

Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2009-November 2010

Environmental Science Division



United States Department of Agriculture

Work sponsored by Commodity Credit Corporation,
United States Department of Agriculture

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by
Applied Geosciences and Environmental Management Section
Environmental Science Division, Argonne National Laboratory

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Notation

BGL	below ground level
CCC	Commodity Credit Corporation
°F	degree(s) Fahrenheit
ft	foot (feet)
gal	gallon(s)
gpm	gallon(s) per minute
GWEX	groundwater extraction
hr	hour(s)
in.	inch(es)
kg	kilogram(s)
L	liter(s)
µg/L	microgram(s) per liter
mg/L	milligram(s) per liter
MCL	maximum contaminant level
MW	monitoring well
NDEQ	Nebraska Department of Environmental Quality
NGPC	Nebraska Game and Parks Commission
NPDES	National Pollutant Discharge Elimination System
USDA	U.S. Department of Agriculture
VOC	volatile organic compound
yr	year(s)

Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2009-November 2010

1 Introduction

This document summarizes the performance of the groundwater restoration systems installed by the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) at the former CCC/USDA grain storage facility in Utica, Nebraska, during the sixth year of system operation, from December 1, 2009, until November 30, 2010.

In the project at Utica, the CCC/USDA is cooperating with multiple state and federal agencies to remove carbon tetrachloride contamination from a shallow aquifer underlying the town and to provide supplemental treated groundwater for use in the restoration of a nearby wetlands area. Argonne National Laboratory has assisted the CCC/USDA by providing technical oversight for the aquifer restoration effort and facilities during this review period.

This document presents overviews of the aquifer restoration facilities (Section 2) and system operations (Section 3), then describes groundwater production results (Section 4), groundwater treatment results (Section 5), and associated groundwater monitoring, system modifications, and costs during the review period (Section 6). Section 7 summarizes the present year of operation. Performance prior to December 1, 2009, has been reviewed previously (Argonne 2005, 2006, 2008, 2009a, 2010).

2 Overview of the Aquifer Restoration Facilities at Utica

The principal components of the groundwater restoration systems at Utica are shown in Figure 2.1. The facilities consist of two main operating units, as described below. The facilities include four groundwater extraction (GWEX) wells. Table 2.1 summarizes construction details for these wells.

2.1 Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units

Extraction wells GWEX1-GWEX3, located in the northern portion of the town, are used to extract contaminated groundwater from the upgradient portion of the contaminant plume. These wells are linked by a distribution system that selectively carries untreated groundwater to either of two discharge points in the northern and southern subbasins of the North Lake Basin Wildlife Management Area (Figure 2.1). At each discharge point, the water is treated to remove carbon tetrachloride by using a custom spray irrigation treatment unit (Figure 2.2). The three extraction wells are operated simultaneously to maintain a critical operating pressure at each treatment unit.

Wells GWEX1-GWEX3 are operated intermittently during the year, subject to local weather conditions and in consultation with the Nebraska Game and Parks Commission (NGPC). The NGPC owns most of the property occupied by the wetlands and has administrative and technical responsibility for management of the wildlife area.

2.2 Well GWEX4 and the Conventional Air Stripper

Extraction well GWEX4 is located near the downgradient toe of the carbon tetrachloride plume (Figure 2.1) and is operated continuously as a containment well. Groundwater produced from GWEX4 is treated by using a conventional (shallow-tray) air stripping technique, and the effluent is discharged to the surface for reinfiltration into the shallow Utica aquifer.

2.3 Monitoring Well Network

A network of seven permanent monitoring points has been established at Utica (Figure 2.1). Wells SB48, SB71, and SB72 were constructed during the early phases of the investigations at Utica. These wells were intended primarily for the measurement of groundwater levels; they do not penetrate the more contaminated zones of the groundwater column identified in detailed vertical-profile sampling (Argonne 2000, 2003). To improve monitoring coverage, additional wells MW1-MW4 were installed at strategic locations along the plume migration pathway in August 2005.

TABLE 2.1 Summary of Construction Details for
GWEX Wells at Utica.

Well	Depth (ft BGL)			Casing Diameter (in.)
	Total Depth	Screen Interval	Gravel Pack Interval	
GWEX1	132	106–126	97–132	8
GWEX2	148	110–145	106–148	8
GWEX3	146	105–140	101–146	8
GWEX4	150	115–145	110–150	6

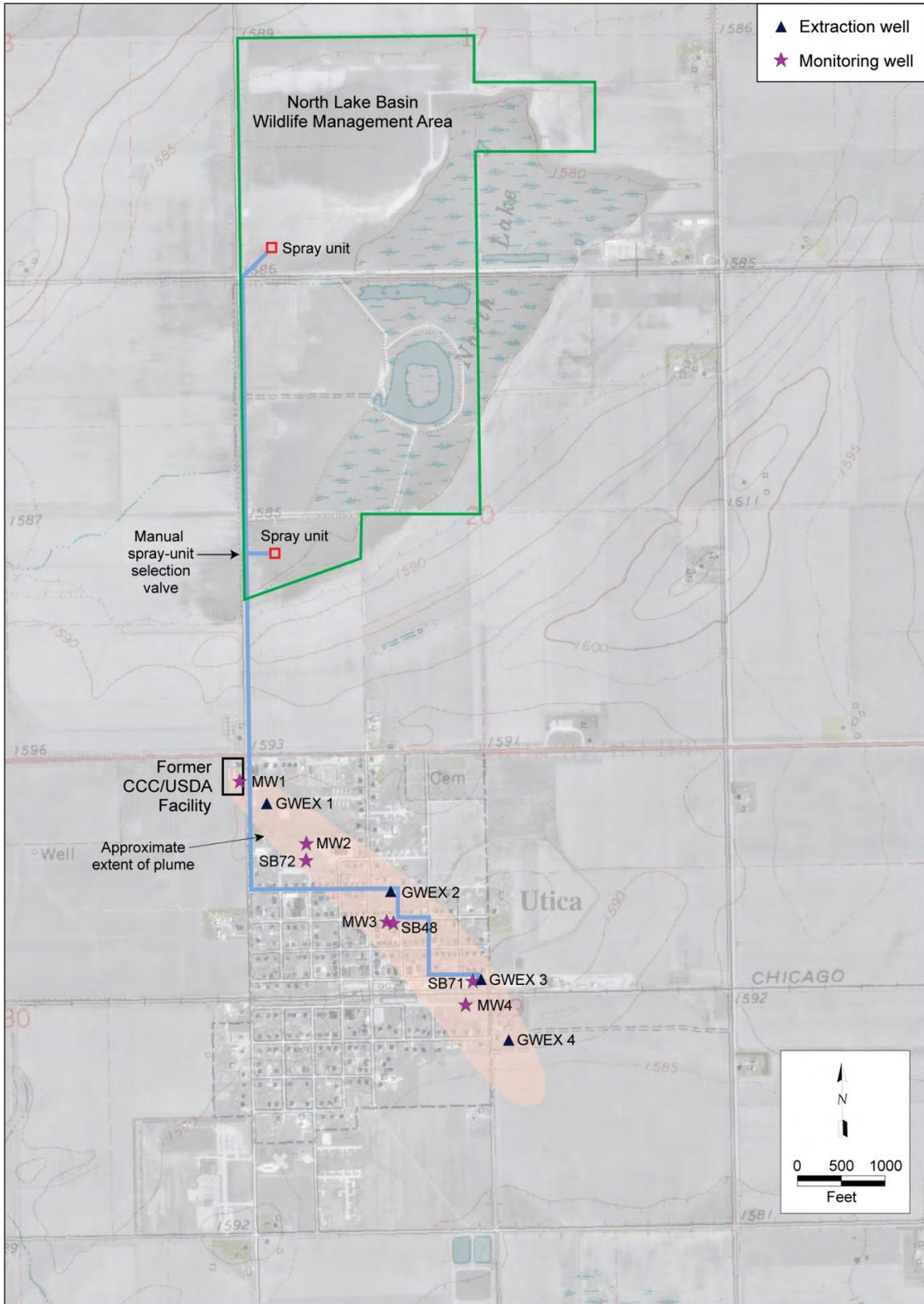


FIGURE 2.1 Locations of the restoration facilities, contaminant plume, and permanent monitoring wells at Utica.



FIGURE 2.2 Spray irrigation unit in operation at Utica.

