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Corrective Action Study for the Former USDA/CCC Facility in Powhattan, Kansas

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

February 2018

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Notation

ARAR	applicable or relevant and appropriate requirement
AS	air sparging
BER	Bureau of Environmental Remediation
BGL	below ground level
CAD	Corrective Action Decision
CAP	Corrective Action Plan
CAS	Corrective Action Study
CCC	Commodity Credit Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter(s)
COKR	Code of Kansas Regulations
CPT	cone penetrometer
d	day(s)
EPA	U.S. Environmental Protection Agency
EUC	Environmental Use Control
ft	foot (feet)
ft^2	square foot (feet)
GAC	granular activated carbon
GCW	groundwater circulation well
gpm	gallon(s) per minute
GWPT	groundwater extraction (pump) and treatment
HDPE	high-density polyethylene
in.	inch(es)
ISCR	*in situ* chemical reduction
KDHE	Kansas Department of Health and Environment
KGS	Kansas Geological Survey
K_h	hydraulic conductivity
LDB	large-diameter borehole
µg/kg	microgram(s) per kilogram
µg/L	microgram(s) per liter
MCL	maximum contaminant level
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
mi	mile(s)
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

NPDES	National Pollutant Discharge and Elimination System
NPR	Nitrogen Presumptive Remedy
NPV	net present value
O&M	operation and maintenance
PRB	permeable reactive barrier
PWS	public water supply
QA/QC	quality assurance/quality control
RACER	Remedial Action Cost Engineering and Requirements
RAO	remedial action objective
RBSL	risk-based screening level
ROI	radius-of-influence
RWD	Rural Water District
s	second(s)
SMPE	Site Monitoring and Performance Evaluation
SVE	soil vapor extraction
TBC	to be considered
TMV	toxicity, mobility, and volume
USDA	U.S. Department of Agriculture
VCI	Voluntary Cleanup Investigation
VCPRP	Voluntary Cleanup Property Redevelopment Program
VI	vapor intrusion
VOC	volatile organic compound
yr	year(s)

Corrective Action Study for the Former CCC/USDA Facility in Powhattan, Kansas

Executive Summary

Low concentrations of carbon tetrachloride and chloroform have been identified in soil and groundwater in Powhattan, Kansas, at and near areas where grain handling operations have occurred for more than a century. Since about 1890, grain has been stored at several locations on the Chicago Rock Island and Pacific Railroad right-of-way by multiple parties, including the Brown County Cooperative Association (now Ag Partners Cooperative, Inc.), and — from 1949 to approximately 1966 — the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA).

The CCC/USDA has prepared this Corrective Action Study (CAS) to evaluate corrective actions to address carbon tetrachloride contamination in groundwater and soil on the portion of the site that it formerly leased and operated. This property and two neighboring parcels on the railroad right-of-way continue to be used for grain storage and handling by the Ag Partners Cooperative, Inc. Ag Partners is concurrently investigating the extent of nitrate and carbon tetrachloride contamination in groundwater that is linked to its operations.

Carbon tetrachloride has been detected in saturated soils at concentrations above the Kansas Department of Health and Environment (KDHE) soil-to-groundwater risk-based screening guideline and in groundwater above the U.S. Environmental Protection Agency maximum contaminant level (MCL) for drinking water. In addition, in as early as the late 1970s, nitrate concentrations exceeded the MCL for this contaminant in groundwater from both private wells and public water supply (PWS) wells within the Powhattan municipality. Due to the nitrate levels detected in the PWS wells, Powhattan was ordered by the KDHE to either obtain water from the Brown County Rural Water District No. 2 (RWD 2) or otherwise complete water supply improvements to provide water in full compliance with all MCLs (KDHE 1989 and Appendix A). The City of Powhattan has obtained water for domestic use from the RWD 2 since June 1995 (KDHE 2006). Therefore, the exposure pathway from contaminated groundwater to humans via ingestion is incomplete. The exposure pathways (1) from contaminated groundwater to surface discharge and then to human or environmental receptors and (2) from contaminated soil directly to humans via dermal contact are also incomplete. For this CAS, all of these possible exposure

pathways have been evaluated to define site-specific goals for corrective actions related to the former CCC/USDA property, as follows:

- Reduce the concentration, mass, and volume of contaminated soil in the northern portion of the CCC/USDA property that is contributing to groundwater contamination.

- Reduce the toxicity, mobility, and volume of contaminated groundwater associated with the contaminated soil in the northern portion of the former CCC/USDA property.

- Reevaluate potential vapor intrusion risks associated with any changes in site conditions since the original investigation.

Four general response actions and ten individual technologies and practices, in addition to the required no-action option, were considered for their potential to meet the site-specific corrective action goals. The identified technologies and practices were screened against criteria outlined in the KDHE CAS guidance. On the basis of this initial review, selected technologies and practices were assembled into three candidate alternatives for further detailed evaluation, as follows:

- Alternative 1: No action (required by the KDHE).

- Alternative 2: Targeted groundwater extraction (pump) and treatment of carbon tetrachloride (GWPT); and,

- Alternative 3: Targeted treatment of carbon tetrachloride by use of *in situ* chemical reduction technology.

The candidate alternatives were evaluated in accord with KDHE requirements, in the context of other site-specific contamination issues. The preferred remedial alternative is Alternative 2 (GWPT). Alternative 2 will accomplish the following:

- Decrease contaminant concentrations in saturated soils that are currently above the soil-to-groundwater regulatory guideline, and therefore represent a potential

continuing source of contamination, in the extreme northern portion of the former CCC/USDA property.

- Treat and constrain the migration of impacted groundwater in and near the northern portion of the formerly leased property.

The recommended alternative also includes periodic groundwater monitoring, reporting of remedy and groundwater monitoring results to the KDHE, and the performance of 5-yr reviews to substantiate the protectiveness of the remedy. If an evaluation of the monitoring results from the monitoring network indicates that groundwater contaminant concentrations are not decreasing, the CCC/USDA will review the current site conditions and historical data to determine the most appropriate approach for addressing the contamination, including extending the operation of the groundwater extraction system. Additional contingency plans will be evaluated in conjunction with the KDHE if such plans become necessary.

1 Introduction

The Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) has prepared this Corrective Action Study (CAS), consistent with the CAS guidance of the Kansas Department of Health and Environment (KDHE), KDHE (2001a), for the CCC/USDA grain storage facility formerly located in Powhattan, Kansas.

1.1 Site Description

Powhattan, Kansas, is a small rural town with 77 residents occupying 38 housing units (2010 Census). Located in the southwestern portion of Brown County, Powhattan is 60 mi north of Topeka, Kansas, in Section 28, Township 3 South, Range 16 East (Figure 1.1). Grain has been stored at several locations in Powhattan on the Chicago Rock Island and Pacific Railroad right-of-way since about 1890, by multiple parties including the Brown County Cooperative Association (now Ag Partners Cooperative, Inc.), and — from 1949 until approximately 1966 — the CCC/USDA. Grain handling activities on the former CCC/USDA property continue; the property is now occupied by Ag Partners. Most notably, a large storage building (approximately 45,000 ft^2) was constructed by Ag Partners in 2005 on part of the former CCC/USDA property (Figure 1.2). Documentation for the boundaries depicted for the former CCC/USDA facility was presented previously (Argonne 2007).

The principal water source for Powhattan residents is the Brown County Rural Water District No. 2 (RWD 2). Connection to the RWD 2 water supply was obtained by the city in June 1995 (KDHE 2006). Previously, Powhattan residents had obtained their water from public water supply (PWS) wells PWS1 and PWS2, located within the city limits (Figure 1.2). Although residents currently rely on the RWD 2 water supply, several private wells are present in proximity to the former CCC/USDA site. Figure 1.3 shows the private well locations and their status, as determined in 2007 (Argonne 2008). In 2011, the status of the private wells was reported to be unchanged (Shoots 2011). No new private wells have been registered in the Kansas Geological Survey (KGS) Water Well Database (KGS 2017) as of May 2017. Private wells continue to be used within the city for lawn and garden irrigation; currently, there are no private wells being used to supply drinking water within the identified area of groundwater contamination.

1.2 Basis for a Corrective Action Study

Carbon tetrachloride concentrations in groundwater at Powhattan are presently above the Kansas Tier 2 risk-based screening level (RBSL) and the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 5.0 µg/L for this contaminant in drinking water (Kansas 2004). In addition, identified carbon tetrachloride concentrations were above the RBSL guideline for the soil-to-groundwater pathway (73.4 µg/kg) in 20 of 196 soil samples collected in a CCC/USDA investigation in 2007 (Argonne 2008). Nineteen of the 20 soil samples were recovered at two locations in the extreme northern portion of the former CCC/USDA leased property. Carbon tetrachloride at concentrations close to or above the MCL has also been detected in groundwater beneath and near the extreme northern portion of the former CCC/USDA property.

The KDHE (2009c) has determined that corrective measures at the former CCC/USDA facility are warranted, although investigations into possible carbon tetrachloride and nitrate contamination of soil and groundwater due to current and past activities at the facilities now operated by Ag Partners are not complete. The Ag Partners operations incorporate the property formerly leased by the CCC/USDA. Based on documents presented in the KDHE Identified Sites List, Ag Partners' activities under the Voluntary Cleanup and Property Redevelopment Program (VCPRP)[1] will include soil excavation to address nitrate contamination, and further response actions to address carbon tetrachloride contamination in groundwater. During the term of its lease, operations at the former CCC/USDA facility did not include the storage, handling, or use of nitrate. As a result, this CAS excludes any consideration of nitrate contamination and focuses on carbon tetrachloride contamination near the northern portion of the former CCC/USDA property.

In keeping with KDHE (2001a) guidance, this CAS compares a baseline "no-action" alternative and additional alternatives for addressing carbon tetrachloride contamination in the extreme northern portion of the former CCC/USDA property.

1.3 Report Organization

The history and nature of the contamination and previous and ongoing investigations at Powhattan are summarized in Section 2. Section 3 evaluates human and environmental targets and potential exposure pathways. Section 4 describes the corrective action goals and applicable or relevant and appropriate requirements (ARARs). Section 5 identifies and screens candidate

[1] The KDHE VCPRP regulations are defined in Kansas Administrative Regulations 28-71-1 through 28-71-12.

technologies for addressing the contamination. Section 6 describes the remedial alternatives, Section 7 analyzes each alternative in detail, and Section 8 compares the alternatives. Section 8 also includes a summary and identifies the recommended corrective action. All references cited in this report are provided in Section 9.

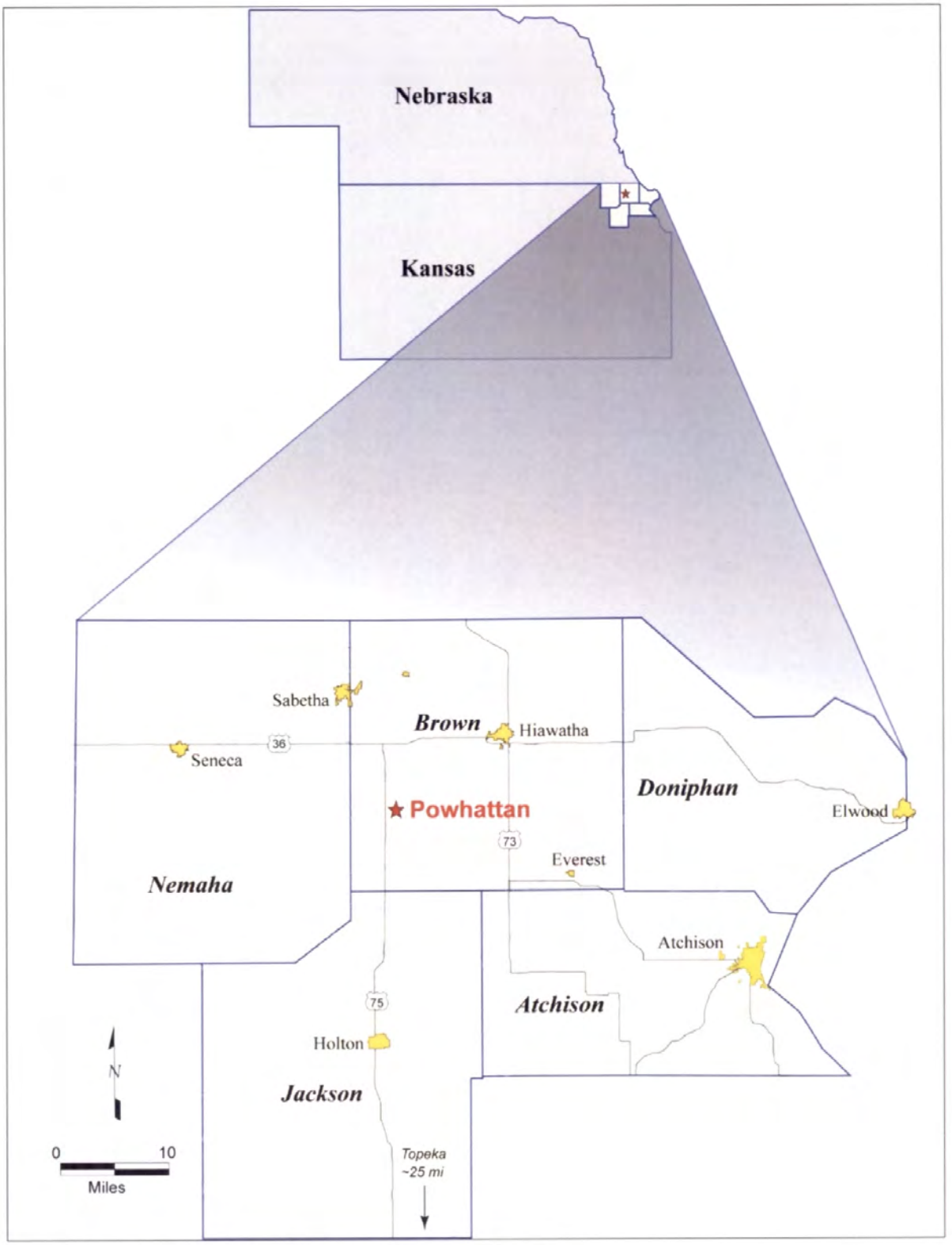

FIGURE 1.1 Locations of Brown County and Powhattan, Kansas.

