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Progress Report on the ISCR Pilot Test Conducted at the Former CCC/USDA Grain Storage Facility in Montgomery City, Missouri, as of April 2013

Environmental Science Division

USDA
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

AMSL	above mean sea level
BGL	below ground level
CCC	Commodity Credit Corporation
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
in.	inch(es)
ISCR	*in situ* chemical reduction
lb	pound(s)
µg/kg	microgram(s) per kilogram
µg/L	microgram(s) per liter
µS/cm	microsiemen(s) per centimeter
MCL	maximum contaminant level
MDNR	Missouri Department of Natural Resources
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
MS	magnetic susceptibility
mV	millivolt(s)
ORP	oxidation-reduction potential
RSL	regional screening level
USDA	U.S. Department of Agriculture
VOC	volatile organic compound
yr	year(s)

Progress Report on the ISCR Pilot Test at the Former CCC/USDA Grain Storage Facility in Montgomery City, Missouri, as of April 2013

1 Introduction and Background

The Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) is conducting an environmental investigation at the former CCC/USDA grain storage facility on the county fairgrounds in Montgomery City, Missouri, to evaluate contamination associated with the former use of grain fumigants containing carbon tetrachloride at the site. The CCC/USDA studies have identified carbon tetrachloride in the soils (primarily unconsolidated glacial tills) at concentrations that exceed the U.S. Environmental Protection Agency (EPA) regional screening level (RSL) values for this compound in residential soils (610 μg/kg) but are below the corresponding RSL for industrial soils (3,000 μg/kg). Concentrations of carbon tetrachloride greater than the EPA maximum contaminant level (MCL; 5.0 μg/L) for this contaminant in drinking water were also identified in the shallow groundwater (Argonne 2012). On the basis of these findings, remedial actions are considered necessary to mitigate the present and potential future impacts of the contamination.

In cooperation with the Missouri Department of Natural Resources (MDNR), the CCC/USDA has initiated a field-scale pilot test to evaluate an *in situ* technology for treatment of the carbon tetrachloride contamination. In this approach, a chemical amendment consisting primarily of slow-release organic matter and zero-valent iron is employed to induce oxygen-depleted, chemically reducing conditions in the subsurface. These conditions foster the *in situ* chemical reduction (ISCR) of carbon tetrachloride and its degradation products (chloroform, methylene chloride, and chloromethane) via both inorganic and biologically mediated processes. The chemical amendment being used, EHC™, was developed by the Adventus Group, Freeport, Illinois, and is now manufactured and distributed by FMC Environmental Solutions, Philadelphia, Pennsylvania.[1]

With the approval of the MDNR (2012), the ISCR technology is being tested in two target areas interpreted to represent contaminant source areas (Figure 1.1). The pilot test is being implemented on behalf of the CCC/USDA by Argonne National Laboratory. Approximately

[1] Further information on the EHC™ material is at this location: http://environmental.fmc.com/solutions/soil-ground-remediation/ehc-iscr-reagent/

80,000 lb of the EHC material was injected by using direct-push techniques at 99 locations in the target areas, from November 9 to December 15, 2012 (Figure 1.2; Argonne 2012).

To determine the geochemical effects of the pilot injections and their impact on the levels of contamination in the test areas, an extended monitoring program (Argonne 2012) is being implemented. The program includes an initial "baseline" sampling event to document pre-treatment conditions and periodic post-injection monitoring events, approximately 1, 2, 4, 6, 9, and 12 months after the completion of the injection program (Argonne 2012). This report provides a brief summary of the specific activities conducted, with a compilation of the monitoring data obtained, during the baseline sampling event (October 2012) and the first, second, and third post-injection monitoring events (in January, February, and April 2013).

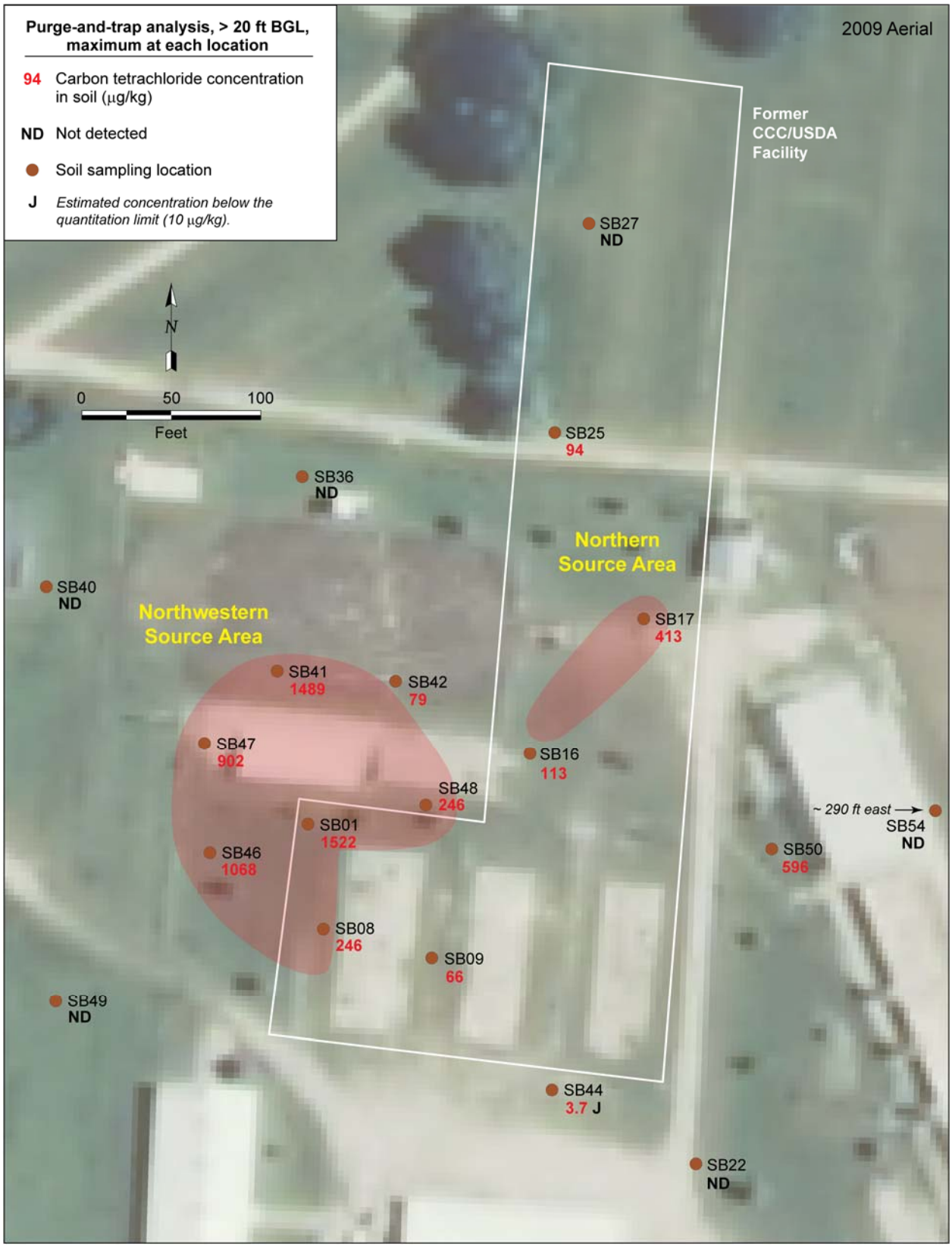

FIGURE 1.1 Pre-injection lateral distribution of carbon tetrachloride in deeper soils (> 20 ft BGL), as determined by purge-and-trap analysis. Red shading highlights hot-spot areas interpreted to represent contaminant source areas to groundwater.

FIGURE 1.2 Distribution of the shallow and deep ISCR pilot test injection points, post-injection coring points, and permanent and temporary groundwater monitoring wells sampled for the pilot test monitoring program.

2 Summary of the Monitoring Activities

A brief review of the monitoring activities conducted to date in conjunction with the ISCR pilot test is presented in this section. Ten permanent monitoring wells (SB01S,M,D; SB08S,D; SB16S; SB17S,D; and SB46S,D) completed in the contaminated glacial tills were selected for periodic sampling under the recommended monitoring plan (Argonne 2012). The locations of these wells and other locations investigated during the monitoring studies (discussed below) are shown in Figure 1.2; construction information for the monitoring points is in Table 2.1.

The results of the laboratory analyses performed during the monitoring program are summarized in Tables 2.2-2.5. Analyses of soil and groundwater samples for volatile organic compounds (VOCs) were performed by the Applied Geosciences and Environmental Management Laboratory at Argonne, in accord with procedures in the *Master Work Plan* (Argonne 2002). Groundwater samples were also submitted to TestAmerica Laboratories, Inc. (South Burlington, Vermont, and University Park, Illinois), for geochemical analyses according to EPA methods.

2.1 Baseline Sampling Event, October 2012

To establish a quantitative baseline for evaluation of the ISCR treatment performance, groundwater sampling at the 10 permanent monitoring wells in the pilot testing area (Figure 1.2) was performed on October 23-24, 2012, approximately 15 days prior to the start of the injection program on November 9, 2012.

Previous experience at Montgomery City, reported separately to the MDNR, demonstrated that groundwater accumulation at many of the permanent monitoring points can be very slow. In some cases, days to weeks (or longer) are required for groundwater to recover to static levels following a sampling event. To avoid excessive depletion of the groundwater at each monitoring point immediately before implementation of the injection program, the baseline sampling was performed without prior purging of the wells. The suite of samples collected at each well was also tailored, as necessary, to limit groundwater withdrawal to a total volume that would not result in exposure of the well screen. In order of priority, and subject to the availability of sufficient groundwater, samples were obtained from each well for the following analyses:

- VOCs
- Methane
- Field parameters — temperature, pH, conductivity, dissolved oxygen (DO), and oxidation-reduction potential (ORP)
- Metals
- Trace metals
- Anions

For the purpose of comparative evaluation, the results of the VOCs analyses for soils in the pilot test areas during the site characterization studies in 2010-2011 were considered representative of the pre-treatment contaminant distribution and levels in soil (Figure 1.1).

The results of the VOCs and geochemical analyses for the groundwater samples collected during the baseline sampling event are in Tables 2.2a-d.

2.2 First (One-Month) Post-Injection Monitoring Event, January 2013

The initial post-injection monitoring event began on January 21, 2013 (36 days after completion of the last EHC injections on December 15, 2012), and was completed on January 25, 2013. In accord with the recommended monitoring program (Argonne 2012), the following activities were conducted during this event:

- Continuous coring (through the use of direct-push techniques) of the unconsolidated soils at seven locations selected in consultation with the CCC/USDA and MDNR program managers (PT1-PT7; Figure 1.2).
- Examination of the recovered soil cores for visual evidence of the amendment distribution achieved as a result of the injection process.

- Sampling of the cored materials at 4-ft intervals with depth, for analyses of VOCs.

- Groundwater sampling for VOCs and selected geochemical analyses, as outlined in Section 2.1, at the 10 pilot test monitoring wells (Figure 1.2).

In addition to these actions, the following investigative activities were also performed in conjunction with the first (January 2013) post-injection monitoring event:

- Upon completion of the coring at PT1 and PT2 (to the west and southwest of the central injection field; Figure 1.2), temporary monitoring wells were installed at each of these locations to facilitate the possible sampling of groundwater for VOCs analyses (Table 2.1). The temporary points were constructed by placing a nominal 0.5-in.-diameter polyvinyl chloride riser and 10-ft, 0.010-in.-slot screen in the direct-push boring. A sand pack was placed around the screened interval, and the remaining annulus was grouted to the surface. Insufficient groundwater for sampling for VOCs analyses accumulated, however, at locations PT1 and PT2 during this field session. The temporary monitoring points were therefore left in place for possible sampling during the next planned (February) sampling event.

- To gain further data on the possible subsurface distribution of the EHC material, measurements of the magnetic susceptibility (MS) of the cored materials were acquired, at 2-in. intervals with depth, through the use of a Bartington Model MS2 meter and MS2E high-resolution sensor (Bartington 2008).

The MS of a material (expressed as a dimensionless number) effectively reflects its ability to respond to or interact with an applied magnetic field. In soils, MS is primarily determined by the iron-bearing components of the material. For most naturally occurring minerals and iron oxides, the MS is relatively low; however, a very strong MS response is associated with the presence of even minute quantities of metallic iron in soil. The results of limited studies have therefore demonstrated that this parameter may be useful for subsurface identification of the zero-valent iron component of the EHC amendment employed at Montgomery City (Dearing 1999; Harkness et al. 2011a,b).

The analytical results for the soil and groundwater samples recovered during the first (January 2013) post-injection monitoring event are in Tables 2.3a-f. The results of the MS surveys conducted on the PT1-PT7 soil cores are illustrated in Figures 2.1-2.7. Geologic logs for the PT1-PT7 borings are in Appendix A.

2.3 Second (Two-Month) Post-Injection Monitoring Event, February 2013

The second post-injection monitoring event was conducted on February 27-28, 2013 (74 days after completion of the injection program on December 15, 2012). The start of this event was delayed slightly beyond the targeted two-month time frame, because poor winter weather conditions at the site precluded sampling earlier in February. Groundwater sampling for VOCs and selected geochemical analyses, as outlined in Section 2.1, was performed during this event at the 10 permanent monitoring wells and the 2 temporary monitoring points (PT1-PT2; Figure 1.2) installed in January 2013.

The analytical results for the groundwater samples collected during the second monitoring event are in Tables 2.4a-d.

2.4 Supplemental Site Visit, March 2013

Figure 1.2 illustrates that the 10 permanent wells available for monitoring of the ISCR pilot test are located near the margins of the injection fields, generally up to 10 ft from the nearest individual injection points. This distribution was selected in part to protect the monitoring wells from potential physical damage during injection and possible direct invasion by the injected amendments. To supplement this network, 3 additional temporary groundwater monitoring points were installed in the more central portion of the injection field west of the former rectangular building foundations (PT8S,M,D; Figure 1.2) on March 29, 2013, in anticipation of the third monitoring event planned for April (Section 2.5). The temporary wells were constructed by using direct-push techniques, as described in Section 2.1, as a cluster penetrating the relatively shallow, middle, and deep portions of the till sequence. Construction data for the PT8 temporary wells is in Table 2.1.

During the March 2013 site visit, the permanent monitoring points were purged by using an inertial pump (Waterra^{TM} flexible tubing equipped with a stainless steel foot valve), in

preparation for the planned third (April 2013) sampling event. A volume of groundwater equivalent to three casing-storage volumes was pumped, if possible, from each well, or the casing was purged "dry" if insufficient water for a three-volume purge could be recovered.