3 Overview of System Operations

The groundwater restoration program at Utica is conducted in accordance with a National Pollutant Discharge Elimination System (NPDES) permit (No. NE0137456) originally granted by the State of Nebraska, Department of Environmental Quality (NDEQ), for the 5-yr period October 1, 2004, to September 30, 2009. The NDEQ (Reuel Anderson) conducted a 5-yr compliance inspection in September 2008 and gave a satisfactory review (the maximum rating available). In accord with NPDES requirements, in spring 2009 the CCC/USDA submitted an application to the NDEQ for renewal of the permit. On September 28, 2009, the CCC/USDA received notice from the NDEQ that the term of the existing NPDES permit had been extended indefinitely, pending review of the renewal application. On April 28, 2010, the CCC/USDA was informed that a draft permit, fact sheet, and public notice had been generated for the Utica site to solicit public comment regarding the proposed NPDES permit renewal, in accord with NDEQ policy. The NDEQ indicated that the public comment period was to end on June 4, 2010. To date, Argonne has received no further communications from the NDEQ concerning the draft permit; the NDEQ has been contacted for further information on the status of the renewal application. The NDEQ has indicated that, in the interim, the requirements of the original NPDES permit remain valid and in force.

3.1 Operation of Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units

Wells GWEX1-GWEX3 and the spray irrigation treatment units operated intermittently, under automated control, during 8 of the 12 months in the current review period (December 2009-November 2010). The treated groundwater was discharged exclusively to the south wetlands subbasin during this period, at the request of the NGPC.

Wells GWEX1-GWEX3 and the spray treatment units were not operated in January-March 2010, because generally low (< 45°F) winter and early spring temperatures precluded the effective use of the spray treatment process during this period.

The operation of wells GWEX1-GWEX3 (and also well GWEX4; see Section 3.2) was suspended for the month of May 2010 to allow recovery of groundwater levels to ambient

elevations in the shallow, contaminated aquifer undergoing restoration. This action was taken to facilitate resampling of the groundwater in the contaminated aquifer for volatile organic compounds (VOCs) analyses, in vertical profiles at selected locations along the identified plume migration pathway, as part of the 5-yr assessment of the restoration efforts at Utica recommended in the *Monitoring Plan* (Argonne 2004) and *Recommendations for Remapping* (Argonne 2009b). The results of the 5-yr resampling and evaluation are being reported separately.

3.2 Operation of Well GWEX4 and the Conventional Air Stripper

Well GWEX4 and the associated air stripper were operated during 5 months of the current review period.

In October 2009, repairs were completed to correct corrosion and perforation of the downhole pump and the connecting riser pipe in GWEX4. These problems had been identified during the previous review period (Argonne 2010). The well was returned to service on October 23, 2009; however, increasing sand production, variations in the flow rates from the well, and periodic fouling of the totalizing flow meter used to document the well's performance were subsequently observed. Periodic cleaning, as well as replacement of the flow meter, was performed from December 2009 until April 2010 (during the current review period) to enable the well to continue operating.

In May 2010, wells GWEX1-GWEX4 were shut down in conjunction with the 5-yr groundwater sampling program outlined in Section 3.1. Because of the problems discussed above, well GWEX4 and the air stripper were not restarted after the sampling event. In August 2010, the pump and riser pipe were removed from GWEX4 to facilitate inspection of the well casing and inlet screen, and a downhole camera survey of the well was conducted. No damage to either the casing or screen was immediately apparent; however, thick deposits of a soft material — possibly algae or bacteria — in deeper parts of the well obscured the screen and prevented detailed inspection. Well GWEX4 and the air stripper have remained out of service since that time, pending the implementation of further efforts to clean, inspect, and repair (if necessary) the well.

4 Groundwater Production Results

The volumes of groundwater extracted from the Utica aquifer, treated, and discharged during the current review period are summarized in Table 4.1. Performance during the 6 yr of system operation to date is summarized in Section 7.

4.1 Production by Wells GWEX1-GWEX3

Wells GWEX1-GWEX3 are equipped with electronically controlled pump drive units linked to digital flow meters that automatically and continuously adjust the flow from each well to maintain user-specified pumping rates. During this review period, the programmed flow rates for these wells were as follows:

- GWEX1, 50 gpm
- GWEX2, 200 gpm
- GWEX3, 125 gpm

The selected rates for GWEX1-GWEX3 were achieved, within ± 0.5 gpm, throughout the review period (Table 4.2).

Wells GWEX1-GWEX3 were pumped for approximately 3,196 hr during the review period, and they discharged approximately 71.9 million gallons (222 acre-feet) of treated water to the North Lake Basin wetlands (Table 4.1). This represents a significant increase (by approximately 21 million gallons, or 42%) relative to the previous reporting period (Argonne 2010), but it is approximately 21% less than the maximum seasonal production total achieved by these wells to date (approximately 91 million gallons during the December 2006-November 2007 review period; see Section 7). The treated groundwater was discharged exclusively to the southern wetlands subbasin during the current review period, at the request of the NGPC.

Operation of the spray irrigation treatment systems was suspended during January-March 2010 because of seasonally cold weather that prohibited the effective use of the spray irrigation treatment process. As described in Section 3.1, GWEX1-GWEX3 and the spray treatment units were temporarily shut down in May 2010 to facilitate sampling of the Utica groundwater under ambient (non-pumping) conditions, as part of the recommended 5-yr progress review (Argonne 2004, 2009b).

4.2 Production by Well GWEX4

Measured groundwater pumping rates (determined from an inline flow meter) at GWEX4 varied significantly because of the increased sand production noted in Section 3.2. The recorded flow rates ranged from approximately 46 gpm to 91 gpm in December 2009-April 2010. GWEX4 was shut down in May 2010 to facilitate groundwater sampling under ambient conditions for the 5-yr progress review. The GWEX4 shutdown for inspection and possible corrective action continued until the end of the review period (November 2010; Section 3.2). The volume of groundwater produced in any one *complete* month of pumping ranged from about 1.2 million gallons to 2.8 million gallons (Table 4.1). Approximately 11.4 million gallons (35.2 acre-feet) of groundwater was treated and discharged during the review period, at an average (365-day) pumping rate of 21.6 gpm. The average flow rate from GWEX4 during the 151 days on which it actually operated during the review period was 52.3 gpm (Table 4.2).

TABLE 4.1 GWEX operation and groundwater production data in December 2009–November 2010.

Month	Wells GWEX1-GWEX3 (gal)				Volume Discharged to Wetlands ^c (gal)		GWEX4	
	Groundwater Produced ^a			Operating Time ^b (hr)	North	South	Groundwater Produced (gal)	Operating Time (days)
	GWEX1	GWEX2	GWEX3					
Dec 09	4,100	16,000	10,000	1.4	— ^d	30,100	2,416,842	31
Jan 10	—	—	—	—	—	—	2,819,216	31
Feb 10	—	—	—	—	—	—	2,535,981	28
Mar 10	—	—	—	—	—	—	1,205,867	31
Apr 10	1,492,700	5,953,400	3,736,400	497.0	—	11,182,500	2,395,148	30
May 10	—	—	—	—	—	—	—	—
Jun 10	1,020,900	4,122,700	2,571,800	342.9	—	7,715,400	—	—
Jul 10	1,984,900	8,042,900	5,012,400	668.5	—	15,040,200	—	—
Aug 10	2,205,100	8,859,700	5,532,300	737.6	—	16,597,100	—	—
Sep 10	923,600	3,728,300	2,300,100	309.0	—	6,952,000	—	—
Oct 10	1,442,000	6,151,400	3,734,400	503.5	—	11,327,800	—	—
Nov 10	468,100	1,577,300	1,007,600	135.7	—	3,053,000	—	—
Column Totals	9,541,400	38,451,700	23,905,000	3,196	—	71,898,100	11,373,054	151

^a Combined total production from wells GWEX1-GWEX4: 83,271,154 gal.

^b Wells GWEX1-GWEX3 operate simultaneously.

^c Total production to wetlands: 71,898,100 gal.

^d Unit not in operation.

TABLE 4.2 Comparison of actual well production rates and target rates.

Well	Pumping Rate (gpm)	
	Target	Actual (Net Average) ^a
GWEX1	50	49.7
GWEX2	200	200.5
GWEX3	125	124.7
GWEX4	60-65	52.3

^a Average for actual periods of operation.

5 Groundwater Treatment Results

Treated groundwater at Utica is discharged under NPDES permit No. NE0137456, issued by the NDEQ on October 1, 2004. The original (5-yr) term of this permit has been indefinitely extended by the NDEQ, pending the NDEQ's finalization of an application for renewal of the permit submitted by the CCC/USDA during the previous (December 2008-November 2009) review period (Argonne 2010).

To comply with the NPDES requirements, samples of treated groundwater are collected monthly, as follows:

- At the outlet of the air stripping unit at GWEX4.
- From the spray discharge at each of the irrigation treatment units (during months of operation).

