1.43	0.29	97.89	-0.60	0.66
10/17/01	103.44	0.76	0.63	100.81	2.17	2.46	99.10	1.21	1.87
11/6/01	104.13	0.69	-1.17	100.34	-0.47	-0.65	100.19	1.09	-1.44
12/5/01	106.13	2.00	0.83	102.72	2.38	1.73	102.84	2.65	1.21
1/8/02	106.36	0.23	2.14	103.33	0.61	2.59	103.04	0.20	2.78
2/7/02	105.31	-1.05	1.09	101.88	-1.45	1.14	101.49	-1.55	1.23
3/7/02	105.03	-0.28	0.95	101.37	-0.51	0.81	101.18	-0.31	1.18
4/1/02	105.19	0.16	0.97	101.52	0.15	0.67	101.49	0.31	0.75
12/3/02	105.47	0.28	-0.66	100.94	-0.58	-1.78	102.05	0.56	-0.79
5/7/03	104.72	-0.75	-0.47	100.70	-0.24	-0.81	100.52	-1.53	-0.97
10/27/03	105.31	0.59	-0.16	102.12	1.42	1.18	102.03	1.51	-0.02
5/12/04	NM	--	--	101.62	-0.50	0.92	101.60	-0.43	1.08
9/29/04	104.23	--	-1.08	100.70	-0.92	-1.42	100.66	-0.94	-1.37
6/8/05	104.89	0.66	--	100.53	-0.17	-1.09	101.42	0.76	-0.18
9/27/05	103.94	-0.95	-0.29	100.50	-0.03	-0.20	100.27	-1.15	-0.39
6/5/06	105.12	1.18	--	101.89	1.39	1.36	101.68	1.41	0.26
11/29/06	105.97	0.85	2.03	102.79	0.90	2.29	102.87	1.19	2.60
6/20/07	104.95	-1.02	-0.17	101.57	-1.22	-0.32	101.59	-1.28	-0.09
6/13/08	105.61	0.65	0.65	102.34	0.77	0.77	102.37	0.78	0.78
11/3/08	NM	--	--	102.51	0.17	-0.28	102.62	0.25	-0.25
Average:	104.61	0.97	--	101.00	0.90	--	100.76	1.20	--
Maximum:	106.36	--	--	103.33	--	--	103.04	--	--
3' BGS Elev.	105.58	--	--	102.61	--	--	102.84	--	--

Notes for Table B-1:

2/7/2001 –	Subdrain system completed, beginning of validation monitoring (shaded green).
Average –	Arithmetic mean of data in column for both groundwater elevation and change in elevation for piezometer.
Maximum –	Maximum groundwater elevation recorded for each piezometer (shaded yellow).
3' BGS Elev. –	Elevation for groundwater to be 3 feet below ground surface (bgs) to meet performance criterion.
GW Elev. –	Elevation of groundwater in piezometer on date shown in feet above mean sea level. Elevations in red are above the 3 feet bgs criterion.
Delta Month –	Change in groundwater elevation since the last measurement (typically the previous month)
Delta Year –	Change in groundwater elevation since the last measurement taken the same month the previous year.
NM –	Depth-to-groundwater not measured at this location on this date.
--	No data available to perform calculation for this cell.
<97 –	Groundwater elevation was lower than the total depth of the well on this date (the well was dry). The numerical value is the approximate elevation of the bottom of the well.

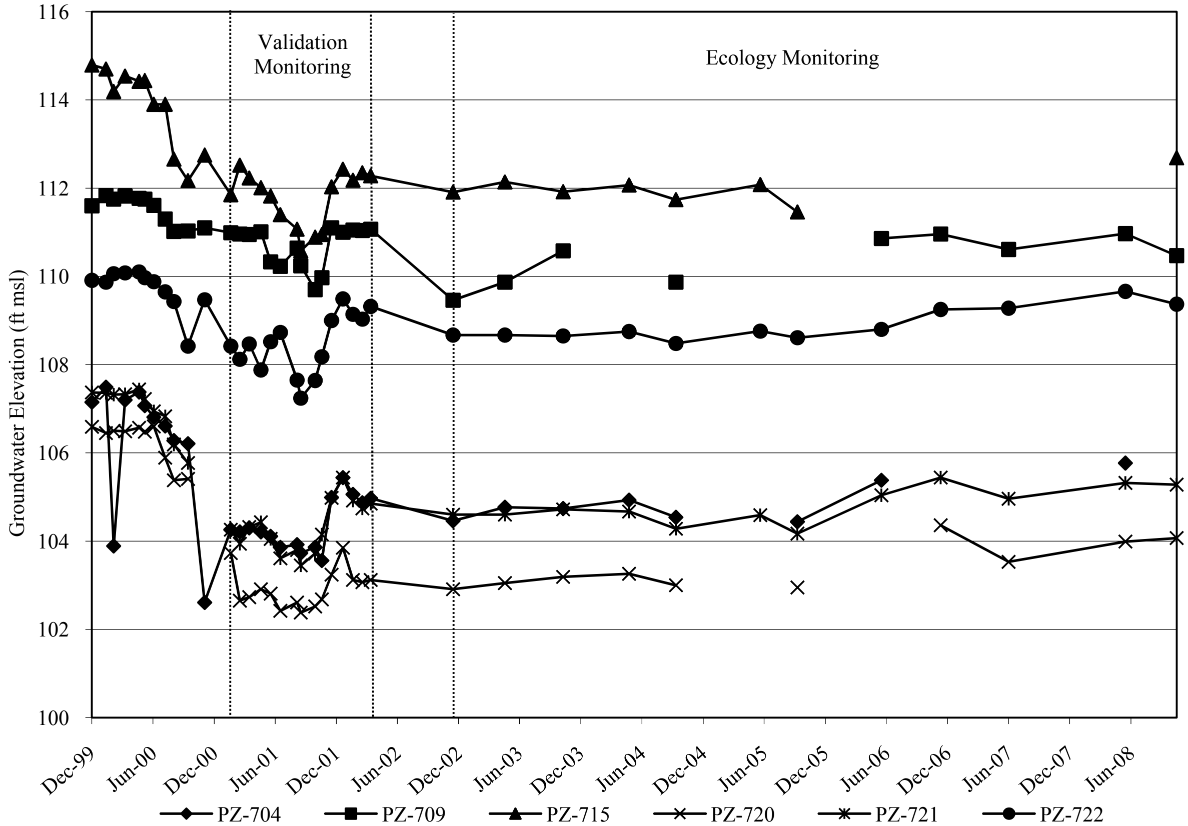


Figure B-1. Groundwater Elevations for Piezometers Influenced by the Subdrain System, December 1999 through November 2008.