2.5 Third (Four-Month) Post-Injection Monitoring Event, April 2013

In accord with the recommended monitoring program (Argonne 2012), the third scheduled post-injection sampling event was conducted on April 24-25, 2013, 130 days after completion of the injection program on December 15, 2012. Groundwater sampling was performed at the 10 pilot test monitoring wells and the 3 temporary monitoring points (PT8S,M,D; Figure 1.2) installed on March 29, 2013.

The analytical data for the groundwater samples collected during the third monitoring event are in Tables 2.5a-d.

TABLE 2.1 Construction data for the permanent and temporary monitoring wells sampled in conjunction with the ISCR pilot test.

Well	Screened Interval (ft BGL)[a]	Casing Diameter (in.)
Permanent monitoring wells		
SB01S	8-18	1.0
SB01M	20-30	1.0
SB01D	47-57	0.5
SB08S	20-30	0.5
SB08D	47-57	0.5
SB16S	8-18	0.5
SB17S	8-18	0.5
SB17D	51.3-61.3	0.5
SB46S	8-18	0.5
SB46D	44.5-54.5	0.5
Temporary monitoring wells		
PT1[b]	46-56	0.5
PT2[b]	44.5-54.5	0.5
PT8S[c]	8-18	0.5
PT8M[c]	20-30	0.5
PT8D[c]	45.2-55.2	0.5

[a] BGL, below ground level.

[b] Temporary well installed in January 2013 and sampled in February 2013.

[c] Temporary well installed in March 2013 and sampled in April 2013.

TABLE 2.2a Field parameters for groundwater samples collected during the baseline (October 2012) pre-injection sampling event.

Monitoring Point	pH[a]	Conductivity[a] (μS/cm)	DO[a] (mg/L)	ORP[a] (mV)	Fe^{2+} [b] (mg/L)
SB01S	5.83	535	3.07	144	0.05
SB01M	6.23	613	2.53	191	0.18
SB01D	6.52	767	4.07	272	0.15
SB08S	7.05	747	4.32	264	0.01
SB08D	7.21	756	6.40	245	0.11
SB16S	6.65	605	5.28	158	0.00
SB17S	6.64	723	4.27	223	0.13
SB17D	7.10	712	4.00	7	0.07
SB46S	6.74	734	4.57	65	0.00
SB46D	6.89	756	3.68	16	0.00

[a] Measurements obtained by using a YSI Model 556 meter and multi-parameter probe.

[b] Ferrous iron determined by using a Hach DR/800 Series colorimeter and appropriate reagents.

TABLE 2.2b Metals concentrations in groundwater samples collected during the baseline (October 2012) pre-injection sampling event.

Monitoring Point	Concentration (μg/L)											
	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
Method detection limit	200	2.0	100	2.0	2.0	5,000	4.0	10	20	200	2.0	5,000
SB01S	ND[a]	ND	152	ND	ND	51,500	ND	0.4 J[b]	7.4 J	128 J	0.04 J	13,100
SB01M	ND	ND	274	ND	ND	69,000	ND	0.3 J	1.5 J	147 J	0.03 J	19,000
SB01D	ND	ND	184	ND	ND	85,500	ND	0.4 J	2.2 J	ND	0.04 J	26,800
SB08S	259	ND	123	ND	ND	63,100	ND	0.2 J	2.4 J	397	0.4 J	17,500
SB08D	ND	ND	210	ND	ND	95,000	ND	0.08 J	1.2 J	89 J	0.03 J	29,000
SB16S	ND	–[c]	–	–	–	51,500	–	–	–	ND	–	12,800
SB17S	ND	ND	280	ND	ND	77,100	ND	0.6 J	0.3 J	254	0.04 J	22,700
SB17D	454	ND	ND	275	ND	98,300	ND	1.8 J	1.1 J	1,030	ND	32,200
SB46S	ND	–	–	–	–	49,400	–	–	–	832	–	13,000
SB46D	166 J	ND	277	ND	ND	85,600	ND	0.5 J	0.9 J	739	0.2 J	26,600

TABLE 2.2b (Cont.)

Monitoring Point	Concentration (µg/L)											
	Manganese	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Method detection limit	15	20	20	250	5,000	2.0	100	2.0	5,000	2.0	4.0	20
SB01S	30	1.5 J	ND	ND	476 J	ND	9,810	0.04 J	91,800	ND	ND	7.2 J
SB01M	213	2.5 J	ND	ND	716 J	4.4	9,720	ND	73,700	ND	ND	ND
SB01D	13 J	18 J	ND	ND	1,860 J	8.1	7,710	ND	65,900	ND	ND	47
SB08S	12 J	6.7 J	ND	ND	895 J	10	10,400	0.04 J	98,000	ND	0.5 J	38
SB08D	ND	8.8 J	ND	ND	960 J	24	8,400	ND	43,600	ND	0.4 J	ND
SB16S	12 J	–	–	ND	1,010 J	–	10,600	–	85,600	–	–	66
SB17S	32	4.4 J	ND	ND	852 J	4.6	11,000	ND	99,300	ND	0.4 J	ND
SB17D	238	4.3 J	ND	ND	1,470 J	17.2	9,480	ND	44,900	ND	1.8 J	ND
SB46S	46	–	–	ND	1,520 J	–	11,000	–	121,000	–	–	690
SB46D	58	9.6 J	ND	ND	2,120 J	11	9,410	ND	41,300	ND	1.3 J	59

[a] ND, not detected at the indicated method detection limit.

[b] J, estimated concentration below the indicated method detection limit.

[c] Sample not analyzed for the specified element.

TABLE 2.2c Anion concentrations in groundwater samples collected during the baseline (October 2012) pre-injection sampling event.

Monitoring Point	Concentration (mg/L)						
	Bromide	Chloride	Nitrate (as N)	Nitrite	Phosphate	Sulfate	Sulfide
Method detection limit	0.25	0.2	0.2	0.2	0.2	2.0	3.0
SB01S	0.5	6.1	0.8	ND[a]	ND	43	5.6
SB01M	0.5	11	0.9	ND	ND	36	7.2
SB01D	0.2	8.9	1.5	ND	ND	39	3.2
SB08D	0.3	12	3.8	ND	ND	14	4.0
SB17S	0.6	21	7.1	ND	ND	41	ND
SB46D	0.3	12	2.8	ND	ND	13	ND

[a] ND, not detected at the indicated method detection limit.

TABLE 2.2d Analytical results for VOCs and dissolved gases in groundwater samples collected during the baseline (October 2012) pre-injection sampling event.

	Concentration (μg/L)					
Monitoring Point	Carbon Tetrachloride	Chloroform	Methylene Chloride	Methane	Ethane	Ethylene
Method detection limit	1.0	1.0	1.0	2.0	4.0	3.0
SB01S	597	153	ND[a]	83	ND	ND
SB01M	5,697	535	ND	14	ND	ND
SB01D	35	74	ND	ND	ND	ND
SB08S	1,004	152	ND	–[b]	–	–
SB08D	983	ND	ND	ND	ND	ND
SB16S	44	7.6	ND	–	–	–
SB17S	126	21	ND	8.3	ND	ND
SB17D	664	31	ND	–	–	–
SB46S	1.1	17	2.3	–	–	–
SB46D	1,330	97	ND	ND	ND	4.2

[a] ND, not detected at the indicated method detection limit.

[b] No analysis for this compound.

TABLE 2.3a Field parameters for groundwater samples collected during the first (January 2013) post-injection monitoring event.

Monitoring Point	pH	Conductivity[a] (μS/cm)	DO[a] (mg/L)	ORP[a] (mV)	Fe^{2+} [b] (mg/L)
SB01S	5.64	4,059	0.13	-346	3.3 limit[c]
SB01M	7.46	914	2.97	-141	0.93
SB01D	5.54	5,995	0.17	-145	3.3 limit
SB08S	7.20	512	6.71	77	0.27
SB08D	7.37	473	6.92	-132	0.19
SB16S	5.91	1,466	2.41	110	1.28
SB17S	7.25	404	7.64	70	0.00
SB17D	7.26	487	8.80	44	0.17
SB46S	5.37	2,757	0.25	-174	3.3 limit
SB46D	6.78	1,597	3.10	-206	1.01

[a] Measurements obtained by using a YSI Model 556 meter and multi-parameter probe.

[b] Ferrous iron determined by using a Hach DR/800 Series colorimeter and appropriate reagents.

[c] Concentration detected is greater than the instrument's maximum reporting limit.

TABLE 2.3b Metals concentrations in groundwater samples collected during the first (January 2013) post-injection monitoring event.

Monitoring Point	Concentration (μg/L)											
	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
Method detection limit	200	2.0	100	2.0	2.0	5,000	4.0	10	20	200	2.0	5,000
SB01S	ND[a]	4.4	3,200	0.2 J[b]	0.8 J	741,000	23	1120	11 J B[c]	550,000	3.8	219,000
SB01M	ND	4.7	855	ND	ND	184,000	ND	19	0.8 J B	182 J	ND	48,500
SB01D	–[d]	–	–	–	–	–	–	–	–	–	–	–
SB08S	ND	0.7 J	131	ND	ND	73,000	ND	0.2 J	1.7 J B	ND	ND	20,400
SB08D	ND	0.5 J	269	ND	ND	91,700	ND	0.7 J	1.0 J B	ND	ND	28,600
SB16S	ND	–	–	–	–	310,000	–	–	–	50,800	–	81,500
SB17S	ND	0.7 J	237	ND	ND	70,000	ND	0.3 J	1.1 J B	ND	ND	21,200
SB17D	ND	0.6 J	190	ND	ND	92,100	ND	1.1 J	1.2 J B	ND	ND	28,700
SB46S	ND	–	–	–	–	420,000	–	–	–	240,000	–	119,000
SB46D	ND	1.1 J	1,590	ND	0.1 J	315,000	5.1	57	4.1 J B	20,400	0.1 J	77,900

TABLE 2.3b (Cont.)

Monitoring Point	Concentration (µg/L)											
	Manganese	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Method detection limit	15	20	20	250	5,000	2.0	100	2.0	5,000	2.0	4.0	20
SB01S	51,000	13 J	340	12,700 B	17,000	1.3 J	21,900	ND	306,000	ND	10	777
SB01M	3,780	5.2 J	15 J	457	1,050 J	1.2 J	11,600	ND	104,000	ND	ND	ND
SB01D	–	–	–	–	–	–	–	–	–	–	–	–
SB08S	19	6.3 J	ND	180 J B	820 J	6.2	11,300	ND	98,000	ND	ND	26
SB08D	146	6.3 J	ND	159 J	1,140 J	3.8	8,720	ND	42,900	ND	0.4 J	12 J
SB16S	6,030	–	–	529 J	3,000 J	–	21,800	–	202,000	–	–	76
SB17S	100	0.9 J	ND	194 J	826 J	4.7	11,200	ND	90,100	ND	ND	6.1 J
SB17D	146	2.5 J	7.1	200 J	2,010 J	3.6	8,480	ND	41,200	ND	0.8 J	502
SB46S	10,000	–	–	16,500	4,840	–	27,800	–	307,000	–	–	251
SB46D	3,530	2.2 J	64	1,530	1620 J	2.2	14,700	ND	61,900	ND	11	28

[a] ND, not detected at the indicated method detection limit.

[b] J, estimated concentration below the indicated method detection limit.

[c] B, element detected in the laboratory blank.

[d] Sample not analyzed for the specified element.

TABLE 2.3c Anion concentrations in groundwater samples collected during the first (January 2013) post-injection monitoring event.

Monitoring Point	Concentration (mg/L)						
	Bromide	Chloride	Nitrate (as N)	Nitrite	Phosphate	Sulfate	Sulfide
Method detection limit	0.25	2.0	0.2	0.2	0.2	2.0	3.0
SB01S	ND[a]	14	ND	31	0.6	41	ND
SB01M	0.2 J[b]	13	ND	2.9	2.3	8.6	ND
SB01D	NA[c]	NA	NA	NA	NA	NA	NA
SB08D	0.1 J	11	0.2 J	0.09 J	ND	15	ND
SB17D	0.1 J	17	0.7	0.1 J	ND	16	ND
SB46D	ND	12	ND	9.7	ND	9.2	ND

[a] ND, not detected at the indicated method detection limit.

[b] J, estimated concentration below the indicated method detection limit.

[c] NA, not analyzed.

TABLE 2.3d Analytical results for VOCs and dissolved gases in groundwater samples collected during the first (January 2013) post-injection monitoring event.

Monitoring Point	Concentration (μg/L)					
	Carbon Tetrachloride	Chloroform	Methylene Chloride	Methane	Ethane	Ethylene
Method detection limit	1.0	1.0	1.0	2.0	4.0	3.0
SB01S	ND[a]	475	174	18	ND	ND
SB01M	3,335	1,473	6.4	11	ND	ND
SB01D	ND	108	30	4.4	ND	ND
SB08S	1,195	175	ND	ND	ND	ND
SB08D	872	121	ND	4.6	ND	ND
SB16S	1.4	35	3.6	9.0	ND	ND
SB17S	122	23	ND	ND	ND	ND
SB17D	988	40	ND	ND	ND	ND
SB46S	ND	3.4	1.9	400	ND	ND
SB46D	ND	47	6.4	3.0	ND	ND

[a] ND, not detected at the indicated method detection limit.

TABLE 2.3e Analytical results for VOCs in soil samples collected at locations PT1-PT3 during the first (January 2013) post-injection monitoring event.

		Concentration (μg/kg)		
Boring	Depth (ft BGL)	Carbon Tetrachloride	Chloroform	Methylene Chloride
PT1	4	ND[a]	ND	ND
	8	ND	ND	ND
	12	ND	ND	ND
	16	ND	ND	ND
	20	ND	ND	ND
	24	ND	ND	ND
	28	ND	ND	ND
	32	ND	ND	ND
	36	ND	ND	ND
	40	ND	ND	ND
	44	ND	ND	ND
	48	ND	ND	ND
	52	ND	ND	ND
	56	ND	ND	ND
PT2	4	ND	ND	ND
	8	ND	ND	ND
	12	ND	ND	ND
	16	ND	ND	ND
	20	ND	ND	ND
	24	ND	ND	ND
	28	ND	ND	ND
	32	ND	ND	ND
	36	ND	ND	ND
	40	ND	ND	ND
	44	ND	ND	ND
	48	ND	ND	ND
	52	ND	ND	ND
	54.2	ND	ND	ND
PT3	4	ND	ND	ND
	8	ND	ND	ND
	12	ND	ND	ND
	16	ND	ND	ND
	20	ND	ND	ND
	24	ND	ND	ND
	28	ND	ND	ND
	32	ND	ND	ND
	36	ND	ND	ND
	40	6.1 J[b]	ND	ND
	44	ND	ND	ND
	48	ND	ND	ND
	52	ND	ND	ND
	56	ND	ND	ND

[a] Not detected at a method detection limit of 10 μg/kg.