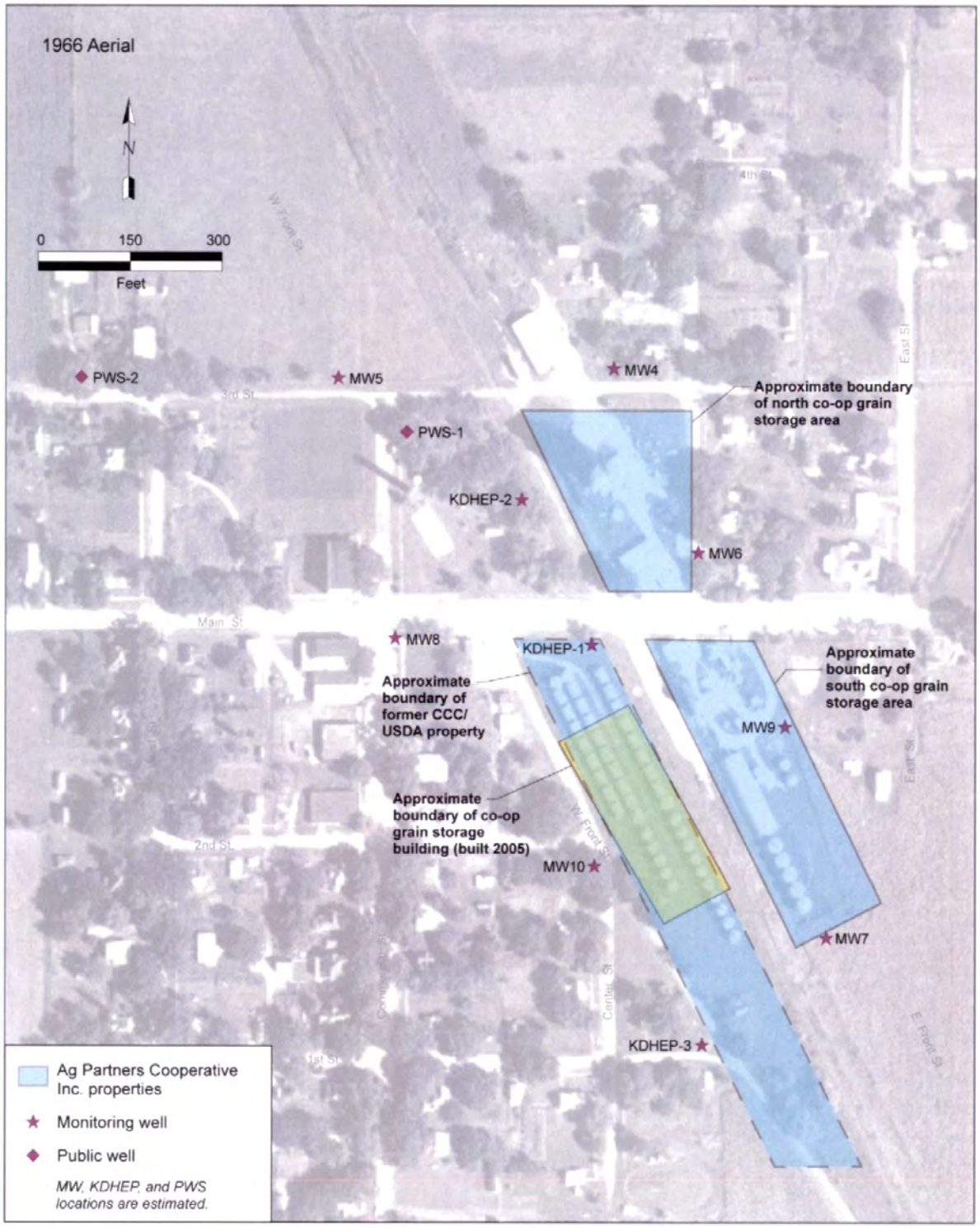

FIGURE 1.2 Approximate locations of the former CCC/USDA facility, other relevant structures and facilities, public water supply wells, and the KDHE monitoring wells installed before 2007. Source of photograph: USDA (1966).

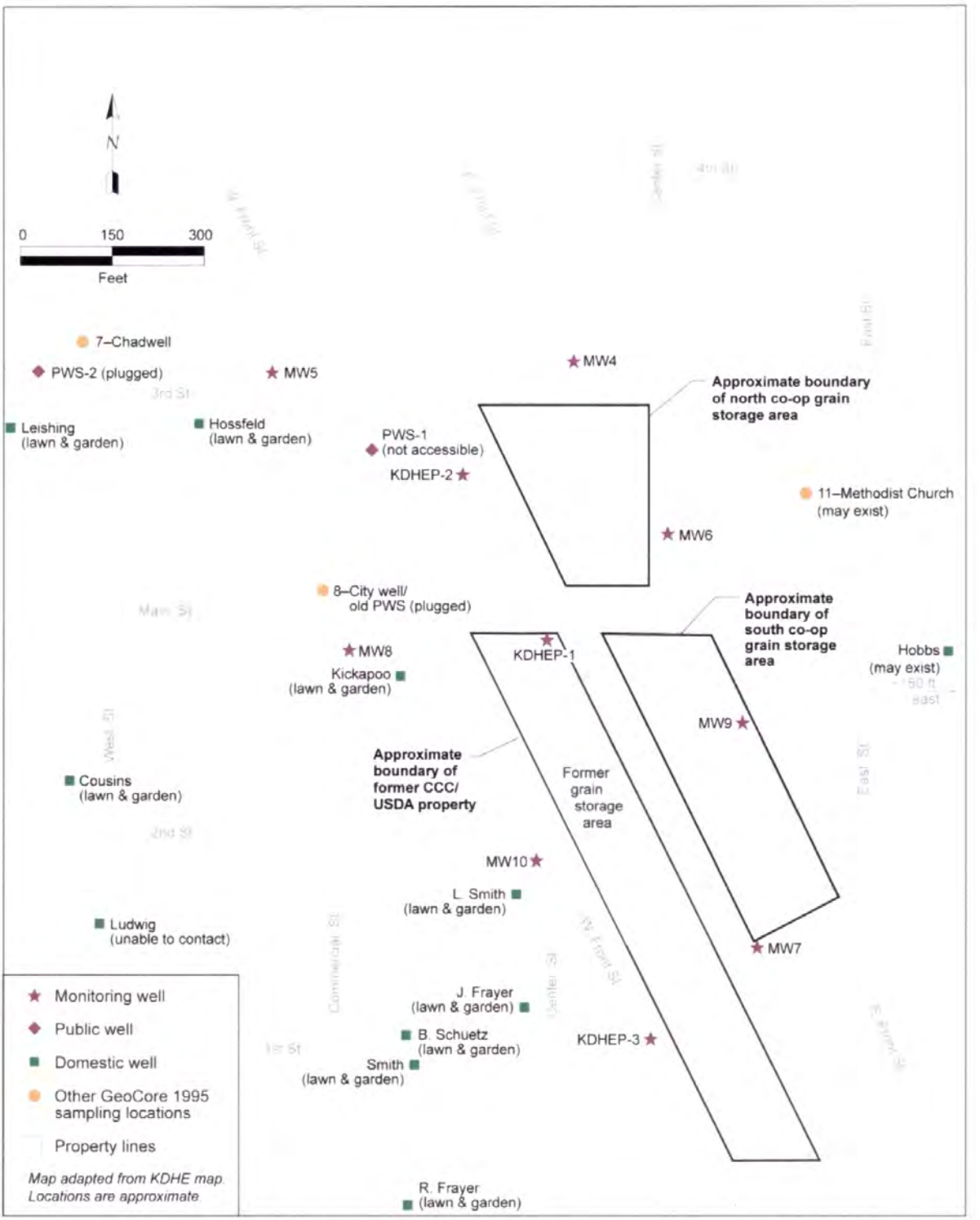

FIGURE 1.3 Status of private wells near the former CCC/USDA property, as determined in a door-to-door survey in July 2007.

2 Summary of Previous Investigations

2.1 KDHE Investigations

Records from the KDHE indicate that the Powhattan PWS wells have been tested for nitrate since 1970, or earlier, and for carbon tetrachloride since 1986. The history and findings of the investigations conducted by the KDHE at Powhattan were previously documented in detail (see Table 2.1 in Argonne [2008] and Appendix A in Argonne [2007]).

Nitrate concentrations detected in the PWS wells have consistently exceeded the MCL of 10 mg/L for this contaminant (Table 2.1 and Figure 2.1). Carbon tetrachloride was initially detected in these wells in 1986. In response to the detection of carbon tetrachloride, the KDHE began several years of assessments, investigations, and long-term monitoring of contaminant levels.

During previous investigations, ten monitoring wells were installed by or for the KDHE (Figure 2.1): three wells (KDHEP-1, KDHEP-2, KDHEP-3) in 1988 and seven wells (MW4-MW10) in 1995. The well depths range from 56-68 ft below ground level (BGL). Except for MW7, all were completed to the top of bedrock. Well MW7 was completed at 56 ft BGL (Table 2.1), at a location where bedrock was encountered at 66 ft BGL.

2.2 CCC/USDA Investigations

In 2007, the CCC/USDA used direct-push (Argonne cone penetrometer [CPT] vehicle) techniques to perform an extensive investigation of carbon tetrachloride contamination in soils and groundwater on and near its former facility. Conducted in four phases, the 2007 investigation included the collection of soil samples for lithologic evaluation and analyses for volatile organic compounds (VOCs), the collection of groundwater samples for VOCs analyses, and the installation of seven additional monitoring wells (MW11-MW17; Figure 2.2) for groundwater sampling and for the monitoring of groundwater levels and the determination of flow directions. The detailed findings (Argonne 2008) included the results of automated measurement of groundwater levels initiated in selected monitoring wells in 2005 (Figure 2.3).

In conjunction with the present CAS evaluation, a limited series of single-well hydraulic tests ("slug" tests) was conducted in 2011 at seven monitoring well locations in the vicinity of the

former CCC/USDA facility (Figure 2.2). In addition, 18 monitoring wells were sampled in March and April 2012. The results of the slug tests and the 2012 sampling are discussed in Section 2.2.1. The primary findings of the CCC/USDA studies are also outlined below.

2.2.1 Geology and Hydrogeology

2.2.1.1 Lithology

Powhattan lies in the dissected till plains section of the central lowlands physiographic province (Schoewe 1948). The subsurface in this area is composed of Pleistocene till and glacial outwash deposits. The till consists of clay with variable zones of silt, sand, gravel, and cobbles; the outwash contains poorly to moderately sorted silt, sand, and gravel. Underlying the till and outwash is a gray shale of the Admire Group. The till and outwash deposits form the primary aquifer in the Powhattan area; however, little water is ordinarily available in wells that are completed in these materials (Bayne and Schoewe 1967).

The site-specific lithologies were identified in the 2007 study through the collection and examination of continuous cores at 13 locations (TI01-TI12 and TI18; Figure 2.2). The results of this analysis were used to construct five interpretive stratigraphic cross sections for the site (Figures 4.2-4.6 in Argonne [2008]).

The predominant lithology consists of a gray-brown to light brown, non-calcareous, silty clay with some evidence of iron staining and iron nodules. This silty clay layer ranged from approximately 42-64 ft thick. At various depths (23.5-56 ft BGL), white carbonate inclusions were observed in all cored boreholes.

The silty clay layer is underlain by a thin zone of silty sandy clay, sandy clay, and trace silty sand. This thin zone, encountered at depths of 42-74 ft BGL, produced limited quantities of water during sampling, under semi-confined conditions. Although refusal was encountered at the base of this water-producing zone (see Section 2.2.1.3) by the CPT unit, no evidence of bedrock material was observed in any core sample. Historical data from existing monitoring wells indicate that light gray to blue-gray shale is present at depths of 61-67 ft BGL.

2.2.1.2 Groundwater Level Monitoring in 2005-2011

Long-term water level monitoring data for wells completed in the lower silty-sandy interval (Figure 2.3) demonstrate a persistent, relatively complex pattern of groundwater levels and hence apparent flow directions (Figures 2.4a, b). Two areas with relatively high groundwater elevations to the northwest and southeast of the large Ag Partners grain storage building, coupled with lower groundwater levels beneath and to the southwest and northeast of the building, form a "saddle" pattern roughly centered on the structure. Data recorded by automatic loggers in selected monitoring wells indicate that the absolute groundwater levels fluctuated by 11 ft or more during the period of continuous observation (2005-2011); however, the relative distribution of water levels across the site has remained consistent through time, possibly reflecting local variations in the influence of recharge across the study area. Recharge might be more effective northwest and southeast of the large storage building, where surface coverage by buildings and parking lots is minimal, than in areas occupied by the building itself, the adjacent gravel-packed or paved aprons, and the residences to the southwest.