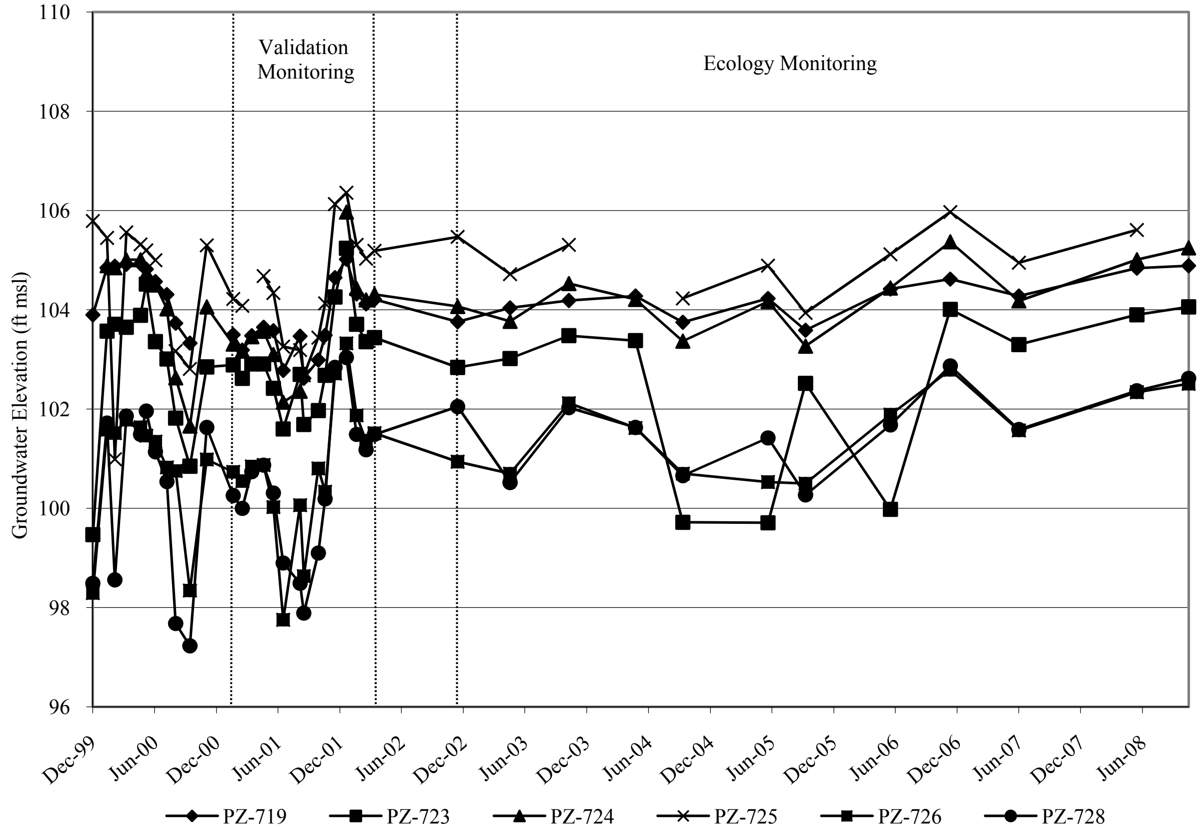


Figure B-2. Groundwater Elevations for Piezometers Beyond the Influence of the Subdrain System, December 1999 through November 2008.

Table B-2: Depth-to-Water and Water Elevations (feet) in Cleanouts from December 2002 through November 2008.

Cleanout	North Rim Elevation	Depth to Water	Water Elevation	Depth to Water	Water Elevation
		December 2002		May 2003	
CO-1	108.39	6.38	102.01	6.38	102.01
CO-2	108.04	--	--	5.95	102.09
CO-3	107.96	--	--	5.72	102.24
CO-4	108.73	6.42	102.31	6.22	102.51
CO-5	109.32	--	--	6.69	102.63
CO-6	109.78	6.59	103.19	6.58	103.20
CO-7	110.73	--	--	6.72	104.01
CO-8	110.96	--	--	6.85	104.11
		October 2003		May 2004	
CO-1	108.39	6.36	102.03	6.35	102.04
CO-2	108.04	5.91	102.13	5.91	102.13
CO-3	107.96	5.71	102.25	5.72	102.24
CO-4	108.73	6.22	102.51	6.21	102.52
CO-5	109.32	6.68	102.64	--	--
CO-6	109.78	6.55	103.23	6.58	103.20
CO-7	110.73	--	--	--	--
CO-8	110.96	6.85	104.11	6.85	104.11
		September 2004		June 2005	
CO-1	108.39	6.37	102.02	6.30	102.09
CO-2	108.04	5.95	102.09	5.90	102.14
CO-3	107.96	5.72	102.24	5.72	102.24
CO-4	108.73	6.22	102.51	6.19	102.54
CO-5	109.32	6.68	102.64	--	--
CO-6	109.78	6.59	103.19	6.58	103.20
CO-7	110.73	6.71	104.02	6.69	104.04
CO-8	110.96	--	--	6.76	104.20
		September 2005		June 2006	
CO-1	108.39	6.36	102.03	6.22	102.17
CO-2	108.04	5.94	102.10	5.75	102.29
CO-3	107.96	5.75	102.21	5.64	102.32
CO-4	108.73	6.21	102.52	6.23	102.50
CO-5	109.32	6.69	102.63	6.68	102.64
CO-6	109.78	6.60	103.18	6.62	103.16
CO-7	110.73	6.71	104.02	6.73	104.00
CO-8	110.96	6.77	104.19	6.76	104.20

-- not measured.

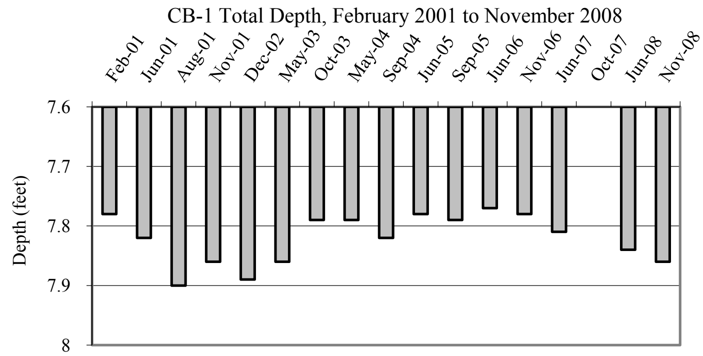
Table B-2 (continued): Depth-to-Water and Water Elevations (feet) in Cleanouts from December 2002 through November 2008.

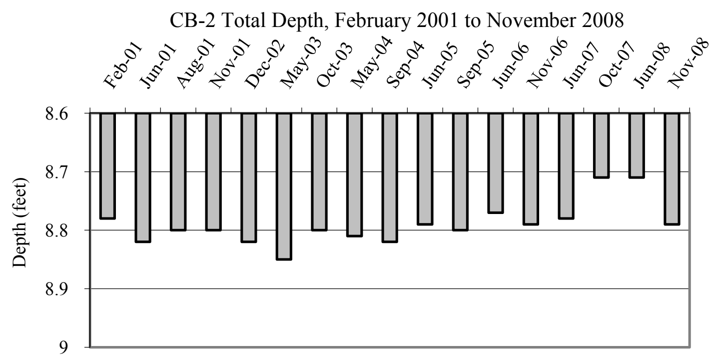
Cleanout	North Rim Elevation	Depth to Water	Water Elevation	Depth to Water	Water Elevation
		November 2006		June 2007	
CO-1	108.39	6.25	102.14	6.20	102.19
CO-2	108.04	5.76	102.28	5.71	102.33
CO-3	107.96	5.58	102.38	5.47	102.49
CO-4	108.73	6.22	102.51	6.18	102.55
CO-5	109.32	6.63	102.69	6.66	102.66
CO-6	109.78	6.65	103.13	6.60	103.18
CO-7	110.73	6.72	104.01	6.70	104.03
CO-8	110.96	6.75	104.21	6.71	104.25
		October 2007		June 2008	
CO-1	108.39	6.21	102.18	6.17	102.22
CO-2	108.04	5.73	102.31	5.65	102.39
CO-3	107.96	5.44	102.52	5.21	102.75
CO-4	108.73	6.12	102.61	5.89	102.84
CO-5	109.32	6.65	102.67	6.40	102.92
CO-6	109.78	6.60	103.18	6.58	103.20
CO-7	110.73	6.72	104.01	6.71	104.02
CO-8	110.96	6.74	104.22	6.72	104.24
		November 2008			
CO-1	108.39	6.11	102.28		
CO-2	108.04	5.62	102.42		
CO-3	107.96	5.26	102.7		
CO-4	108.73	5.95	102.78		
CO-5	109.32	6.51	102.81		
CO-6	109.78	6.61	103.17		
CO-7	110.73	6.71	104.02		
CO-8	110.96	6.73	104.23		

Appendix C. Total Depth for Cleanouts, Catch Basins, and Treatment Lagoon

Table C-1: Total Depth (feet) of Catch Basins, February 2001 through November 2008.

