

# Final Work Plan: ISCR Pilot Test at Montgomery City, Missouri

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Environmental Science Division



United States Department of Agriculture

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

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**Work Plan: ISCR Pilot Test at Montgomery City, Missouri**

**WORK PLAN APPROVAL**

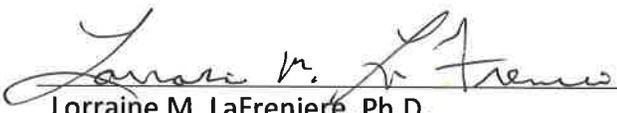
This *Work Plan* has been prepared to provide relevant site-specific information for the field-scale pilot testing of an *in situ* chemical reduction (ISCR) technology for the treatment of carbon tetrachloride contamination identified in the soil and groundwater at the site of the grain storage facility formerly operated by the Commodity Credit Corporation of the U.S. Department of Agriculture in Montgomery City, Missouri.

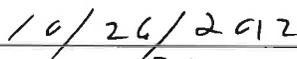
I have reviewed the *Work Plan* for implementation of the field-scale pilot testing at the subject facility and find that the procedures outlined in this document will result in data that meet the project objectives.

APPROVAL

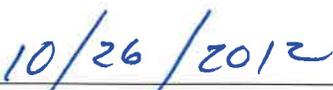
  
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by  
Applied Geosciences and Environmental Management Section  
Environmental Science Division, Argonne National Laboratory

November 2012



United States Department of Agriculture

Work sponsored by Commodity Credit Corporation,  
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## Notation

BGL	below ground level
CCC	Commodity Credit Corporation
CPT	cone penetrometer
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Act Information System
d	day(s)
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
gpm	gallon(s) per minute
in.	inch(es)
ISCR	<i>in situ</i> chemical reduction
KDHE	Kansas Department of Health and Environment
lb	pound(s)
µg/kg	microgram(s) per kilogram
µg/L	microgram(s) per liter
µg/m <sup>3</sup>	microgram(s) per cubic meter
µm	micrometer(s)
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDNR	Missouri Department of Natural Resources
mg/L	milligram(s) per liter
mV	millivolt(s)
ORP	oxidation-reduction potential
psi	pound(s) per square inch
RI/FS	remedial investigation/feasibility study
RSL	regional screening level
USDA	U.S. Department of Agriculture
VOC	volatile organic compound
ZVI	zero-valent iron

## Final Work Plan: ISCR Pilot Test at Montgomery City, Missouri

### 1 Introduction

This document presents a *Work Plan* for field-scale pilot testing of an *in situ* chemical reduction (ISCR) technology for the treatment of carbon tetrachloride contamination identified in soils and groundwater at the site of the grain storage facility formerly operated by the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) in Montgomery City, Missouri. The pilot test is recommended to support the identification and evaluation of candidate remedial technologies for possible implementation at the former Montgomery City facility, in the context of the site characterization (remedial investigation/feasibility study [RI/FS]) being conducted by the CCC/USDA at this location at the request of the Missouri Department of Natural Resources (MDNR).

This *Work Plan* was developed with consideration for U.S. Environmental Protection Agency (EPA) recommendations for the design and use of treatability studies, as outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988).

#### 1.1 Site Background

From September 1949 until September 1966, the CCC/USDA operated a grain storage facility on property leased from the Montgomery County Fair Society (Figure 1.1). During this time, commercial grain fumigants containing carbon tetrachloride were commonly used by the CCC/USDA to preserve grain in storage. In January 2000, carbon tetrachloride was detected in a soil sample (220  $\mu\text{g}/\text{kg}$ ) and two soil gas samples (58  $\mu\text{g}/\text{m}^3$  and 550  $\mu\text{g}/\text{m}^3$ ) collected at the former facility, as a result of a pre-CERCLIS site screening investigation performed by TN & Associates, Inc., on behalf of EPA Region VII (MDNR 2001).

In June 2001, the MDNR conducted further sampling of the soils and groundwater at the former CCC/USDA facility as part of a preliminary assessment/site inspection. The MDNR (2001) confirmed the presence of carbon tetrachloride (maximum concentration 2,810  $\mu\text{g}/\text{kg}$ ) and chloroform (maximum concentration 82  $\mu\text{g}/\text{kg}$ ) in the soils and also detected carbon tetrachloride and chloroform (42.2  $\mu\text{g}/\text{L}$  and 58.4  $\mu\text{g}/\text{L}$ , respectively) in a groundwater sample collected at the former facility. The maximum carbon tetrachloride concentration identified in

the soils was above the EPA regional screening level (RSL) of 610  $\mu\text{g}/\text{kg}$  for residential soils but below the corresponding RSL for industrial soils (3,000  $\mu\text{g}/\text{kg}$ ). The concentration of carbon tetrachloride in groundwater exceeded the EPA maximum contaminant level (MCL) for this compound (5.0  $\mu\text{g}/\text{L}$ ) in drinking water. The observed concentrations of chloroform in the soils and groundwater were, respectively, below the corresponding RSL values (290  $\mu\text{g}/\text{kg}$  for residential soils and 1,500  $\mu\text{g}/\text{kg}$  for industrial soils) and the maximum contaminant level goal (MCLG; 70  $\mu\text{g}/\text{L}$ ) for this compound.

Because the contamination at Montgomery City might be linked to the past use of carbon tetrachloride-based fumigants at its former grain storage facility, the CCC/USDA is conducting investigations to (1) characterize the sources, extent, and factors controlling the subsurface distribution and movement of carbon tetrachloride; (2) evaluate the health and environmental risks potentially represented by the contamination; and (3) assess the need for possible remediation of the identified contamination, as well as viable candidate alternatives. This work is being performed in accord with the Intergovernmental Agreement established between the Farm Service Agency of the USDA and the MDNR and is being conducted on behalf of the CCC/USDA by the Environmental Science Division of Argonne National Laboratory.

## **1.2 Results of the CCC/USDA Investigation Activities**

The studies at Montgomery City are being implemented in phases, with the approval of the MDNR, so that information obtained and interpretations developed during each incremental stage can be used most effectively to guide subsequent aspects of the program.

### **1.2.1 Phase I and Phase II Investigations**

The initial phase of the Montgomery City investigation was conducted in several field sessions in 2010-2011 (Argonne 2010a; the report of the Phase I investigation has been submitted to the MDNR). The field activities during this portion of the program included the following:

- Location, identification, and sampling of private and public wells and the Montgomery City public water distribution system for analyses for volatile organic compounds (VOCs) and geochemicals.

- Collection of shallow and deeper soils — through the use of direct-push technologies — for lithologic characterization and VOCs analyses.
- Installation of temporary and permanent piezometers (monitoring wells) to facilitate groundwater sampling and measurement of groundwater levels.
- Establishment of a groundwater level monitoring network employing water level recording devices.

With the approval of the CCC/USDA and the MDNR, a second phase of investigation was conducted in spring 2012. The field activities during this phase included the following:

- Use of sonic drilling technologies to collect deep unconsolidated soils and shallow bedrock materials at selected locations, for lithologic characterization and VOCs analyses.
- Installation of additional permanent monitoring wells for groundwater sampling, groundwater level measurement, and vertical and lateral expansion of the Phase I monitoring network.

### **1.2.2 Key Findings**

The key findings of the CCC/USDA investigations are summarized as follows:

- The unconsolidated stratigraphic sequence in the study area is dominated by fine-grained, poorly sorted deposits (ranging from approximately 45 ft to 65 ft thick) interpreted as glacial till containing little coarser-grained material. No laterally continuous coarse-grained intervals were identified in the till; however, occasional small pods, lenses, or thin bands (up to approximately 1-2 ft thick) of relatively clean silt or fine-medium sand were observed, along with more subtle textural variations suggesting the presence of vertical layering in the till that is traceable across the investigation area (Figure 1.2).

- At the base of the till sequence, a heterogeneous “rubble” zone (approximately 24-32 ft thick) consisting of unconsolidated, non-calcareous clay, silt, sand, gravel, and abundant chert clasts and cobbles was identified directly overlying fine-to-coarsely crystalline, fossiliferous, and cherty limestone bedrock. The bedrock limestones generally become more uniform, coarsely grained, fossiliferous, and devoid of chert with depth. No evidence of vertical fracturing was observed in the bedrock (Figure 1.2).
- Saturated conditions were apparent in the unconsolidated sequence and underlying bedrock to approximately 1-8 ft BGL (below ground level). The distribution of groundwater levels suggests the presence of vertical and lateral hydraulic communication throughout the area; however, relatively complex apparent hydraulic gradients control groundwater movement in the till sequence.
- Lateral groundwater flow in the unconsolidated sequence appears to be driven by a relative groundwater high near the southern margin of the investigation area, promoting groundwater movement predominantly to the north-northwest in the upper portion of the till. The influence of the high becomes progressively more localized with depth, resulting in an increasingly semi-radial pattern of lateral hydraulic gradients in the deeper tills, particularly near the remaining rectangular foundations (Figure 1.3).
- The apparent local driving forces for vertical groundwater flow vary across the site and might locally be upward or downward. Alternatively, little to no vertical hydraulic gradient might exist.
- Rates of groundwater recharge to monitoring wells completed in the tills are very slow at most locations. These rates, the fine-grained character of the tills, and the varying hydraulic gradients suggest that the potential rates of groundwater movement and contaminant migration through the fine-grained sediments are limited. Initial groundwater recharge rates for monitoring wells completed in the rubble zone at the base of the till suggest that this interval might have a somewhat greater capacity than the overlying tills for transmittal of groundwater. The availability of groundwater from the bedrock limestones

is variable (with short-term production tests yielding  $< 0.25$  gpm to approximately 2 gpm) and appears to be associated primarily with sporadic, localized occurrences of thin, clayey seams in the upper, cherty portion of the bedrock limestone profile.

- The surficial soil and subsurface soil (vadose) zones, as defined by the MDNR (2006), are together relatively thin ( $\leq 8$  ft) or absent. Carbon tetrachloride detected in soils deeper than 8 ft BGL might therefore be associated with both solid soil particles and pore water. With only one exception, no carbon tetrachloride concentrations above  $10 \mu\text{g}/\text{kg}$  were detected at 4 ft BGL.
- Three hot-spot areas for carbon tetrachloride were identified, as follows:
  - The most prominent hot spot, immediately west and northwest of the rectangular foundations (near SB01-SB41-SB46-SB47; Figure 1.4), which has the vertical profile of a source area for contamination in groundwater.
  - A hot spot in the southern portion of the former array of round grain bins (at SB17; Figure 1.4) that also has the vertical profile characteristics of a source area.
  - An apparent third hot spot identified only in soils  $> 28$  ft BGL, approximately 70 ft east-northeast of the rectangular foundations (at boring SB50; Figure 1.4). This hot spot lacks the vertical profile of a source area.
- The distribution of carbon tetrachloride in groundwater in the upper portion of the till sequence (stratigraphic Unit 1 and the upper portion of Unit 2; Figure 1.2) generally coincides with the footprint of the former CCC/USDA facility. Carbon tetrachloride concentrations above the MCL ( $5.0 \mu\text{g}/\text{L}$ ) were detected at most of the locations sampled within this footprint or immediately northwest of the rectangular foundations (Figure 1.5).
- Soil analyses indicate little to no horizontal contaminant migration in stratigraphic Unit 3, because of its relatively uniform, generally fine-grained

character (Figure 1.2). At least locally, however, Unit 3 does not preclude vertical groundwater and contaminant migration between Units 2 and 4.

- The carbon tetrachloride distributions in groundwater in the intermediate and lower portions of the till complex (in stratigraphic Units 2 and 4; Figure 1.2) are similar to that observed in the upper interval; however, the distribution widens to the northeast in the intermediate interval and to both the northeast and southeast in the lower interval (Figures 1.6 and 1.7).
- The highest concentrations of carbon tetrachloride in groundwater, 6,226-10,616 µg/L, were identified in the northwestern hot-spot area at locations SB41 and SB01, in stratigraphic Unit 2 (Figure 1.6).
- Pervasive, highly oxygen-depleted and chemically reducing conditions favorable to the widespread reductive dechlorination of carbon tetrachloride were not identified in the till sequence. Locally, however, such conditions might at times promote limited natural degradation of carbon tetrachloride in groundwater.
- The physical characteristics of the tills suggest that minor fine-scale lithologic variations play a role in groundwater and contaminant migration, as follows:
  - More effective vertical hydraulic communication (relative to other areas) might exist in the hot spot near SB01-SB41-SB46-SB47 (Figure 1.4).
  - Trends in carbon tetrachloride concentrations and groundwater levels suggest preferred lateral migration pathways to the northeast in the intermediate interval (Figure 1.6) and to the northeast and southeast in the lower interval (Figure 1.7), in possible association with localized variations in the horizontal hydraulic conductivities of Units 2 and 4. The observed carbon tetrachloride distributions suggest possible contaminant migration distances of up to approximately 500 ft along these preferred pathways, relative to the apparent contaminant source areas identified northwest of the rectangular foundations (near SB01-SB41-SB46-SB47) and at SB17 (Figure 1.4).

- Limited sampling of groundwater from the basal rubble zone at selected locations (SB56-SB59 in Figure 1.8) indicates that the areal extent of the carbon tetrachloride contamination in this interval is consistent with that observed in the lower portion of the overlying till sequence (Figure 1.7). This observation suggests that lateral migration of carbon tetrachloride in the rubble zone is also limited.
- No carbon tetrachloride was detected in groundwater sampled from the limestones underlying the hot-spot areas identified northwest of the rectangular foundations (near SB01-SB41-SB46-SB47) and at SB17 (Figure 1.9), suggesting that vertical contaminant migration into the shallow bedrock is unlikely.
- The maximum lateral extent of carbon tetrachloride contamination in the groundwater and soils throughout the unconsolidated section is limited to within 100-250 ft of the footprint of the former CCC/USDA facility and the associated concentration hot spots. The identified areas of contamination are therefore confined to the property owned by the Montgomery County Fair Society. Public access to the most contaminated areas on the site is restricted to activities authorized by the Fair Society Board. The most contaminated area is fenced and is not accessible to the public except during authorized activities.