The samples are analyzed to determine the residual concentrations of carbon tetrachloride in the treated groundwater and the pH of the effluent. The results of these analyses are reported to the NDEQ quarterly.

The discharges of treated groundwater at Utica are considered by the NDEQ to contribute to the surface waters of the state. On this basis, the NDEQ has specified the following compliance limits for the outfall from each treatment unit:

- A target maximum residual carbon tetrachloride concentration of 44.2 µg/L.
- An acceptable pH range of 6.5 to 9.0.

In conjunction with the compliance sampling, Argonne collects monthly samples of the untreated groundwater from each extraction well. The samples are analyzed for VOCs to enable estimation of the following:

- Carbon tetrachloride removal efficiencies for the treatment units.
- Quantities of carbon tetrachloride removed from the contaminated aquifer.

The results of the sampling and analysis activities during the review period are summarized in Tables 5.1 and 5.2.

5.1 Results for Wells GWEX1-GWEX3, with Treatment by Spray Irrigation

The concentrations of carbon tetrachloride found in the untreated groundwater from extraction wells GWEX2 and GWEX3 were highest upon initial start-up of the wells in April 2010 (following shutdown for the preceding winter). The concentrations declined in June and then varied with no clear trend during the remainder of review period (Table 5.1). Carbon tetrachloride concentrations at GWEX2 ranged from 21 µg/L to 48 µg/L, while at GWEX3 the levels ranged from 21 µg/L to 66 µg/L.

Observed carbon tetrachloride levels at upgradient extraction well GWEX1 were highest at the beginning and end of the review period (in December 2009 and November 2010), with a minimum in June 2010. The observed concentrations at GWEX1 showed no apparent correlation to the concentrations observed at GWEX2 and GWEX3. Carbon tetrachloride concentrations at GWEX1 ranged from 23 µg/L (in June 2010) to 58-60 µg/L (in December 2009 and November 2010).

The groundwater produced from wells GWEX1-GWEX3 is combined into a single stream for conveyance to the wetlands via a common pipeline. This combined flow is also sampled monthly as an indicator of the weighted average concentration of carbon tetrachloride in the untreated groundwater supplied to the spray irrigation treatment units. The measured concentrations in the combined flow (Table 5.1) varied from 22 µg/L to 53 µg/L during the current monitoring period. The temporal variations in concentration observed in the combined flow stream generally mirrored those observed at wells GWEX2 and GWEX3, which together contribute approximately 87% of the total discharge from the extraction well system.

Treated groundwater sprayed from the irrigation units is collected for analysis at the following four locations at the treatment site during each sampling event:

- Beneath the center point of the “west” irrigation span.
- Beneath the center point of the “center” irrigation span.
- Beneath the center point of the “east” irrigation span.
- At a fourth location visually chosen to reflect the estimated site of maximum spray outfall (“max” value at a position varying from month to month, depending on the prevailing wind and spray conditions at the time of sampling).

The results (Table 5.1) show that the concentrations in all spray samples collected during the review period were below the maximum contaminant level (MCL) of 5.0 µg/L promulgated by the U.S. Environmental Protection Agency for carbon tetrachloride in drinking water. The *maximum* carbon tetrachloride level identified for a single sample of spray discharged from the irrigation treatment units was 1.6 µg/L. The *average* concentration of carbon tetrachloride in the treated groundwater discharged to the wetlands was approximately 0.2 µg/L. The concentrations of carbon tetrachloride in all spray samples were below the maximum target concentration (44.2 µg/L) allowed under the NPDES permit, by roughly an order of magnitude.

The results of the groundwater and spray sample analyses suggest the following *minimum carbon tetrachloride removal efficiency values* for the spray irrigation treatment process:

- More than 94% (based on data for individual samples).
- Approximately 99% (based on the average concentration delivered to the wetlands during the review period).

The results of pH measurements recorded for samples of the treated spray discharge are presented in Table 5.2. In all cases, the observed pH levels (7.40 to 8.73) were within the acceptable range (6.5 to 9.0) specified under the NPDES permit.

5.2 Results for Well GWEX4, with Treatment by Air Stripping

Low concentrations of carbon tetrachloride were detected in the untreated groundwater produced by GWEX4 (3.5 µg/L to 11 µg/L; Table 5.1) for the 5 months (December 2009-April 2010) in which this well was operated during the current review period. The carbon tetrachloride concentration in the untreated groundwater dropped below the MCL of 5.0 µg/L in February 2010, but the concentration returned to levels exceeding the MCL in March and April 2010. Carbon tetrachloride was not detected in the effluent from the air stripping unit throughout the review period, indicating a carbon tetrachloride removal efficiency of > 99% for this process. Measured pH levels in all samples of the air stripper effluent (7.98 to 8.36; Table 5.2) were within the acceptable range (6.5 to 9.0) specified under the NPDES permit.

5.3 Estimated Removal of Carbon Tetrachloride from the Utica Aquifer

The groundwater production and carbon tetrachloride concentration data presented in Tables 4.1 and 5.1, respectively, can be used to estimate the total quantity of carbon tetrachloride extracted by wells GWEX1-GWEX4 from December 1, 2009, to November 30, 2010. The results of these calculations, summarized in Table 5.3, indicate that approximately 8.7 kg (1.4 gal) of carbon tetrachloride was removed from the Utica aquifer by GWEX1-GWEX4 during the present review period. In the previous period (December 2008-November 2009), approximately 9.3 kg (1.5 gal) of carbon tetrachloride was removed. These values are significantly lower than the quantities of carbon tetrachloride recovered annually from the aquifer (23-34 kg/yr) during the first 3 yr of operation of the Utica remedial systems, in November 2004-November 2007.

The reduced quantities of carbon tetrachloride removed from the Utica aquifer in the current review period and in December 2007-November 2009 reflect decreasing trends in the

concentrations of carbon tetrachloride observed in the groundwater produced by wells GWEX2-GWEX4 (see Section 5.4), as well as the limited operation of GWEX1-GWEX3 and the spray treatment units (in December 2007-November 2009) and GWEX4 (in December 2009-November 2010) that have been possible during these review periods (Section 3.1). No decrease in the volumetric throughput (when operating) or contaminant removal efficiency of the groundwater treatment systems was observed during the current period.

5.4 Sampling of Monitoring Wells and Apparent Carbon Tetrachloride Concentration Trends in the Utica Groundwater

Table 5.4 summarizes construction data for the monitoring wells, as well as the results of groundwater sampling and analyses for VOCs during the current review period. Complete monitoring data for wells MW1-MW4, since sampling at these points began in September 2005, are depicted in Figure 5.1. Figures 5.2-5.5 summarize the carbon tetrachloride concentrations measured at GWEX1-GWEX4, respectively, since the routine operation and sampling of these wells began in November 2004.

Except for MW1, carbon tetrachloride concentrations at all of the monitoring wells (Figure 5.1) have been relatively stable, with no persistent rising or falling trends. Carbon tetrachloride concentrations at MW1 have been consistently greater than those at downgradient monitoring wells MW2-MW4 (Figures 2.1 and 5.1). Concentrations at MW1 increased to a maximum in June-October 2007 (Figure 5.1), decreased significantly from October 2007 to November 2008, and then remained relatively stable (100-131 $\mu\text{g/L}$) during the December 2008-November 2009 review period. The concentrations at MW1 oscillated between values of 87 $\mu\text{g/L}$ and 152-185 $\mu\text{g/L}$ during the current (December 2009-November 2010) review period and showed no clear rising or falling trend (Figure 5.1 and Table 5.4).

The identified carbon tetrachloride concentrations at downgradient extraction wells GWEX2-GWEX4 (Figures 5.3-5.5) have declined slowly during the period of record, although short-term variability is apparent within the generally decreasing trend for each well. At GWEX2 and GWEX3, a pattern of relatively higher initial concentrations at each well upon seasonal (spring) start-up is apparent, followed by generally declining contaminant levels during periods

of continuous operation. In contrast, carbon tetrachloride concentrations at upgradient well GWEX1 (Figures 2.1 and 5.2) have shown no clear long-term trend, but the values appear to increase during seasonal periods of continuous operation.

Wells MW1 and GWEX1 are located, respectively, on and near the former CCC/USDA facility property (Figure 2.1). Together, the data for MW1 and GWEX1 (Figures 5.1 and 5.2) might reflect localized influx of carbon tetrachloride from residual contamination in the soils beneath the former CCC/USDA facility to the upgradient shallow groundwater (Argonne 2000, 2003). The stable or decreasing contaminant levels observed at all of the downgradient monitoring and GWEX wells demonstrate, however, that GWEX1 is presently operating effectively as an upgradient capture well.

