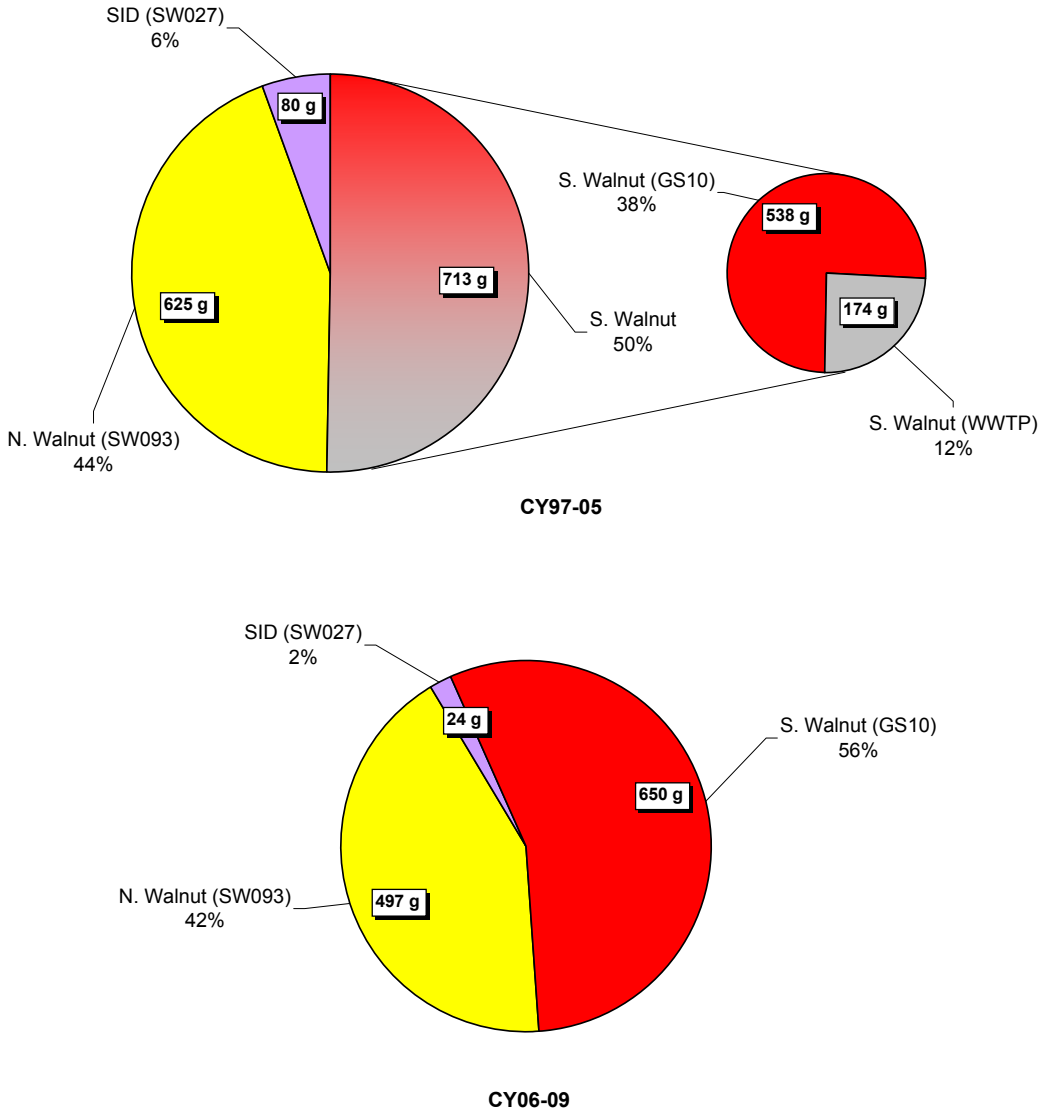


Figure 194. Relative Average Annual Total U Loads from Major COU Drainages and Former WWTP

3.1.5 Groundwater Data Interpretation and Evaluation

This section provides a summary of groundwater monitoring performed in 2010, separated into RFLMA-required and non-RFLMA-required. A discussion of groundwater conditions during 2010, focusing on the most important water-quality aspects in the areas of interest (i.e., the main plumes), is then presented.

3.1.5.1 RFLMA Groundwater Monitoring Activities of 2010

Routine activities of the groundwater monitoring program in 2010 included sample collection, water-level measurement, groundwater treatment system maintenance, and well maintenance.

"Groundwater" monitoring also includes monitoring activities at several surface-water locations, as well as at some locations that may not clearly belong to either category. (Examples of the former include groundwater treatment system-related performance monitoring locations within streams and ponds; examples of the latter include locations monitoring effluent from a treatment system.) However, because all of these locations support groundwater monitoring objectives, the data collected from them in support of these objectives are included as part of the groundwater discussion.

Special, non-RFLMA monitoring was also performed in 2010 to support various objectives. This is discussed in Section 3.1.5.2. The majority of this monitoring focused on the SPPTS. Validated analytical data and other information generated via RFLMA (i.e., routine) and non-RFLMA (i.e., nonroutine) sampling have been reported in the corresponding quarterly reports for 2010 (DOE 2010c, 2010e, 2011b) and are included in Appendix B for the fourth quarter of CY 2010. Unvalidated data are not reported but are summarized in this document.

There were no changes to the network of groundwater monitoring locations during 2010. The groundwater monitoring network set forth in RFLMA is subdivided and categorized as shown in Table 73.

Table 73. RFLMA Monitoring Classifications for the Groundwater Monitoring Network

Well Classification	General Objective	Number of Wells[a]	Monitoring Frequency
AOC	Monitor groundwater quality and water levels in a drainage downgradient of a contaminant plume or group of plumes	9	Semiannual (2x/year)
Boundary	Monitor groundwater quality and water levels in Woman Creek and Walnut Creek drainages at eastern (downgradient) Site boundary	2	Annual (1x/year)
Sentinel	Monitor groundwater quality and water levels near contaminant plume edges and in drainages	28	Semiannual (2x/year)
Evaluation	Monitor groundwater quality and water levels in or near contaminant source areas and in the former IA	42	Biennial (1x/every 2 years)
RCRA	Monitor groundwater quality and water levels upgradient and downgradient of the PLF and the OLF	10	Quarterly (4x/year)
Treatment System[b, c]	Monitor quality of groundwater treatment system influent, effluent, and downgradient surface water	9	Semiannual (2x/year)
Surface-Water Support[b]	Monitor quality of surface water downgradient of contaminant plume	1	Semiannual (2x/year)

[a]The numbers of locations listed are current through 2009.
[b]Treatment system and surface-water support locations are not monitoring wells but are included for completeness.
[c]The PLFTS is discussed separately.

Table 74 presents the full 2010 schedule for RFLMA groundwater sample collection, a subset of which is summarized in Table 75 as those scheduled samples that were not successfully collected (e.g., due to dry conditions). Corresponding analytical results are published in the associated quarterly reports (DOE 2010c, 2010e, 2011b) and Appendix B.

Table 74. Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2010 (by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
Boundary Wells	B	10394	2	2	2			
	B	41691	2	2	2			
Present Landfill	RCRA	70193	1,2,3,4			1,2,3,4		
	RCRA	70393	1,2,3,4			1,2,3,4		
	RCRA	70693	1,2,3,4			1,2,3,4		
	RCRA	73005	1,2,3,4			1,2,3,4		
	RCRA	73105	1,2,3,4			1,2,3,4		
	RCRA	73205	1,2,3,4			1,2,3,4		
	AOC	4087	2,4	2,4	2,4			
	AOC	B206989	2,4	2,4	2,4			
Original Landfill	RCRA	P416589	1,2,3,4			1,2,3,4		1,2,3,4
	RCRA	80005	1,2,3,4			1,2,3,4		1,2,3,4
	RCRA	80105	1,2,3,4			1,2,3,4		1,2,3,4
	RCRA	80205	1,2,3,4			1,2,3,4		1,2,3,4
	AOC	11104	2,4	2,4				
MSPTS	S	15699	2,4					
	TS	MOUND R1-0	2,4					
	TS	MOUND R2-E	2,4					
	TS	GS10	2,4					
	E	00897	2					
ETPTS	S	04091	2,4					
	S	95099	2,4					
	S	95199	2,4					
	S	95299	2,4					
	S	23296	2,4	2,4				
	TS	ET INFLUENT	2,4					
	TS	ET EFFLUENT	2,4					
	TS	POM2	2,4					
	E	3687	2					
	E	05691	2					
	E	03991	2					
SPPTS	S	P210089	2,4	2,4	2,4			
	S	70099		2,4	2,4			
	TS	SPIN		2,4	2,4			
	TS	SPOUT		2,4	2,4			
	TS	GS13		2,4	2,4			
	E	P210189	2	2	2			
	E	79102	2	2	2			
	E	79202	2	2	2			
	E	P208989	2	2	2			
	E	79302		2	2			
	E	79402		2	2			
	E	79502		2	2			
	E	79605		2	2			
	E	00203	2	2	2			
	E	22205	2	2	2			

Table 74 (continued). Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2010 (by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
SPPTS	E	B210489		2	2			
	E	51605		2	2			
Drainages Below Impacted Areas	AOC	10594	2,4	2,4	2,4			
	AOC	00997	2,4	2,4	2,4			
	AOC	00193	2,4	2,4				
Former B371/374	S	37405	2,4	2,4	2,4		2,4	
	S	37505	2,4	2,4	2,4			
	S	37705	2,4	2,4	2,4		2,4	
Former B771/774	S	20205	2,4	2,4			2,4	
	S	20505	2,4	2,4			2,4	
	S	20705	2,4	2,4	2,4		2,4	
Former North-Central IA	S	52505	2,4					
	AOC	42505	2,4					
	E	P114689	2					
	E	P115589	2					
	E	70705	2	2				
	E	33905	2					
	E	21505	2					
	E	20902	2					
Former B559	E	55905	2	2	2			
	E	56305	2	2	2			
Former IHSS 118.1	SS	SW018	2,4					
	E	18199	2					
Former B444 Complex	S	11502	2,4	2,4				
	S	40305	2,4	2,4				
	E	40005	2	2				
	E	40205	2	2				
	E	P419689	2	2				
	E	P416889	2	2				
Former B881	S	00797	2,4	2,4				
	S	88104	2,4	2,4				
	E	88205	2	2				
Former B886	E	22996	2	2				
Former B991	S	99305	2,4	2,4	2,4			
	S	99405	2,4	2,4	2,4			
	S	91305	2,4	2,4	2,4			
Former Oil Burn Pit No. 1	S	33703	2,4					
	E	33502	2					
	E	33604	2					
Former Oil Burn Pit No. 2	S	91203	2,4					
	E	91105	2					
Former SW056	S	45608	2,4					
OU1 Plume	AOC	89104	2,4					
	E	891WEL	2					

Table 74 (continued). Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2010 (by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
903 Pad/Ryan's Pit Plume	S	90299	2,4					
	S	90399	2,4					
	AOC	10304	2,4	2,4	2,4			
903 Pad/Ryan's Pit Plume	E	00191	2					
	E	50299	2					
	E	90402	2					
	E	00491	2					
	E	07391	2	2				
	E	90804	2					
PU&D Yard Plume	S	30002	2,4					
	E	30900	2					

Notes: ID = Identification (name) of well/sampling location
Location classifications: AOC = Area of Concern, B = Boundary, S = Sentinel, E = Evaluation, RCRA = Resource Conservation and Recovery Act, and SS = Surface Water Support
Location types: TS = Treatment System, all others are groundwater monitoring wells or Surface Water Support
SVOCs = semivolatile organic compounds
2 (or other numeral) = Analyte requested for that quarter; if blank, analyte not requested

Table 75. Summary of RFLMA-Required Groundwater Samples Not Successfully Collected in 2010 (by Quarter)

Location		Analytes						Comments
ID	Classification	VOCs	U	Nitrate	Metals	Pu/Am	SVOCs	
4087	AOC	4	4	4				Dry well
95299	S	2, 4						Dry well

Notes: ID = Identification (name) of well/sampling location
RFLMA classifications: AOC = Area of Concern, S = Sentinel
SVOCs = semivolatile organic compounds
2 (or other numeral) in analyte column = Corresponding analyte requested in the indicated calendar quarter of 2010; if blank, analyte not requested

3.1.5.2 Non-RFLMA Groundwater Monitoring Activities of 2010

Non-RFLMA (i.e., nonroutine) groundwater monitoring was performed in 2010 in support of several data needs, which generally fall within the following two categories:

- Investigative sampling; and
- Performance sampling.

Table 76 summarizes non-RFLMA groundwater sample collection performed in 2010. In addition to this non-RFLMA sampling, additional non-RFLMA monitoring was performed through the sitewide measurement of water levels as discussed in Section 3.1.3.5.

As in recent years, most of the non-RFLMA monitoring performed in 2010 was focused on the SPPTS. Most of the additional analytical data collected for the SPPTS were generated by an in-house laboratory and cannot be validated. Due to the significant effort and unusual events related to that treatment system, this topic is discussed separately in Section 3.1.2.10.

3.1.5.3 Groundwater at the Rocky Flats Site: Discussion and Interpretations

This section presents a summary evaluation of groundwater quality at the Site during 2010. Groundwater quality is addressed first, followed by descriptions of special studies and activities. Included in the discussion of water quality are descriptions of the behavior of and any notable activities at the groundwater treatment systems during 2010.

Trend Plots

Numerous statistical trend plots were constructed for this report using analytical data collected from Sentinel, Evaluation, and RCRA wells (see Sections 3.1.2.8 and 3.1.2.9 for discussion of RCRA wells). Although not required by RFLMA, trend plots were also constructed for AOC wells. Trend plots and corresponding summary tables are presented in Appendix B. In addition to these statistical trend plots, many time-series plots were prepared and are included in this report.

The Sanitas software package (version 9.2.05; Sanitas Technologies 2009) was used for statistical calculations, including the ANOVA analyses and construction of statistical trend plots. (This is noted for the purpose of completeness only; this report does not make software recommendations.) For simplicity, trend calculations performed for any but RCRA wells assign the given well a downgradient position. This is appropriate because the fundamental objective of

the other wells is related to detection monitoring or the exit strategy; no interwell statistics were planned for these classes of wells (only intrawell assessment of the trend of an analyte over time at each given well). Only RCRA wells were assigned either upgradient or downgradient positions to support the related statistical evaluations, as described in Section 3.1.2.8 and Section 3.1.2.9.

Analytical data are handled as described in Section 3.1.1.2. Trends for wells sampled more than once a year are calculated and plotted using the S-K statistical method, as recommended for Rocky Flats groundwater data (K-H 2004a) and in accordance with the RFSOG (DOE 2011a). Trends calculated for wells that are sampled less than twice per year, removing aspects of seasonality, employ the Mann-Kendall (M-K) statistical method. S-K trends are only plotted where they are calculated to be at least 80 percent significant, and M-K trends are plotted if at least 95 percent significant.

Table 77 summarizes the results of these trend calculations. Only increasing and decreasing trends calculated to be at least 80 percent significant using the S-K test are included in this table. (Therefore, even if 95 percent significant, trends with zero slope are not included.) Monitoring well classifications that require statistical evaluation of concentration trends according to RFLMA (i.e., Sentinel and downgradient RCRA wells) are included, as are calculations for AOC wells. Refer to Appendix B for the trend plots and associated summary tables, and Figure 2 for well locations. Significant trends for selected analytes and locations are discussed later in this section in the context of their respective groundwater contaminant plumes.

Table 76. Summary of Non-RFLMA-Required Groundwater Samples Collected in CY 2010 (by Quarter)

Area	Location ID	Analytes[a]																	
		VOCs	U	Nitrate	NH_3-N	Metals	U isotopes	P	TOC	Se	TIC	Ca	Fe	Moist	TSS	*DNBART*	Chlorine	Sulfate	Bromine
SPPTS[b]	GS13		1(9), 2(6), 3(2), 4(3)	1(9), 2(7), 3(2), 4(3)			1	1(3), 2									2		
	ITSE		1				1												
	ITSW		1				1												
	SPIN		1(18), 2(13), 3(15) 4(9) (includes two sets of split samples collected in 2nd qtr)	1(18), 2(13), 3(15), 4(9) (includes two sets of split samples collected in 2nd qtr)	1(13), 2(13), 3(12)			1(2)	1(10)			1(11), 2(13), 3(13), 4(9)	1(13), 2(13), 3(13), 4(9)			1(3)			
	SPOUT		1(22), 2(20), 3(21), 4(16) (includes two sets of split samples collected in 2nd qtr)	1(22), 2(20), 3(21), 4(16) (includes two sets of split samples collected in 2nd qtr)	1(13), 2(13), 3(14), 4(9)		1	1(12), 2(13), 3(13), 4(9)	1(11), 2(13), 3(14), 4(9)	3		1(6)	1(13), 2(13), 3(13), 4(9)				2		1(4), 2(3)
	SPPDISCHARGE GALLERY		1(3), 2(2), 3, 4	1(3),2(2), 3, 4			1		3								2		
	SW093		1(5), 2(5), 3(6), 4(7)	1(5), 2(5), 3(6), 4(7)															
	SPCAE		1(18), 2(13), 3(15), 4(9) (includes two sets of split samples collected in 2nd qtr)	1(18), 2(13), 3(15), 4(9) (includes two sets of split samples collected in 2nd qtr)	1(13), 2(13), 3(13), 4(9)			1(12), 2(13), 3(13), 4(9)	1(13), 2(13), 3(14), 4(9)			1(3)	1(3)			1(10), 2(13), 3(13), 4(9)			
	SPZE		1(18), 2(14), 3(15), 4(8) (includes two sets of split samples collected in 2nd qtr)	1(18), 2(14), 3(15), 4(8) (includes two sets of split samples collected in 2nd qtr)	1(13), 2(13), 3(14), 4(8)				1(3)			1(13), 2(13), 3(13), 4(8)	1(13), 2(13), 3(13), 4(8)						
	SPILCA		1(14), 2(13), 3(12)	1(14), 2(13), 3(12)	1(13), 2(13), 3(12)			1(12), 2(13), 3(13), 4(9)	1(13), 2(13), 3(13), 4(9)			1(5)	1(5)						
	ITSS		1	1															
	RISERPIPE1		1(6), 2(4), 3	1(6), 2(4), 3	1(6), 2(4)				1(6), 2(4), 3								1(6), 2(3)	1(6), 2(4)	1(3)
	RISERPIPE2		1(6), 2(4), 3	1(6), 2(4), 3	1(6), 2(4)				1(6), 2(4), 3								1(6), 2(3)	1(6), 2(4)	1(3)
	RISERPIPE3		1(6), 2(4), 3	1(6), 2(4), 3	1(6), 2(4)				1(6), 2(4), 3								1(6), 2(3)	1(6), 2(4)	1(3)
	RISERPIPE4		1(6), 2(4), 3	1(6), 2(4), 3	1(6), 2(4)				1(6), 2(4), 3							1	1(5), 2(3)	1(5), 2(4)	1(3)
	SPCBE		1(12), 2(13), 3(11)	1(14), 2(13), 3(11)	1(11), 2(13), 3(11)				1(13), 2(13), 3(11)			1(3)	1(3)						
	SPDLI			1(7)					1(7)										
	SPDL2			1(7)					1(7)										
	SPDL4		1(2)	1(7)	1(2)				1(7)										
	SPRUNOFF1		2		2														
	1786	2, 3(3)	2	2															

Table 76 (continued). Summary of Non-RFLMA-Required Groundwater Samples Collected in CY 2010 (by Quarter)

Area	Location ID	Analytes[a]																	
		VOCs	U	Nitrate	NH_3-N	Metals	U isotopes	P	TOC	Se	TIC	Ca	Fe	Moist	TSS	*DNBART*	Chlorine	Sulfate	Bromine
ETPTS[c]	ET EFFLUENT	2, 3(3)																	
	ET INFLUENT	4																	
	ETPTSB4	2, 3(3), 4																	
	ETPTSDGOVER	2, 3(3)																	
	POM2	2, 3(3)					1												
MSPTS[d]	MOUND R1-0	2, 3(3)	4																
	MOUND R2-E	2, 3, 4	4																
	MSPTSCHAN1	2, 3																	
	MSPTSCHAN2	2, 3(2)																	
	GS10	3	1(5), 2(5), 3(6), 4(7)																
	11894	3		3															
	49192	4		3															
	91203	4																	
	B206989																		

Notes: [a] The numeral in the "analyte" column (e.g., 2) indicates the 2010 quarter in which the analyte was requested; if blank, analyte not requested. For those locations where more than one non-RFLMA-required sample was collected in the indicated quarter(s), the total number of non-RFLMA samples collected is indicated in parentheses.

[b] The Solar Ponds Plume Discharge Gallery (SPPDischargeGallery) is sampled in accordance with the RFSOG (DOE 2011a). Locations ITSW and ITSE are associated with the Phase I upgrades to the SPPTS and were sampled to evaluate system effectiveness (i.e., quality of additional water being captured by the Phase I upgrades). Locations SPIN, SPOUT, SPCAE, SPZE, and SPILCA are associated with the Phase II/III upgrades to the system and were sampled to evaluate the system effectiveness.

[c] The East Trenches Plume Treatment System (ETPTS) has several associated sampling locations.

[d] Several sampling locations are associated with the Mound Site Plume Treatment System to evaluate the effectiveness of groundwater treatment.

ID = Identification (name) of well/sampling location
Ca = calcium
Fe = iron
NH_3-N = ammonia (as nitrogen)
P = phosphate
Se = selenium
TOC = total organic carbon
VOCs = volatile organic compounds
TSS = total suspended solids

Table 77. Summary of Statistical Trend Calculations by Location

Well	General Location	Analyte	Trend	Significant at 95%?
Sentinel Wells				
00797	B881	**U**	**Increasing**	**Yes**
04091	East Trenches Plume	**Carbon tetrachloride**	**Decreasing**	**Yes[c]**
		PCE	**Decreasing**	**Yes[c]**
11502	B444	PCE	Decreasing	No
		U	Decreasing	No
15699	MSPTS	**1,1,1-TCA**	**Decreasing**	**Yes[c]**
		1,1-DCE	**Decreasing**	**Yes**
		1,2-DCA	Increasing	No
		Chloroform	**Decreasing**	**Yes[c]**
		cis-1,2-DCE	Increasing	No
		PCE	**Decreasing**	**Yes**
		TCE	**Decreasing**	**Yes**
		***trans*-1,2-DCE**	**Increasing**	**Yes[c]**
		VC	**Increasing**	**Yes[c]**
20205	B771	**PCE**	**Increasing**	**Yes[a,c]**
		U	**Increasing**	**Yes**
20505	B771	1,1-DCE	Increasing	No
		cis-1,2-DCE	Decreasing	No
		TCE	Decreasing	No
		U	Decreasing	No
20705	B371	**Am-241**	**Decreasing**	**Yes[d,e]**
		cis-1,2-DCE	Increasing	No
		U	**Increasing**	**Yes[b,d]**
		VC	Increasing	No
23296	ETPTS	**1,1-DCE**	**Increasing**	**Yes[c]**
		Carbon tet	**Decreasing**	**Yes[c]**
		Chloroform	**Decreasing**	**Yes[c]**
		***cis*-1,2-DCE**	**Increasing**	**Yes**
		PCE	**Decreasing**	**Yes**
		TCE	**Decreasing**	**Yes**
		***trans*-1,2-DCE**	**Increasing**	**Yes[c]**
		U	**Decreasing**	**Yes[b]**
33703	OBP#1	1,3-DCB	Increasing	No
		1,4-DCB	**Increasing**	**Yes**
		Chlorobenzene	**Decreasing**	**Yes**
		***cis*-1,2-DCE**	**Increasing**	**Yes[c]**
		***trans*-1,2-DCE**	**Increasing**	**Yes[c]**
		VC	**Increasing**	**Yes[c]**
37405	B371	**Nitrate**	**Increasing**	**Yes[b]**
		U	Decreasing	No
37505	B371	Nitrate	Decreasing	No
		PCE	Increasing	No
		U	**Increasing**	**Yes**
37705	B371	Nitrate	Increasing	No
		U	Increasing	No
40305	B444	*cis*-1,2-DCE	Decreasing	No
		PCE	**Increasing**	**Yes[c]**
		U	Increasing	No

Table 77 (continued). Summary of Statistical Trend Calculations by Location

Well	General Location	Analyte	Trend	Significant at 95%?
45608	Hillside south of B991	**1,1-DCE**	**Increasing**	**Yes[c]**
		cis-1,2-DCE	Decreasing	No
		PCE	**Increasing**	**Yes[c,d]**
		TCE	**Increasing**	**Yes[c,d]**
		***trans*-1,2-DCE**	**Decreasing**	**Yes[b]**
		VC	Increasing	No
52505	North-central IA	***cis*-1,2-DCE**	**Increasing**	**Yes[a,c]**
70099	SPPTS	**Nitrate**	**Decreasing**	**Yes**
		U	Increasing	No
88104	B881	**U**	**Decreasing**	**Yes[d]**
90299	903 Pad/Ryan's Pit Plume-SID	**Carbon tetrachloride**	**Decreasing**	**Yes[c]**
		Chloroform	**Decreasing**	**Yes[b]**
		TCE	**Decreasing**	**Yes**
90399	903 Pad/Ryan's Pit Plume-SID	**1,1-DCE**	**Increasing**	**Yes[a]**
		Carbon tetrachloride	Increasing	No
		Chloroform	Increasing	No
		***cis*-1,2-DCE**	**Increasing**	**Yes[b]**
		PCE	Increasing	No
		TCE	**Increasing**	**Yes[b]**
91203	OBP#2	1,1,1-TCA	Increasing	No
		1,1-DCE	**Increasing**	**Yes[a,c]**
		Carbon tetrachloride	Decreasing	No
		Chloroform	Decreasing	No
		***cis*-1,2-DCE**	**Increasing**	**Yes[c]**
		PCE	Increasing	No
		TCE	Increasing	No
91305	OBP#2	*cis*-1,2-DCE	Decreasing	No
		Nitrate	Increasing	No
		U	Decreasing	No
95199	ETPTS	1,1-DCE	Increasing	No
		cis-1,2-DCE	Increasing	No
		PCE	**Increasing**	**Yes**
		TCE	Increasing	No
99305	B991	***cis*-1,2-DCE**	**Increasing**	**Yes**
		Nitrate	Increasing	No
		PCE	**Increasing**	**Yes**
		TCE	**Increasing**	**Yes**
		U	**Increasing**	**Yes**
99405	B991	***cis*-1,2-DCE**	**Increasing**	**Yes[b,c]**
		Nitrate	Increasing	No
		TCE	**Increasing**	**Yes[c]**
		U	**Decreasing**	**Yes**
P210089	SPPTS	Nitrate	Increasing	No
		U	**Increasing**	**Yes**
RCRA Wells (Downgradient only)				
73005	PLF	B	Increasing	No
		Cr	**Increasing**	**Yes[a,c]**
		Se	Increasing	No
		U	Increasing	No
		Zn	Increasing	N
73105	PLF	**B**	**Increasing**	**Yes**
		U	Decreasing	No

Table 77 (continued). Summary of Statistical Trend Calculations by Location

Well	General Location	Analyte	Trend	Significant at 95%?
73205	PLF	B	Increasing	No
80005	OLF	**B**	**Decreasing**	**Yes**
80105	OLF	B	Decreasing	No
		U	Decreasing	No
80205	OLF	B	Increasing	No
		Cd	Increasing	No
		Se	Increasing	No
		U	**Decreasing**	**Yes[a]**
Evaluation Wells (Only trends that are 95% significant are shown)				
00491	903 Pad/Ryan's Pit Plume	**Chloroform**	**Decreasing**	**Yes**
00897	Mound Plume	**TCE**	**Decreasing**	**Yes**
3687	East Trenches Plume	**1,1-DCE**	**Increasing**	**Yes**
		***cis*-1,2-DCE**	**Increasing**	**Yes**
03991	East Trenches Plume	**Carbon tetrachloride**	**Decreasing**	**Yes**
		Chloroform	**Decreasing**	**Yes**
		PCE	**Decreasing**	**Yes**
		TCE	**Decreasing**	**Yes**
05691	East Trenches Plume	**Carbon tetrachloride**	**Decreasing**	**Yes**
		Chloroform	**Decreasing**	**Yes**
		***cis*-1,2-DCE**	**Decreasing**	**Yes**
		PCE	**Decreasing**	**Yes**
		TCE	**Decreasing**	**Yes**
07391	Ryan's Pit	**Chloroform**	**Decreasing**	**Yes**
		***cis*-1,2-DCE**	**Increasing**	**Yes**
22205	Solar Ponds Plume	**U**	**Increasing**	**Yes**
30900	PU&D Yard Plume	**1,1,1-TCA**	**Decreasing**	**Yes**
		***cis*-1,2-DCE**	**Increasing**	**Yes**
33502	OBP#1	**1,2,4-TCB**	**Decreasing**	**Yes[c]**
		Naphthalene	**Decreasing**	**Yes[c]**
		PCE	**Decreasing**	**Yes[c]**
33604	OBP#1	**TCE**	**Decreasing**	**Yes**
33905	Northern IA	**1,1-DCE**	**Decreasing**	**Yes**
		PCE	**Decreasing**	**Yes**
40005	B444	**U**	**Increasing**	**Yes**
40205	B444	**1,1-DCE**	**Decreasing**	**Yes**
		***cis*-1,2-DCE**	**Decreasing**	**Yes**
		PCE	**Decreasing**	**Yes**
79202	SEPs	**Carbon tetrachloride**	**Decreasing**	**Yes**
		Chloroform	**Decreasing**	**Yes**
		TCE	**Decreasing**	**Yes**
79302	SEPs	**U**	**Increasing**	**Yes**
79502	SEPs	**U**	**Decreasing**	**Yes**
88205	B881	***cis*-1,2-DCE**	**Increasing**	**Yes**
		TCE	**Increasing**	**Yes**
		Toluene	**Increasing**	**Yes**
		Total xylenes	**Increasing**	**Yes**
91105	OBP#2	**Carbon tetrachloride**	**Decreasing**	**Yes**
891WEL	OU-1	**Carbon tetrachloride**	**Decreasing**	**Yes**
		Chloroform	**Increasing**	**Yes[c]**
		***cis*-1,2-DCE**	**Increasing**	**Yes[c]**
		TCE	**Decreasing**	**Yes**

Table 77 (continued). Summary of Statistical Trend Calculations by Location

Well	General Location	Analyte	Trend	Significant at 95%?
P114689	Northern IA	**Carbon tetrachloride**	**Decreasing**	**Yes**
		TCE	**Increasing**	**Yes**
P208989	SEPs	**Chloroform**	**Increasing**	**Yes[c]**
P210189	SEPs	***cis*-1,2-DCE**	**Decreasing**	**Yes**
P416889	Southern IA	***cis*-1,2-DCE**	**Decreasing**	**Yes**
AOC Wells*				
00193	Woman Creek at Pond C-2	Uranium	Decreasing	No
00997	South Walnut Creek at Pond B-5	Nitrate	Decreasing	No
		Uranium	Increasing	No
4087	Landfill Pond Dam	Nitrate	Increasing	No
		Uranium	Decreasing	No
10304	Woman Creek at Pond C-1	Uranium	Increasing	No
10594	North Walnut Creek at Pond A-2	Nitrate	Increasing	No
		Uranium	**Decreasing**	**Yes[b]**
11104	Woman Creek below OLF	Uranium	Decreasing	No
B206989	Landfill Pond Dam	**Nitrate**	**Decreasing**	**Yes**
		Uranium	Decreasing	No

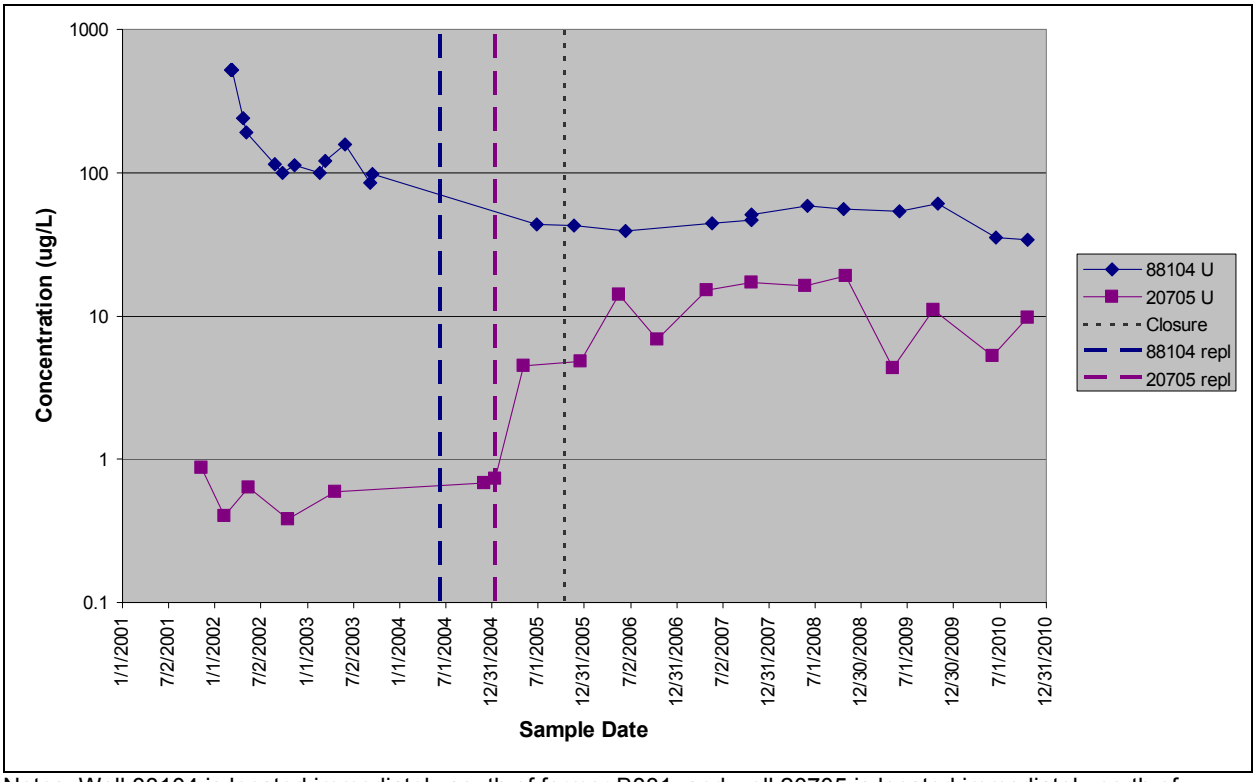
Notes: Only increasing and decreasing trends are included; indeterminate and zero-slope trends are not. Trends are listed if there is an 80% statistical significance; any decisions that may be made would be based on trends having a 95% significance. **Bold** entries designate those trends having a 95% significance; only these trends were assessed for applicability of the footnotes below.
DCA = dichloroethane; DCE = dichloroethene; DCB = dichlorobenzene; OBP = Oil Burn Pit;
PCE = tetrachloroethene; TCB = trichlorobenzene
* Calculating trends for AOC wells is not required by RFLMA, but is provided for informational purposes.
[a] Trend was not calculated to be significant at 80% level in previous (2009) report, but with 2010 data is now 95% significant.
[b] Trend was calculated to be significant in previous (2009) report, but at less than a 95% significance; it now meets the 95% level of significance.
[c] Trend calculated to be significant may not be valid because 25.0 percent or more of the analytical data used to calculate this trend are nondetects. See Section 3.1.1.2 for discussion of how nondetects were handled in trending calculations.
[d] Although the trend is calculated to have a 95% significance, the data used to calculate this trend may be affected by well replacement. Results for this constituent in samples from the original well are markedly different from those from the replacement well. These data sets may be separated in the future, rather than continue to be pooled, as additional data are collected from the replacement well and are sufficient for trending separately.
[e] Samples collected in 2005 were affected by very high turbidity (i.e., muddy water) immediately following installation of the replacement well. Thorough redevelopment reduced the turbidity and, therefore, the Am-241 as well.

As indicated in Table 77, there are a few instances in which a concentration trend did not meet the 95 percent level of significance using 2009 data, but with 2010 data that level was attained; these instances are identified in the table. There are also instances in which a trend that had been calculated to be significant no longer met that test when 2010 data were included in the calculation.

Additional data will be collected in accordance with RFLMA and will further refine the concentration trends. Given that much of the analytical data used in trend calculations were collected before the Site was closed, and in many cases are from wells that were replaced as Site closure proceeded, some instances of slope change due to well replacement are to be expected. This may impact analytical as well as water elevation data. Figure 195 is an example of data that appear (even on a logarithmic concentration scale) to be strongly impacted by well replacements,

as noted in the summary of calculated trends above. If one ignored the fact that these wells were replaced, one might conclude that uranium in well 88104 was on a decreasing trend, and in 20705 was increasing. However, considering the well replacements, it may be more reasonable to conclude that there is no clear trend as of 2010.

For a cross-walk of closure-era original and replacement wells, refer to the *Rocky Flats Site 2006 Integrated Monitoring Plan Background Document* (2006 IMP) (DOE 2006c, Appendix B, Table B-4); since that date, the only well replacement was the abandonment of well 45605 and its replacement with well 45608.



Notes: Well 88104 is located immediately south of former B881, and well 20705 is located immediately north of former B771. "Repl" = replacement; "Closure" = Site closure date (in this case, declaration that closure activities were complete). The date of well replacement is represented by the date the original well was abandoned, because this is the last possible date on which samples from the original location could have been collected.

Figure 195. Time-Series Plot Showing Possible Well-Replacement Artifacts in Concentration Data

Groundwater Plumes with Treatment Systems

Groundwater quality data were obtained for all monitored areas in 2010. Analytical data have been published in quarterly reports issued for 2010 (DOE 2010c, 2010e, 2011b), plus Appendix B, and will not be duplicated here. Appendix B also includes S-K trend plots for CY 2010.

Groundwater quality at the Site in 2010 was largely consistent with data reported in prior years (as can be deduced from the summary of statistical trends presented in Table 77). Generally, groundwater quality within plumes that were identified and characterized through the decades of

pre-closure groundwater monitoring at the Site has not changed much over the years since the Site was closed.

This section describes the general groundwater quality in various areas of interest across the Site, beginning with descriptions of conditions in 2010 at the three main groundwater contaminant plume treatment systems (MSPTS, ETPTS, and SPPTS).

Mound Plume, Oil Burn Pit #2 (OBP#2) Plume, and MSPTS

The Mound Plume (also called the Mound Site Plume) is located north of the former 903 Pad. The source of the plume is a former drum storage area ("the Mound") that was in use in the 1950s. Some of the drums leaked, creating a groundwater contaminant plume extending north toward South Walnut Creek. The drums were removed in 1970, and contaminated soils were removed in 1997. A groundwater treatment system was installed in 1998 to intercept and treat contaminated groundwater before it reaches the creek.

OBP#2 was located just west of the Mound source area, at the southeast corner of the former Protected Area fence. Groundwater monitoring of OBP#2 was not feasible due to security infrastructure until the Protected Area was decommissioned. Groundwater and soil were subsequently sampled, and elevated concentrations of VOCs were detected. This led to a source removal action in 2005 that addressed elevated concentrations in the soils. Supplemental carbon (in the form of Hydrogen Release Compound, HRC) was added to the backfill to enhance biodegradation of residual VOCs. Because the flow path for the OBP#2 Plume is toward FC-4 to the north (generally parallel to the flow direction of the nearby Mound Plume) and potentially along the preferential pathway provided by a utility corridor left by a former storm drain, a gravel drain was installed in 2005 as part of the OBP#2 remediation. This gravel drain intercepts and directs groundwater flowing northward from the OBP#2 source area into the MSPTS intercept trench, from which it is directed to the MSPTS for treatment.

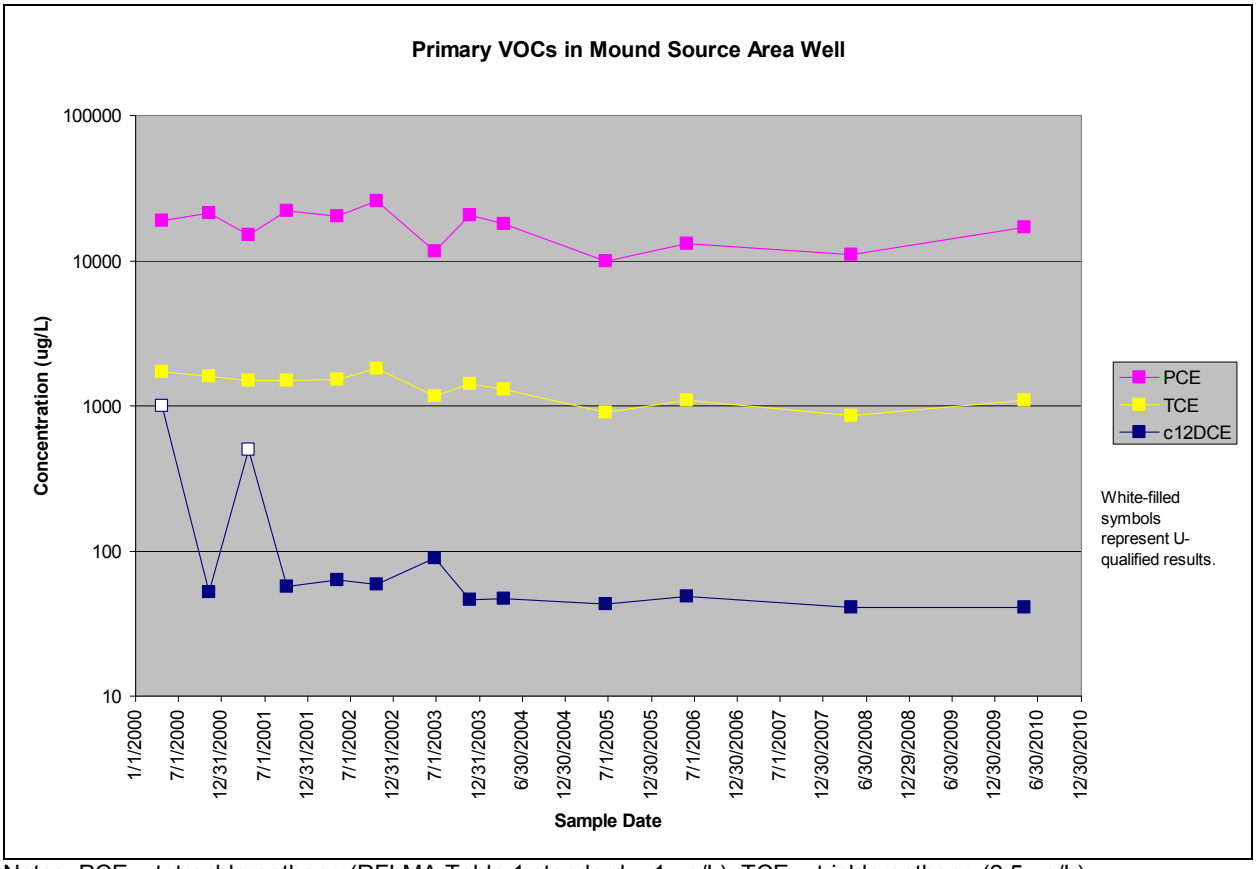
The following paragraphs describe these plumes and the MSPTS.

Mound Plume and OBP#2 Plume

Annual reports for 2006 and 2007 (DOE 2007c, 2008c) provide separate discussions of the Mound Plume and the nearby OBP#2 Plume. Because groundwater flow from the Mound Plume as well as the OBP#2 Plume is captured and treated by the MSPTS, the two plumes have since been discussed as a group. Refer to previous reports for additional detail on closure-era activities in these areas and their impacts on the local groundwater.

Consistent with the technical design of the groundwater monitoring network at the RFS, the two source-area wells, 00897 (Mound) and 91105 (OBP#2), are Evaluation wells that are scheduled for routine monitoring every other year. Both were sampled in 2010.

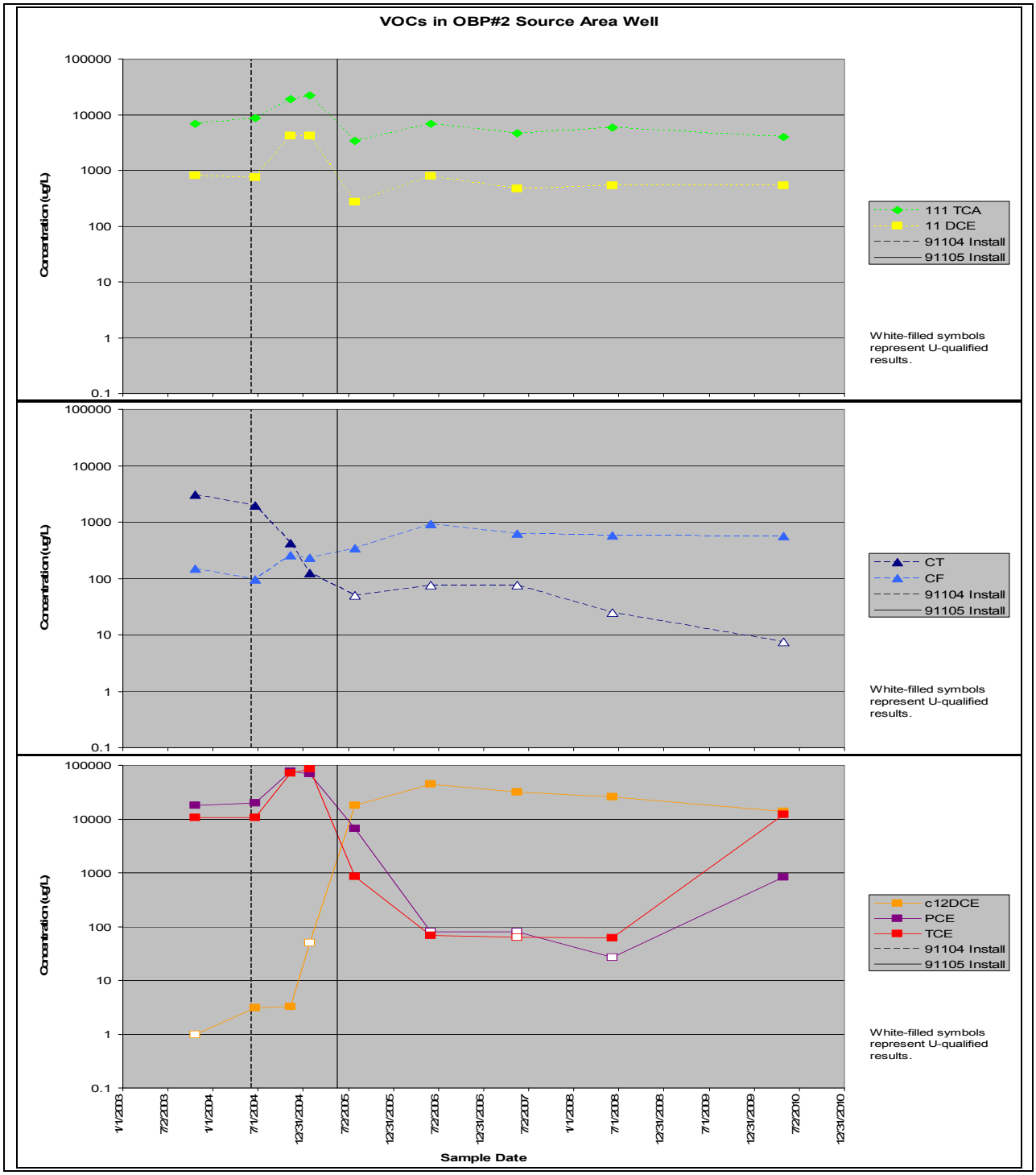
At its source area, the Mound Plume is characterized by elevated concentrations of PCE and TCE. As illustrated on Figure 196, concentrations of these constituents have remained fairly consistent since 2000, as has that of the primary metabolic byproduct from degradation of these compounds, *cis*-1,2-DCE. This suggests the degree to which these VOCs are degrading is low.



Notes: PCE = tetrachloroethene (RFLMA Table 1 standard = 1 µg/L); TCE = trichloroethene (2.5 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L). Several results are qualified ("J," "D"), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

Figure 196. Primary VOCs in Mound Plume Source Area Well 00897

In contrast to the Mound source area, groundwater in the OBP#2 source area was originally characterized by elevated concentrations of 1,1,1-trichloroethane (TCA), PCE, TCE, and 1,1-dichloroethene (DCE). Since the source removal and addition of HRC to the backfill to enhance biodegradation of residual VOCs, concentrations of *cis*-1,2-DCE and other metabolic byproducts have increased in samples from the OBP#2 source-area well, while concentrations of certain parent compounds decreased (Figure 197). Well 91105 is the third to monitor the OBP#2 source area; the previous two (91103, 91104) were installed directly within the contaminated soils (and therefore produced samples with much higher concentrations of VOCs), while the current well is on the downgradient edge of the backfilled source-removal excavation.