Date	CB-1		CB-2		CB-3	
	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original
2/6/01	7.78	--	8.78	--	8.81	--
6/6/01	7.82	-0.04	8.82	-0.04	8.92	-0.11
8/24/01	7.9	-0.12	8.8	-0.02	8.96	-0.15
11/6/01	7.86	-0.08	8.8	-0.02	8.41	0.4
12/2/02	7.89	-0.11	8.82	-0.04	8.95	-0.14
5/7/03	7.86	-0.08	8.85	-0.07	8.93	-0.12
10/27/03	7.79	-0.01	8.80	-0.02	8.93	-0.12
5/12/04	7.79	-0.01	8.81	-0.03	8.93	-0.12
9/29/04	7.82	-0.04	8.82	-0.04	8.91	-0.1
6/8/05	7.78	0.0	8.79	-0.01	8.92	-0.11
9/28/05	7.79	-0.01	8.80	-0.02	8.91	-0.1
6/5/06	7.77	0.01	8.77	0.01	8.93	-0.12
11/29/06	7.78	0.0	8.79	-0.01	8.95	-0.14
6/20/07	7.81	-0.03	8.78	0.0	8.95	-0.14
10/9/07	--	--	8.71	0.07	8.87	-0.06
6/3/08	7.84	-0.06	8.71	0.07	8.93	-0.12
11/3/08	7.86	-0.08	8.79	-0.01	8.91	-0.10





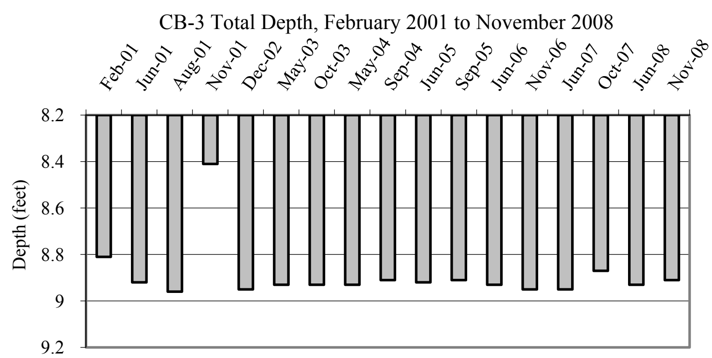


Figure C-1: Total Depth of Catch Basins, February 2001 through November 2008.

Table C-2: Total Depth (feet) of Cleanouts CO-1 to CO-4, February 2001 through November 2008.

Date	CO-1		CO-2		CO-3		CO-4	
	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original
2/6/01	7.82	--	7.1	--	6.84	--	7.84	--
6/6/01	7.82	0.00	7.24	-0.14	6.84	0.00	7.44	0.4
8/24/01	7.78	0.04	7.2	-0.1	6.6	0.24	7.41	0.43
11/6/01	7.79	0.03	7.19	-0.09	6.82	0.02	7.43	0.41
12/2/02	7.79	0.03	7.19	-0.09	6.84	0.00	7.42	0.42
5/7/03	7.87	-0.05	7.23	-0.13	6.82	0.02	7.46	0.38
10/27/03	7.81	0.01	7.21	-0.11	6.84	0	7.42	0.42
5/12/04	7.81	0.01	7.21	-0.11	6.82	0.02	7.43	0.41
9/29/04	7.79	0.03	7.20	-0.1	6.81	0.03	7.39	0.45
6/8/05	7.79	0.03	7.19	-0.09	6.83	0.01	7.37	0.47
9/28/05	7.81	0.01	7.21	-0.11	6.81	0.03	7.38	0.46
6/5/06	7.81	0.01	7.17	-0.07	6.14	0.7	6.71	1.13
11/29/06	7.83	-0.01	7.12	-0.02	6.83	0.01	7.44	0.40
6/20/07	7.8	0.02	7.1	0.0	6.83	0.01	7.38	0.46
10/9/07	7.81	0.01	7.09	0.01	6.83	0.01	7.33	0.51
6/3/08	7.81	0.01	7.09	0.01	6.81	0.03	7.29	0.55
11/3/08	7.81	0.01	7.09	0.01	6.81	0.03	7.28	0.56

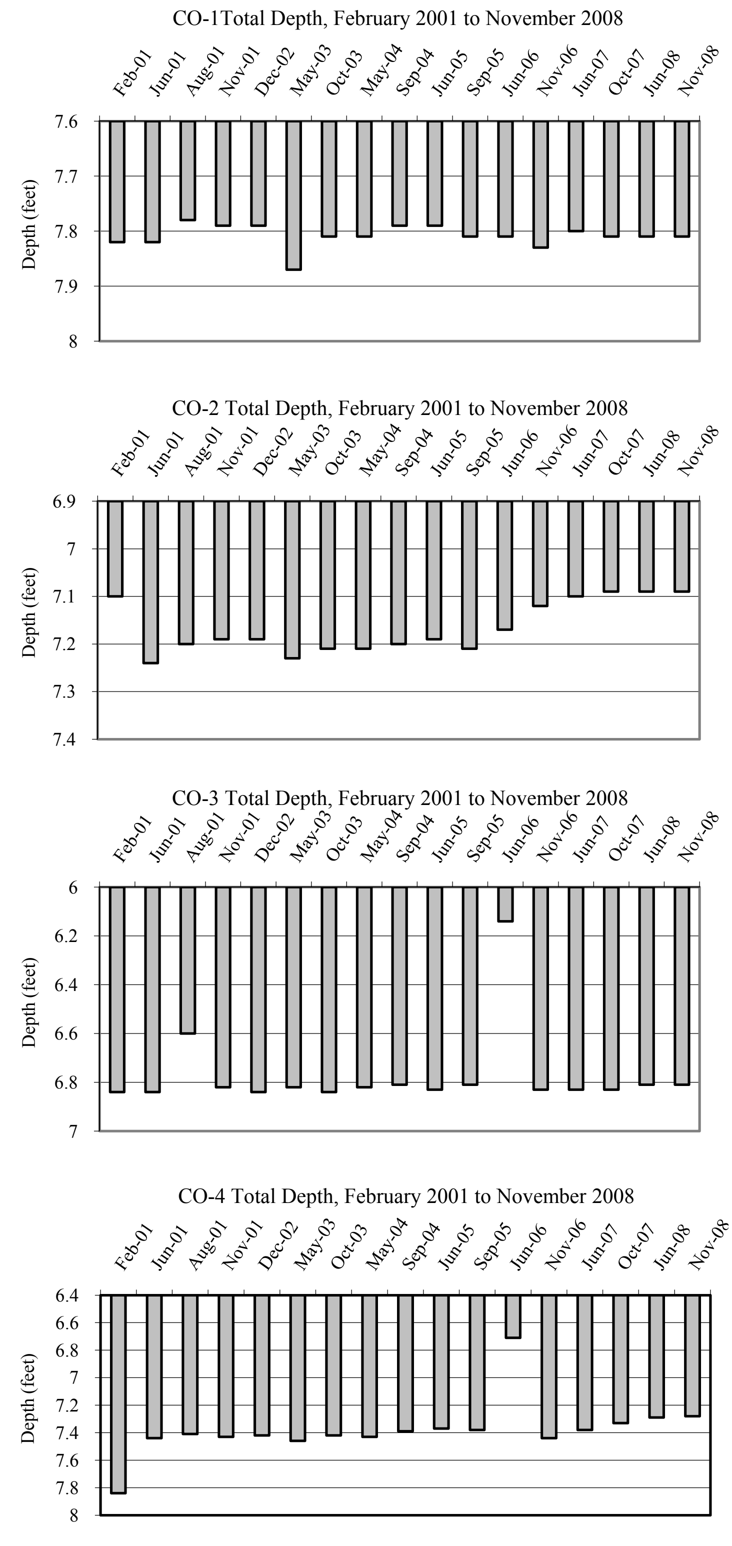


Figure C-2: Total Depth of Cleanouts CO-1 to CO-4, February 2001 through November 2008.