5.5 Evaluation of Groundwater Inorganic Geochemistry

In accord with the approved *Monitoring Plan* (Argonne 2004), samples of the untreated groundwater from individual extraction wells GWEX1-GWEX4 and the (treated) effluent from the air stripper at GWEX4 are collected annually and submitted for inorganic geochemical analyses. Samples from wells GWEX1-GWEX3 and their combined (untreated) effluent were collected for analysis during the current review period in October 2010. Corresponding samples could not be collected from GWEX4 or the treated effluent from this well, because the well remained out of service from May 2010 to the end of the review period (November 2010).

The results of the geochemical analyses are in Table 5.5, together with equivalent data for these sampling locations in the December 2007-November 2008 and December 2008-November 2009 review periods. The October 2010 results indicate no substantial changes in the geochemistry of the groundwater produced by GWEX1-GWEX3 for treatment and discharge to the North Lake Basin wetlands during the current and previous review periods. The results in Table 5.5 indicate a similar finding for the untreated groundwater and treated effluent obtained from GWEX4 during the current and previous review periods.

TABLE 5.1 Analytical results for carbon tetrachloride in untreated groundwater samples and treated effluent samples in December 2009- November 2010.

Month	Carbon Tetrachloride Concentration (µg/L)													GWEX4 Untreated	Stripper Effluent
	GWEX1-GWEX3 Untreated				North Spray Unit Effluent				South Spray Unit Effluent						
	GWEX1	GWEX2	GWEX3	Mixed ^a	West ^b	Center ^b	East ^b	Max ^c	West ^b	Center ^b	East ^b	Max ^c			
Dec 09	60	31	36	28	– ^d	–	–	–	1.3	1.6	ND ^e	ND	5.2	ND	
Jan 10	–	–	–	–	–	–	–	–	–	–	–	–	11	ND	
Feb 10	–	–	–	–	–	–	–	–	–	–	–	–	3.5	ND	
Mar 10	–	–	–	–	–	–	–	–	–	–	–	–	8.4	ND	
Apr 10	48	48	66	53	–	–	–	–	ND	ND	ND	ND	10	ND	
May 10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Jun 10	23	32	45	35	–	–	–	–	ND	ND	0.4J ^f	ND	–	–	
Jul 10	38	27	27	28	–	–	–	–	ND	0.4J	ND	ND	–	–	
Aug 10	41	21	20	22	–	–	–	–	ND	ND	ND	ND	–	–	
Sep 10	48	25	23	27	–	–	–	–	ND	0.5J	ND	ND	–	–	
Oct 10	45	22	21	25	–	–	–	–	0.6J	ND	0.6J	ND	–	–	
Nov 10	58	27	26	31	–	–	–	–	ND	ND	ND	ND	–	–	

^a Analytical results for samples from the combined flows of GWEX1-GWEX3.

^b Samples of spray collected below the center point of the respective irrigation span.

^c Samples of spray collected at the estimated location of maximum spray outfall.

^d Unit not in operation

^e ND, not detected at a method detection limit of 0.1 µg/L.

^f Qualifier J indicates an estimated concentration below the quantitation limit of 1.0 µg/L for the purge-and-trap method.

TABLE 5.2 Values for pH in untreated groundwater samples and treated effluent samples in December 2009-November 2010.

Month	pH							
	GWEX1-GWEX3 Untreated				North Spray Unit ^b	South Spray Unit ^b	GWEX4 Untreated	Stripper Effluent
	GWEX1	GWEX2	GWEX3	Mixed ^a				
Dec 09	7.38-7.42	7.11-7.14	6.97-7.07	7.48-7.82	— ^c	8.27-8.37	7.00-7.04	8.32-8.36
Jan 10	—	—	—	—	—	—	6.84-6.92	8.18-8.36
Feb 10	—	—	—	—	—	—	7.60-7.65	8.35-8.36
Mar 10	—	—	—	—	—	—	6.74-6.86	7.98
Apr 10	7.01-7.08	6.94-6.96	6.90-6.91	7.03-7.15	—	8.14-8.20	6.70-6.77	8.18
May 10	—	—	—	—	—	—	—	—
Jun 10	7.08-7.10	6.92-6.96	6.90-6.95	7.12-7.16	—	8.14-8.21	—	—
Jul 10	7.62-8.00	7.38	7.35-7.44	7.60-7.74	—	8.63-8.73	—	—
Aug 10	6.60-6.81	6.70-6.98	6.81-7.00	7.34-7.78	—	8.20-8.44	—	—
Sep 10	7.14-7.28	6.99-7.04	6.85-6.98	7.39-7.91	—	8.02-8.08	—	—
Oct 10	6.96-7.02	6.83-6.84	6.90-6.92	7.01-7.03	—	8.27-8.35	—	—
Nov 10	7.16-7.25	6.99-7.06	6.89-6.91	7.30-7.31	—	7.40-7.91	—	—

^a Ranges of values for multiple measurements of the combined flows of GWEX1-GWEX3.

^b Ranges of values for spray samples collected at multiple locations at the discharge site.

^c Unit not in operation.

TABLE 5.3 Estimation of carbon tetrachloride removed from the Utica aquifer in December 2009-November 2010.^a

Month	GWEX1-GWEX3				GWEX4			
	Groundwater Extracted		Carbon Tetrachloride		Groundwater Extracted		Carbon Tetrachloride	
	(gal)	(L)	Concentration ^b (µg/L)	Calculated Amount Removed (kg)	(gal)	(L)	Concentration (µg/L)	Calculated Amount Removed (kg)
Dec 09	301,00	113,959	28	0.003	2,416,842	9,150,164	7.2	0.07
Jan 10	— ^c	—	—	—	2,819,216	10,673,552	11	0.12
Feb 10	—	—	—	—	2,535,981	9,601,224	3.5	0.03
Mar 10	—	—	—	—	1,205,867	4,565,412	8.4	0.04
Apr 10	11,182,500	42,336,945	53	2.24	2,395,148	9,068,030	10	0.09
May 10	—	—	—	—	—	—	—	—
Jun 10	7,715,400	29,210,504	35	1.02	—	—	—	—
Jul 10	15,040,200	56,942,197	28	1.59	—	—	—	—
Aug 10	16,597,100	62,836,621	22	1.38	—	—	—	—
Sep 10	6,952,000	26,320,272	27	0.71	—	—	—	—
Oct 10	11,327,800	42,887,051	25	1.07	—	—	—	—
Nov 10	3,053,000	11,558,658	31	0.36	—	—	—	—
TOTAL				8.39				0.35

^a Total carbon tetrachloride removed from the aquifer: 8.74 kg.

^b Concentration in untreated samples of the combined flow from wells GWEX1-GWEX3.

^c Unit not in operation.

TABLE 5.4 Well construction data and analytical results for carbon tetrachloride in groundwater samples from the permanent monitoring wells.

Well	Depth (ft BGL)		Carbon Tetrachloride ($\mu\text{g/L}$)			
	Total	Screened Interval	Jan 10	Apr 10	Jul 10	Oct 10
SB48	98.5	83.5-93.5 ^a	ND ^b	ND	ND	ND
SB71	94.2	84-94	0.6	ND	ND	ND
SB72	122.3	82.6-112.6	8.7	6.1	3.3	1.3
MW1	105	85-100	152	87	185	87
MW2	115	90-110	25	14-15	35	11
MW3	125	100-120	67	36-41	16	37
MW4	125	100-120	6.0-6.7	4.4-4.9	3.0	2.4

^a Ranges of values represent both primary samples and quality control replicates and duplicates.

^b ND, not detected at a method detection limit of 0.1 $\mu\text{g/L}$.

TABLE 5.5 Comparison of inorganic geochemical results for untreated groundwater samples and treated effluent samples.