2.2.1.3 Water-Bearing Zones

No lenses of sand or gravel and no discrete water-bearing zones were identified in the upper 50 ft of the glacial till; only the thin interval of silty-sandy deposits encountered at the base of the till was recognized as a water-bearing unit on the basis of the 2007 Argonne studies (Argonne 2008). Historic well records report, however, that a well formerly owned by the "Powhattan community" (abandoned in 1961) produced water from a sand and gravel interval in the glacial deposits at a depth of 40 ft (Bayne and Schoewe 1967). Records of six private wells installed to a depth of 35 ft or less and two additional private wells installed to a depth of 50 ft or less also suggest that saturated conditions might exist, at least locally, in the upper, predominantly fine-grained portion of the till sequence (Argonne 2007). Groundwater levels measured in the network of monitoring wells completed in the lower silty-sandy interval routinely fall at 5-15 ft BGL across much of the investigation site, further suggesting the potential for occurrence of groundwater at shallower depths in the till complex.

2.2.1.4 Slug Testing in 2011

In support of the present CAS investigation, in 2011 Argonne performed a series of slug tests on seven monitoring wells completed in the lower silty-sandy zone, near the former

CCC/USDA facility in the northern and central portions of the study area (KDHEP-1, KDHEP-2, MW4, MW5, MW6, MW8, MW10; Figure 2.2). The results, summarized in Table 2.2, indicate an average hydraulic conductivity (K_h) of about 1 ft/d across much of the investigation area, with a possible decrease in permeability of approximately an order of magnitude near the northeastern margin of the area (at MW6; Figure 2.2).

Figure 2.5 shows the results of a calculation using the Theis method (strictly for a confined unit) to estimate the drawdown that might be expected in the vicinity of a conventional well, pumping for 90 days at one gpm, from an interval having an average thickness of 10 ft and a K_h of 1 ft/d. The results of this calculation indicate that the basal, more silty-sandy unit might be able to sustain this kind of pumping rate.

2.2.2 Carbon Tetrachloride Contamination in Soil

In 2007, subsurface soil samples were collected in vertical profiles at 12 locations (TI01-TI12) on and immediately adjacent to the former CCC/USDA property and at one location (TI18) outside the property (Figure 2.6). The analytical results for VOCs in the soil samples are summarized in Table 2.3. The lateral distribution of carbon tetrachloride in the soil samples is illustrated in red in Figure 2.6.

Of the 196 soil samples analyzed, 20 contained carbon tetrachloride at concentrations exceeding the KDHE's RBSL guideline of 73.4 µg/kg for the soil-to-groundwater protection pathway (Table 2.3). Of these, 19 samples were collected at borings TI01 and TI02, immediately north of the large Ag Partners building in the northern portion of the former CCC/USDA facility (Figure 2.6). All of the soil samples exceeding the RBSL guideline limit were collected from depths below the routinely measured groundwater level (5-15 ft BGL). Under these conditions, carbon tetrachloride detected in the soils might reflect contamination that is (1) adsorbed to solid soil particles, (2) dissolved in the pore water in the soils, or (3) in a combination of these physical states. Consequently, detections in these soils might in part reflect the influences of vertical and/or lateral groundwater and contaminant migration.

The highest carbon tetrachloride concentration detected in soil beneath the former CCC/USDA property (2,140 µg/kg) occurred at 30 ft BGL at location TI02 (Figure 2.6). Only one soil sample collected at this location (at 10 ft BGL) contained no detectable carbon tetrachloride (Table 2.3), and the seven samples collected at depths of 18-42 ft BGL all contained

carbon tetrachloride at concentrations exceeding the RBSL (140-2,140 µg/kg). At location TI01, 12 samples collected at depths of 14-53 ft BGL contained carbon tetrachloride at concentrations (79-282 µg/kg) exceeding the RBSL. The analytical data from these continuous vertical profiles identified the area at and around locations TI02 and TI01 as a primary source area for the carbon tetrachloride contamination.

Carbon tetrachloride was also detected at concentrations at or above the method detection limit of 10 µg/kg, but below the RBSL of 73.4 µg/kg (with only one exception, at 46 ft BGL at TI18) — in soil samples from the deeper portions of the till sequence (> 34 ft BGL) at four additional locations (TI03, TI04, TI10, and TI18; Table 2.3 and Figure 2.6), and trace levels were detected at TI11. An absence of contamination in samples from the upper portions of all of these boreholes (Table 2.3) suggests possible horizontal contaminant migration from other source areas to the locations of these boreholes, rather than vertical infiltration from a surface release point.

2.2.3 Carbon Tetrachloride Contamination in Groundwater

2.2.3.1 Data from 2007 Sampling

In 2007, groundwater samples were collected at 23 locations on and immediately adjacent to the former CCC/USDA property, generally at depths of 50-66 ft BGL. The targeted sampling depths were defined, in part, by unsuccessful attempts to collect groundwater from shallower depths, over periods of several hours to three days, at multiple locations. Outside the former CCC/USDA property, groundwater samples were collected at 42 locations (Figure 2.2).

The lateral distributions of carbon tetrachloride and chloroform in groundwater in 2007 (maximum concentration at each location) are shown in red in Figures 2.7 and Figure 2.8, respectively. A total of 36 groundwater samples contained carbon tetrachloride at concentrations exceeding the MCL and RBSL values of 5.0 µg/L for this compound. Of these samples, 20 were collected at locations on or immediately adjacent to the former CCC/USDA property. The maximum carbon tetrachloride concentration identified in groundwater, 1,090 µg/L, was detected at boring location TI01, at the northern margin of the former CCC/USDA facility (Figure 2.7). Chloroform was detected at or above the method detection limit of 1.0 µg/L in 33 groundwater samples, and trace levels below the detection limit were found in 15 samples (Figure 2.8). All of the chloroform concentrations measured in groundwater samples were below the MCL and RBSL values of 80 µg/L for this compound.

2.2.3.2 Data from 2012 Sampling

Table 2.4 and Figure 2.9 compare analytical results for carbon tetrachloride in groundwater in 2012 and 2007. Carbon tetrachloride concentrations in 11 of the 18 wells sampled in 2012 were lower than or the same as the 2007 concentrations. The highest concentration detected in 2012 was only 53% of the highest concentration detected in 2007 (288 µg/L versus 542 µg/L at well KDHEP-1). Samples from two wells, MW11 and MW12, had carbon tetrachloride concentrations exceeding the 2007 results.

The results of the 2012 sample event are relatively consistent with results from the 2007 investigation. In general, carbon tetrachloride was detected in the same monitoring wells during both the 2007 and 2012 sample events. However, no distinct pattern of increasing or decreasing concentrations over time is apparent (Figure 2.9).The presence of carbon tetrachloride in the noted monitoring wells as well as in soils from the surface downward into the water bearing zone (at borings TI01 and TI02; Figure 2.6) suggests the presence of a source area located in the northern portion of the former CCC/USDA facility.

2.2.4 Nitrate Contamination in Groundwater

In 2012, nitrate concentrations ranging from 0.38 mg/L to 38 mg/L were identified in groundwater samples collected by the CCC/USDA from 18 monitoring wells (Table 2.4 and Figure 2.10). Nitrate concentrations in groundwater from 12 of the 18 wells sampled were above the MCL of 10 mg/L. The highest nitrate concentrations were detected near the south Ag Partners grain storage area (Figure 2.10).

These data corroborate the nitrate results reported for an investigation conducted by Ag Partners in 2009, discussed in Section 2.3.

2.3 Ag Partners Voluntary Cleanup Investigation in 2009

In December 2009, in accordance with a VCPRP agreement with the KDHE, Ag Partners conducted sampling under a Voluntary Cleanup Investigation (VCI) work plan (Enviro Tech 2008). The 2009 investigation focused on the Ag Partners property and directly adjacent locations. Geoprobe direct-push technology was used to collect soil and groundwater samples for analysis

for VOCs, including carbon tetrachloride, chloroform, and ethylene dibromide, as well as for nitrate and ammonia analyses.

2.3.1 Carbon Tetrachloride in Soil Samples

Soil samples were collected during the Ag Partners VCI at 26 locations across the investigation area, at target depths of 15 ft, 30 ft, and 50 ft BGL. Carbon tetrachloride was detected in four samples collected at two locations (SV11 and SV12), at concentrations ranging from 5.2 µg/kg (at SV11) to 59 µg/kg (at SV12; Table 2 in Enviro Tech 2010). Carbon tetrachloride was also detected in splits of these samples analyzed by Argonne; however, significantly higher concentrations (62-495 µg/kg) were identified at SV12, and carbon tetrachloride was identified at a low level in a sample from an additional location (SV13; 4.9 µg/kg). The Argonne results are illustrated in Figure 2.11.

2.3.2 Carbon Tetrachloride in Groundwater Samples

Ag Partners originally proposed 26 locations for groundwater sampling with the Geoprobe direct-push technology (Enviro Tech 2008); however, sampling was actually attempted at 15 locations (at target depths of 55-65 ft BGL), and sufficient groundwater for sampling could be recovered (within the time constraints imposed for the field activities) at only eight locations. Ag Partners detected carbon tetrachloride in three of the eight samples collected (locations G22, G24, and G26), at concentrations of 17.4-94.0 µg/L (Table 2.5). Similar carbon tetrachloride concentrations were detected in split groundwater samples collected by Argonne at seven of the eight locations sampled by Ag Partners and submitted to an outside laboratory for VOCs analyses (Figure 2.12).

The Ag Partners VCI contractor also analyzed groundwater samples from 17 monitoring wells for grain fumigant compounds. Where VOCs were detected, the results (Enviro Tech 2010) were consistent with the lateral distribution of carbon tetrachloride in groundwater identified in the CCC/USDA investigations (Figure 2.9).

2.3.3 Nitrate in Groundwater Samples

Nitrate was detected at all of the eight direct-push locations sampled for groundwater by Ag Partners. At seven of these locations, nitrate was detected at concentrations in excess of the MCL of 10 mg/L (Table 2.5).

The Ag Partners VCI contractor also analyzed groundwater samples from 17 monitoring wells for nitrogen compounds. Nitrate was detected at concentrations in excess of the MCL for this contaminant (10 mg/L) at 15 of the 17 monitoring wells sampled (Enviro Tech 2010).

2.4 Summary and Designation of Identified Contamination Areas

Elevated carbon tetrachloride concentrations in groundwater near the former CCC/USDA facility were identified by the CCC/USDA and corroborated by the subsequent Ag Partners investigation (Enviro Tech 2010). Elevated nitrate concentrations in groundwater over a wide area were also identified by Ag Partners in 2009 (Enviro Tech 2010) and corroborated by Argonne sampling in 2012 (Figure 2.12). The extent of the area with nitrate values in excess of the nitrate MCL of 10 mg/L (Figure 2.10) is greater than the area where carbon tetrachloride concentrations exceed the MCL and RBSL values of 5.0 µg/L for carbon tetrachloride (Figure 2.9). The series of investigations performed by CCC/USDA and Ag Partners indicates the presence of a contamination source area in the northern portion of the former CCC/USDA facility property and a contamination source area located on the south side of the Ag Partners property that lies east of the former CCC property.

2.4.1 Ag Partners Contamination Source

The KDHE (2006) concluded that carbon tetrachloride detected in the southern portion of the southern Ag Partners property is associated with the Ag Partners grain bins and that "the Co-op [Ag Partners] is the sole potentially responsible party for contamination resulting from operations on the eastern side of the facility." The KDHE (2006) further documented a report that carbon tetrachloride had been used heavily at the "south elevator."

To confirm the KDHE (2006) information, the CCC/USDA investigation in 2007 included collection of groundwater samples at MW7 and at several locations (TI12, TI28, TI29, TI30, TI31, TI37, TI39, TI40, KDHEP-3) immediately southwest of several active grain bins (Figure 2.2). The

results confirmed that a groundwater contaminant plume originating from the source identified by the KDHE (2006) has migrated to the southwest, passing beneath and extending beyond the former CCC/USDA property. Split soil samples from the southern portion of the south grain storage area, collected and analyzed by Argonne during the 2009 Ag Partners VCI investigation, contained carbon tetrachloride at concentrations up to 495 µg/kg. Carbon tetrachloride was not detected in soil samples collected farther south, beyond this area.

The highest carbon tetrachloride concentrations detected in the 2007 CCC/USDA investigation in the groundwater plume emanating from this southern (Ag Partners) source area ranged from 109 µg/L (MW7) to 380 µg/L (TI30; Figure 2.7). Significantly lower concentrations detected immediately to the north, south, and southwest demonstrate a clear separation between the Ag Partner-related plume and the contamination detected on the former CCC/USDA property. During the 2012 CCC/USDA sampling, carbon tetrachloride was not detected in MW7 (Figure 2.9).