Table C-3: Total Depth (feet) of Cleanouts CO-5 to CO-8, February 2001 through November 2008.

Date	CO-5		CO-6		CO-7		CO-8	
	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original	Depth Below Survey Elevation	Change from Original
2/6/01	7.84	--	7.7	--	7.89	--	8.1	--
6/6/01	7.84	0.00	7.72	-0.02	7.86	0.03	8.12	-0.02
8/24/01	7.83	0.01	7.65	0.05	7.82	0.07	8.0	0.1
11/6/01	7.81	0.03	7.65	0.05	7.76	0.13	7.99	0.11
12/2/02	7.83	0.01	7.69	0.01	7.76	0.13	8.0	0.1
5/7/03	7.85	-0.01	7.68	0.02	7.8	0.09	7.97	0.13
10/27/03	7.83	0.01	7.67	0.03	--	--	7.98	0.12
5/12/04	--	--	7.68	0.02	--	--	8.02	0.08
9/29/04	7.81	0.03	7.67	0.03	7.22	0.67	6.85	1.25
6/8/05	--	--	7.61	0.09	7.04	0.85	6.86	1.24
9/28/05	7.71	0.13	7.64	0.06	7.02	0.87	6.92	1.18
6/5/06	7.04	0.8	7.12	0.58	7.07	0.82	6.88	1.22
11/29/06	7.19	0.65	7.72	-0.02	7.79	0.10	7.87	0.23
6/20/07	7.6	0.24	7.7	0.0	7.72	0.17	7.66	0.44
10/9/07	7.57	0.27	7.7	0.0	7.75	0.14	7.23	0.87
6/3/08	7.53	0.31	7.7	0.0	7.67	0.22	7.04	1.06
11/3/08	7.64	0.20	7.7	0.0	7.57	0.32	7.04	1.06

-- not measured.

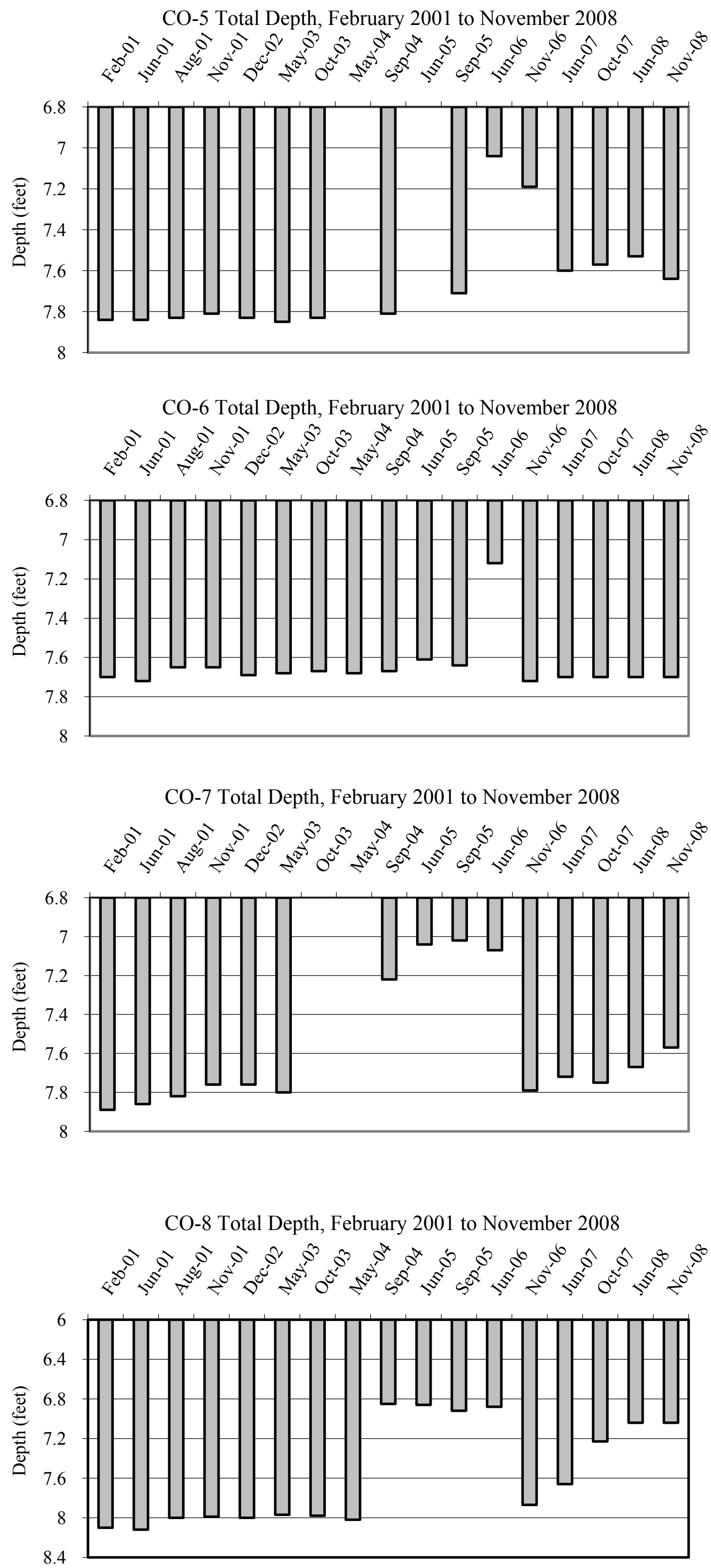


Figure C-3: Total Depth of Cleanouts CO-5 to CO-8, February 2001 through November 2008.

Table C-4: Treatment Lagoon Total Depth and Elevations (feet), June 2008.

Feet From East Bank	Aerator A1 (south)			Aerator A2 (central)			Aerator A3 (north)		
	Depth Below Survey Elev.	Elev. Above Datum	Change from Original	Depth Below Survey Elev.	Elev. Above Datum	Change from Original	Depth Below Survey Elev.	Elev. Above Datum	Change from Original
2	2.62	96.38	0.12	--	--	--	2.56	96.44	0.18
4	3.6	95.4	0.18	3.36	95.64	0.44	3.87	95.13	-0.07
6	3.35	95.65	1.35	4.28	94.72	0.42	5.33	93.67	0.19
8	4.8	94.2	0.8	5.56	93.44	0.46	6.8	92.2	0.06
10	5.8	93.2	0.66	6.37	92.63	0.51	7.3	91.7	0.15
12	6.41	92.59	0.61	6.53	92.47	0.59	7.4	91.6	0.22
14	5.1	93.9	2.56	6.69	92.31	0.65	7.48	91.52	0.14
16	6.93	92.07	0.69	6.98	92.02	0.62	7.6	91.4	0.0
18	7.16	91.84	0.38	7.08	91.92	0.54	7.3	91.7	0.28
20	--	--	--	--	--	--	6.98	92.02	0.28
22	7.23	91.77	0.29	7.09	91.91	0.45	6.18	92.82	0.78
24	6.62	92.38	0.92	6.98	92.02	0.5	5.51	93.49	0.51
26	7.1	91.9	0.32	6.75	92.25	0.59	4.55	94.45	-0.19
28	6.38	92.62	0.88	6.43	92.57	0.53	3.95	95.05	-0.73
30	4.88	94.12	1.72	5.89	93.11	0.47	3.75	95.25	--
32	2.15	96.85	3.03	4.37	94.63	0.51			
34	3.55	95.45	0.37	3.57	95.43	-0.37			
36	2.6	96.4	0.12	2.55	96.45	--			

-- not measured.