### 1.2.3 Potential Risks

Carbon tetrachloride and chloroform were detected in the soils and groundwater at Montgomery City at levels that exceed applicable EPA RSLs and drinking water standards. The potential risks related to the identified contamination are considered to be as follows:

- No carbon tetrachloride or chloroform concentrations exceeding the RSL values (for residential or industrial soils) for these contaminants in soils were detected in either unsaturated or saturated soils at depths of 8 ft BGL or less, at any locations on the site. The unsaturated and shallow saturated soils therefore pose no unacceptable risks to either visitors or workers at the

fairgrounds property, via the potential inhalation (of particulates), incidental ingestion, or dermal contact pathways.

- The MCL (for carbon tetrachloride) and MCLG (for chloroform) values for groundwater reflect risk associated with the use of contaminated groundwater for domestic purposes, including consumption. The results of the CCC/USDA investigations demonstrate that no residents are currently at risk due to use of the contaminated groundwater identified in the saturated till or rubble units; no private or public wells are located in the identified area or depth interval of groundwater contamination. The units hosting the carbon tetrachloride contamination are further recognized as having little capacity to produce groundwater, and hence they are unlikely to be tapped as a future source of groundwater for domestic or other purposes.<sup>1</sup> No carbon tetrachloride or chloroform was detected in the shallow bedrock limestones directly underlying the most contaminated portions of the till sequence, indicating that the identified contamination poses a minimal risk to the deeper, regional bedrock aquifer units that are recognized in the Montgomery City area. The groundwater in these bedrock units beneath the site is a potential future source of drinking water for this area.
- The concentrations of carbon tetrachloride in groundwater in the shallowest zone penetrated by monitoring wells (< 20 ft BGL; shown in Figure 1.5) might pose a current or potential future risk of vapor intrusion to indoor air. Figure 1.5 illustrates, however, that no enclosed, habitable structures presently exist within 100 ft vertically of the identified groundwater contamination, and only two such structures — the Merchant’s Building and the 4-H Building —

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<sup>1</sup> This conclusion is based on the following site-specific observations: (1) No known active wells in the Montgomery City area are completed in the till complex. (2) All known existing private wells and the Montgomery City municipal wells are completed in the regionally developed, much more prolific, deeper (bedrock) aquifer units that underlie the city. (3) All properties in the vicinity of the former CCC/USDA facility have confirmed access to the public water supply, which is uncontaminated by carbon tetrachloride. (4) The documented rates of groundwater accumulation in monitoring wells completed in the till complex demonstrate that the capacity of these deposits to produce groundwater to wells in the vicinity of the identified contamination is limited. These site-specific observations are consistent with the interpretations presented by the MDNR, Division of Land Survey, pertaining to the more general hydrologic characteristics of the glacial deposits in northeastern Missouri (Miller and Vandike 1997) and by the U.S. Geological Survey in its assessment of the groundwater resources of adjacent Audrain County (Emmett and Imes 1984).

fall within approximately 100 ft laterally (upgradient) of the shallow contaminated groundwater. Analyses of indoor air and sub-slab soil vapor samples have demonstrated that these buildings are not impacted by carbon tetrachloride contamination in the vapor phase.

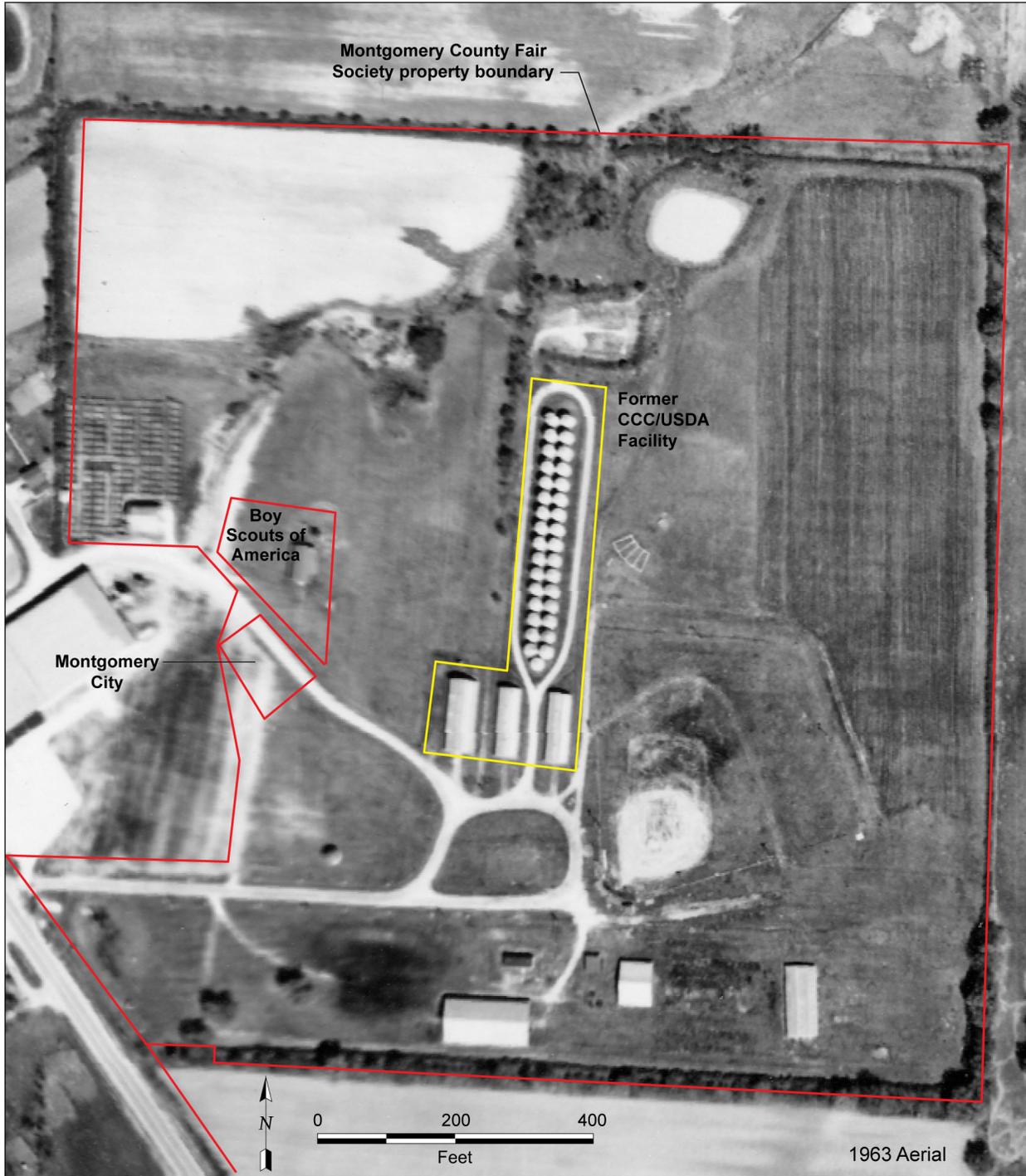


FIGURE 1.1 Maximum development of the former CCC/USDA grain storage facility at Montgomery City, in 1963. Source of photograph: USDA (1963).



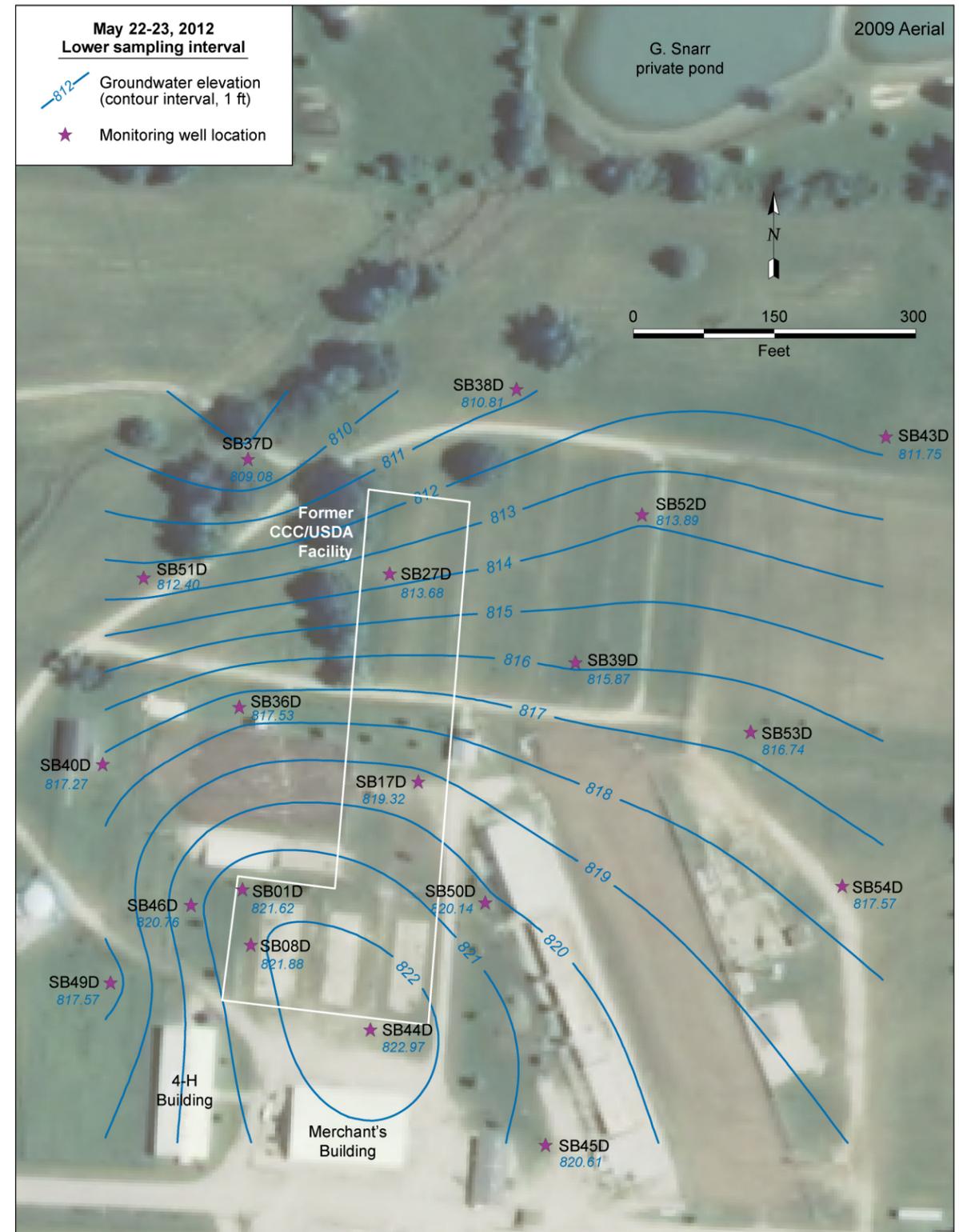


FIGURE 1.3 Interpreted potentiometric surfaces based on groundwater levels measured by hand in monitoring wells completed in the upper sampling interval (left; < 20 ft BGL) and the lower sampling interval (right; > 40 ft BGL) on May 22-23, 2012.



FIGURE 1.4 Lateral distribution of carbon tetrachloride in deeper soils (> 20 ft BGL), as determined by purge-and-trap analysis. The maximum detected value is shown for each location. Source of photograph: NAIP (2009).

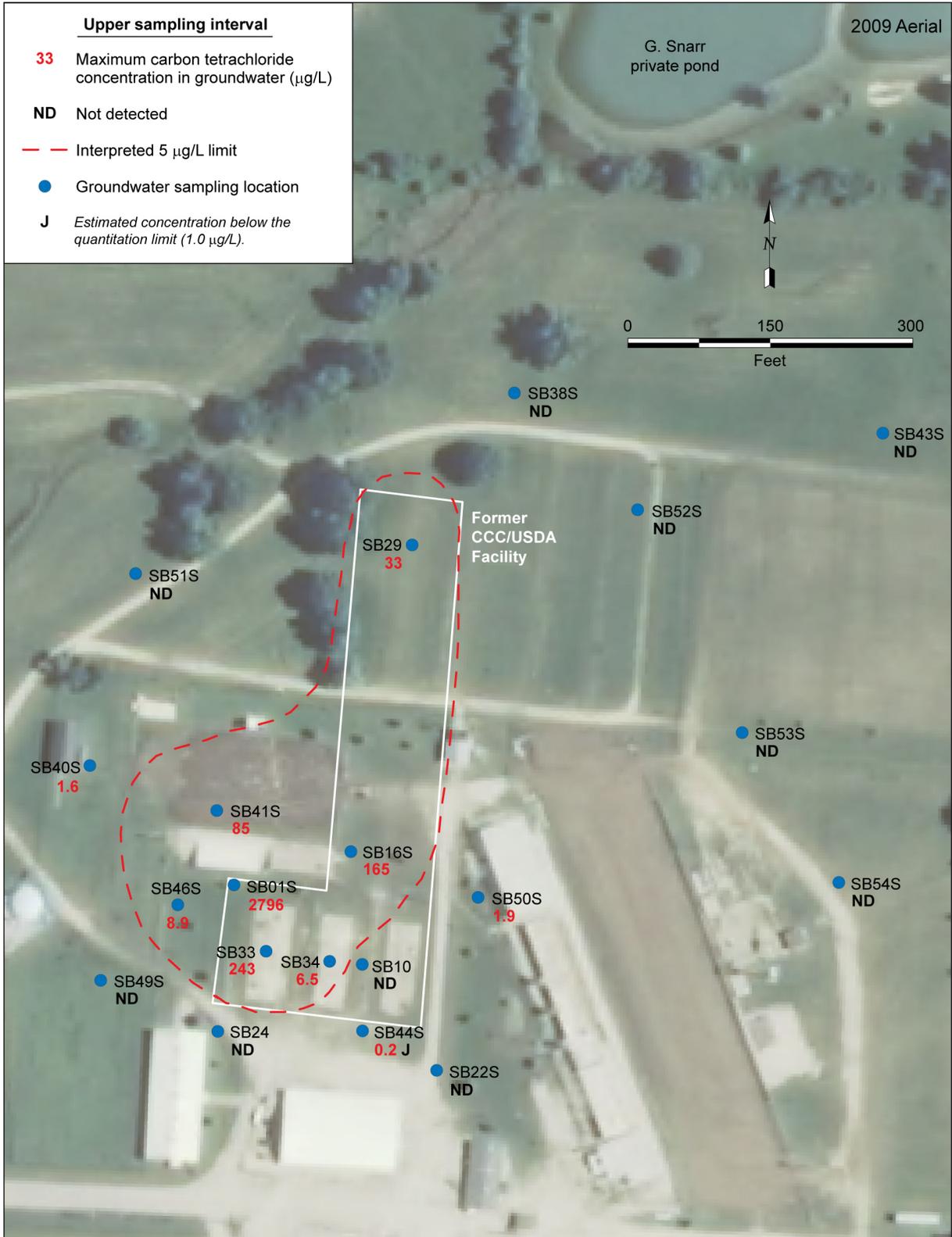


FIGURE 1.5 Maximum carbon tetrachloride concentrations detected in groundwater in the upper sampling interval (< 20 ft BGL). The outline indicates the interpreted 5- $\mu\text{g/L}$  concentration limit. Source of photograph: NAIP (2009).