2.4.2 Contamination Source at the Former CCC/USDA Facility

The results of groundwater sampling events over time, coupled with analytical data for soil samples, indicate a strong association between groundwater contamination and a source area in the northern portion of the former CCC/USDA property.

The area most significantly affected by the identified contamination is near the northeast corner of the former CCC/USDA facility. In this area, during the 2007 investigation, carbon tetrachloride concentrations of up to 2,140 µg/kg were identified in saturated soils, in association with concentrations of up to 1,090 µg/L in groundwater. These levels represent the highest concentrations of carbon tetrachloride identified in both soils and groundwater (Argonne 2008). In the 2012 sampling, carbon tetrachloride concentrations in groundwater at monitoring wells near the north-northwest portion of the former CCC/USDA facility ranged from 218 µg/L at MW11 to 288 µg/L at KDHEP-1. The coupled soil and groundwater data (Figures 2.6-2.9) confirm that this area is a primary source for the contamination detected in groundwater.

As noted above, carbon tetrachloride was also detected at concentrations at or above the method detection limit of 10 µg/kg — but generally below the RBSL of 73.4 µg/kg — in soil samples from the deeper portions of the till sequence (> 34 ft BGL) at four additional locations (TI03, TI04, TI10, and TI18; Table 2.3 and Figure 2.6), and trace levels were detected at TI11.

Nevertheless, an absence of contamination in samples from the upper portions of all of these boreholes (Table 2.3) suggests horizontal contaminant migration from other source areas, rather than vertical infiltration from a surface release point at these boring locations. Horizontal contaminant migration seems likely given the persistent and relatively complex pattern of apparent groundwater flow directions noted in Section 2.2.1.2, as well as episodic absolute groundwater level fluctuations of 11 ft or more documented by the CCC/USDA in this area.

TABLE 2.1 Summary of analytical data for monitoring wells and public water supply wells, 1970 to 2005.[a]

Well	Screen Interval (ft BGL)	Sampling Dates	Number of Sampling Events	Depth to Water (ft BGL)	Nitrate as N (mg/L)	Concentration (μg/L)			
						Carbon Tetrachloride	Chloroform	Ethylene Dibromide	Benzene
Monitoring Wells									
KDHEP-1	55.1-65.1	1988-2005	10	6.85-15.22	8.09-14.6	88-500	7.5-29	ND[b]	ND
KDHEP-2	58.1-68.1	1988-2005	10	7.71-17.00	10.8-18.1	ND-78	ND-4.9	ND	ND
KDHEP-3	52-62	1988-2005	10	4.39-14.85	8.1-32.5	ND-7.8	ND-0.48J[c]	ND	ND
MW4	54.7-64.7	1995-2005	7	9.01-16.72	15.2-31.7	2.1-4.6	ND-0.54	ND	ND
MW5	58-68	1995-2005	7	7.02-17.54	12.1-26.3	ND	ND	ND	ND
MW6	56-66	1995-2005	7	6.72-14.67	9.25-19.1	ND	ND	ND	ND-4.4
MW7	46-56	1995-2005	6	2.87-12.20	15.3-52.1	ND-180	ND-6.4	ND	ND
MW8	55-65	1995-2005	7	10.11-18.73	24.9-39.0	1.3-6.0	ND-1.5	ND	ND
MW9	52-62	1995-2005	7	1.52-12.30	9.9-55.8	ND	ND	ND-3.3	ND
MW10	56-66	1995-2005	7	5.25-15.72	5.5-10.4	24-65	2.4-11.0	ND	ND
Public Water Supply Wells									
PWS 1	Unknown	1971-1988	9	Unknown	18.81-87.0	2.0-4.0	ND	ND	ND
PWS 2	Unknown	1970-1988	7	Unknown	15.53-100	ND	ND	ND	ND

[a] Complete data (including results for private wells) are in Appendix A of the *Work Plan* (Argonne 2007). Analyses for some constituents were omitted in some sampling events.

[b] ND, not detected at the method detection limit indicated in Appendix A of the *Work Plan* (Argonne 2007).

[c] Qualifier J indicates an estimated concentration below the method detection limit.

TABLE 2.2 Results of slug testing in 2011.

		Estimated Hydraulic Conductivity (ft/d)								
		Bouwer-Rice Method				Hvorslev Method				
Well	Casing Diameter (in.)	Slug In Test 1	Slug Out Test 2	Slug In Test 3	Slug Out Test 4	Slug In Test 1	Slug Out Test 2	Slug In Test 3	Slug Out Test 4	Average
KDHEP-1	2	0.85	0.81	0.85	0.81	1.29	1.23	1.29	1.26	1.05
KDHEP-2	2	0.89	0.85	0.89	0.89	1.25	1.19	1.26	1.26	1.06
MW4	2	0.68	0.68	0.71	0.71	1.40	1.40	1.46	1.46	1.06
MW5	2	0.71	0.68	0.71	0.71	1.46	1.40	1.46	1.46	1.07
MW6	4	0.13	0.08	0.09	–	0.28	0.16	0.19	–	0.16
MW8	4	0.81	0.62	0.71	0.68	1.68	1.27	1.46	1.40	1.08
MW10	4	1.23	1.07	1.23	1.12	2.54	2.72	2.55	2.32	1.85

TABLE 2.3 Summary of analytical results for soil samples collected during the 2007 investigation.

				Concentration (µg/kg)		
Location	Number of Samples	Depth (ft BGL)	Sampling Date	Carbon Tetrachloride	Chloroform	Methylene Chloride
TI01	1	2	7/10/07	ND[a]	ND	ND
	1	6	7/10/07	ND	ND	ND
	1	10	7/10/07	ND	2.3 J[b]	ND
	1	14	7/10/07	158	32	ND
	1	18	7/10/07	57	13	ND
	1	22	7/10/07	130	22	ND
	1	24.75	7/10/07	145	29	ND
	1	27	7/10/07	151	29	ND
	1	30.5	7/10/07	104	26	ND
	1	34	7/10/07	198	38	ND
	1	38	7/10/07	250	47	ND
	1	42	7/10/07	269	11	ND
	1	45.5	7/10/07	79	14	ND
	1	46.75	7/10/07	282	7.2 J	ND
	1	50	7/10/07	253	6.3 J	ND
	1	53	7/10/07	93	2.2 J	ND
	1	55	7/10/07	53	1.9 J	ND
	1	58	7/10/07	53	1.9 J	ND
TI02	1	2	7/11/07	3.6 J	ND	ND
	1	6	7/11/07	6.8 J	ND	ND
	1	7.5	7/11/07	2.3 J	ND	ND
	1	10	7/11/07	ND	1.7 J	ND
	1	14	7/11/07	3.6 J	8.9 J	ND
	1	18	7/11/07	217	32	ND
	1	22	7/11/07	396	25	ND
	1	26	7/11/07	759	72	ND
	1	30	7/11/07	2140	61	ND
	1	34.5	7/11/07	1745	59	ND
	1	38	7/11/07	483	31	ND
	1	42	7/11/07	140	6.1 J	ND
	1	46	7/11/07	58	2.3 J	ND
	1	50	7/11/07	14	1.2 J	ND
	1	51	7/11/07	10	1.1 J	ND
	1	54	7/11/07	4.7 J	ND	ND
	1	57.5	7/11/07	4.7 J	ND	ND
	1	58.5	7/11/07	3.5 J	ND	ND

TABLE 2.3 (Cont.)

Location	Number of Samples	Depth (ft BGL)	Sampling Date	Concentration (µg/kg) Carbon Tetrachloride	Chloroform	Methylene Chloride
TI03	10	2-38	7/11-12/07	ND	ND	ND
	1	41.25	7/12/07	1.1 J	1.5 J	ND
	1	42.75	7/12/07	2.1 J	1.7 J	ND
	1	46	7/12/07	7.7 J	2.0 J	ND
	1	50	7/12/07	8.7 J	3.8 J	ND
	1	54	7/12/07	ND	ND	ND
	1	58	7/12/07	10	4.2 J	ND
TI04	10	2-38	7/12-13/07	ND	ND	ND
	1	42	7/13/07	3.4 J	1.5 J	ND
	1	43.25	7/13/07	5.6 J	2.0 J	ND
	1	46	7/13/07	12	3.4 J	ND
	1	48.75	7/13/07	14	3.5 J	ND
	1	51.75	7/13/07	22	4.3 J	ND
TI05	15	2-55.1	7/16-17/07	ND	ND	ND
TI06	16	2-55.2	7/15/07	ND	ND	ND
TI07	14	2-54	7/31/07	ND	ND	ND
TI08	14	1.5-54	7/28-29/07	ND	ND	ND
TI09	17	2-55.3	7/15-16/07	ND	ND	ND
TI10	1	2	7/27/07	7.7 J	ND	ND
	7	6-30	7/27/07	ND	ND	ND
	1	34	7/27/07	29	1.9 J	ND
	1	38	7/27/07	68	5.0 J	ND
	1	42	7/27/07	6.3 J	2.0 J	ND
	1	46	7/27/07	39	2.5 J	ND
	1	50	7/27/07	8.5 J	ND	ND
TI11	11	1.5-42	7/26/07	ND	ND	ND
	1	46	7/26/07	6.5 J	1.0 J	ND
	1	50	7/26/07	5.7 J	4.7 J	ND
	1	54	7/26/07	1.0 J	ND	ND
TI12	12	1.4-46	7/27-28/07	ND	ND	ND
TI18	10	2-38	7/29-30/07	ND	ND	ND
	1	42	7/30/07	13	ND	ND
	1	46	7/30/07	112	11	ND
	1	50	7/30/07	10	ND	ND
	1	54	7/30/07	ND	ND	ND

[a] ND, not detected at an instrument detection limit of 1.0 µg/kg.

[b] Qualifier J indicates an estimated concentration below the purge-and-trap method detection limit of 10 µg/kg.

TABLE 2.4 Analytical results for carbon tetrachloride in groundwater samples collected in 2007 and 2012, with nitrate results for the 2012 samples.[a]

	Carbon Tetrachloride (µg/L)		
	Summer 2007	Spring 2012	Nitrate (mg/L) in Spring 2012
Monitoring wells			
KDHEP-1	542	288	14
KDHEP-2	70	38	21
KDHEP-3	5.0	10	18
MW4	2.3	5.4	16
MW5	ND[b]	0.3 J[c]	16
MW6	0.6 J	1.0	6.2
MW7	109	ND	8.5
MW8	1.1	ND	7.0
MW9	ND	ND	38
MW10	42	19	2.5
MW11	183	218	17
MW12	123	269	25
MW13	0.5 J	0.5 J	33
MW14	ND	ND	30
MW15	ND	ND	7.2
MW16	0.8 J	0.6 J	13
MW17	ND	1.5	17
Private well			
Schuetz, B.	ND	ND	0.38

[a] These wells will also serve as wells for baseline sampling as discussed in Section 6.2.4.1.

[b] ND, not detected at an instrument detection limit of 0.1 µg/L.

[c] Qualifier J indicates an estimated concentration below the purge-and-trap method detection limit of 1.0 µg/L.

TABLE 2.5 Analytical results for direct-push groundwater samples collected during the Ag Partners VCI in August and December 2009.[a]

		Concentration (µg/L)			
Location	Sample Interval (ft BGL)	Carbon Tetrachloride	Chloroform	Methylene Chloride	Nitrate (mg/L)
G1	57-61	< 0.5	< 0.5	< 1.0	20.7
G3	57-61	< 0.5	< 0.5	< 1.0	39.4
G10[b]	55-59	< 0.5	< 0.5	< 1.0	0.88
G19	52-56	< 0.5	< 0.5	< 1.0	57.3
G21	51-55	< 0.5	< 0.5	< 1.0	25
G22	60-64	94.0	10.9	< 1.0	15
G24	61-65	22.7	3.4	< 1.0	20.3
G26	60-64	17.4	0.8	< 1.0	12.9

[a] Source of data: Enviro Tech (2010).

[b] Sample collected in August 2009.