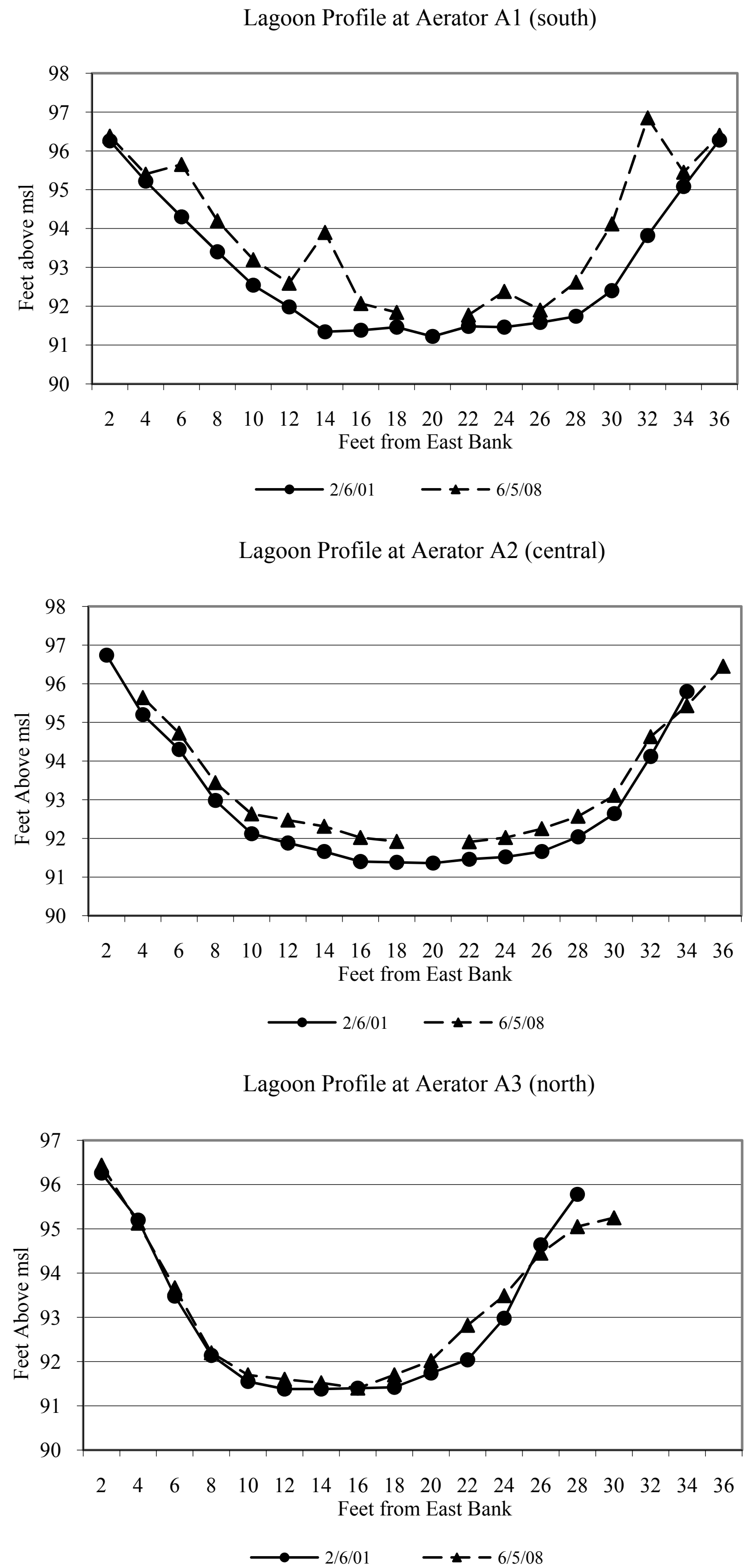


Figure C-4: Treatment Lagoon Depth Profile for June 2008, Compared to Original Depth Profile for February 2001. (msl = mean sea level.)

Appendix D. PCE and TCE Concentrations with Flow Rates, February 2001 through November 2008

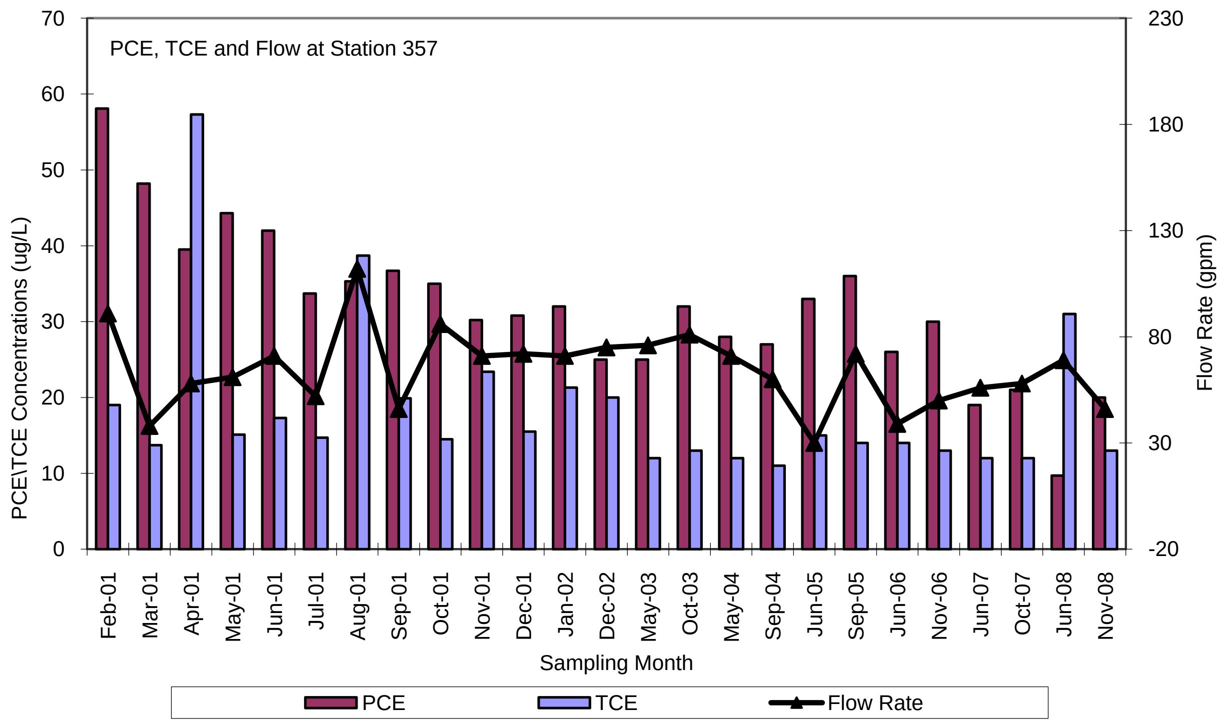
Table D-1. PCE and TCE Concentrations with Flow Rates, February 2001 through November 2008.