Analyte	Concentration (mg/L)																	
	GWEX1			GWEX2			GWEX3			GWEX1-GWEX3			GWEX4 Untreated			GWEX4 Effluent		
	Nov 2008	Nov 2009	Oct 2010	Nov 2008	Nov 2009	Oct 2010	Nov 2008	Nov 2009	Oct 2010	Nov 2008	Nov 2009	Oct 2010	Nov 2008	Nov 2009	Oct 2010	Nov 2008	Nov 2009	Oct 2010
Aluminum	< 0.2 ^a	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	- ^b	-	< 0.2	< 0.2	< 0.2	-	< 0.2	< 0.2	-
Calcium	83.9	82	87	95.4	92	88	99.7	97	100	-	-	92	110	110	-	110	110	-
Chloride	13	18	21	16	19	22	28	23	31	-	-	25	31	29	-	32	29	-
Iron	< 0.1	< 0.1	< 0.2	< 0.1	< 0.1	< 0.2	< 0.1	< 0.1	< 0.2	-	-	< 0.2	< 0.1	< 0.1	-	< 0.1	< 0.1	-
Magnesium	13.2	13	14	15.6	15	15	16.1	16	17	-	-	15	17.7	18	-	17.8	19	-
Manganese	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	-	-	< 0.015	< 0.015	< 0.015	-	< 0.015	< 0.015	-
Phosphate	0.40	< 0.20 H ^c	< 0.2 H	0.39	0.37	< 0.2 H	0.46	< 0.20 H	< 0.2 H	-	-	< 0.2 H	0.42	< 0.20 H	-	0.40	< 0.20 H	-
Phosphorus	0.307	0.28	0.3	0.291	0.31	0.31	0.258	0.31	0.31	-	-	0.25	0.294	0.34	-	0.295	0.3	-
Potassium	5.38	5.3	5.3	5.83	6.2	6	6.48	6.4	6.6	-	-	6.5	6.70	6.5	-	6.50	7	-
Silicon	16.9	16	16	17.2	17	16	17.9	17	17	-	-	15	18.2	17	-	18.2	18	-
Sodium	34	31	37	41.6	36	39	37.8	40	46	-	-	43	44.6	41	-	44.8	47	-
Sulfate	26	20	22	38	32	38	52	38	41	-	-	33	55	48	-	56	48	-
Zinc	0.0395	0.025	< 0.02	< 0.02	< 0.02	0.021	< 0.02	< 0.02	< 0.02	-	-	< 0.02	< 0.02	< 0.02	-	< 0.02	< 0.02	-
Nitrate (as N)	18	10 H	10 H	13	11 H	12 H	18	16 H	18 H	-	-	14 H	20	19 H	-	21	19 H	-

^a Analyte not identified at analytical method detection limit indicated.

^b No analysis.

^c Qualifier H indicates that the holding time before analysis was exceeded.

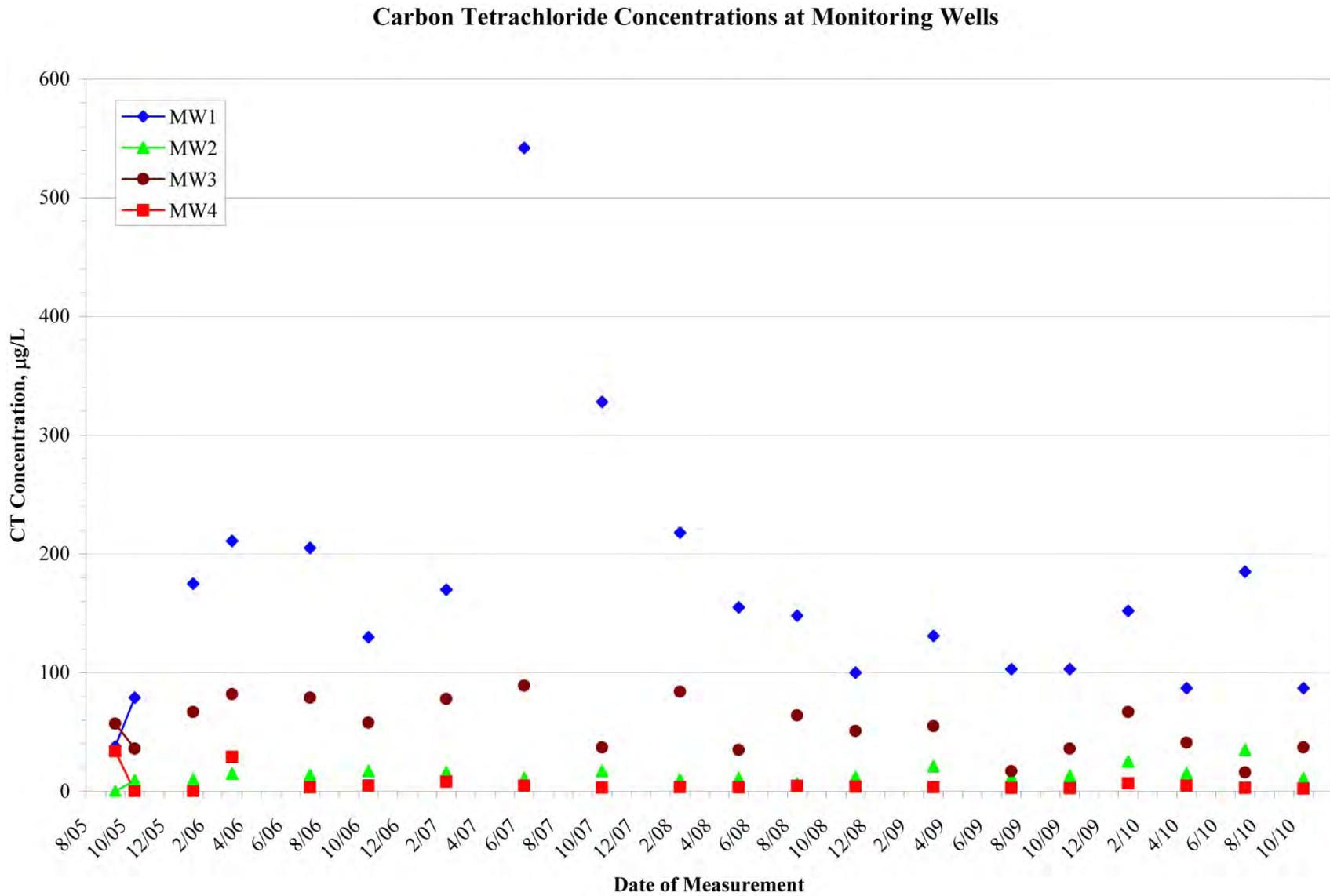


FIGURE 5.1 Carbon tetrachloride concentrations ($\mu\text{g/L}$) at monitoring wells MW1–MW4, September 2005 to November 2010.