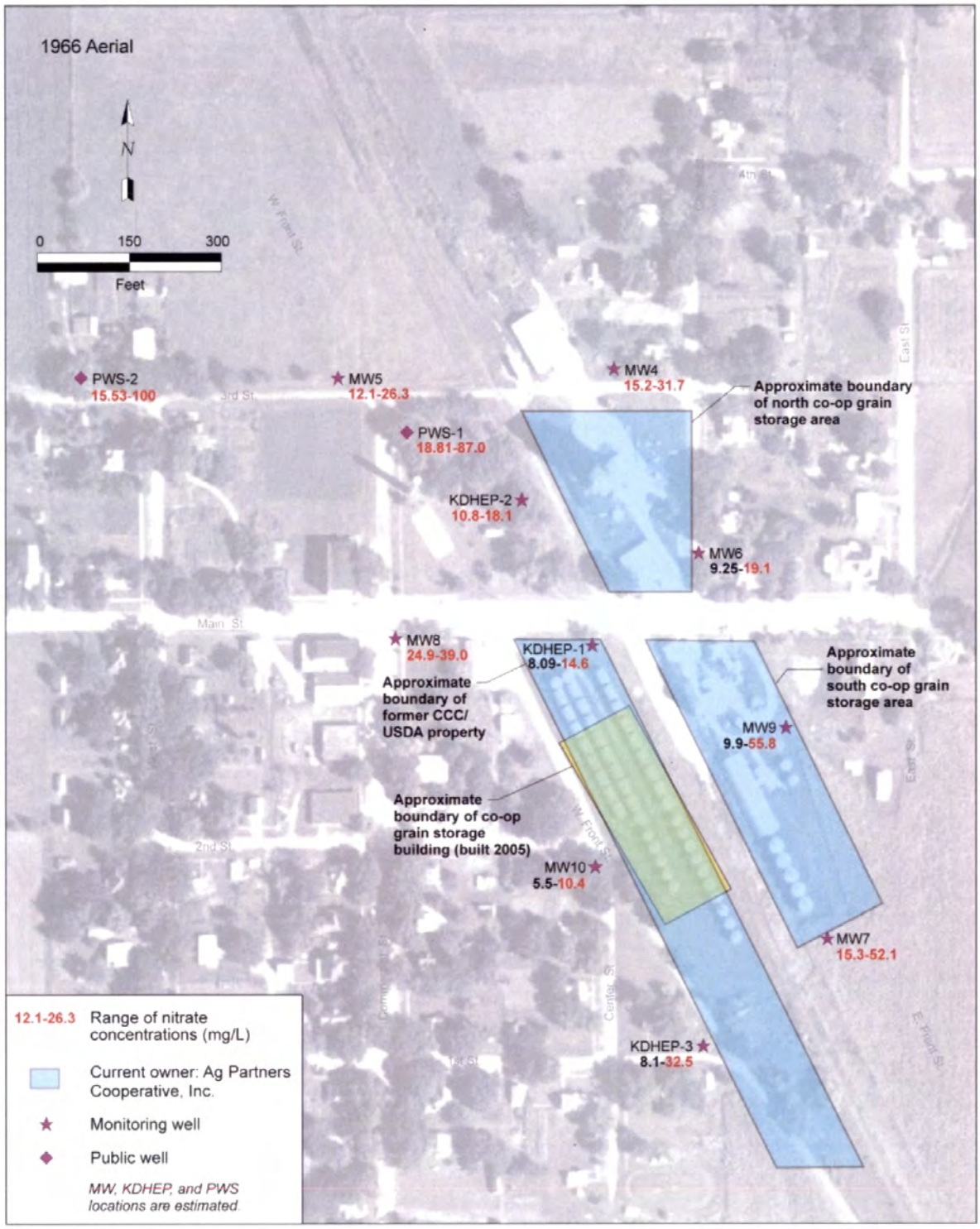

FIGURE 2.1 Historical data for nitrate in groundwater samples from monitoring wells and public water supply wells in 1970-2005. Source of photograph: USDA (1966).

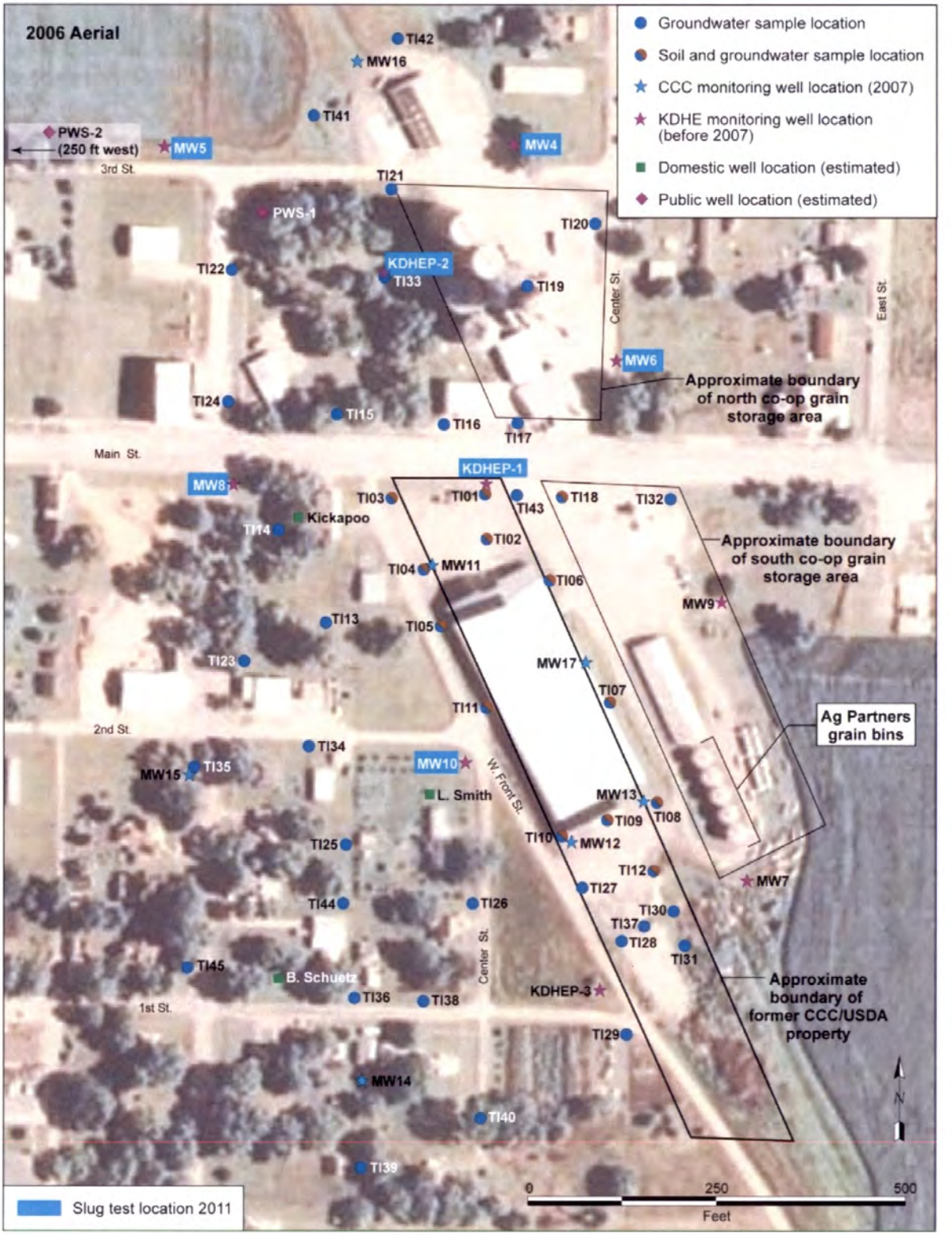

FIGURE 2.2 Sampling locations in the 2007 investigation, with locations of CCC/USDA wells installed in 2007 and slug tests in 2011. Source of photograph: NAIP (2006).

FIGURE 2.3 Network of monitoring wells equipped with data loggers for water level monitoring, as of January 2008. Source of photograph: NAIP (2006).

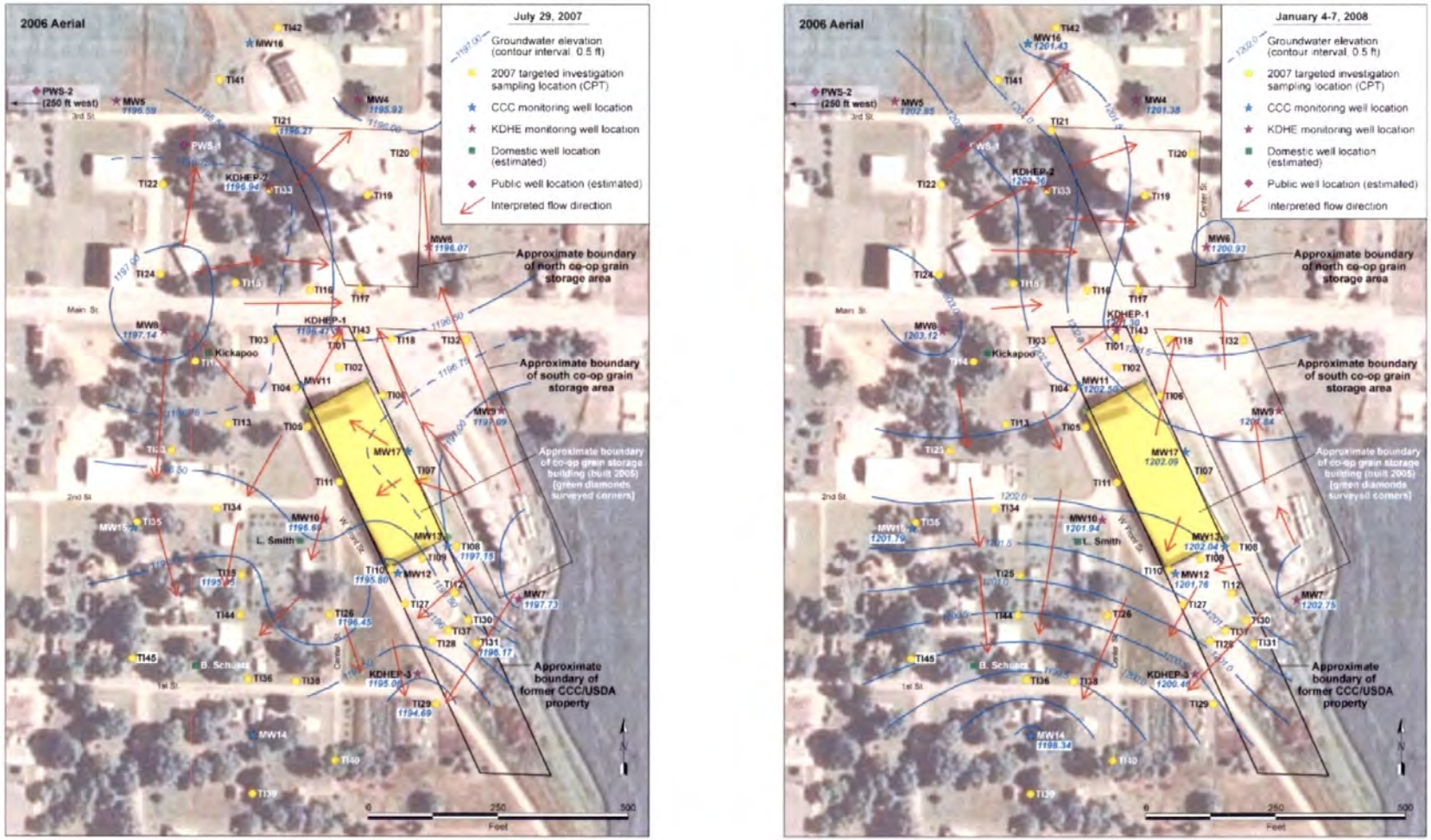

FIGURE 2.4a Groundwater levels and potentiometric surface in July 2007 and January 2008. Source of photograph: NAIP (2006).

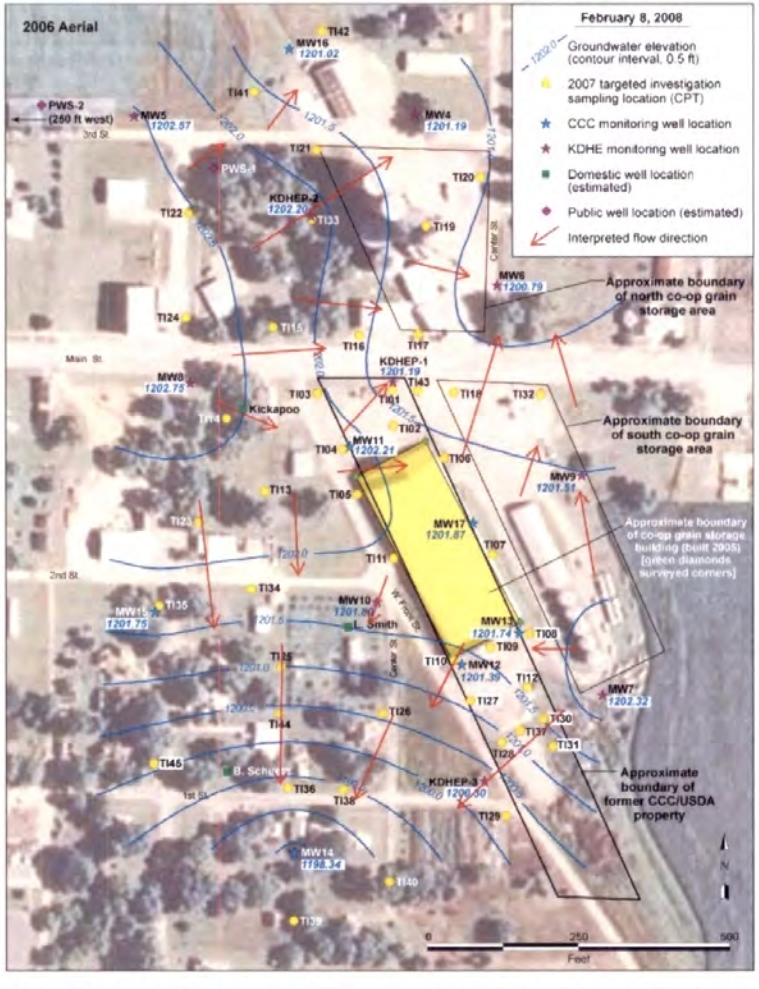

FIGURE 2.4b Groundwater levels and potentiometric surface in February 2008 and August 2011. Source of photograph: NAIP (2006).