[b] J, estimated concentration below the method detection limit of 10 μg/kg.

TABLE 2.3f Analytical results for VOCs in soil samples collected at locations PT4-PT7 during the first (January 2013) post-injection monitoring event.

January 2013 Pilot Test Monitoring Data					Data for Nearest Location Sampled During the 2010-2011 Site Characterization			
		Concentration (μg/kg)					Concentration (μg/kg)	
Boring	Depth (ft BGL)	Carbon Tetrachloride	Chloroform	Methylene Chloride	Boring	Depth (ft BGL)	Carbon Tetrachloride	Chloroform
PT4	4	ND[a]	ND	ND	SB41	4	ND	ND
	8	6.8 J[b]	2.7 J	ND		8	ND	ND
	12	46	7.9 J	ND		12	ND	ND
	16	1,450	32	ND		16	65	2.7 J
	20	2,222	44	ND		20	891	34
	24	2,248	42	ND		24	1,110	44
	28	2,618	51	ND		28	1,489	54
	32	33	ND	ND		32	388	14
	36	ND	ND	ND		36	236	8.0 J
	40	ND	ND	ND		40	4.8 J	ND
	44	ND	ND	ND		44	ND	ND
	48	ND	ND	ND		48	1.7 J	ND
	52	ND	ND	ND		52	ND	ND
	56	ND	ND	ND		56	ND	ND
	60	ND	ND	ND				
PT5	4	ND	ND	ND	SB01	4	ND	ND
	8	5.5 J	3.7 J	ND		8	ND	ND
	12	1,674	76	ND		12	338	19
	16	288	62	ND		16	2,353	111
	20	836	81	ND		20	1,751	86
	24	904	76	ND		24	1,095	55
	28	1,129	50	ND		28	1,400	59
	32	2,865	86	ND		32	1,522	46
	36	1,371	65	ND		36	1,125	44
	40	148	6.7 J	ND		40	87	3.1 J
	44	131	5.1 J	ND		44	78	ND
	48	240	7.4 J	ND		48	229	5.1 J
	52	137	8.5 J	ND		52	120	8.2 J
	56	37	5.3 J	ND		56	23	2.4 J
PT6	4	ND	ND	ND	SB08	4	ND	ND
	8	ND	ND	ND		8	ND	ND
	12	ND	ND	ND		12	473	40
	16	23	4.3 J	ND		16	263	10
	20	34	6.8 J	ND		20	157	9.4 J
	24	43	3.6 J	ND		24	162	6.8 J
	28	68	3.5 J	ND		28	120	7.5 J
	32	181	6.4 J	ND		32	219	8.9 J
	36	360	ND	ND		36	221	6.4 J
	40	378	7.1 J	ND		40	52	3.1 J
	44	520	7.5 J	ND		44	75	3.1 J
	48	576	8.9 J	ND		48	128	4.2 J
	52	746	13	ND		52	246	5.8 J
	56	597	63	ND		56	189	5.0 J

TABLE 2.3f (Cont.)

January 2013 Pilot Test Monitoring Data					Data for Nearest Location Sampled During the 2010-2011 Site Characterization			
		Concentration (μg/kg)					Concentration (μg/kg)	
Boring	Depth (ft BGL)	Carbon Tetrachloride	Chloroform	Methylene Chloride	Boring	Depth (ft BGL)	Carbon Tetrachloride	Chloroform
PT7	4	ND	ND	ND	SB17	4	ND	ND
	8	ND	ND	ND		8	11	2.2 J
	12	ND	ND	ND		12	376	9.6 J
	16	12	ND	ND		16	23	1.8 J
	20	14	ND	ND		20	28	2.0 J
	24	12	ND	ND		24	27	2.4 J
	28	14	ND	ND		28	27	2.0 J
	32	20	ND	ND		32	34	2.4 J
	36	16	ND	ND		36	26	ND
	40	9.2 J	ND	ND		40	6.7 J	1.7 J
	44	ND	ND	ND		44	3.4 J	ND
	48	19	ND	ND		48	96	ND
	52	31	ND	ND		52	304	2.4 J
	56	28	ND	ND		56	413	3.4 J

[a] Not detected at a method detection limit of 10 μg/kg.

[b] J, estimated concentration below the method detection limit of 10 μg/kg.

TABLE 2.4a Field parameters for groundwater samples collected during the second (February 2013) post-injection monitoring event.

Monitoring Point	pH[a]	Conductivity[a] (µS/cm)	DO[a] (mg/L)	ORP[a] (mV)	Fe^{2+} [b] (mg/L)
SB01S	5.97	2,634	1.21	-121	1.39
SB01M	6.18	1,113	7.80	-185	0.92
SB01D	6.22	2,047	5.94	-107	2.63
SB08S	7.29	555	6.88	-129	0.11
SB08D	7.63	350	10.65	-45	0.33
SB16S	6.27	1,203	5.30	-76	1.08
SB17S	7.55	542	1.73	244	0.66
SB17D	8.42	221	5.96	168	0.15
SB46S	6.01	1,782	7.38	-1	2.35
SB46D	6.11	1,470	2.00	-21	1.08
PT1	7.22	547	5.92	260	0.04
PT2	7.55	557	4.96	256	0.01

[a] Measurements obtained by using a YSI Model 556 meter and multi-parameter probe.

[b] Ferrous iron determined by using a Hach DR/800 Series colorimeter and appropriate reagents.

TABLE 2.4b Metals concentrations in groundwater samples collected during the second (February 2013) post-injection monitoring event.

Monitoring Point	Concentration (μg/L)											
	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
Method detection limit	80	2.0	100	2.0	2.0	10,000	4.0	10	20	200	2.0	5,000
SB01S	8.9 J	2.6	3,390	ND[a]	0.1 J[b]	1,060,000	6.8	492	4.8 J	389,000	0.5 J	240,000
SB01M	548	6.8	1,020	ND	0.1 J	181,000	1.5 J	17	8.3 J	1,130	6.1	49,400
SB01D	8.1	2.1	1,360	ND	ND	509,000	3.1 J	113	3 J	419,000	0.4 J	144,000
SB08S	12 J	1 J	131	ND	ND	70,100	0.1 J	0.1 J	5.4 J	301	0.1 J	18,400
SB08D	10 J	0.4 J	252	ND	ND	92,300	ND	0.5 J	0.8 J	89 J	0.04 J	27,300
SB16S	ND	–[c]	–	–	–	276,000	–	–	–	17,400	–	71,300
SB17S	352	0.9 J	241	ND	ND	68,800	0.6 J	0.95 J	1.5 J	607	0.2 J	20,400
SB17D	157	1.2 J	157	ND	ND	59,600	1.1 J	1 J	4.3 J	522	0.3 J	11,300
SB46S	ND	–	–	–	–	634,000	–	–	–	168,000	–	162,000
SB46D	11 J	11	1,830	ND	0.3 J	327,000	1.3 J	53	3.1 J	10,500	0.8 J	90,300

TABLE 2.4b (Cont.)

Monitoring Point	Concentration (μgL)											
	Manganese	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Method detection limit	15	20	20	250	5,000	2.0	100	2.0	10,000	2.0	4.0	20
SB01S	80,700	8 J	102	4,770 B[d]	20,200	ND	16,600	ND	295,000	ND	0.7 J	149
SB01M	5,170	5.8 J	25	640 B	4,270	ND	9,950	0.02 J	107,000	ND	2.7 J	39
SB01D	29,800	6.8 J	65	3,360	15,600	ND	14,300	ND	134,000	0.1 J	0.5 J	90
SB08S	41	7.1 J	1.1 J	190 J B	713 J	10	9,970	ND	84,600	ND	0.6 J	7.8 J
SB08D	78	5.5 J	2.3 J	168 J B	1,030 J	2.4	8,230	ND	43,900	ND	ND	4.7 J
SB16S	3,780	–	–	487 B	2,520 J	–	15,300	–	182,000	–	–	62
SB17S	8.8 J	3.1 J	3.6 J	208 J B	665 J	1.8 J	10,700	ND	83,000	ND	1.2 J	ND
SB17D	164	3.2 J	8.8 J	274 B	4,620 J	5.2 J	4,950	ND	18,800	ND	3 J	596
SB46S	17,200	–	–	9,500 B	5,160	–	21,100	–	332,000	–	–	50
SB46D	5,990	3.5 J	59	1,580 B	2,090 J	0.8 J	14,500	ND	69,300	ND	2.5 J	4.9 J

[a] ND, not detected at the indicated method detection limit.

[b] J, estimated concentration below the indicated method detection limit.

[c] Sample not analyzed for the specified element.

[d] B, element detected in the associated laboratory blank.

TABLE 2.4c Anion concentrations in groundwater samples collected during the second (February 2013) post-injection monitoring event.

Monitoring Point	Concentration (mg/L)						
	Bromide	Chloride	Nitrate (as N)	Nitrite	Phosphate	Sulfate	Sulfide
Method detection limit	0.25	2.0	0.2	0.2	0.2	1.0	3.0
SB01S	ND[a]	18	ND	33	ND	20	ND
SB01M	0.3	15	ND	2.6	ND	20	ND
SB01D	ND	16	ND	32	ND	16	ND
SB08D	0.12 J[b]	10	ND	ND	ND	17	ND
SB17D	ND	12	0.80	0.04 J	ND	12	ND
SB46D	ND	11	ND	ND	ND	0.09 J	ND

[a] ND, not detected at the indicated method detection limit.

[b] J, estimated concentration below the indicated method detection limit.

TABLE 2.4d Analytical results for VOCs and dissolved gases in groundwater samples collected during the second (February 2013) post-injection monitoring event.

Monitoring Point	Concentration (µg/L)					
	Carbon Tetrachloride	Chloroform	Methylene Chloride	Methane	Ethane	Ethylene
Method detection limit	1.0	1.0	1.0	2.0	4.0	3.0
SB01S	4.4	1,776	129	29	ND[a]	ND
SB01M	3,480	1,342	5.0	14	ND	ND
SB01D	113	197	26	ND	ND	ND
SB08S	1,496	169	1.3	ND	ND	ND
SB08D	1,201	127	ND	ND	ND	ND
SB16S	0.3 J	35	8.3	19	ND	ND
SB17S	112	30	ND	ND	ND	ND
SB17D	832	40	ND	ND	ND	ND
SB46S	ND	4.5	2.4	860	ND	ND
SB46D	240	494	9.1	7.2	ND	ND
PT1	ND	ND	ND	–[b]	–	–
PT2	ND	ND	ND	–	–	–

[a] ND, not detected at the indicated method detection limit.

[b] No analysis for this compoud.

TABLE 2.5a Field parameters for groundwater samples collected during the third (April 2013) post-injection monitoring event.

Monitoring Point	pH	Conductivity[a] (μS/cm)	DO[a] (mg/L)	ORP[a] (mV)	Fe^{2+} [b] (mg/L)
SB01S	6.38	2,534	2.17	-5	0.77
SB01M	7.24	822	3.37	-64	0.14
SB01D	6.39	2,266	1.06	-259	1.04
SB08S	7.64	617	4.97	195	0.03
SB08D	7.45	567	4.80	228	0.09
SB16S	6.47	1,802	2.04	-90	0.81
SB17S	7.43	589	2.20	-191	2.06
SB17D	7.39	501	4.72	-99	0.17
SB46S	6.65	2,299	2.55	7	0.89
SB46D	6.52	1,895	0.81	-23	0.50
PT8S	6.90	2,740	5.00	92	0.89
PT8M	7.38	647	1.82	-112	0.07
PT8D	5.96	13,805	0.75	38	3.3 limit[c]

[a] Measurements obtained by using a YSI Model 556 meter and multi-parameter probe.

[b] Ferrous iron determined by using a Hach DR/800 Series colorimeter and appropriate reagents.

[c] Concentration detected is greater than the instrument's maximum quantitation limit.

TABLE 2.5b Metals concentrations in groundwater samples collected during the third (April 2013) post-injection monitoring event.

Monitoring Point	Concentration (μg/L)											
	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
Method detection limit	80	2.0	100	2.0	2.0	5,000	4.0	10	20	200	2.0	5,000
SB01S	15.2 J	2.1	3,650 B[a]	ND[b]	0.16 J[c] B	754,000	3.1 J B	202	2.7 J	130,000	0.42 J B	190,000
SB01M	7.8 J	2.1	477 B	ND	0.091 J B	136,000	0.12 J B	1.8 J	4.8 J	530	0.23 J B	38,400
SB01D	7.1 J	7.3	1,420 B	ND	0.061 J B	489,000	2 J B	56.1	1.8 J	167,000	0.76 J B	137,000
SB08S	15.1 J	0.88 J	126 B	ND	0.092 J B	67,800	1.7 J B	0.3 J	5.2 J	ND	0.055 J B	18,900
SB08D	30.2 J	0.96 J	265 B	ND	0.057 J B	98,400	0.35 J B	0.79 J	2.9 J	ND	0.37 J B	30,700
SB16S	–[d]	–	–	–	–	376,000	–	–	–	14,600	–	101,000
SB17S	109	1.1 J	312 B	ND	0.1 J B	72,300	ND	2.4 J	2.3 J	270	0.15 J B	22,500
SB17D	58 J	1.1 J	266 B	ND	0.1 J B	91,000	0.82 J B	0.83 J	4.3 J	204	0.12 J B	29,700
SB46S	–	–	–	–	–	401,000	–	–	–	36,600	–	119,000
SB46D	10.2 J	9.9	1,590 B	ND	0.28 J B	441,000	0.74 J B	43.6	5.5 J	8,930	0.92 J B	129,000
PT8M	145	0.91 J	293 B	ND	ND	85,500	0.92 J B	1.4 J	1.6 J	384	0.18 J B	24,200
PT8D	73.1 J	3 J[e]	9,910 B	0.51 J	8.4 J B[f]	3,840,000	46.9 B	588	17.1 J	6,420,000	17.6 B	1,020,000

TABLE 2.5b (Cont.)