Carbon Tetrachloride Concentrations at Extraction Well GWEX1

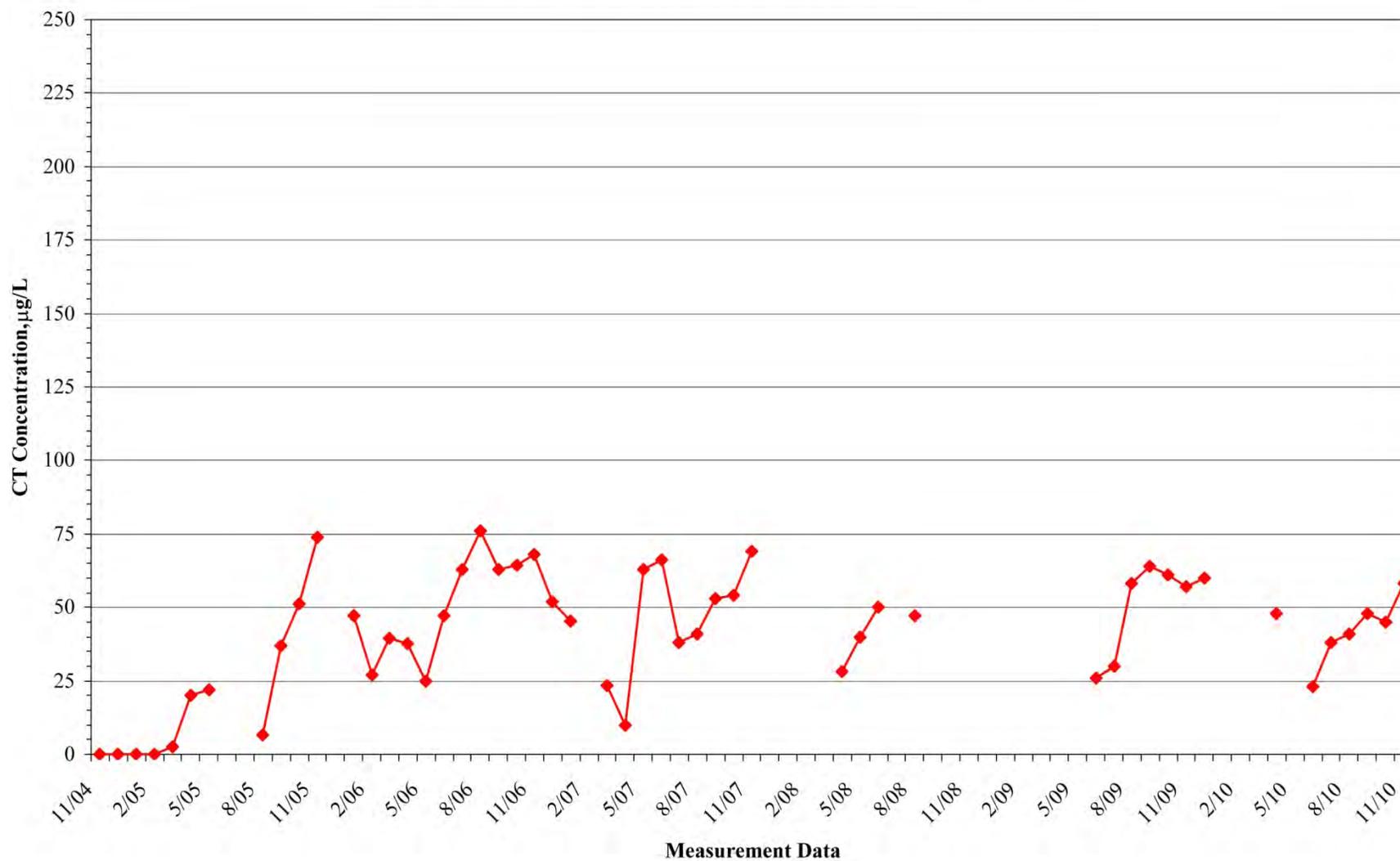


FIGURE 5.2 Carbon tetrachloride concentrations (µg/L) at extraction well GWEX1, November 2004 to November 2010.

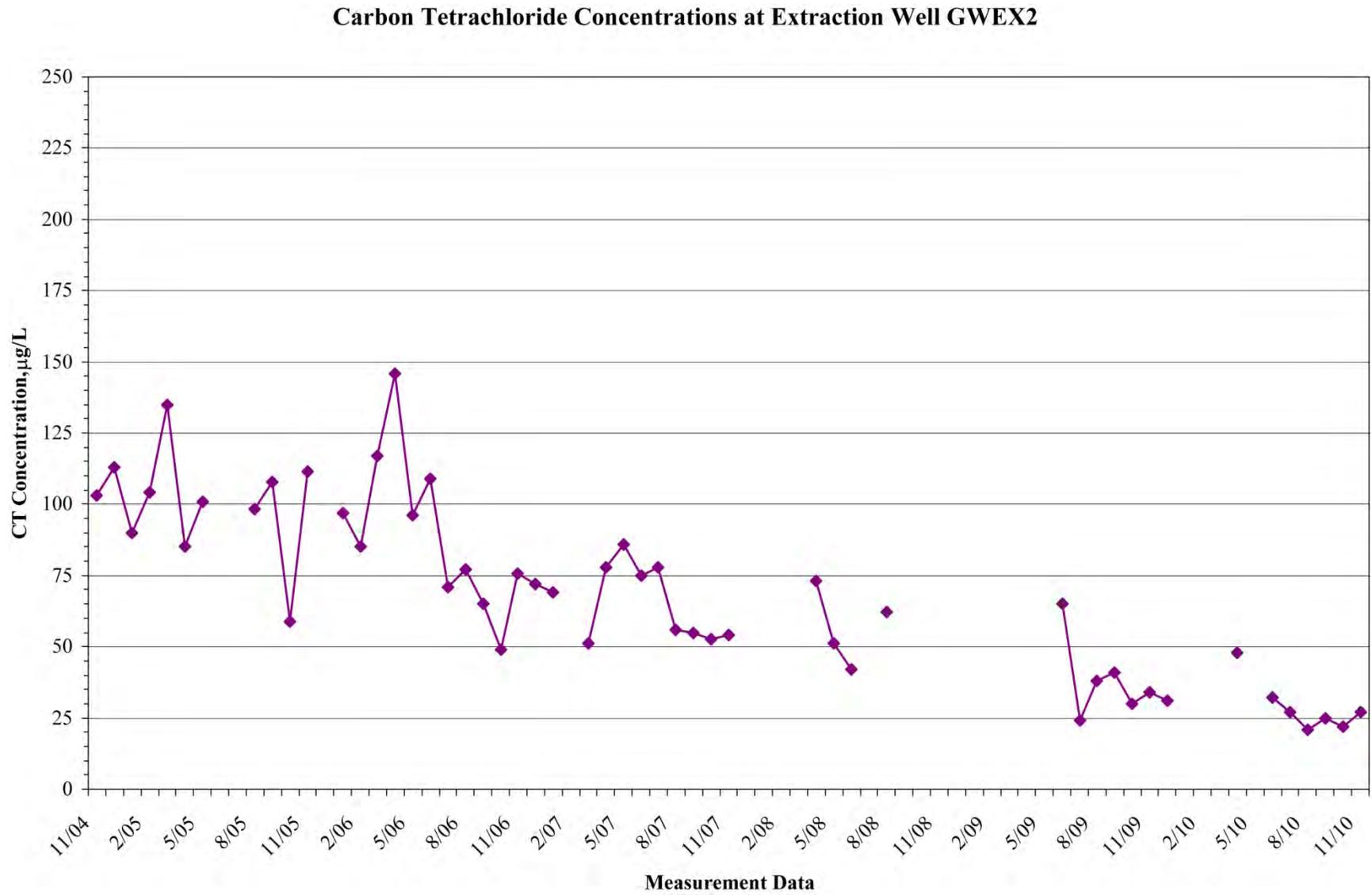


FIGURE 5.3 Carbon tetrachloride concentrations (µg/L) at extraction well GWEX2, November 2004 to November 2010.

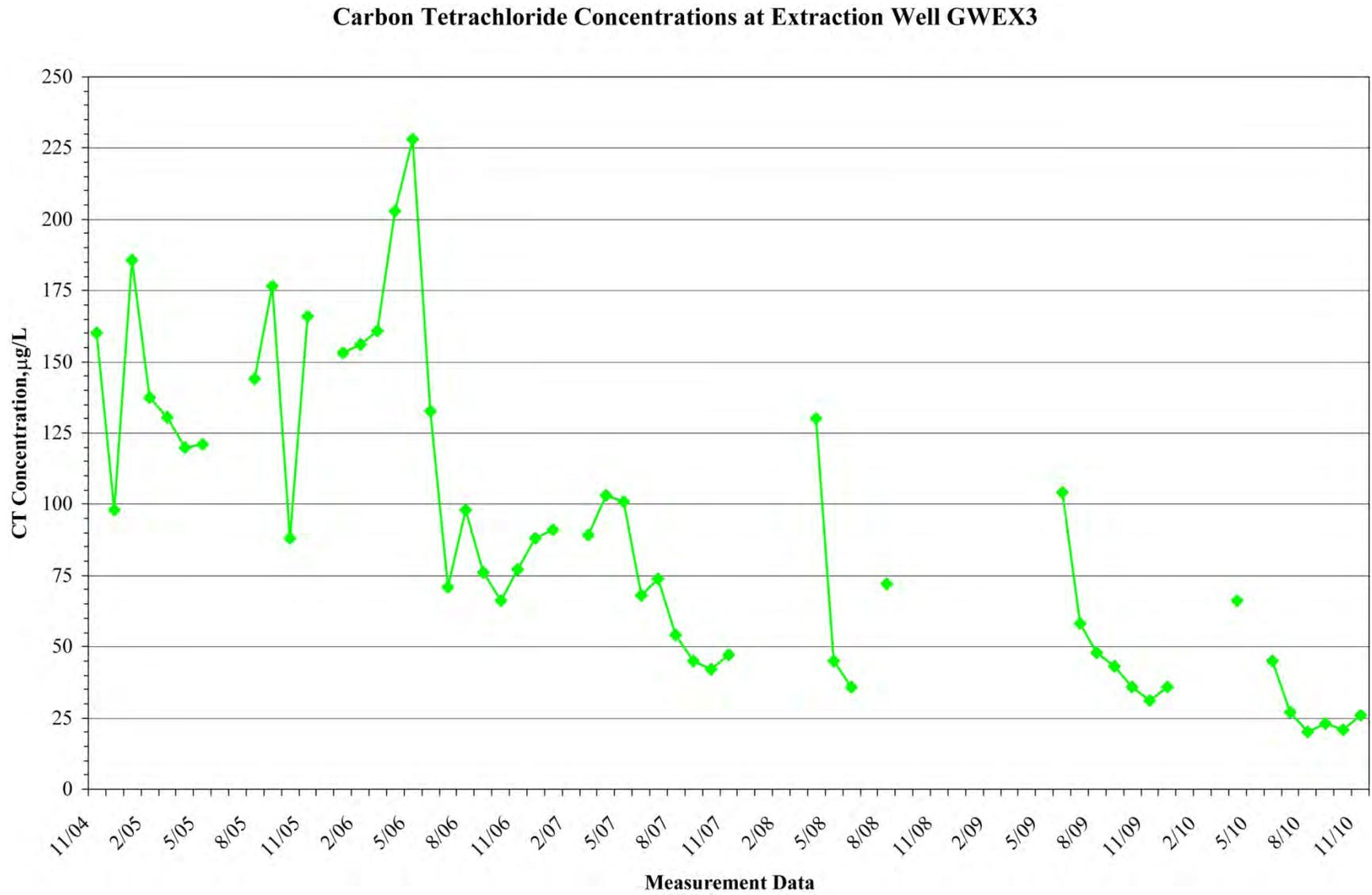


FIGURE 5.4 Carbon tetrachloride concentrations (µg/L) at extraction well GWEX3, November 2004 to November 2010.