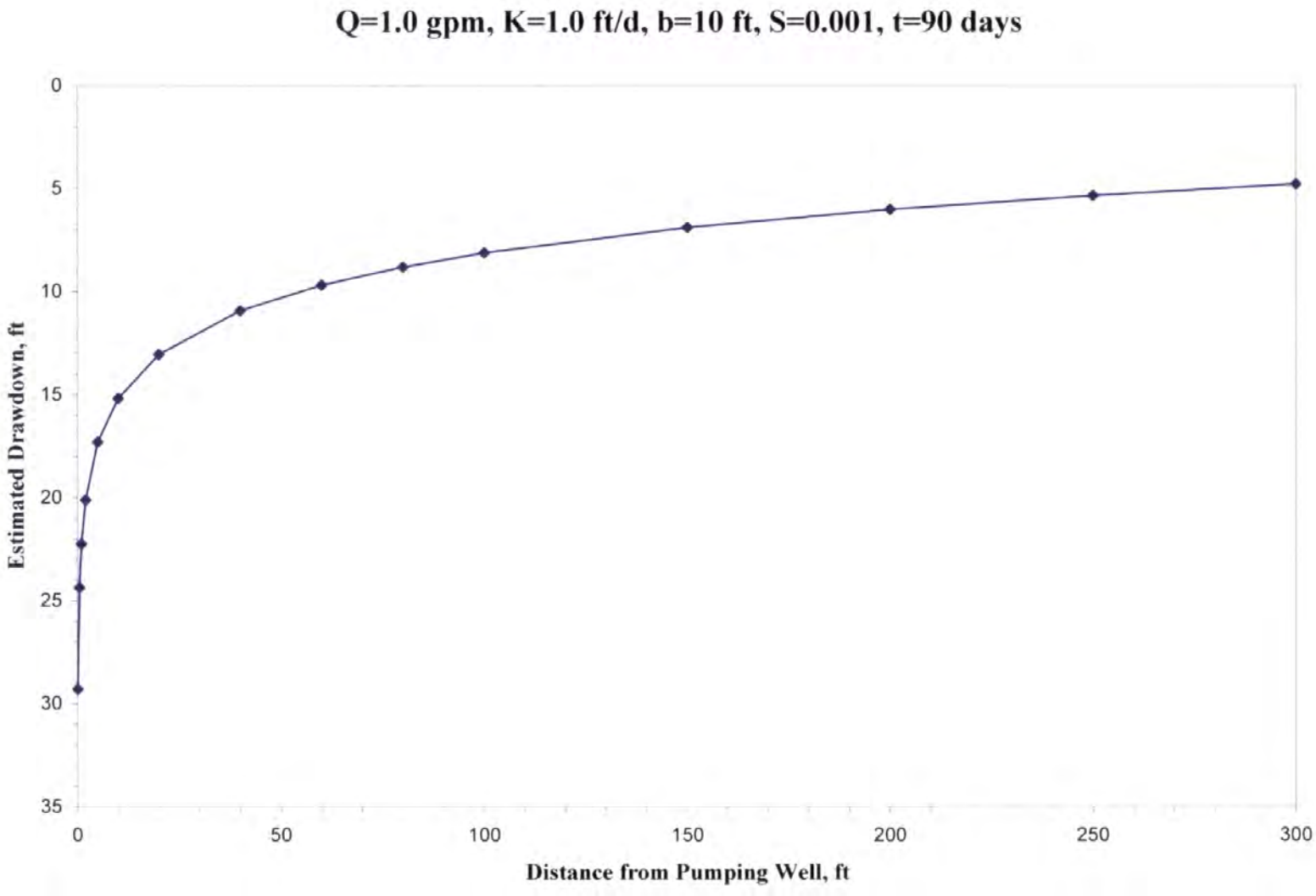

FIGURE 2.5 Estimated drawdown expected in the vicinity of a conventional well pumping for 90 d at 1 gpm, from an interval having an average thickness of 10 ft and a K_h of 1 ft/d. Drawdown was calculated by using the Theis method for a confined unit.

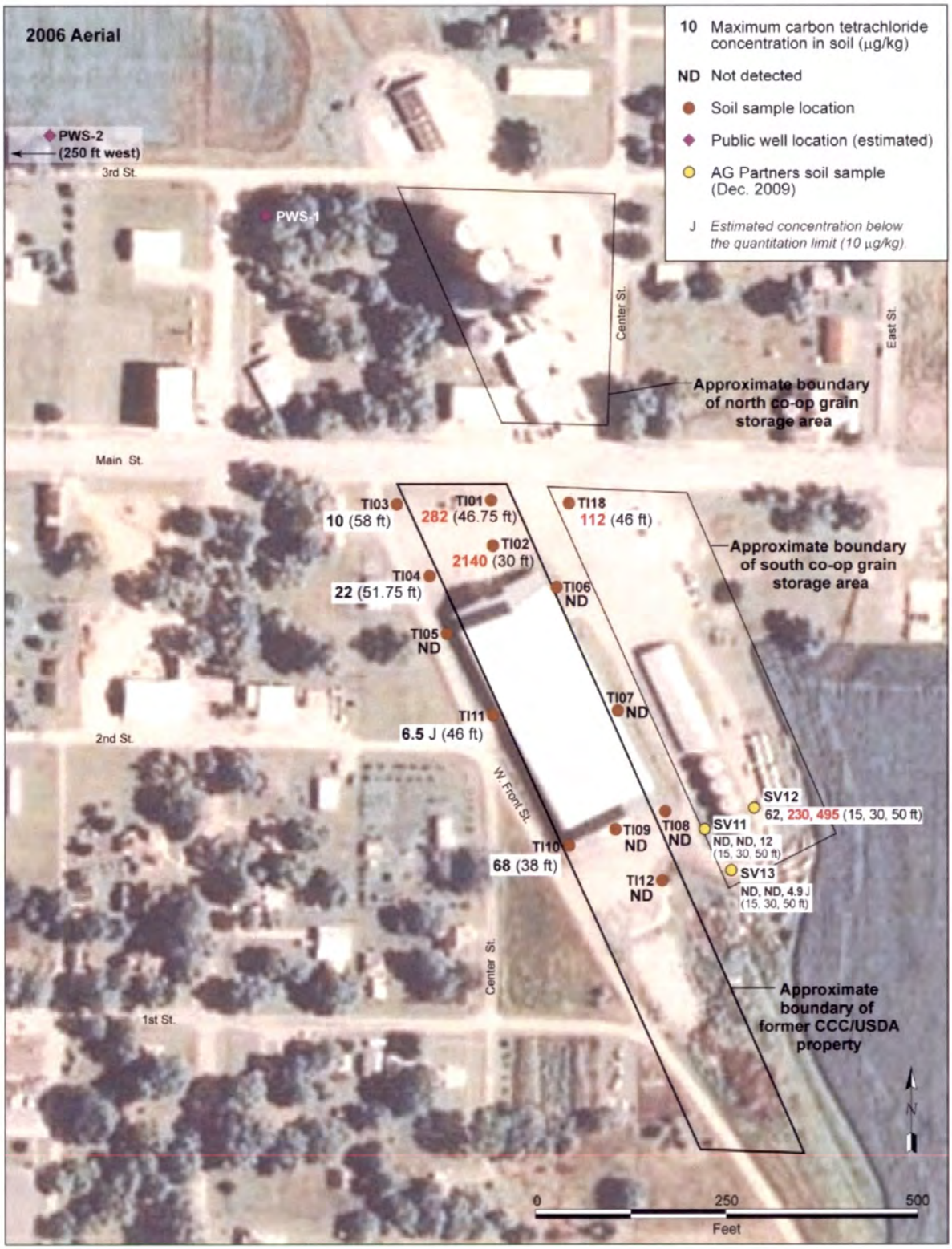

FIGURE 2.6 Carbon tetrachloride concentrations (maximum at each location) in subsurface soil samples collected during the 2007 investigation. Source of photograph: NAIP (2006).

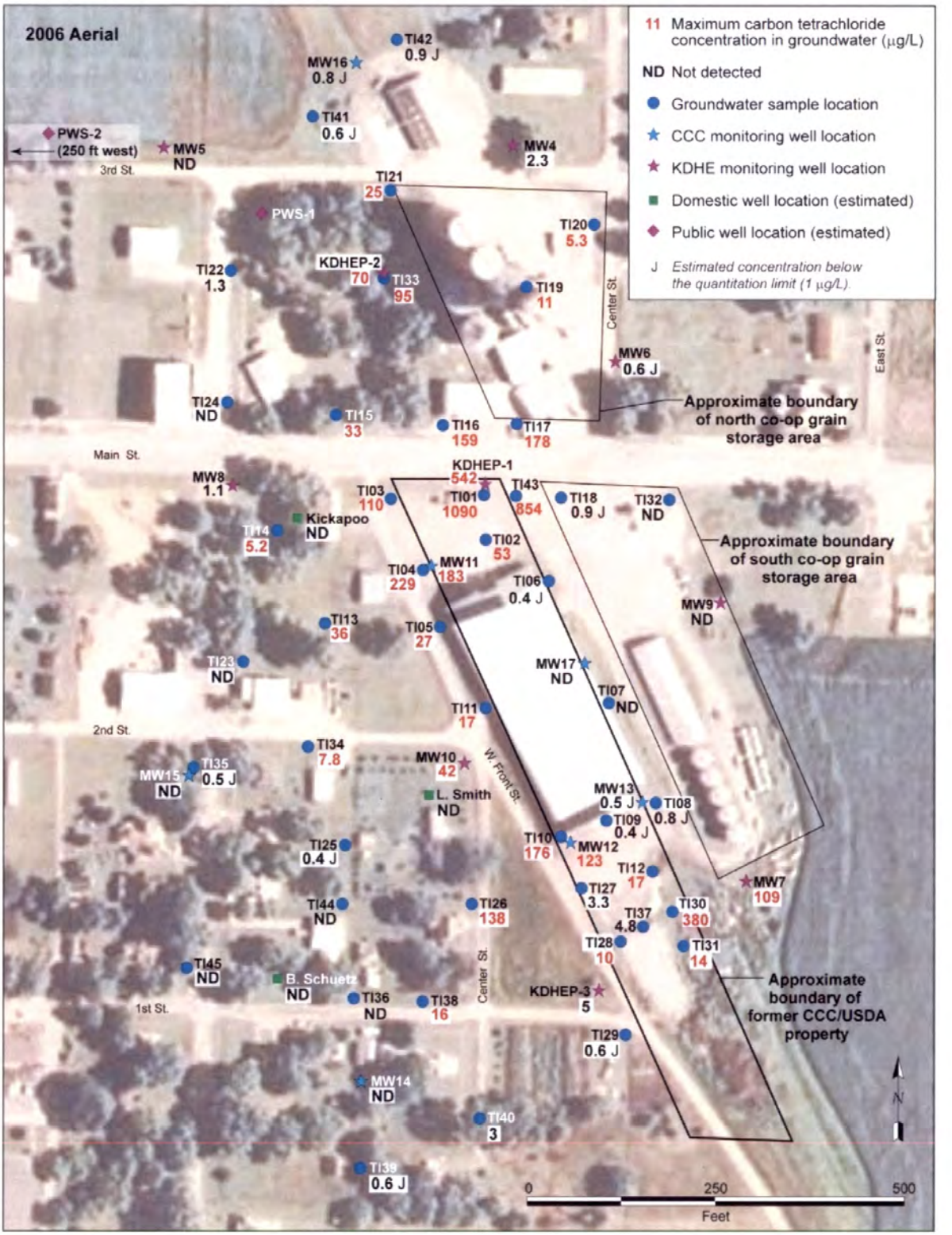

FIGURE 2.7 Carbon tetrachloride concentrations (maximum at each location) in groundwater samples collected during the 2007 investigation. Source of photograph: NAIP (2006).