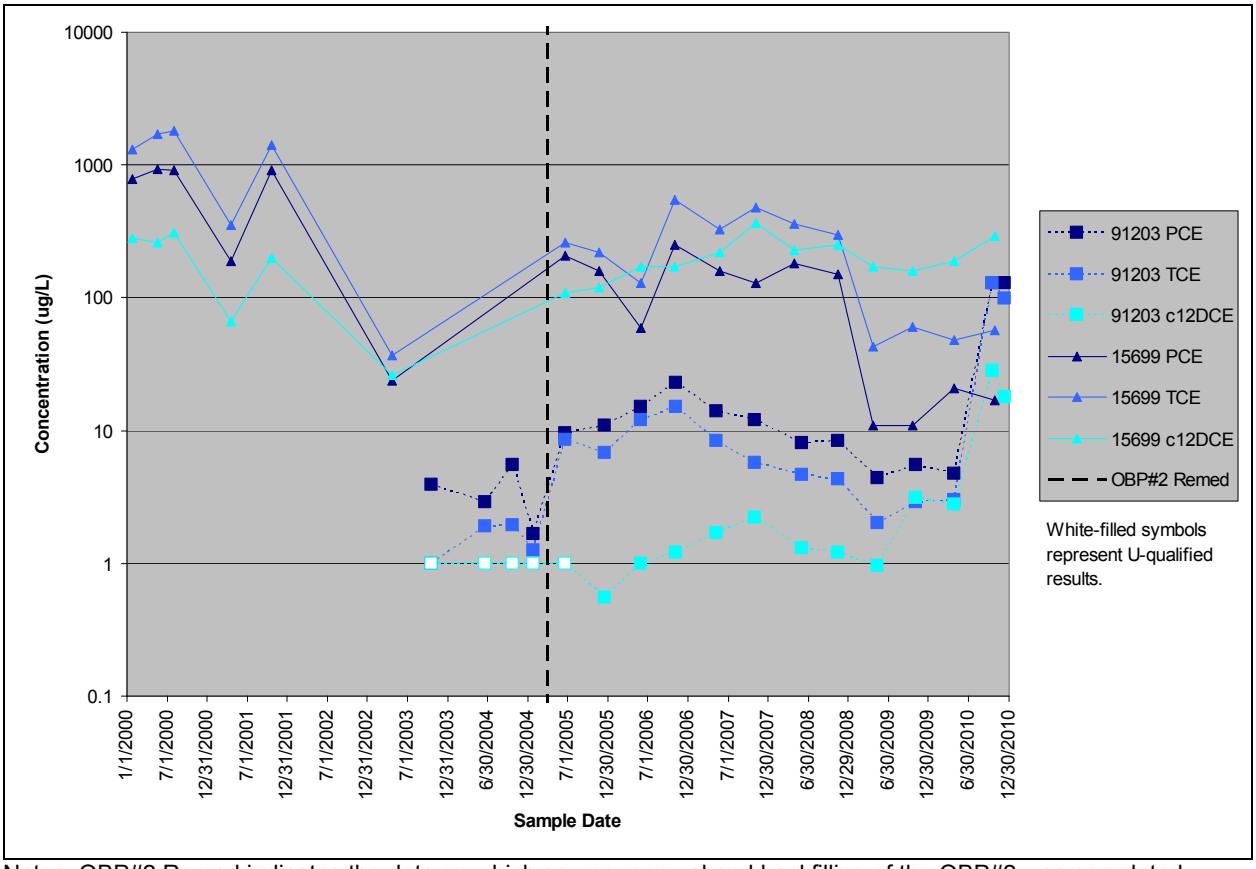


Notes: 111TCA = 1,1,1-trichloroethane (RFLMA Table 1 standard = 200 µg/L); 11DCE = 1,1-dichloroethene (7 µg/L); CT = carbon tetrachloride (1 µg/L); CF = chloroform (3.4 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L); PCE = tetrachloroethene (1 µg/L); TCE = trichloroethene (2.5 µg/L). 91104 Install and 91105 Install are dates on which those wells replaced their predecessor wells. Several results are qualified ("J," "D"), but for simplicity are not shown differently. Note logarithmic concentration scales.

Figure 197. Primary VOCs in OBP#2 Source Area Well 91105 (and Predecessors)

As shown on Figure 197, the effects of source removal on concentrations of 1,1,1-TCA and 1,1-DCE in groundwater from the source area have been limited. However, concentrations of carbon tetrachloride have declined significantly as those of its primary daughter product, chloroform, have increased. Similarly, concentrations of PCE and TCE decreased sharply as those of primary daughter product *cis*-1,2-DCE (and vinyl chloride, not illustrated) increased following completion of the source removal. The data from samples collected in 2010 suggest concentrations of PCE and TCE are increasing, while those of associated daughter products *cis*-1,2-DCE and VC remain high but are decreasing somewhat. Additional samples from this well will assist in defining longer-term trends.

The Mound and OBP#2 Plumes are also monitored by Sentinel wells positioned downgradient of the source areas, along flow paths to surface water. Figure 198 displays reported concentrations of PCE, TCE, and *cis*-1,2-DCE in samples from Sentinel wells 15699 (downgradient of the Mound and MSPTS groundwater intercept trench) and 91203 (downgradient of OBP#2). As noted in previous annual reports (e.g., DOE 2010d), the concentrations of these constituents in samples from well 15699 that were collected prior to closure show fairly close correlation, and the relative concentration of each reflected its position in the degradation pathway of PCE. (With successive dechlorination, PCE is transformed to TCE and then to *cis*-1,2-DCE, 1,1-DCE, and VC [K-H 2004d, ATSDR 2007].) Since mid-2006, however, concentrations of these constituents have followed a different pattern: those of PCE and TCE have continued to show correlation, while concentrations of *cis*-1,2-DCE have increased relative to the parent compounds PCE and TCE; this increase has been especially evident since 2008. (Although not included on the figure, a similar pattern is evident for VC.) This is interpreted as a reflection of the reconfiguration of source waters to the MSPTS—i.e., the addition of the OBP#2 plume, which contains relatively higher concentrations of daughter products such as *cis*-1,2-DCE following the addition of HRC to the OBP#2 source-area backfill at the completion of source removal activities. Given that well 15699 is positioned downgradient of the MSPTS groundwater collection trench, this trench has received significantly more *cis*-1,2-DCE since 2006, and the trench is not lined, it is to be expected that samples from this well would show a change in water quality to similar to that of the MSPTS influent.

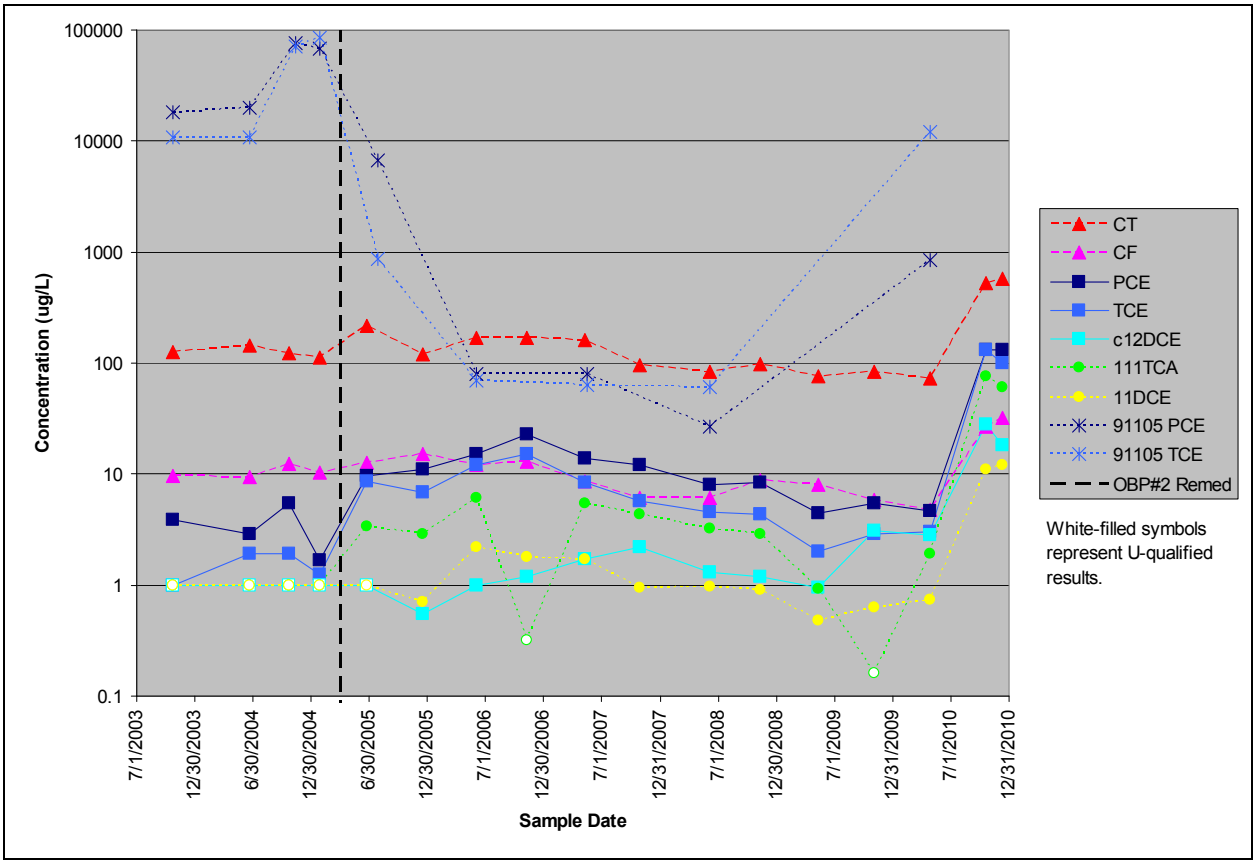


Notes: OBP#2 Remed indicates the date on which source removal and backfilling of the OBP#2 was completed (April 1, 2005). PCE (RFLMA Table 1 standard = 1 µg/L); TCE (2.5 µg/L); *cis*-1,2-DCE (c12DCE in the figure above, 70 µg/L). Several results are qualified ("J," "D"), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 198. VOC Concentrations in Samples from Mound Plume and OBP#2 Plume Downgradient Wells 15699 and 91203

Samples from well 91203 show an increase in the concentrations of some VOCs that generally coincides with the disruption associated with remediation of OBP#2 completed on April 1, 2005. These concentration increases leveled off and began to decrease somewhat, but more recently—particularly in the fourth quarter of 2010—concentrations of VOCs in samples from well 91203 were higher. Figure 199 focuses more closely on conditions at well 91203 and includes additional VOCs not typically detected, or present at relatively lower concentrations, in samples from well 15699: carbon tetrachloride, chloroform, 1,1,1-TCA, and 1,1-DCE. Some of these constituents, such as carbon tetrachloride, are also not as strongly elevated in samples from OBP#2 source-area well 91105 (Figure 197). Clearly visible on Figure 199 is the increase in VOC concentrations in the fourth quarter of 2010. (The initial results from the sample collected in that quarter, on October 20, 2010, appeared anomalous, triggering the collection—proactively, as it was not required by the RFLMA—of a confirmatory sample on December 13, 2010. This second sample confirmed the elevated VOC results.) Reasons for this increase are uncertain. The relatively higher snowmelt and rainfall received in the first half of 2010 may have mobilized residual contaminants in the vadose zone, essentially acting to flush them into the more mobile groundwater within the saturated zone. Supporting this mechanism is the fact that OBP#2 source area well 91105, which is located generally upgradient of well 91203, had increased concentrations of PCE and TCE in 2010 (Figure 197, Figure 199). However, unlike source-area

well 91105, downgradient well 91203 shows an increase in carbon tetrachloride, chloroform, and *cis*-1,2-DCE as well. Estimated travel times (discussed in Section 3.1.3.5 and summarized in Table 38) from well 91105 to 91203 typically have been in the range of 3.5 to 4 years but were estimated at under 2 years in the second quarter of 2010. As noted in Section 3.1.3.5, these calculated travel times are estimates only and apply to pure water, not dissolved constituents such as these VOCs, which would be retarded to some degree, taking longer to move the same distance. Therefore, given the travel time estimates, the elevated detections could relate to VOC source-removal activities in early 2005 or some other mechanism. Additional sampling may help to identify the cause of these increased concentrations.



NOTES: Data from OBP#2 source area well 91105 are designated as such, all other are from well 91203.
CT = carbon tetrachloride (RFLMA Table 1 standard = 1 µg/L); CF = chloroform (3.4 µg/L);
PCE = tetrachloroethene (1 µg/L); TCE = trichloroethene (2.5 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L); 111TCA = 1,1,1-trichloroethane (200 µg/L); 11DCE = 1,1-dichloroethene (7 µg/L).
OBP#2 Remed = date on which source removal and backfilling of the OBP#2 was completed (April 1, 2005).
Several results are qualified ("J," "D"), but are not shown differently for the sake of simplicity. Note logarithmic concentration scales.

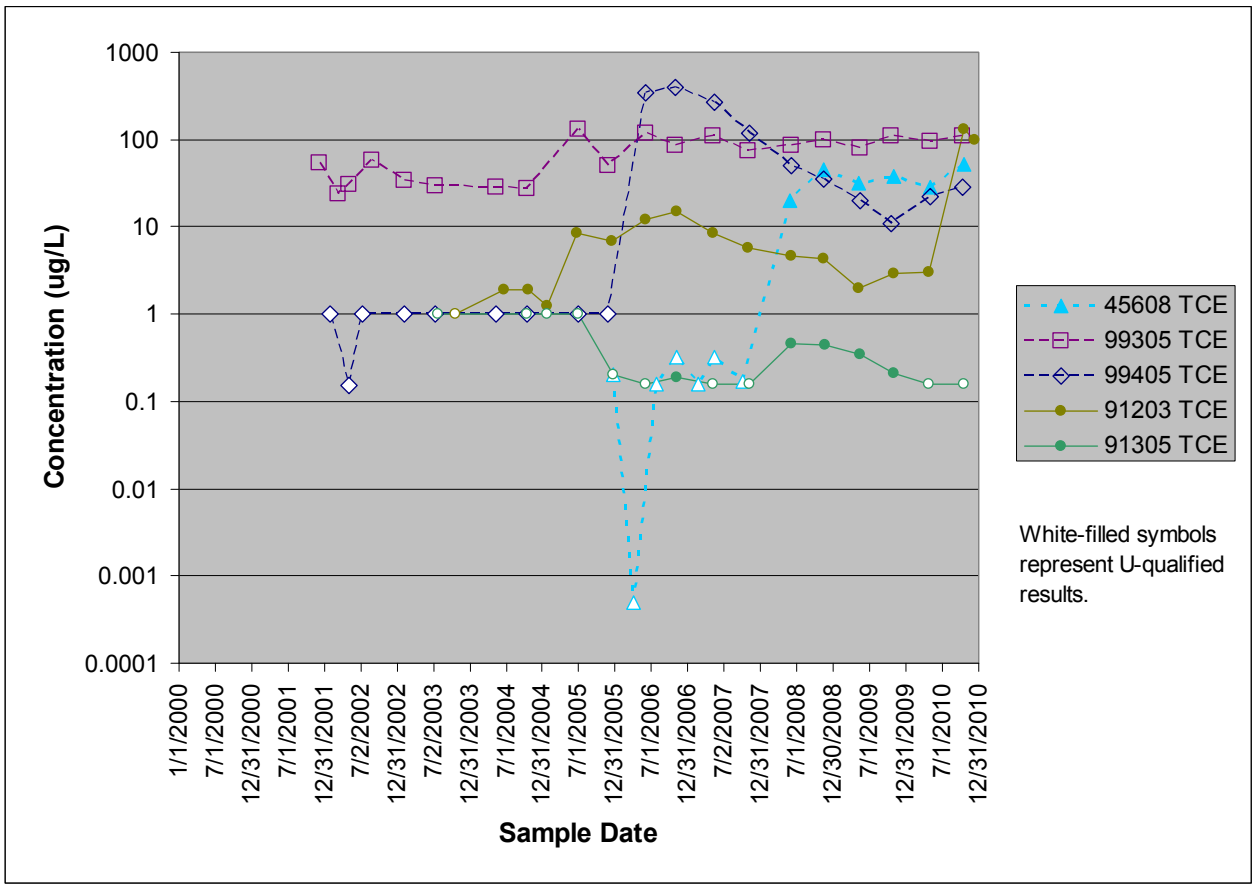
Figure 199. VOCs in Well 91203, Downgradient of OBP#2

S-K trend calculations indicate the presence of several statistically significant trends in monitoring wells at the Mound and OBP#2 plumes (Table 77 and Appendix B). Groundwater samples from Mound source-area well 00897 show a decreasing trend in TCE concentrations at a 95 percent level of significance (which is visually apparent on Figure 196), while OBP#2 source area well 91105 shows a similarly significant decreasing trend in carbon tetrachloride concentrations (see Figure 197). In a generally downgradient direction from the OBP#2 source

area, well 91203 data indicate a potential for increasing trends in 1,1,1-TCA, 1,1-DCE, *cis*-1,2-DCE, PCE, and TCE; however, each of these trends either reflects the presence of numerous nondetects in the data set or does not meet the 95 percent level of significance (Table 77). Data from this well also suggest a potential decreasing trend in the concentrations of carbon tetrachloride and chloroform, neither of which meets the 95 percent level of significance.

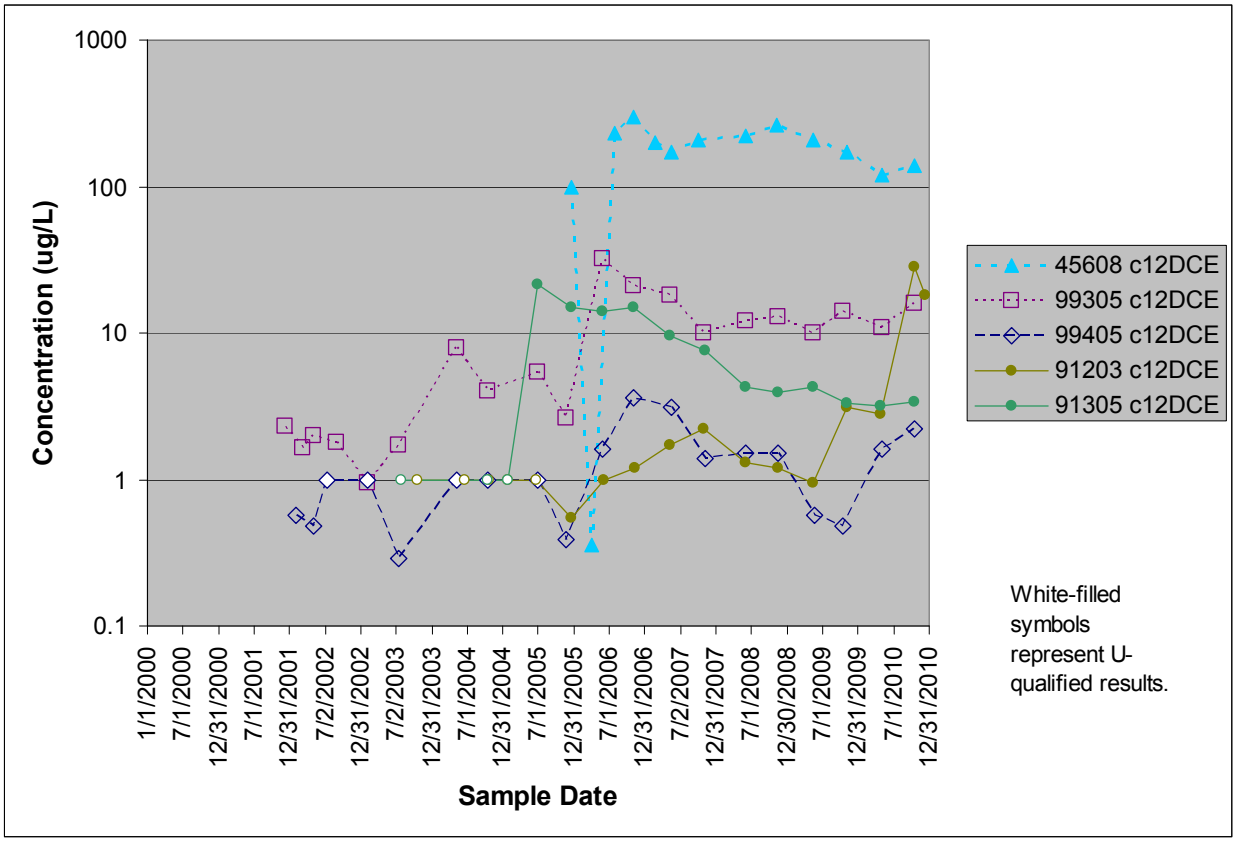
S-K trend calculations for analytical data from Sentinel well 15699 (Table 77 and Appendix B), located downgradient of the Mound plume and the MSPTS groundwater intercept trench, also identify several trends. Those meeting the 95 percent level of significance include increasing concentrations of daughter products *trans*-1,2-DCE and vinyl chloride (although both trends are based on numerous nondetects in the data set), and less-significant increasing trends in *cis*-1,2-DCE and 1,2-DCA. Decreasing trends with a 95 percent statistical significance are calculated for 1,1-DCE, PCE, and TCE; they are also calculated for 1,1,1-TCA and chloroform, but these two trends include numerous nondetects in the data set. The decreasing PCE and TCE trends are visually apparent on Figure 198.

Sentinel well 91305 is also located in this area, west of well 91203 and adjacent to FC-4. Concentrations of VOCs in samples from well 91305 do not suggest any increase similar to that observed at 91203. Data from this well suggest it monitors a mix of waters. Comparisons of degradation byproducts and parent compounds suggest the low concentrations of contaminants reported in well 91305 are contributed by the French-drain-affected hillside south of former B991 (located west-southwest of well 91305) as well as the B991 hillside itself (due west of the well). Additional contributions may be received from the OBP#2 source area to the south/southeast of well 91305. Figure 200 illustrates concentrations of TCE (a commonly used solvent during the production era, which in that sense is a parent compound, but is also a daughter product from the partial dechlorination of PCE) in samples from wells in this area, including 45608 (on the hillside south of B991), 99305 and 99405 (on the 991 hillside), 91203 (downgradient to side-gradient of OBP#2), and 91305. The time-series plots in this figure may be compared with those presented on Figure 201, which focuses on the daughter product *cis*-1,2-DCE. TCE concentrations in samples from well 91305 are lower than those reported by its neighbors, while *cis*-1,2-DCE concentrations are more comparable. The patterns in TCE time-series plots are most similar for wells 91305, 45608, and 99405. A relationship with well 99405 is reasonable, given this well's location at the valley bottom on the 991 hillside; also, the roughly 3- to 4-year delay between the TCE increase observed at well 99405 and that at well 91305 seems reasonable. The increase in TCE concentrations observed at well 45608 coincides with this well's replacement in 2008, an artificial influence that calls into question whether this increase can be reasonably considered representative of general groundwater conditions in this area. (Water quality at well 45608 is discussed further in the section on other plumes below.) With respect to *cis*-1,2-DCE, which increases in well 91305 before TCE increases, the patterns illustrated in the time-series plots are not as similar. The plot for well 91305 appears somewhat similar to that for well 99305, also on the 991 hillside but farther upgradient than its neighbor, 99405. The extensive reworking of the entire area as a part of closure precludes definitive explanation of the specific VOC sources monitored by well 91305. Monitoring will continue according to RFLMA, and additional data may help to explain specific relationships.



Notes: Applicable RFLMA surface-water action level for TCE: 2.5 µg/L (DOE 2007a). Several results are qualified (J) but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 200. Concentrations of TCE in Samples From Wells Near FC-4 Constructed Wetland



Notes: Applicable RFLMA surface-water action level for *cis*-1,2-DCE: 70 µg/L (DOE 2007a). Several results are qualified (J, D) but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 201. Concentrations of cis-*1,2-DCE in Samples From Wells Near FC-4 Constructed Wetland*

Mound Site Plume Treatment System

The MSPTS was the first groundwater intercept/treatment system installed at the Site to incorporate ZVI and is actually among the first of its type in the world. This work was completed in 1998. The first media replacement activity was conducted in the summer of 2006. Routine maintenance activities performed at the MSPTS in 2010 are discussed in Section 2.5.1.

As with all years from 2005 on, flow rates through the MSPTS in 2010 were above pre-2005 levels. This is attributed to the routing of groundwater flow from the OBP#2 area into the MSPTS intercept trench. (For additional background, see the 2005 Annual Report). Table 78 provides annual estimates of the volume of water treated by the MSPTS, which in 2010 is estimated at approximately 420,000 gallons. This represents a significant increase over the volumes treated in the past few years, and with respect to other post-closure years was second only to that treated in 2006. The general decline in MSPTS volumes that had been apparent since 2005 was reversed in 2010. This may be due to the wetter spring in 2010 together with more effective water management. Figure 202 presents the corresponding hydrograph, and Figure 203 provides a hydrograph for CY 2010. The lower flows evident on Figure 203 for the first part of 2010 are related to clogging of the media: The system at the time was operating in series flow configuration (i.e., all water was routed through Cell 1, then through Cell 2). As Cell 1 was more clogged, this slowed the flow rate through the system and caused influent water to back up in the

groundwater intercept trench. This flow configuration was then changed to parallel flow (in which the water was split, with a portion routed through Cell 1 and the balance through Cell 2), which allowed flows to be treated more quickly. In the future, this system will be operated primarily in a parallel, upflow configuration.

Table 78. Estimated Volumes of Water Treated by the MSPTS

Calendar Year	Annual Estimates of Volume Treated (gallons)	Estimated Cumulative Volume Treated (gallons)
2000	258,000	660,000
2001	119,000	780,300
2002	53,000	833,000
2003	82,000	915,000
2004	86,000	1,001,000
2005	506,000	1,507,000
2006	430,000	1,937,000
2007	326,000	2,263,000
2008	358,000	2,621,000
2009	287,000	2,908,000
2010	420,000	3,328,000

Note: Estimates for years 2000 through 2004 are compiled from K-H (2000a, 2000b, 2000c, 2000d, 2002, 2003, 2005a, 2005b).

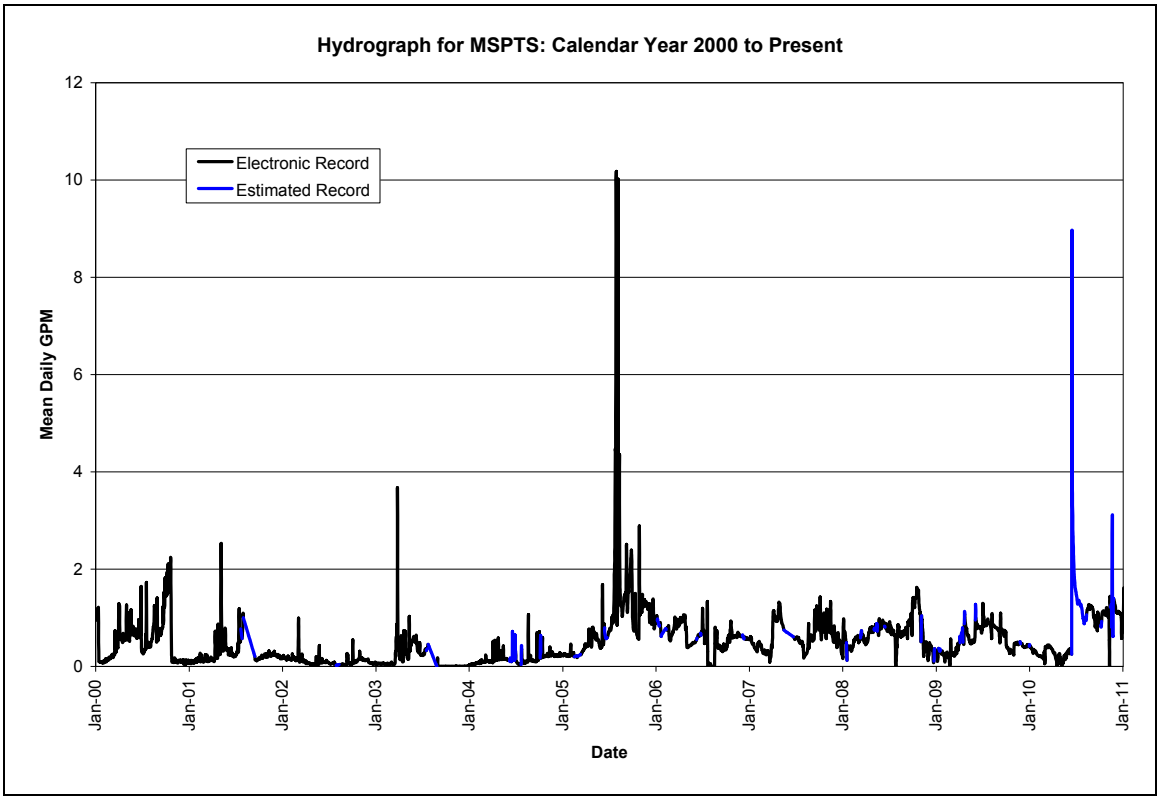


Figure 202. Hydrograph for MSPTS From 2000 Through 2010

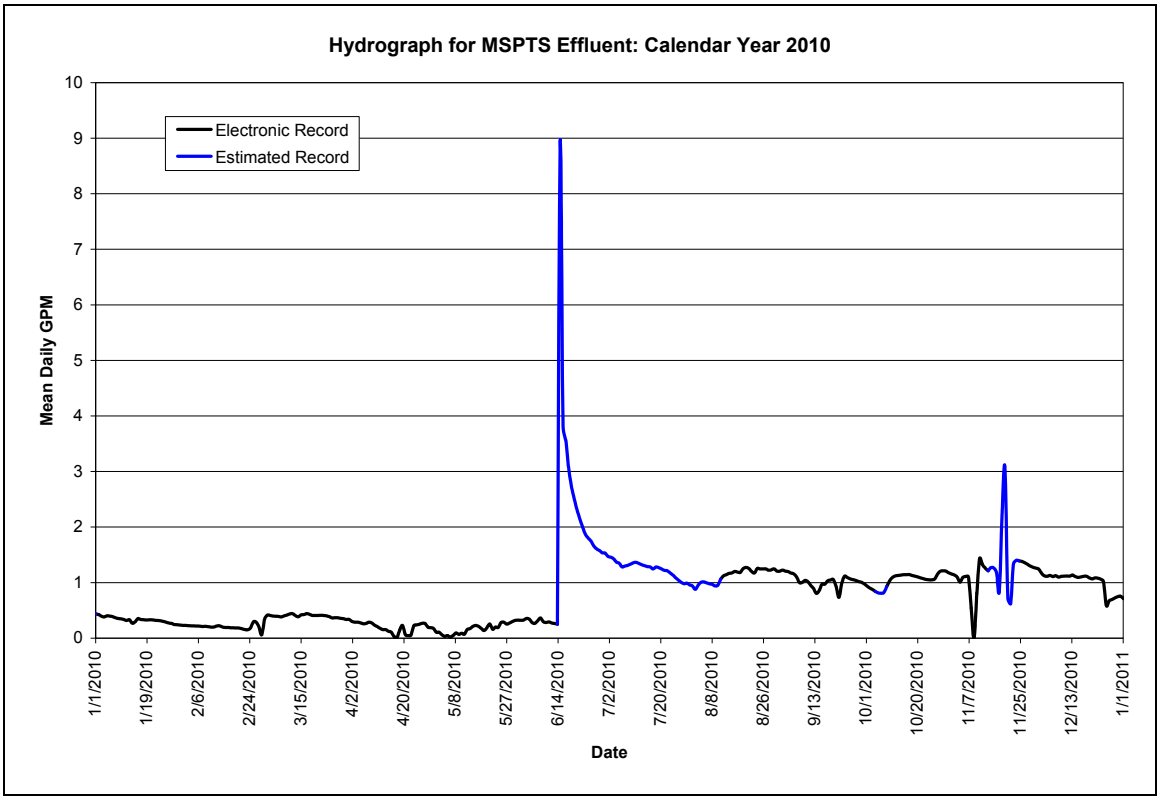


Figure 203. Hydrograph for MSPTS for CY 2010

The MSPTS was sampled twice in 2010 (April, October) in accordance with RFLMA. In response to results from the April event, additional samples were collected in June, July, August, and September 2010. Analytical data representing MSPTS influent and effluent continue to illustrate the dramatic effect the addition of OBP#2-related groundwater has on the system.

Nine VOCs were detected in 2010 in MSPTS influent at concentrations exceeding their respective Table 1 levels (DOE 2007a), an increase of two compared with results from samples collected in 2009. The VOCs that exceeded Table 1 levels in 2010 included 1,1,1-TCA, 1,1-DCE, carbon tetrachloride, chloroform, *cis*-1,2-DCE, methylene chloride, PCE, TCE, and VC. Of these, 1,1,1-TCA and methylene chloride were additions to the 2009 list. 1,1,1-TCA was included in the 2007 and 2008 lists of constituents exceeding Table 1 values in MSPTS influent but did not exceed that value in 2009. The presence of 1,1,1-TCA in MSPTS influent was not prevalent until 2007 and represents a primary contaminant from the OBP#2 source area. Methylene chloride has been inconsistently detected in system influent at concentrations above the Table 1 value: twice in 2000 it was reported at elevated concentrations, but on both occasions was both J- and B-qualified (estimated value, and also detected in the blank); it was also detected at concentrations exceeding the RFLMA Table 1 value in three samples in 2006, and detected in the single (J-qualified) sample in 2010.

Whereas in 2009 two VOCs were detected in MSPTS treated effluent at concentrations exceeding RFLMA Table 1 values, in 2010 eight VOCs exceeded their respective Table 1 values: 1,1-DCE, 1,2-DCA, chloroform, *cis*-1,2-DCE, methylene chloride, PCE, TCE, and VC. This behavior is related to the reduced treatment capacity of the ZVI media within the MSPTS

and the higher flow rates observed in 2010. However, some of these constituents are more recalcitrant; the reductive dechlorination of polychlorinated constituents (such as PCE, TCE, and carbon tetrachloride) occurs more readily than that of mono- and dichlorinated compounds (e.g., *cis*-1,2-DCE, VC, methylene chloride) (EPA 2000). Therefore, these partially chlorinated daughter products require a greater residence time in ZVI media for adequate treatment to be accomplished. However, under higher flow rates such as were observed in 2010, the residence time instead decreases. Due to observed clogging, the ZVI media was scheduled to be replaced, and consideration of additional measures was also begun; this subject is discussed more fully below. The applicable RFLMA values have changed for some VOCs (carbon tetrachloride, PCE, and TCE, among others) since the end of 2009 when several Temporary Modifications terminated and the underlying standards became applicable.

Table 79 summarizes MSPTS influent and effluent analytical data. Refer to the quarterly reports (DOE 2010c, 2010e, 2011b) and Appendix B for additional water-quality data for the MSPTS. Data representing MSPTS influent clearly show the influence of closure activities performed upgradient of the system, particularly the installation of an engineered preferential pathway (the backfilled storm drain corridor and associated cross-cutting gravel drain) that now routes groundwater impacted by the OBP#2 into the MSPTS groundwater intercept trench. (For more information on this feature, see K-H 2005c.) Because the OBP#2 source area was remediated and HRC was added to the backfill to stimulate biodegradation of residual VOCs, the concentrations of daughter products *cis*-1,2-DCE, 1,1-DCE, and VC in MSPTS influent have increased. As explained above, these represent some of the more recalcitrant constituents.

Figure 204 illustrates how concentrations of PCE, TCE, and *cis*-1,2-DCE in MSPTS influent and effluent were affected by closure activities. While closure-related work did not appear to affect influent concentrations of PCE or TCE markedly, those of *cis*-1,2-DCE increased by two to three orders of magnitude. More recently, 2010 saw a sharp increase in the parent compounds (PCE and TCE) in the system influent, potentially as a result of higher water levels acting to flush residual contamination from the vadose zone into the saturated zone. This is more easily visible on Figure 205, which focuses on the period from just before the OBP#2 remediation (completed April 1, 2005) to the end of 2010. Evidence for the greater difficulty in dechlorinating constituents with fewer chlorine atoms is also seen, as is the effect of higher flows/shorter residence times on treatment effectiveness: The 2010 increase in PCE and TCE at elevated flow rates led to a more effective treatment of PCE (four chlorine atoms) than TCE (three chlorine atoms), and *cis*-1,2-DCE (two chlorine atoms) treatment is strongly hampered by the shorter residence times. Figure 206 and Figure 207 provide similar depictions of time-series plots for the daughter products 1,1-DCE and VC in MSPTS influent and effluent. These figures further illustrate the challenges faced by the system in 2010.

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Table 79. Selected VOC Data (µg/L) from MSPTS Influent and Effluent

DATE	1,1,1-TCA		1,1-DCE		CT		CF		*cis*-1,2-DCE		MCl		PCE		TCE		VC	
	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E
1/27/2000	8 (J)	1 (U)	**10**	1 (U)	**110**	1 (U)	**25**	1 (U)	57	1	**5 (BJ)**	1 (B)	**120**	0.1 (J)	**150**	1 (U)	10 (U)	1 (U)
2/8/2000	9 (J)	1 (U)	**10**	1 (U)	**110**	1 (U)	**25**	1 (U)	59	2	**6 (JB)**	2 (B)	**96**	1 (U)	**140**	1 (U)	10 (U)	0.1 (J)
3/7/2000	9 (J)	1 (U)	**12**	1 (U)	**110**	1 (U)	**26**	1 (U)	62	2	14 (B)	0.9 (JB)	**100**	1 (U)	**160**	1 (U)	10 (U)	1 (U)
4/26/2000	7 (J)	1 (U)	**10**	1 (U)	**96**	1 (U)	**24**	1 (U)	61	4	20 (B)	0.8 (JB)	**110**	1 (U)	**140**	1 (U)	10 (U)	0.2 (J)
5/15/2000	6	1 (U)	**8**	1 (U)	**49 (D)**	1 (U)	**19**	1 (U)	42 (D)	3	0.1 (JB)	0.7 (BJ)	**68 (D)**	1 (U)	**87 (D)**	1 (U)	**0.3 (J)**	1 (U)
6/14/2000	8	1 (U)	**10**	1 (U)	**130**	1 (U)	**24**	1 (U)	42	1	3 (BJ)	0.2 (BJ)	**130**	1 (U)	**150**	1 (U)	10 (U)	1 (U)
7/19/2000	4 (J)	1 (U)	6	1 (U)	**63**	1 (U)	**12**	1 (U)	42	2	4 (JB)	0.9 (JB)	**64**	1 (U)	**79**	1 (U)	5 (U)	1 (U)
8/16/2000	10 (J)	1 (U)	**10 (J)**	1	**180**	1 (U)	**31**	1 (U)	39	1 (J)	23 (B)	0.3 (BJ)	**100**	1 (U)	**140**	1 (U)	10 (U)	1 (U)
9/13/2000	5.9	0.5 (U)	7	0.5 (U)	**122**	0.5 (U)	**25.4**	0.5 (U)	32.1	0.74	1 (U)	0.57	**65.3**	0.5 (U)	**99.9**	0.5 (U)	1 (U)	0.5 (U)
10/25/2000	6.3	0.5 (U)	**8**	0.5 (U)	**133**	0.5 (U)	**25.6**	0.5 (U)	37.3	0.69	1 (U)	0.5 (U)	**68.7**	0.33 (J)	**104**	0.5 (U)	1 (U)	0.5 (U)
4/19/2001	4 (D)	1 (U)	5 (D)	1 (U)	**73 (D)**	1 (U)	**20 (D)**	0.6 (J)	38 (D)	3	2 (U)	**6**	**44 (D)**	1 (U)	**76 (D)**	1 (U)	2 (U)	1 (U)
10/25/2001	3.4	1 (U)	5.1	1 (U)	**130**	1 (U)	**23**	1 (U)	23	0.9 (J)	1 (U)	1 (U)	**50**	1 (U)	**74**	1 (U)	1 (U)	1 (U)
4/25/2002	2.9	1 (U)	4.5	1 (U)	**110**	1 (U)	**26**	1 (U)	24	1.8	1 (U)	1 (U)	**41**	1 (U)	**76**	1 (U)	1 (U)	1 (U)
10/21/2002	2.6	1 (U)	1.06	1 (U)	**155**	1 (U)	**27.5**	1 (U)	11.3	1 (U)	1 (U)	1 (U)	**33.6**	1 (U)	**46.8**	1 (U)	1 (U)	1 (U)
4/17/2003	2.8	1 (U)	2.5	0.23 (J)	**73**	1 (U)	**19**	0.93 (J)	23	4.4	1 (U)	3.5 (B)	**31**	0.38 (J)	**38**	0.31 (J)	**0.81 (J)**	1 (U)
12/1/2003	2	1 (U)	2	1 (U)	**104 (D)**	1 (U)	**21.4**	1 (U)	9	1	1 (U)	1 (U)	**22.6**	1 (U)	**31.4**	1 (U)	1 (U)	1 (U)
6/9/2004	1.34	1 (U)	1.49	1 (U)	**91.9**	1 (U)	**22.4**	1 (U)	6.98	1 (U)	1 (U)	1 (U)	**21.5**	1 (U)	**28.3**	1 (U)	1 (U)	1 (U)
10/20/2004	2.07	1 (U)	2.47	1 (U)	**100**	1 (U)	**24.6**	1 (U)	5.59	0.83 (J)	1 (U)	1 (U)	**25.7**	0.72 (J)	**29.4**	2.74	1 (U)	1 (U)
6/21/2005	1 (U)	1 (U)	1.58	1 (U)	**110**	1 (U)	**30.4**	0.48 (J)	3.93	2.04	0.74 (J)	1 (U)	**29.1**	1.66	**34.9**	1.28	1 (U)	1 (U)
11/18/2005	11 (J)	1 (U)	5.2	0.67 (J)	**150**	1 (U)	**31**	0.42 (J)	20	6.3	1 (U)	1 (U)	**81**	4.5	**90**	1.6	1 (U)	1 (U)
4/25/2006	35	0.16 (U)	**18**	4.8	**81**	0.19 (U)	**56**	0.16 (U)	**920**	**390**	**20**	1.7	**150**	**5.7**	**150**	**7.6**	0.68 (U)	**5.6**
6/5/2006	27.4	1 (U)	1 (U)	1 (U)	**60.1**	1 (U)	**45**	1 (U)	**2040 (D)**	**793 (D)**	**27.2**	1 (U)	**125 (D)**	3	**158 (D)**	4.6	**6**	**8.6**
10/5/2006	53.3	1 (U)	**73.1**	1 (U)	**60.1**	1 (U)	**45.1**	1 (U)	**6580 (D)**	0.78 (J)	**6.9**	**7.3**	**87.2**	1 (U)	**93.7**	1 (U)	**26.1**	1 (U)
6/26/2007	11	0.43 (U)	5.2	1.4 (J)	3.4 (J)	0.51 (U)	**4.1**	0.43 (U)	**320**	**590**	0.32 (U)	2.6 (J)	**6.8**	0.53 (U)	**5.3**	0.43 (U)	**12**	**48**
7/24/2007	**290**	0.32 (U)	**95**	0.52 (J)	**48 (J)**	0.38 (U)	**77**	0.32 (U)	**6500**	**330**	21 (U)	**6.7**	**94**	0.4 (U)	**88**	0.32 (U)	**350**	**18**
8/6/2007	**370**	0.16 (U)	**99**	0.35 (J)	**58**	0.19 (U)	**99**	0.16 (U)	**7700**	**130**	8.5 (U)	3.3	**89**	0.2 (U)	**88**	0.16 (U)	**420**	**8.6**
8/16/2007	180	0.32 (U)	**47**	0.4 (J)	**24**	0.38 (U)	**67**	0.32 (U)	**4500**	**190**	4.1 (U)	5.4 (U)	**28**	0.4 (U)	**42**	0.32 (U)	**420**	**34**
10/9/2007	**300**	0.16 (U)	**93**	0.44 (J)	**42**	0.19 (U)	**88**	0.16 (U)	**5800**	**300**	13 (U)	**4.8**	**70**	0.2 (U)	**93**	0.16 (U)	**470**	**36**
11/8/2007	**270**	0.16 (U)	**94**	0.5 (J)	**40**	0.19 (U)	**85**	0.16 (U)	**5400**	**140**	13 (U)	**4.7**	**78**	0.2 (U)	**110**	0.16 (U)	**590**	**36**
4/29/2008	**340**	0.16 (U)	**94 (J)**	1.3 (J)	**30**	0.19 (U)	**100**	0.45 (J)	**5700**	**310**	**6.4 (J)**	**6.2 (J)**	**97**	0.32 (J)	**100**	0.56 (J)	**44**	**28**
11/11/2008	**310**	0.16 (U)	**71**	0.14 (U)	**35**	0.19 (U)	**80**	0.16 (U)	**5900**	2.2	9.2 (U)	1.3 (U)	**88**	0.2 (U)	**89**	0.17 (J)	**32 (J)**	**4.2 (J)**
4/21/2009	45	0.16 (U)	**27**	1.6	**7.2**	0.19 (U)	**8.6**	0.16 (U)	**1500**	**95**	1.6 (U)	4.1 (B)	**18**	0.53 (J)	**37**	1.9	**92**	**47**
10/26/2009	110	0.16 (U)	**36**	0.14 (U)	**27**	0.19 (U)	**19**	0.16 (U)	**2600**	1.8	1.6 (U)	0.46 (J)	**53**	0.2 (U)	**77**	0.58 (J)	**130 (J)**	**1.5 (J)**
4/27/2010	75	0.16 (U)	**25**	5.6	**3.3**	0.19 (U)	**6.3**	0.16 (U)	**1900**	**360**	2.1	0.82 (J)	**32**	0.2 (U)	**79**	**3.5**	**79**	**150**
6/22/2010	6	35	2.2	**24**	0.4	1.3 (U)	0.46	**9.9**	**110**	**1800**	0.39	5.6 (U)	**8.7**	**29**	**9.3**	**77**	**0.4**	**270**
7/28/2010	190	15	**42**	**8.5**	**11**	0.76 (U)	**22**	3.3 (J)	**2800**	**790**	**7.7**	**6.4**	**74**	**11**	**230**	**40**	**70**	**40**
8/26/2010	120	12	**22**	**12**	**9.7**	0.38 (U)	**15**	**3.5**	**1700**	**960**	3.1	4.3 (B)	**44**	**20**	**160**	**84**	**2**	**160**
9/29/2010	**220**	8.3	**43**	**10**	**19**	0.38 (U)	**27**	3	**2200**	**690**	1.6	0.64 (U)	**88**	**11**	**350**	**93**	**9**	**130**
10/28/2010	**400**	9.7	**68**	**7.5**	**27**	0.38 (U)	**49**	3.4	**3700**	**590**	3.2	2.2 (U)	**270**	**6.5**	**810**	**100**	**64**	**75**

Notes: 1,1,1-TCA = 1,1,1-trichloroethane; 1,1-DCE = 1,1-dichloroethene; CT = carbon tetrachloride; CF = chloroform; *cis*-1,2-DCE = *cis*-1,2-dichloroethene; MCl = methylene chloride; PCE = tetrachloroethene; TCE = trichloroethene; VC = vinyl chloride. R1-0 = influent, R2-E = effluent; formal sampling location names are Mound R1-0 and Mound R2-E. Shaded, bold value indicates detected concentration exceeds corresponding applicable level stipulated in RFLMA Attachment 2, Table 1 (DOE 2007a); if detection limit exceeded that concentration and constituent was qualified as nondetect, result is not highlighted as an exceedance. Lab and validation qualifiers (wherein the validation qualifier supersedes the lab qualifier if they differ): J = result is estimated below the sample quantitation limit; U = analyte not detected at the indicated concentration; B = chemical was also detected in the blank; D = analysis was performed at a dilution.

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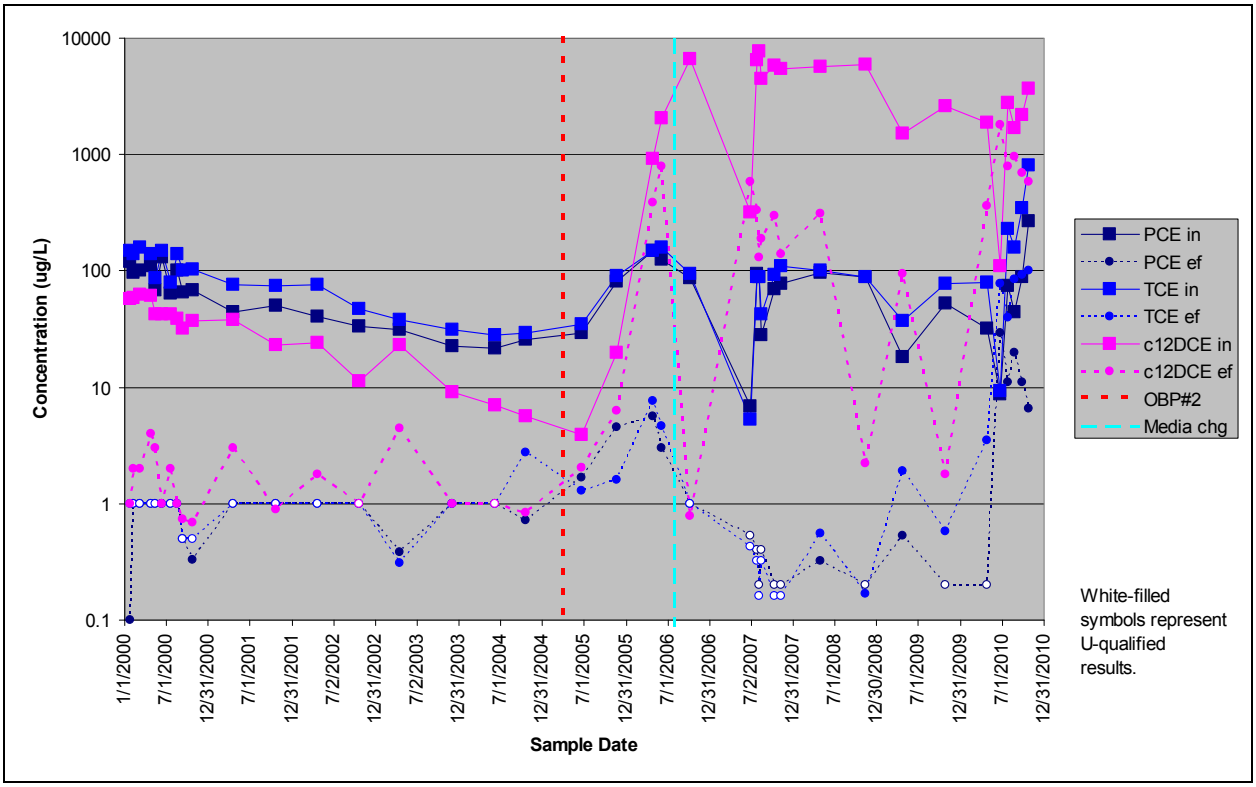
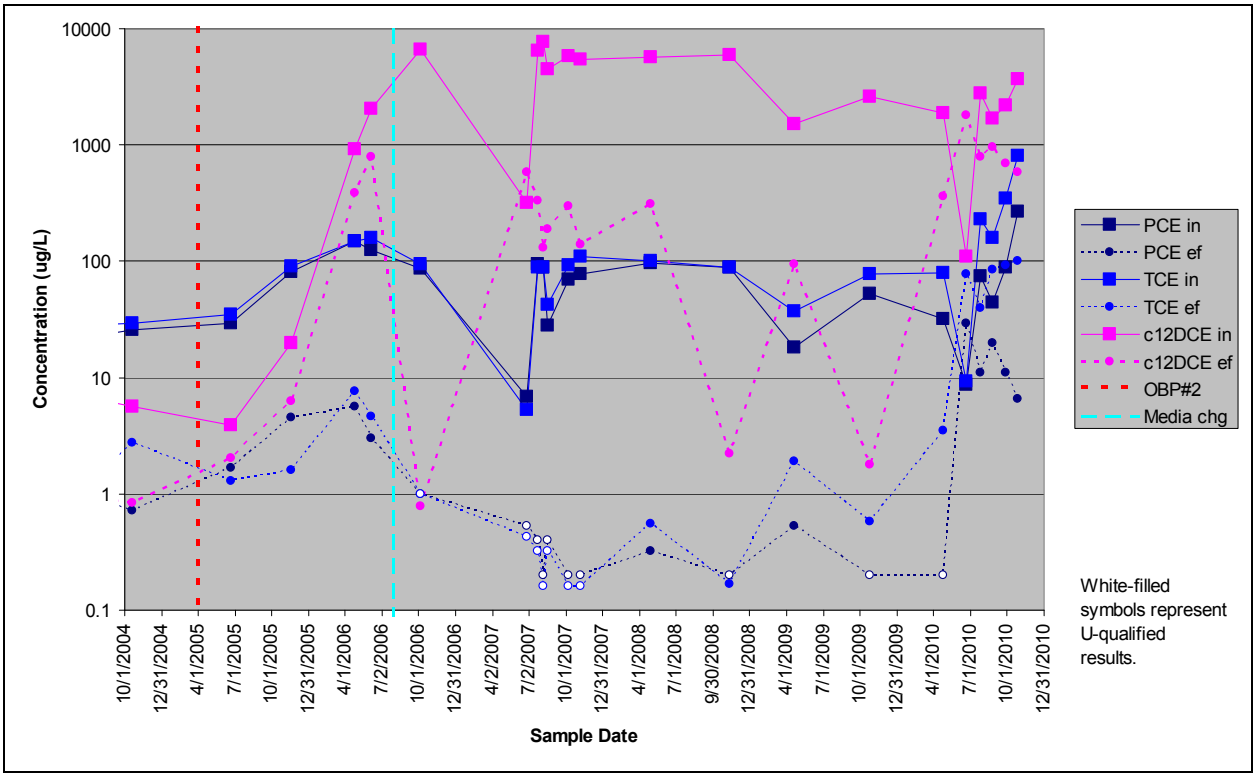


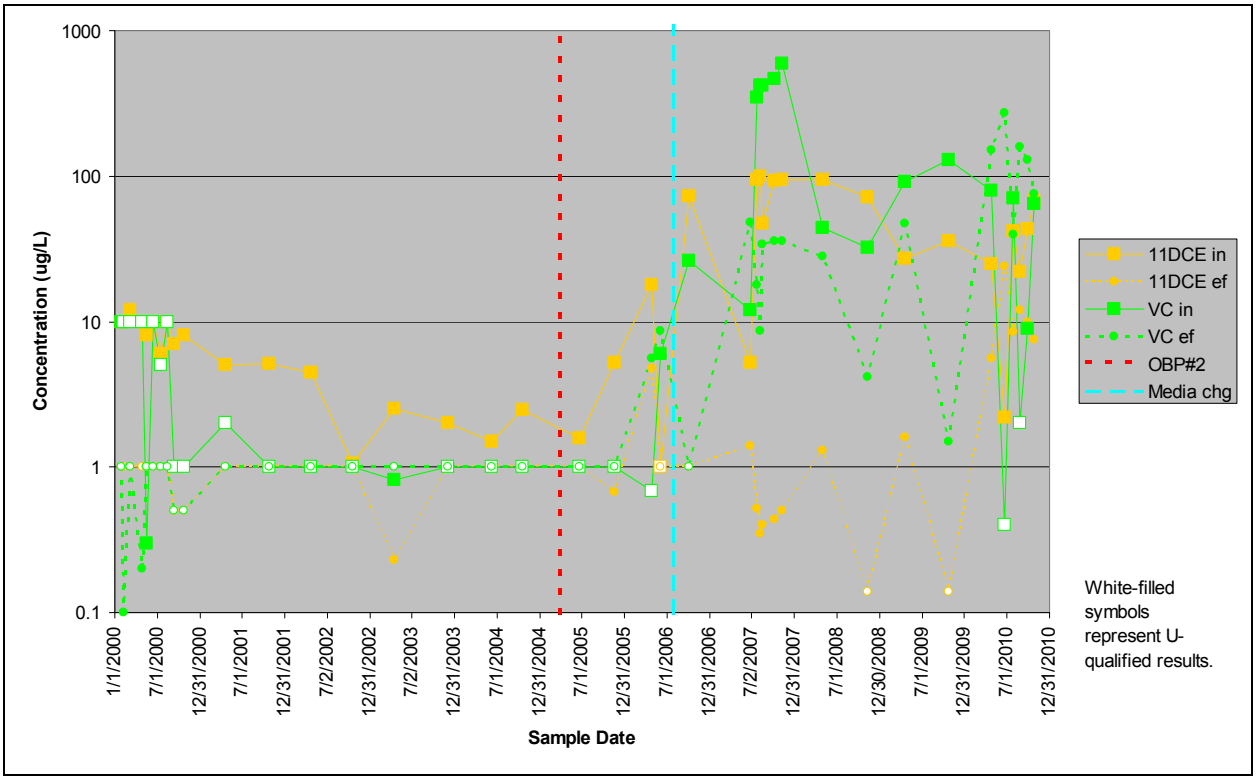
Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70; in = influent (Mound R1-0); ef = effluent (Mound R2-E). Lab qualifiers not indicated except for U (analyte not detected at the indicated concentration); other qualified data plotted at reported value for simplicity. Note logarithmic concentration scale.