Monitoring Point	Concentration (µg/L)											
	Manganese	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Method detection limit	15	20	20	250	5,000	2.0	100	2.0	5,000	2.0	4.0	20
SB01S	64,400	4.8 J	61.8	1,390	12,300	ND	13,800	0.025 J	276,000	ND	0.73 J	40
SB01M	1,450	1.5 J	4.7 J	182 J	792 J	ND	11,700	0.014 J	98,500	ND	ND	13.6 J
SB01D	20,500	2.9 J	27.4	2,450	8,070	ND	13,800	ND	139,000	ND	0.77 J	122
SB08S	21.3	5.6 J	4.7 J	15.4 J	988 J	10.4	9,580	ND	86,600	ND	0.8 J	118
SB08D	150	5.3 J	4.1 J	20.1 J	1,330 J	17.2	8,910	ND	45,300	ND	1.7 J	119
SB16S	7,990	–	–	481	2,360 J	–	13,100	–	199,000	–	–	54.3
SB17S	603	3.9 J	4.9 J	23.7 J	596 J	0.78 J	9,470	ND	85,600	ND	1 J	4.7 J
SB17D	108	4.7 J	5 J	23.2 J	1,160 J	17.1	8,070	ND	40,300	ND	1.6 J	27
SB46S	6,730	–	–	1,720	3,230 J	–	14,100	–	298,000	–	–	33.8
SB46D	7,240	5.5 J	64.2	2,600	2,300 J	ND	12,900	ND	94,900	ND	2.3 J	6.9 J
PT8M	84.7	11.2 J	6.1 J	28.9 J	1,050 J	3.7	10,000	ND	71,500	ND	0.74 J	10.2 J
PT8D	68,300	ND	309	40,800	68,600	ND	15,300	ND	170,000	ND	1.8 J	562

[a] B, element detected in the associated laboratory blank.

[b] ND, not detected at the indicated method detection limit.

[c] J, estimated concentration below the indicated method detection limit.

[d] Sample not analyzed for the specified element.

[e] The method detection limit for arsenic in this analysis was 10 µg/L.

[f] The method detection limit for cadmium in this analysis was 10 µg/L.

TABLE 2.5c Anion concentrations in groundwater samples collected during the third (April 2013) post-injection monitoring event.

Monitoring Point	Concentration (mg/L)						
	Bromide	Chloride	Nitrate (as N)	Nitrite	Phosphate	Sulfate	Sulfide
Method detection limit	0.25	2.0	0.2	2.0	0.2	2.0	0.05
SB01S	ND[a]	15	ND	35	ND	1.4 J[b]	0.025 J
SB01M	ND	13	ND	ND	ND	25	0.18
SB01D	ND	12	ND	ND	ND	1.9 J	0.48
SB08D	0.4	11	2.3	ND	ND	17	0.023 J
SB17D	0.4	19	2.4	ND	ND	14	0.018 J
SB46D	ND	13	ND	16	ND	3.9	0.075
PT8D	ND	47	ND	ND	ND	42	0.16 J

[a] ND, not detected at the indicated method detection limit.

[b] J, estimated concentration below the indicated method detection limit.

TABLE 2.5d Analytical results for VOCs and dissolved gases in groundwater samples collected during the third (April 2013) post-injection monitoring event.

Monitoring Point	Concentration (µg/L)					
	Carbon Tetrachloride	Chloroform	Methylene Chloride	Methane	Ethane	Ethylene
Method detection limit	1.0	1.0	1.0	2.0	4.0	3.0
SB01S	1.9	3,202	217	150	ND[a]	ND
SB01M	6,267	1,176	76	13	ND	ND
SB01D	3.3	305	30	4.2	ND	ND
SB08S	941	55	ND	ND	ND	ND
SB08D	1,077	54	ND	ND	ND	ND
SB16S	1.8	41	6.2	82	ND	ND
SB17S	194	45	1.0	ND	ND	ND
SB17D	975	52	ND	ND	ND	ND
SB46S	ND	ND	4.9	2,500	ND	ND
SB46D	148	280	4.6	14	4.5	ND
PT8S	962	562	143	–[b]	–	–
PT8M	3,347	1,176	19	13	ND	ND
PT8D	8.8	70	7.9	1,100	58	ND

[a] ND, not detected at the indicated method detection limit.

[b] Sample not analyzed for this compound.

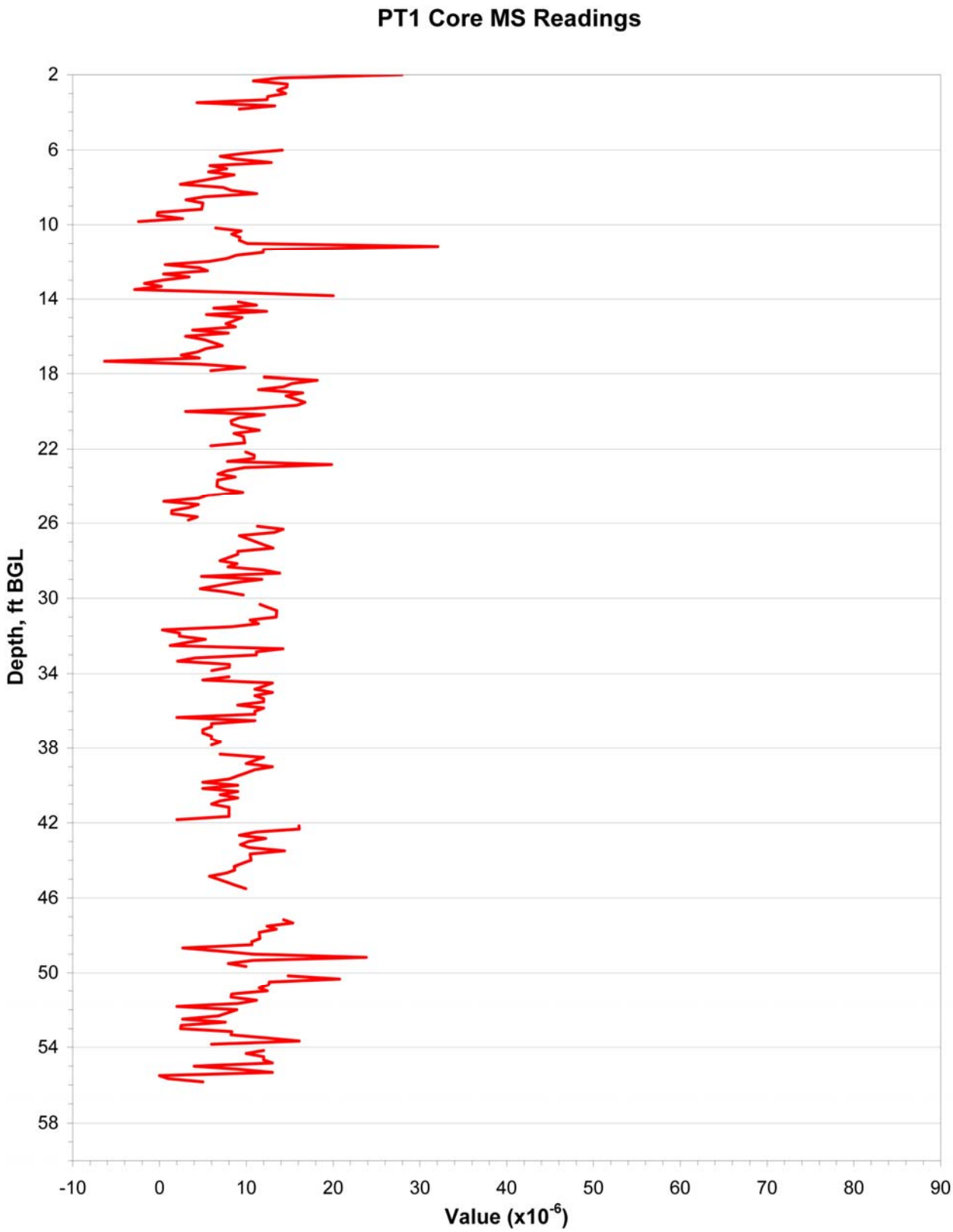

FIGURE 2.1 Magnetic susceptibility profile for the unconsolidated soil (till) sequence penetrated at investigative boring PT1.

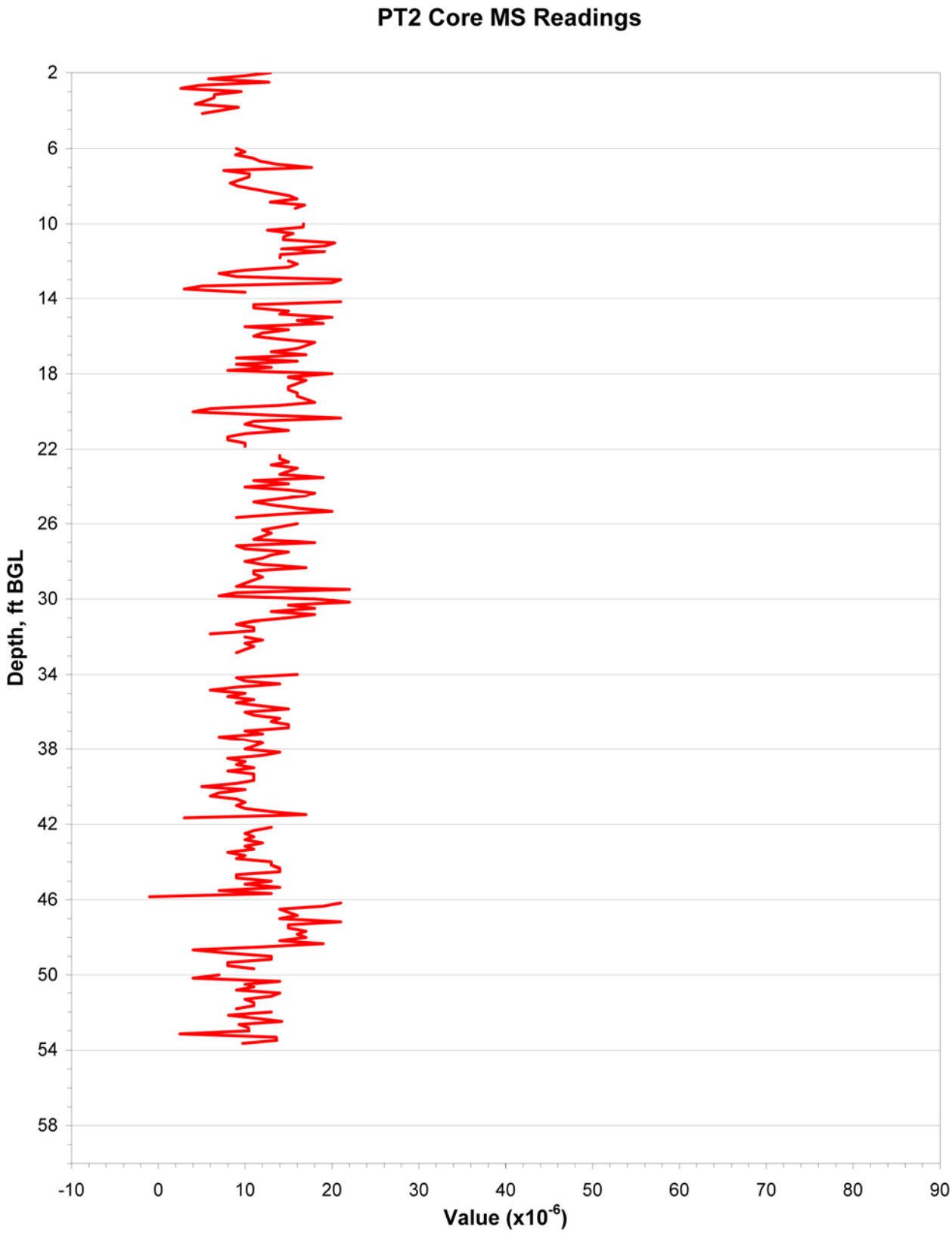

FIGURE 2.2 Magnetic susceptibility profile for the unconsolidated soil (till) sequence penetrated at investigative boring PT2.

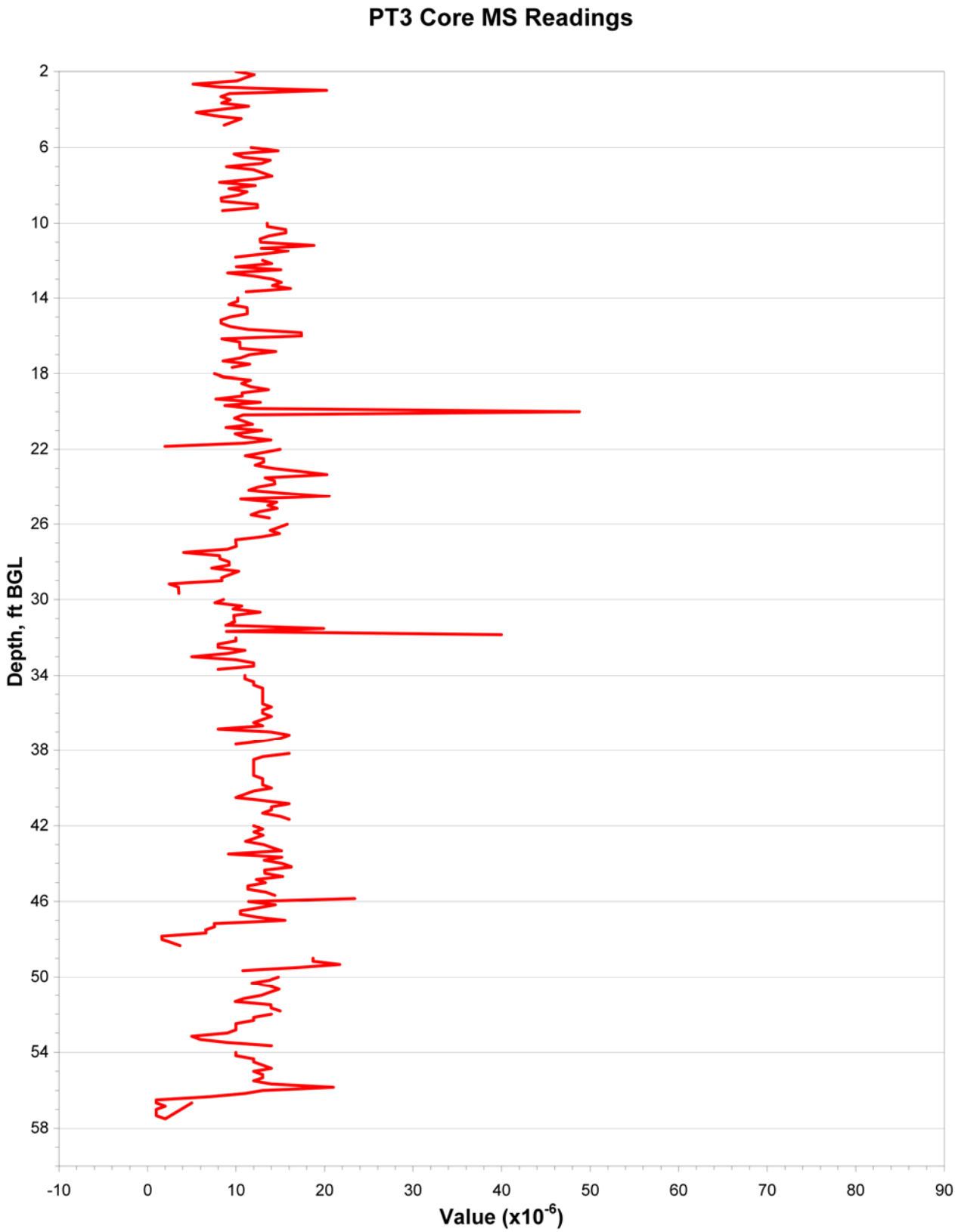

FIGURE 2.3 Magnetic susceptibility profile for the unconsolidated soil (till) sequence penetrated at investigative boring PT3.