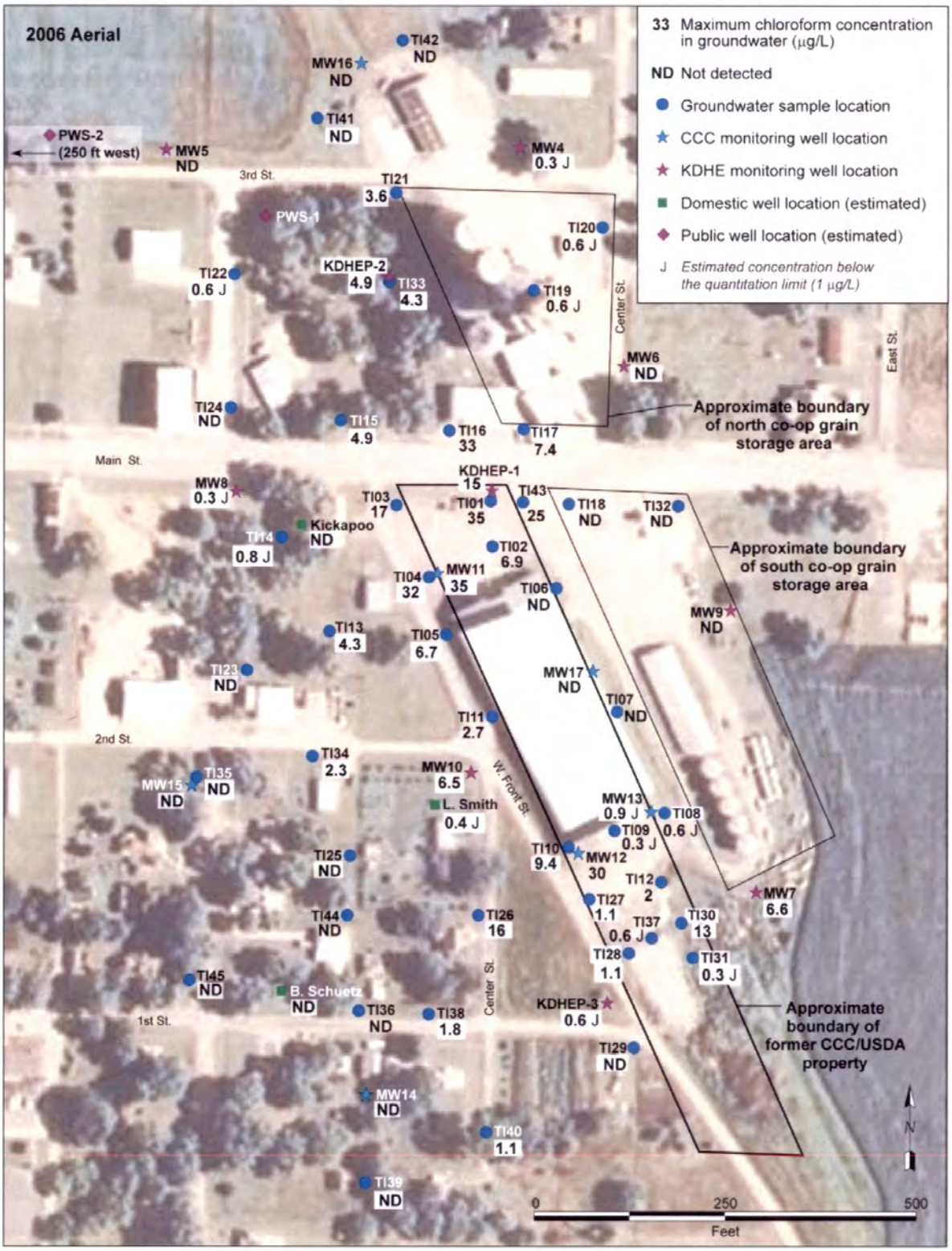

FIGURE 2.8 Chloroform concentrations (maximum at each location) in groundwater samples collected during the 2007 investigation. Source of photograph: NAIP (2006).

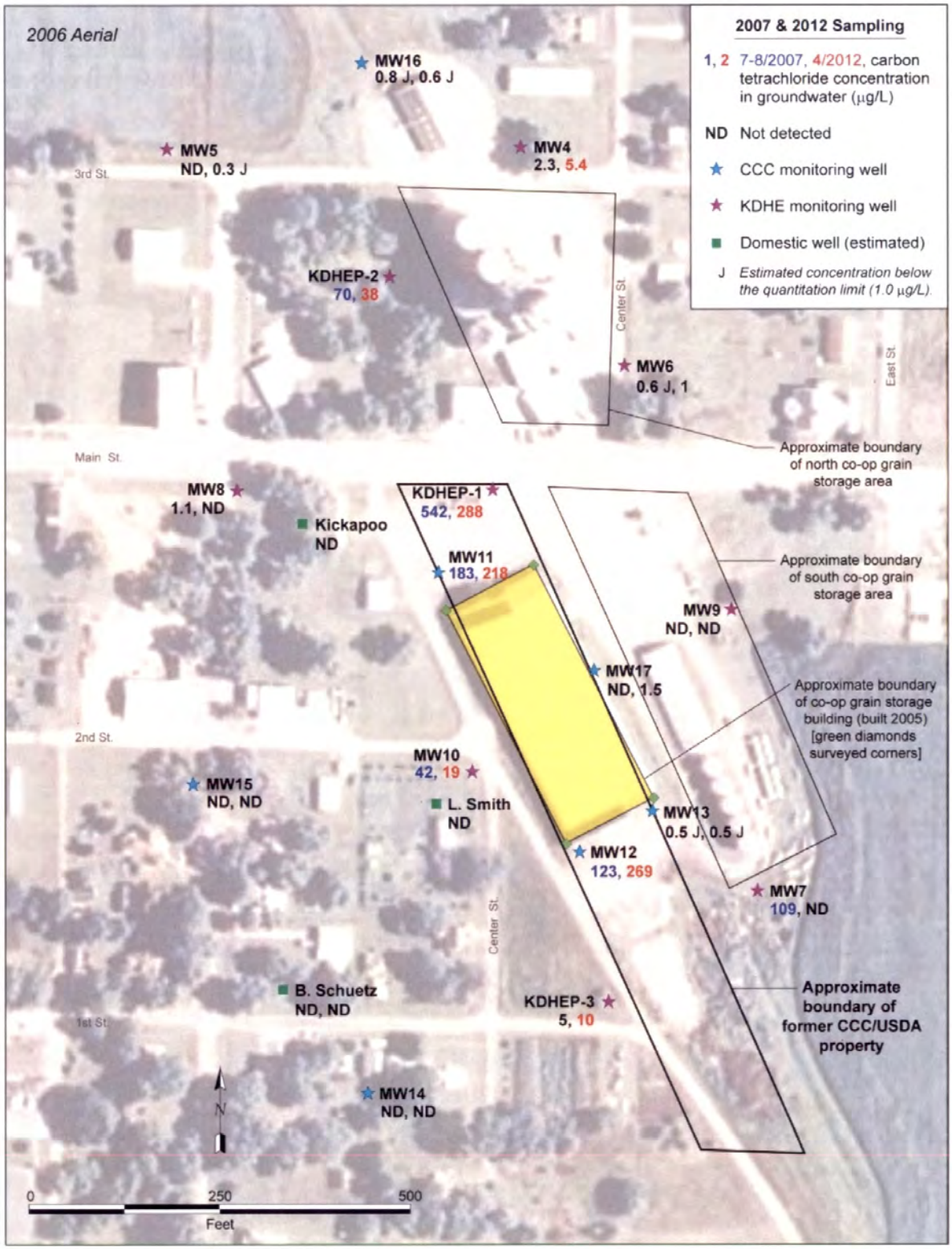

FIGURE 2.9 Carbon tetrachloride concentrations in groundwater samples collected in 2007 and 2012. Source of photograph: NAIP (2006).

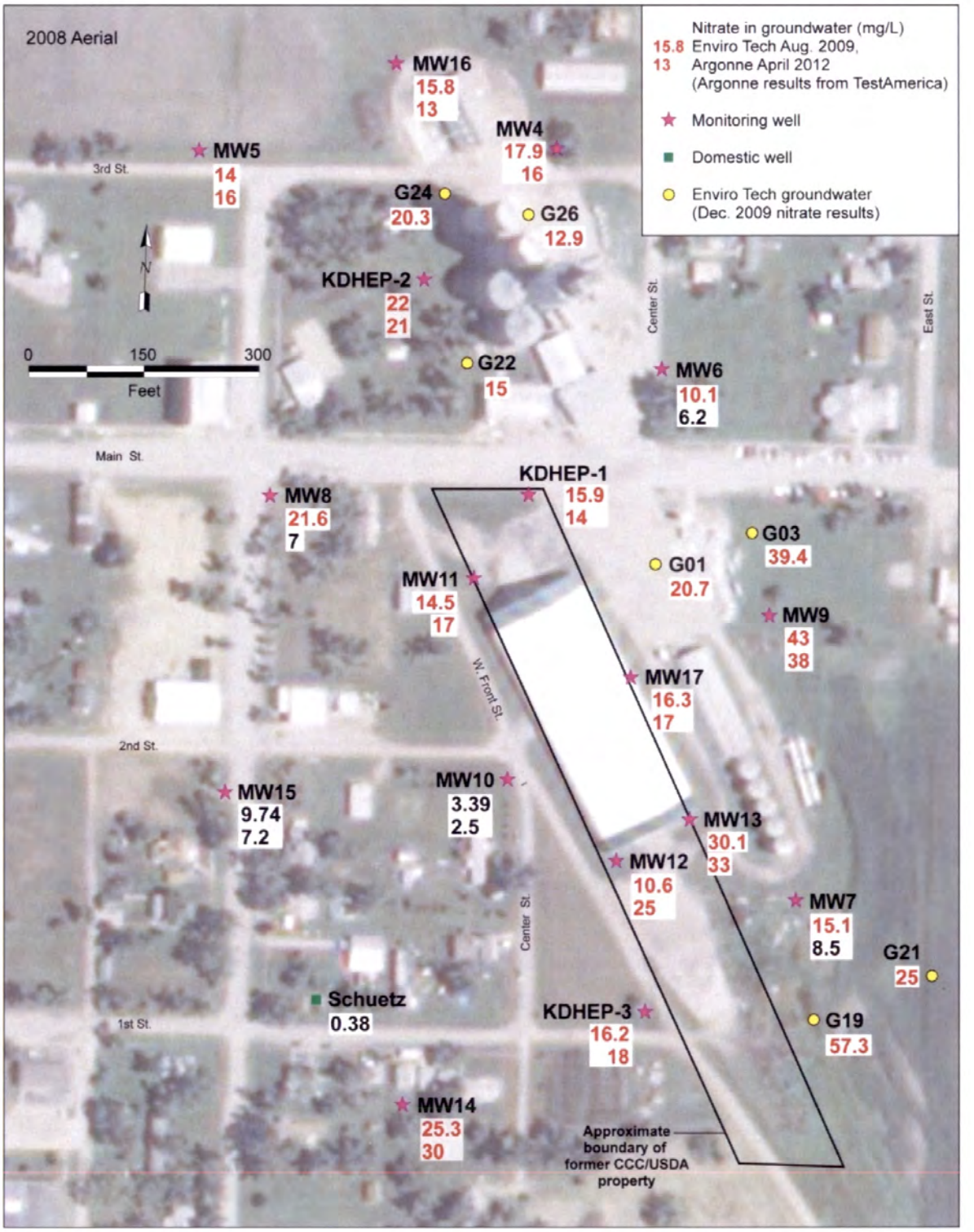

FIGURE 2.10 Nitrate concentrations in groundwater samples collected in 2012. Source of photograph: NAIP (2008).

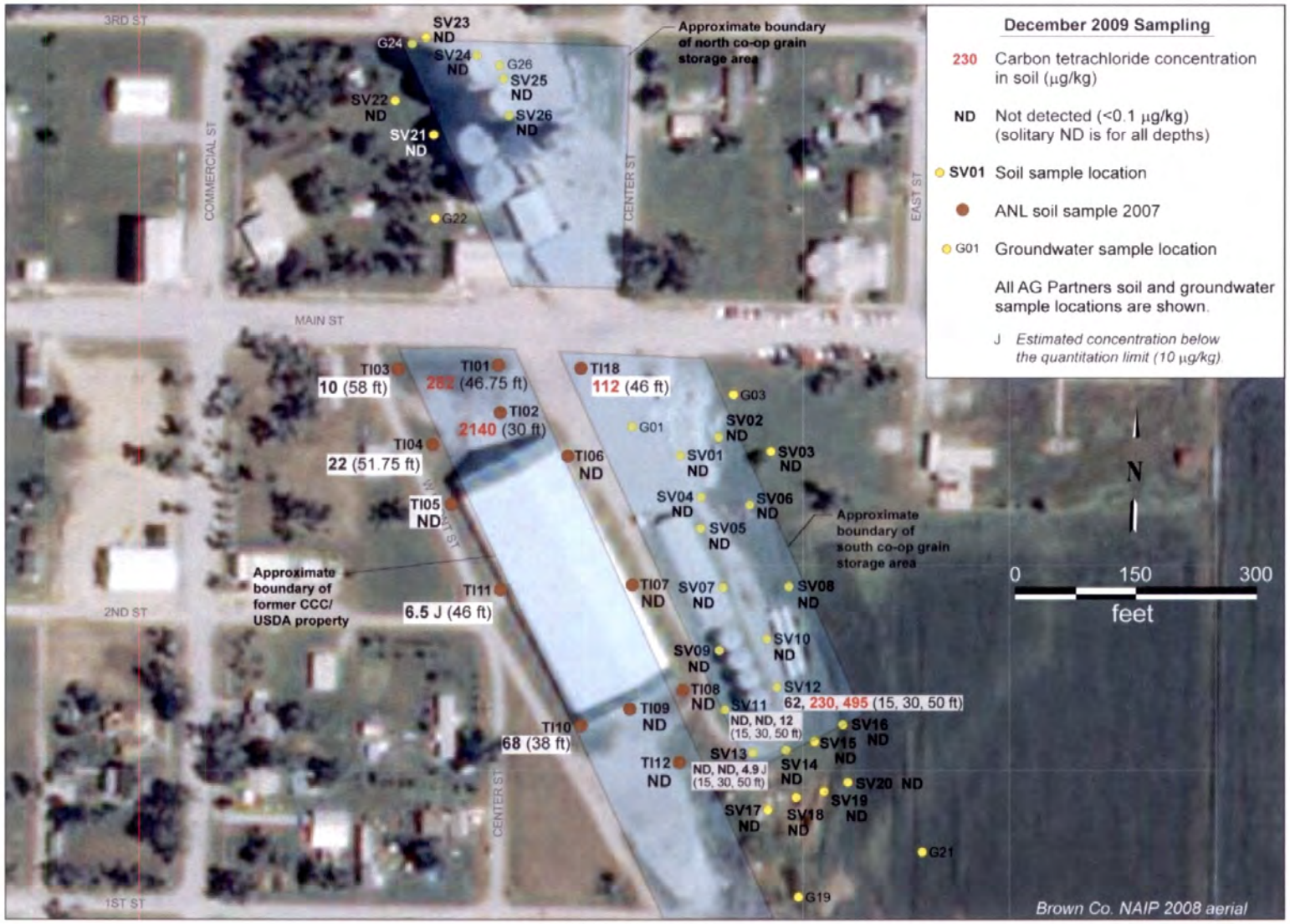

FIGURE 2.11 Ag Partners VCI soil sampling locations in 2009, with analytical results for carbon tetrachloride in split soil samples collected by Argonne. Source of photograph: NAIP (2008).