Figure 204. Concentrations of PCE, TCE, and cis-1,2-DCE in MSPTS Influent and Effluent



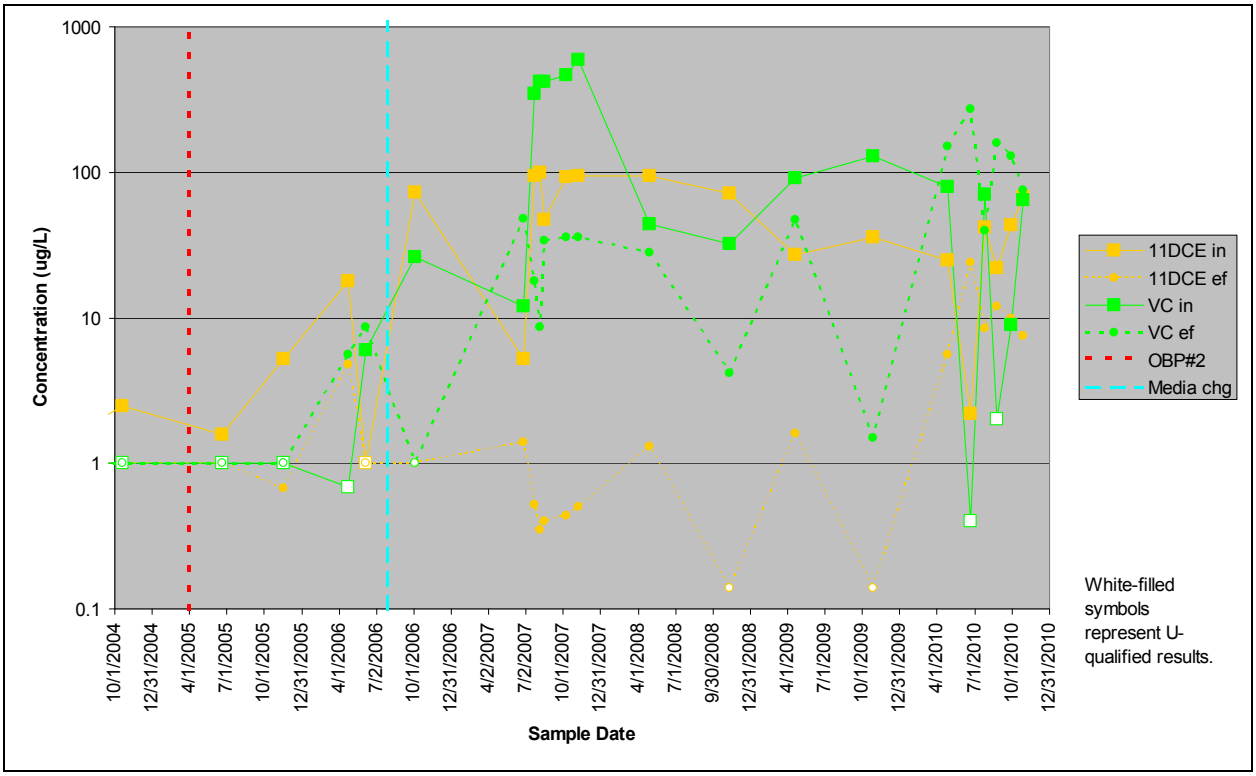
Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70; in = influent (Mound R1-0); ef = effluent (Mound R2-E). Lab qualifiers not indicated except for U (analyte not detected at the indicated concentration); other qualified data plotted at reported value for simplicity. Note logarithmic concentration scale.

Figure 205. Recent Concentrations of PCE, TCE, and cis-1,2-DCE in MSPTS Influent and Effluent



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): 1,1-DCE, 7; VC, 0.2; in = influent (Mound R1-0); ef = effluent (Mound R2-E). Lab qualifiers not indicated except for U (analyte not detected at the indicated concentration); other qualified data plotted at reported value for simplicity. Note logarithmic concentration scale.

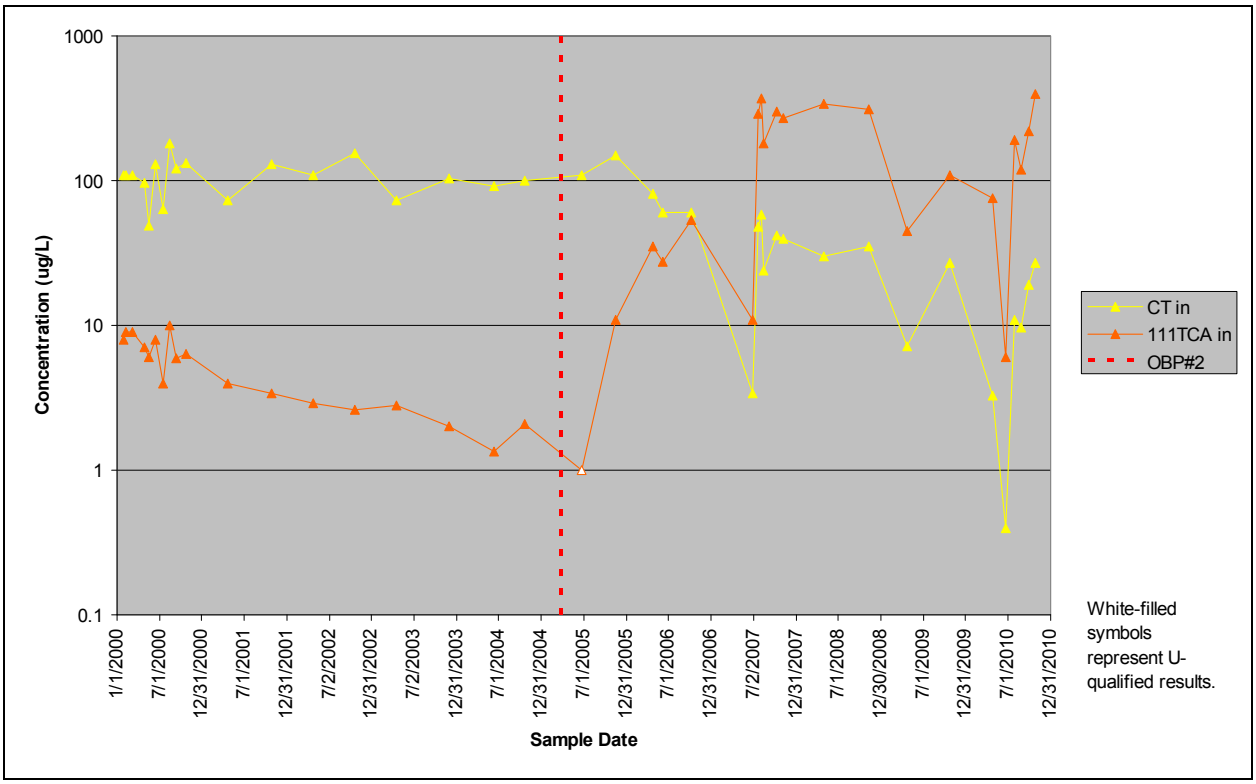
Figure 206. Concentrations of 1,1-DCE and VC in MSPTS Influent and Effluent



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): 1,1-DCE, 7; VC, 0.2; in = influent (Mound R1-0); ef = effluent (Mound R2-E). Lab qualifiers not indicated except for U (analyte not detected at the indicated concentration); other qualified data plotted at reported value for simplicity. Note logarithmic concentration scale.

Figure 207. Recent Concentrations of 1,1-DCE and VC in MSPTS Influent and Effluent

Figure 208 provides time-series plots for carbon tetrachloride and 1,1,1-TCA in system influent. Carbon tetrachloride is not detected in system effluent, and the same typically applies to 1,1,1-TCA though this constituent was detected at concentrations lower than the RFLMA Table 1 value in the samples collected after May 2010. This figure shows the variable effect on influent contaminant distributions following the OBP#2-related work and the higher flows of 2010; it also illustrates a distinction between the Mound and OBP#2 plumes. The time-series plot for carbon tetrachloride in system influent shows carbon tetrachloride in groundwater from the OBP#2 source area has not contributed to an overall increase in the concentrations of this constituent; instead, overall concentrations of this compound have decreased. Even the high-water conditions in 2010 did not boost carbon tetrachloride concentrations in system influent to those seen prior to closure, before the system collection infrastructure was enhanced to receive the OBP#2 water. The time-series plot for 1,1,1-TCA shows the importance of this compound in distinguishing between the Mound and OBP#2 plumes. Additional time-series plots and discussion of these plumes are provided above, in the discussion of the Mound and OBP#2 Plumes.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): CT = carbon tetrachloride, 1; 1,1,1-TCA, 200; in = influent (Mound R1-0); ef = effluent (Mound R2-E). Lab qualifiers not indicated except for U (analyte not detected at the indicated concentration); other qualified data plotted at reported value for simplicity. Note logarithmic concentration scale.

Figure 208. Concentrations of Carbon Tetrachloride and 1,1,1-TCA in MSPTS Influent

Analytical results from the samples collected in April 2010 drove regulatory consultation, the results of which included monthly sampling at MSPTS locations as well as non-RFLMA locations. This activity is described in greater detail below.

In addition to the constituents summarized in Table 79, other VOCs were detected in MSPTS effluent in 2010 (see DOE 2010c, 2010e, 2011b and Appendix B.6 for the data). The only other VOC reported at a level exceeding the applicable RFLMA Table 1 concentration was 1,2-DCA. Three samples of effluent reported detections of 1,2-DCA exceeding the 1 µg/L RFLMA Table 1 value for this constituent. Collected in April, August, and September, the results ranged from 1.3 µg/L to 1.8 µg/L, and two were J-qualified.

Six grab samples for the analysis of VOCs were collected in 2010 at the surface water performance location for the MSPTS, surface-water station GS10. As in prior years, VOC detections were reported (Table 80). In the June 2010 sample, two constituents—TCE and vinyl chloride—exceeded the corresponding RFLMA Table 1 standard.

Table 80. Summary of VOCs Detected in 2010 at GS10

Date	Constituent	Result (µg/L)	Qualifier
4/27/2010	1,1,1-Trichloroethane	0.47	J
4/27/2010	*cis*-1,2-Dichloroethene	12	
4/27/2010	Trichloroethene	0.49	J
6/22/2010	1,1,1-Trichloroethane	1.5	
6/22/2010	1,1-Dichloroethene	0.58	J
6/22/2010	Chloroform	0.49	J
6/22/2010	*cis*-1,2-Dichloroethene	70	
6/22/2010	Tetrachloroethene	0.93	J
6/22/2010	***Trichloroethene***	***2.8***	
6/22/2010	***Vinyl chloride***	***0.69***	***J***
7/28/2010	1,1,1-Trichloroethane	0.54	J
7/28/2010	1,1-Dichloroethene	0.24	J
7/28/2010	Chloroform	0.18	J
7/28/2010	*cis*-1,2-Dichloroethene	42	
7/28/2010	Methylene chloride	0.36	J
7/28/2010	Tetrachloroethene	0.62	J
7/28/2010	Trichloroethene	2.2	
8/26/2010	*cis*-1,2-Dichloroethene	25	
8/26/2010	Tetrachloroethene	0.34	J
8/26/2010	Trichloroethene	1.8	
9/29/2010	*cis*-1,2-Dichloroethene	20	
9/29/2010	Trichloroethene	2.2	
10/28/2010	*cis*-1,2-Dichloroethene	11	
10/28/2010	Trichloroethene	1.3	

The detections reported in 2010 at GS10 exceed those in recent years, both in the number of constituents and, in several cases, the reported concentration. Detections in recent years have consistently included *cis*-1,2-DCE, plus two detections of 1,2-DCA (one each in 2007 and 2008) and one of TCE (in 2007).

The treatment media in the MSPTS will be replaced in early 2011. The effect of this replacement will be an improvement in the treatment effectiveness. In addition, a polishing component will be installed, as discussed in greater detail below.

MSPTS Regulatory Consultation and Effluent Polishing Component

Before groundwater from the OBP#2 source area was routed to the MSPTS for treatment, system effluent typically reported few, if any, detectable concentrations of VOCs. Since 2006, when the effects of increased contaminant load and flows to the MSPTS from the OBP#2 source area became evident, system effluent has contained residual VOCs (see preceding text and associated figures, and Table 79 for data summary). These constituents typically include low concentrations of parent compounds and more elevated concentrations of the daughter products *cis*-1,2-DCE and vinyl chloride. Concentrations in 2010 were elevated with respect to previous data, particularly for parent compounds. The presence of these VOCs is due to a combination of factors: With the addition of flows related to the OBP#2 area, the MSPTS now receives higher flows than before; this was particularly true in 2010. In addition, those flows contain higher concentrations of VOCs overall, as well as higher concentrations of metabolic byproducts. As discussed above, these byproducts, such as *cis*-1,2-DCE and vinyl chloride, are recalcitrant and

require more time within the ZVI media to be reductively dechlorinated. However, under conditions of higher flow rates, water instead is present within the media for a shorter time. Further exacerbating this limit on the degree to which the influent water was treated, the media in 2010 was increasingly clogged with mineral precipitates. This is a natural response to the general groundwater chemistry at Rocky Flats, which includes elevated concentrations of dissolved oxygen (which acts to form iron oxide and iron oxyhydroxide precipitates within the ZVI media), calcium, and carbonate (both of which react within the ZVI to form calcite, with the latter ion also reacting with dissolved iron from the ZVI to form siderite). These processes result in decreasing amounts of fresh ZVI available to treat the VOCs present in the influent stream and, at some point, the amount of fresh ZVI within the media is insufficient to meet the treatment needs. This point was reached in 2010.

The second quarter sample results, which are summarized above in Table 79 and are presented in full in DOE 2010e, led to consultation with CDPHE. (This consultation, summarized in Contact Record 2010-07, also included the subject of treatment at the ETPTS, which is discussed in the corresponding section below.) While it was recognized that the MSPTS media was in need of replacement, additional data were desired to assess how the VOC concentrations varied as the system effluent moved into the receiving Functional Channel. To support this evaluation, two non-RFLMA sampling points were selected within FC-4: MSPTSCHAN1 was located within FC-4 close to the MSPTS effluent discharge gallery where accessible, pooled water was visible among the riprap, but flow was not evident; MSPTSCHAN2 was located a short distance downstream of MSPTSCHAN1 in FC-4, and was the nearest point to MSPTSCHAN1 that had easily accessible, turbulently flowing water. These locations are illustrated in Figure 209.

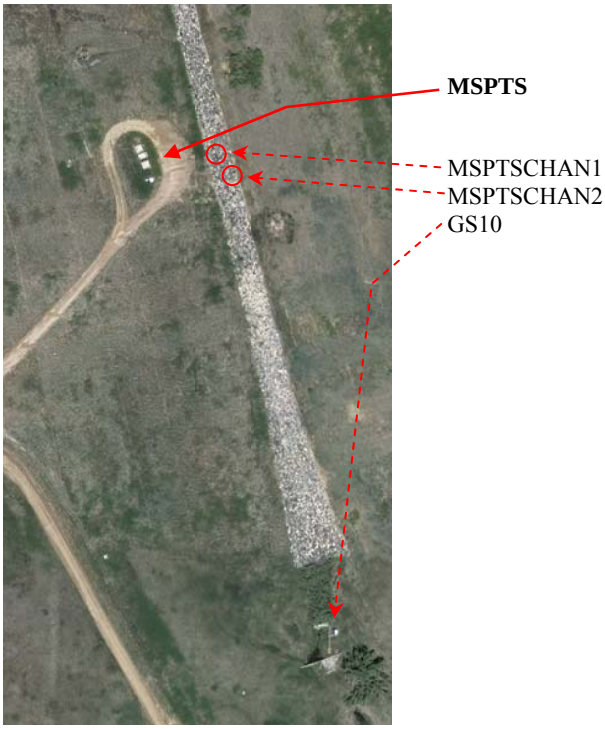


Figure 209. MSPTS With Approximate Locations of Extra Sampling Points With Respect to Treatment System and Surface Water Performance Location

In accordance with Contact Record 2010-07, additional samples were collected at the RFLMA locations and the extra locations identified above. This evaluation sampling occurred in June, July, August, September, and October. During each event, each location was visited for sampling. In June, conditions at MSPTSCHAN1 and MSPTSCHAN2 were as described above. During the July event these two locations presented accessible, standing water. In August and September, both of these locations were dry. During the October sampling event only MSPTSCHAN1 had water. Analytical results for these samples are summarized in Table 81; estimated flow rates and residence times corresponding to those sample dates are provided below in Table 82. For comparison, several additional values are provided that correspond to samples collected in 2008 and 2009. These data clearly show the change in conditions at the MSPTS in 2010: with the exception of the April 2010 figures, which are lower due to the series flow configuration that applied at that time and to the clogged media that acted to hold back the flow, flow rates in 2008 and 2009 were most often well below those in 2010, and as a result, the residence times were significantly longer. If the April 2010 values are omitted, the average flows for the 2010 samples (that is, an overall average of only those average flow figures corresponding to the samples collected over the year) are more than twice the flows in 2008, and more than 50 percent higher than those in 2009. Similarly, the average residence times (again, omitting the clog-related April data) for 2010, again averaging only the residence times estimated for the sample dates, are less than half the corresponding figure in 2008, and about 60 percent of the average for 2009 samples. Conditions such as these almost certainly would have challenged the MSPTS even if the treatment cells contained fresh ZVI, particularly given the high concentrations of recalcitrant compounds in MSPTS influent.

Table 81. Summary of Results From RFLMA and non-RFLMA Locations Used to Evaluate MSPTS

Constituent (RFLMA standard)	Month (2010)	R1-O (influent)	R2-E (effluent)	MSPTSCHAN1	MSPTSCHAN2	GS10
Chloroform (3.4)	June	0.46 (J)	**9.9**	1	0.54 (J)	0.49 (J)
	July	**22**	3.3 (J)	0.87 (J)	0.19 (J)	0.18 (J)
	Aug	**15**	**3.5**	NF	NF	ND
	Sept	**27**	3	NF	NF	ND
	Oct	**49**	**3.4**	1.2	NF	ND
cis-1,2-DCE (70)	June	**110**	**1800**	**160**	**84**	70
	July	**2800**	**790**	**200**	36	42
	Aug	**1700**	**960**	NF	NF	25
	Sept	**2200**	**690**	NF	NF	20
	Oct	**3700**	**590**	**300**	NF	11
PCE (1—PQL)	June	**8.7**	**29**	**2.4**	**1.2**	0.93 (J)
	July	**74**	**11**	**3.4**	0.57 (J)	0.62 (J)
	Aug	**44**	**20**	NF	NF	0.34 (J)
	Sept	**88**	**11**	NF	NF	ND
	Oct	**270**	**6.5**	**2.1**	NF	ND
TCE (2.5)	June	**9.3**	**77**	**7.3**	**3.8**	**2.8**
	July	**230**	**40**	**12**	2.2	2.2
	Aug	**160**	**84**	NF	NF	1.8
	Sept	**350**	**93**	NF	NF	2.2
	Oct	**810**	**100**	**40**	NA	1.3
Meth. Chloride (4.6)	June	0.39 (JB)	**5.6 (JB)**	0.62 (JB)	0.49 (JB)	0.49 (JB)
	July	**7.7 (J)**	**6.4**	0.83 (J)	0.36 (J)	0.36 (J)
	Aug	3.1 (JB)	4.3 (B)	NF	NF	ND
	Sept	ND	ND	NF	NF	ND
	Oct	ND	2.2	1	NF	ND
VC (0.2—PQL)	June	ND	**270**	**7.7**	**2.6**	**0.69 (J)**
	July	**70**	**40**	**13**	**0.6 (J)**	ND
	Aug	ND	**160**	NF	NF	ND
	Sept	**9**	**130**	NF	NF	ND
	Oct	**64**	**75**	**16**	NF	ND
1,1-DCE (7)	June	2.2	**24**	1.9	0.91 (J)	0.58 (J)
	July	**42**	**8.5**	2.1	0.33 (J)	0.24 (J)
	Aug	**22**	**12**	NF	NF	ND
	Sept	**43**	**10**	NF	NF	ND
	Oct	**68**	**7.5**	2.3	NF	ND

Notes: Constituents and corresponding RFLMA Table 1 values are as indicated. GS10 is surface water performance location. See text for descriptions of non-RFLMA locations MSPTSCHAN1 and MSPTSCHAN2. Shaded, bold values exceed corresponding RFLMA Table 1 value. NF = no flow (unable to sample). ND = nondetect. J = result is estimated; B = constituent was also detected in the blank.

Table 82. Flow Rates and Residence Times at the MSPTS in 2008, 2009, and 2010

MSPTS				
Sample Date	**Flow (avg., gpm)**	**Flow (annual avg. sample dates, gpm)**	**Estimated HRT (hours)**	**HRT (annual avg. sample dates, hours)**
4/29/2008	0.71	0.54	128.80	182.62
11/11/2008	0.38		236.44	
4/21/2009	1.12	0.85	80.78	118.01
10/26/2009	0.58		155.25	
4/27/2010	0.17[a]	1.36[b] (1.16)	528.00[a]	72.36[b] (148.30)
6/22/2010	2.27		39.75	
7/28/2010	1.08		84.00	
8/26/2010	1.23		73.50	
9/29/2010	1.02		89.11	
10/28/2010	1.20		75.46	

Notes: avg. = average; gpm = gallons per minute; annual avg. sample dates = average of the values corresponding to the samples listed for that year (not a true annual average for the year); HRT = hydraulic residence time. Average flow and corresponding HRT calculated from flow data corresponding to the specific sample date.

[a] Cell 1 was clogged, restricting water from flowing through the system; flow configuration was changed after this date, allowing water to flow through the cells more rapidly.

[b] Figure omits the anomalous value of April 27; value in parentheses corresponds to average calculated with that value included.

The GS10 sample results were evaluated in accordance with RFLMA Attachment 2, Figure 11. The concentrations do not exceed the 85th percentile of the results for the corresponding RFLMA standards in Attachment 2, Table 1.

These results demonstrate that residual VOCs in system effluent dissipate very quickly. As noted, the media at the MSPTS will be replaced in early 2011. Fresh media should significantly improve the treatment effectiveness at this system. Even so, due to the detections of VOCs in the effluent and the fact that the MSPTS was not designed to treat elevated concentrations of recalcitrant daughter products of chlorinated ethenes, the addition of an effluent polishing component was considered. The intent would be to further reduce residual concentrations of VOCs present in MSPTS effluent.

The effort to design an appropriate polishing component began in the latter half of 2010. The initial focus was on an engineered riffle system, such as that comprising the PLFTS. Design documents and calculations were reviewed for that system and used to draft a preliminary scale of an MSPTS polishing component. Outside expertise was secured via a firm experienced with air stripping technologies and theory. Staff for LM and the outside firm developed additional formulae and calculations that significantly expanded the scale of this component. The design criteria included a 3 gpm flow (which actually represents an estimated maximum that would only apply for a short duration) and the worst-case effluent concentrations in Table 79 and Table 81. Several resulting design options were generated and considered, varying based on such parameters as desired or available slope, the number and configuration (height and width) of the individual aerating steps, and the overall length of the unit; environmental conditions also affected the design, primarily with respect to the wind speed. For example, assuming a 10 mph wind speed, one design for a riffle system to provide polishing for such a flow would be approximately 8 feet wide, 60 feet long and include 37 steps, each 3 inches high. Although it would be desirable to cover the unit with grating to enhance safety and reduce the amount of

windblown debris that might accumulate on the steps, this would reduce the effective wind speed, requiring either omission of the grating or compensation via a larger riffle component. In addition, flows would be limited to 1 millimeter in depth, and the drip edge on each step—i.e., where the flow would depart one step and drop to the next—was of paramount importance in achieving the necessary turbulence and aeration. All of these requirements and the overall size added up to a polishing component that would be much larger and costly, and require much more maintenance, than was envisioned for a "passive" addition. One cost estimate, for example, was approximately $100,000 for construction alone, without grating, specialized drip edges, other additions that might be desired for maintenance or health and safety, or the associated operation and maintenance required.

The focus then moved to a more "off-the-shelf" alternative: a readily-available, prefabricated stacking tray or tower air stripper. The same flow and concentration figures were used to determine that the cost of the air stripper itself would be very reasonable—in the several thousand dollar range—but the cost for the solar power infrastructure required to support the associated blowers and pumps would be on the order of $375,000. This was infeasible, even without considering the cleaning and other maintenance needed for such a system.

Although polishing was desired, the alternatives described above were not feasible. Therefore, a third alternative was developed. First, standard landscaping mist nozzles and hose were used with a hand-held photoionization detector (PID) used for health-and-safety purposes to monitor breathing air for VOCs. Water from a treatment system was sprayed through the nozzles into a bucket, and the headspace was monitored with the PID to confirm that VOCs were being volatilized. As 2010 ended, this approach was being developed for additional testing; the intent was to install a successfully tested unit within the existing MSPTS effluent manhole and use a solar-powered pump to spray the water. Rather than design for worst-case flow and water quality, the unit would be tested and optimized in place under actual conditions. With respect to the two options described above, costs would be comparably low, and therefore the overall unit would be feasible to install and would provide improvements to the effluent water quality. The intent was to devise and test a near-scale unit, then install a more permanent air stripper informed by these test results as a part of the media replacement activity scheduled to be completed by March 31, 2011. Additional information, discussion, and resulting operational data from the air stripper will be provided in the 2011 Annual Report.

East Trenches Plume and Treatment System

The East Trenches Plume is an area of groundwater contamination named after several buried disposal trenches that contribute VOCs to groundwater. These trenches are located on the pediment south of South Walnut Creek, in former OU 2. The source of this plume is residual VOC contamination associated predominantly with Trenches T-3 and T-4, which were remediated in 1996. In addition, a portion of the 903 Pad Plume flows from its source area toward the northeast and merges with the East Trenches Plume. A treatment system (the ETPTS) was installed in 1999 to intercept and treat contaminated groundwater flowing toward the B-series ponds and South Walnut Creek.

East Trenches Plume

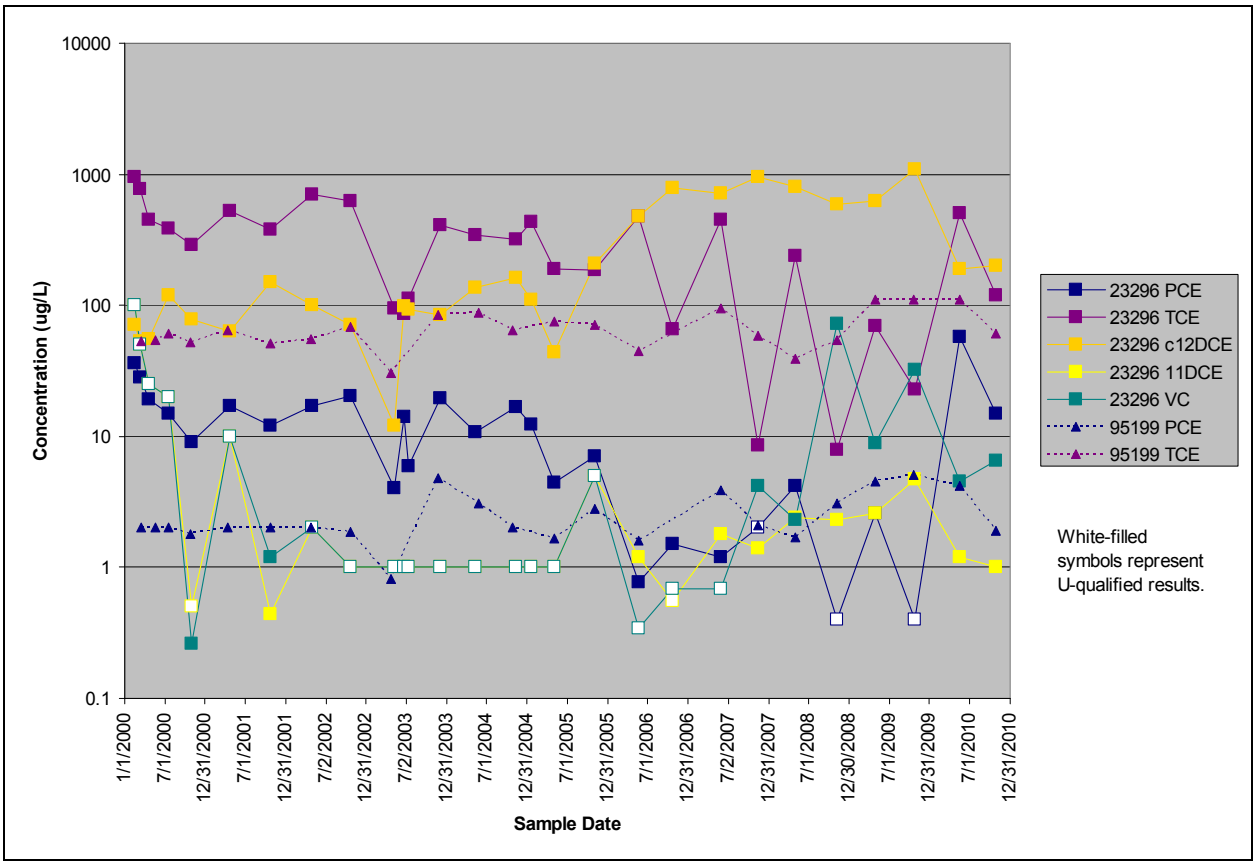
Evaluation wells 3687 and 05691 monitor the primary source areas of the East Trenches Plume, Trenches T-3 and T-4, respectively. More distal portions of the plume are monitored by Evaluation well 03991 and Sentinel well 04091 to the east-northeast. Sentinel wells 95099, 95199, 95299, and 23296 monitor the ETPTS and downgradient portions of the plume along South Walnut Creek. AOC well 00997, situated at the mouth of Pond B-5 in the South Walnut Creek drainage, also supports monitoring of this plume. Well 00191 monitors groundwater closest to the source area of the 903 Pad Plume and is discussed in the context of the 903 Pad/Ryan's Pit Plume later in this section.

All of the East Trenches Plume Evaluation wells were sampled once in 2010, and all Sentinel wells and the AOC well at Pond B-5 were sampled twice in 2010. Analytical data for these wells in 2010 were generally consistent with those from recent years.

Of the wells sampled along South Walnut Creek in support of the East Trenches Plume, well 95299 was dry, and RFLMA Table 1 standards were exceeded in samples from wells 23296 and 95199. This is consistent with past conditions, as is the fact that samples from well 23296 contained the highest concentrations of VOCs of this group of wells.

Figure 210 displays three VOCs that, since 2007, have been most commonly detected in one or both of wells 23296 and 95199 at concentrations exceeding the corresponding RFLMA action level: TCE, *cis*-1,2-DCE, and VC. Also displayed are PCE and 1,1-DCE at well 23296, and PCE at well 95199. Concentrations of *cis*-1,2-DCE in samples from well 23296 show a fairly gradual increase at this logarithmic scale, though the 2010 concentrations decrease to levels last observed in 2005; a somewhat similar pattern is also evident in concentrations of 1,1-DCE. (Statistical calculations confirm the visual appearance of trends in samples from well 23296, as noted in Table 77: S-K calculations indicate 95 percent significant increasing trends are present in 1,1-DCE and both 1,2-DCE isomers. In addition, similarly significant decreasing trends are calculated for carbon tetrachloride, chloroform, PCE, and TCE.) Conversely, compared with data for samples collected prior to about 2007 from well 23296, more recent concentrations of TCE, PCE, and VC have varied sharply from sample to sample. A seasonal pattern is apparent. Concentrations of VC are seen to vary inversely with those of PCE and TCE: concentrations of TCE and PCE are relatively higher, and concentrations of VC are relatively lower in the second calendar quarters, and then in the fourth quarters this is reversed. This may be attributed to seasonal effects on biodegradation, wherein reduced recharge in the fourth quarter allows waters to become more locally reducing; these geochemical conditions would be expected to promote increased levels of reductive dechlorination of parent compounds. The second quarter may be marked by more frequent precipitation and consequently greater amounts of oxygenated recharge, which would act to reduce this dechlorination and potentially flush contaminants into the saturated zone. However, given that *cis*-1,2-DCE and 1,1-DCE are intermediate metabolic byproducts between the parent compounds (PCE and TCE) and the final chlorinated byproduct (VC), one might expect those intermediate constituents to also reflect a seasonal pattern rather than that described above. Additional factors, therefore, must be affecting the concentrations reported in samples from well 23296. An alternative explanation may be that residual PCE and TCE are mobilized during relatively higher-water second quarters, increasing the relative concentrations of these constituents compared to that of VC. This explanation would require that these higher-water flows also contribute sufficient *cis*-1,2-DCE and 1,1-DCE to result in the

relatively uniform concentrations apparent in these constituents. Additional monitoring data may help to clarify factors affecting contaminant concentrations observed in groundwater samples from well 23296.



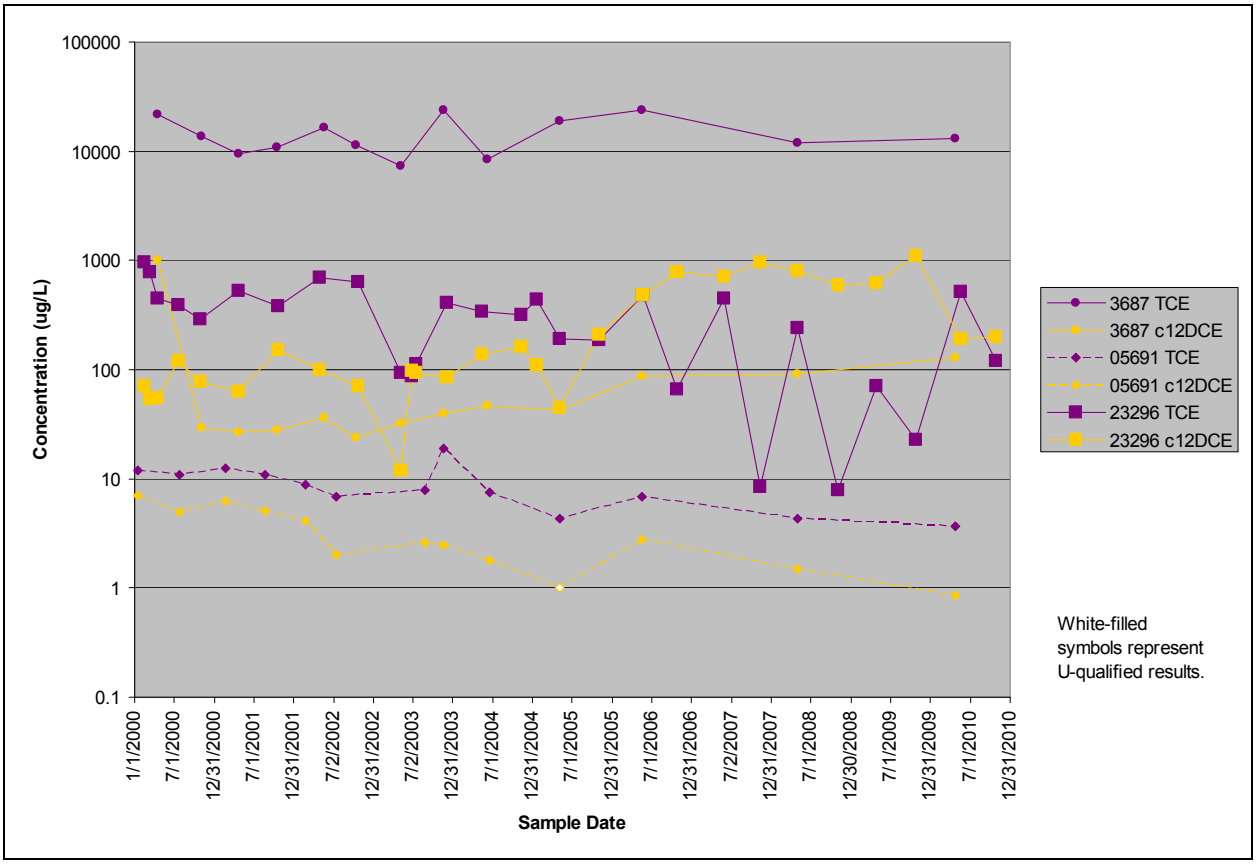
Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; c12DCE = *cis*-1,2-DCE, 70; 1,1-DCE = 7; VC, 0.2. Several results are qualified ("J," "D"), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 210. Most Commonly Detected VOCs in Sentinel Wells Downgradient of the ETPTS

Concentrations of PCE and TCE in samples from well 95199 have been much more uniform than concentrations of constituents discussed above in well 23296, although an increasing trend in PCE concentrations at the 95 percent statistical significance is calculated for this well (Table 77). Little *cis*-1,2-DCE, 1,1-DCE, VC, or other metabolic byproducts from the degradation of PCE and TCE are reported in samples from well 95199. This well is deeper and a bit farther from flowing surface water than well 23296, and although both monitor groundwater within the unconsolidated surficial materials, this physical separation from the more sharply varying near-surface conditions may help to explain these differences. The location of well 23296 at the valley bottom may also provide additional organic carbon in the subsurface materials to support increased biodegradation.

Figure 211 illustrates how concentrations of a common solvent compound (TCE) and daughter product (*cis*-1,2-DCE) vary from the source area wells (Evaluation wells 3687 and 05691) to downgradient Sentinel well 23296. Concentrations of TCE are highest in samples from source-area well 3687 and have remained relatively consistent over the RFLMA period of record.

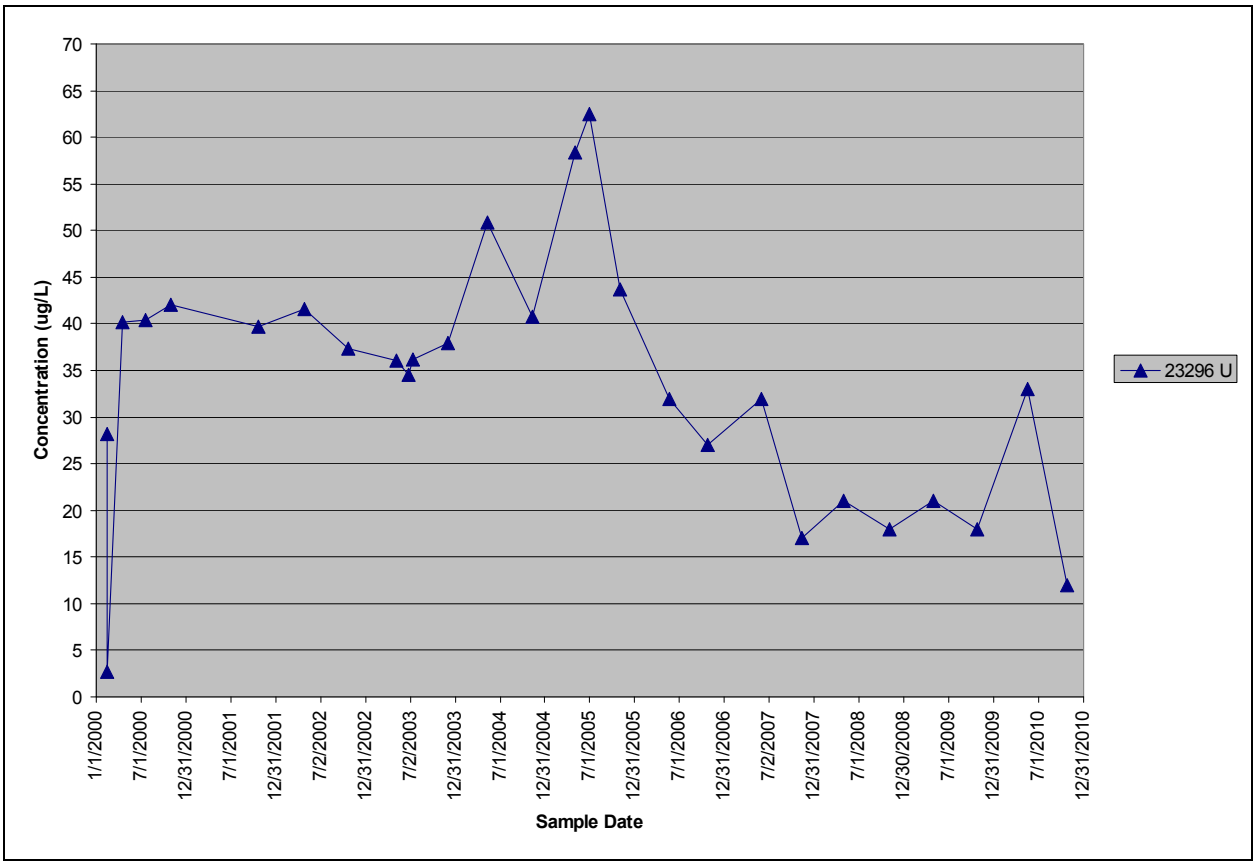
Conversely, concentrations of TCE in samples from well 05691 are several orders of magnitude lower and appear to be on a decreasing trend; this trend is confirmed by S-K trending results (Table 77) to meet the 95 percent level of significance. Concentrations of the daughter product *cis*-1,2-DCE in samples from these two source-area wells also differ in magnitude and trend: statistically significant trends are calculated for this constituent at each of these wells, but the trend is increasing in samples from well 3687 (as is that of 1,1-DCE, another daughter product on the same degradation pathway), and decreasing in samples from well 05691. As shown on Figure 211, by 2010 these opposing trends had led to a difference in *cis*-1,2-DCE concentrations of approximately two orders of magnitude (higher in well 3687, lower in well 05691).



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): TCE, 2.5; c12DCE = *cis*-1,2-DCE, 70. In addition to nondetects (U-qualified results), several other results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 211. Comparison of VOCs in East Trenches Source Area Wells and Downgradient Well 23296

Sentinel well 23296 is also monitored for U, for which S-K statistical calculations now indicate a decreasing trend with a 95 percent level of significance (Table 77). A decreasing trend was also indicated in calculations performed for the 2009 Annual Report (DOE 2010d), but the trend did not meet this level of significance. Figure 212 provides a time-series plot of U concentrations in samples from well 23296. With the exception of what appear to be seasonal increases in U concentrations in the second quarters of 2004, 2005, and 2010 (possibly 2007 as well)—none of which approach or exceed the U threshold of 120 µg/L—the visually apparent downward trend is fairly consistent. The results from 2004 and 2005 are most likely affected by closure activities, while the results from 2010 may reflect seasonal effects.



Note: U= uranium; applicable RFLMA value (µg/L; DOE 2007a) is the groundwater threshold of 120 µg/L.

Figure 212. Concentrations of Uranium in Samples From Well 23296

Evaluation well 03991, located near the eastern edge of the East Trenches Plume, was sampled in 2010 for analysis of VOCs. Data were generally consistent with previous results. Decreasing trends that meet the 95 percent level of statistical significance (Table 77) were identified for carbon tetrachloride, chloroform, PCE, and TCE. Of these, carbon tetrachloride is the constituent that has exceeded the corresponding RFLMA Table 1 value of 1 µg/L (the PQL). In 2010, the concentration at this well was measured at 3.5 µg/L, the lowest yet measured; the range has been 3.5 µg/L to 13 µg/L.

Sentinel well 04091 is located on the eastern edge of the East Trenches Plume and was sampled twice in 2010. No VOCs were detected in either sample. Samples from this well are represented by significant (at the 95 percent confidence level) decreasing trends for carbon tetrachloride and PCE. These constituents were most recently detected in samples from well 04091 in 2007.

AOC well 00997 is located near the inlet to Pond B-5. This well was sampled twice in 2010 (May and October). All constituents were below the RFLMA Table 1 levels or uranium threshold. No VOCs were detected. U was detected at concentrations of 18 µg/L in May and 14 µg/L in October, which is within the typical range at this well. Nitrate is also analyzed at this location, and in 2010 the results were 0.025 mg/L (estimated, J-qualified) in the second-quarter sample and nondetect in the fourth-quarter sample.

East Trenches Plume groundwater will continue to be monitored in accordance with RFLMA. As more data are collected, additional significant trends should become evident.

East Trenches Plume Treatment System

The ETPTS was installed in 1999. Its design is very similar to that of the MSPTS. However, the intercept trench for the ETPTS is 1,200 feet long, compared to the 220-foot-long MSPTS trench. The longer trench is required to intercept the broader East Trenches Plume as it flows toward South Walnut Creek and the B-series ponds.

The ETPTS treated approximately 1,606,000 gallons of water in 2010, almost four times the volume treated in 2009 and similar to the volumes treated in each of the final two pre-closure years, 2004 and 2005 (Table 83). This very large increase reverses the pattern of overall decreasing flows observed since closure and is attributed to the very wet spring and resulting groundwater recharge that continued to feed the system through the year. Figure 213 presents a hydrograph showing ETPTS flow estimates since January 2000. (Refer to the 2009 Annual Report [DOE 2010d] for information on correction of anomalous flows previously reported for the year 2006). The higher flows in 2010 are clearly evident on this figure.

Figure 214 provides a hydrograph for CY 2010 at the ETPTS and shows the effects of the higher precipitation and the lengthy discharge period that resulted. The potentiometric surface maps presented and discussed in Section 3.1.3.5 provide additional evidence of this recharge in the form of a higher water table.

Table 83. Estimated Volumes of Water Treated by the ETPTS

Calendar Year	Annual Estimates of Volume Treated (gallons)	Estimated Cumulative Volume Treated (gallons)
2000	1,633,000	2,800,000
2001	1,900,000	4,700,000
2002	≤1,000,000	5,700,000
2003	2,100,000	7,800,000
2004	1,500,000	9,300,000
2005	1,800,000	11,100,000
2006	675,000	11,775,000
2007	951,000	12,726,000
2008	629,000	13,355,000
2009	406,000	13,761,000
2010	1,606,000	15,367,000

Note: Estimates for years 2000 through 2004 are compiled from K-H (2000a, 2000b, 2000c, 2000d, 2002, 2003, 2005a, 2005b).