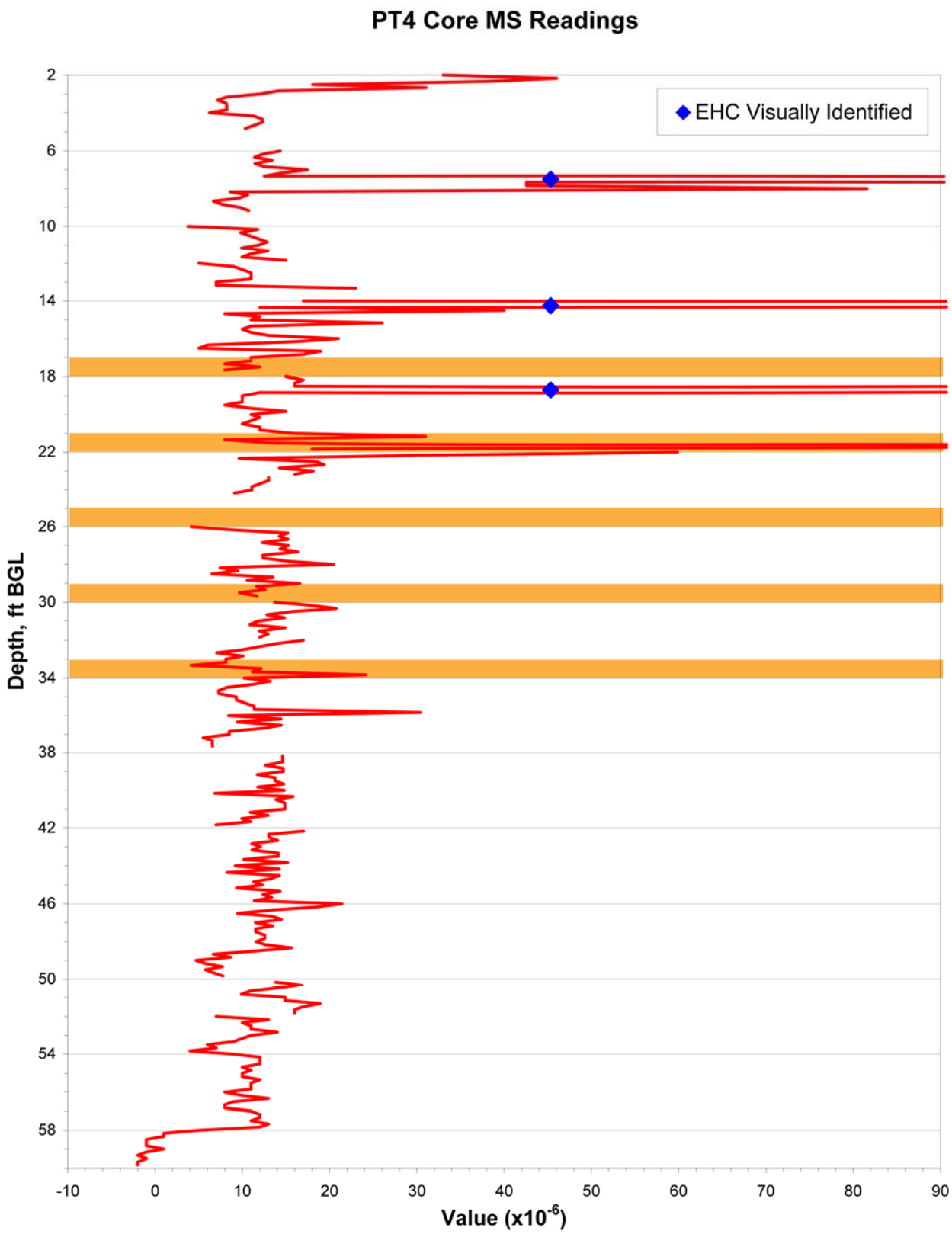

FIGURE 2.4 Magnetic susceptibility profile for the unconsolidated soil (till) sequence penetrated at investigative boring PT4. Shaded bands indicate the discrete depth intervals injected with the EHC amendment in the immediate vicinity of this (post-injection) boring.

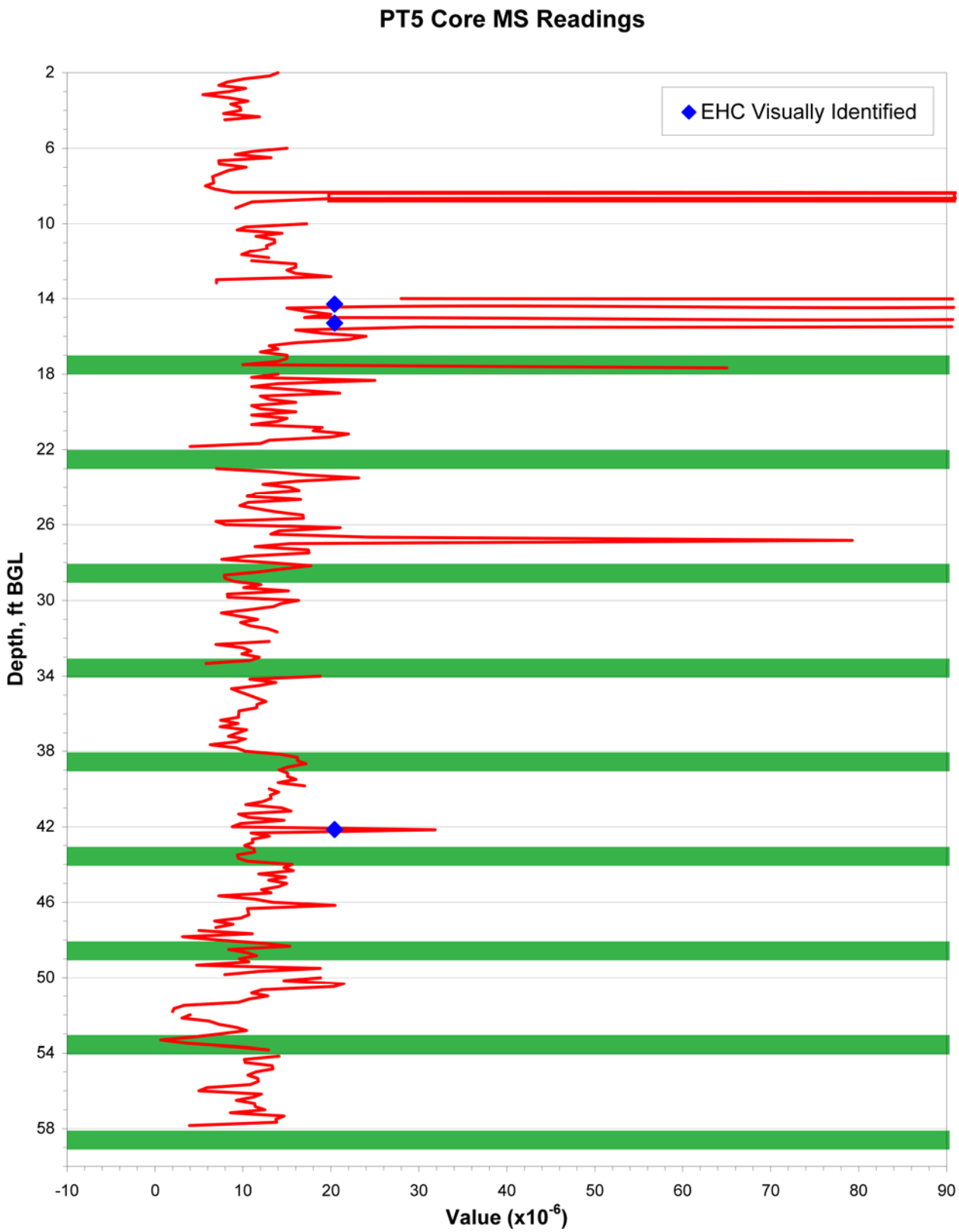

FIGURE 2.5 Magnetic susceptibility profile for the unconsolidated soil (till) sequence penetrated at investigative boring PT5. Shaded bands indicate the discrete depth intervals injected with the EHC amendment in the immediate vicinity of this (post-injection) boring.

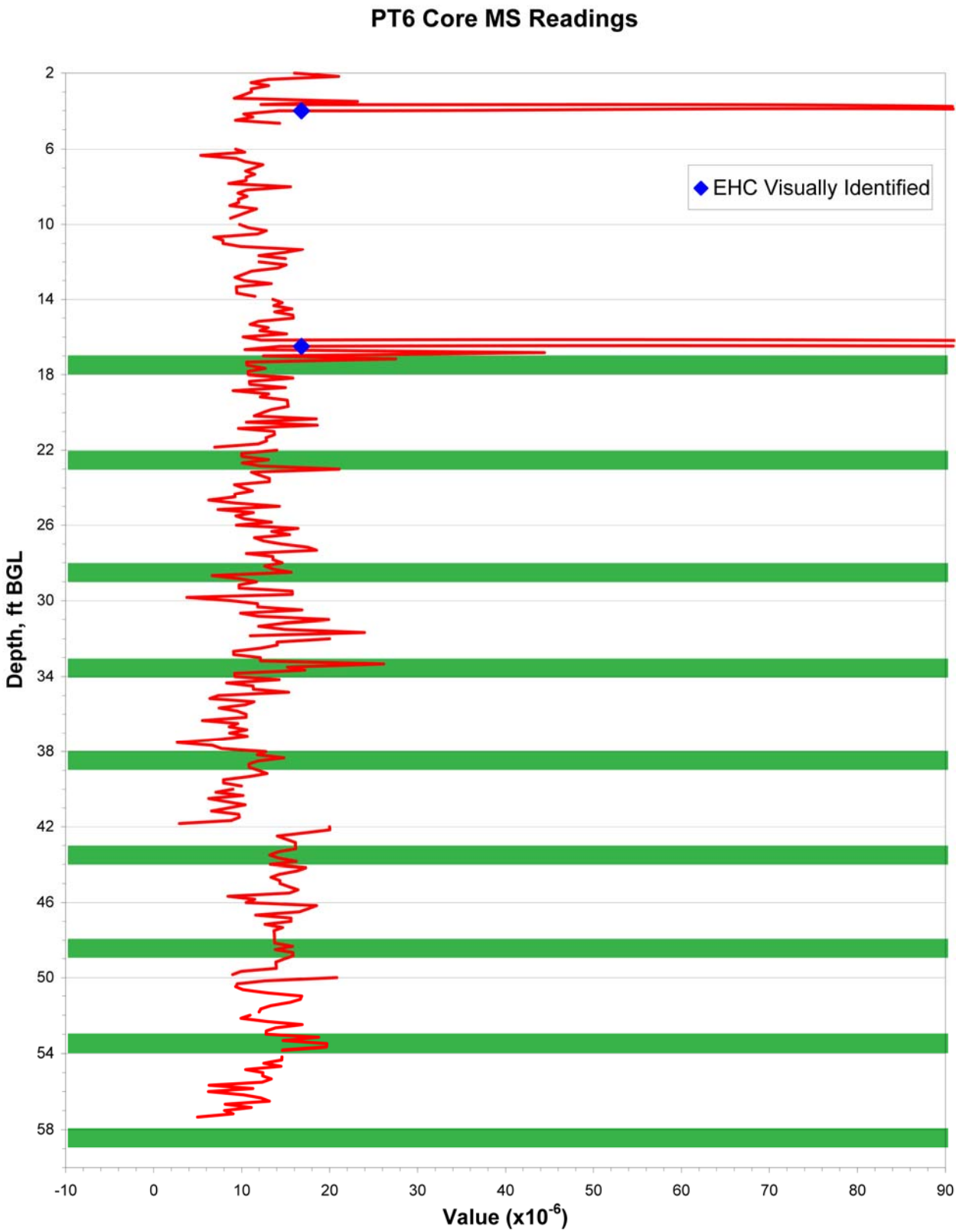

FIGURE 2.6 Magnetic susceptibility profile for the unconsolidated soil (till) sequence penetrated at investigative boring PT6. Shaded bands indicate the discrete depth intervals injected with the EHC amendment in the immediate vicinity of this (post-injection) boring.

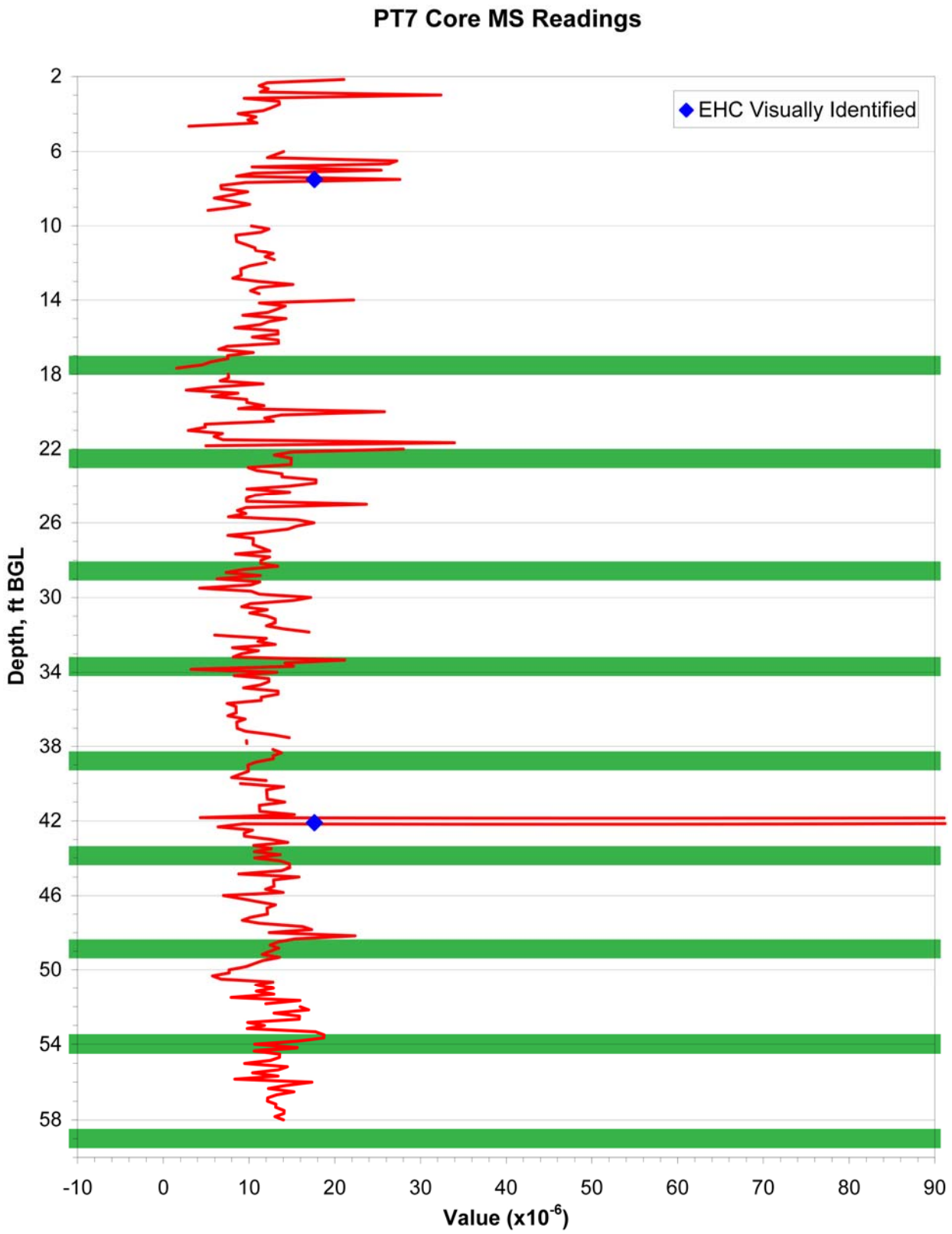

FIGURE 2.7 Magnetic susceptibility profile for the unconsolidated soil (till) sequence penetrated at investigative boring PT7. Shaded bands indicate the discrete depth intervals injected with the EHC amendment in the immediate vicinity of this (post-injection) boring.