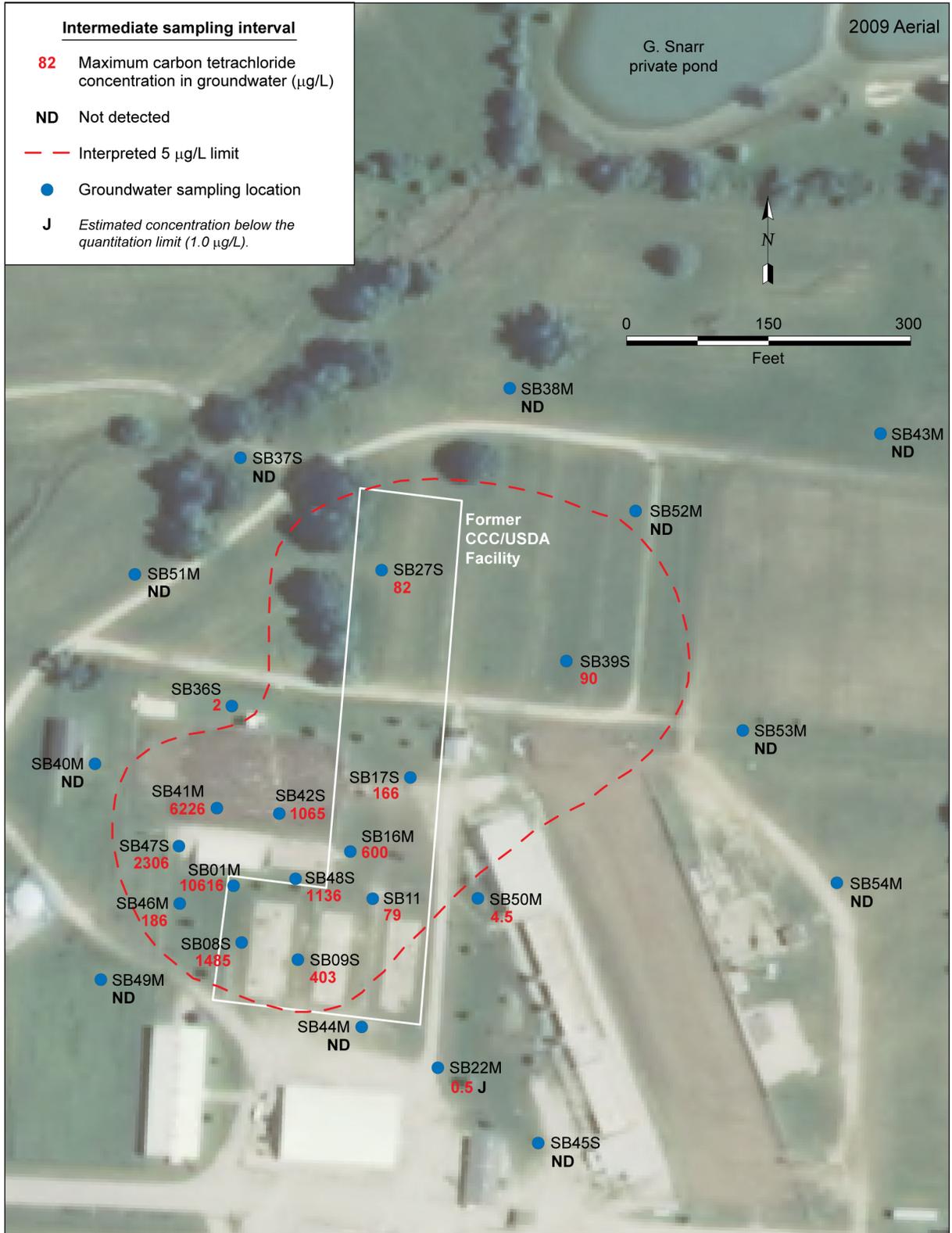


FIGURE 1.6 Maximum carbon tetrachloride concentrations detected in groundwater in the intermediate sampling interval (20-30 ft BGL). The outline indicates the interpreted 5- $\mu\text{g/L}$  concentration limit. Source of photograph: NAIP (2009).

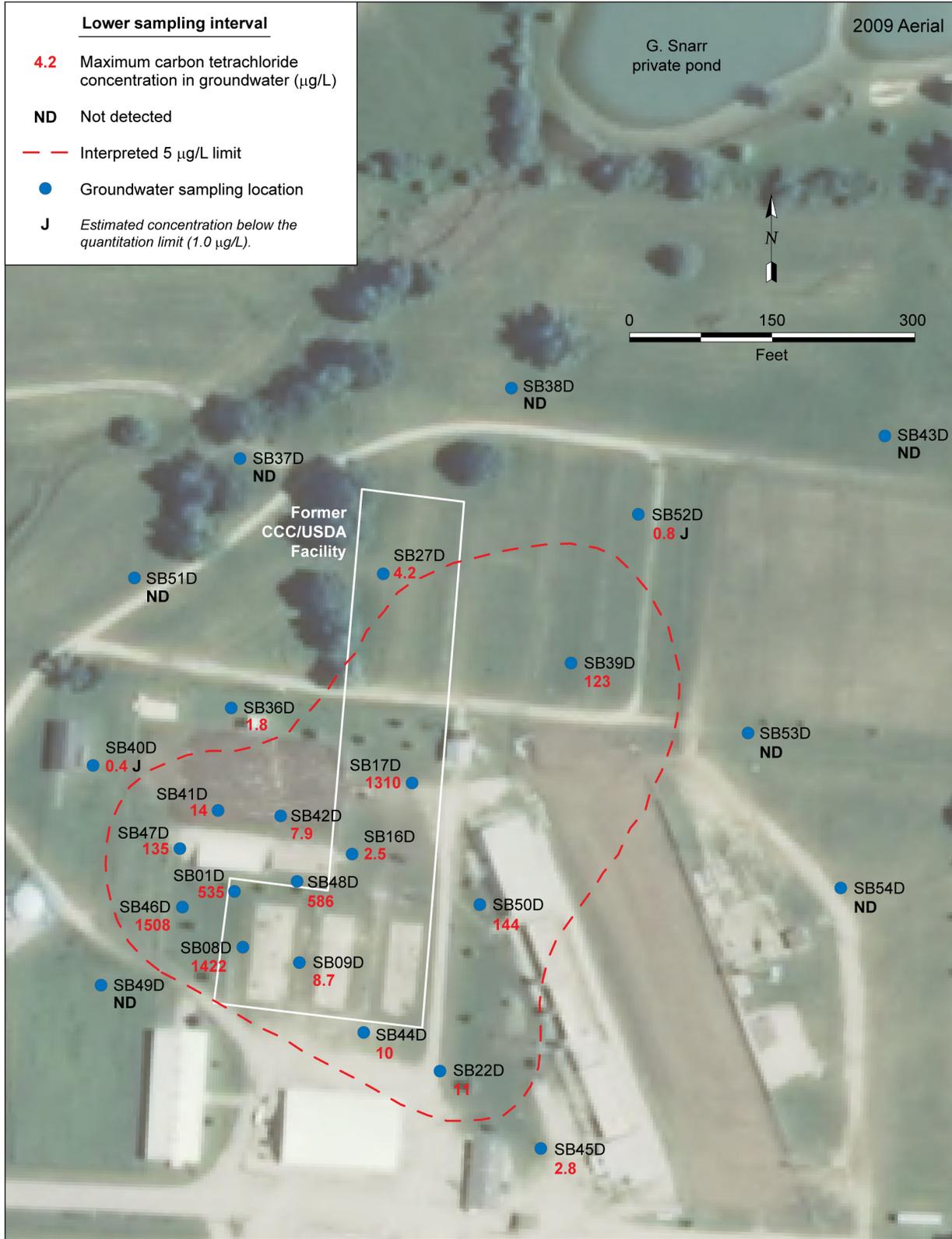


FIGURE 1.7 Maximum carbon tetrachloride concentrations detected in groundwater in the lower sampling interval ( $> 40$  ft BGL). The outline indicates the interpreted 5- $\mu\text{g/L}$  concentration limit. Source of photograph: NAIP (2009).

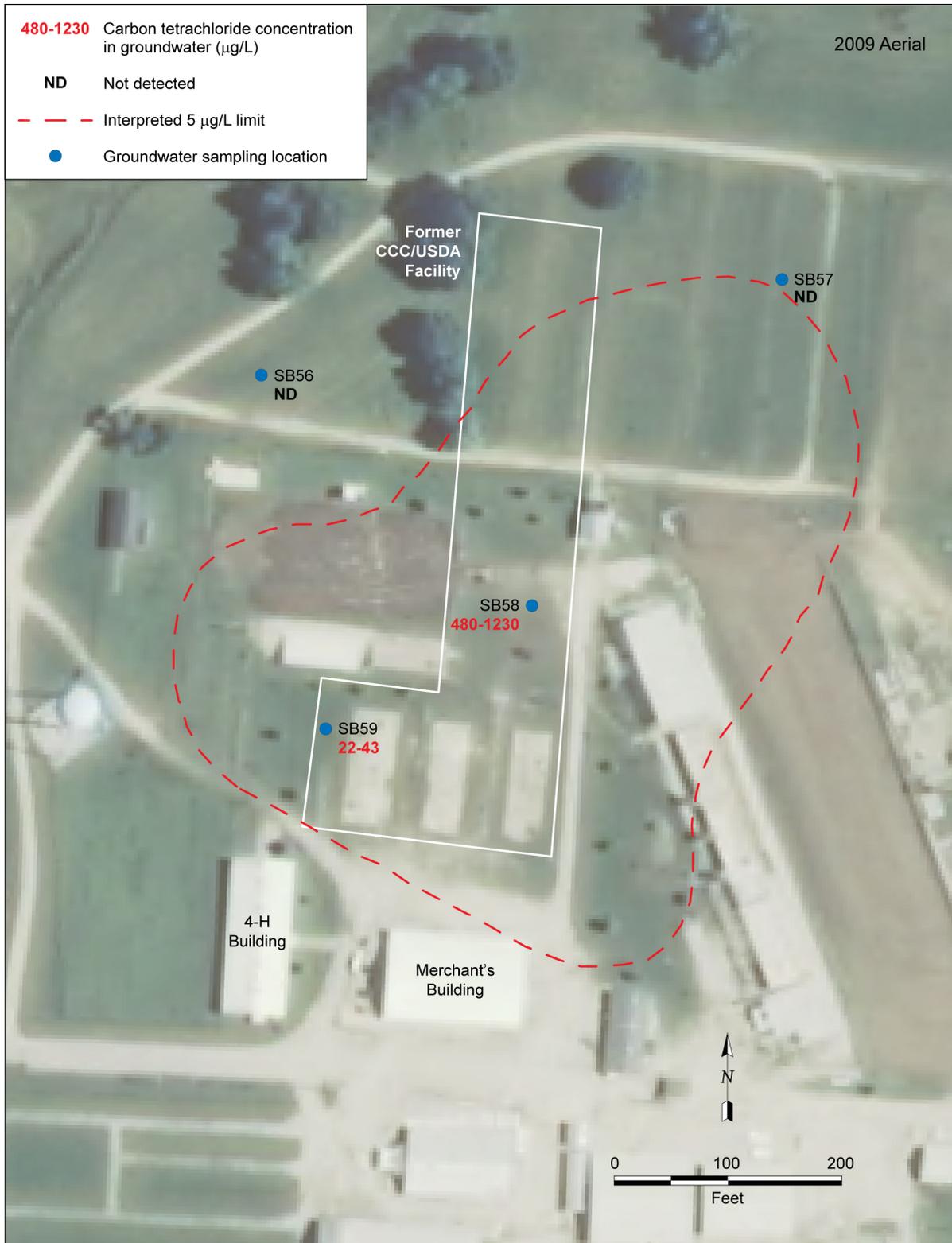


FIGURE 1.8 Carbon tetrachloride concentrations detected in groundwater in monitoring wells completed in the rubble zone overlying the bedrock at the base of the till sequence. The outline indicates the interpreted 5- $\mu\text{g/L}$  concentration limit in the lower monitoring interval (> 40 ft BGL). Source of photograph: NAIP (2009).



FIGURE 1.9 Carbon tetrachloride concentrations detected in groundwater in monitoring wells completed in the Burlington limestone. The outline indicates the interpreted 5-µg/L concentration limit in the lower monitoring interval (> 40 ft BGL). Source of photograph: NAIP (2009).

## 2 Overview of the Recommended Pilot Test

The CCC/USDA is recommending an initial field-scale pilot test of a commercially available ISCR treatment technology, to assess the efficacy of this approach for potential remediation of the soil and groundwater at the Montgomery City site. The specific technical objectives of the test and a synopsis of the program are presented below.

### 2.1 Pilot Test Objectives

The specific technical objectives of the test are to evaluate the ISCR approach in terms of the following criteria:

- *Implementability* — To identify and evaluate any potential technical or logistic concerns associated with the implementation of ISCR technology under the site-specific lithologic and hydrologic conditions at Montgomery City.
- *Effectiveness* — To determine the ability of this technology to effectively address the levels of contamination identified in the soils and groundwater at this site.
- *Viability* — To test the ISCR approach (using the EHC<sup>®</sup> material developed by the Adventus Group) as a potential remedial technology for this site, as well as potentially at other former CCC/USDA sites in Missouri that might have similar hydrogeologic characteristics, geochemical features, and remedial requirements.

### 2.2 Synopsis of the Field Testing Program

With the approval of the Kansas Department of Health and Environment (KDHE), the CCC/USDA and Argonne pilot-tested the use of the EHC material for the *in situ* treatment of carbon tetrachloride in relatively fine-grained sediments at the former CCC/USDA facility in Centralia, Kansas (Argonne 2009). The EHC material is currently marketed by FMC Environmental Solutions, Philadelphia, Pennsylvania (<http://environmental.fmc.com/solutions/soil-ground-remediation/ehc-iscr-reagent/>).