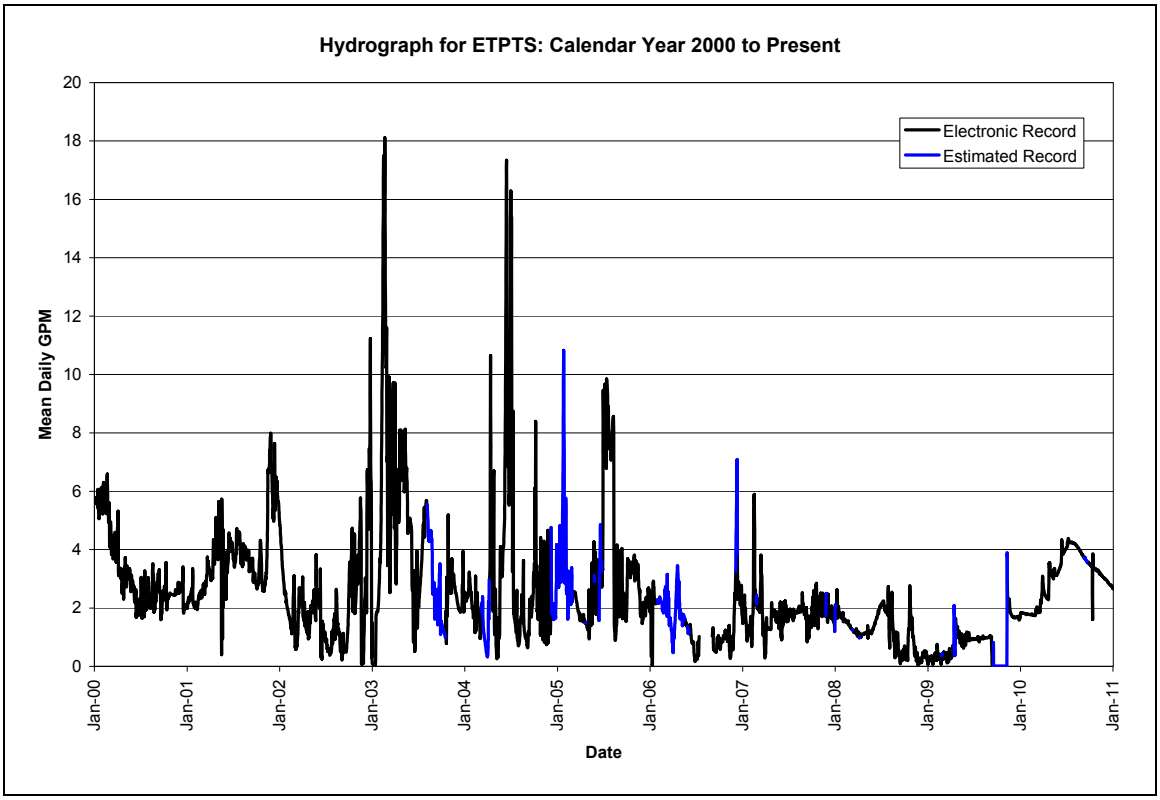


Figure 213. Hydrograph for ETPTS From 2000 through 2010

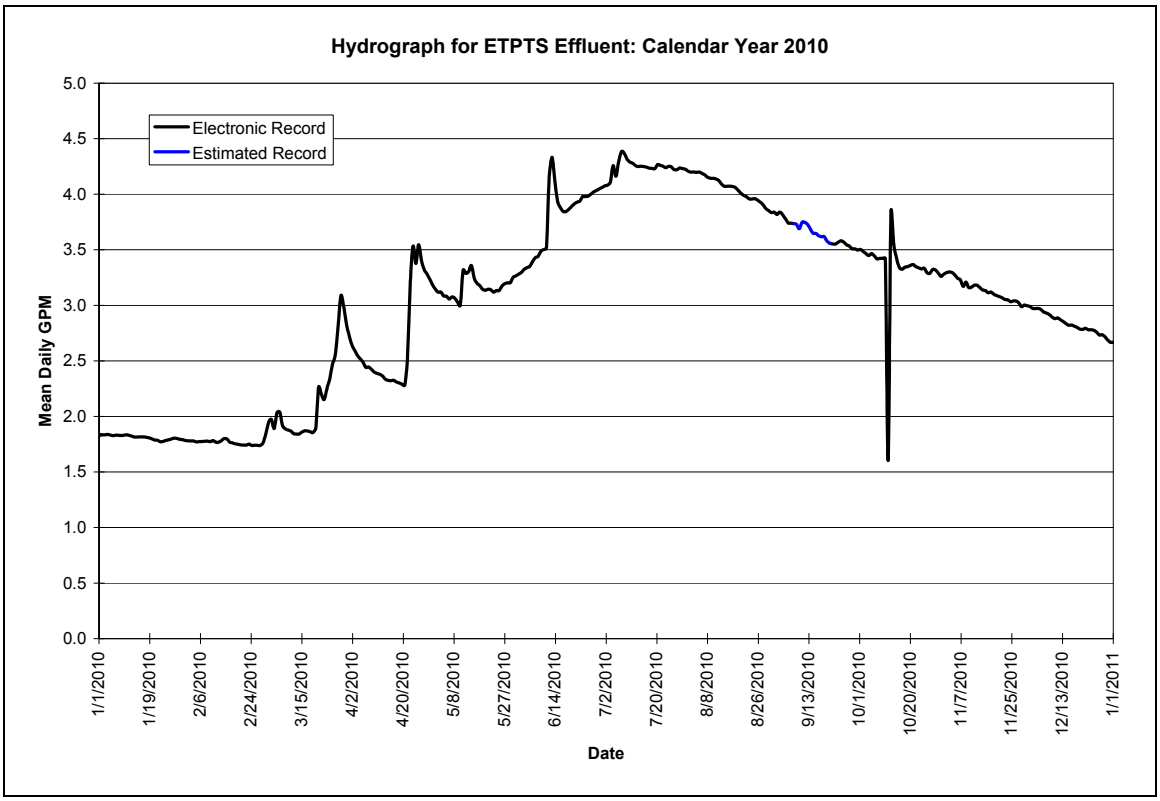


Figure 214. Hydrograph for ETPTS for CY 2010

Routine maintenance activities at the ETPTS were conducted through 2010, as discussed in Section 2.5. The ETPTS was sampled twice in 2010 for routine RFLMA requirements (May and October), and four additional times (June, July, August, and September) to support an evaluation similar to that described above for the MSPTS. This activity is discussed in greater detail below and in Contact Record 2010-07.

ETPTS effluent water quality in 2010 continued to reflect a dramatic reduction in VOC load, but some VOCs were detected in the effluent. Even though the media was replaced in late 2009, system effluent contained some VOCs at concentrations exceeding the respective RFLMA Table 1 values. The higher flow rates described above and illustrated on Figure 213 and Figure 214 would have reduced residence times and corresponding levels of treatment that would have extended through the fourth quarter. A summary of the VOCs that most commonly exceed RFLMA Table 1 values in system influent, plus *cis*-1,2-DCE and VC as dechlorination-related constituents, is presented in Table 84; refer to quarterly reports (DOE 2010c, 2010e, 2011b) and Appendix B.6 for additional data from 2010.

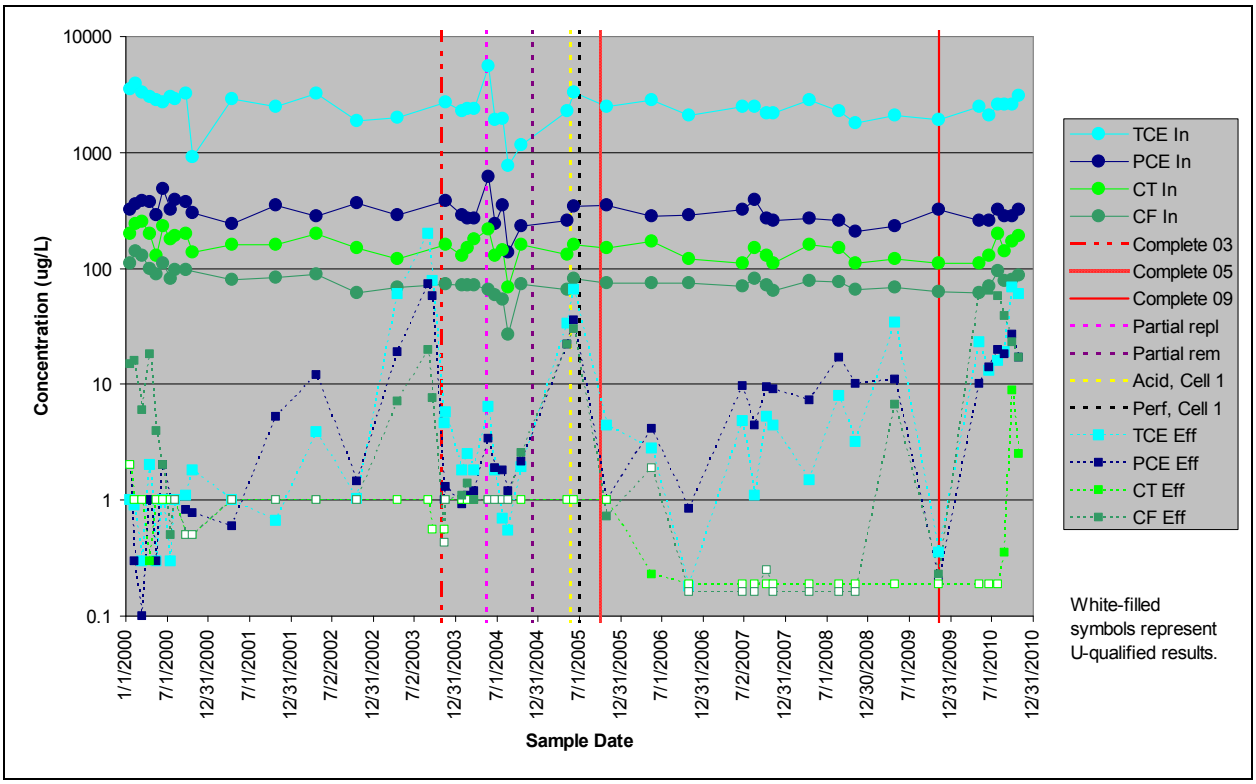
Table 84. Summary of Recent VOC Data From ETPTS Influent and Effluent

DATE	CT		CF		MCl		PCE		TCE		Cis-1,2-DCE		VC	
	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef
1/28/2004	**130**	1 (U)	**71**	1.1	5 (U)	**20**	**290**	0.93 (J)	**2300**	1.8	40	9.5	5 (U)	1 (U)
2/25/2004	**150**	1 (U)	**71**	1.4	2.7 (JB)	**19 (B)**	**270**	1.1	**2400**	2.5	40	10	10 (U)	1 (U)
3/22/2004	**180**	1 (U)	**71**	1	2.6 (JB)	**21**	**270**	1.2	**2400**	1.8	39	9.7	6.7 (U)	**0.39 (J)**
5/26/2004	**216**	1 (U)	**65.1**	1 (U)	1 (U)	**17**	**618 (D)**	3.38	**5510 (D)**	**6.36**	28	11.5	1 (U)	1 (U)
6/22/2004	**130**	1 (U)	**59**	1 (U)	**6.7 (JB)**	**14 (B)**	**240**	1.9	**1900**	1.8	29	8	10 (U)	1 (U)
7/29/2004	**142 (D)**	1 (U)	**54.1**	1 (U)	2.3	**14.1 (B)**	**354 (D)**	1.8	**1960 (D)**	0.69 (J)	29.4	7.7	1 (U)	1 (U)
8/19/2004	**68.1**	1 (U)	**26.6**	1 (U)	1 (U)	**13.7**	**137 (D)**	1.2	**774 (D)**	0.55 (J)	13.3	7.4	1 (U)	1 (U)
10/20/2004	**160**	1 (U)	**72.9**	2.56	1 (U)	**15.6**	**230 (D)**	**2.13**	**1170 (D)**	1.91	32.6	11.3	1 (U)	1 (U)
5/12/2005	**131**	1 (U)	**66**	**22.2**	1 (U)	**14.6**	**256 (D)**	**21.9**	**2280 (D)**	**33.1**	30.4	36.4	1 (U)	1 (U)
6/7/2005	**160**	1 (U)	**81**	**30**	10 (U)	**22 (B)**	**340**	**36**	**3300**	**66**	33	44	10 (U)	1 (U)
11/2/2005	**151**	1 (U)	**74.8**	0.73 (J)	250 (U)	**18.2**	**350**	1 (U)	**2500**	4.4	50.7	39.6	50 (U)	**1.2**
5/17/2006	**170**	0.23 (J)	**75 (J)**	1.9	0.32 (U)	**32**	**280**	4.1	**2800**	2.8	46	27	0.17 (U)	**0.77 (J)**
10/31/2006	**120**	0.19 (U)	**75**	0.16 (U)	6.4 (U)	0.32 (U)	**290**	0.85 (J)	**2100**	0.18 (J)	40 (J)	4.3 (J)	3.4 (U)	0.17 (U)
6/26/2007	**110**	0.19 (U)	**70**	0.16 (U)	1.6 (U)	0.32 (U)	**320**	**9.7**	**2500**	4.8	30	40	0.85 (U)	**1.2**
8/16/2007	**150**	0.19 (U)	**81**	0.16 (U)	**8 (JB)**	0.73 (JB)	**390**	4.4	**2500**	1.1	32	51	2.7 (U)	**1.7**
10/9/2007	**130**	0.19 (U)	**71**	0.25 (J)	3.2 (U)	1.7	**270**	**9.5**	**2200**	**5.3**	34	22	1.7 (U)	**0.43 (J)**
11/8/2007	**110**	0.19 (U)	**64**	0.16 (U)	3.2 (U)	0.32 (U)	**260**	**9.1**	**2200**	4.4	32	21	1.7 (U)	**0.46 (J)**
4/16/2008	**160**	0.19 (U)	**78**	0.16 (U)	**36 (B)**	1.5 (B)	**270**	**7.3**	**2800**	**1.5**	43	30	7.6 (U)	**1**
8/25/2008	**150**	0.19 (U)	**77**	0.16 (U)	1.6 (U)	0.89 (J)	**260**	**17**	**2300**	**7.9**	42	20	1.9 (U)	0.38 (U)
11/5/2008	**110**	0.19 (U)	**66**	0.16 (U)	**9.7 (J)**	0.88 (J)	**210**	**10**	**1800**	**3.2**	31	16	3.8 (U)	**0.5 (J)**
4/28/2009	**120**	0.19 (U)	**68**	**6.7 (J)**	8.9 (U)	4.5 (U)	**230**	**11 (J)**	**2100**	**34**	30	45	3.8 (U)	0.38 (U)
11/12/2009	**110**	0.19 (U)	**63 (J)**	0.23 (J)	0.32 (U)	**6.3 (J)**	**320**	0.2 (U)	**1900**	0.35 (J)	36	0.3 (J)	0.4 (U)	0.4 (U)
5/6/2010	**110**	0.19 (U)	**62**	**63**	2.3 (U)	**8.2 (B)**	**260**	**10**	**2500**	**23**	30	57	2 (U)	0.4 (U)
6/22/2010	**130**	0.19 (U)	**70**	**64**	2.1 (U)	**8.4 (B)**	**260**	**14**	**2100**	**13**	34	55	2.7 (U)	0.4 (U)
7/28/2010	**200**	0.19 (U)	**95**	**57**	3.7 (J)	**15**	**320**	**20**	**2600**	**16**	43	55	4 (U)	**0.76 (J)**
8/26/2010	**140**	0.35 (J)	**78**	**39**	**5.8 (JB)**	**19 (B)**	**280**	**18**	**2600**	**19**	37	56	4 (U)	0.4 (U)
9/29/2010	**170**	**8.8**	**79**	**23**	1.6 (U)	**14**	**280**	**27**	**2600**	**68**	39	50	2 (U)	0.4 (U)
10/28/2010	**190**	**2.5**	**87**	**17**	1.3 (U)	**11**	**320 (*)**	**17**	**3100**	**60**	44 (J)	59	1.6 (U)	**0.84 (J)**

Notes: Constituents and their respective, applicable RFLMA levels (µg/L; DOE 2007a): CT = carbon tetrachloride, 5; CF = chloroform, 3.4; MCl = methylene chloride, 4.6; PCE, 5; TCE, 5; *cis*-1,2-DCE, 70; VC, 0.2. ET In = influent (ET INFLUENT), ET Ef = effluent (ET EFFLUENT). Shaded, bold value indicates detected concentration exceeds corresponding RFLMA standard. Lab qualifiers: J = estimated value; U = analyte not detected at the indicated concentration; B = chemical was also detected in the blank; D = analysis was performed at a dilution.

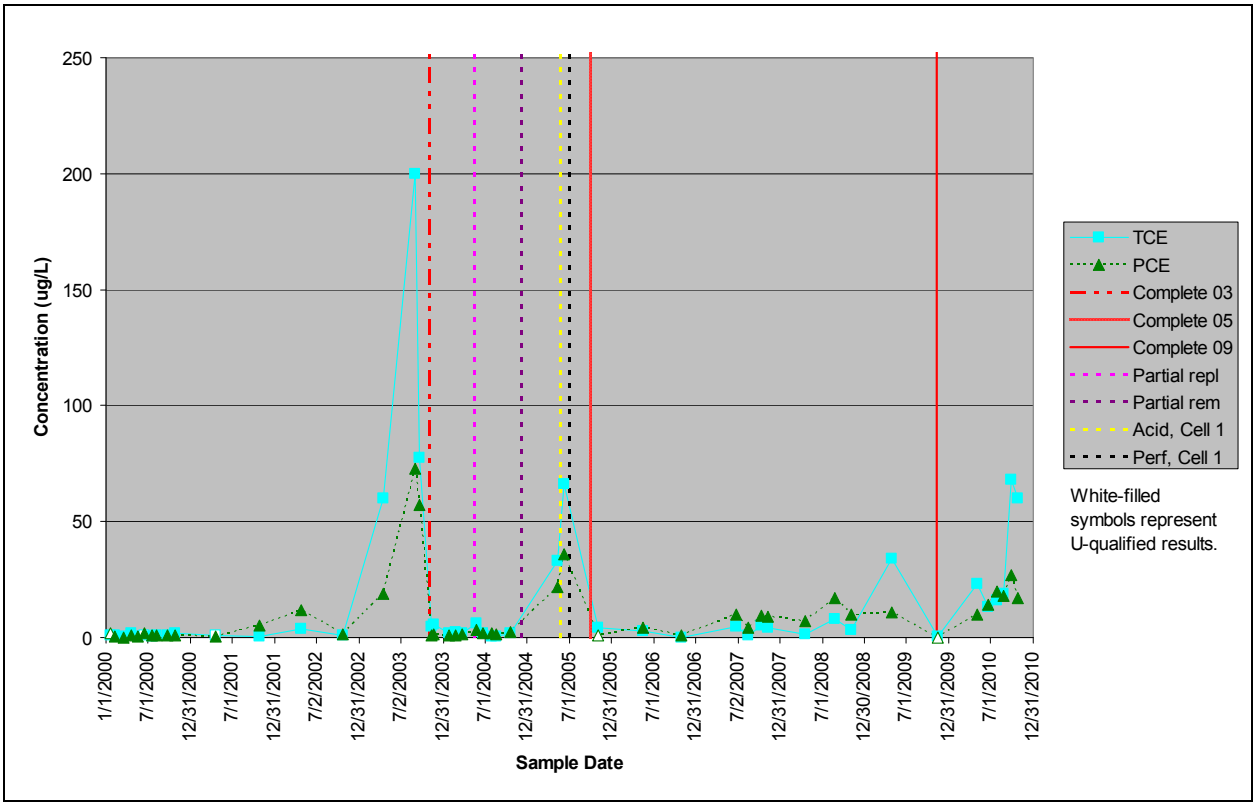
Several of the primary VOCs present in ETPTS influent are presented in the time-series plots in Figure 215. This figure is crowded, but it illustrates several conditions. First, influent concentrations have remained fairly consistent since 2000 for each of the VOCs illustrated. (However, note the slight increase in 2010, potentially related to enhanced mobilization of residual contaminants in the vadose zone because of the wetter conditions.) Conversely, concentrations in system effluent have varied widely, and not always with respect to media replacement or other maintenance activities. Although concentrations in system effluent demonstrate that the bulk of the VOCs is consistently removed from the influent, water quality of the effluent does not always meet treatment targets. These treatment targets—the RFLMA Table 1 values—have changed for some VOCs (carbon tetrachloride, PCE, and TCE, among others) since the end of 2009 when several Temporary Modifications terminated and the underlying standards became applicable.

Figure 216 provides a time-series plot showing only TCE and PCE in system effluent.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; CT, 1; CF, 3.4. Complete (year abbreviation) = year in which complete media replacement was performed; Partial repl = partial media replacement (May 2004); Partial rem = partial media removal (December 2004); Acid, Cell 1 = acid treatment of Cell 1 media (May 2005); Perf, Cell 1 = perforation of Cell 1 media crust (June 2005). Dates for some activities are rounded to the month. Several results are qualified ("J," "D"), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

Figure 215. Primary VOCs in ETPTS Influent and Effluent



Notes: Complete (year abbreviation) = year in which complete media replacement was performed; Partial repl = partial media replacement (May 2004); Partial rem = partial media removal (December 2004); Acid, Cell 1 = acid treatment of Cell 1 media (May 2005); Perf, Cell 1 = perforation of Cell 1 media crust (June 2005). Dates for some activities are rounded to the month. Constituents and their respective RFLMA Table 1 standards (µg/L; DOE 2007a): TCE, 2.5; PCE, 1. In addition to nondetects (U-qualified results), several other results were J-qualified but for simplicity are not shown differently.

Figure 216. TCE and PCE in ETPTS Effluent

The performance monitoring location for the ETPTS is POM2, which is located in Pond B-4. Sampling at this location in support of the ETPTS began in 2005. Grab samples were collected from POM2 in May, June, July, August, September, and October 2010. (This monthly frequency supported the RFLMA requirements as well as the evaluation outlined in Contact Record 2010-07.) Several samples reported detections of VOCs at less than 1 µg/L (Table 85). In all cases the concentrations were J-qualified (estimated) and below the applicable RFLMA Table 1 levels.

Table 85. Summary of VOCs Detected in 2010 at POM2

Date	Constituent	Result (µg/L)	Qualifier
5/6/2010	Chloroform	0.22	J
5/6/2010	*cis*-1,2-Dichloroethene	0.32	J
5/6/2010	Trichloroethene	0.38	J
6/22/2010	Chloroform	0.3	J
6/22/2010	*cis*-1,2-Dichloroethene	0.3	J
7/28/2010	Chloroform	0.3	J
7/28/2010	*cis*-1,2-Dichloroethene	0.24	J
9/29/2010	Trichloroethene	0.21	J

Additional evaluation sampling of the ETPTS was performed in 2010, as noted above. This sampling was very similar to that performed at the MSPTS and described above in the corresponding text. VOCs have been routinely detected in ETPTS effluent since the system was installed in 1999 and have been reported and discussed as the data are issued. These residual VOCs typically include low concentrations of parent compounds as well as some daughter products (Table 84). Concentrations in 2010 were elevated with respect to many previous data, which is attributed to the corresponding flow conditions. The presence of these VOCs is due primarily to inadequate residence time within the treatment media, which was exacerbated by the relatively higher flows (and corresponding lower residence times) observed in 2010. As discussed in the text for the MSPTS, some of the constituents detected in the effluent are recalcitrant and require more time within the ZVI media to be reductively dechlorinated.

The second quarter sample results, which are summarized above in Table 84 and are presented in full in DOE 2010e, led to consultation with CDPHE. (This consultation, summarized in Contact Record 2010-07, also included the subject of treatment at the MSPTS, which is discussed in the corresponding section above.) As at the MSPTS, at the ETPTS additional data were desired to assess how the VOC concentrations varied as the system effluent moved into the receiving drainage. To support this evaluation, two non-RFLMA sampling points were selected beyond the ETPTS discharge gallery: ETPTSDGOVER was located at the overflow of the discharge gallery for this system, and ETPTSB4 was located where this overflow enters former Pond B-4. These locations are illustrated in Figure 217.

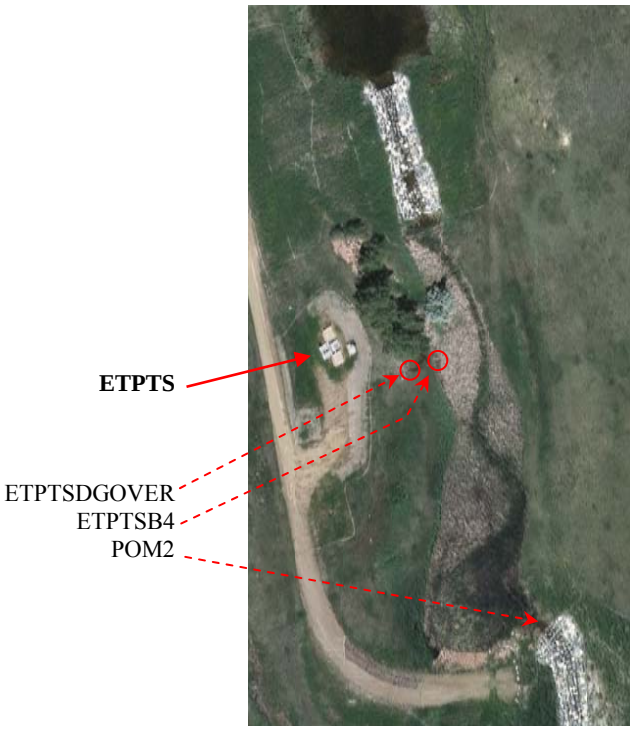


Figure 217. ETPTS With Approximate Locations of Extra Sampling Points With Respect to Treatment System and Surface Water Performance Location

In accordance with Contact Record 2010-07, additional samples were collected at the RFLMA locations and the extra locations identified above. This evaluation sampling occurred in June,

July, August, September, and October. During each event, each location was visited for sampling. Analytical results for these samples are summarized in Table 86. The estimated flow rates and residence times corresponding to those sample dates are provided below in Table 87. For comparison, several additional values are provided that correspond to samples collected in 2008 and 2009. These data clearly show how different conditions were at the ETPTS in 2010 compared to the two preceding years: without exception, flow rates in 2008 and 2009 were well below those in 2010, and the residence times in the earlier years were significantly longer. The average flows for the 2010 samples (i.e., an overall average of only those average flow figures corresponding to the samples collected over the year) are approximately four times higher than the 2008 average, and about twice that in 2009. Similarly, the average residence times for 2010 (again, averaging only the residence times estimated for the sample dates) are about a quarter of the corresponding figure in 2008, and under half the average for 2009 samples.

Table 86. Summary of Results From RFLMA and non-RFLMA Locations Used to Evaluate ETPTS

Constituent (RFLMA standard)	Month (2010)	ET Influent	ET Effluent	ETPTS DGOVER	ETPTS B4	POM2
Chloroform (3.4)	June	**70**	**64**	**60**	**10**	0.3 (J)
	July	**95**	**57**	**57**	**6.9**	0.3 (J)
	Aug	**78**	**39**	**39**	1.1	ND
	Sept	**79**	**23**	**18**	ND	ND
	Oct	**87**	**17**	**17**	ND	ND
PCE (1 - PQL)	June	**260**	**14**	**12**	**1.3**	ND
	July	**320**	**20**	**16**	**1.4**	ND
	Aug	**280**	**18**	**18**	0.94 (J)	ND
	Sept	**280**	**27**	**17**	0.53 (J)	ND
	Oct	**320**	**17**	**15**	0.99 (J)	ND
TCE (2.5)	June	**2100**	**13**	**11**	1.3	ND
	July	**2600**	**16**	**14**	1.5	ND
	Aug	**2600**	**19**	**19**	1.3	ND
	Sept	**2600**	**68**	**85**	**3.8**	0.21 (J)
	Oct	**3100**	**60**	**56**	**3.5**	ND
Meth. Chloride (4.6)	June	2.1 (JB)	**8.4 (B)**	**7.7 (B)**	1.6 (B)	ND
	July	3.7 (J)	**15**	**15**	2.8	ND
	Aug	**5.8 (JB)**	**19 (B)**	**19 (B)**	1.8 (B)	ND
	Sept	**ND**	**14**	**12**	ND	ND
	Oct	**ND**	**11**	**8.7**	ND	ND
VC (0.2 - PQL)	June	ND	ND	ND	ND	ND
	July	**0.76 (J)**	ND	**0.52 (J)**	ND	ND
	Aug	ND	ND	ND	ND	ND
	Sept	ND	ND	ND	ND	ND
	Oct	ND	**0.84 (J)**	**0.68 (J)**	ND	ND

Notes: Constituents and corresponding RFLMA Table 1 values are as indicated. POM2 is surface water performance location. See text for descriptions of non-RFLMA locations ETPTSDGOVER and ETPTSB4. Shaded, bold values exceed corresponding RFLMA Table 1 value. ND = nondetect. J = result is estimated; B = constituent was also detected in the blank.

Table 87. Flow Rates and Residence Times at the ETPTS in 2008, 2009, and 2010

ETPTS				
Sample Date	**Average Flow (gpm)**	**Flow (avg. sample dates, gpm)**	**Estimated HRT (hours)**	**HRT (est. avg. sample dates, hours)**
4/16/2008	1.08	0.93	131.59	156.68
8/25/2008	0.75		190.27	
11/5/2008	0.96		148.17	
4/28/2009	1.29	1.86	110.54	84.40
11/12/2009	2.43		58.25	
5/6/2010	3.09	3.67	46.00	39.17
6/22/2010	3.92		36.25	
7/28/2010	4.22		33.50	
8/26/2010	3.96		35.75	
9/29/2010	3.51		40.63	
10/28/2010	3.32		42.92	

Notes: avg. = average; gpm = gallons per minute; annual avg. sample dates = average of the values corresponding to the samples listed for that year (not a true annual average for the year); HRT = hydraulic residence time. Average flow and corresponding HRT calculated from flow data corresponding to the specific sample date.

The sample results were evaluated in accordance with RFLMA Attachment 2, Figure 11. The concentrations do not exceed the 85th percentile of the results for the corresponding RFLMA standards in Attachment 2, Table 1.

These results demonstrate that the residual VOCs in system effluent dissipate very quickly and do not represent a threat to surface water quality. Results from samples collected at POM2 show that the applicable RFLMA standards are being met consistently at this surface water performance location. The media at the ETPTS was replaced in 2009. The objective of the ETPTS is to protect surface water quality, and in this respect the system is performing adequately. Even so, efforts to optimize system performance will continue.

Solar Ponds Plume and Treatment System

The Solar Ponds Plume (SPP) is an area of elevated nitrate and U concentrations in groundwater. (**Note:** The analytical data report concentrations of nitrate+nitrite as nitrogen; this is typically referred to herein simply as nitrate.) Liquid wastes generated during the production era were stored in the former Solar Evaporation Ponds (SEPs), which were located on the pediment in the northeastern portion of the former IA. Leakage from these ponds over the years is the source of the groundwater plume. The following paragraphs describe the plume, the treatment system installed to address this contamination, and activities conducted in 2010 at this system.

Solar Ponds Plume

Groundwater in the SEP area is contaminated with nitrate and U. Groundwater in the westernmost portion of this area, generally coinciding with the location of former Pond 207C, is also contaminated with VOCs. However, due to the more localized nature of VOC contamination, it is not considered part of the SPP, but rather as a separate plume.

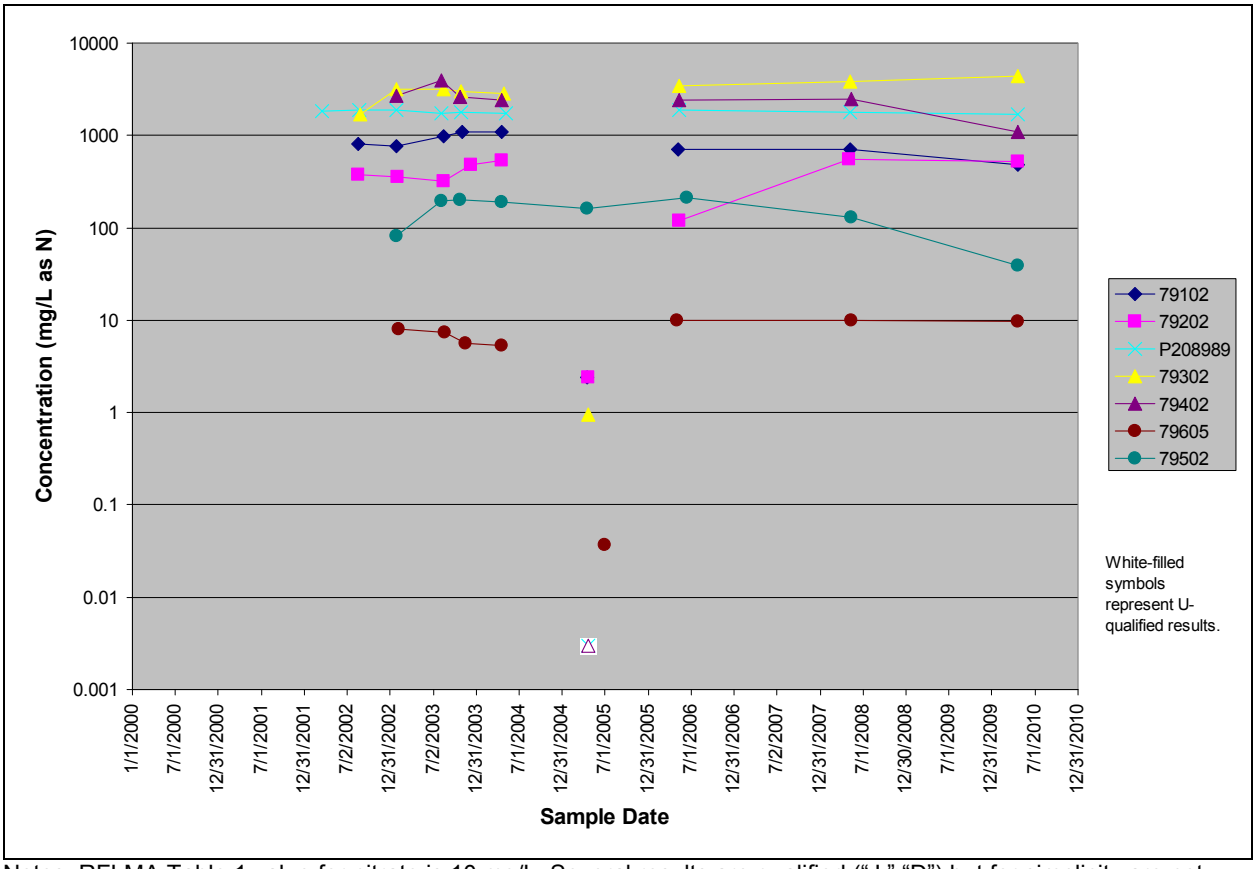
The source area of the SPP (the former SEPs) is monitored by a line of eight Evaluation wells installed immediately downgradient of the SEPs (generally along the north, east, and south sides of the former SEPs). Another Evaluation well is positioned at the south edge of former Pond 207C, in the vicinity of the VOC source area. This distribution effectively monitors groundwater flowing north/northeastward, the primary contaminant flow path, as well as eastward and southeastward, which are much less significant flow paths.

Additional wells monitoring the SPP are located at greater distances from the source. This includes Evaluation wells situated both upgradient and downgradient of the SPPTS groundwater intercept trench, Sentinel wells adjacent to that trench and in South Walnut Creek near former B991, and an AOC well near former Pond A-1.

In 2010, each of the Evaluation wells was sampled once, and the Sentinel and AOC wells were sampled twice in accordance with RFLMA.

The highest observed concentrations of nitrate in the source area were reported in samples from wells 79302 and 79402, both of which are situated in the vicinity of the northeastern corner of the former SEPs. Since late 2003, Evaluation well 79302 has consistently produced water with the highest concentration of nitrate; in 2010, the result was 4,400 mg/L nitrate (as N). Figure 218 illustrates concentrations of nitrate in these Evaluation wells. However, due to the consistently low concentrations of nitrate in samples from well 00203 (i.e., less than 10 mg/L except for the initial outlier of 20 mg/L in the first sample, collected in early 2003), which is located generally south of the former SEPs, data from this well are not illustrated. The gaps in the time-series plots shown on this figure are related to erroneous data (single-digit nondetects) reported for samples collected from these wells in April 2005. Although these results are included in the figure, they are not connected to the other data because they are considered anomalous and nonrepresentative. (Refer to the 2006 Annual Report, DOE 2007c, for additional discussion.)

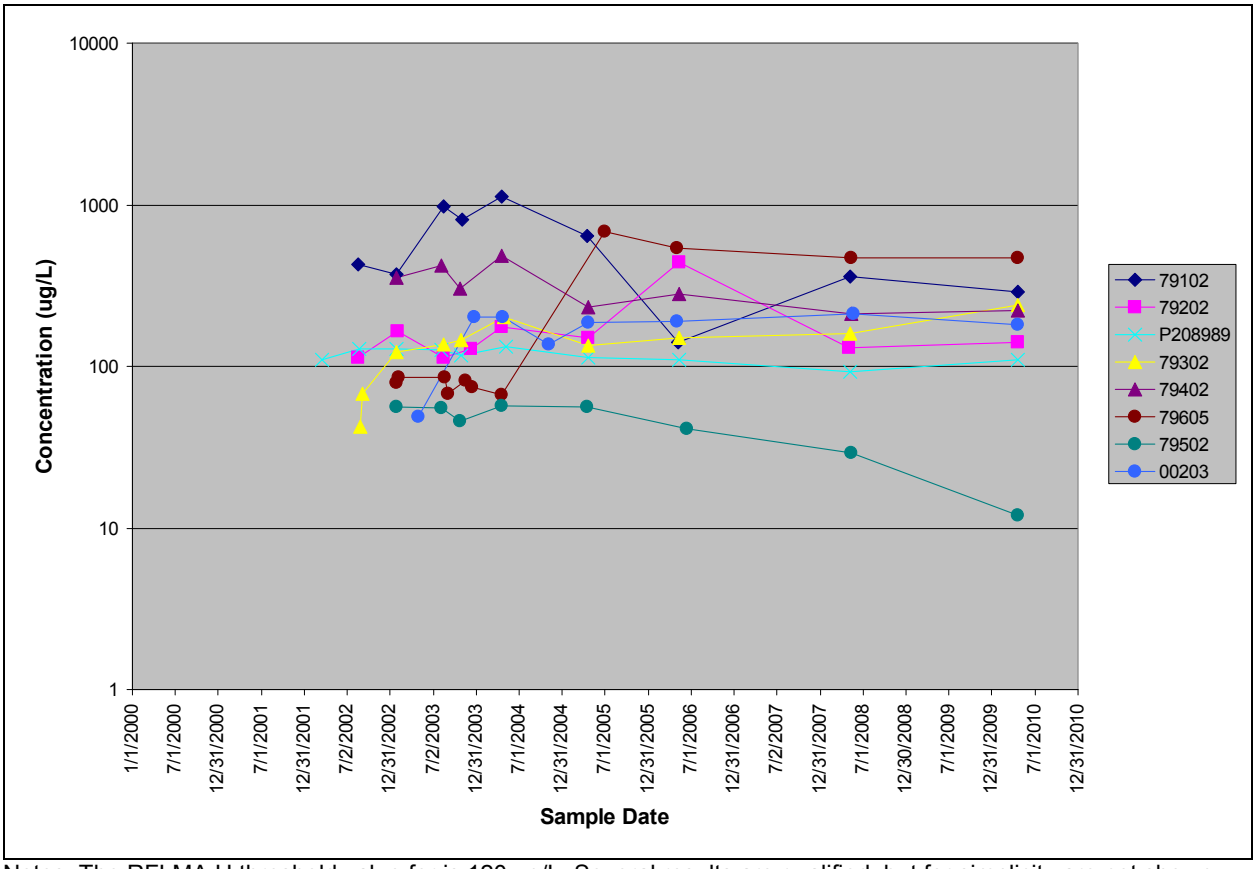
None of the time-series plots for nitrate corresponds to an increasing or decreasing trend meeting the 95 percent level of statistical significance. Instead, nitrate concentrations in samples collected from these wells appear fairly consistent. Some slight trends are visually suggested by the time-series plots (Figure 218), but will require additional data to confirm. Given that the nitrate-contaminated groundwater is present within relatively tight claystone with very low hydraulic conductivities, flushing or degrading the elevated nitrate will take some time.



Notes: RFLMA Table 1 value for nitrate is 10 mg/L. Several results are qualified ("J," "D") but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 218. Concentrations of Nitrate in SPP Source Area Evaluation Wells

As noted above, the former SEPs were also the source of uranium contamination in the groundwater. The highest concentration of U reported in 2010 from the source area was in a sample from Evaluation well 79605 (470 µg/L), which is located on the east edge of the former SEPs. Of the wells represented in Figure 219, this well has produced the samples with the highest concentrations of U since 2005, when the existing well was installed to replace damaged original well P207989 (which produced the samples shown through 2004, and was located not quite 5 feet away from the replacement well). Note that the effect of well replacement is obvious on the U time-series plot, but not on that for nitrate (Figure 218). This may be due to variations in the distribution of natural, rather than anthropogenic, U. Rocky Flats groundwater can contain elevated levels of natural (i.e., not Site-related) U attributable to the local geology, which hosts the U-bearing Schwartzwalder mine approximately 5 miles to the southwest of this well. Samples from well 79605 (and its predecessor) have not been analyzed using high-resolution isotopic methods, and the relative abundance of natural versus anthropogenic U at this location is not known. This also applies to groundwater samples from well 00203, which are low in nitrate but contain an average of about 170 µg/L to 185 µg/L of U, depending on whether the first sample collected from this well (approximately 50 µg/L) is included in the average.



Notes: The RFLMA U threshold value for is 120 µg/L. Several results are qualified, but for simplicity are not shown differently. Note logarithmic concentration scale.

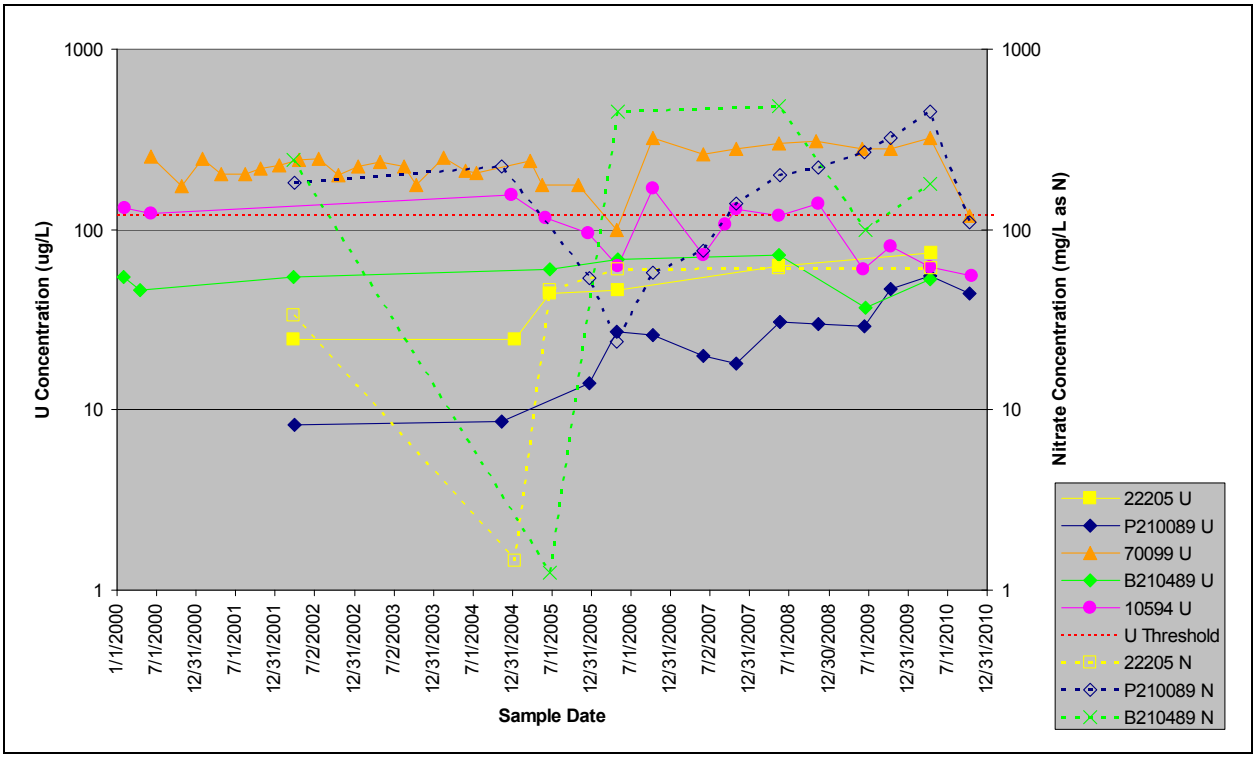
Figure 219. Concentrations of Uranium in SPP Source Area Evaluation Wells

Of the wells represented in Figure 219, trends with a 95 percent confidence are calculated for U in samples from well 79302 (increasing) and 79502 (decreasing).

Figure 220 displays U and nitrate concentrations from wells downgradient of the SPP source area. With respect to the SPPTS and associated groundwater intercept trench, wells that are illustrated include upgradient (22205), side-gradient (P210089 and, to some extent, 70099), and downgradient (B210489, 10594) wells. Nitrate data for wells 70099 and 10594 are not included because concentrations are low (nondetect to low single-digit mg/L). Data from wells 99305 and 99405, both located in the South Walnut Creek drainage adjacent to former B991, are not illustrated because nitrate concentrations are uniformly low—in 2010, the highest level reported was 2.6 mg/L—and U present in these wells has been repeatedly shown to be natural. Although several U results from AOC well 10594 have exceeded the 120 µg/L threshold, the last time that occurred was in 2008. Since the signing of RFLMA, no two consecutive routine samples from well 10594 have exceeded that concentration. If two consecutive routine samples exceed the threshold value in the future, a reportable condition as defined by RFLMA for AOC wells will exist at this well, and consultation with the regulators will follow. As has been reported previously (e.g., DOE 2008c), U in this well has been repeatedly characterized as 100 percent natural, most recently in September 2007.

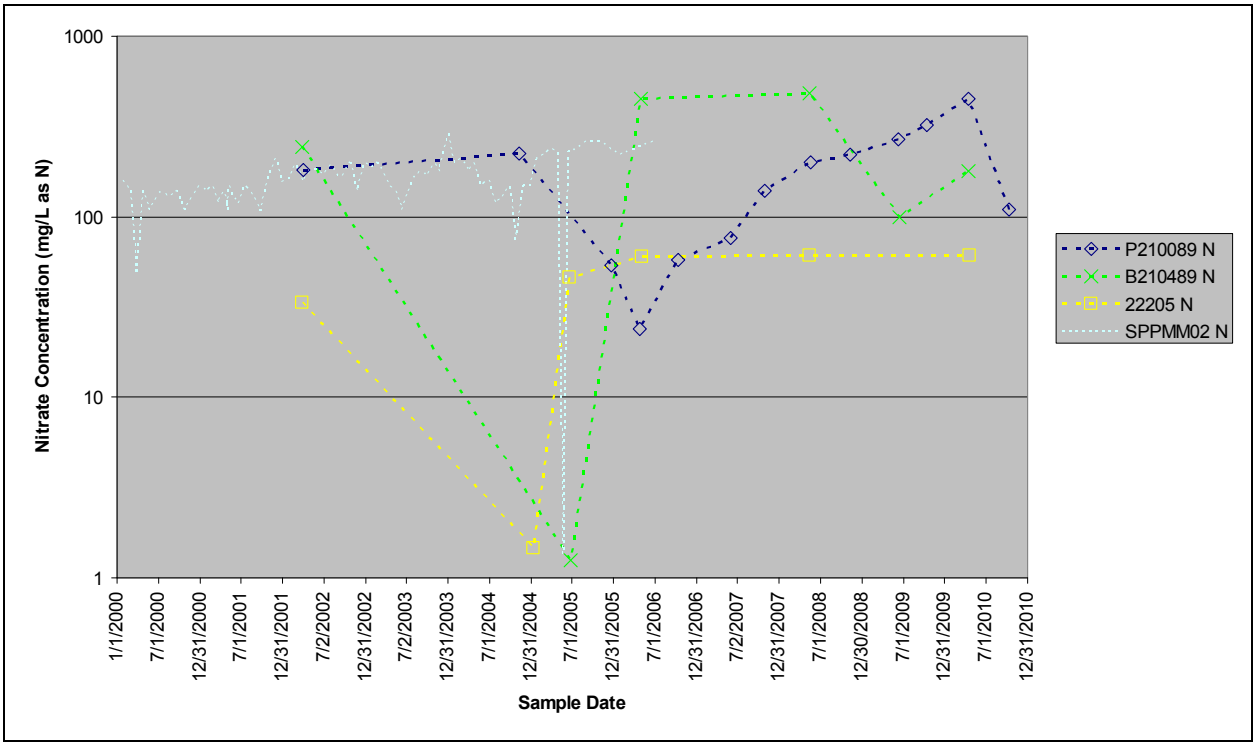
The variable concentrations of nitrate and U in several of these wells is evident on Figure 220. The wells nearest the source area (Evaluation well 22205 and Sentinel well P210089) do not produce groundwater samples with the highest concentrations of U; rather, this is the case with samples from well 70099, located near the northwestern end of the SPPTS groundwater intercept trench. Of all these wells, even most-distal well 10594 consistently produces samples with higher concentrations of U than does well P210089 and, until 2010, well 22205. Based on the current pattern, it appears concentrations of U in well P210089 will exceed those in well 10594 in the near future.

In contrast to the pattern described above for U, among these wells concentrations of nitrate are most often highest in wells P210089 and B210489 and, as noted above, are uniformly low in wells 70099 and 10594. Evaluation well B210489 is located near the SPP Discharge Gallery, and therefore may be receiving higher-nitrate groundwater from the area around that feature, given that it became saturated with higher-nitrate waters for years before the SPPTS upgrades (discussed below) were installed. Evidence for this is somewhat circumstantial but is found in the apparent correlation in the sharp decrease in nitrate concentrations that occurred during 2005−2006 in samples from wells 22205, B210489, P210089, and the original SPPTS influent monitoring point, the piezometer referred to for that purpose as SPPMM02 (Figure 221). The cause of this dip in concentrations may be dilution from dust-suppression waters being transported by ITS lines, bedding, and surrounding materials.



Note: U = total uranium, N = nitrate+nitrite as nitrogen. Note logarithmic concentration scales.

Figure 220. U and Nitrate Concentrations in Wells Downgradient of the Former SEPs



Note: N = nitrate+nitrite as nitrogen. SPPMM02 = original SPPTS influent monitoring location, a piezometer located near the true influent point. Note logarithmic concentration scale.