3 Preliminary Findings of the Pilot Test Monitoring Studies

As noted in Section 1, monitoring will be conducted for at least 1 yr, to document the impacts of the EHC amendment injections on the subsurface geochemical environment and the distribution and concentrations of carbon tetrachloride in the treated areas. The data obtained to date will be evaluated further as the treatment processes and the monitoring program continue. A complete, rigorous analysis of the data and possible trends in the monitoring results will occur in future reports.

The information currently available supports the following working observations and interpretations regarding the performance of the ISCR treatment during the first four months after injection:

- Determination of the MS of the soil cores recovered during the first sampling event at locations PT1-PT3, outside the ISCR injection fields to the west, demonstrated that the natural MS of the materials is relatively uniform and low throughout the soil column (Figures 2.1-2.3). Visual examination of the PT1-PT3 cores indicated that the isolated, more elevated "spikes" in MS response observed in the PT1 and PT3 traces correspond with either thin partings of naturally occurring iron mineralization or iron-stained, more silty-sandy materials.

- Similarly low MS levels were also identified throughout most of the soil sequence penetrated at investigative borings PT4-PT7, in and near the injection fields (Figures 2.4-2.7). These results demonstrate that extensive invasion of the soils at these locations by the injected amendments had not occurred within the initial month period after injection. Figures 2.4-2.7 illustrate, however, the occurrence of multiple thin intervals of very high MS response at each location. Examination of these cores visually confirmed the presence of the EHC amendment along thin, roughly horizontal partings in the soils, in association with many of the identified MS spikes. These observations, together with the relative boring locations depicted in Figure 1.2, suggest that the EHC amendment was dispersed along locally preferred pathways, to distances of approximately 8-10 ft or more from the nearest injection point(s), within one month following injection.

- With only one exception, no carbon tetrachloride or chloroform was detected in soils at borings PT1-PT3, to the west of the primary identified contaminant source area and injection field. The exception was a trace level of carbon tetrachloride, below the method detection limit of 10 μg/kg for this compound, identified in the soil sample from boring PT3 at 40 ft below ground level (BGL; Table 2.3e and Figure 1.2). No carbon tetrachloride or chloroform was detected in the groundwater at these locations (Table 2.3d).

- Carbon tetrachloride analysis results for the cores collected at borings PT4-PT7 during the first post-injection sampling event are compared in Table 2.3f to corresponding data obtained for borings near these locations during the 2010-2011 characterization studies. Although some differences exist, the vertical distribution and magnitude of the contaminant concentrations observed for each pair of neighboring borings are generally similar, suggesting that the ISCR injections had little significant short-term impact on the carbon tetrachloride contamination in the soils at the sampled locations.

- Except for wells SB17S and SB17D, Tables 2.3a and 2.4a indicate that decreased ORP levels were generally detected in the groundwater at the permanent monitoring wells during the first two months (January and February 2013) after injection, resulting in a transient shift from positive to negative ORP values. Negative ORP levels persisted at wells SB01S, SB01M, SB01D, SB16S, and SB46D in the third (April 2013) sampling event (Table 2.5a), but no consistent trends in the ORP levels are readily apparent. At the remaining locations, ORP levels returned to positive values in the third (April 2013) monitoring event. In contrast, negative ORP readings were obtained at the SB17S and SB17D locations for the first time during the third monitoring event.

- The negative ORP values noted above indicate the local (and/or transient) development of relatively more reducing conditions across much of the pilot test treatment area in response to the EHC injections. The minimum ORP levels observed (locally ranging from approximately -76 mV to -346 mV) suggest that an environment more conducive to the reductive dechlorination of carbon tetrachloride by biologically mediated process was generated. These

levels are not sufficient, however, to facilitate direct (inorganic) geochemical reductive dechlorination of carbon tetrachloride at this point in the pilot test.

- Low DO levels (< 1 mg/L) favorable to possible anaerobic biological processes were indicated at several locations (SB01S, SB01D, SB46S) during the first (January 2013) monitoring event (Table 2.3a) and were detected at well SB46D and temporary monitoring point PT8D during the third (April 2013) sampling event (Table 2.5a). Tables 2.3a, 2.4a, and 2.5a indicate, however, that variably aerobic conditions have generally prevailed at the monitoring locations during the post-injection review period.

- No significant changes in the pH of the groundwater have been identified as a result of the ISCR injection program. The identified pH levels in the pilot testing areas remain relatively neutral, ranging from approximately 5.4 to 8.4 (Tables 2.3a, 2.4a, and 2.5a).

- Dramatically increased conductivity levels (Tables 2.3a, 2.4a, and 2.5a) have coincided with increased concentrations of multiple dissolved ionic species (particularly total iron, ferrous iron, calcium, magnesium, manganese, phosphorous, potassium, and sodium; Tables 2.3b, 2.4b, and 2.5b) in the groundwater at monitoring wells SB01S, SB01D, SB16S, SB46S, and SB46D, and to a lesser extent at SB01M, in the post-injection sampling events. Similar high concentrations of the ionic species were also detected at temporary monitoring point PT8D, sampled during the third (April 2013) monitoring event (Table 2.5b). These observations are consistent with the anticipated effects of dissolution of the EHC amendment in the groundwater at these locations (Adventus 2007, 2009).

- The levels of dissolved iron and manganese identified at the locations noted above presently exceed the EPA secondary maximum contaminant level values for these elements (300 μg/L and 50 μg/L, respectively), by as much as several orders of magnitude. These elevated levels of dissolved iron and manganese are a direct result of the EHC amendment. The concentrations are expected to decrease to acceptable levels with time (Adventus 2009).

- Low levels of arsenic (less than the EPA MCL of 10 mg/L for this element) were identified in the groundwater at all monitoring points sampled for trace metals analyses (Tables 2.3b, 2.4b, and 2.5b) after the ISCR injections. An arsenic concentration of 11 mg/L was detected during the second (February 2013) sampling event at monitoring well SB46D only; this level decreased to 9.9 mg/L in the third (April 2013) monitoring event.

- Tables 2.3d, 2.4d, and 2.5d indicate decreased concentrations of carbon tetrachloride and increased concentrations of the reductive dechlorination products chloroform and methylene chloride (relative to the corresponding baseline analyses), at monitoring wells SB01S, SB01D, SB16S, SB46S, and SB46D after the ISCR treatment. No clear changes in the concentrations of these compounds had been identified through April 2013 at the SB01M, SB08S, SB08D, SB17S, or SB17D monitoring points.

- A low level of carbon tetrachloride (8.8 μg/L) was detected in groundwater at temporary monitoring point PT8D, in the central portion of the injection field west of the rectangular foundations (Figure 1.2), during the third (April 2013) monitoring event (Table 2.5d). Although no baseline sampling data are available for this location, very high levels of chloroform, and to a lesser extent methylene chloride, were detected relative to carbon tetrachloride in groundwater collected from the PT8S, PT8M, and PT8D temporary wells in April 2013 (Table 2.5d), strongly suggesting that reductive dechlorination has occurred and might continue in the groundwater at this location.

- Although the analytical results for soil and groundwater samples acquired to date provide positive evidence for short-term impacts of the injected EHC amendment on the groundwater geochemistry and contaminant levels in the subsurface, the effects thus far are highly localized. Continued sampling in the pilot testing areas, in accord with the recommended monitoring program (Argonne 2012), will be necessary to evaluate the longer-term effectiveness, lateral and vertical extent, and permanence of the ISCR treatment in the testing areas. Technical experts from both FMC (the marketer of EHC) and Vironex (the injection contractor) have evaluated the present results and recommend allowing additional time for the EHC material to reach its full potential toward achieving the remedial goals.

4 References

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Appendix A:

Core Logs for Borings PT1-PT7

Argonne National Laboratory

Well ID: PT1

Project: Montgomery City, MO Pilot Test **Elevation:** Not surveyed **Log Date:** 1/22/2013

Geologist: Bob Sedivy **Depth:** 56 ft BGL

Depth ft BGL	Water Sample	CCl4 (ug/L)	Soil Sample	CCl4 (ug/kg)	Lithology	LITHOLOGY DESCRIPTION	Elev ft AMSL
0						NOT CORED	0
						TOPSOIL: With fine roots.	
						TILL: Clay, silt, and fine sand, occasional medium sand grains, minor black grains, few fine roots, patchy dark brown staining, soft, friable, pale brown 10YR.	
				ND		TILL: Clay, silt and fine sand, occasional medium sand grains, patchy bright red-orange staining and corroded appearance, dense, stiff, reddish brown 5YR.	
-5						TILL: Clay, silt, and fine-medium sand, poorly sorted, variably sandy, occasional small black patches, grains, or coated grains, mottled pale orange-brown staining, dense, stiff, yellowish brown 10YR.	-5
						NO RECOVERY	
				ND		TILL: Clay, silt, and fine sand, minor medium sand, fairly uniform texture, occasional black patches, small veins, or coated grains at 6.4-6.8', more abundant and darker patchy to mottled orange-brown staining than 3.1-4.2', dense, stiff to slightly plastic with depth, brown 10YR.	
-10						TILL: Clay, silt, and fine sand, uniform texture, occasional black grains or coated grains, non-calcareous ½" pebble at 8.75', occasional fine, bright yellow-orange veins, patchy orange-brown staining decreases with depth, little to no staining at 9.6-10', dense, slightly plastic with depth, gray to yellowish brown 10YR.	-10
				ND		TILL: Clay, silt, and fine sand, minor medium sand, fairly uniform texture but variably sandy, occasional small black to orange veins, dense, stiff, gray 10YR.	
						TILL: Clay, silt, and fine-medium sand, poorly sorted, variably sandy, abundant calcareous and non-calcareous pebbles to 1/8", occasional pebbles to 3/8", minor black grains, veins, and coated grains, pervasive orange-brown staining, dense, stiff, yellowish brown 10YR.	
-15							-15
				ND			
-20				ND		TILL: As above, but occasional calcareous and non-calcareous pebbles to ¾" (majority are < ½").	-20
				ND			
-25							-25

PT1 Pg. 2

Depth	W.S. CCl4	S.S. CCl4	LITH	LITHOLOGY	Elev
		ND			
-30				TILL: As above, locally less sandy and slightly more plastic, little to no staining at 37.2-38' and 39.2-40', yellowish brown to grayish brown 10YR.	-30
		ND			
-35					-35
		ND			
-40		ND		TILL: Clay, silt, and fine sand, minor medium sand, minor non-calcareous coarse sand grains and occasional pebbles to 1/8", fairly unifor texture, little staining to local small orange-brown patches that increase in abundance at 46.5-48.8', dense, plastic, grayish brown 10YR.	-40
		ND			
-45					-45
		ND		TILL: Clay, silt, and fine-medium sand, poorly sorted, hard, calcareous-cemented?, rusty dark brown, black veins, grains, and coated grains, and white to rusty brown calcareous pebbles to ¾", dense to friable-broken (where cemented), brown 10YR.	
-50	ND			TILL: Clay, silt, and fine-medium sand, poorly sorted, occasional black grains, abundant calcareous and non-calcareous pebbles to ¼", several ½" calcareous pebbles at 52', occasional black grains, patchy to prevasive orange-brown staining, brown 10YR to yellowish brown 10YR with depth.	-50
		ND		TILL: As 40-48.8', but with less abundant coarse grains, plastic, grayish brown 10YR.	
-55		ND		TILL: Clay, silt, and fine-medium sand, poorly sorted, very heterogeneous with abundant black patches, veins, and coated grains and large calcareous patches, black-brown staining, veins and corroded-appearing patches pervasive at 54.5-55.5', angular ~1" chert clast at 55.2', calcareous pebbles to ¾" at 55.5-56'. (PUSHED 54-56' BUT RECOVERED 48') NO VISIBLE MOISTURE EXCEPT AS NOTED.	-55