Sample		Sampling Month											
Station	COC	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02
350	PCE (µg/L)	1.0 U	0.5 U	0.5 U	0.5 U	NF	NF	0.5 U	NF	NF	0.5 U	0.5 U	0.5 U
(M St. SD)	TCE (µg/L)	1.0 U	0.5 U	0.5 U	0.5 U	NF	NF	0.5 U	NF	NF	0.5 U	1.5	1.7
	Flow (gpm)	2.6	1.3	1.6	0.04	0	0	126	0	0	Trace	39	72
356	PCE (µg/L)	1.0 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.50 U	0.5 U	0.5 U	0.5 U	0.5 U
(Ustrm)	TCE (µg/L)	1.0 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.38 J	0.5 U	0.5 U	0.5 U	0.5 U
	Flow (gpm)	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU
357	PCE (µg/L)	58.1	48.2	39.0	44.3	42.0	33.7	35.3	36.7	35	30.2	30.8	32.0
(CO-6)	TCE (µg/L)	19.0	13.7	57.3	15.1	17.3	14.4	38.7	19.9	14.5	23.4	15.5	21.3
	Flow (gpm)	91	38	58	61	71	52	112	46	86	71	72	71
358	PCE (µg/L)	48.4	37.3	35.2	39.5	38.1	26.8	28.2	32.7	28.4	24.0	24.9	26.9
(CO-4)	TCE (µg/L)	36	34.3	36.8	37.2	39.0	34.4	36.5	36.3	31.3	30.3	31.5	25.9
	Flow (gpm)	81	94	77	88	88	69	59	80	75	78	101	120
359	PCE (µg/L)	26.7	24.4	24.4	20.8	22.5	17.3	17.5	19.9	17.8	15.7	12.6	14.5
(CO-1)	TCE (µg/L)	24.9	27.1	28.0	25.5	25.9	25.3	25.1	25.7	23.1	22.6	20.4	24.2
	Flow (gpm)	157	118	135	150	135	114	121	111	137	111	169	118
360	PCE (µg/L)	24.7	19.6	23.2	19.5	18.8	14.8	16.8	18	15.7	15.2	11.3	12.5
(TPO)	TCE (µg/L)	23.9	20.9	26.5	24.7	23.8	23.9	24.6	24.2	22.1	21.9	18.7	21.4
	Flow (gpm)	142	154	154	154	109	129	166	195	161	161	160	213
361	PCE (µg/L)	1.1	0.48	0.87	1.1	0.44	0.39 J	0.5 U	0.4	0.88	0.52	0.56	0.68
(LE)	TCE (µg/L)	1.0	0.90	1.1	1.5	0.92	0.62	0.5 U	0.6	1.3	0.83	0.94	1.1
	Flow (gpm)[a]	0 (137)	505	0 (540)	159 (524)	FU	FU	FU (178)	FU (128)	FU (372)	FU (337)	859 (1,465)	668 (846)
362	PCE (µg/L)	NF	NF	NF	NF	NF	NF	0.5 U	NF	NF	NF	0.5 U	NF
(MSt.CBO)	TCE (µg/L)	NF	NF	NF	NF	NF	NF	0.5 U	NF	NF	NF	0.5 U	NF
	Flow (gpm)	NF	NF	NF	NF	NF	NF	Trace	0	0	NF	Trace	NF
364	PCE (µg/L)												
Deschutes	TCE (µg/L)												
	Flow (gpm)												

Table D-1 Continued.

Sample Station	COC	Sampling Month Dec-02	May-03	Oct-03	May-04	Sep-04	Jun-05	Sep-05	Jun-06	Nov-06	Jun-07	Oct-07	Jun-08	Nov-08
350	PCE (µg/L)	1 U	1 U	0.5 U	0.5 U	1 UJ	1 U	1 U	2 U	1 U	0.5 U	--	0.5 U	0.5 U
(M St. SD)	TCE (µg/L)	0.76 J	0.44 NJ	0.61 NJ	0.78 NJ	1 UJ	0.63 J	1 U	0.97 J	1.4	0.56	--	1.4	1.8
	Flow (gpm)	5	11	28	32	4	20	NM	19	16	10	--	21	30
356	PCE (µg/L)	1 U	1 U	0.5 U	0.5 U	1 UJ	1 U	1 U	2 U	1 U	0.5 U	0.5 U	0.5 U	0.5 U
(Ustrm)	TCE (µg/L)	2 U	1 U	0.5 U	0.5 U	1 UJ	1 U	1 U	2 U	1 U	0.5 U	0.5 U	0.5 U	0.5 U
	Flow (gpm)	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU	FU
357	PCE (µg/L)	25	25	32	28	27	33	36	26	30	19	21	9.7	20
(CO-6)	TCE (µg/L)	20	12	13	12	11	15	14	14	13	12	12	31	13
	Flow (gpm)	75	76	81	71	60	30	72	39	50	56	58	69	46
358	PCE (µg/L)	22	20	22	20	19	22	26	18	21	17	16	8.9	15
(CO-4)	TCE (µg/L)	36	27	34	34	30	36	37	34	32	27	30	28	28
	Flow (gpm)	16	55	76	79	44	63	73	69	66	97	88	147	101
359	PCE (µg/L)	12	11	13	11	11	13	16	11	12	9.6	10	6	8.6
(CO-1)	TCE (µg/L)	23	19	24	21	22	27	29	24	22	18	20	20	19
	Flow (gpm)	176	170	197	201	161	189	164	166	193	214	203	205	189
360	PCE (µg/L)	13	10	12	10	10 J	13	14	10	12	9.5	9.5	5.9	8.5
(TPO)	TCE (µg/L)	26	18	23	26	21 J	26	25	24	22	17	19	19	19
	Flow (gpm)	81	101	111	121	78	87	97	107	137	127	101	109	118
361	PCE (µg/L)	1.3	3	1.7	3.9	0.4 J	0.51 J	0.58 J	0.39 J	0.73 J	0.9	0.71	0.6 NJ	0.63
(LE)	TCE (µg/L)	2.8	5.4	3.5	11	0.9 J	1.4	1.3	1.5 J	1.5	1.6	1.3	1.4	1.5
	Flow (gpm)	364	166	755	52	225	77	347	234	926	295	486	873	902
362	PCE (µg/L)	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	0.5 U	NF
(MSt.CBO)	TCE (µg/L)	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	0.5 U	NF
	Flow (gpm)	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	Trace	NF
364	PCE (µg/L)			0.30 J	0.5 U	1 UJ	0.36 J	1 U	2 U	0.59 J	0.46 J	0.5 U	0.5 U	0.45 J
Deschutes	TCE (µg/L)			0.70 J	0.61 NJ	1 UJ	0.90 J	1 U	0.98 J	1.2	0.62	0.5 U	1	0.98
	Flow (gpm)			NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

COC – Contaminant of concern.
[a] – Flow for station 361: The water flow was difficult or impossible to measure using the stream cross-section technique. Numbers in parentheses are flow rate measurements at a pair of parallel culverts downstream of station 361 and considered to be representative of flow at station 361.
FU – Water flow rate was unmeasurable with the available instrument.
NF – There was no water flow at this station on this date.
NM – Flow at this station was not measured.
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.
NJ – There is evidence that the analyte is present. The associated numerical result is an estimate.