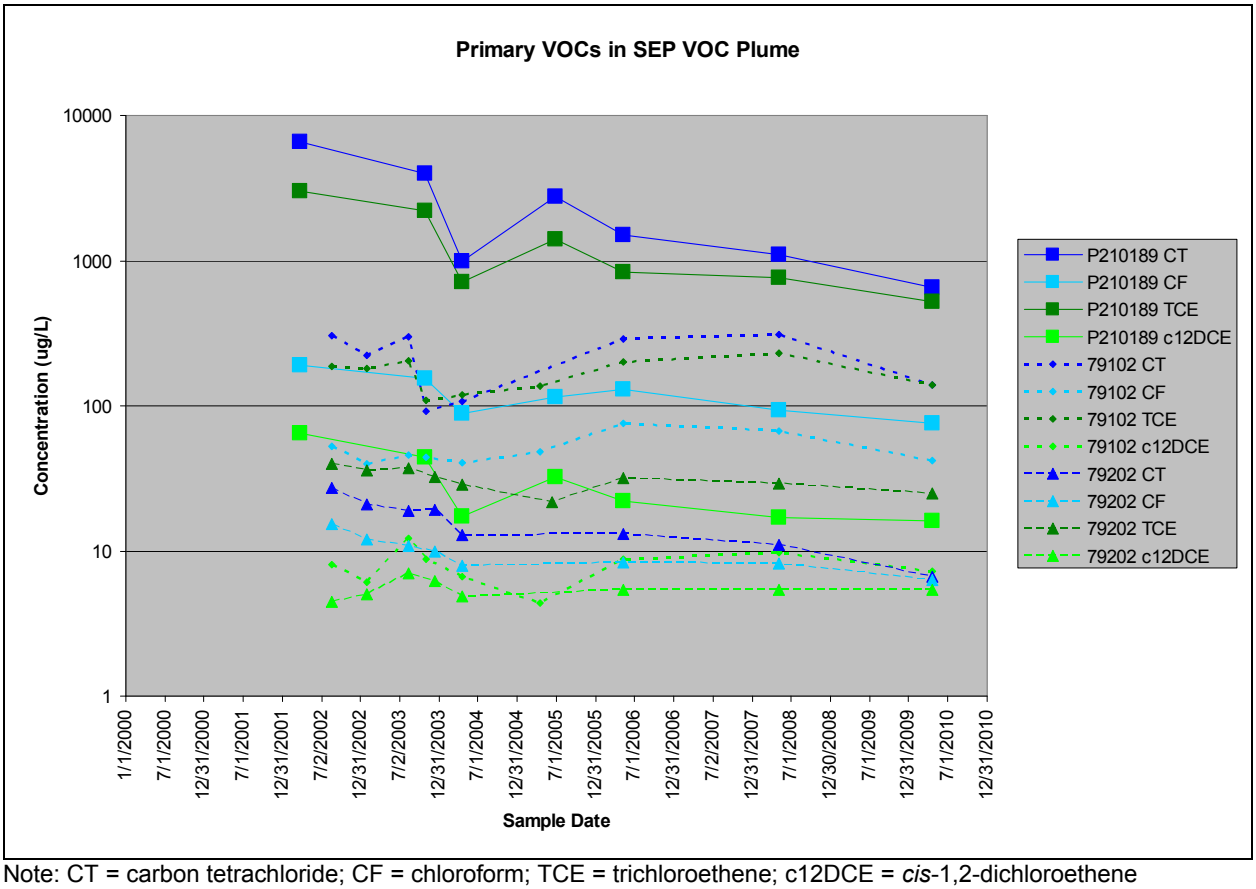
Figure 221. Nitrate Downgradient of the SEPs, Showing Correlation Among Wells and System Influent

Several trends meeting the 95 percent level of statistical significance are calculated for the well-analyte combinations displayed on Table 77. A decreasing trend in U is confirmed at well 10594, and an increasing trend in U is confirmed at wells 22205 and P210089 (see Table 77 and Appendix B). Not illustrated on the figure because concentrations are typically nondetect to low single-digits, a decreasing trend for nitrate in samples from well 70099 is also calculated. Additional years of data will help to clarify any patterns in contaminant concentrations and distributions that may be present in the wells illustrated on Figure 220.

Solar Ponds-Area VOC Plume

The VOC plume in the western SEP area was also monitored in 2010. Each of the Evaluation wells designated to monitor this plume was sampled once per the RFLMA. Results from those wells monitoring the source area are illustrated on Figure 222 and are generally consistent with previous data. Some decrease in concentration is apparent for VOCs in samples from well 79202, and a statistically significant (at the 95 percent level) decreasing trend is calculated for carbon tetrachloride, chloroform, and TCE at this location (see Table 77 and Appendix B). A similarly significant trend was calculated for *cis*-1,2-DCE at well P210189 (decreasing). Evaluation well P208989, which is located due east of well 79202 and on the north edge of the center of the former SEPs, also monitors VOCs but is not included on Figure 222. This well reported J-qualified detections, all below 1 µg/L, of 1,3-DCB, chloroform, PCE, and TCE in the sample collected in 2010. Results for chloroform at well P208989 were found to reflect a statistically significant (at 95 percent) increasing trend, but this may not be viable because the data set includes numerous nondetects. Downgradient (to the north) of the source area, the sample

collected from Evaluation well 22205 did not contain any confirmed detections of VOCs. Similarly, as in 2009, VOCs were not detected in samples collected in 2010 from Sentinel well P210089, which is located farther to the north/northeast of the VOC source area, nor were VOCs detected in AOC well 10594, located between former Ponds A-1 and A-2.



Note: CT = carbon tetrachloride; CF = chloroform; TCE = trichloroethene; c12DCE = *cis*-1,2-dichloroethene

Figure 222. Primary VOCs in the SEP-Area VOC Plume

Solar Ponds Plume Treatment System

Like the ETPTS, the SPPTS was installed in 1999. In basic terms, the system is very similar to the MSPTS and ETPTS, with an intercept trench (1,100 feet long) and two original treatment cells. However, unlike the ETPTS and MSPTS, this system is designed to treat water with elevated concentrations of nitrate and U rather than VOCs. As such, the treatment media in the original SPPTS treatment cells differs from the ZVI media in the MSPTS and ETPTS. The treatment media in these SPPTS cells consists of organic material (sawdust) with a small fraction of ZVI in the first cell and ZVI with pea gravel in the second cell.

Another difference between the SPPTS and the other two systems is that the water collected in the intercept trench is actively pumped into the treatment cells rather than flowing into the cells by gravity. This is accomplished using a solar-charged, battery-powered pump system. This component of the SPPTS, together with the collection well that houses the pump and is installed within the trench, was added in 2002.

Finally, the last major difference between the SPPTS and the other systems is the extensive study and effort that has been expended over the past several years to improve collection and treatment of contaminated groundwater by this system. Several factors drove these efforts, including (1) historically, concentrations of nitrate and uranium measured at the DG typically exceeded those in untreated influent to the system, even though this is where effluent confirmed to be adequately treated may surface following its discharge; (2) accessing and maintaining the treatment media and plumbing within the original structure is costly and difficult; and (3) the original treatment media used may not be optimal over the long term. In addition, operational difficulties were experienced in the spring of 2005 that forced a more immediate response (see DOE 2007c for discussion). Previous annual reports have discussed various components of the post-closure work (DOE 2007c, 2008c, 2009d, 2010d), which has included repairs, subsurface exploration, treatability studies, and the design and construction of system upgrades. Those upgrades, particularly their effects on water quality, are discussed at length below.

It is important to understand that perhaps the single and most fundamental challenge to achieving consistently reliable treatment by the SPPTS is the lack of electrical power. Although it supports many tools and critical components, several kilowatts of solar-based power cannot substitute for full-time, on-demand line power.

Maintenance activities at the SPPTS were conducted throughout 2010 and are reported in Section 2.5.3. The main focal point at the SPPTS in 2010 was continued optimization of the system, particularly the upgrades referred to as Phases II and III. Refer to that section for a discussion of operation and optimization activities. The text below provides a summary of the results related to water treatment.

The SPPTS treated approximately 738,000 gallons in 2010. This is the highest volume ever treated by this system (Table 88), a statement that previously had applied to the 2009 volume. In fact, the estimated volume treated in 2010 exceeded that treated in all of 2003, 2004, and 2005 combined. The increase in volume relative to previous years is again due to the installation of the Phase I groundwater collection sump and associated upgrades (see DOE 2009d) as well as the heavy spring 2010 precipitation. Figure 223 presents a hydrograph showing flow from January 2000 through the end of 2010. The hydrograph for CY 2010 is presented as Figure 224. The period of no flow in April in the latter figure is related to the biocide application reported in Section 2.5.3.

Table 88. Estimated Volumes of Water Treated by the SPPTS

Calendar Year	Annual Estimates of Volume Treated (gallons)	Estimated Cumulative Volume Treated (gallons)
2000[a]	64,000	64,000
2001[a]	424,000	452,700
2002	5,600[b]	458,000
2003	340,000	797,000
2004	230,000	1,027,000
2005	140,000	1,167,000
2006	251,000	1,418,000
2007	244,000	1,662,000
2008	280,000	1,942,000
2009	524,000	2,466,000
2010	738,000	3,204,000

Notes: Estimates for years 2000 through 2004 are compiled from K-H (2000a, 2000b, 2000c, 2000d, 2002, 2003, 2005a, 2005b).

[a] Annual and cumulative volume estimates for 2000 and 2001 are suspect, as a sum of the volumes presented in each of the quarterly reports for 2000 and statements regarding the volume for 2001 disagree by approximately 35,000 gallons.

[b] Most of this volume was from the former Modular Storage Tanks (K-H 2003).

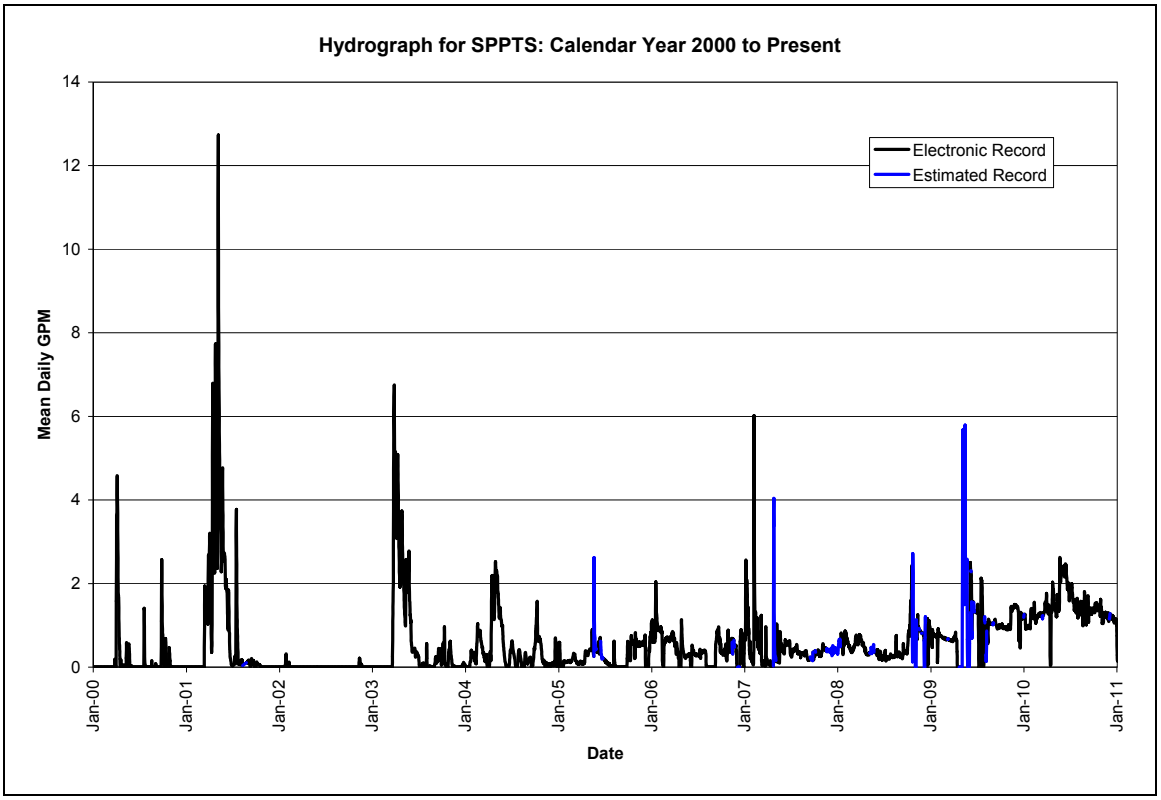


Figure 223. Hydrograph for SPPTS From 2000 Through 2010

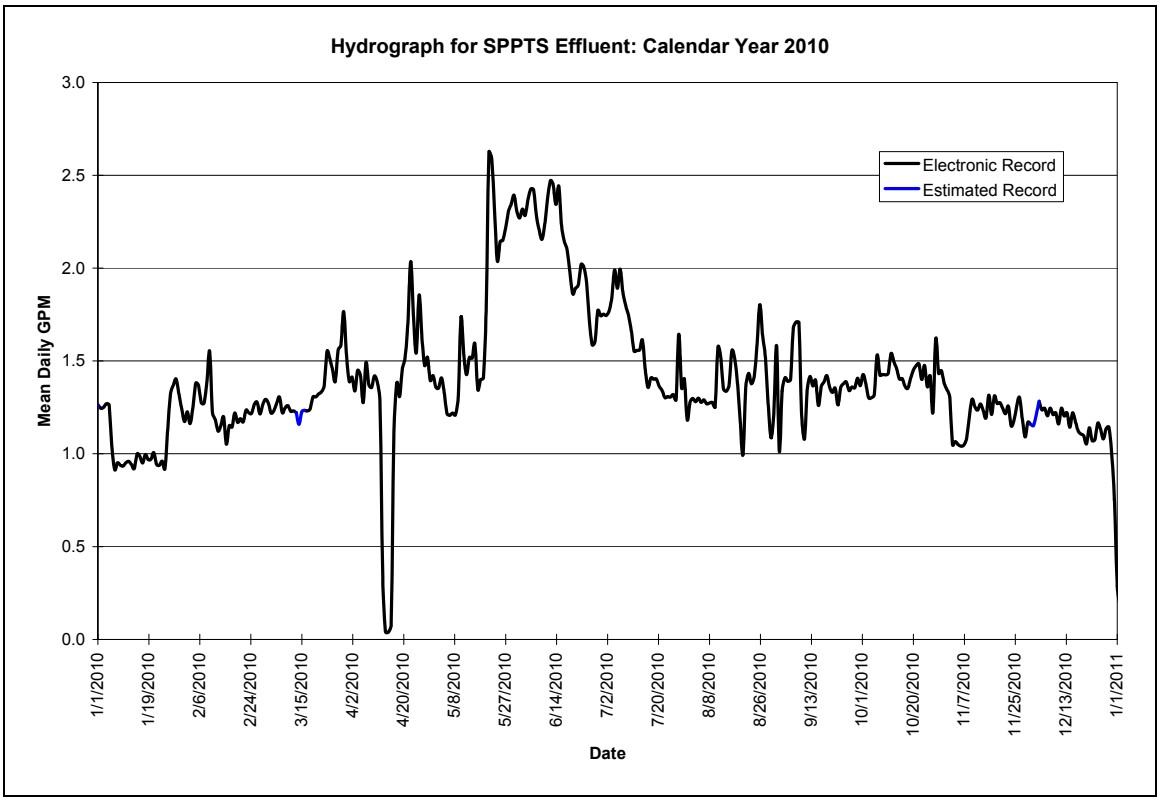
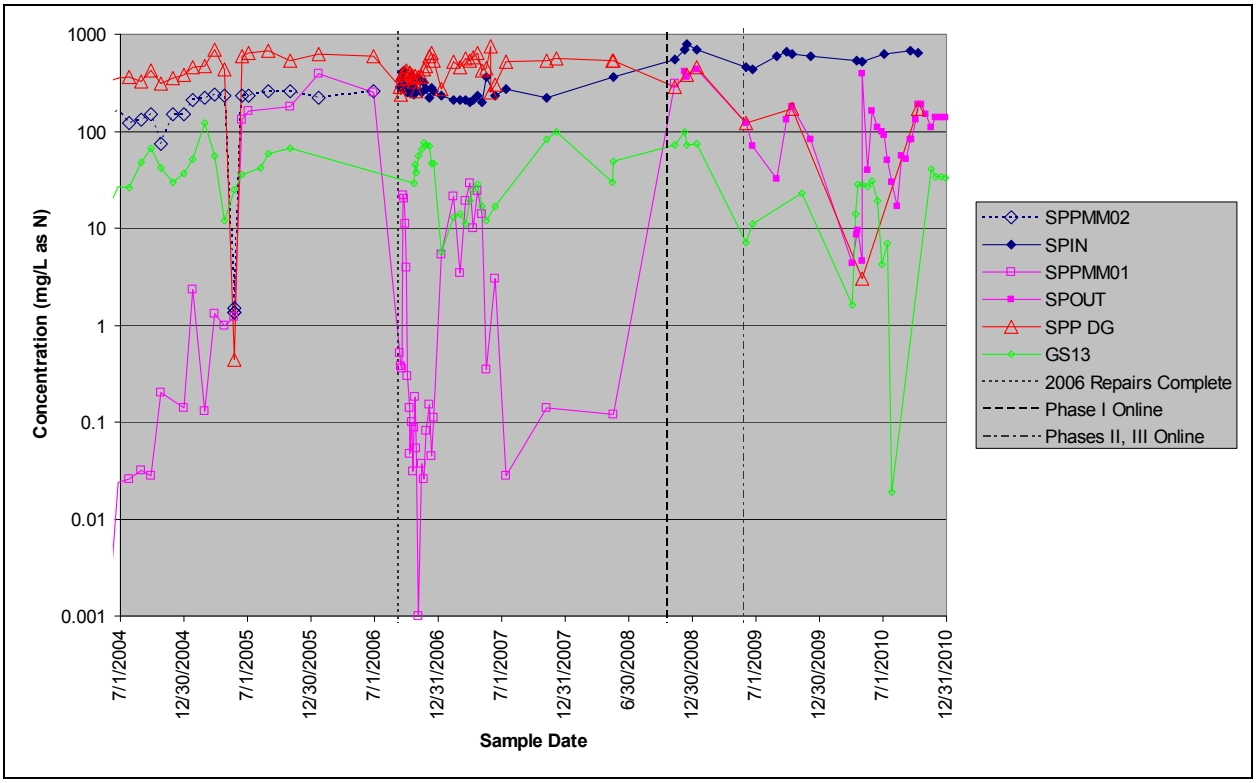


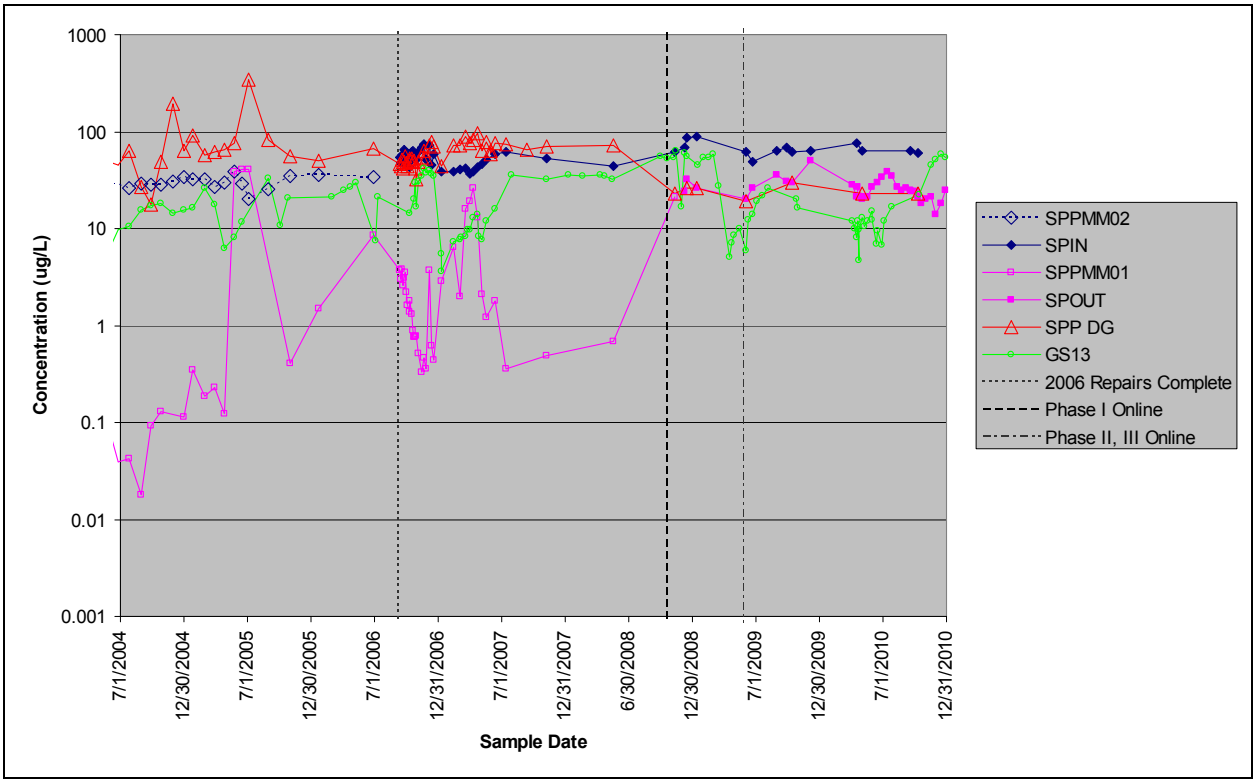
Figure 224. Hydrograph for SPPTS for CY 2010

Figure 225 provides an illustration of nitrate concentrations in SPPTS monitoring locations since mid-2004; Figure 226 shows a similar graph for U concentrations. (Only validated results from contract laboratories are included in these figures, not the supporting data generated by the Environmental Sciences Laboratory (ESL) in Grand Junction because those data cannot be validated. However, those data are useful and are considered separately as discussed below.) In both figures, the effects of valve changes made in mid-2005 are obvious on concentrations of these constituents in the effluent, and to some degree at the SPP Discharge Gallery (DG) and GS13 as well (see the 2006 Annual Report, DOE 2007c, for additional discussion of these events). The isolated late-2004 and mid-2005 spikes in U concentration at the DG (Figure 226) have been discussed previously (DOE 2010d) and are not addressed here.



Notes: SPPMM02 = historical "influent" monitoring location; SPIN = true system influent (collection well); SPPMM01 = historical system effluent location, replaced in late 2008 with SPOUT; SPP DG = SPP Discharge Gallery; GS13 = surface water performance location. Analytical data from SPPMM02 and SPPMM01 are included for comparison only; these locations are no longer monitored. See the 2006 Annual Report (DOE 2007c) for a more detailed discussion of location SPPMM02, as well as a discussion of the activities responsible for the abrupt concentration changes seen in data for May 24, 2005; and see the 2008 Annual Report (DOE 2009d) for more information on SPOUT. Some data are qualified (e.g., U, B, J), but are not displayed differently for simplicity. All data are from contract laboratories (not the ESL). Note logarithmic concentration scale.

Figure 225. Concentrations of Nitrate in Samples From SPPTS Monitoring Locations



Notes: SPPMM02 = historical "influent" monitoring location; SPIN = true system influent (collection well); SPPMM01 = historical system effluent location, replaced in late 2008 with SPOUT; SPP DG = SPP Discharge Gallery; GS13 = surface water performance location. Analytical data from SPPMM02 and SPPMM01 are included for comparison only; these locations are no longer monitored. See the 2006 Annual Report (DOE 2007c) for a more detailed discussion of location SPPMM02, as well as a discussion of the activities responsible for the abrupt concentration changes seen in data for May 24, 2005; and see the 2008 Annual Report (DOE 2009d) for more information on SPOUT. Some data are qualified (e.g., U, B, J), but are not displayed differently for simplicity. All data are from contract laboratories (not the ESL). Note logarithmic concentration scale.

Figure 226. Concentrations of U in Samples From SPPTS Monitoring Locations

Validated contract lab data indicate nitrate concentrations in 2010 at the performance monitoring location for the SPPTS, GS13, were within their typical range. However, given that the 10 mg/L drinking water standard now applies rather than the 100-mg/L Temporary Modification that expired at the end of CY 2009, GS13 now commonly exceeds the RFLMA Table 1 value for nitrate. A major factor in the numerical results for nitrate is the sampling methodology used for this analyte: nitrate samples are collected as grabs, whereas samples for the analysis of U are primarily collected as automated flow-weighted composite samples. The latter method is much more representative of actual overall conditions in surface water, including at GS13, because the sampling apparatus operates continually, regardless of weather conditions (except when frozen solid), hour, or date. This includes during high-flow conditions, such as during and after storms and periods of snow melt, when manual sampling is less likely. Conversely, grab samples are only collected when sampling personnel are instructed and able to visit the location, and many fewer grab samples are collected than are individual grabs within the automated composite samples. Samples for the analysis of nitrate are not collected using automated equipment because of the associated sample handling requirements: samples collected for the analysis of U need not be refrigerated, but samples collected for nitrate must be immediately refrigerated. Studies performed in Florida (Burke et al. 2002) have evaluated the collection of samples for the analysis

of nitrate using automated equipment such as that deployed at Rocky Flats, but without refrigeration; if retrieved, preserved, and shipped to the lab within 7 days, analytical results are equivalent to samples collected using the EPA-required refrigeration and preservation. Use of this method at Rocky Flats is under consideration and testing is planned. If employed, concentrations of nitrate reported at GS13 using the automated sampling equipment would be expected to contrast sharply (i.e., be much lower) with those obtained via grab samples.

Concentrations of U at GS13 were also within their typical range, though as discussed below, the average and median concentrations following installation of the Phase II and Phase III upgrades are now very similar to pre-closure conditions. In fact, concentrations of U in 2010 are somewhat lower than they were following site closure and prior to the installation of the Phase I upgrades.

Summary of SPPTS Upgrades

As noted above, several upgrades have been made to the SPPTS since site closure. These upgrades are summarized below in Table 89.

Table 89. Summary of SPPTS Construction and Upgrades

Upgrade Phase (Year Installed)	Summary Description	Summary of Associated Features and Nomenclature
"Phase 0" (1999)	Original SPPTS constructed: Groundwater intercept trench bisects previously installed French drain network called the Interceptor Trench System, or ITS, and feeds collected water by gravity through two cells operated in series: Cell 1 contains sawdust plus 10% ZVI for nitrate treatment; Cell 2 contains pea gravel and 15% ZVI for U treatment. Effluent is routed into a downgradient limb of the ITS and thence to a line to the subsurface discharge gallery.	SPPMM02 = "influent" location accessed at piezometer a.k.a. 71099 SPPMM01 = effluent location accessed in manhole SPP Discharge Gallery (a.k.a. DG) in valley bottom GS13 = surface water performance at mouth of Pond A-1
"Phase 0.1" (2002)	Collection well equipped with solar-powered pump is installed to deliver collected groundwater to cells.	SPIN (name later assigned to influent flow from this pump)
Phase I (2008)	Collection sump and gravel drain installed at terminal points of ITS, adjacent to location of former Interceptor Trench Pump House (ITPH).	ITSS = ITS Sump, the constructed sump that receives water collected by the upgrade ITS-E = east ITS line where it empties into ITSS ITS-W = west ITS line where it empties into ITSS
	Piping installed to transfer water from ITSS to SPIN, and to discharge treated system effluent from effluent manhole to DG; SPIN vault provides access point to flows from the former, and ITSS vault provides access to flows from the latter.	SPOUT = effluent location accessed in ITSS vault
Phase II (2009)	Easily accessible cell installed to treat U upstream of nitrate treatment; initially incorporates citrate dosing of influent.	SPZE = effluent from Phase II cell
Phase III (2009)	Installed: two pilot-scale nitrate treatment cells to evaluate alternative treatment approaches; associated vault to house carbon supply (added to one of the Phase III cells); vault to allow flow configuration, control, dosing, monitoring, programming, and telemetry infrastructure; associated water storage sump to provide influent in the event of dry conditions; and solar power and plumbing infrastructure to support all of this.	Cell A = pilot-scale nitrate treatment cell using inert media dosed with liquid carbon Cell B = pilot-scale nitrate treatment cell using organic (reactive) corn stover media SPILCA = dosed influent to Cell A SPCAE = effluent from Cell A SPCBE = effluent from Cell B
Phase IV (proposed)	Install full-scale nitrate system based on previous testing and results	To be determined

The first of these upgrades to be installed after Rocky Flats was closed was constructed in 2008. Additional components were installed to capture more of the contaminated groundwater and transfer it to the groundwater intercept trench, from which it would be routed to the treatment cells; in addition, a new line was installed to transport treated effluent from the system to the DG. These improvements are collectively referred to as the Phase I upgrades.

Two additional "phases" of upgrades were installed concurrently the following year, 2009. Phase II focused on making the U treatment cell more accessible and, based on successful laboratory testing, positioning this as the first step of the treatment train so that media beyond that component could be considered non-radioactive for waste disposal purposes. Phase III focused on the installation of two pilot-scale nitrate treatment cells to evaluate more effective and efficient methods of treating the nitrate. Both of these are discussed at greater length below and in Section 2.5.3.

The effects of the Phase I upgrades in late 2008 can be seen on Figure 225 and Figure 226 above, with concentrations of nitrate and U in system influent increasing significantly as the elevated flow rates and concentrations overwhelmed the system's capacity to provide effective treatment. While the system may have been able to treat these concentrations given sufficient residence time, the increased flow rates reduced residence time below that necessary to achieve satisfactory treatment. This in turn affected concentrations of nitrate and U reported at downgradient locations. The date of completion of Phases II and III is also indicated on both figures, and the resulting improvement in water quality at the DG is clearly evident: even though the system has not been operating ideally, concentrations of the target contaminants at the DG have dropped significantly. However, concentrations in system effluent are most often still above effluent target levels. Optimization efforts continued through 2010 on both of these upgrades to effect treatment improvements.

Since completion of Phases II and III, concentrations of nitrate and U at downgradient locations, particularly the DG but also including GS13, have been somewhat reduced, as seen on these figures. Table 90 presents summary statistics for concentrations of nitrate and U for the years 2000 through 2010 at several locations of interest. These statistics are shown for both contract laboratory-only results (i.e., without ESL data) and for combined contract laboratory and ESL data. (For economic reasons, the ESL was used to analyze the samples collected as often as weekly to evaluate the effects of the Phase I, II, and III upgrades and optimization efforts. Therefore, the data set is more robust if ESL data are also included.) These statistical results further confirm the patterns evident on Figure 225 and Figure 226. Concentrations of nitrate and U in system influent, as represented at SPIN, increased dramatically as a result of the Phase I upgrades, which focused on collecting additional contaminated groundwater. At the same time, despite the reduced treatment effectiveness documented at effluent monitoring locations SPPMM01 and SPOUT, relative to pre-Phase I levels the contaminant concentrations at the DG remain greatly reduced. This is because the contaminated groundwater that had been issuing untreated at the DG is now collected by Phase I and (at least partially) treated by the SPPTS, resulting in overall reduced contaminant loads at the DG. The effects of the Phase II and III upgrades can also be seen, as concentrations of nitrate measured at SPOUT and the DG dropped sharply. This effect is also evident in the summary statistics for surface water location GS13, where SPPTS performance is measured.

Table 90. Summary Statistics for U and Nitrate Concentrations From 2000 through 2010 at Historical and Current SPPTS Monitoring Locations

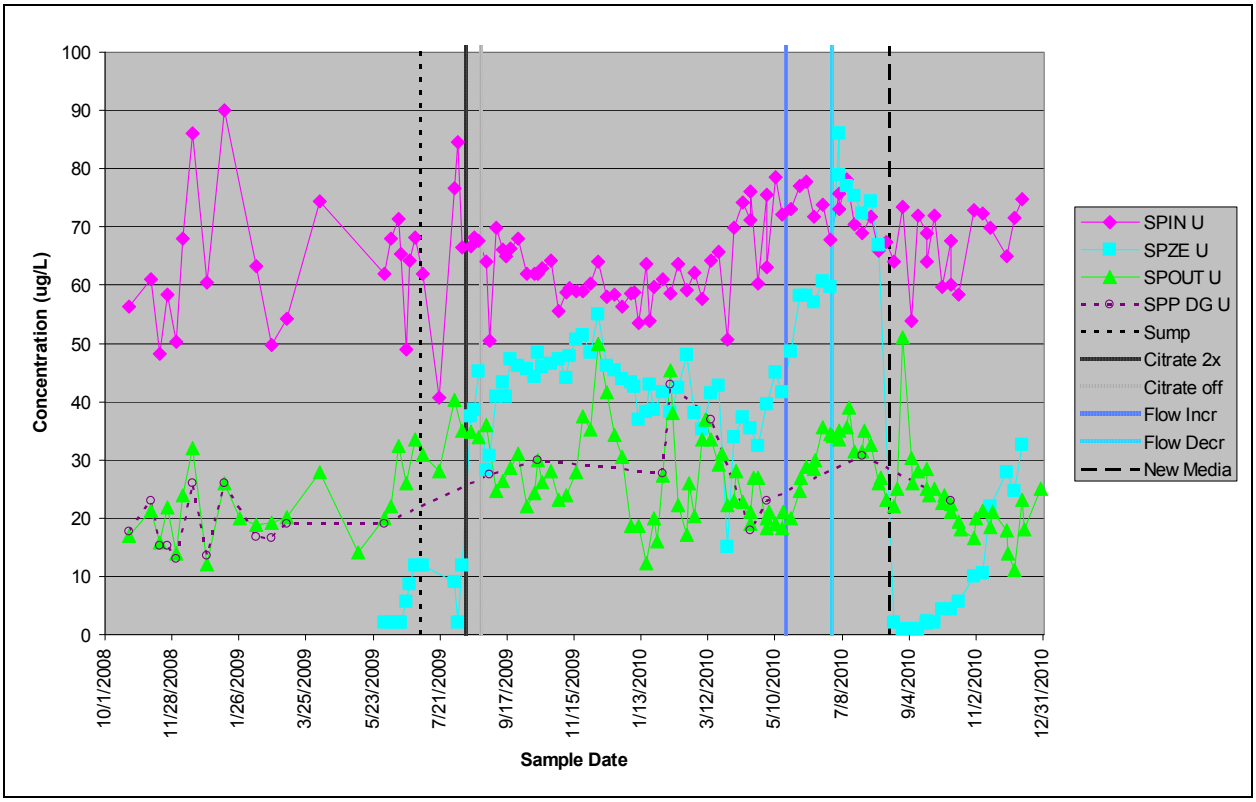
	Nitrate			Uranium		
SPIN	**Average**	**SD**	**Median**	**Average**	**SD**	**Median**
Pre-closure	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Post-closure, pre-Phase I	276.7	59.7	270.0	52.4	9.8	52.0
Post-Phase I	682.5	99.1	695.0	76.3	14.0	77.0
with ESL data	645.3	64.0	646.3	63.1	13.3	60.5
Post-Phase II, III	561.7	90.0	595.0	61.5	6.5	63.0
with ESL data	589.7	71.5	589.4	65.3	7.4	64.9
SPPMM02						
Pre-closure	160.7	45.9	156.0	28.4	4.6	28.8
Post-closure, pre-Phase I (n=3)	246.7	23.1	260.0	35.0	1.0	34.9
Post-Phase I	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
SPOUT						
Pre-closure	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Post-closure, pre-Phase I	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Post-Phase I (n=3)	403.3	40.4	410.0	27.3	4.2	26.0
with ESL data	393.5	100.6	421.0	20.3	5.5	20.0
Post-Phase II, III	102.5	51.9	101.5	32.2	10.2	30.5
with ESL data	83.4	66.4	70.2	26.9	7.5	26.0
SPPMM01						
Pre-closure	6.1	27.0	0.1	3.0	10.5	0.1
Post-closure, pre-Phase I	26.6	77.8	0.4	3.7	5.7	1.7
Post-Phase I (n=1)	310.0	*N/A*	310.0	21.0	*N/A*	21.0
with ESL data	283.0	112.8	329.2	16.7	3.0	15.5
SPP Discharge Gallery						
Pre-closure	259.9	123.2	233.0	52.8	44.7	43.3
Pre-closure without 3 U outliers	*N/A*	*N/A*	*N/A*	44.9	16.9	43.0
Post-closure, pre-Phase I	449.8	123.2	425.0	60.5	14.6	56.0
Post-Phase I (n=3)	376.7	85.0	380.0	25.0	1.7	26.0
with ESL data	379.7	117.9	385.1	18.4	4.6	16.7
Post-Phase II, III	145.0	35.4	145.0	24.5	7.8	24.5
with ESL data	57.6	63.8	28.0	27.0	7.3	25.3
GS13						
Pre-closure	24.9	17.6	23.0	12.1	6.1	11.8
Post-closure, pre-Phase I	41.2	26.2	38.0	23.0	13.1	21.4
Post-Phase I	80.3	13.2	74.0	38.3	22.6	52.3
with ESL data	88.5	61.4	75.0	36.1	18.7	38.1
Post-Phase II, III	13.7	8.2	11.0	17.0	6.2	17.7
with ESL data	18.5	13.4	18.1	18.1	11.9	15.1

Notes: SPIN = true system influent (collection well); SPPMM02 = historical "influent" monitoring location; SPPMM01 = historical system effluent location, replaced in late 2008 with SPOUT; GS13 = surface water performance monitoring location. N/A indicates location was not monitored, or the indicated statistic cannot be calculated. Where three or fewer results form the basis for the statistics presented, the number of samples is indicated parenthetically (e.g., n = 3). Refer to 2009 Annual Report (DOE 2010d) for additional information on the outliers noted for the Discharge Gallery statistics. Closure date used is October 2005; Phase I date

Table 90 (continued). Summary Statistics for U and Nitrate Concentrations From 2000 through 2010 at Historical and Current SPPTS Monitoring Location

used is October 20, 2008. Analytical data from SPPMM02 and SPPMM01 are included for comparison only; these locations are no longer monitored. See the 2006 Annual Report (DOE 2007c) for a more detailed discussion of location SPPMM02, and see the 2008 Annual Report (DOE 2009d) for more information on SPOUT. Data used to calculate the statistics were taken at face value, regardless of qualifier. This is largely irrelevant, but nitrate and U were frequently not detected prior to spring 2005 in effluent monitoring location SPPMM01, so the resulting statistically generated values would be expected to be biased high. Data from ESL are not validated, but typically correspond very closely to results from split samples sent to contract labs. ESL results for nitrate used to calculate the statistics include those for nitrate only as well as for nitrate plus nitrite.

The effects on water quality from the installation of these phased upgrades are illustrated graphically below. Figure 227 illustrates U concentrations at various locations via time-series plots and focuses on the Phase II Cell. The early (i.e., mid-2009) breakthrough of U in effluent from this treatment cell is obvious. This cell had initially removed U as designed, but within weeks the effluent sampled at SPZE (see Table 89) showed detectable concentrations of U. Over the subsequent months of 2009, the levels of U in effluent from the Phase II cell increased. Reasons for this behavior were not known.



Notes: U = uranium; SPIN = system influent; SPZE = effluent from Phase II Cell; SPOUT = system effluent; SPP DG = SPP Discharge Gallery. Sump = date of sump subsidence, Citrate 2x = date on which citrate dosing was doubled, Citrate off = date on which citrate dosing was discontinued; refer to DOE 2010d for additional discussion of and information on these events. Flow Incr = date on which flows through the Phase II cell were increased from approximately 1.5 gpm to approximately 2.4 gpm - 3 gpm; Flow Decr = date on which flows were reduced to approximately the previous rates. New Media = date on which Phase II Cell media replacement was completed and the cell was placed back into operation. Some data are qualified (e.g., U, B, J), but are not displayed differently for simplicity. Data are from contract laboratories as well as the ESL.

Figure 227. Concentrations of U in Effluent From the Phase II Cell

As reported in the 2009 Annual Report (DOE 2010d), four nonexclusive hypotheses were developed to explain the reduced effectiveness of the Phase II cell. One of these is physical, and the remaining three are chemical (based on passivation of the ZVI):

- Preferential flow paths had developed.
- The high concentrations of nitrate promote formation of precipitates such as ferric oxyhydroxides on the ZVI grains.
- Dosing with citrate resulted in precipitates coating the ZVI grains.
- The nitrate and/or citrate accelerated weathering of feldspars in the granitic pea gravels to clays that coated the ZVI grains.

Tracer testing and microscopy was performed in 2010. Results of these efforts led to two significant conclusions: First, a purely physical cause (i.e., preferential flow) was not indicated. Second, the condition of the media as examined microscopically indicated no unusual physical conditions and suggested the media should still be treating adequately.

As can be seen on Figure 227, U treatment by the Phase II cell (as measured at SPZE) was improving slightly in the spring of 2010, but then worsened. This decrease in treatment effectiveness is also expressed at SPOUT, and coincides with an operational change: flows through the system, including the Phase II cell as the first component in the system, were increased in late May to manage the heavy spring recharge. That extra water had collected in the SPPTS intercept trench and had to be managed—i.e., fed through the system for treatment. These data also illustrate that when flow rates were decreased again at the end of June, concentrations at SPOUT gradually decreased. However, by July the Phase II cell was no longer effectively removing U, and media replacement was scheduled.

The media replacement was planned and completed the following month, in August 2010. Several adjustments to the media and operation were made in order to address or inform the assessment of the above hypotheses:

- Citrate dosing was not performed;
- A quartzitic pea gravel was used rather than the feldspathic gravel used originally;
- A fresh lot of ZVI was used;
- The ZVI ratio in the media was increased.

The new media, installation of which was completed in mid-August 2010, had an immediate effect on U concentrations measured at SPZE and, to a lesser degree, at SPOUT. Given the large volume of the original SPPTS structure, considerable time is necessary to drain the water within, which leads to a delay in responses measured at SPOUT.

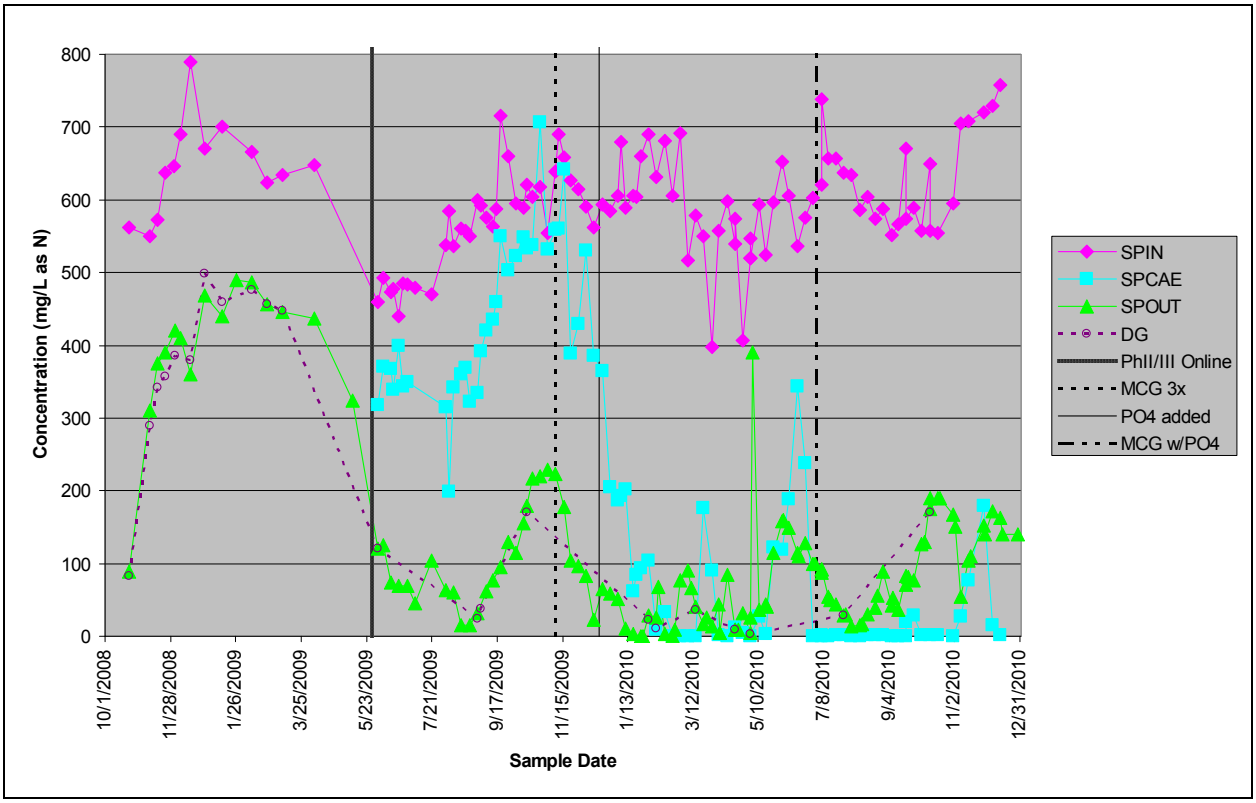
Figure 227 also illustrates U concentrations in effluent from that cell, as measured at SPZE, were increasing as 2011 drew to a close. Reasons for this were uncertain, but several mechanisms that had been under consideration as reasons for the failure of the initial media can be ruled out. Weathering of feldspars in the granitic pea gravel cannot be the cause, as the replacement pea gravel is composed of crushed quartzite. In addition, citrate dosing was never implemented after being discontinued in 2009, eliminating that as a factor. Instead, the causes for reduced U treatment appear limited to the naturally elevated concentrations in groundwater of dissolved

oxygen (DO) and major ions such as calcium and carbonate, and the elevated concentrations of nitrate from the SPP. Given that the MSPTS and ETPTS use pure ZVI to treat groundwater of a similar character but without the nitrate, and perform acceptable treatment for some years, by process of elimination it would appear that the cause for the quick reduction in effective U treatment by the SPPTS Phase II cell is the elevated nitrate in the influent. The elevated major ions and DO likely play a part, but nitrate is suggested as the primary factor. This is surprising, given that untreated, high-nitrate water collected from SPIN was used in lengthy laboratory tests to assess whether U could be treated as a first step (rather than following nitrate treatment); in those tests, U removal was excellent and early breakthrough of U, with or without citrate dosing, was not experienced. However, the scale of these laboratory tests was necessarily small, so scaling up to full-size may have posed complications unforeseen in the lab tests.

The treatment performance of the Phase II cell with the replacement media is improved relative to that of the initial batch of media, but by late 2010 was no longer meeting targets. Therefore, as 2010 ended, efforts were underway to assess possible treatment alternatives or adjustments that would meet those targets and could be implemented at the SPPTS. As previously noted, a fundamental limitation on feasible solutions is the lack of electrical power other than solar. Results of this consideration will be provided in the 2011 Annual Report.

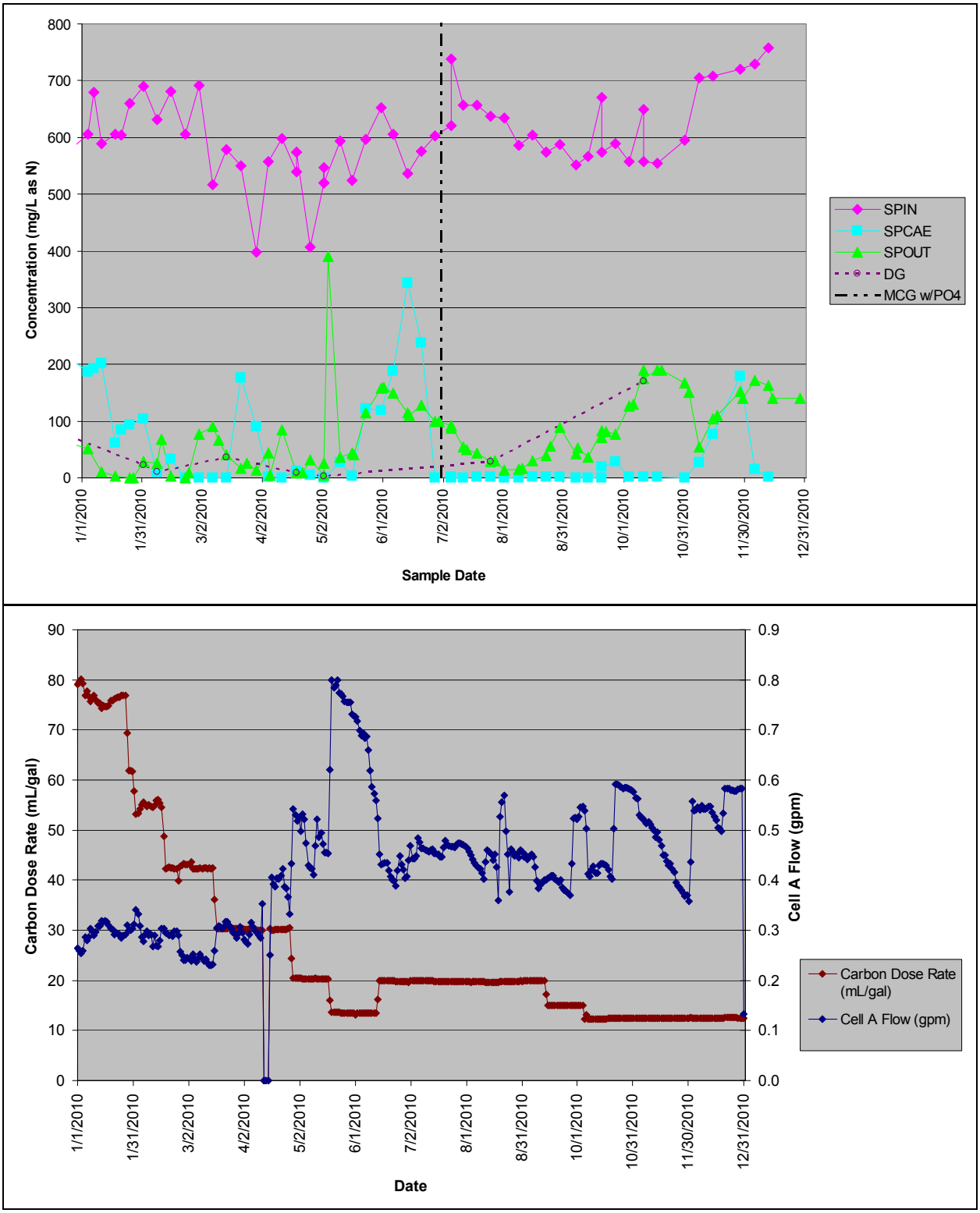
Operation and optimization of the two pilot-scale Phase III cells continued in 2010. Cell A, which is filled with an inert plastic media and cell influent is dosed with a liquid carbon source (MicroCg, a proprietary blend manufactured by EOS), continued to outperform Cell B. The latter cell is filled with organic media, corn stover. The primary differences are in available surface area for the denitrifying bacteria and the quality and bioavailability of the carbon. The inert media in Cell A provides a much higher surface area (a principal design requirement of inert media), and the liquid carbon is more bioavailable than is the plant matter in Cell B. Therefore, it is to be expected that Cell A would be able to effectively treat greater flows than Cell B.

Analytical data collected from the installation of Phase I through the end of 2010 are illustrated on Figure 228. Figure 229 focuses on conditions in CY2010, showing these analytical data together with dose rates for the liquid carbon and Cell A influent flow rates. Flow through Cell A was continuous, and typically represented about a third of the total SPPTS flow, as can be seen when comparing the SPPTS hydrograph in Figure 224 with the Cell A flows presented in Figure 229.