Argonne National Laboratory

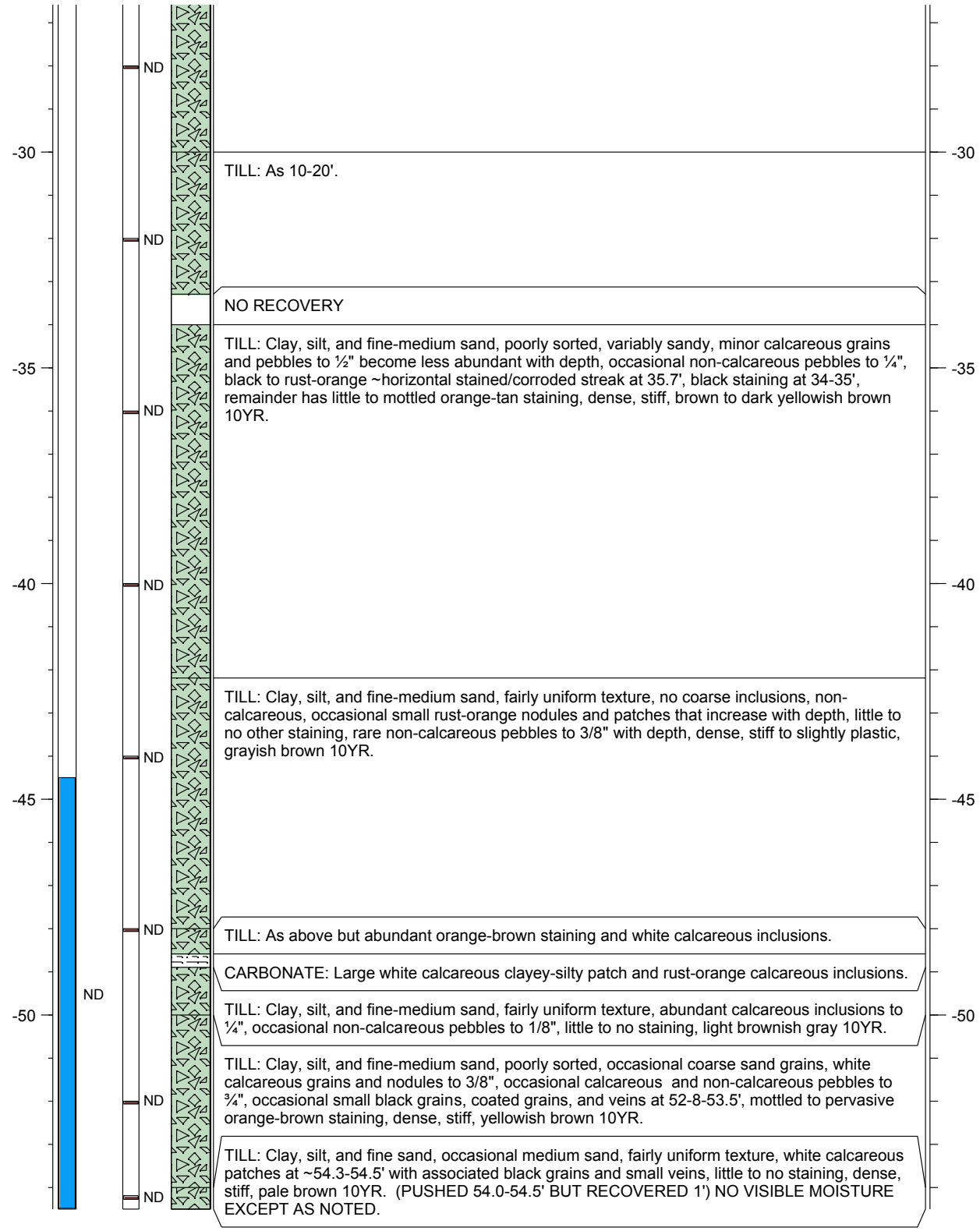
Well ID: PT2

Project: Montgomery City, MO Pilot Test **Elevation:** Not surveyed **Log Date:** 1/22/2013

Geologist: Bob Sedivy **Depth:** 54.5 ft BGL

Depth ft BGL	Water Sample	CCl4 (ug/L)	Soil Sample	CCl4 (ug/kg)	Lithology	LITHOLOGY DESCRIPTION	Elev ft AMSL
0						NOT CORED	0
						TILL: Clay, silt, and fine sand, minor medium sand, non-calcareous, no coarse inclusions, dark orange-brown staining decreases to bleached white to light gray appearance with depth, small rust-orange stained or corroded patches, dark yellowish brown to light gray 10YR with depth.	
			ND				
-5						NO RECOVERY	-5
						TILL: Clay, silt, and fine sand, minor medium sand, rare coarse sand grains, non-calcareous, small black coated grains, variable patchy to mottled, orange-tan to black staining that is most prominent at 6-6.7' 7.1-7.5', and 7.6-8.2', bleached appearance to pale yellow staining at 7.5-7.6', dense, stiff, grayish brown to light gray 10YR.	
			ND				
						TILL: Clay, silt, and fine sand, minor medium sand, occasional coarse sand grains, minor black grains and small veins, mottled to pervasive orange-tan staining, dense, stiff, yellowish brown 10YR.	
-10						NO RECOVERY	-10
						TILL: Clay, silt, and fine-medium sand, poorly sorted, variably sandy, variably abundant black and coated grains, small veins and streaks, white calcareous grains and nodules to 1/8", ~1" calcareous patch at 15.5-15.6', occasional calcareous and non-calcareous pebbles to ¾" (majority ≤ ½"), variably mottled to pervasive orange-tan staining, dense, stiff, yellowish brown 10YR.	
			ND				
-15							-15
			ND				
-20			ND			TILL: As above, calcareous patch at 21.8', ½"-¾" pebbles at 28.6' and 29.75'.	-20
			ND				
-25							-25

PT2 Pg. 2


Depth
W.S.
CCl4
S.S.
CCl4
LITH
LITHOLOGY
Elev
-30
-35
-40
-45
-50
ND
TILL: As 10-20'.
NO RECOVERY
TILL: Clay, silt, and fine-medium sand, poorly sorted, variably sandy, minor calcareous grains and pebbles to ½" become less abundant with depth, occasional non-calcareous pebbles to ¼", black to rust-orange ~horizontal stained/corroded streak at 35.7', black staining at 34-35', remainder has little to mottled orange-tan staining, dense, stiff, brown to dark yellowish brown 10YR.
TILL: Clay, silt, and fine-medium sand, fairly uniform texture, no coarse inclusions, non-calcareous, occasional small rust-orange nodules and patches that increase with depth, little to no other staining, rare non-calcareous pebbles to 3/8" with depth, dense, stiff to slightly plastic, grayish brown 10YR.
TILL: As above but abundant orange-brown staining and white calcareous inclusions.
CARBONATE: Large white calcareous clayey-silty patch and rust-orange calcareous inclusions.
TILL: Clay, silt, and fine-medium sand, fairly uniform texture, abundant calcareous inclusions to ¼", occasional non-calcareous pebbles to 1/8", little to no staining, light brownish gray 10YR.
TILL: Clay, silt, and fine-medium sand, poorly sorted, occasional coarse sand grains, white calcareous grains and nodules to 3/8", occasional calcareous and non-calcareous pebbles to ¾", occasional small black grains, coated grains, and veins at 52-8-53.5', mottled to pervasive orange-brown staining, dense, stiff, yellowish brown 10YR.
TILL: Clay, silt, and fine sand, occasional medium sand, fairly uniform texture, white calcareous patches at ~54.3-54.5' with associated black grains and small veins, little to no staining, dense, stiff, pale brown 10YR. (PUSHED 54.0-54.5' BUT RECOVERED 1') NO VISIBLE MOISTURE EXCEPT AS NOTED.

Argonne National Laboratory

Well ID: PT3

Project: Montgomery City, MO Pilot Test **Elevation:** Not surveyed **Log Date:** 1/25/2013

Geologist: Bob Sedivy **Depth:** 58 ft BGL

Depth ft BGL	Soil Sample	CCl4 (ug/kg)	Lithology	LITHOLOGY DESCRIPTION	Elev ft AMSL
0				NOT CORED	0
				TILL: Clay, silt, and fine sand, variable minor medium sand, occasional very small black grains and dark rusty-brown patches, thin pod of white clay, silt, and fine sand at 4.65', patchy to mottled orange-brown staining, grayish brown to dark grayish brown 10YR.	
	ND				
-5				NO RECOVERY	-5
				TILL: Clay, silt, and fine sand, variable medium sand, poorly sorted, occasional non-calcareous pebbles to ½", occasional irregular pods of white clay, silt, and fine sand, variably abundant black grains, coated grains, and patches, small black to bright orange veins, particularly at 6.4-6.8', variable pale mottled to dark patchy orange staining that becomes more pervasive with depth, dense, stiff, brown to grayish brown to yellowish brown 10YR.	
	ND				
				NO RECOVERY	
-10				TILL: Clay, silt, and fine-medium sand, poorly sorted and variably sandy, frequent non-calcareous pebbles to ½", occasional calcareous grains and nodules to ¼", minor black grains, coated grains and pebbles, patches, and veins particularly at 12.2-14', black to dark orange-brown thin partings at 12.25' and 13.2' (~horizontal) and 13.6' (~vertical), abundant patchy orange-brown staining at 10-11.5', pervasive orange-brown staining at 11.5-20', dense, stiff, yellowish brown 10YR.	-10
	ND				
-15					-15
	ND				
-20	ND			TILL: As above, with ~¾" non-calcareous pebbles at 21.7' and 27.55'.	-20
	ND				
-25					-25
	ND				

PT3 Pg. 2

Depth	S.S.	CCl4	LITH	LITHOLOGY	Elev
-30				TILL: As 10-20', but staining decreases with depth, and dark brown to black stained granular patch at 32-32.2'.	-30
		ND			
				TILL: Clay, silt, and fine sand, minor medium sand, occasional coarse sand grains, fairly uniform texture, rare dark rust-orange nodules to 1/8", no coarser inclusions or staining, dense, stiff to slightly plastic, dark gray to dark grayish brown 10YR.	
-35					-35
		ND			
-40		6.1J		TILL: As above, but increasing abundance of small, dark rust-brown patches and nodules at 45-46.15', and slightly plastic to plastic, dark grayish brown to grayish brown 10YR with depth.	-40
		ND			
-45					-45
				TILL: Clay, silt, and fine-medium sand, poorly sorted, calcareous pebbles and patches and non-calcareous pebbles to ½", ~1" angular chert clast at 49.3', minor black to dark brown stained grains and patches, and dark rust-orange-brown stained partings at 47' and 47.35', core ribboned 47.5-49.3' (chert blocked cutting shoe), patchy to pervasive orange-brown staining, dense, stiff, yellowish brown 10YR.	
		ND			
-50					-50
				TILL: Clay, silt, and fine sand, minor medium sand, occasional coarse sand grains, fairly uniform texture, occasional clayey-silty pods to ¾", occasional non-calcareous coarse sand grains and pebbles at 54-56.6', white calcareous patch with associated black to dark brown staining at 56.3-56.5', faint, patchy to mottled orange brown staining at 50-54', dense, stiff, brown to yellowish brown 10YR.	
		ND			
-55					-55
		ND			
				CLAY, SILT AND SAND: Abrupt transition from above to clay, silt, and fine-medium sand, poorly sorted, bleached appearance, non- to very slightly calcareous, with irregular clayey pods and partings, dense, stiff, light gray to pale yellow 2.5Y.	
				NO RECOVERY: NO VISIBLE MOISTURE EXCEPT AS NOTED.	

Argonne National Laboratory

Well ID: PT4

Project: Montgomery City, MO Pilot Test **Elevation:** Not surveyed **Log Date:** 1/23/2013

Geologist: Bob Sedivy **Depth:** 61.5 ft BGL

Depth ft BGL	Soil Sample	CCl4 (ug/kg)	Lithology	LITHOLOGY DESCRIPTION	Elev ft AMSL
0				NOT CORED	0
				TILL: Clay, silt, and fine sand, non-calcareous, thin parting of silty medium to coarse sand at 2', minor streaky pale orange-tan staining, soft, very dark grayish brown 10YR.	
				TILL: Clay, silt, and minor fine sand, fairly uniform texture, non-calcareous, dense, stiff, dark yellowish brown 10YR.	
				TILL: Clay, silt, and fine sand, non-calcareous, bright red-orange stained corroded-appearing grains, patches, and streaks, dense, stiff, brown 10YR.	
		ND		TILL: Clay, silt, and fine sand, minor medium sand, non-calcareous, red-orange stained grains, streaks, and patches as above become less abundant with depth and more pale yellow-orange, dense, stiff, grayish brown 10YR.	
-5				NO RECOVERY	-5
				TILL: Clay, silt, and fine sand, minor medium sand, non-calcareous, variable yellow-orange stained and corroded grains as above, ~ ½" ~horizontal vein of dark rusty brown EHC (iron plus organic matter) at 7.5', Light brownish gray 2.5Y.	
		6.8 J			
				NO RECOVERY	
-10				TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, abundant yellow-orange stained and corroded grains, patches, and streaks, fine black veins and corroded appearing patches to 1/8" at 12.5-13.5', dense, stiff, yellowish brown 10YR.	-10
		46			
				NO RECOVERY	
				TILL: As 10-13.7'.	
-15				VEIN: Friable, dark rusty brown ~horizontal vein of EHC (iron plus organic matter).	-15
		1450		TILL: As 10-13.7', black veining and patches (as 12.5-13.5'), particularly at 16.4-16.7', occasional granular calcareous nodules and patches to 1/4", ½" black coated pebble at 17.1', ~ ½" dark rusty-brown EHC vein at 18.7', variable yellowish staining, dense, stiff, yellowish brown 10YR.	
				TILL: As above, occasional calcareous nodules and patches and non-calcareous pebbles to ½".	

PT4 Pg. 2

Depth	S.S.	CCl4	LITH	LITHOLOGY	Elev
-20		2222		TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, calcareous nodules and patches to ¼", occasional non-calcareous pebbles to ¼", variable to pervasive orange-tan staining, dense, stiff, yellowish brown 10YR.	-20
				SAND: Poorly sorted fine-coarse sand, abundant medium to coarse subangular quartz and minor chert and dark grains, calcareous cemented with depth?, soft, damp, dark yellowish brown 10YR.	
				SAND: As above but pervasive calcareous cement, bleached appearance, light yellowish brown 10YR to white 2.5Y.	
				TILL: As 20-21.4', but minor thin black veins and grains at 22.6-23.4' that decrease with depth, and more uniform paler color with depth.	
		2248		TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, ~1/2" shaly? pebble at 24.3', light yellowish brown 10YR.	
-25				NO RECOVERY	-25
				SAND: Core ribboned, poorly sorted calcareous medium-coarse grained sand with calcareous and non-calcareous pebbles to ¼", weak calcareous clayey-silty cemented?, brownish yellow 10YR.	
				TILL: Clay, silt, and variably abundant fine-medium sand, abundant white calcareous grains and nodules to 1/8", occasional non-calcareous pebbles to ½", occasional very small black grains, coated grains, or veins, yellowish brown 10YR.	
		2618		SAND: Silty medium to coarse sand, minor chert and dark grains, trace of black veins and very small grains, weak calcareous cemented, friable to dusty, brownish yellow 10YR.	
				TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, calcareous nodules to ¼", dense, stiff.	
-30				SAND: As 28-28.2', predominantly medium sand, light gray 2.5YR.	-30
				TILL: As 28.2-28.5.	
				SAND: As 28.5-28.6'.	
		33		TILL: Clay, silt, and fine-medium sand, variably sandy, calcareous grains and nodules to ½", occasional non-calcareous pebbles to 1/8", dense, stiff, light olive brown 2.5Y.	
				SAND: Irregular pod of silty fine white sand, dry.	
				TILL: Clay, silt, and fine-medium sand, minor coarse sand, variably sandy, calcareous grains and nodules to 1/8", occasional calcareous and non-calcareous pebbles to ½", minor dark grains and black streaks, pervasive orange-brown staining decreases slightly with depth, dense, stiff to slightly plastic, yellowish brown 10YR.	
-35					-35
		ND			
				TILL: Clay, silt, and fine sand, minor medium sand, more uniform texture than 30.3-38.1', generally non-calcareous, little or no staining or coarse inclusions, dense, stiff to slightly plastic, grayish brown 10YR.	
-40		ND		TILL: As above, slight mottled rusty-orange staining and patches to 1/8" at 45-46'.	-40