The EHC material is a proprietary mixture of slow-release, food-grade organic carbon and zero-valent iron (ZVI) that is capable of inducing ISCR conditions. When introduced into saturated soils, the material is designed to create highly chemically reducing, oxygen-depleted conditions that will foster both inorganic and biologically mediated reductive dechlorination of carbon tetrachloride and chloroform.

The pilot test of the EHC material at the former CCC/USDA facility in Centralia, Kansas, encountered hydrogeologic and contaminant conditions roughly similar to those at Montgomery City. The identified characteristics of the Centralia site that mirror those encountered at Montgomery City include the following:

- In the immediate vicinity of the pilot test area, the stratigraphic sequence that hosts the contaminated saturated zone at Centralia is dominated by silty-clayey till, which overlies silty-clays to clayey-silts containing discontinuous, thin intervals of poorly sorted sand.
- Depths to groundwater in the vicinity of the injection field at Centralia generally range from 15 ft to 20 ft BGL. The depth interval targeted for ISCR treatment in these materials ranged from either (1) 20 ft to 60 ft BGL or (2) 40 ft to 60 ft BGL, depending on the specific location in the injection field.
- Groundwater levels across the Centralia site have remained relatively stable throughout Argonne's period of observation (2005 to date) and show little response to individual rainfall events or seasonal rainfall patterns.
- Extended groundwater sampling and monitoring demonstrated that the migration rates of the groundwater and carbon tetrachloride contamination at Centralia are extremely slow. The presently identified contaminant distribution is restricted to within approximately 100 ft of the footprint of the former grain storage structures.
- Initial carbon tetrachloride concentrations exceeding 2,000 µg/L were identified at Centralia in the area targeted for testing of the ISCR methodology.

- An evaluation of contaminant data and selected geochemical parameters for the groundwater at Centralia, in accord with EPA (1998) protocols, suggested a limited, potentially localized capacity for natural reductive dechlorination of carbon tetrachloride at this site. Pervasive conditions favorable to this process were not identified, however, throughout the saturated deposits.

To date, the experience at Centralia (Argonne 2009; Alvarado et al. 2010; Yan et al. 2010) indicates an effective lifetime for the EHC material of at least four years after injection. The EHC material is discussed further in Section 3.

The pilot test at Montgomery City will be implemented by injecting the EHC material into contaminated soils and groundwater. The CCC/USDA recommends pilot testing of the ISCR treatment technology in the two contamination hot spots recognized as possible contaminant source areas, near existing borings SB01-SB41-SB46-SB47 and SB17 (Figures 1.4, 1.6, and 1.7). These areas encompass the highest concentrations of carbon tetrachloride and chloroform identified in the soils and groundwater at the former facility, and therefore they will permit rigorous evaluation of the EHC product.

A three-dimensional pattern of injection points targeting the selected areas will be used to distribute the EHC material in the volumes of contaminated saturated sediments. The injections will be performed by a licensed contractor (to be approved by the CCC/USDA and MDNR program managers) in accord with MDNR requirements, under the supervision of FMC and Argonne technical personnel.

The data acquired in the CCC/USDA investigations at Montgomery City (summarized in Section 1.2) provide quantitative information on the distribution and concentrations of carbon tetrachloride and chloroform in the contaminated soils and groundwater, for use in subsequent evaluation of the ISCR treatment effects. After the injection program, the CCC/USDA will sample the treated soils at selected locations in the injection areas and will periodically sample the existing network of groundwater monitoring points in the vicinity of the pilot test area. The purpose will be to document (1) the distribution and potential effects of the EHC material in the treatment areas shortly after the injection program and (2) the changes in contaminant concentrations over time in response to the treatment.

The details of the recommended pilot test program are discussed in Section 3.

### 3 Pilot Test Design

The CCC/USDA investigations have shown that the unconsolidated units hosting the soil and groundwater contamination at Montgomery City consist predominantly of fine-grained glacial tills having low permeabilities. These characteristics limit the movement of groundwater and have restricted the migration of carbon tetrachloride and chloroform to the immediate vicinity of the former CCC/USDA facility.

Pilot testing of the ISCR treatment technology is recommended to address the most contaminated hot-spot areas identified near SB01-SB41-SB46-SB47 and SB17, which are inferred to represent probable contaminant source areas (Figures 1.4, 1.6, and 1.7). The pilot test will (1) determine the site-specific operational techniques required for optimal implementation and monitoring of the ISCR approach and (2) verify the effectiveness of this approach for treatment of the carbon tetrachloride and chloroform contamination at this site.

The design basis, design specifications, and proposed monitoring activities are outlined below. A working schedule for implementation of the injection and monitoring activities will be developed and submitted upon CCC/USDA and MDNR review and approval of the recommended pilot testing program.

#### 3.1 Design Basis

Although ISCR is a relatively new remedial approach, the EHC product has been demonstrated to be effective in the treatment of carbon tetrachloride contamination in groundwater (<http://environmental.fmc.com/solutions/soil-ground-remediation/ehc-iscr-reagent>). The product has been employed by the CCC/USDA for this purpose in a field-scale pilot test initiated, with regulatory approval, in 2007 at the former CCC/USDA grain storage facility in Centralia, Kansas (Argonne 2009; Alvarado et al. 2010; Yan et al. 2010).

The EHC material (which is available in several physical forms to meet site-specific needs) is designed to promote the degradation of carbon tetrachloride and other chlorinated organics through the combined action of both direct inorganic and biologically mediated processes, under highly reducing conditions (with very low oxidation-reduction potential [ORP]). The organic component of the EHC material is hydrophilic and rich in nutrients. In combination with a high surface area, these properties promote the growth of naturally occurring

bacteria in the subsurface. As the bacteria grow, indigenous heterotrophic species deplete the available dissolved oxygen (DO), thereby reducing the local ORP. As the bacteria grow, they also ferment carbon and release volatile fatty acids that diffuse from the fermentation site into the contaminated soil and groundwater and provide electron donors for other bacteria, including dehalogenators and halorespiring species. Small ZVI particles in the EHC material (< 5-45  $\mu\text{m}$ ) provide a large reactive surface area that promotes abiotic dechlorination and causes a further drop in ORP in the treated media due to chemical oxygen scavenging.

FMC reports that ORP values as low as -500 mV can be achieved in the contaminated medium after injection of the EHC material (<http://environmental.fmc.com/solutions/soil-ground-remediation/ehc-iscr-reagent>). Under these conditions (illustrated as reaction pathway B in Figure 3.1), many normally recalcitrant organic compounds, including carbon tetrachloride, can become thermodynamically unstable and be degraded via pathways that produce few, if any, of the undesirable intermediate degradation products (including chloroform, dichloromethane, and chloromethane; shown in pathway A of Figure 3.1) that are generated as a result of progressive reductive dechlorination under the less extreme conditions typically encountered in more naturally reducing environments. Enhanced degradation of the intermediate compounds illustrated in pathway A is also promoted by the extremely reducing conditions created by the EHC material. Information provided by FMC (Mueller 2012b) indicates that the only additional expected by-products resulting from the application of EHC as recommended are hydrogen, dissolved organic carbon, and methane. The produced hydrogen could serve as an energy source for microbial processes.

Research conducted by Adventus, the developer of EHC (Mueller 2012b) and information reported by others (Texas A&M 2012) indicate that mobilization of trace metals is not expected as a response to EHC injection. Specific factors supporting this interpretation include the following:

- Application of the EHC amendment does not result in acidification of the groundwater. The introduction of a carbon source in conjunction with ZVI results in a well-buffered system that should maintain the pH near its initial natural value.
- Under the highly reducing conditions generated by the EHC amendment, oxidized species that might be present — such as sulfate, nitrate, iron ( $\text{Fe}^{3+}$ )

oxides, and trace metals such as arsenic that are commonly associated with the iron oxides — are reduced. Under these conditions, in the presence of ZVI/Fe<sup>2+</sup> and sulfide, many heavy metals form immobile precipitates or are coprecipitated or strongly adsorbed (arsenic) via the formation of ferrous sulfide minerals. If required (because high initial metals concentrations or unacceptable mobilization are observed), a modified form of EHC containing a slow-release sulfide (EHC-M) can be employed to enhance the sequestering effect. Conditions necessitating use of the EHC-M material are not expected at Montgomery City, but they will be evaluated as part of the monitoring program outlined in Section 3.3.

- The EHC material is not itself a significant source of trace metals (Mueller 2012b).

Transient increases in the concentrations of dissolved iron and manganese have been observed in response to application of the EHC amendment (Mueller 2012b); however, FMC's experience indicates that the areal and temporal impacts of these increases are typically limited. In light of the relatively small application area proposed for this pilot test and the current lack of evidence that the contaminated glacial deposits are used as a groundwater source, no unacceptable changes in the concentrations of dissolved iron and manganese are anticipated.

A detailed summary of the ISCR pilot test conducted by the CCC/USDA at Centralia and the results of monitoring conducted at the site over the nine months immediately following the test injections has been provided to the MDNR (Argonne 2009). Continued monitoring of the Centralia test area has documented the longevity of the EHC amendments (Argonne 2010b, 2011). These reports of the Centralia pilot test are on a compact disc attached to this *Work Plan*.

Briefly, the results of the Centralia pilot test have demonstrated the following:

- EHC in both slurry form and a more fluid, aqueous variant (originally EHC-A; now identified as EHC-L by FMC) were injected, by using direct-push techniques, into an interval of glacial tills, silts, clays, and sand, approximately 60 ft thick, that hosts the contaminated vadose and saturated zones at Centralia. Injection pressures exceeding 300 psi required to achieve placement of the slurry resulted in frequent emergence of the injected fluid at

- the surface. Emergence of the slurry was randomly observed, and it also occurred at the locations of several pre-existing borings in and near the injection field that acted as conduits for preferential vertical movement of the injected fluids. These conditions did not, however, preclude completion of the planned injection program.
- The ISCR materials initially (within approximately five weeks of injection) generated extremely reducing, oxygen-depleted conditions (with ORP values of -200 mV to -550 mV and DO < 1 mg/L) in the injection field. Less dramatic reductions in DO and ORP were also observed initially at monitoring points outside the treatment area (Figure 3.2).
  - The ORP and DO values have remained consistently lower in the injection field (generally < -100 mV and < 1.0 mg/L, respectively) than at monitoring points outside the injection area, as shown by the most recent (2011) sampling results (Figure 3.3). The extremely low ORP levels observed initially, however, were maintained for only approximately 5-7 weeks after injection. The continuing low DO and ORP levels in the injection area should be conducive to enhanced biodegradation of carbon tetrachloride, but they are not sufficient to promote thermodynamic instability or abiotic breakdown of carbon tetrachloride.
  - A reduction of 96-99% in the levels of carbon tetrachloride in groundwater in the injection area (from concentrations initially > 1,000 µg/L at several locations) was observed within the first 5-7 weeks after injection (Figure 3.4). Decreases in carbon tetrachloride concentrations of approximately 20-70% were also observed at most of the monitoring points within 100 ft of the injection area in this time frame (Figure 3.4 [left and center panels]). Continued monitoring of the groundwater has shown that the carbon tetrachloride concentrations in the injection area have remained at or near those observed immediately following the injection, or have continued to decrease over time (Figure 3.4 [right panel])

- The observations at Centralia are consistent with the predicted active lifetime of one to five years for the EHC material estimated by the manufacturer (Mueller 2012a).

The CCC/USDA investigations indicate that the lithologies and depths of groundwater and soil contamination at Montgomery City are roughly comparable to those at the Centralia test area, although the levels of carbon tetrachloride contamination identified in the primary hot spot at Montgomery City (near SB01-SB41-SB46-SB47) are as much as approximately five times higher than those at Centralia. The investigations further indicate that, at least locally, the conditions in the sediments and groundwater at Montgomery City are potentially conducive to the natural reductive dechlorination of carbon tetrachloride. The proposed ISCR treatment approach is therefore expected to enhance the degradative processes that are already occurring (to a limited degree) at this site. The present results also indicate that the rates of groundwater and contaminant migration at Montgomery City are very slow; hence, significant residence time is expected for the contaminants and the injected amendments in the hot-spot areas targeted for treatment during the pilot test.

## **3.2 Design Specifications**

The design of the proposed Montgomery City pilot test program summarized below was developed as a collaborative effort involving scientific and technical staff of the CCC/USDA, Argonne and FMC. The design is based on the analytical data and the geologic, hydrogeologic, and geochemical interpretations summarized in this document. The design is intended to meet the pilot test objectives outlined in Section 2.1.

### **3.2.1 Pilot Test Treatment Areas**

The areas selected for the field-scale pilot test are focused on two hot-spot areas located (1) near borings SB01-SB41-SB46-SB47 and (2) near boring SB17 (Figure 3.5). These two areas, which reflect the highest concentrations of carbon tetrachloride and chloroform identified in soils and groundwater, are inferred to represent probable source areas for the contamination. As Figure 3.5 shows, the proposed target area near boring SB17 extends southwestward toward SB16, to address the elevated levels of carbon tetrachloride in groundwater also identified near the latter well (at intermediate depths; Figure 1.6).

### 3.2.2 Distribution of Injections Points and Injection Operations

The proposed areal distribution of ISCR injection points is illustrated in Figure 3.6.

A total of 102 injection points is recommended. A lateral spacing of approximately 10 ft between most injection points is indicated, reflecting an anticipated average radius of influence of 5 ft per injection point. The recommended spacing is based on experience of FMC personnel and the prospective contractors with injection of the EHC material at other sites having roughly comparable subsurface characteristics, as well as on experience of the CCC/USDA at the Centralia, Kansas, pilot test site (Argonne 2009). As the injection of EHC material progresses at Montgomery City, this spacing might be modified, if necessary, to ensure that an adequate distribution of material is achieved in the target areas and/or to address any implementation issues that arise during the injection program.

The contractor will accomplish the injections by using direct-push equipment (Geoprobe, cone penetrometer [CPT], or similar) that has been specially adapted to permit the placement of EHC material in slurry form at specific target depths in the subsurface. Injection of the EHC over successive 2- to 3-ft vertical intervals, separated by intervals of similar thickness that will not be injected, is recommended by the manufacturer to maintain control over the injection process and to achieve the required subsurface distribution of the amendments.