Notes: SPIN = system influent; SPCAE = effluent from Phase III Cell A; SPOUT = system effluent; DG = SPP Discharge Gallery. PhII/III Online = date on which the Phase II and Phase III components were put online. MCG 3x = date on which the carbon dose rate was approximately tripled in an effort to boost the population of denitrifying bacteria; PO4 added is date on which phosphate addition began, via separate dosing; MCG w/PO4 is date on which custom-blended MCG with PO4 began to be used. Some data are qualified (e.g., U, B, J), but are not displayed differently for simplicity. Data are from contract laboratories as well as the ESL.

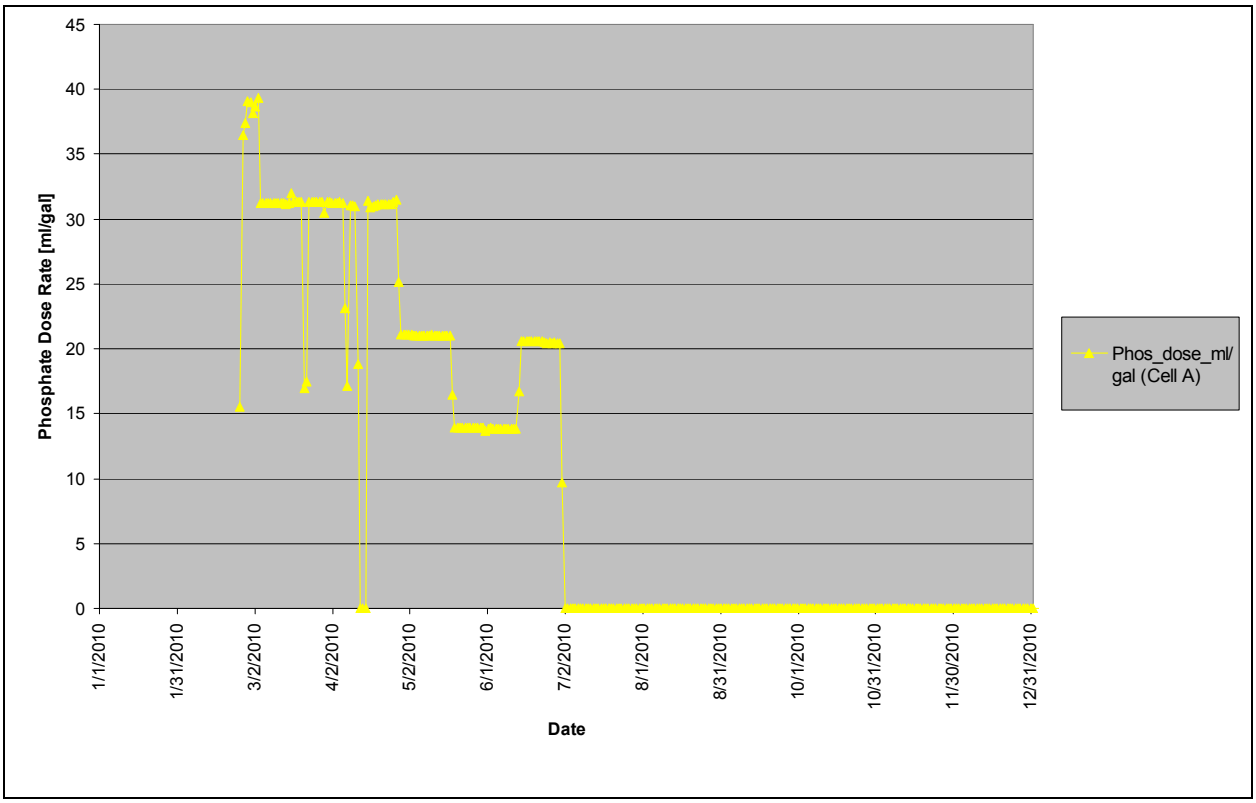
Figure 228. Concentrations of Nitrate in Effluent From Phase III Cell A



Notes: Top portion: SPIN = system influent; SPCAE = effluent from Phase III Cell A; SPOUT = system effluent; DG = SPP Discharge Gallery. MCG w/PO4 is date on which custom blend of liquid carbon with added phosphorus began to be used. Some data are qualified (e.g., U, B, J), but are not displayed differently for simplicity. Data are from contract laboratories as well as the ESL.
Bottom portion: dose rate is in units of mL MCG per gallon of influent water.

Figure 229. Cell A Nitrate, Carbon Dose Rates, and Flow Rates in CY 2010

As shown on Figure 229, optimization efforts focusing on carbon dose rates and influent flow rates were conducted through the year. This also occurred with phosphorus dose rates in the first portion of 2010, which led to the use of Rocky Flats-specific, custom-blended MicroCg beginning on July 1. This is illustrated below on Figure 230; the zero values shown from July onward correspond to the switch to the custom-blended carbon.



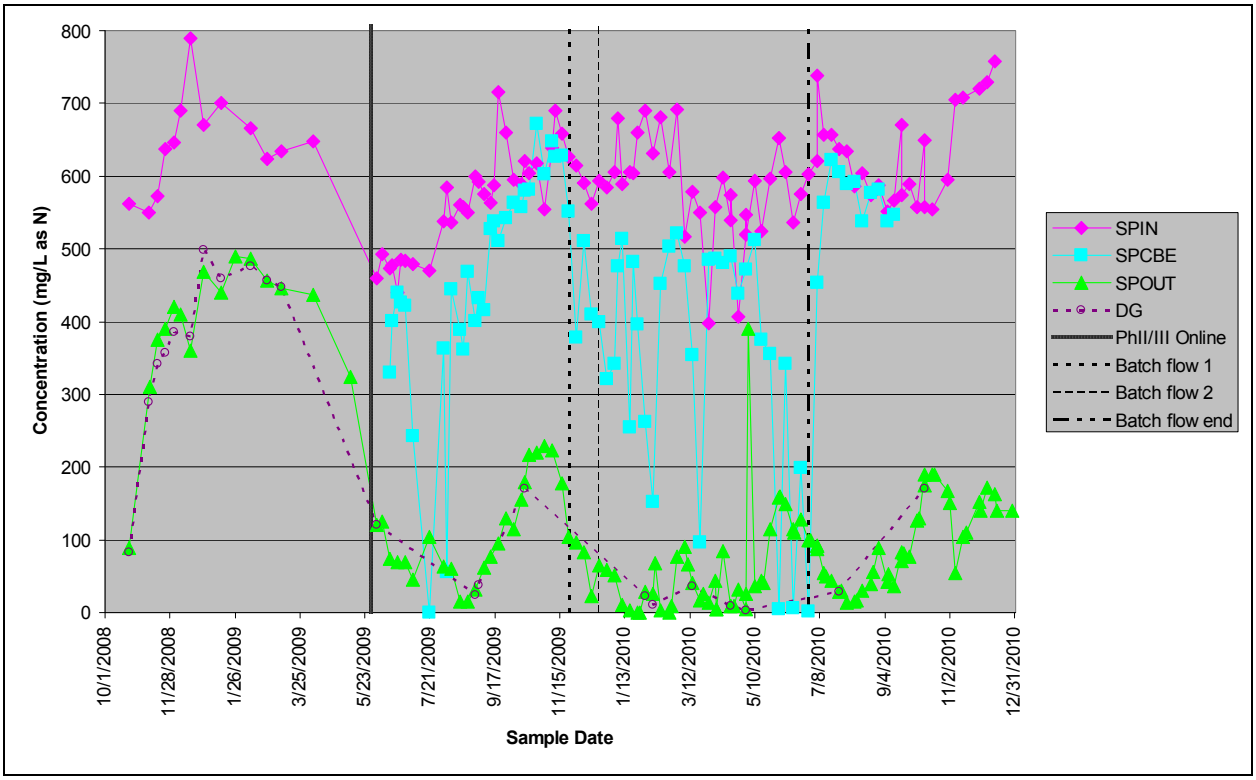
Notes: Phos_dose_ml/gal = dose rate for separately-dosed phosphate solution, is in units of mL per gallon of influent water. Influent was not dosed prior to Feb 25, 2010, in an attempt to depend solely on naturally occurring phosphorus. Dosing was deactivated on July 1, when a carbon source that contained phosphorus at the optimized ratio began to be used.

Figure 230. Cell A Phosphate Dose Rates in CY 2010

Another important Cell A attribute that was tested and optimized was recirculation: Cell A is equipped with a recirculation pump that is designed to enhance flow through the cell, based on the fact that denitrifying bacteria thrive under higher velocity flows than Cell A would otherwise present. Although this recirculation pump does not provide flows in the optimal range for these bacteria, it does improve conditions. Testing of the pump was performed by installing two clear, in-line, media-filled pipe segments of differing diameters that were operated in series. The contents of these pipes were visually examined for biofilm development on the media within the pipes. (This component was installed on October 23, 2009, and is referred to as the flow loop in DOE 2010d) The pipe segments, which had diameters of 2 inches and 4 inches and were plumbed directly to the pump, were routinely inspected. Rates of biofilm development on the media did not appear to vary from the larger pipe (in which water moved more slowly) to the narrower pipe (with faster flows). Samples were collected from the end point of each of these pipe segments and showed no significant differences. Recirculation was also tested by turning the pump off for a time, and then back on. When the pump was deactivated between July 15 and

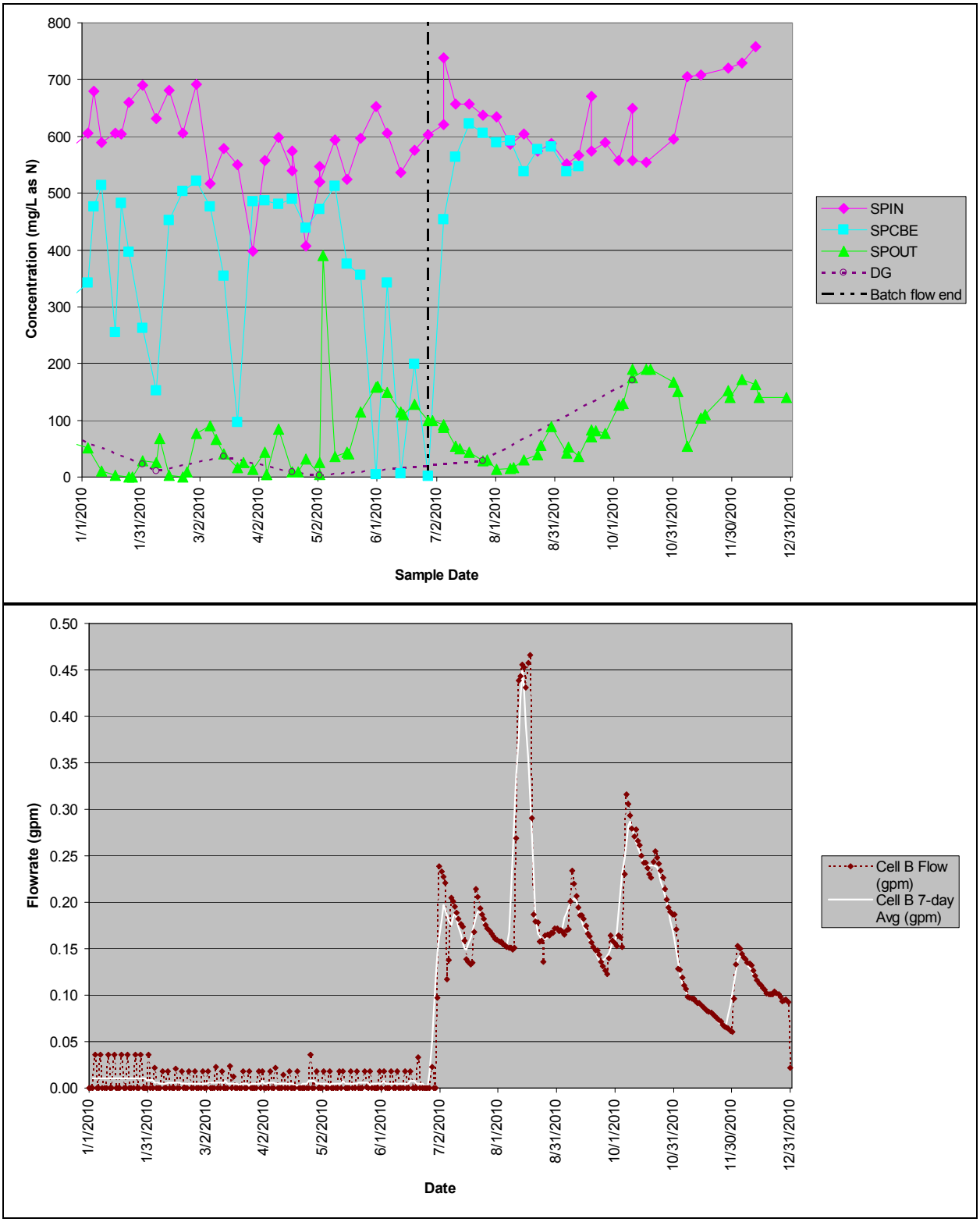
August 18, 2010, certain indicators—such as smell and water appearance, as well as changes in other chemical parameters not illustrated on Figure 229—showed that the cell operated more effectively under the higher flow rates afforded by the recirculation pump. Recirculation was then restored and maintained through the rest of 2010.

Cell B optimization efforts were much more limited. By design, this cell was testing a more passive, flow-through organic media as opposed to the active approach of Cell A. No additional amendments were provided to Cell B via the influent, nor was water within the cell recirculated. In contrast to Cell A, flow through Cell B was neither continuous nor a significant fraction of overall SPPTS flows. Figure 231 illustrates the overall performance of this cell, and Figure 232 focuses on 2010 data and corresponding flows. Reduced treatment in winter months was attributed to heat loss: although insulation was installed over the cell, it continued to lose heat that was not adequately replenished under the batch-flow operations. Adding a small (e.g., 26 gallons) aliquot of relatively warmer groundwater twice weekly was insufficient to keep the cell contents warm, and denitrifying bacteria do not function well in cold temperatures. However, this would not be sufficient to explain the reduced treatment during summer months. As illustrated in both figures, there were occasions when the cell treated flows adequately and effluent targets (10 mg/L nitrate) were met, but performance was very inconsistent. The timing of sampling vs. addition of influent may have played a role, but this seems implausible given the extremely small volume of these additions compared to the overall size of the cell, unless preferential flow paths were present within the media that caused some influent to flow straight to the effluent sampling point. This was not tested, but again the very small volume of the additions and the fact that effluent samples were collected using consistent methods and from the same point suggests such an explanation has some flaws. Average flow rates on a gallon-per-minute basis under batch flow operations began at approximately 0.01 gpm and were later halved to approximately 0.005 gpm, which is slightly less than 4 teaspoons per minute.



Notes: SPIN = system influent; SPCBE = effluent from Phase III Cell B; SPOUT = system effluent; DG = SPP Discharge Gallery. PhII/III Online = date on which the Phase II and Phase III components were put online. Batch flow 1 provided approximately 105 gallons per week; batch flow 2 approximately halved that to 52 gallons per week; batch flow was ended and continuous flows resumed when indicated. Some data are qualified (e.g., U, B, J), but are not displayed differently for simplicity. Data are from contract laboratories as well as the ESL.

Figure 231. Concentrations of Nitrate in Effluent From Phase III Cell B



Notes: Top portion: SPIN = system influent; SPCBE = effluent from Phase III Cell B; SPOUT = system effluent; DG = SPP Discharge Gallery. Batch flow was ended and continuous flows resumed when indicated. Some data are qualified (e.g., U, B, J), but are not displayed differently for simplicity. Data are from contract laboratories as well as the ESL.

Bottom portion: during batch flow operation, two pulses of influent (batches) per week were added to the cell.

Figure 232. Cell B Nitrate and Flow Rates in CY 2010

The results illustrated above may be used in considering the design requirements of a full-scale nitrate treatment cell based on the Cell B approach. Cell B contains approximately 140 cubic feet of corn stover. Ignoring the inconsistency with which effective treatment was demonstrated and increasing this volume sufficiently to treat the entire SPPTS flow (assuming an average flow rate of 1.6 gpm), simple mathematical extrapolation suggests a media volume of about 45,000 cubic feet, or approximately 3 times the entire volume of the original structure (including treatment cells and overburden), would be required. This depends on treatment performance meeting critical assumptions, most especially that treatment would be consistently effective, flows would not exceed 1.6 gpm, and preferential flow would not be present. To provide a safety margin and to accommodate periods of higher flow, the volume would be increased significantly, perhaps to 5 times the volume of the existing structure, or about 75,000 cubic feet. Some method of hydraulic control would need to be incorporated, because to achieve effective treatment, the influent must flow through the entire bulk of the irregular organic media, not along preferential pathways. Upflow configuration enhances flow dynamics, but additional engineering would be required to provide dependable flow control, which would further increase the size and complexity of the treatment cell. Therefore, in June 2010 it was concluded that the Cell B approach would not be feasible for treating SPPTS influent. However, rather than discontinue operation of this cell, continuous flow was resumed under the assumption that the cell was still providing some useful treatment. In September 2010 periodic sampling of the effluent from Cell B was curtailed.

As 2010 ended, efforts were underway to design a full-scale nitrate treatment cell based on the Cell A treatment methodology. Results will be reported in 2011. In the interim, the SPPTS continues to operate, and efforts to further optimize the performance of Cells A, B, and the Phase II cell will continue.

Other Plumes

In accordance with RFLMA, the source areas as well as downgradient contaminant migration pathways for other groundwater contaminant plumes at Rocky Flats were monitored during 2010.

This section presents a summary discussion of data collected in 2010 from several plumes/areas of interest. These include the 903 Pad/Ryan's Pit Plume, the collection of small plumes collectively referred to as the IA Plume, the VC Plume (or OBP#1 Plume) located south of the former B371 complex, the IHSS 118.1 Plume (also called the carbon tetrachloride plume) located north-northwest of former B776, the PU&D Yard Plume, and the OU 1 Plume. A short summary of data from other locations of special interest is then presented.

903 Pad/Ryan's Pit Plume

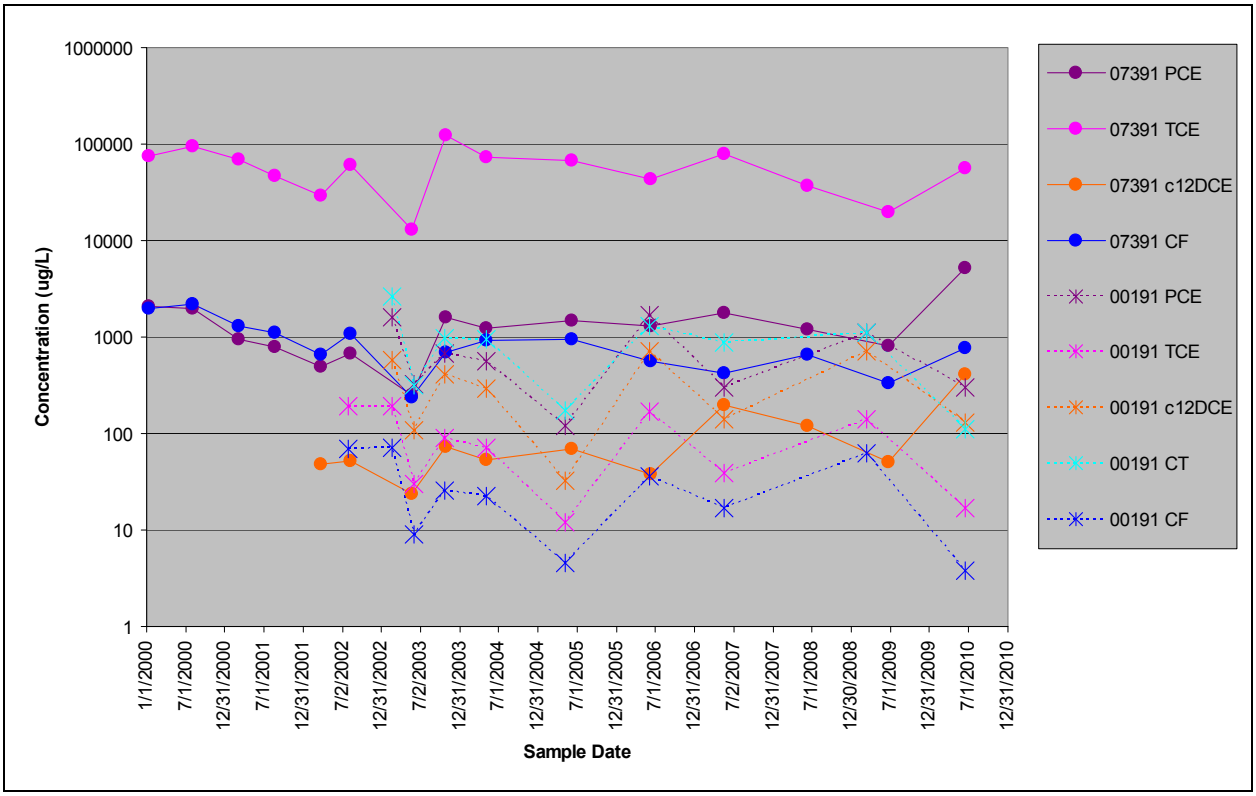
The source areas and downgradient portions of the 903 Pad/Ryan's Pit Plume were monitored in June 2010. (Sentinel and AOC wells monitoring this plume were also sampled in October 2010.) Water quality was generally consistent with previous data. As expected, the two source-area wells, Evaluation wells 00191 just east of the former 903 Pad and 07391 just south of former Ryan's Pit, produced samples with the highest overall concentrations of contaminants. Concentrations of TCE from well 07391 are approximately 2 orders of magnitude higher than

any other VOCs reported in this plume, including at well 00191. As is typical for these source areas, the 903 Pad components are primarily carbon tetrachloride and PCE, while the main constituent in groundwater from the Ryan's Pit source area is TCE. The concentration of the metabolic byproduct *cis*-1,2-DCE increased somewhat in both source-area wells, and in 2010 was slightly higher than that of carbon tetrachloride in the samples from well 00191 (130 µg/L vs. 110 µg/L). This may be related to application of HRC in both source areas just prior to closure.

Also as expected, terminal well 10304, an AOC well located on the northern bank of and along the flow path to Woman Creek, produced samples with the lowest concentrations of VOCs. Samples collected from this well in 2010 yielded a single, J-qualified detection of TCE reported at an estimated concentration of 0.68 µg/L. However, wells between the source areas and this AOC well produce samples with VOC concentrations that often do not reflect their relative distance from the source areas. Sentinel well 90399, which is located on the north side of the SID, next-farthest from the source areas, produced samples with concentrations of VOCs that exceed those reported in wells that are closer to the source areas and, with respect to certain VOCs, even including well 00191. This is also consistent with previous data.

Ryan's Pit source-area well 07391 reported a concentration of PCE (5,200 µg/L) that was above the previous range for this well (250 µg/L to 2,100 µg/L since the year 2000). The concentration of TCE was consistent with that of previous years, being reported at 56,000 µg/L (TCE has ranged from 13,000 µg/L to 124,000 µg/L). An increase in reductive dechlorination of the residual source material may be indicated by the somewhat stronger increase in *cis*-1,2-DCE, which was reported in the 2010 sample at a concentration of 410 µg/L; this constituent is calculated to be on an increasing trend at the 95 percent confidence (Table 77). The range for this constituent since 2002 has been 24 µg/L to 200 µg/L (prior to 2002, detection limits reported for this compound were 1,000 µg/L and 5,000 µg/L, and therefore samples from 2000 until 2002 are represented solely by nondetects). Even so, given that PCE more than doubled and both it and TCE are reported in the thousands to tens of thousands of micrograms per liter, the higher concentration reported for this daughter product does not suggest a substantial increase in biodegradation of parent compounds. Time-series plots of the primary constituents are presented in Figure 233. (Carbon tetrachloride is omitted for 07391, because results for this constituent reported since 2000 consist of nondetects at detection limits ranging from 1 µg/L to 5,000 µg/L, and a single detection in 2003 of 7.1 µg/L.) A second trend meeting the 95 percent level of significance is calculated for chloroform in samples from well 07391, where it is decreasing in concentration.

No similarly significant increasing or decreasing trends are calculated for well 00191. Concentrations of the primary VOCs in samples from this well are also illustrated on Figure 233. Carbon tetrachloride is the VOC present at the highest concentrations at this location, but these concentrations are typically 1 to 2 orders of magnitude lower than those of the primary contaminant, TCE, at well 07391. Concentrations of PCE at location 00191 are occasionally greater than at 07391, but not in 2010; the same applies to concentrations of *cis*-1,2-DCE.



Notes: c12DCE = *cis*-1,2-DCE; CF = chloroform; CT = carbon tetrachloride. Several results are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

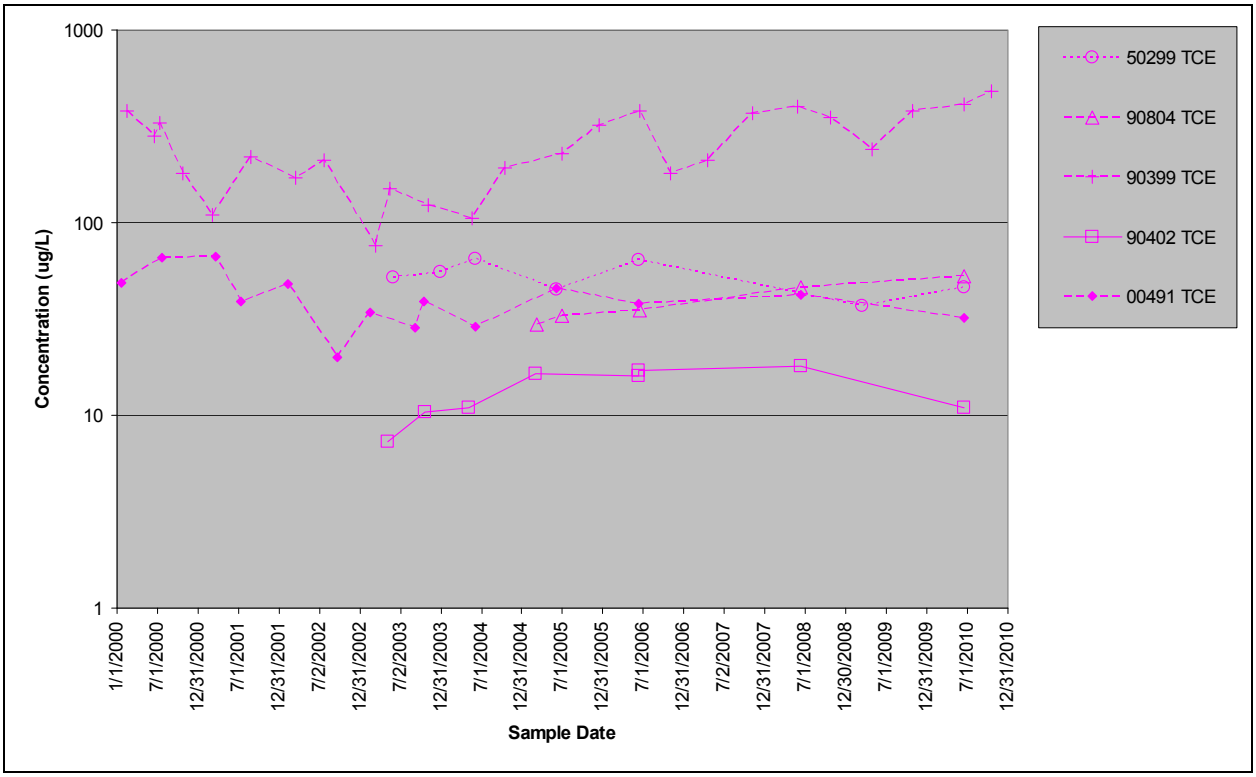
Figure 233. Primary VOCs in 903 Pad/Ryan's Pit Plume Source Area Wells

In addition to the source area wells and the AOC well identified above, other wells monitoring this plume along the pathway to Woman Creek include Evaluation wells 90402, 00491, 50299, 90804, and Sentinel wells 90299 and 90399. Of these, trends meeting the 95 percent level of statistical significance (Table 77) are calculated for well 00491 (chloroform; decreasing), 90399 (1,1-DCE, *cis*-1,2-DCE, and TCE; all increasing), and 90299 (carbon tetrachloride, chloroform, and TCE; all decreasing). Some of these trends are questionable due to the presence of nondetects in the data set.

The unusual distribution of TCE illustrates the point made above regarding concentrations not decreasing with increasing distance from the source area. Time-series plots of TCE are provided below in Figure 234. Except for source area well 07391, concentrations of TCE appear highest in well 90399, which is located farthest from the source area, and lowest in well 90402, which is closest to the sources but side-gradient with respect to former Ryan's Pit. Between these two wells, the concentrations of TCE in samples from wells 50299, 00491, and 90804 have varied inconsistently. Time-series plots of carbon tetrachloride (Figure 235) illustrate a different pattern, with well 50299 reporting the highest concentrations, though in 2010 results from Sentinel well 90399 were essentially equivalent.

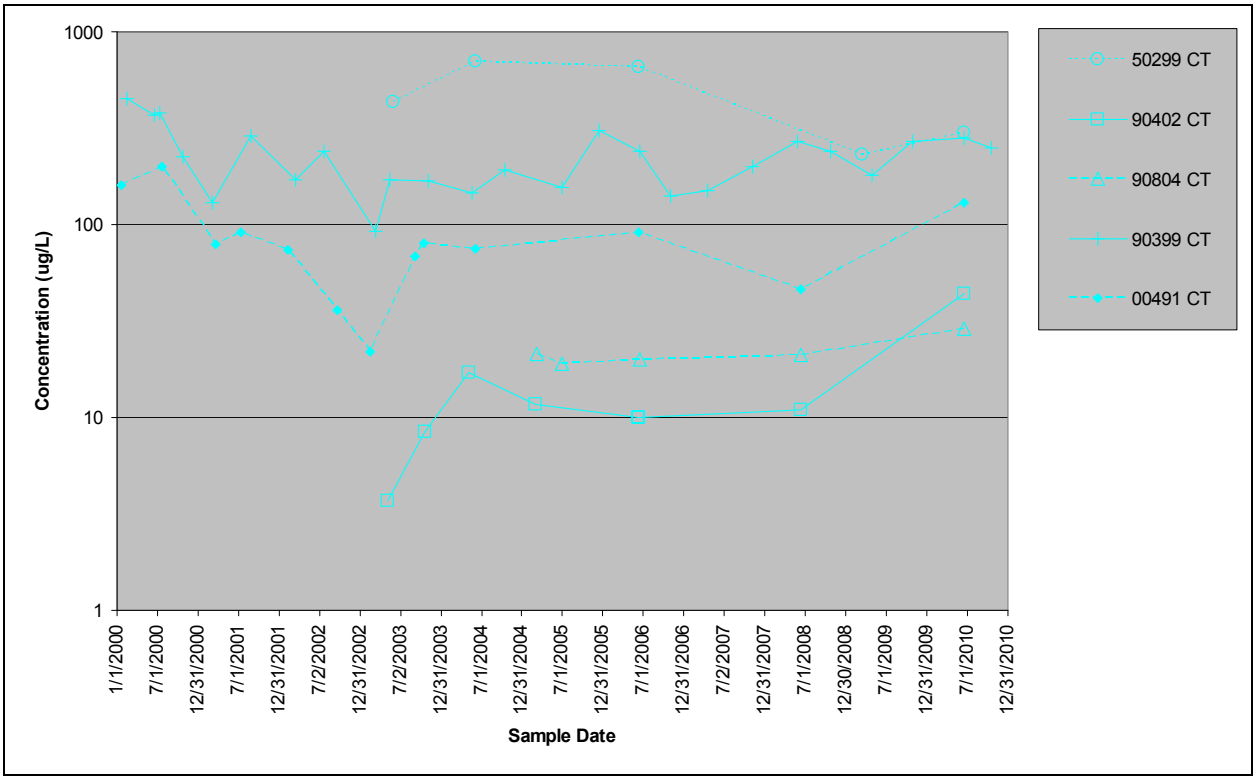
Finally, time-series plots for chloroform in samples from the same wells are presented in Figure 236. Chloroform is the first metabolic byproduct formed from the dechlorination of carbon tetrachloride, but was also used in various processes at Rocky Flats. (Therefore, its presence is not necessarily indicative of dechlorination.) This plot shows concentrations of

chloroform are essentially equivalent in groundwater collected from wells 90399, 00491, and 50299. The first of these is located at the SID, while the other two are east of former Ryan's Pit, just south of the pediment top. Concentrations of this constituent in samples from wells 90804 and 90402 are significantly lower than in the other three wells.



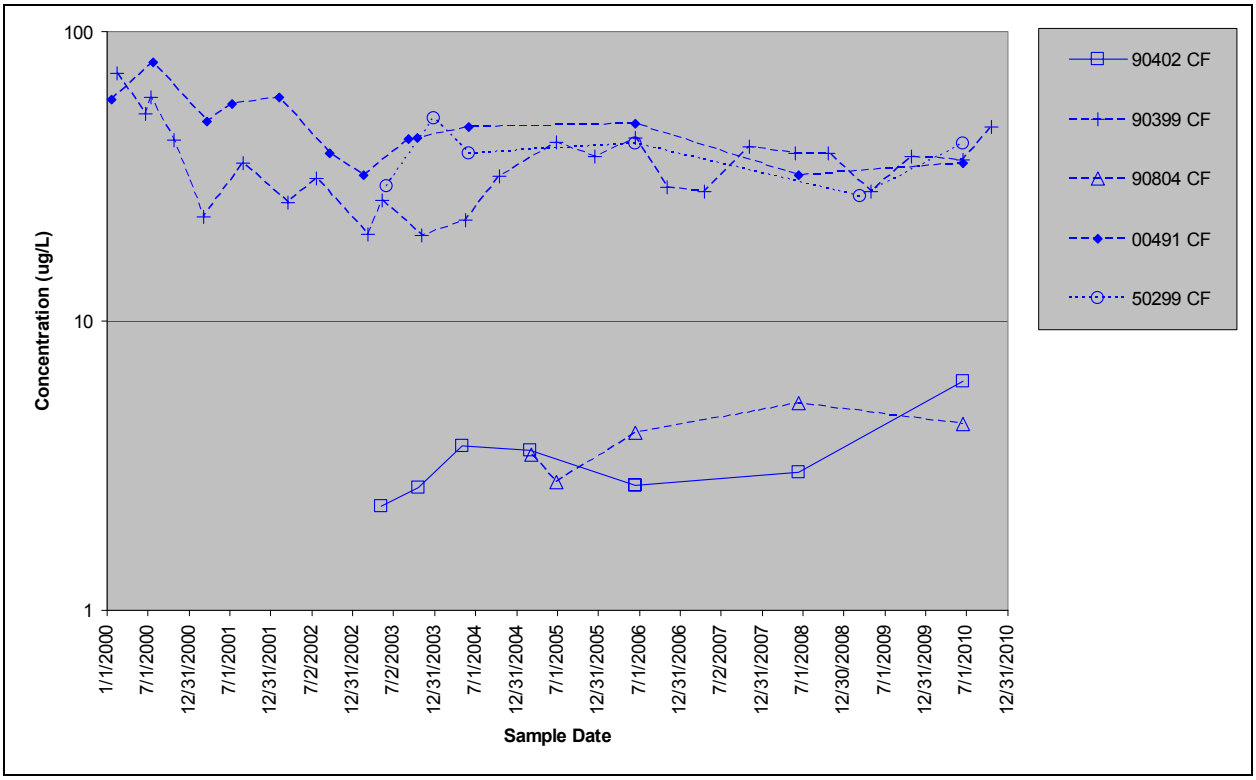
Notes: Several results are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 234. TCE in Samples From Wells Within the 903 Pad/Ryan's Pit Plume



Notes: CT = carbon tetrachloride. Several results are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 235. Carbon Tetrachloride in Samples From Wells Within the 903 Pad/Ryan's Pit Plume

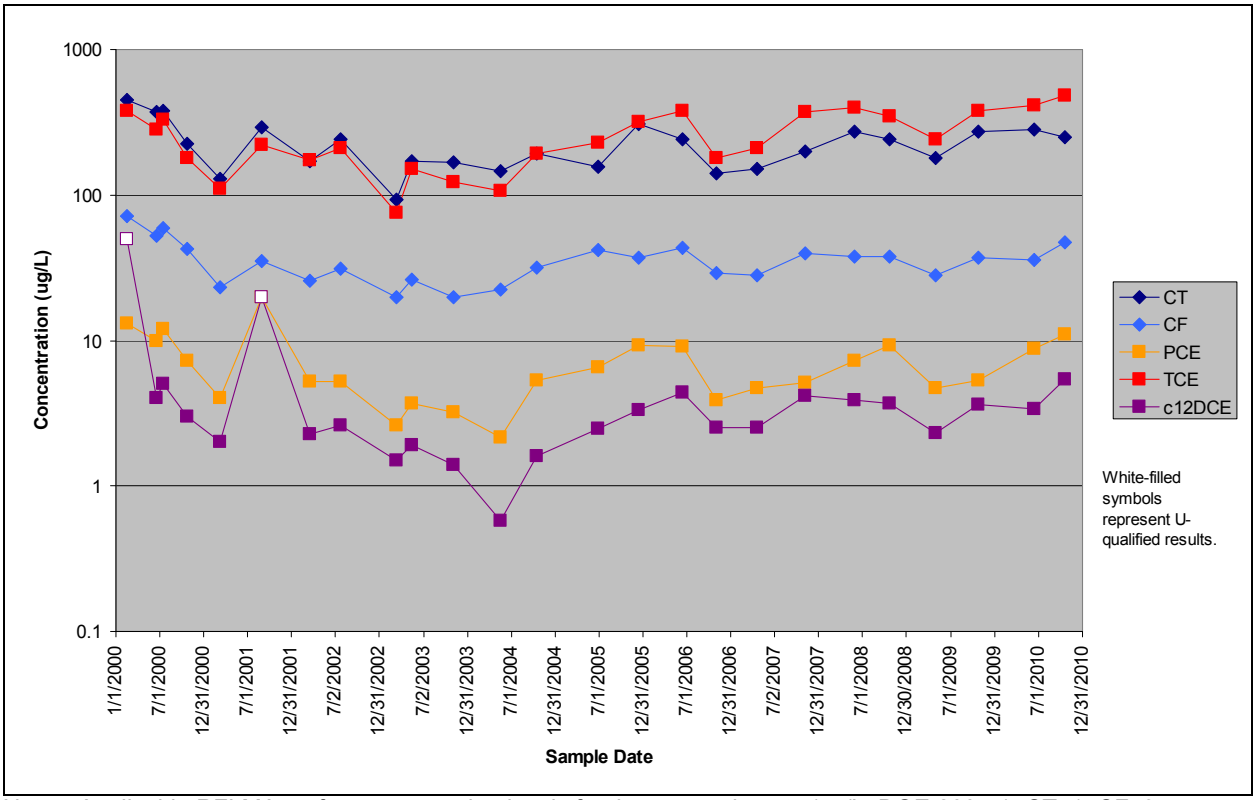


Notes: CF = chloroform. Several results are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 236. Chloroform in Samples From Wells Within the 903 Pad/Ryan's Pit Plume

Downgradient Sentinel well 90299, which is typically dry, was recharged by the significantly higher precipitation in the spring of 2010 and produced samples in both sampling events (second and fourth quarters). The last time this well produced samples was in 2007. Consistent with its position on the margin of the plume, only three detections of VOCs, all at very low concentrations, were reported in 2010. Chloroform was detected in the second quarter, and TCE in both quarters; the TCE result in June of 1.4 µg/L was the only result not J-qualified, and was the highest concentration reported of any VOC detected in samples from this well.

Because of the importance of Sentinel well 90399, a series of time-series plots is provided showing the main VOCs present in samples from this well (Figure 237). Concentrations of these constituents have remained fairly consistent over the past several years. As shown, concentrations of carbon tetrachloride and TCE—the two dominant VOCs in the two source areas for the 903 Pad/Ryan's Pit Plume—are very similar, supporting the conclusion that both source areas contribute to the contamination reported in samples from this well. While biodegradation of the PCE to TCE may also be contributing to the higher TCE concentrations, previous reports and technical studies (K-H 2004d; ATSDR 2007) suggest this mechanism would be of minor importance in this area.



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): CT, 1; CF, 3.4; PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. In addition to the nondetects ("U"-qualified results), several other results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 237. VOCs in Downgradient 903 Pad/Ryan's Pit Plume Well 90399

The AOC well at the mouth of Pond C-2, 00193, also supports the monitoring of the 903 Pad/Ryan's Pit Plume. The sample collected in June 2010 from this well reported a J-qualified detection of TCE with a concentration estimated at 0.23 µg/L. No other VOC detections were reported in 2010. The highest concentration of any VOC in the data set for this location is 12 µg/L of *cis*-1,2-DCE in a sample collected in May 2008. This constituent has been detected on three occasions, most recently in April 2009 (0.17 µg/L, J-qualified). TCE is the VOC detected most frequently at this location; it has been detected in five samples, the earliest of which was collected in May 2003. None of the reported concentrations of any VOC detected in samples from this well has exceeded the applicable RFLMA Table 1 value for the corresponding constituent.

U concentrations reported in samples collected in 2010 from AOC well 00191 were consistent with previous data. Samples from this well have reported U concentrations ranging from 36 µg/L to just over 93 µg/L; results in 2010 were 74 µg/L and 63 µg/L for the second and fourth quarters, respectively.

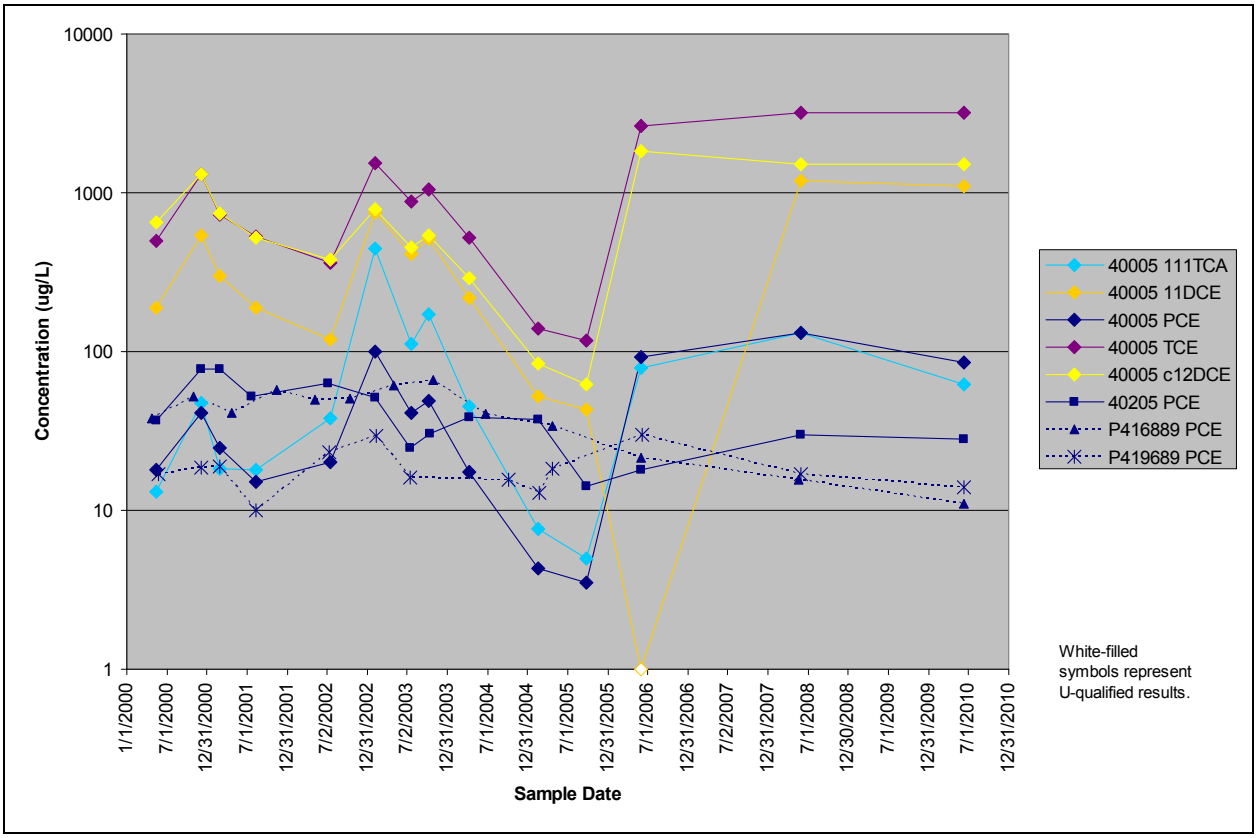
IA Plume

The IA Plume is actually a collection of several small VOC plumes grouped together for convenience and, in some cases, because of uncertainties regarding specific sources. This

discussion defines the IA Plume as three loosely defined segments: the South, Central, and North IA Plumes.

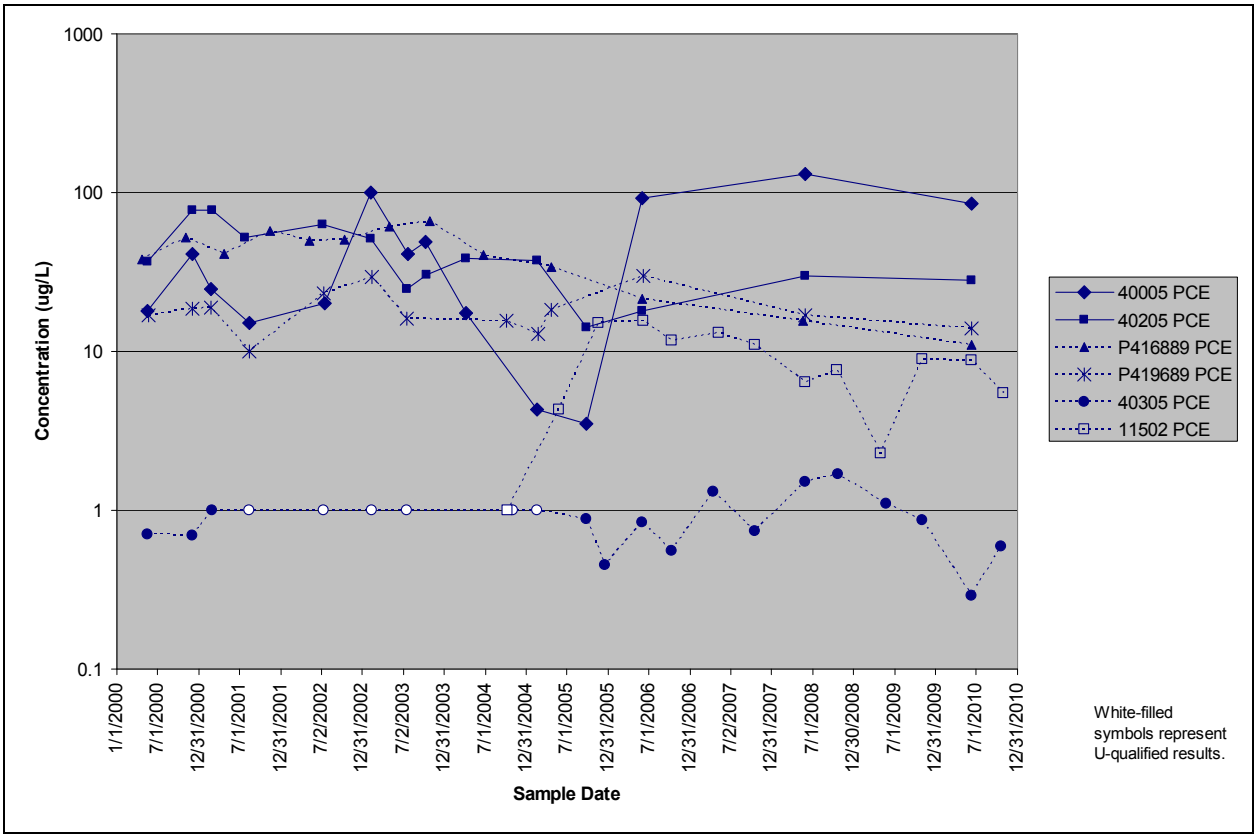
The pathway to surface water for the southern portion of the IA Plume is monitored by AOC well 11104. One VOC detection was reported in 2010. The May sample reported an estimated (J-qualified) concentration of 1,3-DCB of 0.64 µg/L (RFLMA Table 1 standard is 94 µg/L). Concentrations of U, samples for which are collected because of the proximity of the OLF and former B444, continue to be well below the U threshold of 120 µg/L; the highest concentration in 2010 was reported at 33 µg/L. A decreasing trend in U is suggested at this well, but does not meet the 95 percent level of statistical significance (Table 77).

Upgradient of well 11104, wells monitoring the South IA Plume include Sentinel wells 11502 and 40305, and Evaluation wells 40005, 40205, P419689, and P416889. Each of these wells was sampled in 2010 in accordance with RFLMA. Results are consistent with past data. As with results prior to closure, the highest VOC concentrations of these wells are reported at Evaluation well 40005 (Figure 238). With the exception of the anomalous nondetect in 2006, VOCs in well 40005 are distributed fairly uniformly. The fact that the concentrations of daughter products such as *cis*-1,2-DCE and 1,1-DCE are not increasing as those of parent compounds like PCE and TCE decrease suggests minimal degradation is occurring. VOC concentrations in groundwater downgradient of this location appear to vary inconsistently from location to location. However, with the post-closure stabilization of hydrologic conditions evident now for the past few years, as illustrated more clearly on Figure 239, the previous, apparently random "trends" in PCE concentrations that were typical prior to closure have since become more uniform. The well closest to the local source area (40005) produces samples with the highest concentrations of PCE, and locations increasingly farther downgradient from this well produce samples with successively lower concentrations of PCE. Concentrations of PCE reported in samples from Sentinel wells monitoring this area, including side-gradient 40305 and downgradient 11502, support this pattern. Note that PCE in well 40305 is calculated to be on an increasing trend with a 95 percent level of statistical significance (Table 77), but the data set includes numerous nondetects, and in 2010 the lowest concentration of PCE at this location since 2000 was reported (Figure 239).