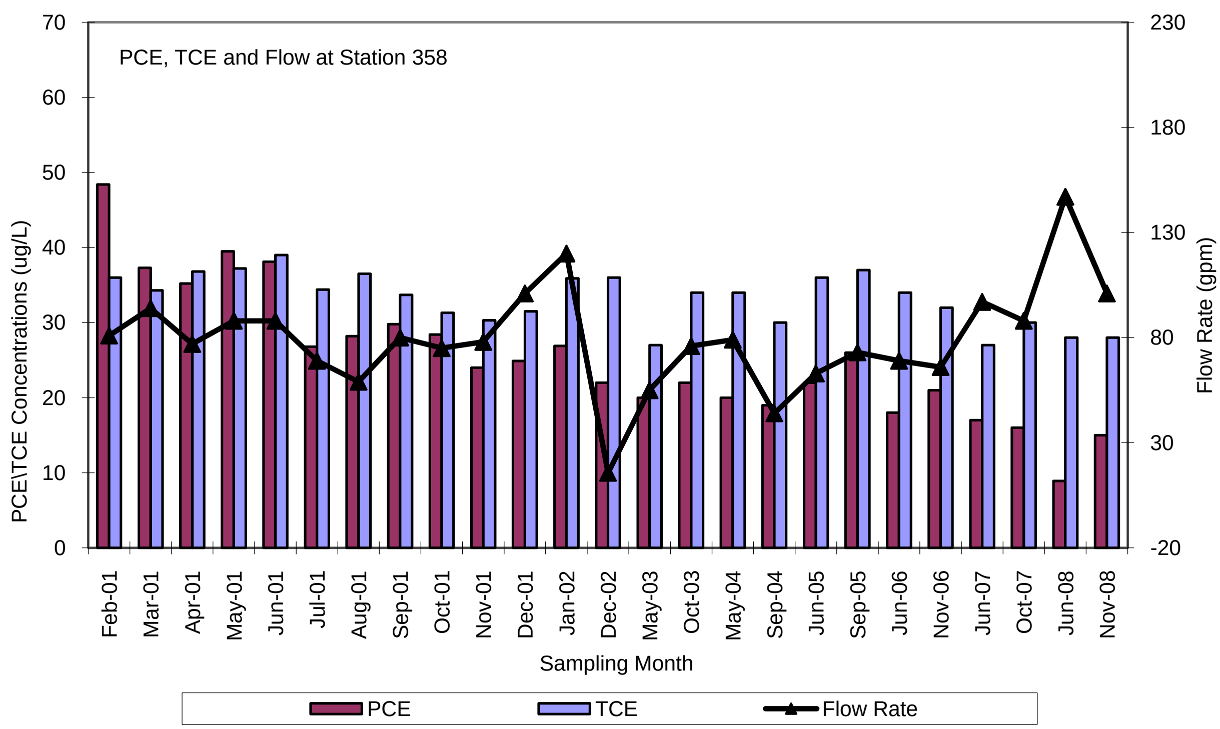
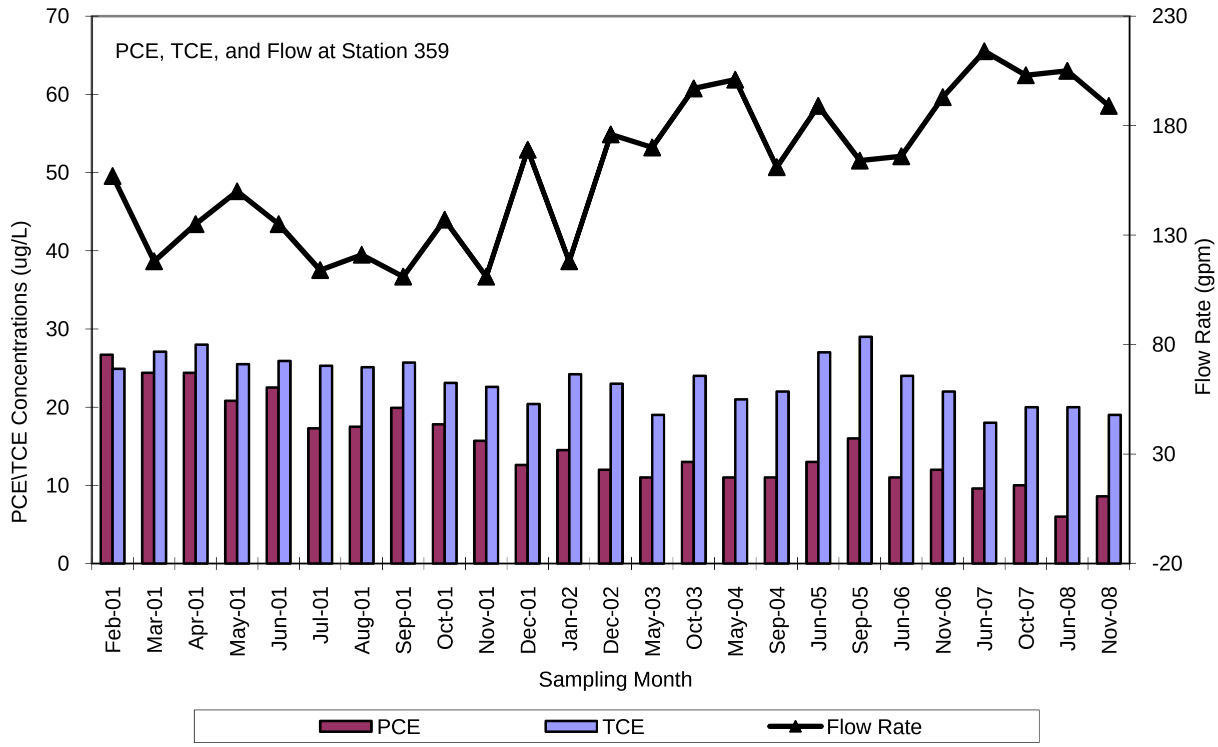


Figure D-1. PCE and TCE Concentrations with Flow Rates, February 2001 through November 2008.



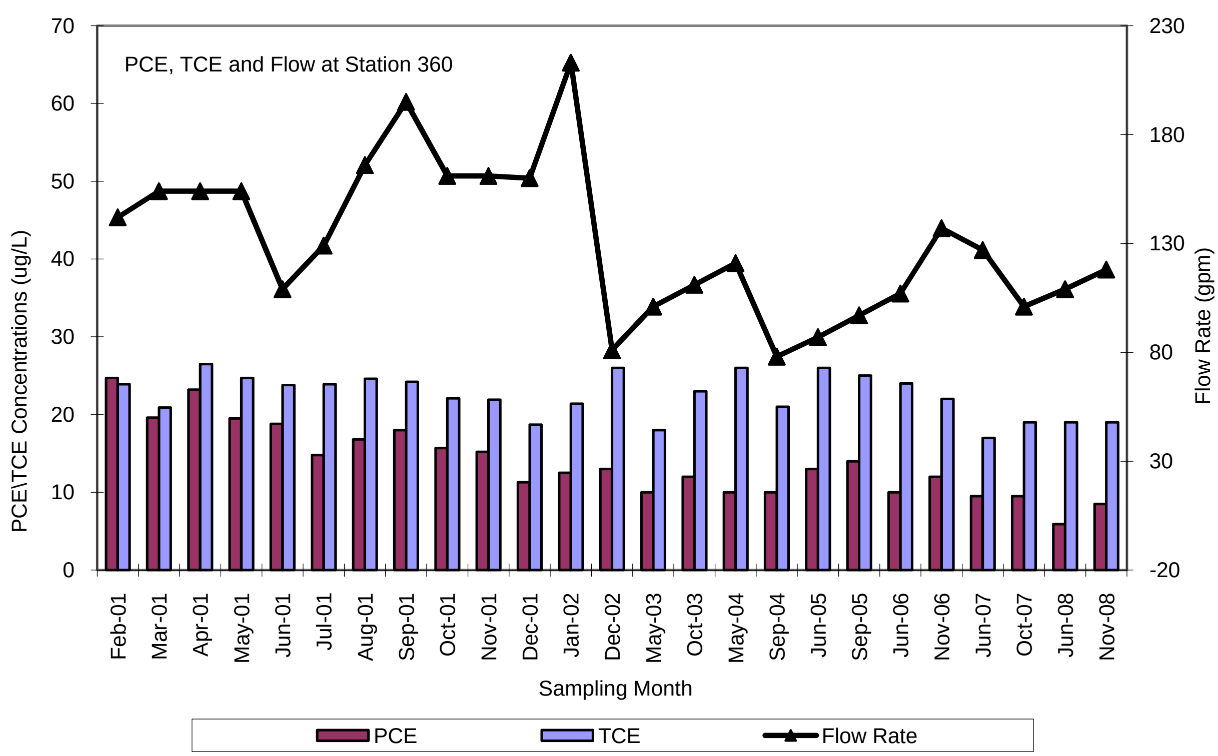


Figure D-1 (continued).