The injection program recommended for this site is targeted to result in an increase of only approximately 4.3% in the relative saturation of the available pore space in the injected formation. This value is much lower than the target saturations that might be required for other types of injected amendments, and hence less significant induced pressure build-up in the formation should result from the injection process. The recommended relatively thin vertical target intervals (2-3 ft) and the strategy of injecting alternating intervals will also help to minimize the potential for over-saturation and over-pressurization of the injected zones. Finally, as discussed in Section 1.1, the generally low permeability of the glacial deposits identified at Montgomery City has restricted the lateral migration of carbon tetrachloride (and chloroform) over the lifetime of the contamination to within 100-250 ft of the footprint of the former grain storage structures, and the hot-spot areas targeted for the pilot test lie relatively near the center of the existing contaminant distribution. Consequently, any lateral mobilization that might be promoted by transient pressure effects in the injection field are unlikely to result in significant net expansion of the existing contaminant distribution.

Vertical mobilization of the contaminants or the injected amendments into the deeper bedrock aquifers is not anticipated. The existing site data indicate that the shallow bedrock limestones underlying the pilot test area are generally dense and coarse grained, and they show no evidence of vertical fracture development (Section 1.2.2 and Figure 1.2).

As outlined in Section 1.2.2, the identified concentrations of carbon tetrachloride and chloroform in the soils and groundwater vary vertically in the proposed treatment areas. To accommodate these variations in a logistically reasonable way, injection of the EHC material at each proposed location is recommended in one of two vertical patterns, as follows:

- At 68 injection points (indicated as green circles in Figure 3.6), the EHC material will be injected into 9 intervals spanning the 45-ft depth range from 15 ft to 60 ft BGL.
- At 34 injection points (orange circles in Figure 3.6), the injection will occur into 5 intervals spanning the 20-ft depth range from 15 ft to 35 ft BGL.

The relationship of the proposed vertical injection patterns to the identified contaminant distributions in the target treatment areas is illustrated schematically in Figures 3.7-3.9.

Additional descriptions of the equipment and details of the procedures to be used during injection of the EHC material will be provided by the injection contractor, upon approval by the CCC/USDA and MDNR program managers of the proposed pilot test injection program outlined in this document. A detailed health and safety plan for the injection component of the pilot test will also be provided by the contractor; this plan will meet Argonne standards and will be approved by Argonne.

### **3.2.3 Preparation of the EHC Material**

The approximate volume of soils and groundwater targeted for treatment in the pilot test areas is 371,250 ft<sup>3</sup>. The treatment will be performed with the standard EHC material, which is supplied in a solid, dry powder form. The EHC material will be mixed on-site immediately prior to injection, with uncontaminated (by VOCs) water from the Montgomery City municipal supply system, to form an injection slurry containing approximately 29% solids by weight. The slurry

will be injected, in accord with the procedures outlined in Section 3.2.2, to yield an approximate concentration of EHC in amended groundwater of 0.9 lb/ft<sup>3</sup>, or 0.2% (mass of EHC to total mass of saturated soil treated). The concentrations of EHC proposed for the current test are roughly twice those employed for the Centralia pilot test, to address the higher initial contaminant levels targeted for treatment at Montgomery City.

The material safety data sheet for the EHC material is in Appendix A.

### **3.3 Monitoring of the Pilot Test**

The CCC/USDA will conduct a program of soil and groundwater sampling and analysis as part of the pilot study, to provide a basis for evaluation of (1) the operational procedures and techniques employed for emplacement of the EHC material under the site-specific conditions at Montgomery City and (2) the geochemical effectiveness of the ISCR treatment technology. The primary elements of the monitoring program will be as follows:

- Pre-treatment sampling and analysis of groundwater at selected locations, to supplement the site characterization data obtained during the CCC/USDA investigations (Section 1.2.2).
- Initial post-injection sampling and analysis of soils and groundwater in and near the treated areas, to investigate the distribution of EHC achieved in the subsurface and the short-term geochemical impacts of the EHC amendment in these media.
- Subsequent periodic sampling and analysis of groundwater in and near the injection areas, to document the potential longer-term effects of the ISCR treatment.

The proposed activities and analyses to be conducted during each element of the monitoring program and the recommended time frames for implementation are summarized below. The locations of the proposed monitoring activities are shown in Figure 3.10.

### 3.3.1 Pre-Treatment Baseline Contaminant Distribution in Soil and Groundwater

As summarized in Section 1.2.2, the site characterization efforts in 2010-2012 have provided a detailed picture of the geochemical environment and carbon tetrachloride distribution in both soils and groundwater. These studies have also demonstrated low rates of groundwater movement and contaminant migration in the areas recommended for treatment in the pilot test, indicating that little change in the concentrations and distribution of carbon tetrachloride and chloroform will have occurred since completion of the investigations in spring 2012.

To supplement the data already in hand, groundwater samples will be collected in a suite of 10 existing monitoring wells in and near the proposed injection areas (SB01S/M/D, SB08S/D, SB16S, SB17S/D, SB46S/D; Figure 3.10), immediately before the injection program is implemented. The resulting samples from all wells will be submitted for laboratory analyses for VOCs and dissolved methane, and samples from wells SB01S/M/D will be submitted for laboratory analysis of cations (Al, Ca, Fe, Mg, Mn, K, P, Na, Si, and Zn; EPA Method 6010B) and trace metals (Al, As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mo, Ni, Se, Ag, Tl, V; EPA Method 6020). Samples for analyses of cations and trace metals may also be collected at additional locations among the suite of 10 monitoring wells, subject to the availability of sufficient groundwater. Selected additional parameters (including temperature, conductivity, pH, ORP, DO, and reduced iron [Fe<sup>2+</sup>]) content will be determined in the field in accord with procedures in the *Master Work Plan* (Argonne 2002).

The results of this sampling event, together with the data acquired in 2010-2012, will constitute the baseline data set reflecting pre-treatment subsurface conditions in the pilot test areas. These data will serve as a quantitative basis for subsequent evaluation of the ISCR program impacts.

### 3.3.2 Evaluation of the Injection Process and the Initial Effects on Soil and Groundwater

Experience at the Centralia pilot test location indicates that significant subsurface geochemical responses to the injection of the EHC amendment can be expected in a relatively short time frame after injection. To investigate the potential short-term impact of the EHC injection and the resulting distribution of EHC material in the saturated soils, the following sampling and analyses will be performed *approximately one month after the injection program is completed*:

- The Argonne 22-ton, track-mounted crawler CPT vehicle will be used to collect soil samples for visual examination and VOCs analysis at the seven locations shown in Figure 3.10, as well as samples for total organic carbon analysis at locations and depths to be selected in the field. At each location, soil samples for VOCs analysis will be collected at successive 4-ft intervals from 8 ft to 60 ft BGL (or refusal of the CPT coring device).
- Groundwater samples to be analyzed for VOCs, dissolved methane, cations, trace metals, and selected geochemical parameters will be collected at the 10 monitoring points shown in Figure 3.10, as described in Section 3.3.1.

### **3.3.3 Periodic Groundwater Monitoring during the First Year after Injection**

Periodic groundwater sampling for analysis for VOCs, dissolved methane, cations, trace metals, and selected geochemical parameters, as outlined in Section 3.3.1, will be performed at the 10 monitoring well locations shown in Figure 3.10, approximately two months, four months, six months, nine months, and one year after completion of the EHC injections, to determine and document the effectiveness of the ISCR treatment. Continued monitoring of the treatment areas beyond the initial one-year period may be proposed, if the results of the pilot study provide technical justification, to document the site-specific longevity of the EHC amendment and to further support the RI/FS investigation.

### **3.4 Performance Evaluation of the ISCR Treatment Approach**

The results of the sampling and analysis activities performed under the monitoring program described in Section 3.3 will be compiled and presented to the CCC/USDA and MDNR program managers for review following (1) the first two months after injection, (2) the first six months after the injection, and (3) the recommended initial one-year observation period.

### **3.5 Proposed Schedule**

Implementation of the pilot study is planned for the fall of 2012. A detailed schedule for the implementation will be provided upon review and approval of this *Work Plan* by the CCC/USDA and MDNR program managers.

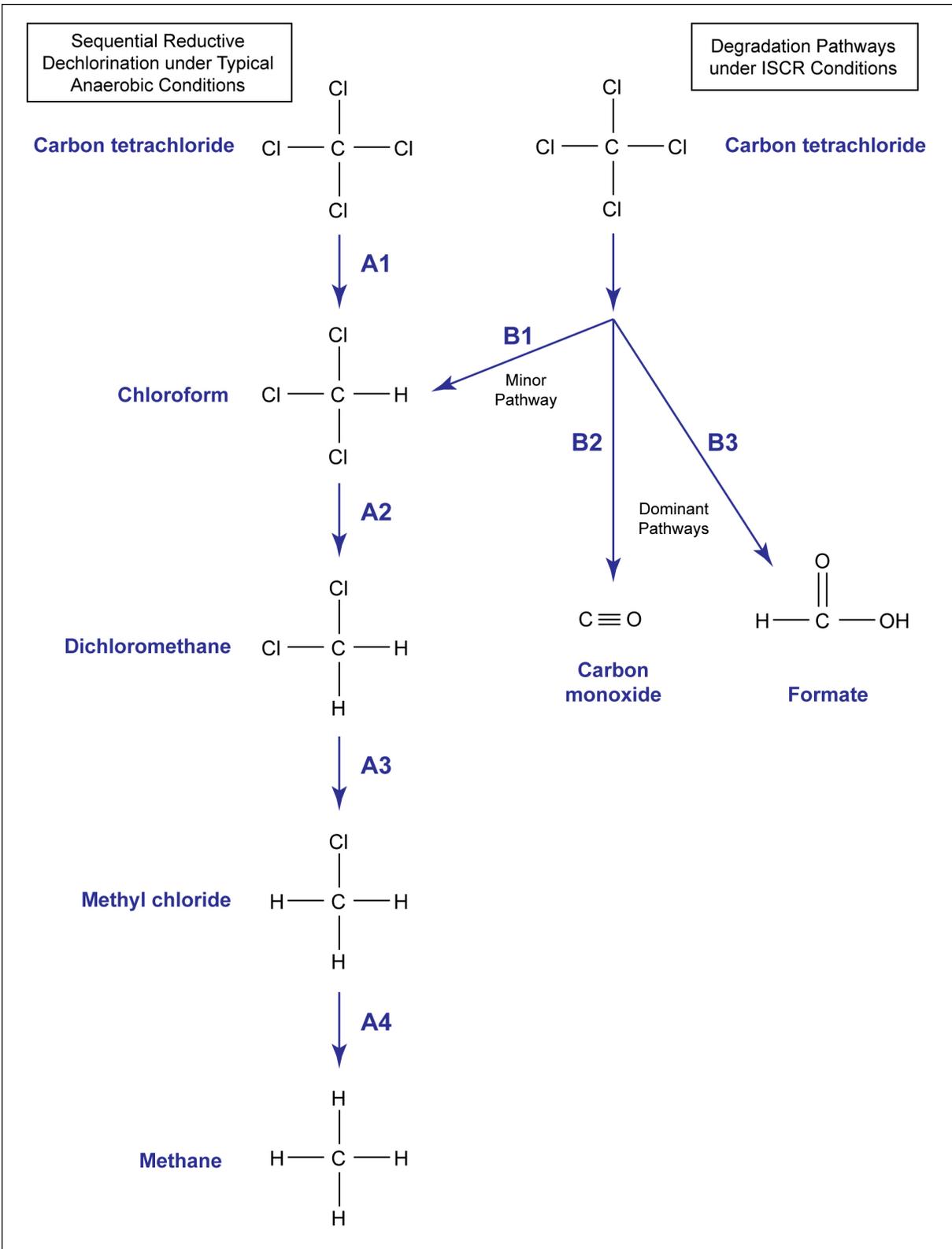


FIGURE 3.1 Schematic representation of reaction pathways for the reductive dechlorination of carbon tetrachloride under possible naturally occurring reducing conditions (left sequence, "A" pathway) and in the presence of the EHC amendment (right sequence, "B" pathway).