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): 1,1,1-TCA, 200; 1,1-DCE, 7; PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. In addition to the nondetects ("U"-qualified results), several other results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 238. VOCs in South IA Plume



Notes: Applicable RFLMA surface-water action level for PCE (µg/L; DOE 2007a) is 1. Several results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 239. PCE in South IA Plume

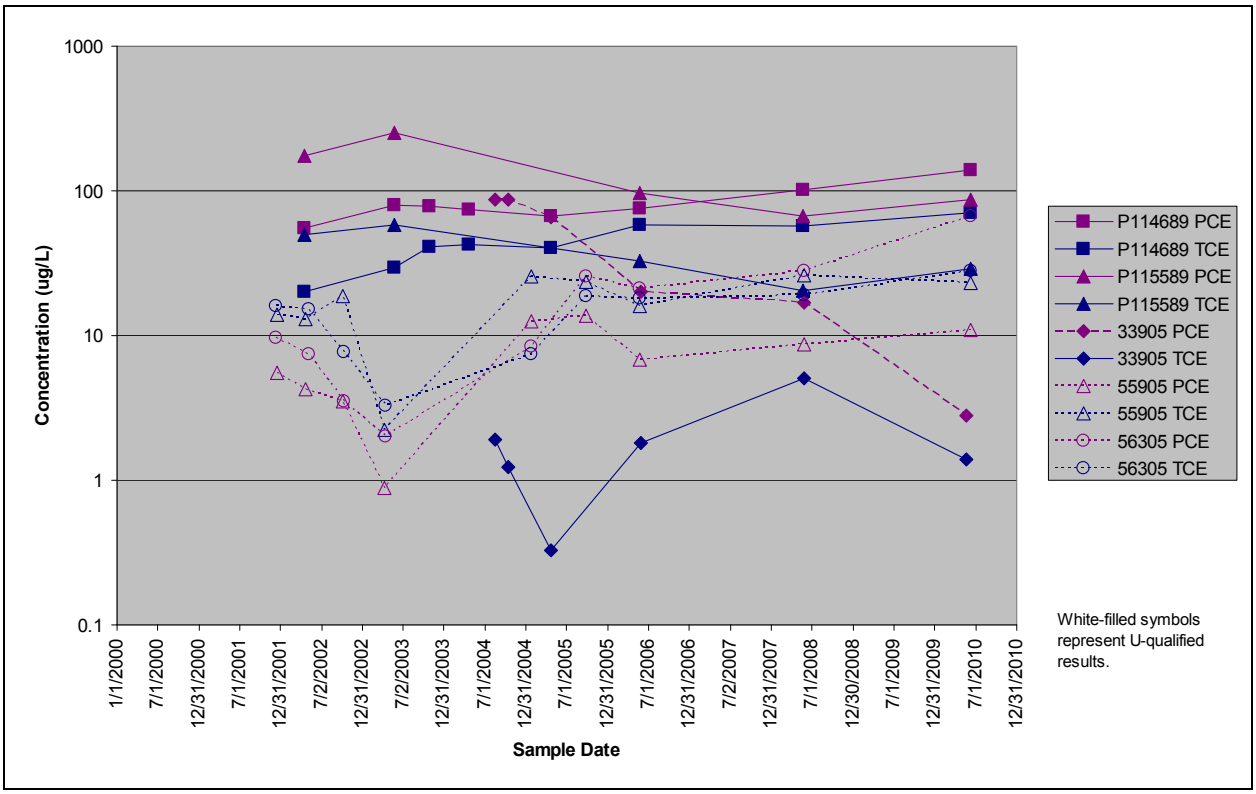
Of the wells illustrated in the time-series plots above for the South IA Plume, statistical trends in VOC concentrations having a 95 percent level of significance are also calculated for 40205 (1,1-DCE, *cis*-1,2-DCE, and PCE; all decreasing) and P416889 (*cis*-1,2-DCE, decreasing). In addition, an increasing trend in U concentrations meeting the same level of significance is calculated for well 40005, but the highest detection reported has been 1.4 µg/L. In 2010, the concentration of U at this well was reported at 1.1 µg/L. (Refer to Appendix B for plots of statistically calculated trends.)

The central portion of the IA Plume, for the purposes of this report, is monitored by Evaluation wells P115589, P114689, 70705, 33905, 55905, and 56305. Each of these wells was sampled in 2010. Some of these wells also have certain building-specific objectives: well 70705 monitors downgradient of former B707, and wells 55905 and 56305 monitor former B559.

Several time-series plots were constructed for the Central IA Plume. A selection of these is provided here. Of the wells in this grouping, P114689 monitors groundwater with the highest concentrations of VOCs. Because these wells do not all monitor a single source area, but rather several small sources and commingled plumes, clear contaminant distribution patterns can be difficult to distinguish.

Time-series plots of PCE and TCE concentrations in samples from wells P114689, P115589, 55905, and 56305 (Figure 240) illustrate a distinction that existed prior to site closure between

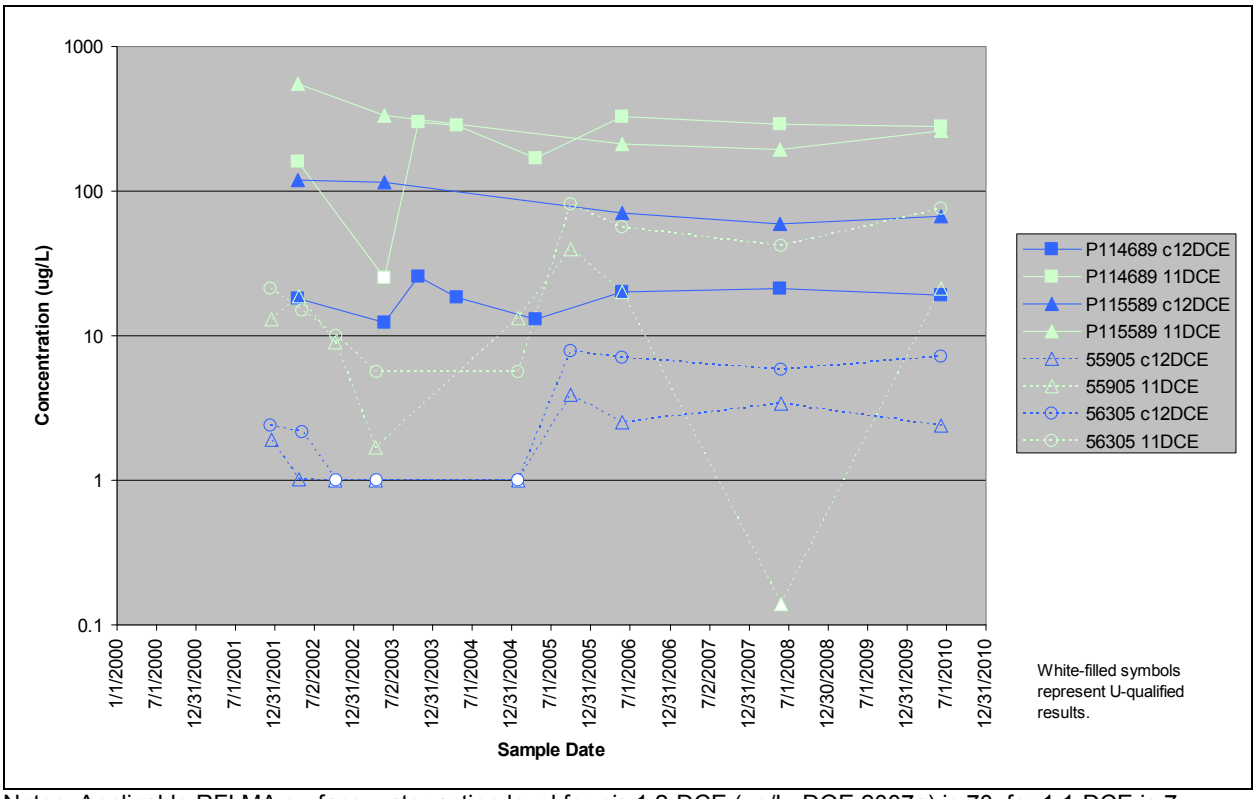
the two more centralized wells (P114689 and P115589) as compared to the two B559-area wells. Since closure, concentrations of these constituents are more similar. Concentrations of TCE in samples from well P114689 are on an increasing trend at the 95 percent level of significance; an increasing trend in PCE concentrations here is also visible but does not meet that level of statistical significance. Concentrations of PCE in samples from well 33905, located just south of FC-2, north of P115589 and northwest of P114689, illustrate a decreasing trend that meets the 95 percent level of significance. Concentrations of TCE in this well vary differently, and do not follow the relatively consistent decreasing pattern observed in PCE concentrations. Additional data will help to illustrate relationships and will also support the calculation of additional statistically significant trends.



Notes: Applicable RFLMA surface-water action level for PCE (µg/L; DOE 2007a) is 1, for TCE is 2.5. Several results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 240. PCE and TCE in Central IA Plume Wells

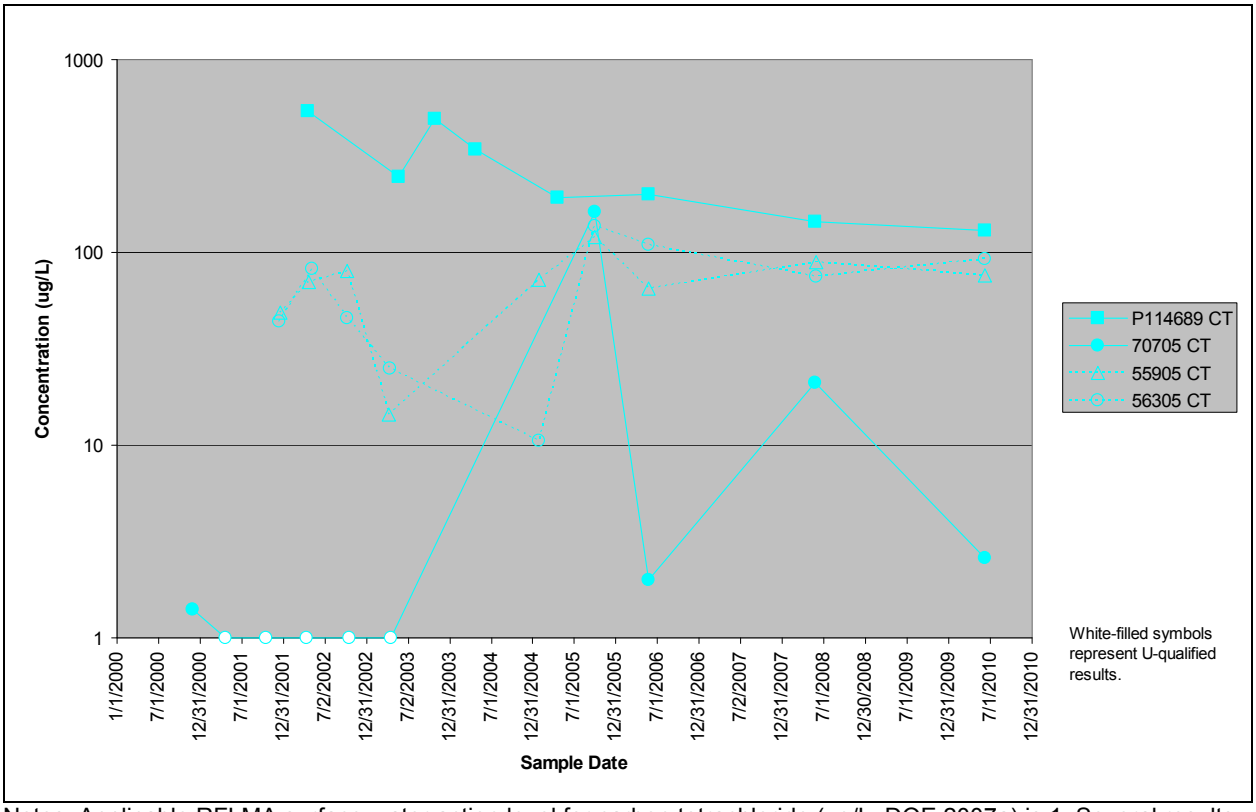
Concentrations of *cis*-1,2-DCE and 1,1-DCE—primary metabolic products from dechlorination of PCE and TCE—in selected Central IA Plume wells are illustrated in Figure 241. Not shown on the time-series plots due to their significantly lower concentrations are results from well 33905, where concentrations of 1,1-DCE are on a decreasing trend with 95 percent significance (Table 77); concentrations have dropped from 7.5 µg/L in 2004 to nondetect in 2010 (with a detection limit of 0.23 µg/L). Concentrations of *cis*-1,2-DCE at this location have varied irregularly between a range of 0.5 µg/L (the result in 2010) to 3.1 µg/L. Daughter-product concentrations appear to have increased somewhat in the B559 area at closure but have not continued to increase. These results are consistent with previous findings that the typical, aerobic groundwater conditions at Rocky Flats do not enhance biodegradation of chlorinated compounds (Kaiser-Hill 2004d).



Notes: Applicable RFLMA surface-water action level for *cis*-1,2-DCE (µg/L; DOE 2007a) is 70, for 1,1-DCE is 7. Several results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 241. Concentrations of cis-*1,2-DCE and 1,1-DCE in Central IA Plume Wells*

Carbon tetrachloride is a primary VOC constituent in several Central IA Plume wells (Figure 242). Data from well P114689 for this constituent support the calculation of a decreasing trend meeting the 95 percent level of significance. The distribution of this compound varies from that of PCE and TCE; for example, the RFLMA data set for well P115589 does not include any detections of carbon tetrachloride. Similarly, well 70705, located on the eastern side of former B707, has reported varying concentrations of carbon tetrachloride but comparatively low concentrations of PCE (up to 2.6 µg/L, and half of the results are nondetects) and TCE (to 1.4 µg/L, again with half the results being nondetects). These varied conditions are evidence for multiple contaminant sources contributing to what is collectively termed the IA Plume.

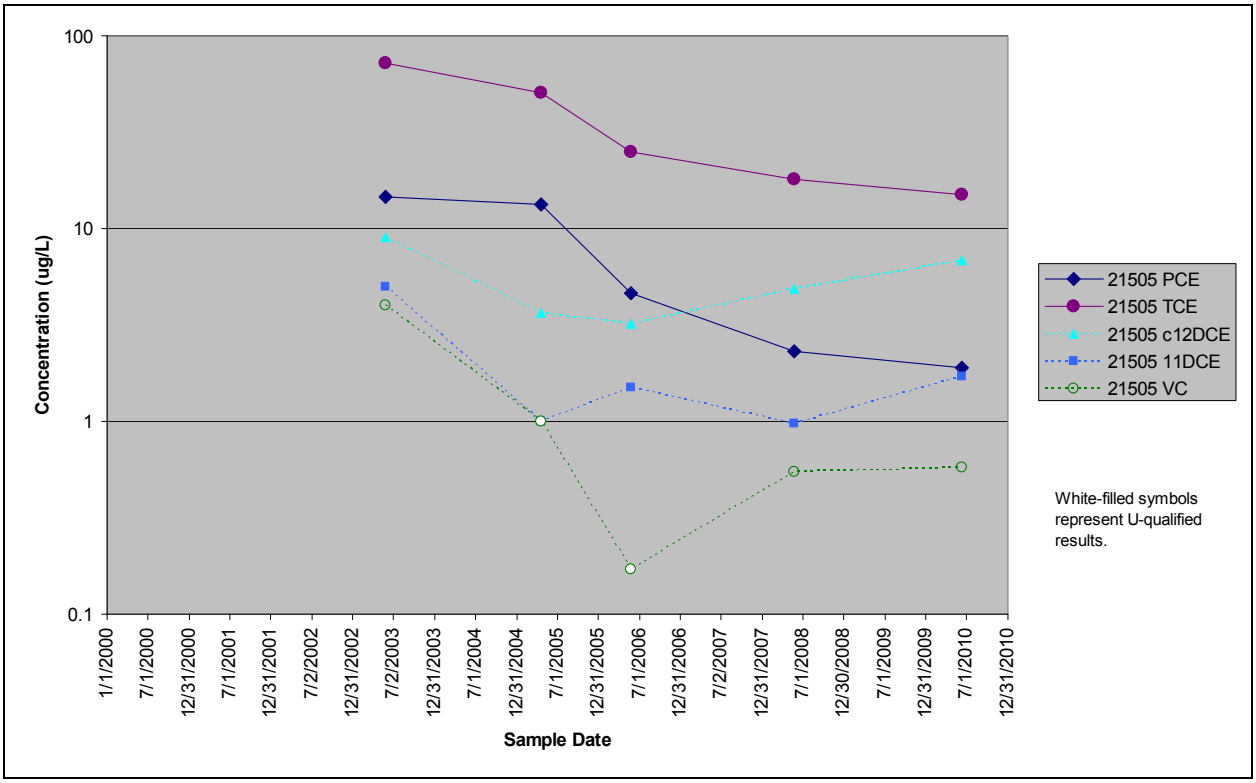


Notes: Applicable RFLMA surface-water action level for carbon tetrachloride (µg/L; DOE 2007a) is 1. Several results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 242. Carbon Tetrachloride in Central IA Plume Wells

Wells monitoring the North IA Plume were also sampled in 2010. These include Evaluation well 21505 and Sentinel well 52505 along FC-2, and AOC well 42505. Although they also monitor the North IA Plume, wells 18199, 20902, 20705, 20505, and 20205 are discussed below in the context of the IHSS 118.1 Plume; and wells 33502, 33604, and 33703 are discussed in the section on the Vinyl Chloride Plume.

Evaluation well 21505 was sampled in June 2010. Results were generally consistent with previous data, although the results for PCE and TCE were both lower than in previous samples in the data set. This location is adjacent to a marshy area that is between the only two locations at which good evidence for biodegradation was identified prior to site closure (Kaiser-Hill 2004d): well 33502, which monitors the Vinyl Chloride Plume within a buried drainage, and the predecessor to well 52505 (well 1986). Concentration data from well 21505 suggest that conditions at this location may also be conducive to biodegradation of chlorinated compounds, as concentrations of primary contaminants (in this case, PCE and TCE) are decreasing somewhat as those of their metabolic byproducts (*cis*-1,2-DCE and 1,1-DCE) increase slightly (Figure 243). Concentrations of VC, the terminal chlorinated byproduct in the PCE/TCE degradation pathway, do not define a clear pattern.



Notes: Applicable RFLMA surface-water action level for PCE (µg/L; DOE 2007a) is 1, TCE is 2.5, *cis*-1,2-DCE is 70, 1,1-DCE is 7, and VC is 0.2. Several results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 243. VOC Concentrations in North IA Plume Well 21505, Showing Evidence of Biodegradation

The terminal end of the North IA Plume is monitored by Sentinel well 52505 and AOC well 42505. Both of these wells were sampled twice in 2010 (June and October). Concentrations of VOCs at well 52505 remain very low, with fewer detections reported in 2010 than in 2009. Only *cis*-1,2-DCE was detected in 2010, at J-qualified concentrations of 0.34 µg/L and 0.65 µg/L in June and October, respectively. (The RFLMA standard for this constituent is 70 µg/L.) The detections of VC reported in samples from this well in fourth-quarter 2007 and 2008 were not repeated in 2009 or 2010.

VOC detections in samples from well 42505 were also reduced relative to the results in 2009. In the June sample, 1,3-DCB was reported at a J-qualified concentration of 0.47 µg/L (RFLMA standard is 94 µg/L), and in the October sample, TCE was reported at a J-qualified concentration of 0.22 µg/L (RFLMA standard is 2.5 µg/L).

In accordance with RFLMA requirements, analytical data from Sentinel well 52505 were analyzed for trend. An increasing trend in *cis*-1,2-DCE was calculated to meet the 95 percent level of significance but is based on a data set in which more than half the results are nondetects. Although not required by the RFLMA, data from AOC well 42505 were also analyzed for trend; no statistically significant increasing or decreasing trends were indicated.

VC Plume

The VC Plume emanates from OBP#1 and nearby metal disposal/destruction sites. These source areas were on the margin of a valley that was filled during construction of the B371 complex and became the site of Sage Avenue and the Portal 2 parking lots, among other facilities. The plume resides within the buried drainage, and groundwater flow appears to be routed by that feature. This is the only Rocky Flats area where VC is confirmed to be present at such elevated concentrations, which is indicative of the active biodegradation occurring here.

The VC Plume is monitored by source-area Evaluation wells 33502 and 33604 (33502 is located some 175 feet upgradient of 33604) and Sentinel well 33703 (approximately 110 feet downgradient of 33604). Both Evaluation wells were sampled in May 2010, and the Sentinel well was sampled in May and October 2010.

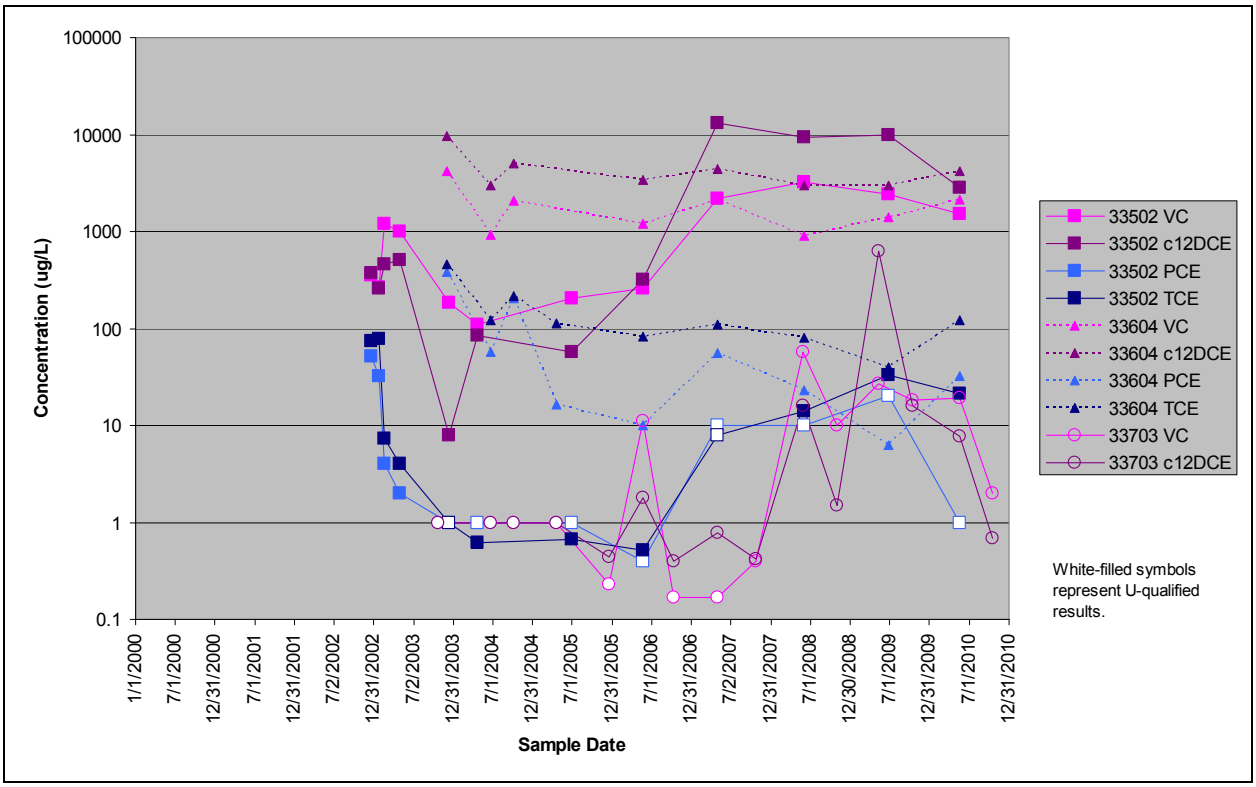
Well 33502 is one of only two locations where strong evidence for biodegradation was found (K-H 2004d); the second location identified in that report is well 1986, the predecessor to well 52505, as discussed above. (If it had existed at the time of that study, well 33604 almost certainly would have provided similarly strong evidence for biodegradation.) This is a likely explanation for both the high concentrations of VC and *cis*-1,2-DCE as well as the extremely limited aerial extent over which these concentrations have been observed. This biodegradation is probably a result of the decomposing organic remains of the vegetation that once grew within the now-buried valley. This process would consume oxygen, providing an anaerobic environment and carbon source suitable for the naturally-occurring bacteria that perform reductive dechlorination of the solvents most commonly found at the Site. Parent compounds, including PCE and TCE, are also detected in the groundwater in this area but at much lower concentrations than those of the metabolic byproducts. While VC and *cis*-1,2-DCE are reported in groundwater samples from source-area wells 33502 and 33604 at concentrations in the hundreds to thousands of micrograms per liter, PCE and TCE are typically reported in the tens to hundreds (and PCE is frequently not detected in samples from well 33502, as has been the case since late 2003, including the sample collected in 2010).

A time-series plot of the concentrations of primary parent and daughter compounds in source-area wells 33502 and 33604 and downgradient well 33703 is presented as Figure 244. Concentrations of TCE in samples from well 33502 remain near their 2002 highs, as has been the case since 2007, though results from 2010 are slightly lower. Concentrations of the metabolic byproducts *cis*-1,2-DCE and VC both remain above concentrations reported prior to 2007. A decreasing trend in PCE concentrations that meets the 95 percent level of significance is indicated for this well, but the data set contains numerous nondetects; this trend may not be real. (Refer to Appendix B for plots of statistically-calculated trends.)

At well 33604, concentrations have been more uniform, particularly with respect to the daughter products. Concentrations of the constituents shown in Figure 244 for this well are within their historical ranges. Even so, a decreasing trend with a 95 percent significance is calculated for TCE.

Concentrations of *cis*-1,2-DCE and VC in samples from Sentinel well 33703 have varied; following 2 years of second-quarter increases, in fourth quarter 2010 their concentrations were lower than in any sample collected since 2007. Even so, the data for well 33703 support the

calculation of increasing trends for these constituents (as well as for the isomer *trans*-1,2-DCE), but the many nondetects in the data set suggest these trends may not be viable. (**Note:** Sentinel well 33703 has developed a subsurface kink in its casing that is worsening to the point that sample collection may soon be impossible. This well will be replaced in early 2011.) The time-series plots displayed in Figure 244 suggest any geochemical changes that may have been due to the removal of impermeable surfaces over this area have not led to sharp reductions in the rates of reductive dechlorination in the source area.



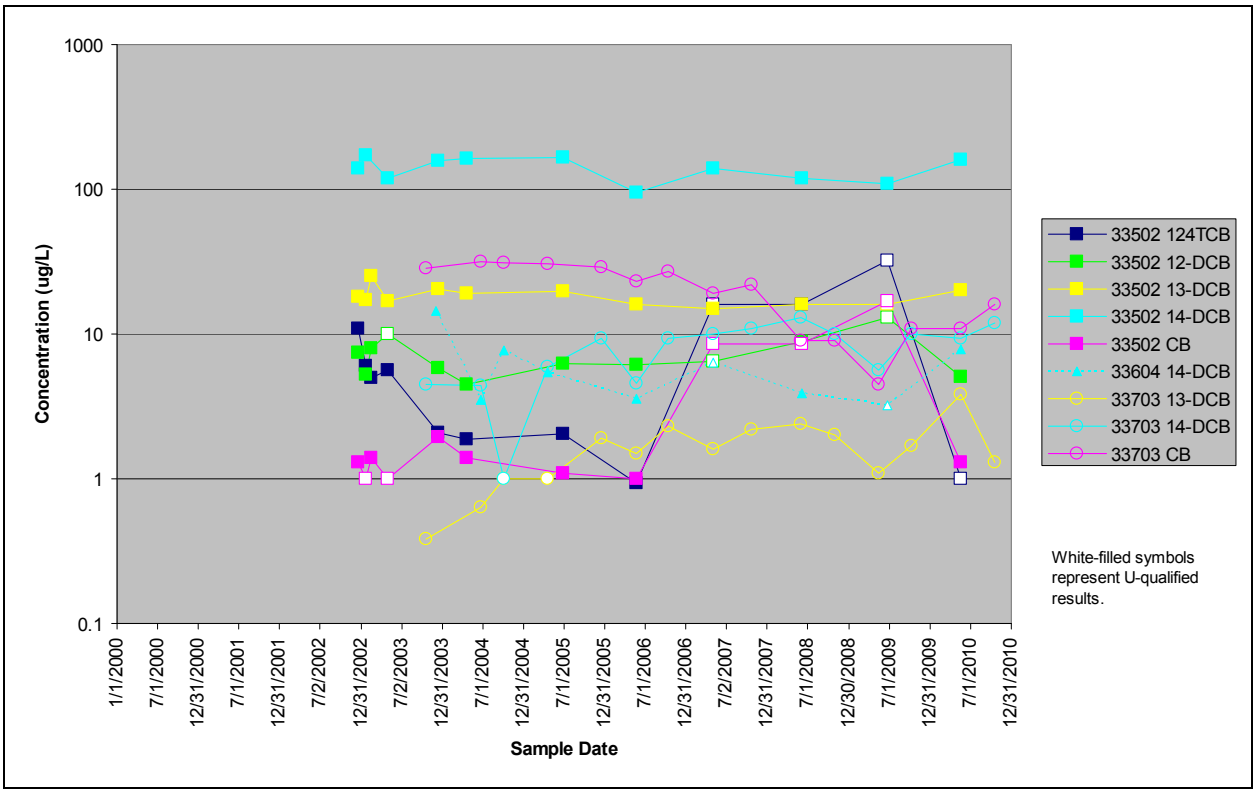
Notes: VC = vinyl chloride; c12DCE = *cis*-1,2-DCE. Applicable RFLMA surface water action levels for these constituents (µg/L; DOE 2007a): VC, 0.2; *cis*-1,2-DCE, 70; PCE, 1; TCE, 2.5. In addition to the nondetects ("U"-qualified results), several other results were qualified (J, D), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 244. Primary VOCs in the VC Plume Source Area

The parent compounds PCE and TCE were reported as nondetects in both samples collected in 2010 from Sentinel well 33703. As noted in the 2009 Annual Report (DOE 2010d), the fact that the Vinyl Chloride Plume is dominated by partially dechlorinated metabolic byproducts rather than the corresponding parent products (such as PCE and TCE) means that the concentrations of these latter constituents would be reduced. The detections of TCE reported in 2009, which were the first such detections reported at this well, were not repeated in 2010.

Several chlorinated benzene compounds are also detected in samples from VC Plume wells. These most commonly include one or more of the following: 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and chlorobenzene. These compounds are industrial and agricultural chemicals; one of the primary uses for several are as pesticides or insecticides. Figure 245 presents time-series plots for the most commonly detected

of these compounds in the three VC Plume wells. No 1,2,4-trichlorobenzene has been detected in samples from wells 33604 or 33703, and the last time it was reported in a sample from well 33502 was May 2006. (A decreasing trend that is 95 percent significant is calculated for 1,2,4-TCB at this location, but a third of the results in the data set are nondetects.) This compound can be degraded anaerobically to both 1,2-DCB and 1,4-DCB, which then can degrade to chlorobenzene (USGS 2006). The relatively consistent concentrations of 1,2-DCB and 1,4-DCB (and probably chlorobenzene as well) suggest that 1,2,4-TCB degradation did not result in an increase in these daughter products at well 33502. Nearest well 33604 has also not shown a clear increasing trend in either of these constituents: 1,2-DCB has not yet been detected, concentrations of 1,4-DCB are low and inconsistent, and chlorobenzene has only been detected once (in 2003). Although 1,2-DCB is infrequently detected at Sentinel well 33703, concentrations of 1,4-DCB have increased in samples collected this location, and an increasing trend meeting the 95 percent level of significance is calculated for 1,4-DCB (Table 77). A similarly significant, decreasing trend is calculated at this well for chlorobenzene, but data reported since mid-2009 suggest that concentrations of this constituent may be rebounding.



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): VC, 0.2; *cis*-1,2-DCE, 70; PCE, 1; TCE, 2.5. In addition to the nondetects ("U"-qualified results), several other results were qualified (J, D), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 245. Chlorinated Benzene Compounds in Samples From VC Plume Wells

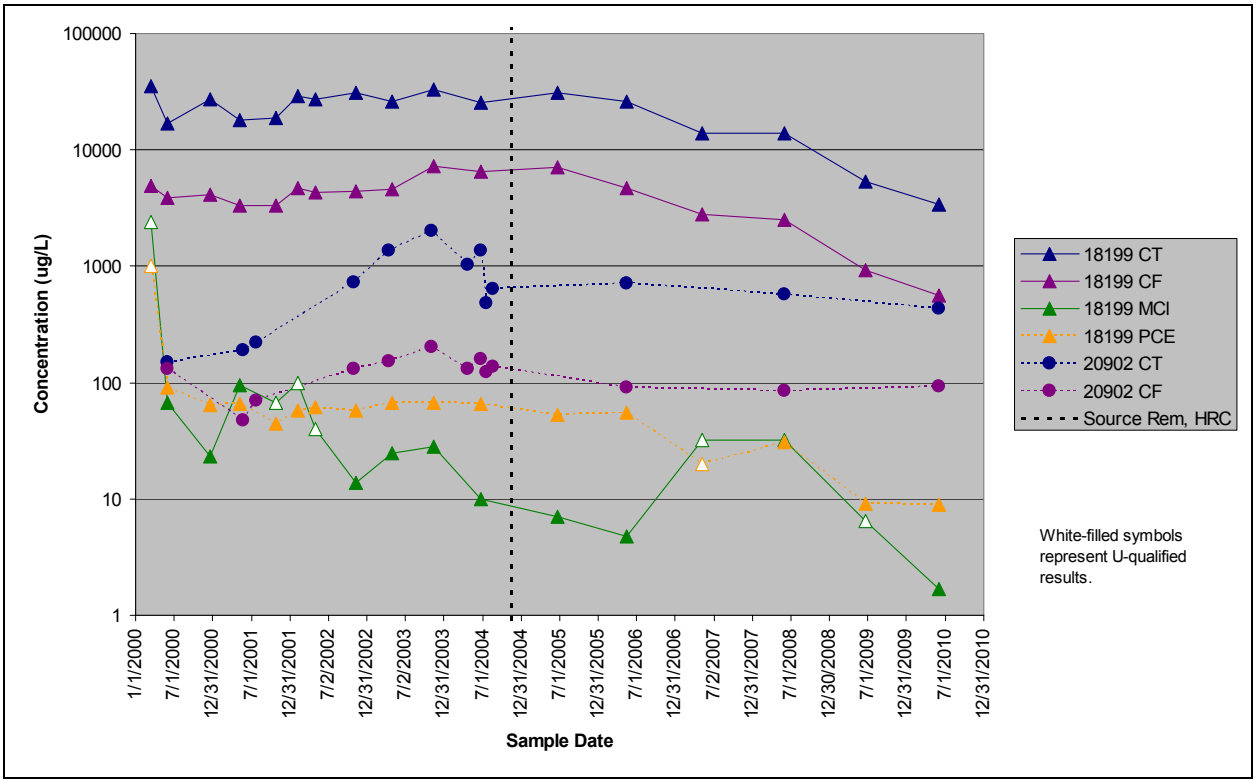
IHSS 118.1 (Carbon Tetrachloride) Plume

Former IHSS 118.1 is the source of a plume of groundwater contaminated with carbon tetrachloride. In late 2004, dense, nonaqueous phase liquid source material was removed along

with an adjacent subsurface tank group referred to as B730. The carbon source HRC was added to the backfill material to enhance biodegradation of residual contamination.

Evaluation well 18199, installed in 1999 to characterize the source area, is located immediately north of the former IHSS, roughly 80 to 90 feet north-northwest of the area in which free-phase carbon tetrachloride was present and perhaps 30 feet north of the source-removal excavation boundaries. The plume has been mapped to extend to Evaluation well 20902, located approximately 350 feet to the northwest. Both of these wells were sampled in June 2010. The three Sentinel wells generally north of the source area, along the northern side of former B771, were also sampled and support the evaluation of this plume to determine whether a more northerly groundwater flow path from the IHSS 118.1 source area is indicated. (With the closure of B771 and abandonment of the associated foundation drain system, the anticipated flow path for this plume was more northerly).

As stated in the 2009 Annual Report (DOE 2010d) and supported by data from samples collected in 2010 from well 18199, concentrations of carbon tetrachloride and chloroform, the primary contaminants in this plume, appear to be decreasing in groundwater in the source area (Figure 246). The visually apparent decreasing concentrations in samples from this well do not yet support the calculation of a decreasing trend that meets the 95 percent level of significance. (Refer to Appendix B for plots of statistically calculated trends.) Increased rates of biodegradation do not appear to be the mechanism of this decrease: there are no evident increasing trends in the concentrations of the principal carbon tetrachloride daughter products, chloroform, methylene chloride, and chloromethane (the terminal daughter products, methane and CO_2, are not analyzed). Data for other daughter products, such as (for PCE) TCE and *cis*-1,2-DCE, are most often not detected. Concentrations of the primary compounds, carbon tetrachloride and chloroform, in samples from well 20902 appear more uniform since an increase that ended in the 2003–2004 time frame (Figure 246). Here, a slight increase in the daughter product (chloroform) with respect to the parent (carbon tetrachloride) may be indicated, but if present, it is slight. Additional samples will help to confirm the presence of longer-term trends in contaminant concentrations.



Notes: CT = carbon tetrachloride; CF = chloroform; MCl = methylene chloride; Source Rem, HRC = date on which source removal and backfilling with soil and HRC was completed. Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): CT, 1; CF, 3.4; MCl, 4.6; PCE, 1. Several results were qualified (J, D, E, and, for methylene chloride in particular, B), but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 246. Concentrations of VOCs in the IHSS 118.1 Plume

Sentinel wells 20705, 20505, and 20205, all of which are located generally north of IHSS 118.1 and the former B771 complex, are monitored to evaluate the effects on groundwater of the closure of B771 and to determine whether a more northerly groundwater flow path from the IHSS 118.1 source area is indicated. As in 2009, such a path is not suggested by analytical data collected in 2010, which are generally consistent with pre-closure results. The three detections of low concentrations of carbon tetrachloride reported in 2008 and early 2009 were not confirmed in 2010. (In each of these cases, the reported concentrations were estimated at less than 1 µg/L.) The only detection of chloroform in 2010 was reported at an estimated (J-qualified) concentration of 0.78 µg/L in the fourth-quarter sample collected from well 20205, which is located at the eastern end of this line of three wells, just north (downgradient) of former Bowman's Pond and B774. This compound was also detected at estimated concentrations (less than 1 µg/L) in both samples collected in 2008 from this well.

Seepage velocities summarized in Table 38 are similar to those calculated in previous years and indicate that contaminants in the groundwater migrating from source area well 18199 to downgradient well 20505 could have been detected in this downgradient well as early as 2006. Based on the analytical data collected through 2010, this has still not occurred. While it would take some time for groundwater to saturate the backfill of the former B771 area, observations of seeps on this hillside (see Section 3.1.3.6) suggest that has been completed. Elevated concentrations of IHSS 118.1 Plume contaminants have not been detected in samples collected

from downgradient well 20505. This may be evidence of contaminant retardation, or it could indicate that groundwater is being diverted in another direction or that these constituents are being degraded before they reach well 20505. While the flow path from 18199 to 20505 appears reasonable, groundwater may be diverted (for example, around the sides of the building) by the presence of disrupted foundation drains and associated corridors, the backfilled B771, and backfilled/disrupted subsurface utility corridors. Evidence for this may be represented by the relatively consistent concentrations of these contaminants in well 20902, which was downgradient of the source area before the foundation drains were disrupted and the building was removed. There is insufficient well control to determine more accurately the flow path(s) from the IHSS 118.1 source area. These wells will continue to be monitored and the data assessed to evaluate the potential for contaminant migration from IHSS 118.1 to this area.

Consistent with previous years, other VOCs that are less representative of the IHSS 118.1 Plume were detected in samples from some of these Sentinel wells. In particular, the same Bowman's Pond–area well reported continued detections of PCE, though at lower concentrations than in recent years: The highest concentration in 2010 was 1.4 µg/L. TCE was also detected at this location in the fourth-quarter sample, again at a relatively low concentration (estimated at 0.41 µg/L). Well 20505, which is closer to the predicted northerly flow path from IHSS 118.1, had detections of VOCs in both samples collected in 2010: TCE (to 1.4 µg/L), 1,1-DCE (to 2.6 µg/L), *cis*-1,2-DCE (to 9.1 µg/L), and VC (to 2.5 µg/L). Well 20705, the westernmost of this line of wells and located nearest FC-2, also reported detections of daughter products: *cis*-1,2-DCE (to an estimated 0.51 µg/L), VC (single, fourth-quarter detection estimated at 0.78 µg/L), and methylene chloride (single, fourth-quarter detection estimated at 0.33 µg/L). These results suggest that the former B771 hillside does not represent a significant pathway for VOC migration.

Several trends were calculated for these three Sentinel wells (Table 77; Appendix B). Those that are at least 95 percent statistically significant include PCE (increasing at well 20205, but the data set contains numerous nondetects) and U (increasing at both 20205 and 20705). Time-series plots of U concentrations in samples from all three of these wells are provide below in Figure 247. From this figure, it can be seen that concentrations of U in samples from wells 20505 and 20705 are similar, while those from well 20205 contain higher concentrations of U. Even so, these values are well below the U threshold.

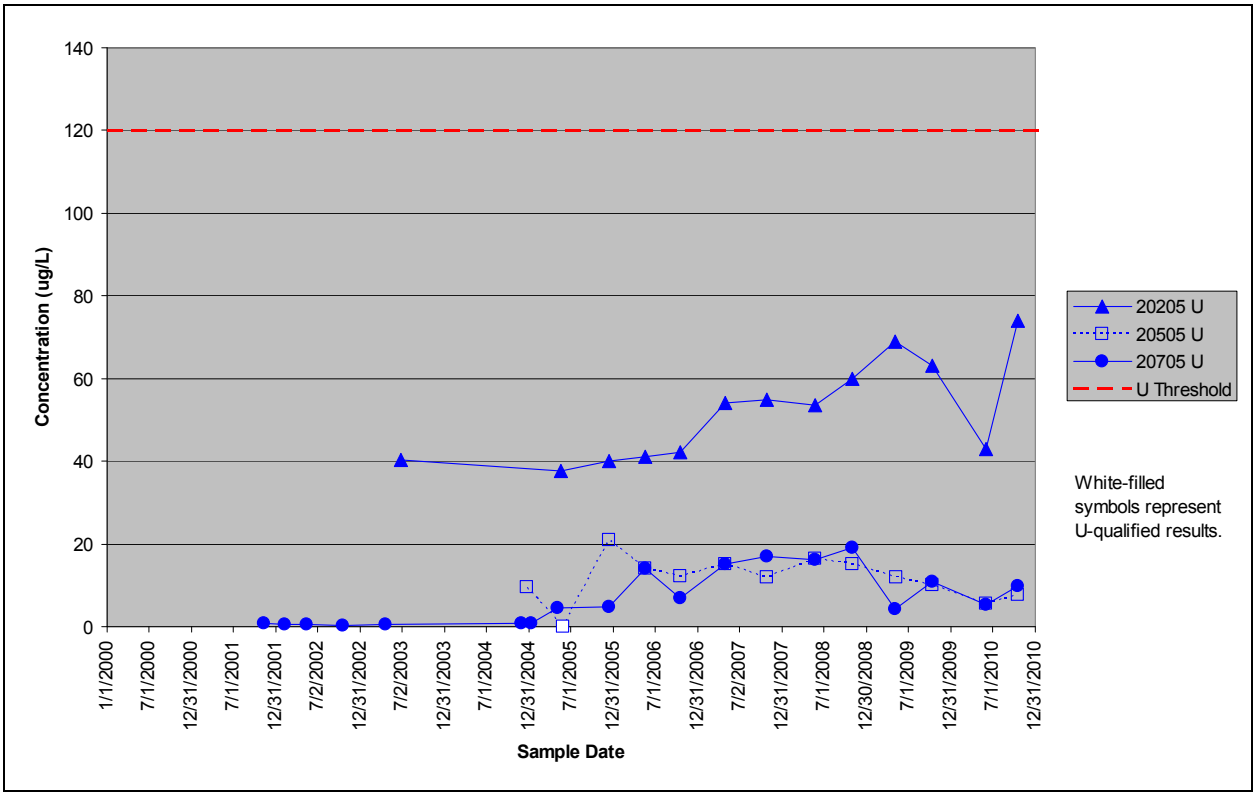


Figure 247. U in Groundwater Along North Side of Former B771

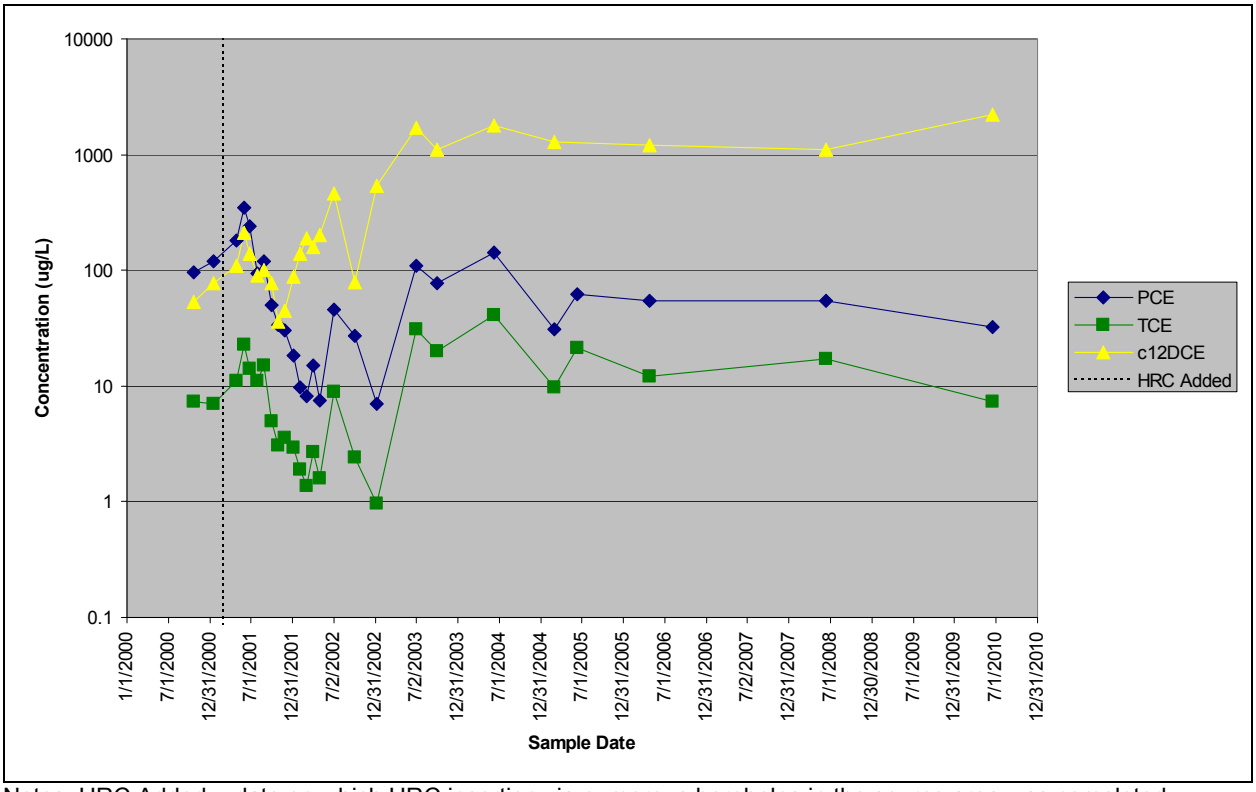
These wells will continue to be monitored, and the data will be evaluated in accordance with RFLMA.

PU&D Yard Plume

The PU&D Yard Plume is an area of groundwater with low concentrations of primarily PCE-family VOCs (PCE, TCE, and *cis*-1,2-DCE). This area was the site of the first application of the proprietary carbon source HRC performed at Rocky Flats, which took the form of a treatability study begun in early 2001 (K-H 2001, 2002; see K-H 2005b for a final summary report on this study). This plume is monitored by Evaluation well 30900 in the source area and Sentinel well 30002 to the east, at the margin of North Walnut Creek. In addition, upgradient PLF RCRA wells 70393 and 70693 monitor the plume as it flows toward the PLF. Each of these wells was monitored in 2010 in accordance with RFLMA.

Source area Evaluation well 30900 produced samples in June 2010 that contained fairly typical concentrations of VOCs. However, the concentration of *cis*-1,2-DCE, 2,200 µg/L, represented the highest concentration of that constituent reported to date in the source-area well (Figure 248). (The previous high concentration was 1,780 µg/L reported in June 2004, which in turn represented a new high since the 1,700 µg/L reported in July 2003. Note that these elevated concentrations were measured in samples collected during the relatively warmer and higher-water periods. Conversely, the 2005 and 2006 samples were collected in March and April, respectively. Samples were not collected in 2007, and the 2008 sample was collected in June—but that was a relatively dry year.) This increase in a primary daughter product from the

breakdown of PCE and TCE is coupled with a mild decrease in the concentrations of these parent compounds. This potentially signifies a mid-2010 boost to dechlorination rates in this area. The spring 2010 precipitation was greater than usual, as illustrated by the hydrograph for this well (Appendix A): the highest water level yet measured in this well was recorded in this time period. Therefore, the warmer conditions coupled with the higher water table may have acted to stimulate the naturally occurring bacteria that have been dechlorinating the parent compounds. As suggested in previous reports (e.g., K-H 2005b), a higher water table may flush additional electron donor material (HRC, if any yet remains in the soil column; otherwise, humic or other carbon-rich substances) as well as VOCs through the source area, helping to provide nutrients to these bacteria. Even if no HRC remains, one would expect locally reducing geochemical conditions to persist here for some time.



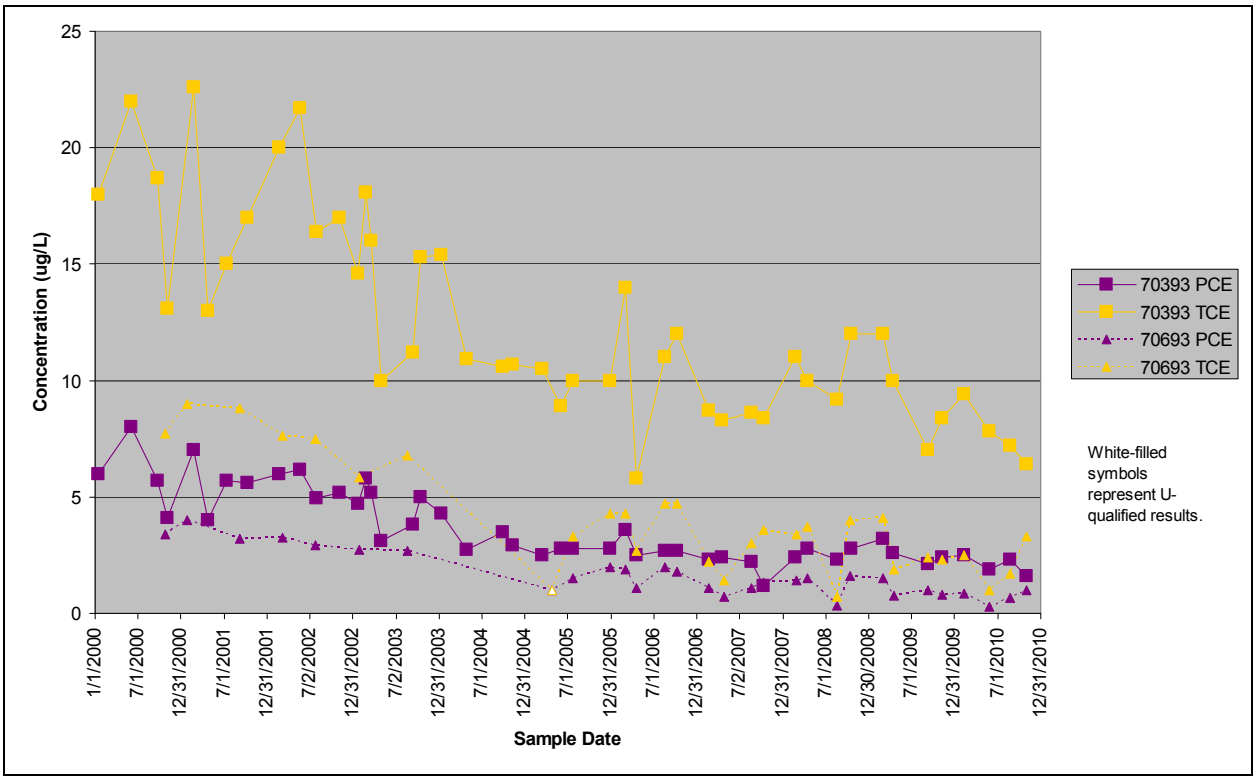
Notes: HRC Added = date on which HRC insertion via numerous boreholes in the source area was completed. Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. Several results were qualified (J, D, E), but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 248. Primary VOCs in the PU&D Yard Plume Source Area

Samples from Sentinel well 30002 were collected in May and October 2010. The fourth-quarter sample reported a single VOC detection of 1,3-DCB at an estimated (J-qualified) concentration of 0.63 µg/L. This constituent was also detected in the fourth-quarter 2008 sample. The corresponding RFLMA Table 1 value is 94 µg/L. No other VOCs were detected at this location.