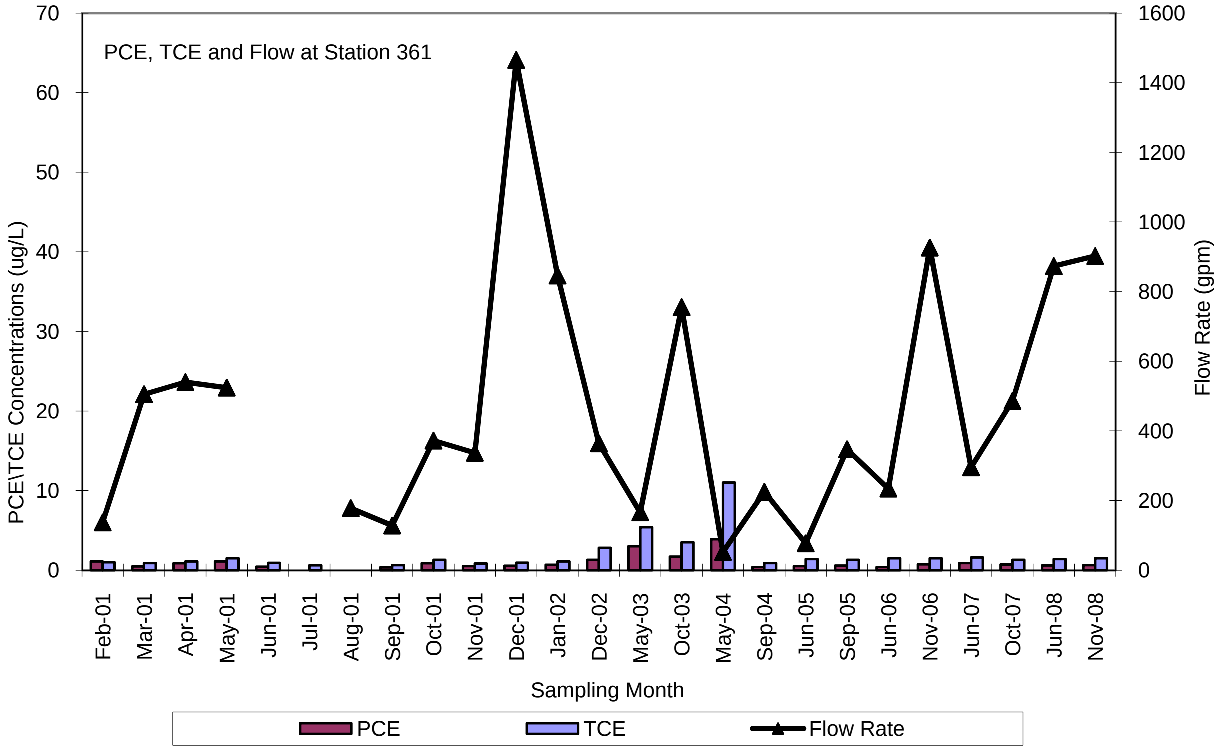


Figure D-1 (continued).

Appendix E. Lagoon Performance Calculations

Percent Contaminant Reduction by Lagoon for October 9, 2007

Measured Parameters

Lagoon influent		
PCE	9.5	µg/L
TCE	19	µg/L
Flow	101	gpm
Lagoon effluent		
PCE	0.71	µg/L
TCE	1.3	µg/L
Flow	486	gpm

Overall Percent Reduction

$$\frac{\text{Influent Concentration - Effluent Concentration}}{\text{Influent Concentration}} \text{ x } 100 = \text{Percent Reduction}$$

PCE: 93%
TCE: 93%

Residence Time

Lagoon volume = 556.3 cubic yards.

Convert to gallons = 112,350 gallons.

Calculate residence time:

$$\frac{112{,}350 \text{ gal}}{486 \text{ gal/min}}$$

Theoretical Residence time = 231 minutes or approximately 4 hours.

Percent Contaminant Reduction by Lagoon for June 5, 2008

Measured Parameters

Lagoon influent		
PCE	5.9	µg/L
TCE	19	µg/L
Flow	109	gpm
Lagoon effluent		
PCE	0.6	µg/L
TCE	1.4	µg/L
Flow	873	gpm

Overall Percent Reduction

$$\frac{\text{Influent Concentration - Effluent Concentration}}{\text{Influent Concentration}} \times 100 = \text{Percent Reduction}$$

PCE: 90%
TCE: 93%

Residence Time

Lagoon volume = 556.3 cubic yards.

Convert to gallons = 112,350 gallons.

Calculate residence time:

$$\frac{112{,}350 \text{ gal}}{873 \text{ gal/min}}$$

Theoretical Residence time = 129 minutes or approximately 2 hours.

Percent Contaminant Reduction by Lagoon for November 3, 2008

Measured Parameters

Lagoon influent		
PCE	8.5	µg/L
TCE	19	µg/L
Flow	118	gpm
Lagoon effluent		
PCE	0.63	µg/L
TCE	1.5	µg/L
Flow	902	gpm

Overall Percent Reduction

$$\frac{\text{Influent Concentration - Effluent Concentration}}{\text{Influent Concentration}} \times 100 = \text{Percent Reduction}$$

PCE: 93%
TCE: 92%

Residence Time

Lagoon volume = 556.3 cubic yards.

Convert to gallons = 112,350 gallons.

Calculate residence time:

$$\frac{112{,}350 \text{ gal}}{902 \text{ gal/min}}$$

Theoretical Residence time = 125 minutes or approximately 2 hours.

Appendix F. Glossary, Acronyms, and Abbreviations

Catch basin: Large underground container for the collection of sediment and other debris from stormwater run-off. Designed to catch or collect the dirt and debris, and prevents it from entering surface water.

Cleanout: A 15-inch diameter vertical pipe that extends from the ground surface to the subdrain pipe. Allows access to the subdrain to monitor the subdrain's performance and provides access for cleaning.

Effluent: An out flowing of water from a natural body of water or from a man-made structure.

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

Influent: Water flowing into a natural body of water or man-made structure.

Piezometer: A small-diameter, non-pumping well used to collect groundwater quality samples and hydraulic head measurements.

Scouring: Removal of sediment from the bottom of a natural body of water or man-made structure by flowing water.

Sediment: Solid fragmented material that is transported and deposited by water.

Subdrain: Below-ground slotted or perforated pipe used to collect groundwater. The perforated pipe is wrapped in filter fabric and buried in a trench with filter sand.

Sump: Located at the bottom of the cleanout, the sump is used to catch or collect sediment in the subdrain.

Acronyms and Abbreviations

bgs	Below ground surface
CB	Catch basin
Cis-1,2-DCE	Cis-1,2-dichloroethene
CO	Clean out
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
gpm	Gallons per minute
msl	Mean sea level
MTCA	Model Toxic Control Act
PCE	Tetrachloroethene

PVC	Polyvinyl chloride
PZ	Piezometer
RPD	Relative percent difference
SOP	Standard operating procedure
TCE	Trichloroethene
VC	Vinyl chloride
VOC	Volatile organics compounds
WAC	Washington Administrative Code
μg/L	Micrograms per liter