PT4 Pg. 3

Depth	S.S.	CCl4	LITH	LITHOLOGY	Elev
		ND			
-45					-45
				TILL: Clay, silt, and fine sand, minor medium sand, occasional coarse sand grains, abundant calcareous grains and nodules to ¼", larger calcareous patches at 46.3', 46.85', and 49', occasional calcareous and non-calcareous pebbles to ½", minor black grains, coated grains and pebbles, and small veins, pervasive orange-tan staining, dense, stiff, yellowish brown 10YR.	
		ND			
				TILL: As above, but little to no staining, light brownish gray 2.5Y.	
-50				TILL: As 46-49.4'.	-50
		ND			
				TILL: Clay, silt, and fine sand, minor medium sand, uniform texture, few to no calcareous inclusions, one ~¾" non-calcareous pebble at 56.7', little to no orange or black staining, increases slightly with depth, dense, stiff to slightly plastic, grayish brown 10YR.	
-55					-55
		ND			
				CLAY AND SILT: Abrupt transition to dense, stiff, hard clay and silt, white/bleached appearance, non-calcareous, no coarse inclusions, pale mottled yellow-orange staining. NO VISIBLE MOISTURE EXCEPT AS NOTED.	
-60		ND			-60

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Well ID: PT5

Project: Montgomery City, MO Pilot Test **Elevation:** Not surveyed **Log Date:** 1/24/2013

Geologist: Bob Sedivy **Depth:** 57 ft BGL

Depth ft BGL	Soil Sample	CCl4 (ug/kg)	Lithology	LITHOLOGY DESCRIPTION	Elev ft AMSL
0				NOT CORED	0
				TILL: Clay, silt, and fine-medium sand, non-calcareous, mottled to pervasive orange-brown staining, yellowish brown 10YR.	
				TILL: Clay, silt, and fine-medium sand, non-calcareous, small bright red-orange stained or corroded appearing grains and patches, dense, stiff to slightly plastic, brown 10YR.	
		ND		TILL: Clay, silt, and fine sand, non-calcareous, minor black grains and small veins, dense, stiff, yellowish brown 10YR.	
-5				NO RECOVERY	-5
				TILL: Clay, silt, and fine-medium sand, variably sandy, non-calcareous, black grains, coated grains, and patches at 6.2-6.3', variably mottled orange-brown staining at 6.6-6.8', abundant thin black (rare) to bright yellow-orange veins and staining at 8-9.4', grayish brown to yellowish brown 10YR.	
		5.5 J			
				NO RECOVERY	
-10				TILL: Clay, silt, and fine-medium sand, non-calcareous, occasional non-calcareous pebbles to ½", abundant mottled to pervasive yellow-orange to orange-brown staining, yellowish brown 10YR.	-10
		1674		TILL: Clay, silt, and fine-medium sand, abundant black grains, coated grains, and patches, calcareous patch at 13-13.1', occasional non-calcareous pebbles to 3/8", dense, stiff, abundant mottled to pervasive orange-brown staining, yellowish brown 10YR.	
				NO RECOVERY	
-15				TILL: As above, at 14.3' thin ~horizontal parting of dark rusty-red EHC, at 15.3-15.5' ~horizontal vein of dark rust-red EHC.	-15
		288		TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, occasional black grains, coated grains, and thin veins, minor calcareous grains and nodules to 1/8", occasional non-calcareous pebbles to 1/8"-1/4", larger calcareous patches at 17.75' and 18.2-18.3', abundant mottled to pervasive orange-brown staining, dense, stiff, grayish brown to yellowish brown 10YR.	
-20		836		TILL: Clay, silt, and fine-medium sand, minor coarse sand, non-calcareous pebbles to ½", minor black grains, coated grains, and small veins, minor small calcareous nodules, abundant mottled to pervasive orange-brown staining, dense, stiff, yellowish brown 10YR.	-20
				NO RECOVERY	
				TILL: As 20-21.1', black to dark rust-brown patch at 27.4-27.7'.	
		904			
-25					-25

PT5 Pg. 2

Depth	S.S.	CCl4	LITH	LITHOLOGY	Elev
		1129			
-30				TILL: Clay, silt, and fine sand, minor medium sand, more uniform texture than above, occasional white non-calcareous coarse sand-size grains, little to no staining, dense, stiff to slightly plastic, grayish brown 10YR.	-30
		2865			
				TILL: Clay, silt, and fine-medium sand, more abundant coarse grains than above, occasional non-calcareous pebbles to ½", rust orange-brown parting at 36.75', variable patchy to mottled orange-brown staining, dense, stiff to slightly plastic, grayish brown 10YR.	
-35					-35
		1371			
				TILL: As 30-32.8, but with occasional pale orange-brown staining.	
-40		148			-40
				TILL: Clay, silt, and fine sand, variable minor medium sand, occasional coarse sand grains, minor small black grains and veins, thin dark red parting of EHC at 42.15', patchy to mottled orange-brown to orange staining, dense, stiff, brown to yellowish brown 10YR.	
		131			
-45					-45
				TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, variably sandy, calcareous and non-calcareous pebbles to ½", calcareous pods of fine-medium sand at 49.1' and 49.6', occasional small black grains, coated grains, and veins, ½"-¾" calcareous pebbles at 47.7-47.9', variable patchy dark orange-brown staining, dense, stiff, brown to yellowish brown 10YR.	
		240			
-50					-50
				TILL: As above, calcareous pod of fine-medium sand at 50.9-51', ½"-¾" calcareous patch and pebbles at 51.4-51.6'.	
		137			
				TILL: Transitional zone between intervals described above and below.	
				TILL: Clay and silt, minor fine sand, fairly uniform texture, rare white non-calcareous pebbles to 1/8", occasional very pale patchy yellow-tan staining, dense, plastic, grayish brown 10YR.	
-55					-55
		37		TILL: Clay, silt, and fine sand, abundant black staining, coated grains, and veins, abundant rust-brown to orange round silty nodules to 1/8", very dark grayish brown to dark brown 10YR. (PUSHED 54-57' BUT RECOVERED 4') NO VISIBLE MOISTURE EXCEPT AS NOTED.	

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Well ID: PT6

Project: Montgomery City, MO Pilot Test **Elevation:** Not surveyed **Log Date:** 1/24/2013

Geologist: Bob Sedivy **Depth:** 56.5 ft BGL

Depth ft BGL	Soil Sample	CCl4 (ug/kg)	Lithology	LITHOLOGY DESCRIPTION	Elev ft AMSL
0				NOT CORED	0
				TILL: Clay, silt, and fine sand, minor medium sand, small patches of dark orange-brown staining to mottled pale orange staining, dense, stiff, grayish brown to brown 10YR.	
		ND		TILL: Clay, silt, and fine sand, minor medium sand, rare small black grains, small patches of dark orange-brown staining to mottled pale orange staining, dense, stiff, ~ ¼" vein of rusty brown EHC at 4', pale brown to yellowish brown 10YR.	
-5				NO RECOVERY	-5
		ND		TILL: Clay, silt, fine sand and variable medium sand, very fine black to bright yellow-orange veining, variably patchy orange-brown staining, dense, stiff, grayish brown to yellowish brown 10YR.	
-10				TILL: Clay, silt, fine sand and variable medium sand, occasional coarse sand grains, occasional calcareous and non-calcareous pebbles to ¼", variable black veins, partings, grains and coated grains especially at 13.8-15' and 17.6', pervasive orange-brown staining, dense, stiff, yellowish brown 10YR.	-10
		ND			
-15		23			-15
-20		34		TILL: Clay, silt, and abundant fine-medium sand, occasional calcareous and non-calcareous pebbles to ¾" (majority ≤ ½"), minor dispersed black grains and coated pebbles, ~½" dark rusty orange-brown pod with corroded appearance at 20.3', pervasive orange-brown staining, yellowish brown 10YR.	-20
		43			
-25					-25

PT6 Pg. 2

Depth	S.S.	CCl4	LITH	LITHOLOGY	Elev
		68			
-30				TILL: As above, but with pebbles ≤ ½" only.	-30
		181			
-35				TILL: Clay, silt, and fine-medium sand, variably sandy, occasional coarse sand size grains and pebbles to 1/8", pervasive orange-brown stain becomes patchy and disappears with depth, dense, stiff to slightly plastic with depth, yellowish brown to grayish brown 10YR.	-35
		360			
-40		378		TILL: As above, with occasional rust-orange nodules and small veins with depth, one ~½" non-calcareous pebble at 41.8'.	-40
		520		TILL: Clay, silt, and fine-medium sand, occasional coarse sand, occasional non-calcareous pebbles to ¼", minor black grains, patches to ¼", and coated grains especially at 46-7-47.5', pervasive orange-brown staining decreases with depth, dense, slightly plastic to stiff with depth, yellowish brown to grayish brown 10YR with depth.	
-45					-45
		576		TILL: Clay, silt, and fine-medium sand, abundant white calcareous nodules and pebbles to ¼" at 49-50', patchy dark orange-brown staining, dense, stiff, yellowish brown to dark grayish brown 10YR.	
-50				TILL: Clay, silt, and fine-medium sand, calcareous and non-calcareous pebbles to ¼", ~¼" seam of silty fine to medium sand at 50.2', minor patchy orange-brown staining, dense, stiff, grayish brown 10YR.	-50
		746		TILL: Clay, silt, and fine-medium sand, variably sandy, becomes less sandy at 55.5-56.5', calcareous and non-calcareous pebbles to ¼", black patchy staining, grains and coated grains at 54-54.2', ¾" chert shard at 55.8', 1" chert clast in core catcher at 56.5', patchy to pervasive orange-brown staining, dark grayish brown to brown to yellowish brown 10YR. NO VISIBLE MOISTURE THROUGHOUT EXCEPT AS NOTED.	
-55					-55
		597			

Argonne National Laboratory

Well ID: PT7

Project: Montgomery City, MO Pilot Test **Elevation:** Not surveyed **Log Date:** 1/24/2013

Geologist: Bob Sedivy **Depth:** 57 ft BGL

Depth ft BGL	Soil Sample	CCl4 (ug/kg)	Lithology	LITHOLOGY DESCRIPTION	Elev ft AMSL
0				NOT CORED	0
				TILL: Clay, silt, and fine sand, minor medium sand, occasional fine roots present to 3', minor black grains and black to brown or very dark orange stained patches, dense, stiff, color changes from dark grayish brown to pale brown 10YR with depth.	
		ND			
-5				NO RECOVERY	-5
				TILL: Clay, silt, and fine sand, minor medium sand, black veins and partings and dark orange-brown staining at 6.9-7', very thin parting of rusty-brown EHC at 7.5', variable patchy bright orange to pale orange staining, dense, stiff, brown 10YR to gray 2.5Y.	
		ND		SILT AND CLAY: With trace fine sand, dense, light gray 10YR.	
				TILL: As 6-7.9'.	
-10				NO RECOVERY	-10
				TILL: Clay, silt, and fine sand, variable medium sand, occasional patchy pale orange staining, dense, stiff to slightly plastic, light brownish gray 2.5Y.	
		ND			
				TILL: Clay, silt, and fine-medium sand, occasional small black veins, grains, and patches to 1/8", occasional calcareous and non-calcareous pebbles to ½", variable patchy to mottled orange-brown staining, dense, stiff, light gray 2.5Y to yellowish brown 10YR.	
-15					-15
		12			
				TILL: As above, with large white calcareous patches and pebbles.	
				TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, occasional calcareous and non-calcareous pebbles to 3/8", minor small black grains and patches, patchy orange-brown staining, dense, stiff, yellowish brown 10YR.	
-20		14			-20
				TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains, minor predominantly non-calcareous pebbles to ½", occasional black coarse sand-size grains and coated grains, pervasive orange-brown staining, dense, stiff to very slightly plastic, yellowish brown 10YR.	
		12			
-25					-25

PT7 Pg. 2

Depth	S.S.	CCl4	LITH	LITHOLOGY	Elev
		14			
-30				TILL: Clay, silt, and fine-medium sand, occasional non-calcareous pebbles to 3/8", dark rusty orange silty partings with small black grains and patches to 1/8" at 30.5' and 32.9', pervasive orange-brown staining, dense, stiff, yellowish brown 10YR.	-30
		20			
-35				TILL: Clay, silt, and fine-medium sand, occasional coarse sand grains and pebbles to 1/8", one ~1" chert clast at 34.05', dark rusty orange parting with black grains and patches at 34.95', little-or-no to pale orange staining, dense, stiff to slightly plastic with depth, grayish brown to brown 10YR.	-35
		16			
				TILL: Clay, silt, and fine-medium sand, abundant black grains, patches, and coated grains, abundant to pervasive dark orange staining, dark yellowish brown 10YR.	
-40		9.2 J		TILL: Clay, silt, and fine sand, minor medium sand, fairly uniform texture, one ¼" non-calcareous pebble, mottled orange-brown staining decreases with depth, dense, stiff to slightly plastic, dark grayish brown 10YR.	-40
				TILL: Clay, silt, and fine sand, minor medium sand, fairly uniform texture, rare non-calcareous pebbles to ¼", very thin, ~horizontal parting of rusty-brown EHC (iron and organic matter) at 42.1', little-or-no to very pale orange staining at 40-42.5' and 43.5-46', patchy orange-brown staining at 42.5-43.5', dense, plastic, brown 10YR to grayish brown 2.5Y.	
		ND			
-45				SAND: ~¼" horizon or pod of clean medium sand, clear to white or orange-stained sub-rounded grains.	-45
				TILL: Clay, silt, and fine-medium sand, variably sandy, occasional calcareous and non-calcareous pebbles to ½", minor small black veins, grains, and coated grains especially at 46.1-47.2', one ~1" chert pebble at 53.3', patchy dark to pale orange-brown staining, dense, stiff, dark yellowish brown to yellowish brown 10YR.	
		19			
-50					-50
		31			
-55				TILL: Clay, silt, and fine sand, minor medium sand, fairly uniform texture, ~½" pod of white fine-medium sand at 55.5', minor dark rusty brown to black nodules to 1/8", ~1" angular chert shard stuck in coring shoe, occasional black patches and thin veins, mottled pale orange-brown staining, dense, stiff to slightly plastic, brown 10YR. NO VISIBLE MOISTURE THROUGHOUT EXCEPT AS NOTED.	-55
		28			

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