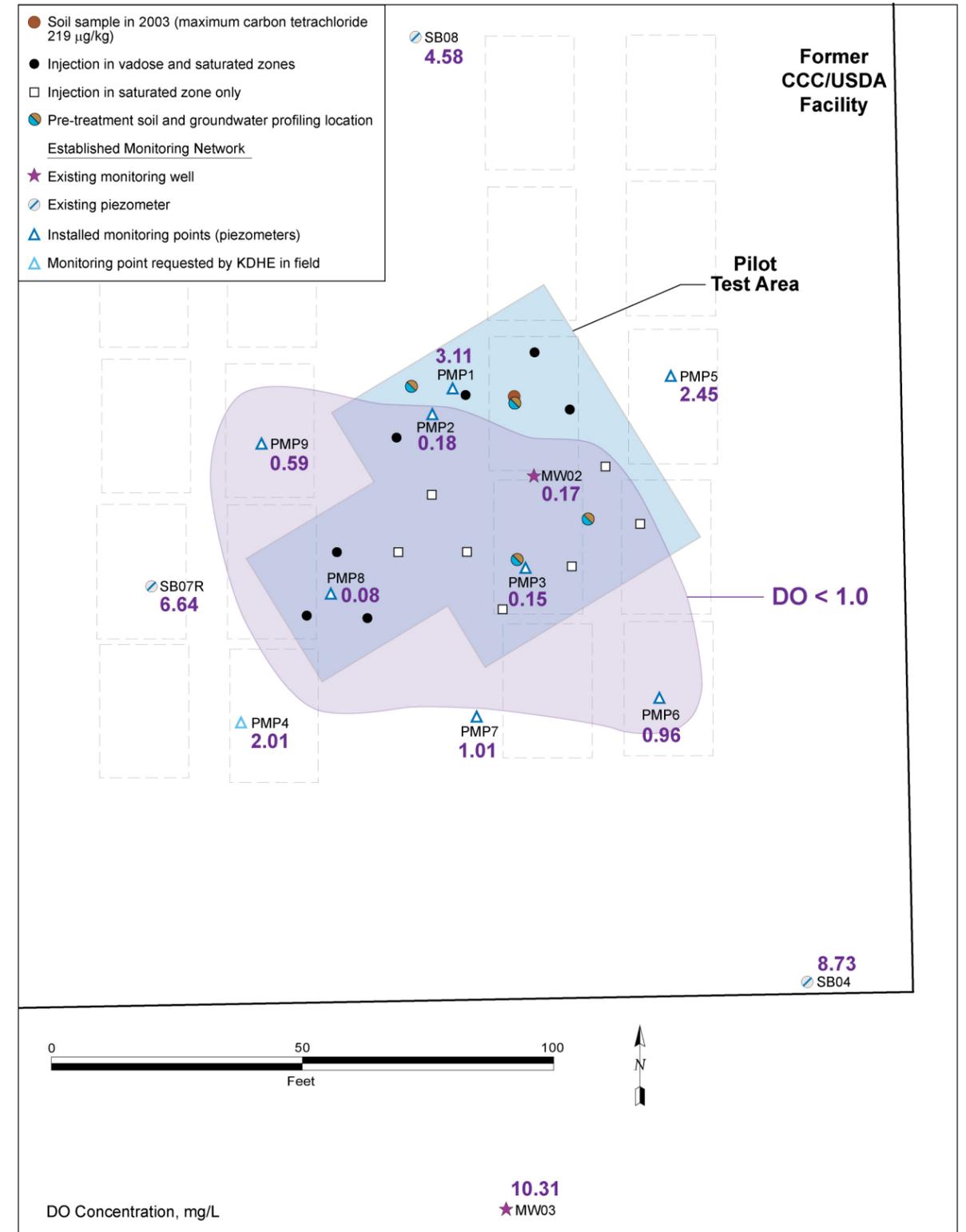
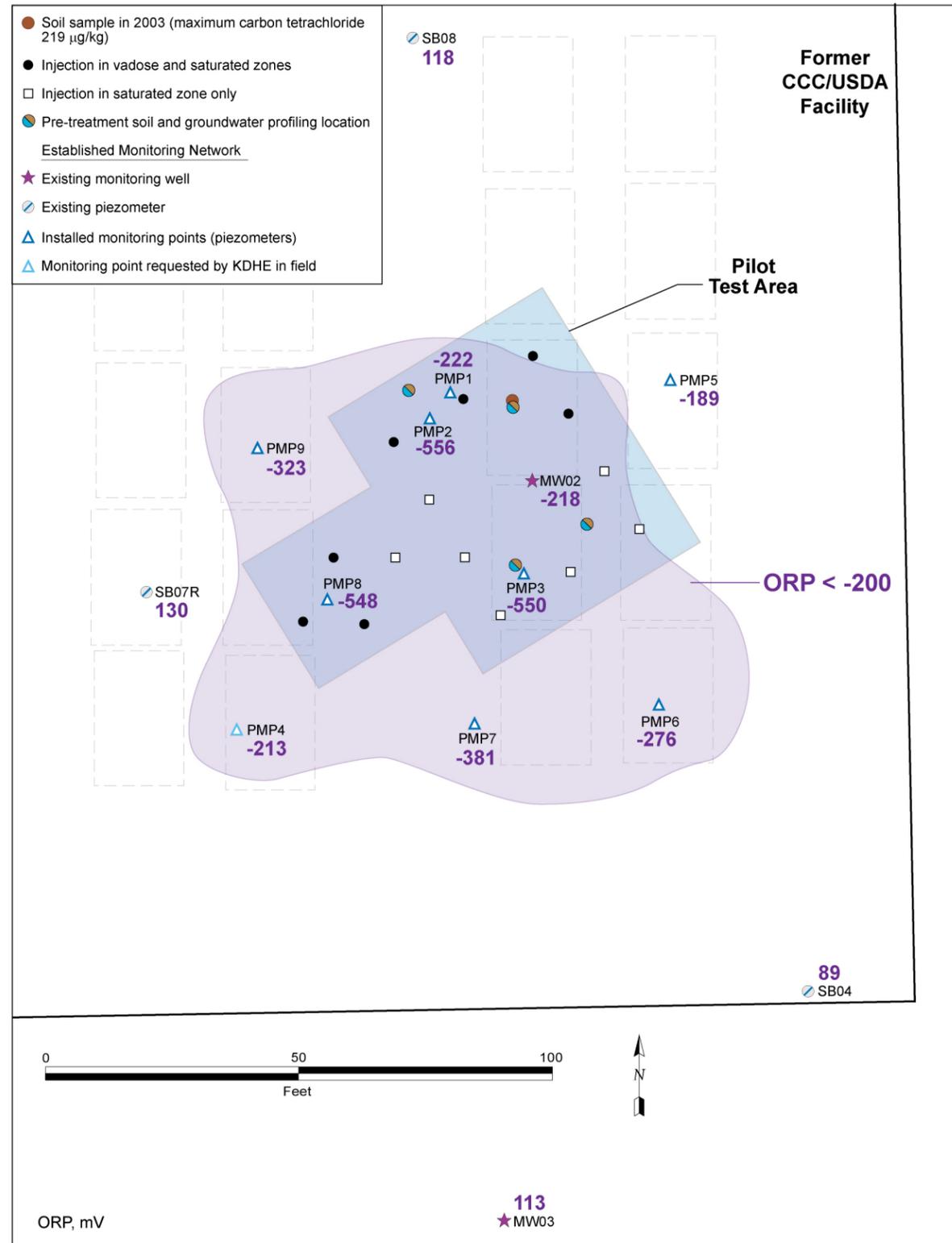


FIGURE 3.2 Oxidation-reduction potentials (left) and dissolved oxygen concentrations (right) in groundwater samples collected in January 2008 at permanent monitoring points in the Centralia, Kansas, pilot test area, approximately five weeks after completion of the injection program in December 2007.

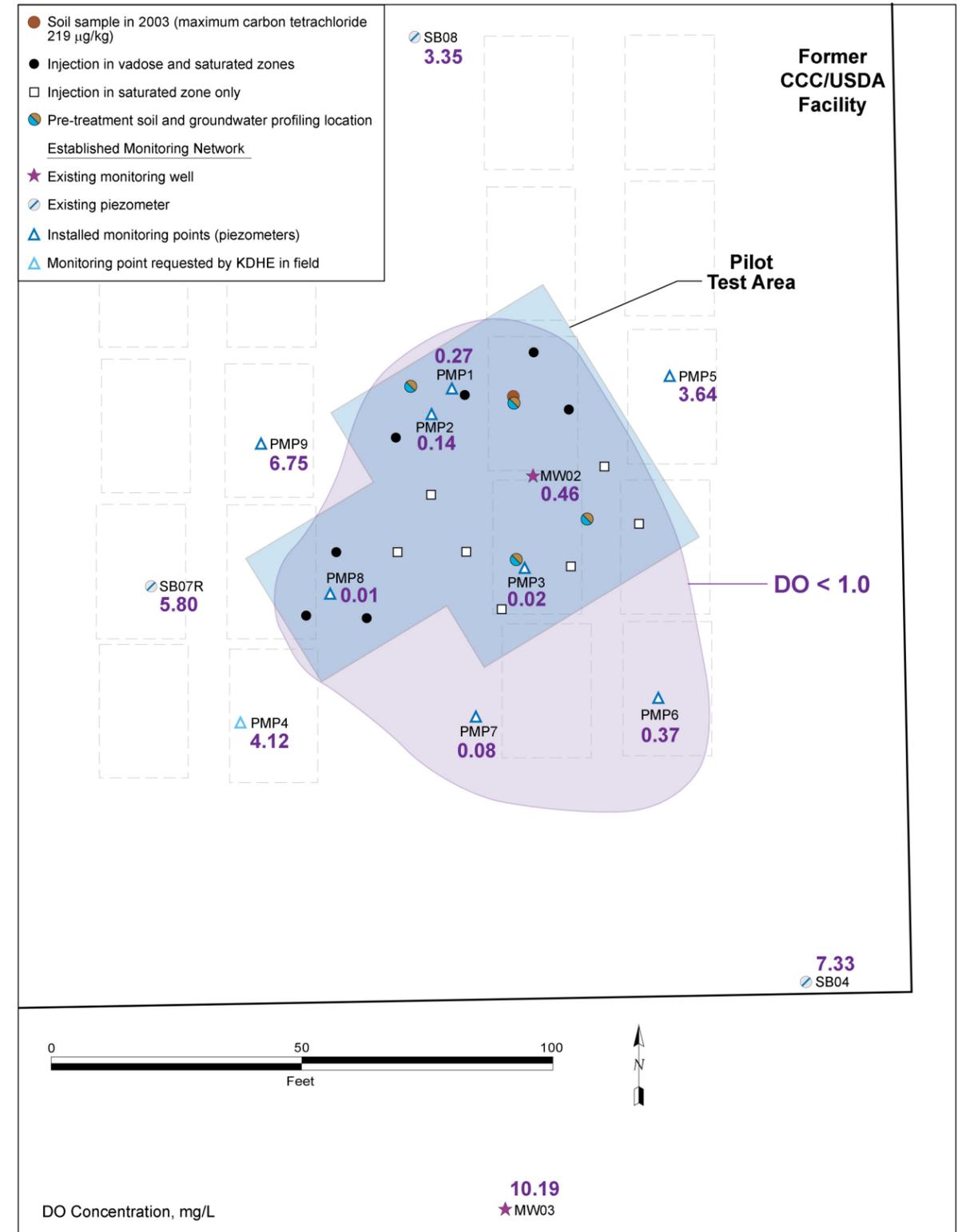
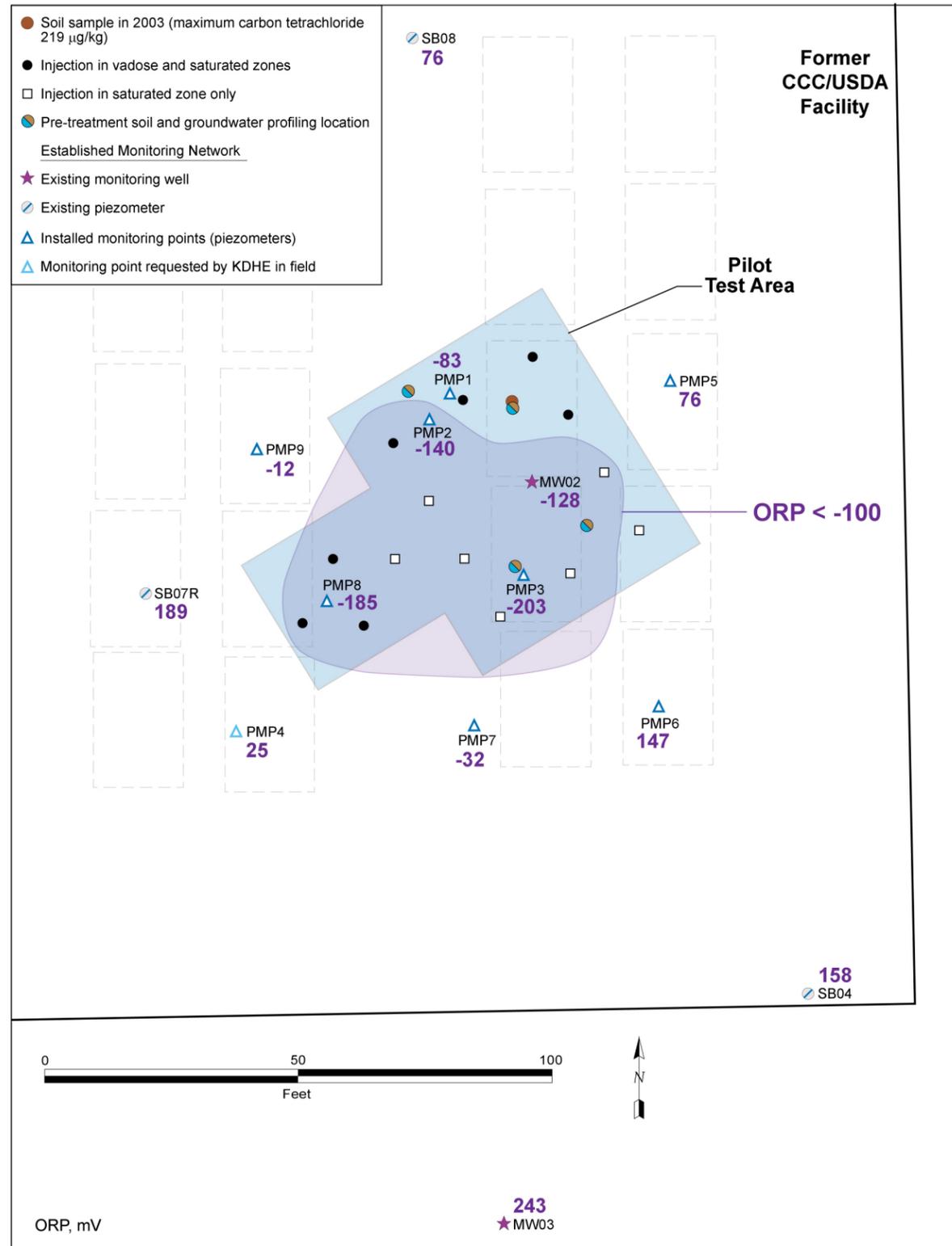


FIGURE 3.3 Oxidation-reduction potentials (left) and dissolved oxygen concentrations (right) in groundwater samples collected in 2011 at permanent monitoring points at the Centralia, Kansas, pilot test area, approximately four years after completion of the injection program in December 2007.



FIGURE 3.4 Carbon tetrachloride concentrations in groundwater samples collected at the Centralia, Kansas, pilot test area at permanent and temporary monitoring points, (left) in December 2007, prior to the injection of EHC at permanent monitoring points; (center) in January 2008, approximately 5-7 weeks after the injection program was completed; and (right) in 2011, four years after completion of the injection program.