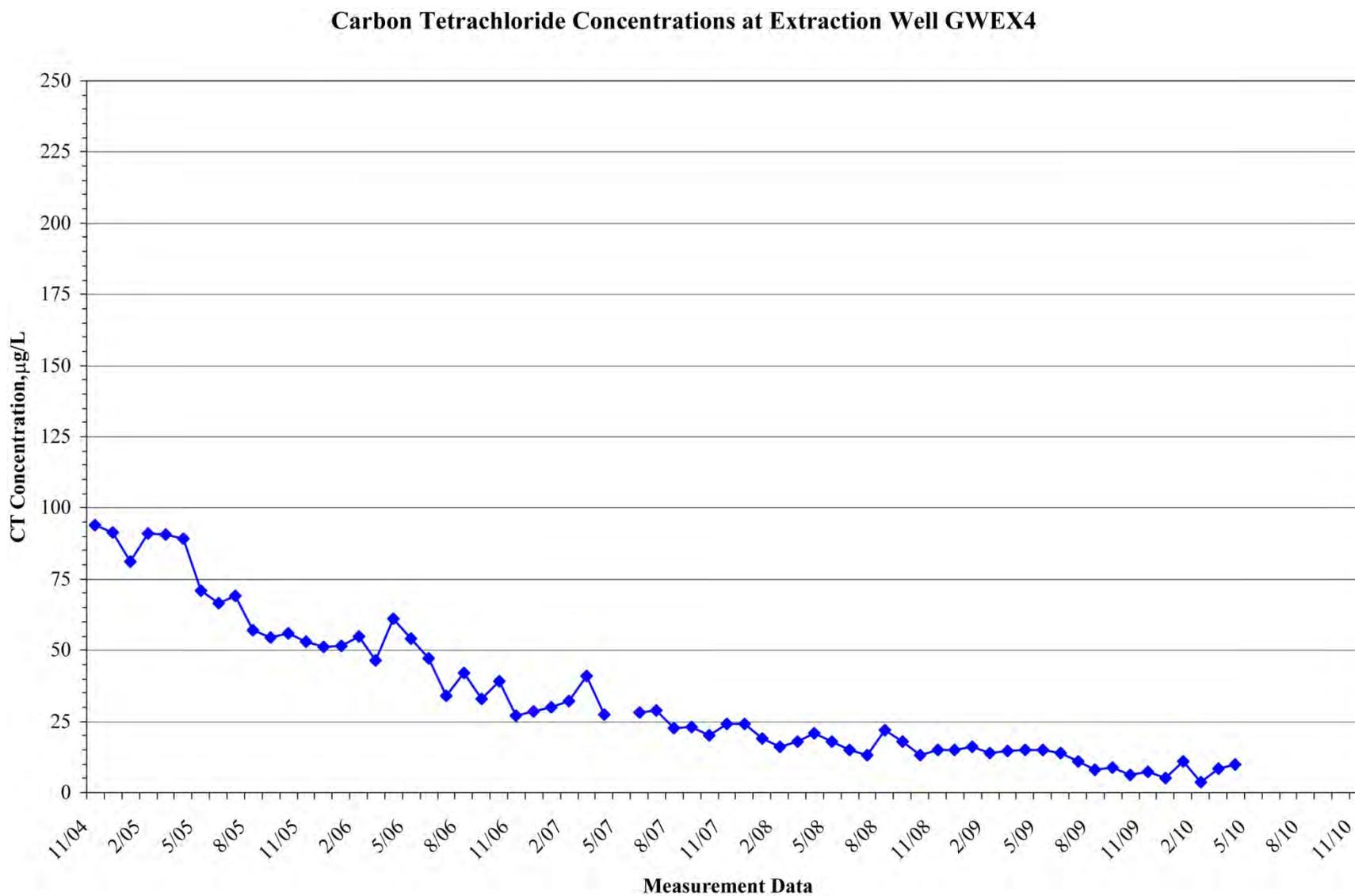


FIGURE 5.5 Carbon tetrachloride concentrations (µg/L) at extraction well GWEX4, November 2004 to November 2010.

6 Operation, Maintenance, and System Modifications

6.1 Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units

No maintenance was required on extraction wells GWEX1-GWEX3 during the current review period.

Maintenance and repairs for the spray irrigation units and the groundwater delivery system were limited to the following activities:

- Periodic field inspection of the units and all operating parameters.
- Seasonal mowing along the gravel access roads and pads at the north and south spray treatment sites.
- Replacement of the pressure sensor (located on one of the irrigation spans) at the south spray treatment site (with a spare gauge obtained previously), to correct intermittent pressure readings that caused GWEX1-GWEX3 and the treatment system to shut down sporadically in July 2010.

6.2 Well GWEX4 and the Air Stripping Unit

Maintenance and repairs for well GWEX4 and the air stripping unit included the following:

- Well GWEX4 was returned to service on October 23, 2009, following repairs to the pump and riser pipe that had been completed during the previous review period (Argonne 2010). During the current period — because of increasing sand production, variations in the flow rates from the well, and periodic fouling of the totalizing flow meter used to document the well's performance — periodic cleaning of the flow meter was required in December 2009-April

2010. In addition, the flow meter was replaced in January 2010 and again in February 2010 to allow the well to continue operating.

- Well GWEX4 was shut down in May 2010 for the 5-yr performance assessment recommended under the approved *Monitoring Plan* (Argonne 2004) and was not operated for the remainder of the current review period because of the problems noted above. In August 2010 the pump and riser pipe were removed, and a downhole camera survey of the well was conducted. No damage to the casing or screen was readily apparent; however, thick deposits of an unidentified soft material in the deeper parts of the well prevented a detailed inspection of the screen. Alternatives for cleaning and further inspection (or possible repairs) needed to return the well to service were under consideration at the end of the review period.

6.3 Operating and Maintenance Costs

Operating and maintenance costs for the aquifer restoration systems at Utica are summarized in Table 6.1. These costs include one-time expenses incurred during the current review period (through November 2010) associated with removal of the pump and inspection of the well casing and screen at GWEX4. Additional costs that might be required to return this well to service will be reported during the next (December 2010-November 2011) review period.

The total operating and maintenance costs for the Utica project during the current review period (\$144,785) decreased by approximately 10% relative to the equivalent costs for December 2008-November 2009 (\$160,101) and were the second lowest annual costs incurred during the initial 6 yr of operation (Table 6.1). The routine operating costs for the current review period were the third lowest to date. Although remediation monitoring costs increased relative to the previous (December 2008-November 2009) review period, this expense was in large measure offset by decreased general management, technical oversight, and logistics support costs during the current review period. Non-routine costs (\$4,645) during the current review period were approximately 18% of those incurred in December 2008-November 2009.

Table 6.1 also includes one-time costs incurred during the current review period as part of a 5-yr assessment of the groundwater restoration efforts at Utica. These costs are not directly associated with the operation and maintenance of the treatment systems at the site in December 2009-November 2010. The costs for the 5-yr assessment (\$86,978) primarily reflect resampling of the groundwater for VOCs analysis, in vertical profiles at selected locations along the identified plume migration pathway, through use of the Argonne cone penetrometer vehicle (Argonne 2004, 2009b). The results of the 5-yr assessment are being reported separately.

TABLE 6.1 Summary of operating and maintenance costs for the Utica restoration project.