RCRA wells 70393 and 70693, which are sampled quarterly, continue to be impacted by the PU&D Yard Plume. Time-series plots of PCE and TCE in these wells is presented as Figure 249. Detections of *cis*-1,2-DCE are infrequent. From 2003 through 2009, only TCE concentrations in

samples from well 70393 exceeded the then-applicable RFLMA Table 1 standards. However, with the expiration of Temporary Modifications for both PCE and TCE, the basis of comparison has changed; the applicable value for PCE is 1 µg/L, and for TCE is 2.5 µg/L (DOE 2007a). So, although concentrations of these constituents were on the whole very similar in 2010 to those reported in recent years, there were more cases in which they exceeded the applicable standards. Each of the four quarterly samples collected from well 70393 exceeded the RFLMA standard for PCE and TCE, while the fourth-quarter sample from well 70693 exceeded the standard for TCE. As illustrated on Figure 249, a decreasing trend in the concentration of both of these analytes at both wells remains visually apparent. As upgradient RCRA wells, trending is not required; however, statistical trend calculations were performed (Appendix B), and results indicate decreasing trends meeting the 95 percent level of confidence for both constituents at both wells. Whether application of HRC to the PU&D Yard Plume source area has contributed to these apparent declining concentrations is not known, but the infrequency with which the metabolic byproducts of PCE are detected suggests its effects on groundwater monitored by these two RCRA wells are minimal.



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): PCE, 1; TCE, 2.5. Several results were qualified as estimated (J), but for simplicity are not shown differently.

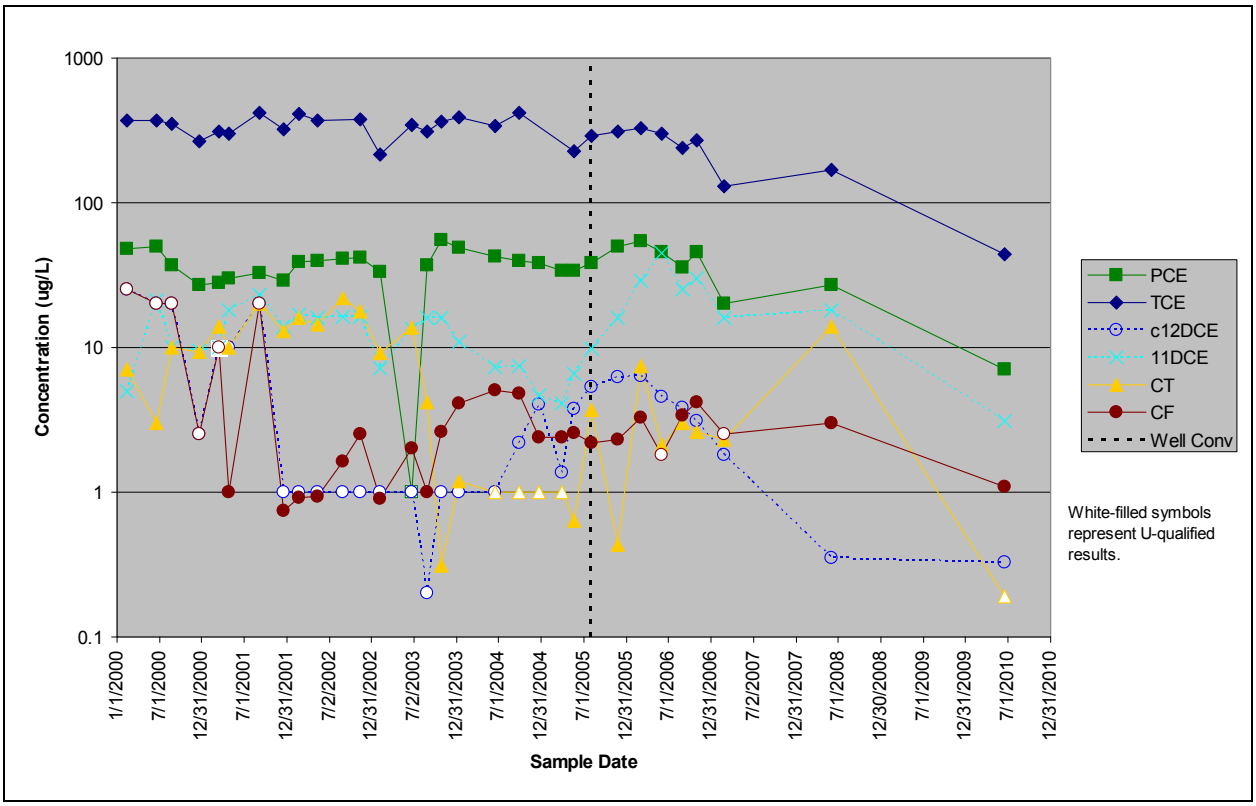
Figure 249. Concentrations of Primary PU&D Yard Plume Source Area VOCs in Upgradient PLF RCRA Wells

OU 1 Plume

The OU 1 Plume is located on the 881 Hillside, east of former B881 and immediately south of the former Contractor Yard. Its source area, former IHSS 119.1, was a drum and scrap metal storage area. This source area is monitored by Evaluation well 891WEL (the modification of

which, in 2005, has been detailed in previous documents, e.g., DOE 2006c), and the pathway to surface water is monitored by AOC well 89104, located to the south adjacent to Woman Creek (Figure 2).

Evaluation well 891WEL was sampled in June 2010, and AOC well 89104 was sampled in May and October 2010. Concentrations of the primary VOCs in the Evaluation well were decreased relative to most past results (Figure 250), and several trends meeting the 95 percent level of statistical significance are calculated: carbon tetrachloride and TCE are shown to be on decreasing trends, while chloroform and *cis*-1,2-DCE are calculated to be on increasing trends (Table 78; Appendix B). Of these, trends for chloroform and *cis*-1,2-DCE are suspect due to the numerous nondetects in the dataset; the calculated decreasing trend for TCE is clearly evident on the time-series plots of Figure 250.



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; 1,1-DCE, 7; CT, 1; CF, 3.4. Well conv = date on which the former industrial pump-operated collection well was converted to a more standard, manually sampled well. Several results were qualified (D, J), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 250. Primary VOCs in the OU1 Plume

No VOCs were detected in the samples collected in 2010 from AOC well 89104. These results are consistent with previous data. Two validated detections of VOCs have been reported at this well: methylene chloride in 2006 (which was qualified as estimated and also with an indication that this compound was also detected in the blank), and 1,3-DCB in 2009 (also estimated). The OU1 Plume will continue to be monitored in accordance with RFLMA.

Other Areas

In addition to the major plumes discussed above, other areas warrant mention because they may be of interest. These are summarized below.

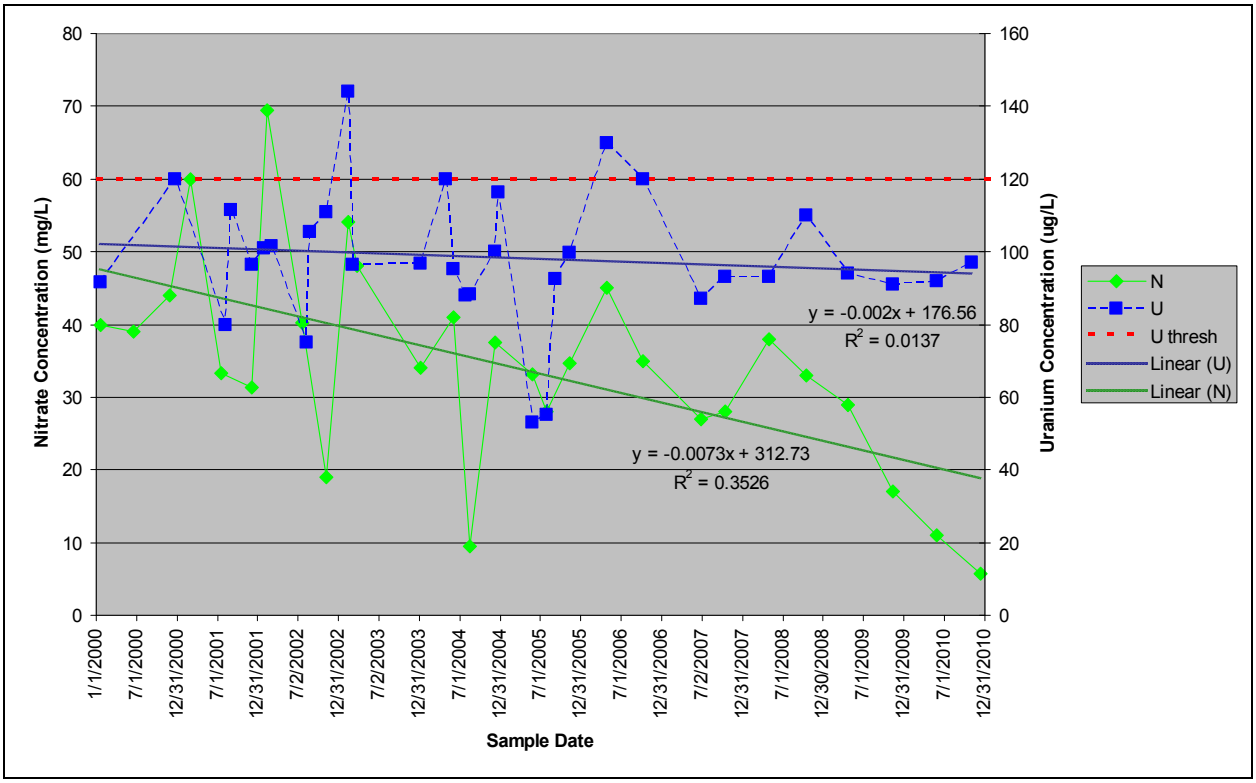
AOC well B206989: This well is located east of the Landfill Pond dam. Well B206989 entered a reportable condition in 2007 due to concentrations of nitrate that exceeded the applicable RFLMA Table 1 standard of 10 mg/L for that location. (The Temporary Modification value of 100 mg/L nitrate, effective through the end of CY 2009, did not apply to the No Name Gulch drainage.) Concentrations of nitrate that exceeded 10 mg/L in samples from this well were neither new nor unexpected; instead, the reportable condition was set up by the well being reclassified from a Sentinel well to an AOC well upon the signing of RFLMA. (The former classification has no reportable conditions, while the latter does.) Rather than waiting for two successive samples to exceed the 10 mg/L standard, upon receipt of the first results after RFLMA went into effect (which exceeded the applicable RFLMA standard, as expected), LM held discussions with CDPHE, and Contact Record 2007-06 was issued to document the resulting agreement.

As reported in the 2008 Annual Report (DOE 2009d), concentrations of nitrate in the well had met the 80 percent level of significance for a decreasing trend. Additional discussions were held with CDPHE. As a result, in 2009 surface water was sampled at two locations in No Name Gulch downstream of the well (DOE 2010d). Nitrate was not detected in either sample.

In 2009, the decreasing trend was calculated to meet the 95 percent level of significance, and data collected in 2010 continue to support this (see Table 77 and Appendix B.3). The results for the second-quarter 2010 sample were reported at a concentration of 11 mg/L, while the fourth-quarter sample was reported at a new low since 2000 of 5.7 mg/L. That result represents the second time since 2000 that groundwater from well B206989 has contained concentrations of nitrate that are below the 10 mg/L standard.

Concentrations of U in groundwater samples from well B206989 have not exceeded the 120 µg/L total U threshold since 2006, and a reportable condition for U at this location has not yet existed. S-K trending for U (Appendix B.3) indicates that the data show a decreasing trend, but at a significance that is below 95 percent.

Figure 251 provides updated time-series plots of nitrate and U in groundwater samples collected through the end of 2010 from well B206989. The trend lines shown on this figure for each constituent are simple regression curves; the associated negative slopes indicate the general trends are decreasing, but the low R^2 values for each of these trend lines confirm the data are widely variable. The trend tables and plots in Appendix B offer more valid statistical results.



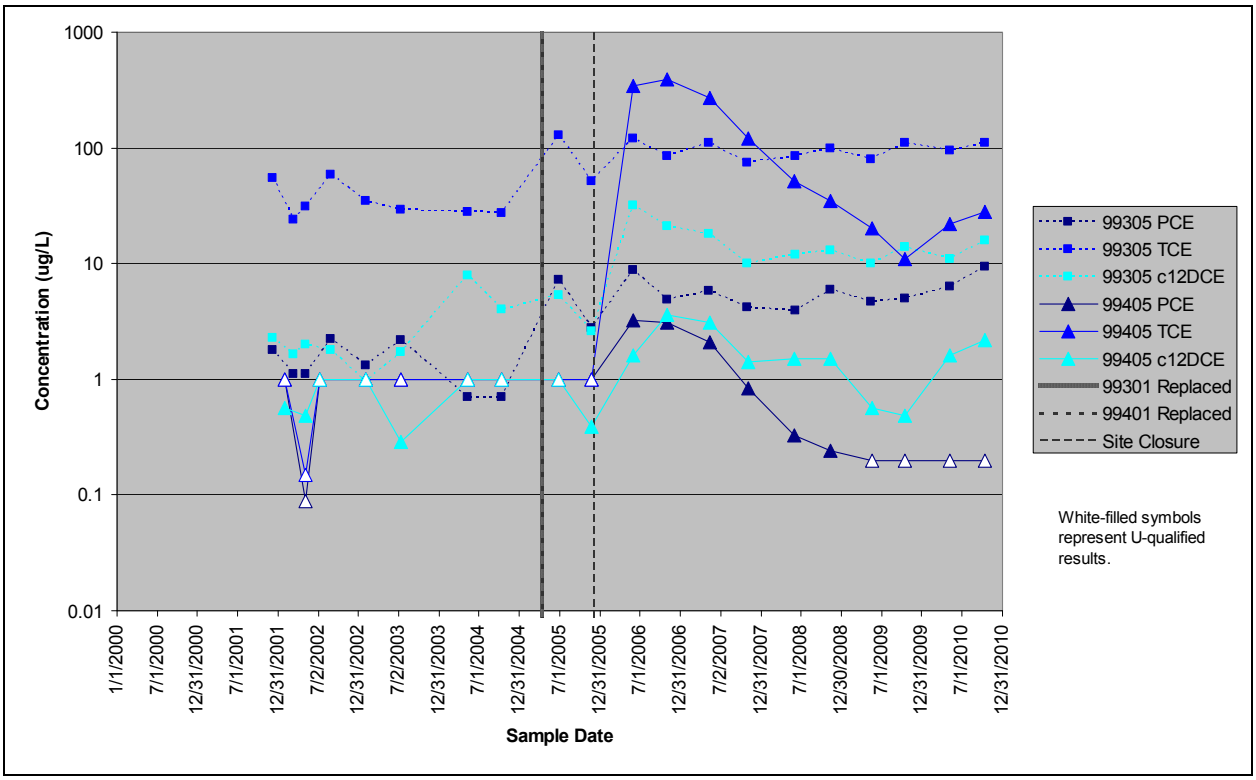
Notes: N = nitrate, U = uranium, U thresh = uranium threshold. The applicable action level for nitrate is 10 mg/L; that for U is 120 µg/L (DOE 2007a). Simple linear regression trend lines are shown for each, together with the corresponding equation and correlation coefficient. Note the use of two *y* axes to help illustrate the concentrations of the different constituents.

Figure 251. Concentrations of Nitrate and U in Groundwater Samples From AOC Well B206989

Former B991: Groundwater samples from wells 99305 and 99405 are monitored for VOCs, nitrate, and U. Both of these wells are located near the eastern edge of former B991, with well 99405 positioned in the east loading dock area (i.e., slightly southwest of well 99305 and closer to FC-4 and the valley bottom). Samples collected in May and October 2010 continued the post-closure pattern of higher concentrations of VOCs than were typical prior to closure. The noteworthy constituents include PCE, TCE, and *cis*-1,2-DCE, although concentrations of PCE and *cis*-1,2-DCE in samples from well 99405 have frequently been estimated or nondetect.

Figure 252 illustrates results for these constituents in both wells, together with the dates of well replacements (when 99305 replaced 99301 and 99405 replaced 99401) and site closure. As shown on this figure, VOC-related water quality changes occurred suddenly and uniformly for these three constituents at well 99405. Conversely, at well 99305 concentrations of these constituents appear to have started to increase earlier, but their increase was not as sharp and was not followed by steady declines. From 2006 through 2009, VOC concentrations in samples from well 99405 were clearly decreasing, but data from 2010 reversed this trend for PCE and TCE. These compounds increased slightly in concentration, but *cis*-1,2-DCE remained nondetect. Concentrations of these constituents in samples from well 99305 were not previously decreasing, as they were at 99405, but with 2010 data it appears that PCE in particular is showing a slight increasing trend. The visible trends in VOC concentrations over the entire data set are confirmed by statistical calculations: at well 99305, trends meeting the 95 percent level of significance are calculated for *cis*-1,2-DCE, PCE, and TCE (all increasing); at well 99405, similarly significant

trends are calculated for increasing *cis*-1,2-DCE and TCE. The trends for TCE and *cis*-1,2-DCE at well 99405 are suspect due to the numerous nondetects in the data set.



Notes: c12DCE = *cis*-1,2-DCE. Applicable RFLMA action levels for these constituents (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. In addition to the nondetects ("U"-qualified results), several other results were qualified (J), but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 252. Concentrations of Primary VOCs in B991-Area Groundwater

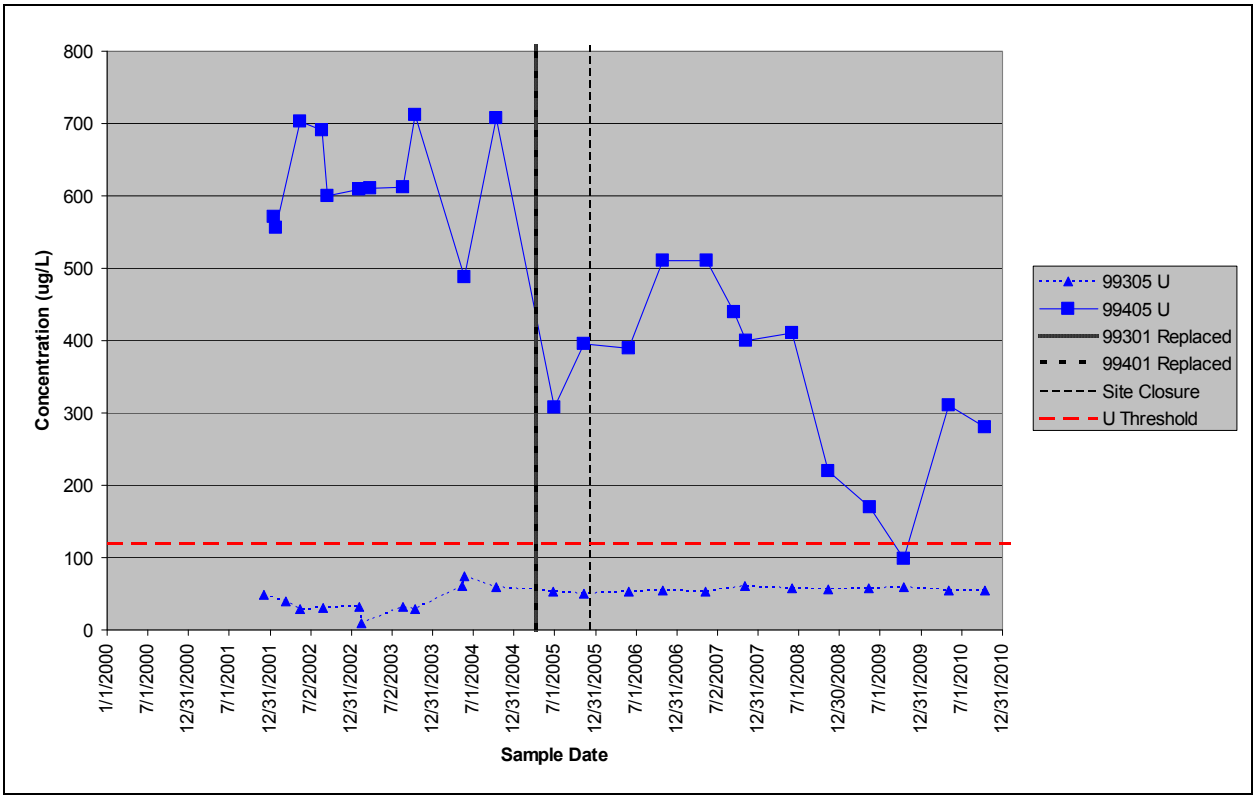
The dates of well replacement do not appear to be a factor in the water quality illustrated for well 99405; the observed changes instead relate to other activities performed to close the Site. Conversely, well replacement appears to coincide with the changes observed at well 99305, at least for PCE and TCE; the increases in *cis*-1,2-DCE concentrations appear to occur over two distinct steps. The mechanism for these increases is not known, but greater impacts would be expected at that location from B991 D&D than from well replacement.

Concentrations of U in samples collected from 2006 through 2009 at well 99405 displayed a remarkable decrease (Figure 253), but in 2010 the concentrations increased to levels that were still lower than—but generally more consistent with—previous conditions. From an overall high in the 700 µg/L range prior to closure, in 2009 the concentration of U at this location had decreased to 98 µg/L. In 2010 the results were 310 µg/L and 280 µg/L for the May and October samples, respectively. Although concentrations have been variable, the overall trend in U concentrations at well 99405 is visually evident, and this decreasing trend is confirmed to have a statistical significance of 95 percent (Table 77, Appendix B).

Mechanisms responsible for the variability in U concentrations are not certain. The springs of 2009 and 2010 were both relatively moist, yet concentrations of U did not behave similarly, so

relatively significant changes in climate would not be an obvious cause. Other possible mechanisms include hydrologic and geochemical changes that have occurred as a result of Site closure, such as removal of the water supply, associated leakage, and chlorinated water; removal of impermeable surfaces and resumption of direct recharge of groundwater by precipitation; removal of foundation drains; and so on, with possible changes in redox conditions as a result of some of these factors. This location has been analyzed on multiple occasions for signs of U contamination through high-resolution isotopic analyses, and in each instance the results have shown the U to be 100 percent natural—i.e., there has been no site-related U contamination in the samples.

Unlike conditions at well 99405, concentrations of U at nearby well 99305 have always been much lower and, since 2004, have been very uniform, despite the fact that these wells are only about 115 feet apart. Results in 2010 are consistent with previous data, with reported concentrations in the second and fourth quarter samples at 55 µg/L and 54 µg/L, respectively. Even so, trend calculations meeting the 95 percent level of significance indicate that U is on an increasing trend.



Notes: Applicable RFLMA action level (µg/L; DOE 2007a) for U (threshold), 120. U data include results for U-mass and converted isotopic activities. Several results were qualified (J, B, N, and, for two U-235 results, U) but for simplicity are not shown differently.

Figure 253. Concentrations of U in B991 Sentinel Wells

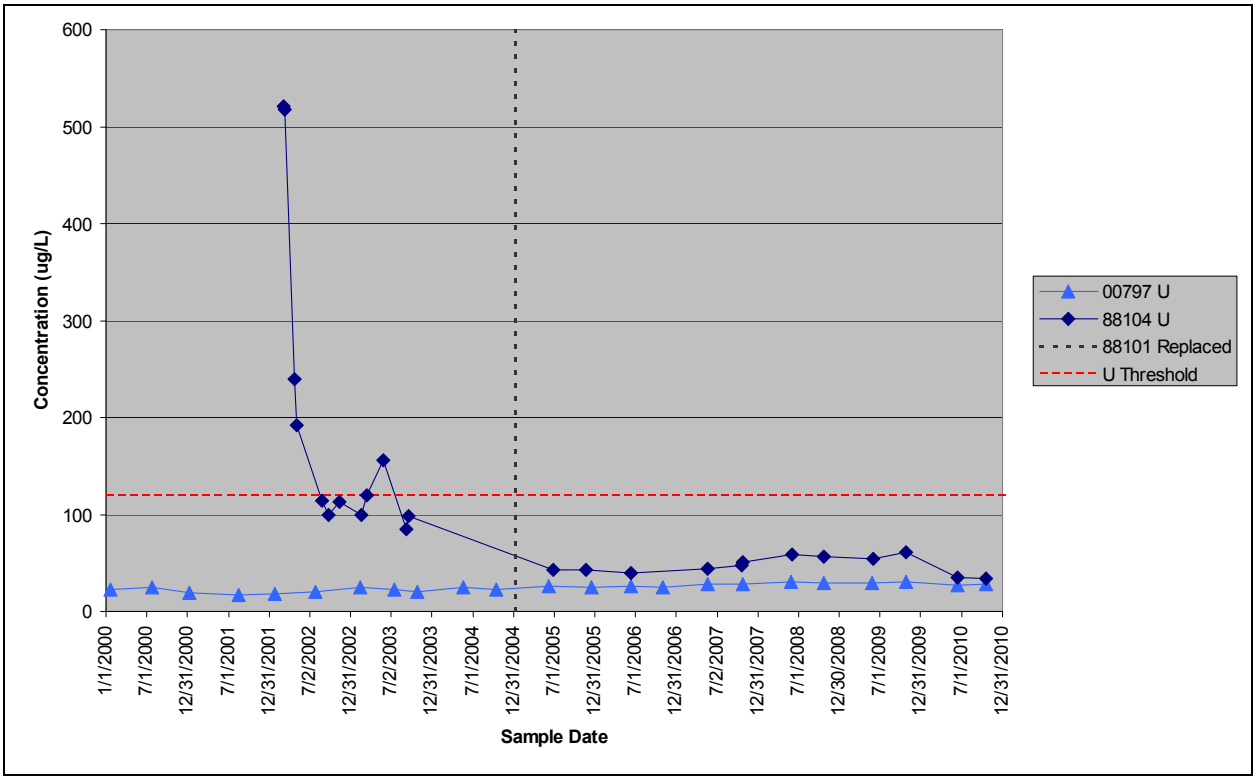
Both of the B991 wells are also monitored for nitrate to evaluate the potential for migration of the SPP toward South Walnut Creek. As noted above in the discussion of the SPP, concentrations of nitrate reported for samples from these wells continue to indicate this is not an

effective pathway for migration of the SPP constituents. The samples collected in 2010 gave results that were consistent with previous data; the highest concentration reported was 2.6 mg/L.

Former B881 and 800 Area: Consistent with recent annual reports (e.g., DOE 2007c, 2008c, 2009d, 2010d), S-K calculations performed in 2010 indicate there is a statistically significant (at the 95 percent confidence level) decreasing trend for U in Sentinel well 88104, while in Sentinel well 00797 the trend for this analyte is increasing (Table 77, Appendix B). The trend calculated for well 88104 is complicated by the well replacement performed in 2004, when well 88101 was replaced with well 88104. The replacement well is located approximately 110 feet south of the original location, which was adjacent to the southern side of the building. Concentrations of U in the original well (88101) had decreased significantly between the installation and final sampling of that well (from a maximum concentration of approximately 521 µg/L in March 2001, to approximately 85 µg/L in September 2003), and concentrations of U in the replacement well have actually been fairly uniform, ranging from 34 µg/L to 61 µg/L (Figure 254). The 2010 results of samples from well 88104 were 35 µg/L and 34 µg/L for the second and fourth quarter samples, respectively, and represent a visible decrease in concentrations. Nearby, samples from Evaluation well 88205 frequently had nondetect concentrations of U, as was the case with the last two samples collected (in 2008 and in 2010). This well is located adjacent to the small, former B887 and the associated underground RCRA waste storage tanks that were near the southwest corner of B881.

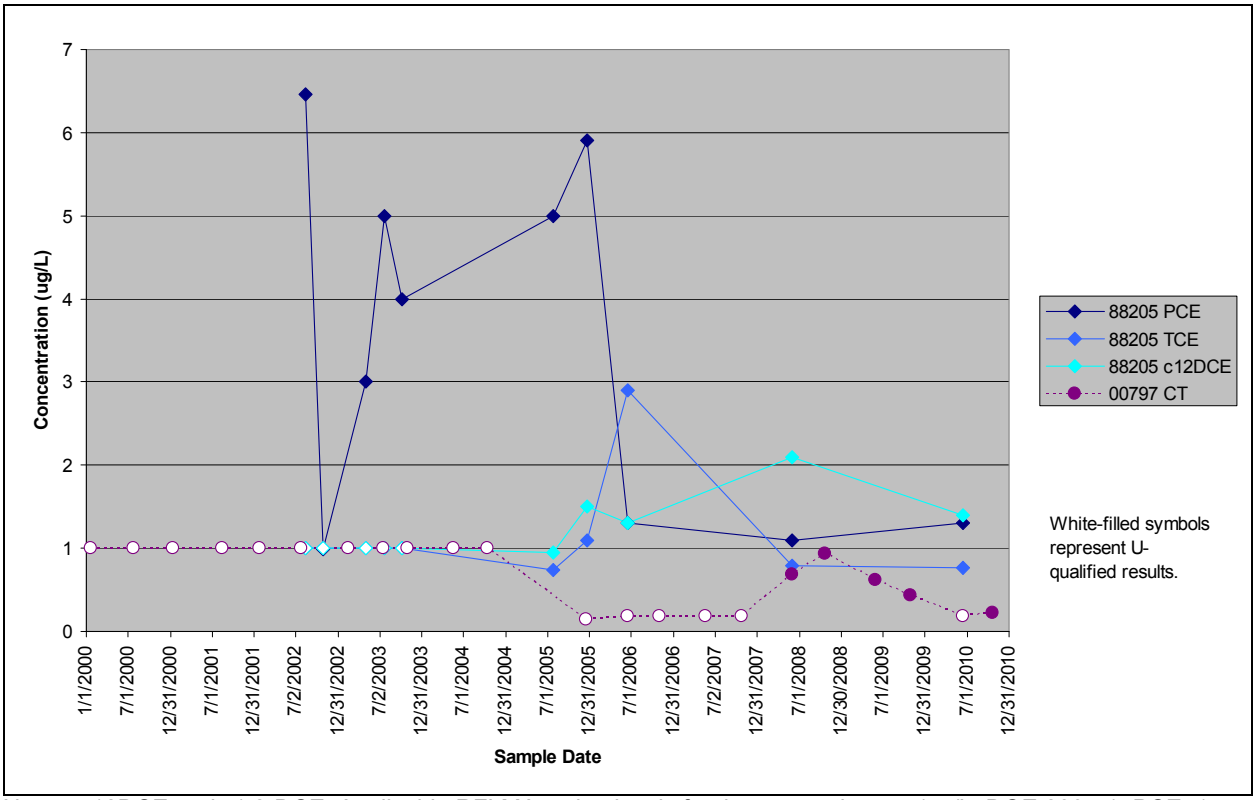
Concentrations of U in samples from Sentinel well 00797, located approximately 250 feet south of well 88104, have ranged between slightly less than 17 µg/L to 29 µg/L since 2000. As illustrated on Figure 254, concentrations of U at wells 88104 and 00797 are below the U threshold. (This also applies to samples from well 88205, given that U is frequently not detected, but a time-series plot is not presented for this well because of these low to nondetect concentrations.)

Wells monitoring the area downgradient of former B881 are also sampled for VOCs. However, few VOCs are routinely detected. Most common detections include *cis*-1,2-DCE, PCE, and TCE in samples from well 88205; and carbon tetrachloride from well 00797. Nondetects for these constituents are also common. Detections of VOCs in samples from well 88104 are infrequent, with the samples collected in 2010 reporting one detection of 1,3-DCB (second quarter, 1.4 µg/L) and one detection of bromoform (fourth quarter, 0.35 µg/L, J-qualified). Figure 255 shows time-series plots of the most commonly detected VOCs in samples from wells 88205 and 00797.



Notes: Applicable RFLMA action level (µg/L; DOE 2007a) for U (threshold), 120. U data include results for U-mass and converted isotopic activities. Several results were qualified (J, B, N, and, for two U-235 results, U) but are not shown differently for simplicity.

Figure 254. Concentrations of U in Samples From B881 Sentinel Wells



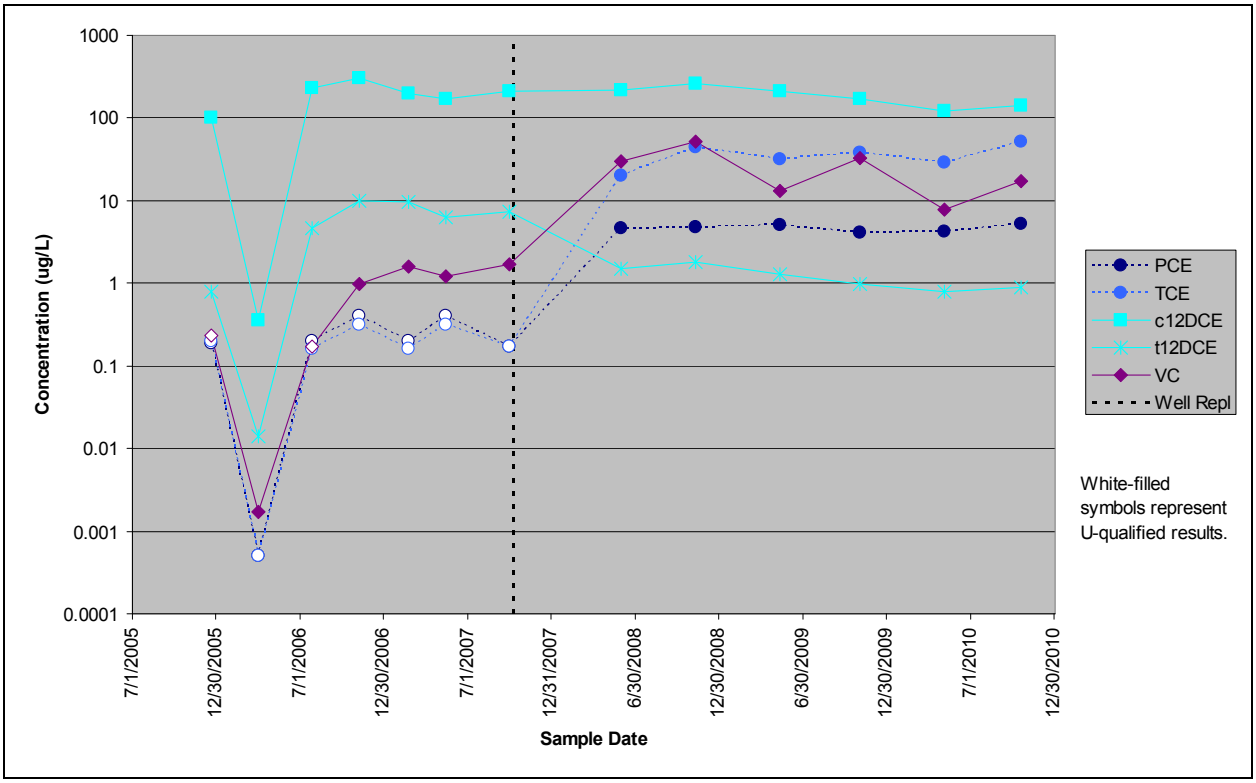
Notes: c12DCE = *cis*-1,2-DCE. Applicable RFLMA action levels for these constituents (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. In addition to the nondetects ("U"-qualified results), several other results were qualified (J), but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 255. Concentrations of Primary VOCs in B881-Area Groundwater

Elsewhere in the former 800 Area, Evaluation well 22996 monitors groundwater downgradient of former B886, as well as other 800-Area buildings that are farther upgradient (such as B865 and B883). This well is sampled for VOCs and U. Detections of VOCs are infrequent. TCE is the most commonly detected VOC, with four detections reported since 2000, including one in the sample collected in May 2010. This sample reported a concentration of TCE estimated (J qualified) at 0.23 µg/L. For the first time since 2000, PCE was also detected in this well, at an estimated concentration of 0.24 µg/L. Concentrations of U at this location are consistently low, typically in the single-digit range. In the May 2010 sample, the concentration was reported at 8.5 µg/L.

Hillside south of former B991: The hillside south of former B991 contains the remains of a French drain that was installed during the construction of the hillside to stabilize it. The outfall from this drain was removed prior to closure, and the drain was interrupted because the outfall (former surface water location SW056) produced water containing VOCs. For that reason, when the French drain was removed, HRC was added to the backfill to stimulate biodegradation of VOCs. Sentinel well 45605 was installed to monitor groundwater adjacent to the drain interruption, but the hillside slumped. The area was regraded, and Sentinel well 45608 was installed to replace the abandoned 45605. For more detail on the hillside and French drain, see the 2006 Annual Report (DOE 2007c); for information on the well abandonment and hillside regrading, see the 2007 and 2008 Annual Reports (DOE 2008c, 2009d).

Well 45608 was sampled twice in 2010 (May, October). The continuing detections of 1,2-DCE and VC are an indication that biodegradation is still occurring upgradient of the well, though whether this is due to placement of HRC in the drain backfill is unknown. Water quality at this location changed in late 2007 (Figure 256). Well replacement, reconfiguration of the hillside during the regrading performed in 2007, and/or consumption of the HRC added to backfill may be factors in the changes visible on this figure.



Notes: c12DCE = *cis*-1,2-DCE; t2DCE = *trans*-1,2-DCE; Well Repl = date on which well 45605 was abandoned, with subsequent samples collected from its replacement, well 45608. RFLMA Table 1 values (DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70; *trans*-1,2-DCE, 100; VC, 0.2. In addition to the nondetects ("U"-qualified results), several other results were qualified (J, D), but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 256. Concentrations of VOCs in Groundwater South of Former B991

Circumstantial evidence suggests that well replacement may play a significant part in observed changes in contaminant distribution. Lines of evidence include the water level in the replacement well, which has always been higher than in the original well; and the replacement well was strongly artesian, at least into 2010 (it has since stopped flowing freely). However, due to the regraded hillside, the top of the well casing for the replacement well is at a lower elevation than was the case for the original well, which would be a factor in the artesian behavior of the former well (though this would not affect the absolute water level). PCE and TCE were not detected in samples collected before 2008 from the original well but have been consistently detected in samples collected since that date from the replacement well. At the same time, concentrations of VC increased by an order of magnitude, and those of *trans*-1,2-DCE decreased overall by almost as much. These constituents, including PCE and TCE, were consistently detected in samples collected from the original drain outfall, SW056; the concentrations of PCE and TCE prior to the drain's removal were consistent with the results for these constituents in samples from

well 45608 (see DOE 2005b for tabulated data from SW056). Concentrations of VC in the replacement well are seen to vary seasonally, being slightly higher in fourth quarter samples than in second quarter samples. As discussed above with respect to ETPTS-area well 23296, this may be related to the relatively drier conditions in the typical fourth quarter allowing the water longer residence time in areas of active dechlorination; even so, a similar pattern is not suggested by other daughter products, nor is a reverse pattern suggested by the parent products. If anything, TCE concentrations follow a similar but more muted seasonal pattern, though this compound is both a metabolic byproduct of PCE as well as a solvent used during Site operation.

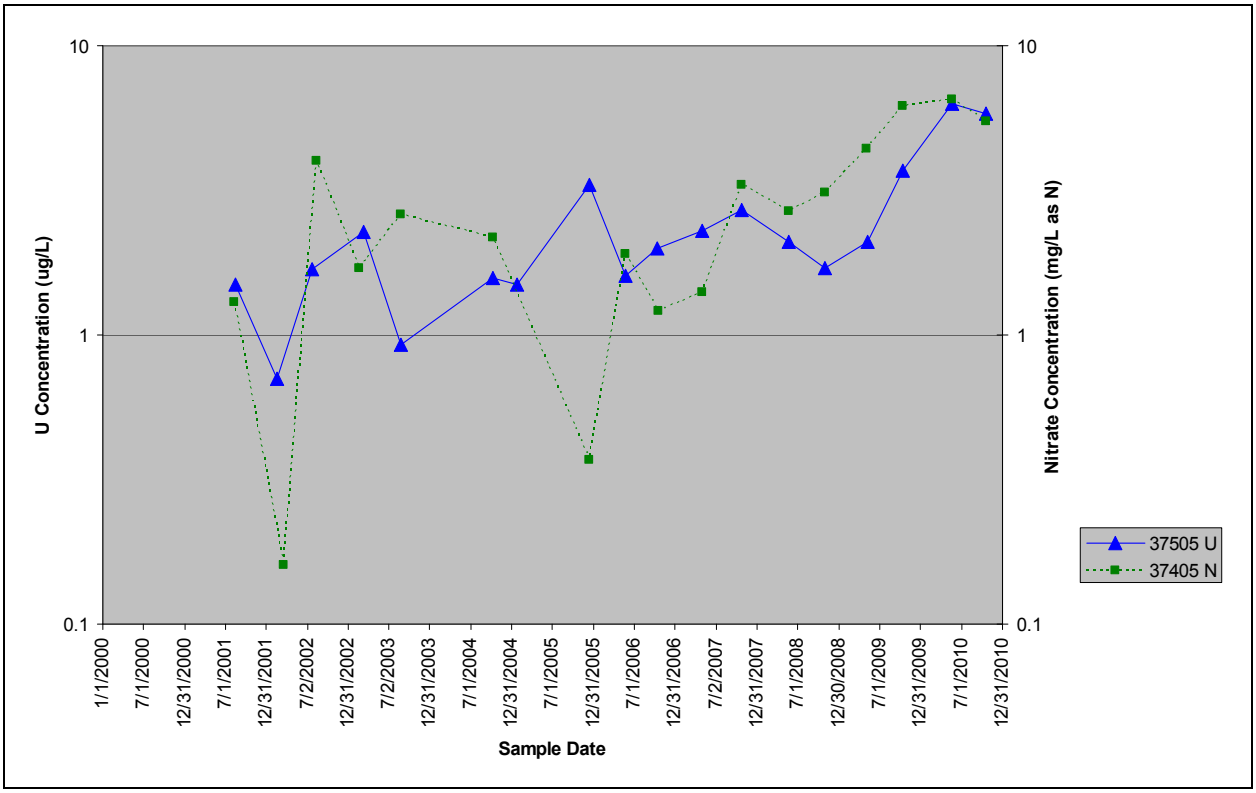
Trends identified as statistically significant with a 95 percent level of confidence include increasing 1,1-DCE, PCE, and TCE; and decreasing *trans*-1,2-DCE (Table 77). Note that all but the *trans* -1,2-DCE trend is complicated by the presence of numerous nondetects in the data set, making the associated trends suspect. Additional data may assist in confirming the various trends and patterns; well 45608 will continue to be monitored according to RFLMA.

Areas monitored for Plutonium and Americium: Groundwater immediately downgradient of the former B371 and B771 complexes is monitored for Pu and Am due to the production-era missions of these buildings. Although abundant technical research (much of which focused specifically on Rocky Flats) has indicated that the groundwater regime does not constitute a meaningful migration pathway for these constituents, these analytes were included in the RFLMA monitoring for these wells to provide stakeholder assurance. Therefore, it is not surprising that the groundwater monitoring wells at Rocky Flats that are sampled for Pu and Am consistently report results for these constituents that are qualified as nondetects.

In 2010, without exception, the five wells monitored for Pu and Am (Sentinel wells 20205, 20505, and 20705 at former B771; and 37405 and 37705 at former B371) reported values qualified as nondetects for these radionuclides. Reported values ranged from –0.00392 pCi/L to 0.0133 pCi/L, again all qualified as nondetects. (As an activity-based analysis that is compared against the activity in a laboratory blank, the analysis always generates a number.) In fact, the only Pu or Am results reported since Site closure that are not qualified as nondetects have been three J-qualified results in samples collected in December 2005, the highest activity of which was 0.0238 pCi/L (representing Am in a sample from well 20705).

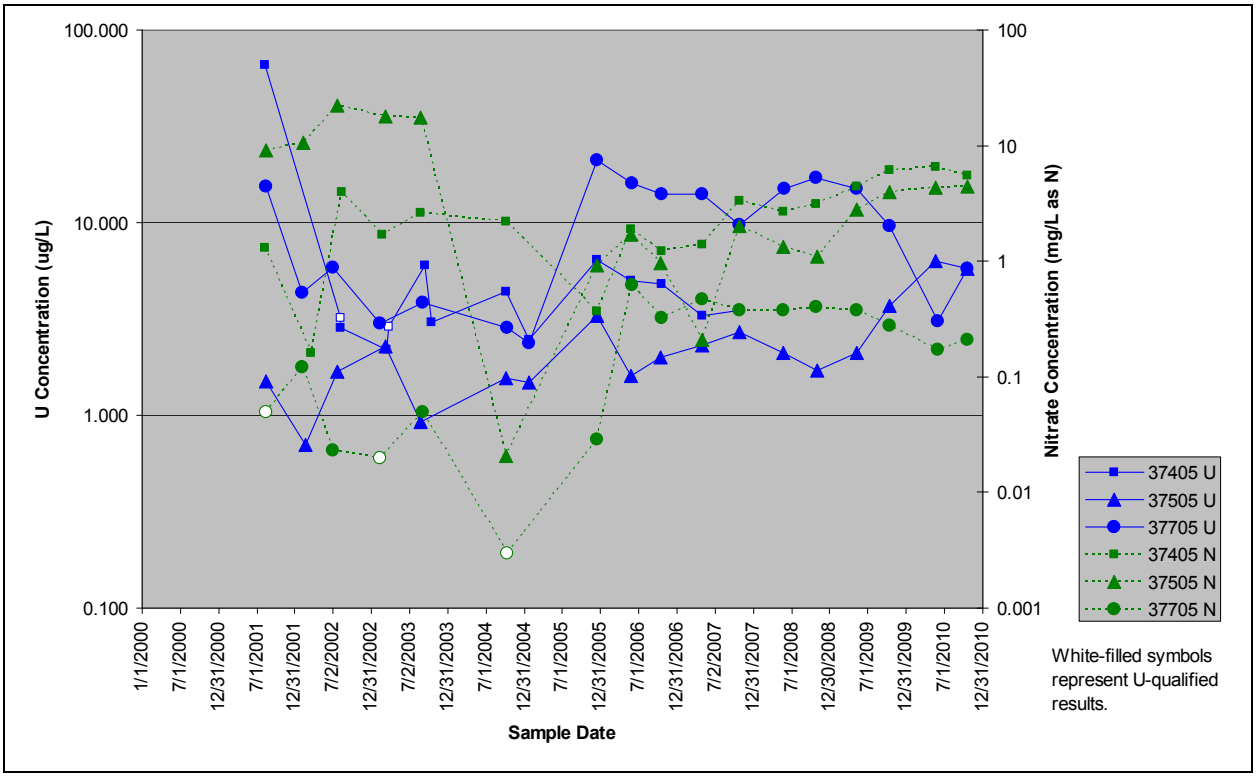
These areas are also monitored for other constituents. The groundwater downgradient of the former B771 complex is discussed above in the context of the IHSS 118.1 Plume and will not be repeated here. Groundwater at the former B371 complex is also analyzed for VOCs, nitrate, and U. Of the VOCs, the most commonly reported detection (consistently reported at J-qualified concentrations below 1 µg/L) is of PCE in samples collected from well 37505. The highest concentration reported in 2010 was estimated at 0.62 µg/L. VOCs were not detected in 2010 in samples collected from wells 37405 and 37705 and historically have been detected only rarely in samples from these wells.

S-K trending results (see summary in Table 77, and Appendix B) indicate an increasing trend meeting the 95 percent level of confidence for nitrate in samples from well 37405 and for U in samples from well 37505. These data are presented below in time-series plots (Figure 257). For context, Figure 258 includes concentrations of these constituents reported in samples from each of the 371-area wells.



Notes: U data include results for U-mass and converted isotopic activities. Several results were qualified but are not shown differently for simplicity. Note logarithmic concentration scales.

Figure 257. Concentrations of U and Nitrate With Significant Trends in Samples From B371 Sentinel Wells



Notes: U data include results for U-mass and converted isotopic activities. Several results were qualified but are not shown differently for simplicity. Note logarithmic concentration scales.

Figure 258. Concentrations of U and Nitrate in Samples From B371 Sentinel Wells

East Government property boundary (former Rocky Flats Environmental Technology Site [RFETS] boundary): Boundary wells 10394 (Woman Creek and Indiana Street) and 41691 (Walnut Creek and Indiana Street) are located far outside the DOE-controlled area of the COU, on refuge lands managed by the U.S. Fish and Wildlife Service. Monitoring these wells is not required to support the remedy, and the associated groundwater data do not support technical objectives of the RFS monitoring network. Nonetheless, they are monitored to meet operational requirements stipulated in RFLMA.

These wells were each sampled once in 2010 (June). As in 2006 and 2009, results included detections of 1,3-DCB, an insecticide that is also used to make herbicides, at both wells. The applicable RFLMA standard for this constituent is 94 µg/L, and the reported concentrations in the 2010 samples were 0.52 µg/L (estimated) at well 10394 and 1.5 µg/L at well 41691. Nitrate was detected at an estimated concentration of 0.021 mg/L at well 41691. Concentrations of U were within their previously reported ranges at these locations (8.3 µg/L at well 41691 and 3.7 µg/L at well 10394).

3.2 Ecological Monitoring

3.2.1 Introduction

The Ecology group conducts ecological monitoring of the Site's ecological resources to ensure regulatory compliance and to preserve, protect, and manage those resources. Ecological