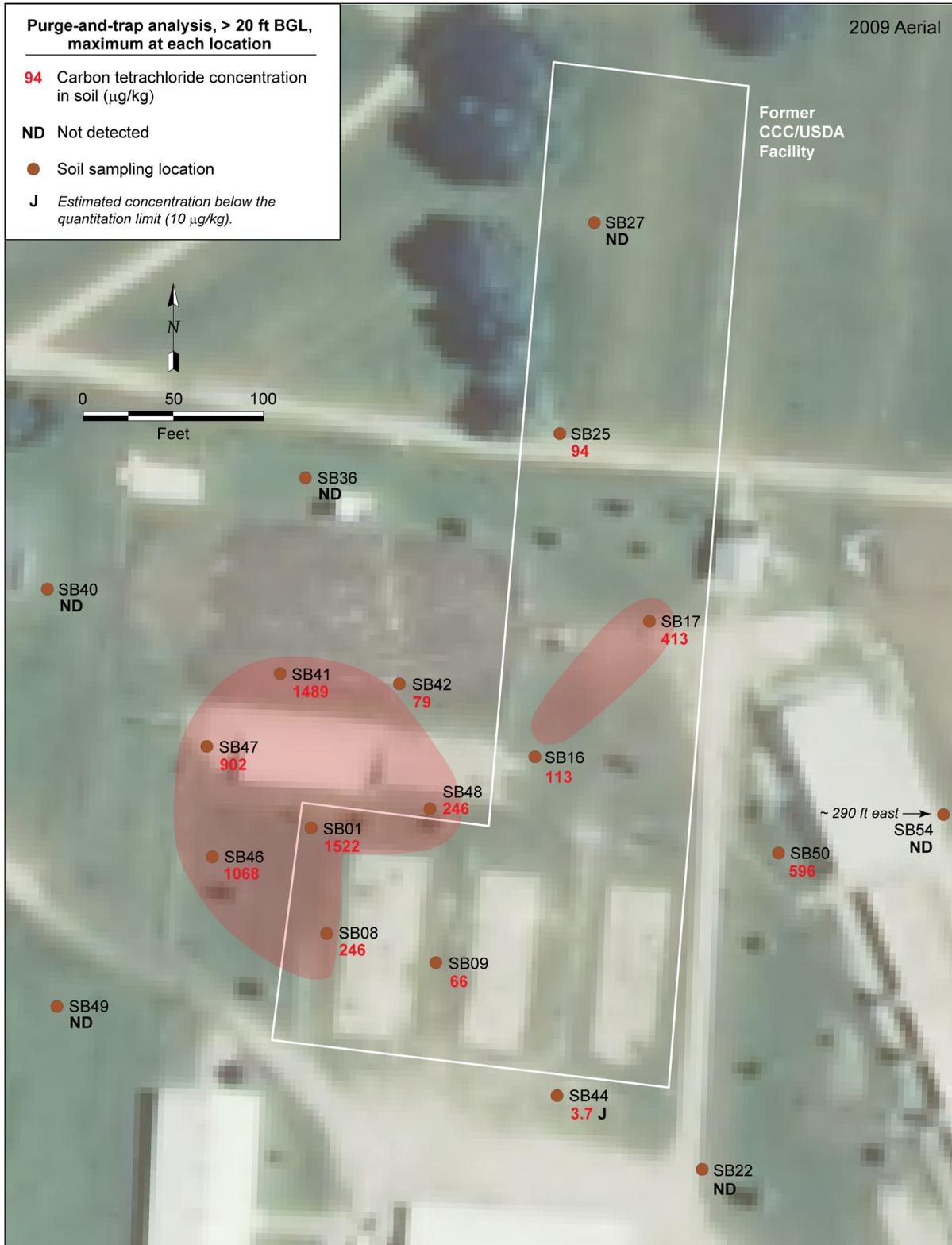


FIGURE 3.5 Lateral distribution of carbon tetrachloride in deeper soils (> 20 ft BGL), as determined by purge-and-trap analysis, and areas targeted for ISCR treatment (red shading) in the proposed pilot test at Montgomery City. The maximum detected value is shown for each location. Source of photograph: NAIP (2009).



FIGURE 3.6 Proposed injection points for the ISCR pilot test. Source of photograph: NAIP (2009).

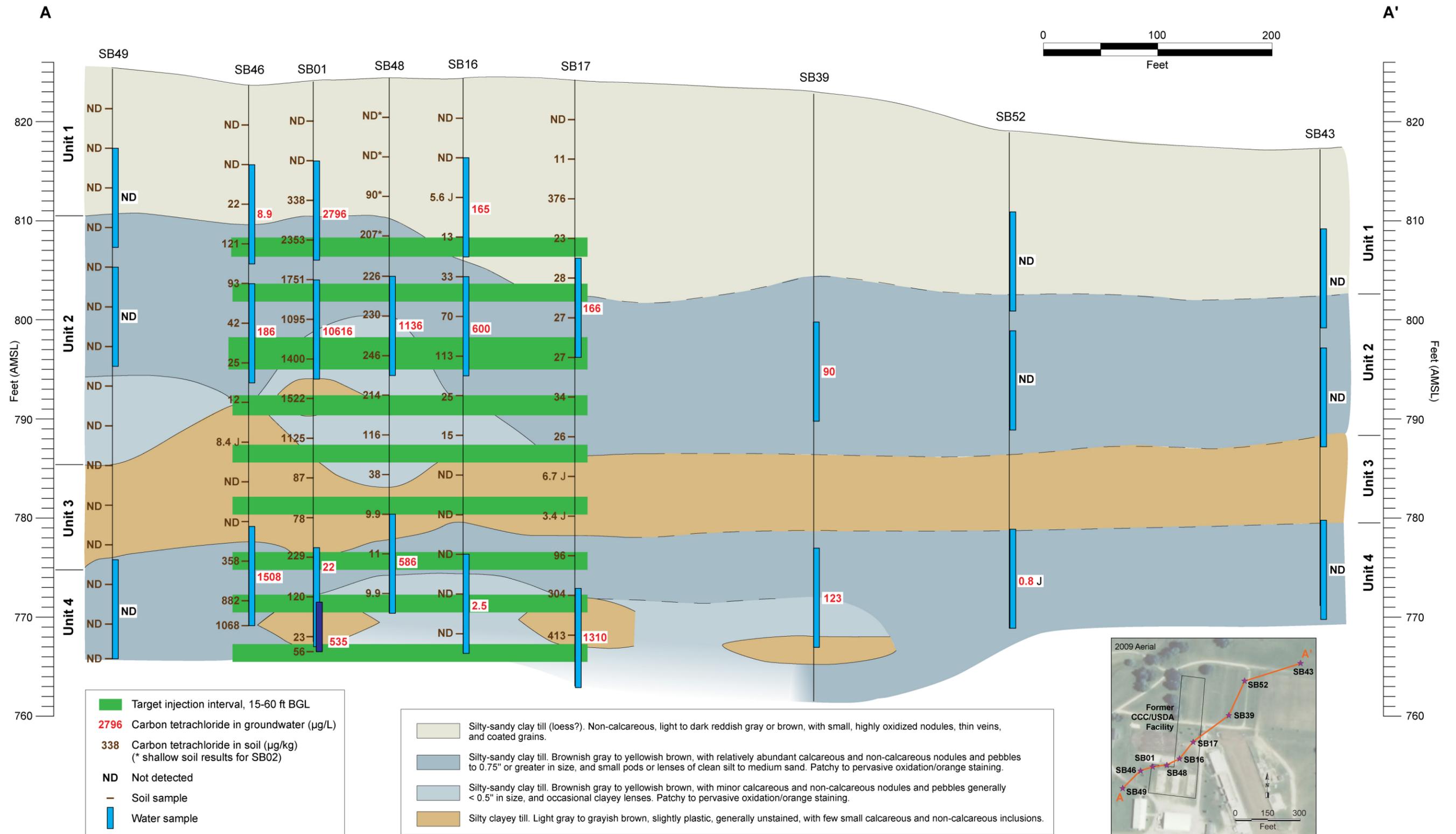


FIGURE 3.7 Southwest-to-northeast hydrogeologic cross section A-A' (vertically exaggerated), showing the distribution of maximum carbon tetrachloride concentrations identified in unconsolidated soils and groundwater and proposed ISCR injection locations. Green bars schematically highlight the spacing of vertical intervals targeted for the injection of ISCR material.

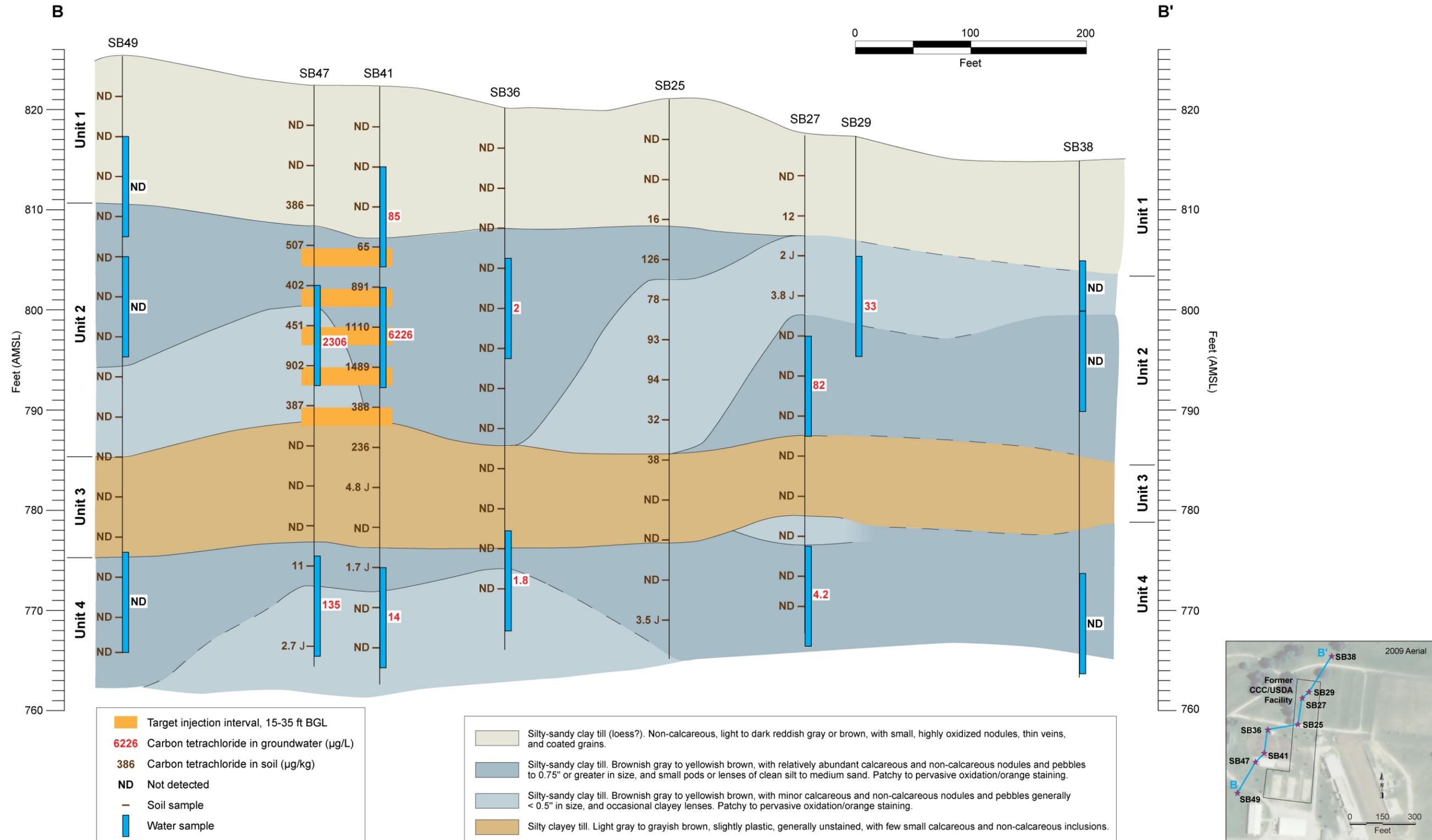


FIGURE 3.8 Southwest-to-northeast hydrogeologic cross section B-B' (vertically exaggerated), showing the distribution of maximum carbon tetrachloride concentrations identified in unconsolidated soils and groundwater and proposed ISCR injection locations. Orange bars schematically highlight the spacing of vertical intervals targeted for the injection of ISCR material.

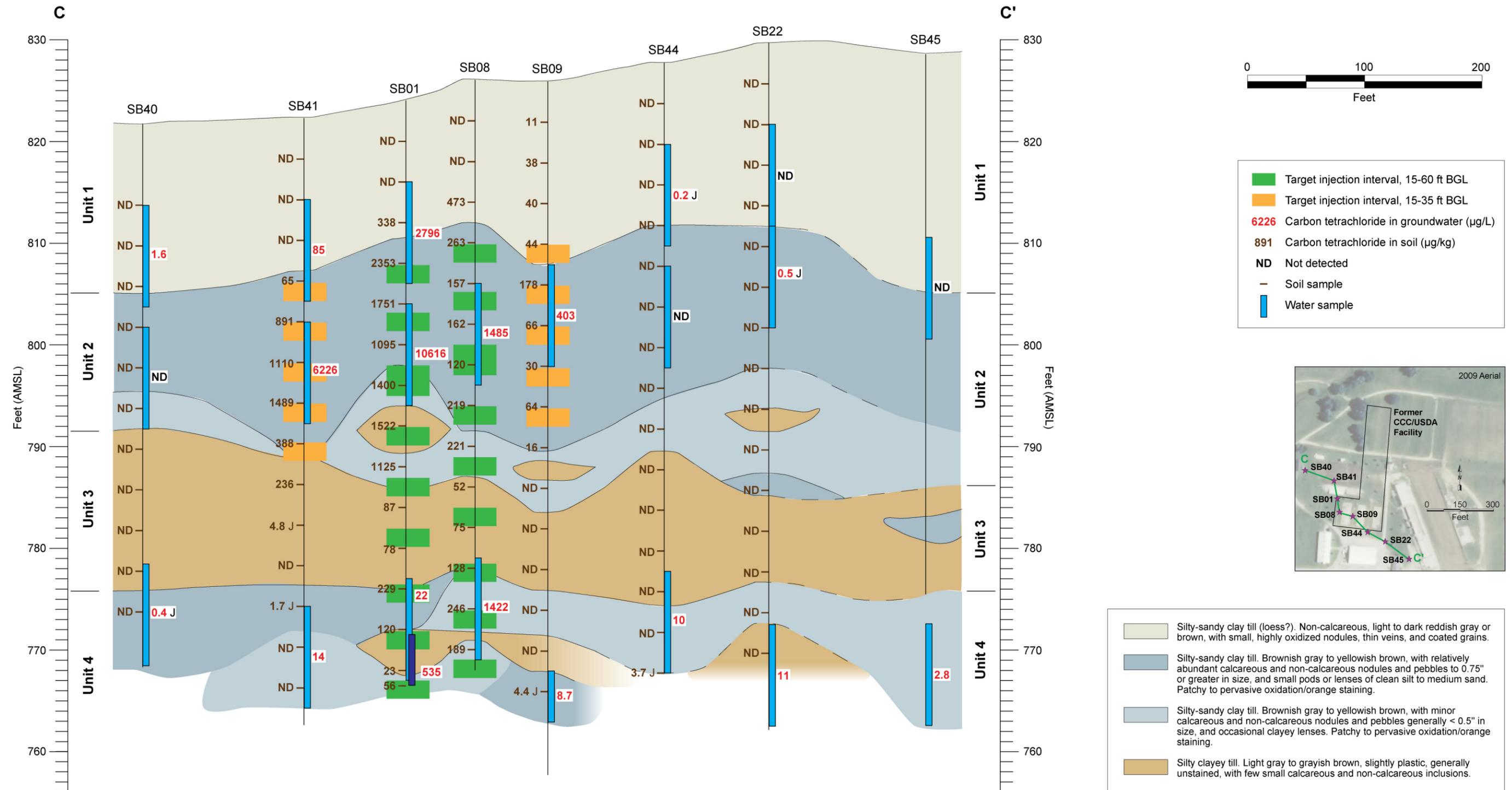


FIGURE 3.9 Northwest-to-southeast hydrogeologic cross section C-C' (vertically exaggerated), showing the distribution of maximum carbon tetrachloride concentrations identified in unconsolidated soils and groundwater and proposed ISCR injection locations. Green and orange bars schematically highlight the spacing of vertical intervals targeted for the injection of ISCR material.