Item	Cost (\$)					
	Oct 2004- Nov 2005	Dec 2005- Nov 2006	Dec 2006- Nov 2007	Dec 2007- Nov 2008	Dec 2008- Nov 2009	Dec 2009- Nov 2010
<i>Routine Costs</i>						
General Management	18,127	17,699	5,544	4,891	4,634	2,988
Logistics Support	64,145	74,713	10,475	24,959	40,464	8,964
Remediation Monitoring	170,880	110,546	97,164	118,036	76,788	123,831
Technical Oversight	17,727	5,228	13,537	8,119	12,051	4,357
SUBTOTAL	270,879	208,186	126,720	156,006	133,937	140,140
<i>Non-routine Costs</i>						
Monitoring Network Establishment	11,707					
Radio Control System		5,140				
Irrigation Span Repairs		57,591				
Valve Actuator Replacement			5,071			
Repair of Spray Pad Control Panels, Replacement of Pressure Sensors			2,265		9,628	
Redress Spray Pads and Entry Roads					2,968	
Wetlands Survey and Staff Gauge Construction					6,845	
GWEX1 Repairs				12,075		
GWEX4 Repairs					6,723	4,645
SUBTOTAL	11,707	62,731	7,336	12,075	26,164	4,645
<i>Five-Year Plume Redefinition Sampling^a</i>						86,978
TOTAL (routine and non-routine costs)	282,586	270,916	134,056	168,081	160,101	144,785

^a Costs incurred during the December 2009-November 2010 review period, but not directly associated with the operation or maintenance of the groundwater restoration systems.

7 Summary

Historical performance data and costs for the first 6 yr of operation of the Utica remedial systems are summarized in Tables 7.1 and 7.2.

A combined total of approximately 83 million gallons of contaminated groundwater was extracted and treated during the operation of the aquifer restoration systems at Utica from December 1, 2009, to November 30, 2010. Approximately 86% of the total volume treated (71.9 million gallons; 222 acre-feet) was used to supplement the natural water entering the North Lake Basin Wildlife Management Area. Discharge of treated groundwater to the wetlands was not possible during four months of the current review period, because of (1) inclement winter weather conditions (January-March 2010) and (2) a temporary shutdown of the extraction wells in May 2010 to facilitate groundwater sampling from the Utica aquifer under ambient (non-pumping) flow conditions for the 5-yr review of system performance.

Groundwater modeling studies performed by Argonne during the development of the aquifer restoration approach for Utica (Argonne 2000) indicated that, *on average*, the extraction of approximately 97 million gallons of groundwater per year would be required to maintain hydraulic control of the groundwater plume and achieve cleanup of the aquifer in an estimated 10-15 yr. The actual groundwater produced during the December 2009-November 2010 review period represents approximately 86% of this average annual goal. The highest annual production to date (approximately 119 million gallons; 123% of the annual target) was achieved in the December 2006-November 2007 monitoring period. The cumulative volume of groundwater extracted and treated by the Utica systems since the aquifer restoration efforts began (Table 7.2) now represents 88% of the theoretical cumulative target for the 6-yr period November 2004-November 2010 (down only slightly from 89% for the 5-yr period November 2004-November 2009; Argonne 2010).

The original modeling studies (Argonne 2000) suggested that the natural groundwater flow and the contaminant migration rates at this site are sufficiently low to accommodate periodic fluctuations in the volume of groundwater extracted annually, as long as the target *average* extraction rate is generally maintained. The slightly low groundwater recoveries

observed during the current (December 2009-November 2010) and previous (December 2007-November 2008 and December 2008-November 2009) review periods therefore do not represent an immediate concern. The observed trends in carbon tetrachloride concentrations documented at wells GWEX1-GWEX4 (Section 5.4; Figures 5.2-5.5) indicate that the combined extraction well system is continuing to restrict downgradient migration of contamination within the Utica aquifer. Continued monitoring after well GWEX4 is restarted in the upcoming review period will reveal the effect of the extended shutdown beginning in May 2010 and will indicate whether greater concern about the extraction rate is warranted.

Sampling and analysis of the effluent water from the air stripping and spray irrigation treatment units indicated that during the December 2009-November 2010 review period these systems functioned at a minimum efficiency of 94% (on the basis of data for individual samples from the spray treatment units). Efficiencies are approximately 99% for the spray treatment units (calculated on the basis of the average concentration delivered to the wetlands during the review period) and > 99% for the outfall from the air stripping unit. Carbon tetrachloride concentrations in all discharges of treated water at the site were below the permitted maximum target (44.2 µg/L) by roughly an order of magnitude.

Calculations based on the volumes and measured carbon tetrachloride concentrations of the groundwater extracted and treated during the review period indicated that a total of approximately 8.7 kg (1.5 gal) of carbon tetrachloride was removed from the Utica aquifer during the December 2009-November 2010 review period. No decrease in the volumetric throughput (when operating) or contaminant removal efficiency of the groundwater treatment systems was observed during the current period (Table 7.1). Table 7.2 shows that a total of approximately 108.3 kg (18.7 gal) of carbon tetrachloride has been removed from the Utica aquifer during the first 6 yr (November 2004 to November 2010) of operation of the Utica treatment systems.

The costs incurred by Argonne for operating and maintenance of the aquifer restoration effort at Utica during the December 2009-November 2010 review period were approximately \$144,785, reflecting an approximate 9.6% decrease in total costs but an approximate 5% increase in routine costs relative to the previous (December 2008-November 2009) review period.

Expected additional costs associated with the repairs initiated at well GWEX4 during the current review period will be included in the next (December 2010-November 2011) annual report.

TABLE 7.1 Summary of performance of the groundwater restoration systems at Utica.

	Review Period					
	Oct 2004- Nov 2005	Dec 2005- Nov 2006	Dec 2006- Nov 2007	Dec 2007- Nov 2008	Dec 2008- Nov 2009	Dec 2009- Nov 2010
Groundwater Produced (gal)	66,364,652	113,949,510	119,274,680	55,228,674	76,693,459	83,271,154
Groundwater Produced (% of annual goal)	68	117	123	57	79	86
Groundwater Discharged to Wetlands (gal)	34,611,960	84,365,500	90,954,300	25,675,200	50,633,300	71,898,100
Carbon Tetrachloride in Combined Untreated Groundwater from GWEX1-GWEX3 (µg/L)	100-122	71-139	48-90	43-89	30-65	22-53
Carbon Tetrachloride in Treated Spray Discharge ^a (range of values, µg/L)	ND ^b -7.2	ND-6.9	ND-3.7	ND-4.0	ND-1.9	ND-1.6
Carbon Tetrachloride in Treated Spray Discharge ^a (average, µg/L)	1.45	0.91	0.61	1.13	0.28	0.17
Carbon Tetrachloride in Untreated Groundwater at GWEX4 (µg/L)	53-95	26-70	20-43	13-24	6.1-16	3.5-11
Carbon Tetrachloride in Treated Air Stripper Effluent ^a (µg/L)	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride Removed (kg, gal)	23, 3.8	34, 5.6	25, 4.1	8, 1.3	9.3, 1.5	8.74, 1.4
Minimum Carbon Tetrachloride Removal Efficiency for Spray Treatment (%)						
Based on Individual Samples	> 94	> 93	> 95	> 92	> 94	> 94
Based on Averages	~ 99	~ 99	~ 98	~ 98	~ 99	~ 99
Carbon Tetrachloride Removal Efficiency for Air Stripper (%)	> 99	> 99	> 99	> 99	> 99	> 99
pH of Treated Spray Discharge ^c	7.01-8.18	7.10-8.32	7.09-8.36	7.88-8.51	7.48-8.43	7.40-8.73
pH of Treated Air Stripper Effluent ^c	7.01-8.35	7.50-8.58	7.79-8.33	7.71-8.41	6.73-8.45	7.98-8.36
Costs (\$)						
Routine	270,879	208,186	126,720	156,006	133,937	140,140
Non-routine	11,707	62,731	7,336	12,075	26,164	4,645
TOTAL	282,586	270,916	134,056	168,081	160,101	144,785

^a Compliance level, 44.2 µg/L.

^b ND, not detected at a method detection limit of 0.1 µg/L.

^c Compliance level, 6.5-9.0.

TABLE 7.2 Results of the groundwater extraction and treatment efforts at Utica, November 2004 to November 2010.

Period of Operation	GWEX1- GWEX3		GWEX4		Groundwater Produced (% of annual goal)
	Production (gal)	Carbon Tetrachloride Removed (kg)	Production (gal)	Carbon Tetrachloride Removed (kg)	
2004-2005	34,611,960	14.2	31,752,692	9.0	68
2005-2006	84,365,500	29.2	29,584,010	5.0	117
2006-2007	90,954,300	21.8	28,320,380	3.0	123
2007-2008	25,675,200	6.0	29,553,474	2.0	57
2008-2009	50,633,300	8.0	26,060,159	1.3	79
2009-2010	71,898,100	8.4	11,373,054	0.4	86
Totals	358,138,360	87.6	156,643,769	20.7	88 ^a

^a Average production.

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