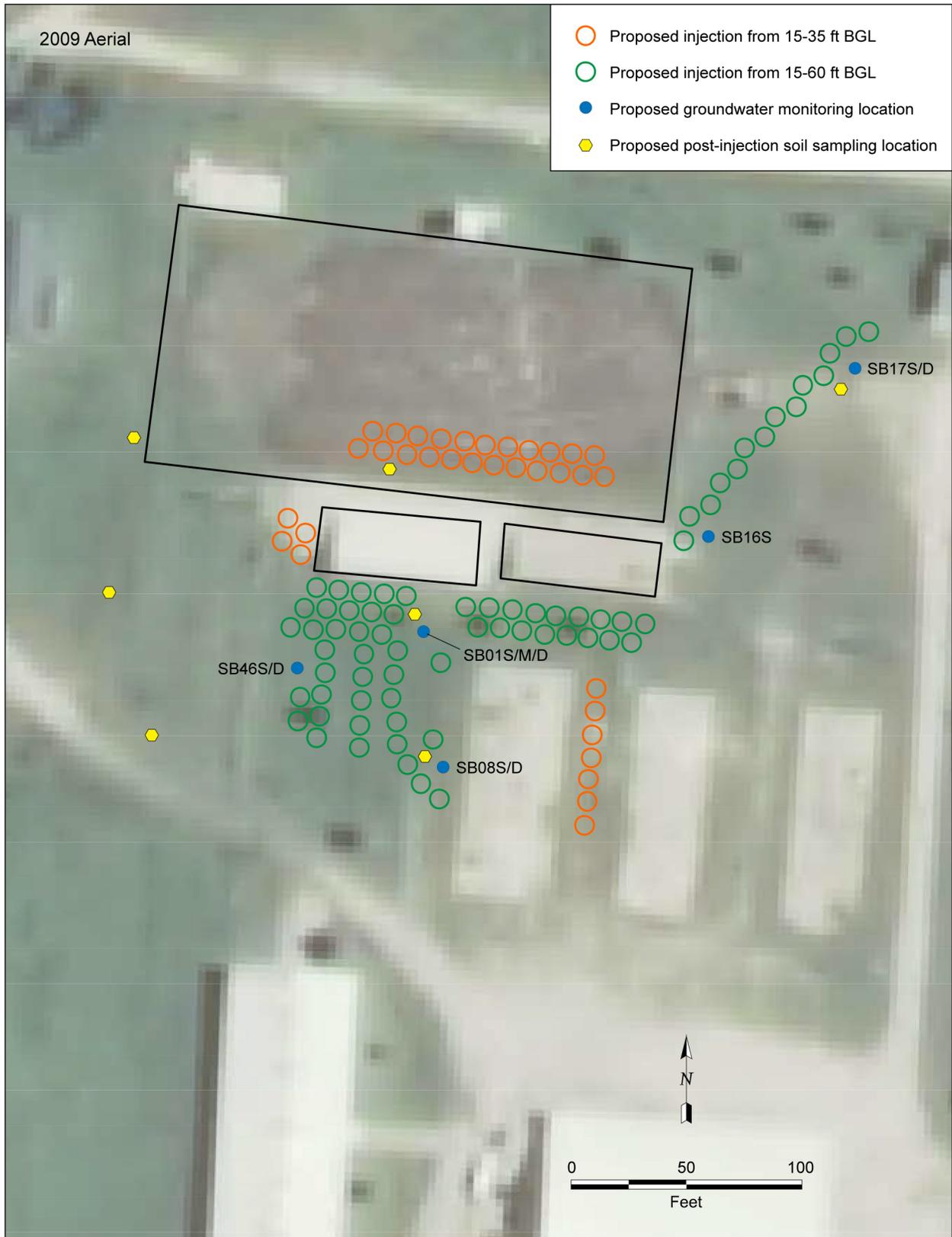


FIGURE 3.10 Proposed monitoring points for the ISCR pilot test. Source of photograph: NAIP (2009).

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**Appendix A:**

**EHC — Material Safety Data Sheet (MSDS)**

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# Material Safety Data Sheet

## EHC®

MSDS #: EHC-C  
Revision Date: 2012-04-30  
Version 1



This MSDS has been prepared to meet U.S. OSHA Hazard Communication Standard 29 CFR 1910.1200 and Canada's Workplace Hazardous Materials Information System (WHMIS) requirements.

### 1. PRODUCT AND COMPANY IDENTIFICATION

<b>Product name</b>	EHC®
<b>Recommended use</b>	Bioremediation product for the remediation of contaminated soil and groundwater only. Not for use in potable drinking water.
<b>Manufacturer</b>	<b>Emergency telephone number</b>
FMC CORPORATION FMC Peroxygens 1735 Market Street Philadelphia, PA 19103 Phone: +1 215/ 299-6000 (General Information) E-Mail: msdsinfo@fmc.com	For leak, fire, spill or accident emergencies, call: +1 703-527-3887 (CHEMTREC) +1 303 / 595 9048 (Medical - Call Collect)

### 2. Hazards identification

#### Emergency Overview

##### CONTAINMENT HAZARD:

Any vessel that contains wet EHC must be vented due to potential pressure build up from fermentation gases

#### Potential health effects

##### Acute Toxicity

###### Eyes

No significant health effects anticipated  
Product dust may cause mechanical eye irritation.

###### Skin

None known .

###### Inhalation

Inhalation of dust in high concentration may cause irritation of respiratory system.

###### Ingestion

Ingestion may cause gastrointestinal irritation, nausea, vomiting and diarrhea.

##### Chronic Toxicity

No known chronic effects of components present at greater than 1%.

### 3. Composition/information on ingredients

#### Ingredients

Chemical Name	CAS-No	Weight %
Iron	7439-89-6	18-48
Organic Amendment	Proprietary	52-82

**4. First aid measures**

<b>Eye contact</b>	In case of contact, immediately flush skin with plenty of water. Get medical attention if irritation develops and persists.
<b>Skin contact</b>	Wash off with soap and water.
<b>Inhalation</b>	Remove person to fresh air. If signs/symptoms continue, get medical attention.
<b>Ingestion</b>	Rinse mouth with water and afterwards drink plenty of water or milk. Call a poison control center or doctor immediately for treatment advice.

**5. Fire-fighting measures**

<b>Flammable properties</b>	Combustible material.
<b>Suitable extinguishing media</b>	Dry chemical, CO <sub>2</sub> , sand, earth, water spray or regular foam.
<b>Explosion Data</b>	
<b>Sensitivity to Mechanical Impact</b>	not applicable
<b>Sensitivity to Static Discharge</b>	not applicable
<b>Specific hazards arising from the chemical</b>	Dry or powdered ingredients are combustible. Dispersal of finely divided dust from products into air may form mixtures that are ignitable and explosive. Minimize airborne dust generation and eliminate sources of ignition.

<b>NFPA</b>	<b>Health Hazard</b> 1	<b>Flammability</b> 1	<b>Stability</b> 0	<b>Special Hazards</b> -
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**NFPA/HMIS Ratings Legend**      Severe = 4; Serious = 3; Moderate = 2; Slight = 1; Minimal = 0

**6. Accidental release measures**

<b>Personal precautions</b>	Avoid dust formation. For personal protection see section 8.
<b>Methods for containment</b>	Cover powder spill with plastic sheet or tarp to minimize spreading and keep powder dry.
<b>Methods for cleaning up</b>	Sweep or vacuum up spillage and return to container.

**7. Handling and storage**

<b>Handling</b>	Minimize dust generation and accumulation. Keep away from open flames, hot surfaces and sources of ignition. Refer to Section 8.
<b>Storage</b>	Keep tightly closed in a dry and cool place. Keep away from open flames, hot surfaces and sources of ignition. Any vessel that contains .? must be vented due to potential pressure build up from fermentation gases.

**8. Exposure controls/personal protection**

**Exposure guidelines**      Local nuisance dust standards apply.

**Occupational exposure controls**

**Engineering measures** None under normal use conditions. Provide appropriate exhaust ventilation at places where dust is formed.

### **Personal Protective Equipment**

**General Information** If the product is used in mixtures, it is recommended that you contact the appropriate protective equipment suppliers, These recommendations apply to the product as supplied

**Respiratory protection** Whenever dust in the worker's breathing zone cannot be controlled with ventilation or other engineering means, workers should wear respirators or dust masks approved by NIOSH/MSHA, EU CEN or comparable organization to protect against airborne dust.

**Eye/face protection** Safety glasses with side-shields

**Skin and body protection** No special precautions required.

**Hand protection** No special precautions required

**Hygiene measures** Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and immediately after handling the product.

## **9. Physical and chemical properties**

<b>Appearance</b>	Light-tan powder
<b>Physical state</b>	solid
<b>Odor</b>	odorless
<b>pH</b>	5.6 (as aqueous solution)
<b>Melting Point/Range</b>	No information available.
<b>Freezing point</b>	No information available
<b>Boiling Point/Range</b>	not applicable
<b>Flash Point</b>	not applicable
<b>Evaporation rate</b>	not applicable
<b>Autoignition Temperature</b>	No information available.
<b>Flammable properties</b>	Combustible material
<b>Vapor pressure</b>	No information available
<b>Vapor density</b>	No information available
<b>Density</b>	0.80 g/mL
<b>Water solubility</b>	practically insoluble
<b>Percent volatile</b>	No information available
<b>Partition coefficient:</b>	not applicable
<b>Viscosity</b>	No information available
<b>Oxidizing properties</b>	not applicable

**10. Stability and reactivity**

<b>Stability</b>	Stable.
<b>Conditions to avoid</b>	Heat, flames and sparks
<b>Materials to avoid</b>	Oxidizing agents Strong acids
<b>Hazardous decomposition products</b>	None known
<b>Hazardous polymerization</b>	Hazardous polymerization does not occur

**11. Toxicological information**Acute effects

**Remarks** The product has not been tested. Data is based on component.

**Eye irritation** No data available for the formulation. Non-irritating (rabbit) (based on components)  
**Skin irritation** No data available for the formulation. Non-irritating (rabbit) (based on components)

**LD50 Oral** Iron: 98.6 g/kg (rat)  
**LD50 Dermal** No information available  
**LC50 Inhalation:** Iron: > 100 mg/m<sup>3</sup> 6 hr (rat)

Chronic Toxicity

**Chronic Toxicity** No known chronic effects of components present at greater than 1%.

**Carcinogenicity** Contains no ingredient listed as a carcinogen.

**12. Ecological information**Ecotoxicity

The environmental impact of this product has not been fully investigated

Chemical Name	Toxicity to algae	Toxicity to fish	Toxicity to microorganisms	Toxicity to daphnia and other aquatic invertebrates
Iron		LC50= 13.6 mg/L Morone saxatilis 96 h LC50= 0.56 mg/L Cyprinus carpio 96 h		

**13. Disposal considerations**

<b>Waste disposal methods</b>	This material, as supplied, is not a hazardous waste according to Federal regulations (40 CFR 261). This material could become a hazardous waste if it is mixed with or otherwise comes in contact with a hazardous waste, if chemical additions are made to this material, or if the material is processed or otherwise altered. Consult 40 CFR 261 to determine whether the altered material is a hazardous waste. Consult the appropriate state, regional, or local regulations for additional requirements
<b>Contaminated packaging</b>	Dispose of in accordance with local regulations

**14. Transport information**

<b><u>DOT</u></b>	not regulated
<b><u>TDG</u></b>	not regulated
<b><u>ICAO/IATA</u></b>	not regulated
<b><u>IMDG/IMO</u></b>	not regulated

**15. Regulatory information****International Inventories**

<b>TSCA Inventory (United States of America)</b>	-
<b>DSL (Canada)</b>	Complies
<b>NDSL (Canada)</b>	Complies
<b>EINECS/ELINCS (Europe)</b>	Complies
<b>ENCS (Japan)</b>	-
<b>IECSC (China)</b>	Complies
<b>KECL (Korea)</b>	-
<b>PICCS (Philippines)</b>	Complies
<b>AICS (Australia)</b>	Complies
<b>NZIoC (New Zealand)</b>	Complies

**U.S. Federal Regulations****SARA 313**

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372.

**SARA 311/312 Hazard Categories**

<b>Acute Health Hazard</b>	no
<b>Chronic Health Hazard</b>	no
<b>Fire Hazard</b>	no
<b>Sudden Release of Pressure Hazard</b>	no
<b>Reactive Hazard</b>	no

**CERCLA**

This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material.

**International Regulations**

Mexico - Grade No information available

**Canada**

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazard Class  
 not determined

**16. Other information**

HMIS	Health Hazard 1	Flammability 1	Stability 0	Special precautions -
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NFPA/HMIS Ratings Legend Severe = 4; Serious = 3; Moderate = 2; Slight = 1; Minimal = 0

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**Prepared By**

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**End of Material Safety Data Sheet**



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