FIGURE 2.12 Ag Partners VCI groundwater sampling locations in 2009, with analytical results for carbon tetrachloride in split groundwater samples collected by Argonne. Source of photograph: NAIP (2008).

3 Evaluation of Current and Potential Future Human and Environmental Exposure Targets and Pathways

This evaluation of potential exposure targets and pathways addresses the identified source area at the northern limit of the former CCC/USDA facility where remediation is proposed.

Although no risks were identified in association with potential direct contact with contaminated soil or as a result of seepage of contaminated groundwater to surface water, future contaminant migration in the saturated soils and groundwater is a possibility. Unacceptable risks might also be associated with human exposure to contaminated groundwater if it is used as a drinking water source in the future.

3.1 Soil-to-Groundwater Exposure Pathway

Carbon tetrachloride concentrations exceeding the KDHE's RBSL guideline of 73.4 µg/kg for protection of the soil-to-groundwater pathway were identified at two locations (Argonne 2008). At the extreme northern end of the former CCC/USDA facility (the northern source area), contaminant levels up to 2,140 µg/kg were detected in (predominantly saturated) soil samples at depths of 14-53 ft BGL in investigative borings TI01 and TI02. Carbon tetrachloride was also detected at a concentration above the RBSL in a single soil sample recovered from nearby boring TI18 (112 µg/kg at 46 ft BGL), at the adjacent northwest corner of the Ag Partners property (Table 2.3 and Figure 2.7). These results represent a potential continuing source of contamination to the surrounding groundwater in and near the northern portion of the former CCC/USDA property.

A second confirmed source area for carbon tetrachloride contamination was identified by the KDHE (2006) at the southeastern end of the Ag Partners property. Consideration of the potential impacts of this source area is being addressed separately by Ag Partners in coordination with KDHE. This area was also investigated during the Ag Partners VCI investigation. Source areas sampled during the VCI investigation (soil sample locations SV 11, SV 12 and SV 13) are shown on Figure 2.6.

3.2 Water Supply and the Groundwater Exposure Pathway

Prior to 1995, Powhattan was served by both private wells and PWS wells located within the municipality. In 1989, the KDHE ordered Powhattan to seek an alternate PWS source because of long-term violations of the MCL for nitrate in the groundwater from the city's two PWS wells, PWS1 and PWS2 (KDHE 1989 and Appendix A). One of the PWS wells was also contaminated with carbon tetrachloride, but the concentration was below the MCL (maximum 4.0 μg/L). In 1995, the use of wells PWS1 and PWS2 for public water supply was discontinued when a source of uncontaminated water became available from the Brown County RWD 2. Private wells continue to be used within the city for lawn and garden irrigation; however, currently there are no private wells being used to supply drinking water in the identified area of groundwater contamination.

Under the current conditions, there is no identified risk of exposure to contaminated groundwater via ingestion or other domestic uses. In the absence of enforced measures to prevent the future drilling of private domestic wells, or if existing private (lawn and garden) wells are misused for drinking water supply, future risk might exist in association with this potential exposure pathway.

3.3 Summary

No current or future risks are associated with direct exposure to near-surface soils or the seepage of groundwater to surface water.

Because Powhattan residents have been served by the RWD 2 public water supply system since 1995, there are no human health risks related to the use of contaminated groundwater as a domestic (drinking) water source. However, in the absence of enforced regulations to prevent future drilling of domestic wells, or in the event that existing wells are misused as a drinking water source, future risk might exist from this exposure pathway.

At present, potential continued contamination of the groundwater is an identified risk, because (saturated) soil is contaminated above the RBSL guideline for the soil-to-groundwater pathway in the northern source area.

4 Corrective Action Goals and Regulatory Considerations

4.1 Site-Specific Goals

The site-specific goals of any proposed remedial action at the former CCC/USDA facility concern soil, groundwater, and indoor air potentially impacted by groundwater. These goals are as follows:

- Reduce the concentration, mass, and volume of contaminated soil in the northern portion of the former CCC/USDA facility that is contributing to groundwater contamination.

- Reduce the toxicity, mobility, and volume of contaminated groundwater associated with the contaminated soil in the northern portion of the former CCC/USDA facility.

4.2 Regulatory Considerations

4.2.1 Applicable or Relevant and Appropriate Requirements and Guidance to be Considered

The KDHE guidance for the preparation of a CAS (KDHE 2001a) lists "compliance with Federal and State applicable, or relevant and appropriate requirements" as one of the criteria that must be evaluated in the CAS process. The CAS guidance also refers to and adopts several regulations and guidance documents related to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Section 121 of CERCLA and provisions of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP; EPA 1990) require the EPA to ensure that cleanup actions implemented under CERCLA meet the specifications of ARARs.

Applicable requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance. Only those state standards that are

identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

Relevant and appropriate requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that, while not attaining the status of being "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance, nevertheless address problems or situations sufficiently similar so that their use is well suited to the particular site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be relevant and appropriate.

As described by the EPA (1990), ARARs can be placed in three categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs address certain chemical species or classes of contaminants and relate to the allowable limits of contaminant concentrations in various environmental media (soil, groundwater, surface water, air). These ARARs can be used to determine cleanup levels. Location-specific ARARs are based on the specific setting and nature of the site, such as proximity to wetlands, floodplains, or archaeological resources. Action-specific ARARs relate to specific response actions (e.g., excavation or treatment activities) proposed for implementation at the site.

In addition to ARARs, the NCP (EPA 1990) provides for the use of other advisories, criteria, or guidance "to be considered" (TBC). The TBCs are advisories, criteria, and standards that are issued by the federal or state regulatory body but are not legally binding because they have not been promulgated. The identification of TBCs is not mandatory; however, they are to be used, as appropriate, to complement the ARARs.

Potential ARARs for the proposed actions described in Sections 5, 6, and 7 were identified on the basis of the nature of the contamination, the site location, and the proposed activities. A comprehensive list of potential ARARs and TBCs, including both federal and Kansas requirements, is in Appendix B. Chemical-specific and action-specific ARARs are discussed below in relation to the Powhattan site.

4.2.2 Chemical-Specific ARARs

Cleanup levels are generally established on the basis of chemical-specific ARARs, which are requirements or risk-based numerical limits establishing the allowable amount or concentration of a hazardous substance that may exist in or be released to the environment. The contaminants of concern in this case are carbon tetrachloride and chloroform, and a potential chemical-specific ARAR would be the Kansas-administered Federal Safe Drinking Water Regulations, which establish MCLs pertaining to public water supplies as potential ARARs. The MCL for carbon tetrachloride is 5.0 µg/L, as is the Kansas Tier 2 RBSL. The MCL for chloroform is 80 µg/L, as is the Kansas Tier 2 RBSL.

Nitrate contamination present is not from CCC/USDA operations and, therefore, is not the responsibility of CCC/USDA. The MCL for nitrate is 10 mg/L; however, because the KDHE takes into account the background concentration of nitrate in groundwater, alternative cleanup goals may be considered (KDHE BER-047). Nitrate-laden waters could be targeted for beneficial reuse, such as makeup water at an operational facility or irrigation.

4.2.3 Action-Specific ARARs

4.2.3.1 Well Placement and Construction Regulations

Regulations included in the Code of Kansas Regulations (COKR) 28-30 — Water Well Contractor's License and Water Well Construction[2] — are considered applicable for this CAS. The regulations provide protective measures for the installation of new water supply wells. Included in construction regulations for wells that are not used for PWS (and thus are applicable to the construction of private water wells and monitoring wells) are a well placement component and a well construction component. More specifically, COKR 28-30-6 (a), (b) (c), (f) and (j) specify the following:

[2] The Water Well Contractor's License and Water Well Construction regulations are part of Code of Kansas Regulations 28-30 and can be found at:
http://www.kdheks.gov/waterwell/download/Article_30_AMENDED_2013.pdf

(a) Each water well shall be so located as to minimize the potential for contamination of the delivered or obtained groundwater and to protect groundwater aquifers from pollution and contamination.

(b) The following requirement for grouting shall be met: each constructed water well and each reconstructed water well shall be sealed by grouting the annulus between the casing and the boring from ground level to at least 20 ft.

(c) If groundwater is encountered at a depth less than the minimum grouting requirement, the grouting requirement may be modified by the secretary to meet local conditions.

(f) Casing shall meet the following requirements: (1) each water well shall have durable watertight casing from at least one foot above the finished ground surface to the top of the producing zone of the aquifer; and (2) the watertight casing shall extend at least 20 ft below the ground level. Exceptions to either of these requirements may be granted by the secretary if warranted by local conditions.

(j) Each groundwater-producing zone that is known or suspected to contain natural or man-made pollutants shall be cased and grouted in accordance with subsection (b) during construction of any water well to prevent the movement of groundwater to either overlying or underlying fresh groundwater zones.

4.2.3.2 Licensing and Professional Certifications

Regulations included in COKR 66-6-1 through 66-14-12, Kansas Board of Technical Professions, establish requirements for the licensing of professionals such as engineers, land surveyors, and geologists. These regulations will be applicable if the services of a geologist, engineer, or land surveyor are required to implement a corrective action alternative.

4.2.3.3 Water Appropriation Regulations

Regulations included in COKR 5-1-1 through 5-10-6 and COKR 5-50-1 through 5-50-8 establish requirements for obtaining water. If water appropriations are required for the implementation of a corrective action, these regulations will be applicable.

4.2.4 Advisories, Criteria, and Guidance

A chemical-specific TBC is the Kansas Tier 2 RBSL guidelines for the soil-to-groundwater pathway. The values are 73.4 µg/kg for carbon tetrachloride and 850 µg/kg for chloroform.

The Kansas vapor intrusion (VI) guidance (KDHE 2007) defines "buildings of concern" for chlorinated VOCs as those within 100 ft laterally and 40 ft vertically of the contamination. At Powhattan, there are no receptors within 100 ft of the confirmed soil contamination source and the primary water-bearing zone is greater than 40 ft BGS. Consequently, the VI guidance is not considered TBC guidance unless site conditions have changed since the original investigation.

Although nitrate contamination did not originate from operations at the former CCC/USDA facility, KDHE guidance on the investigation and remediation of nitrate and ammonium contamination affects the evaluation and implementation of alternatives described in this CAS. KDHE (2014) guidance pertains to agriculture and bulk distribution-related sites that include the use, manufacture, transportation and/or distribution of chemicals resulting in nitrogen contamination (which is the case at the Powhattan site). The *Presumptive Remedy Policy Investigation and Cleanup of Nitrogen at Agriculture-Related Sites in Kansas*, KDHE Bureau of Environmental Remediation (BER) policy BER-RS-047 (hereafter referred to as the Nitrogen Presumptive Remedy [NPR]) is to be used along with the updated policy *Guidelines for Investigating and Remediating Nitrate/Ammonia Contamination from Agricultural Chemical Releases*-revised June 2010, BER-RS-050, to address nitrate contamination in soil and groundwater. The two BER policies describe soil excavation and land application as a remedial approach for soil with nitrate contamination, and pump and irrigate or pump and the use of extracted water for mixing water at fertilizer plants as two typical groundwater-related presumptive remedies. The NPR also poses the use of institutional controls such as Environmental Use Controls (EUCs) as a component of the cleanup strategy to manage risks.

Cleanup levels set out in the NPR guidance are 200 mg/kg total nitrogen for the upper 24 in. of soil and 40 mg/kg for soil deeper than 24 in. Cleanup levels for groundwater are 10 mg/L. The guidance notes that an alternative cleanup level may be set if the background concentration of nitrate is above that 10 mg/L threshold level, as is the case at Powhattan.

Nevertheless, this CAS does not address the remediation of nitrate contamination caused by Ag Partners and the predecessor operators of the agricultural co-op.

The KDHE policy BER-RS-023, Scope of Work for a Corrective Action Plan/Corrective Action (CAP/CA), provides TBCs guidance regarding the content of the CAP and corrective action to be used to address the remedial actions required by KDHE Corrective Action Decisions (CADs). The CAP documents the basis for the design and implementation of remedial actions with the level of detail commensurate with the complexity of proposed actions. The primary objectives of the CAP are as follows:

- Develop preliminary design for proposed remedial actions;
- Develop schedule identifying critical path tasks necessary to implement remedial actions;
- Collect supplemental data as necessary to support remedy design and implementation;
- Develop detailed design plans and specifications for the remedial actions;
- Develop Contingency Plans that identify alternative corrective actions to be implemented in the event of a significant remedy failure; and,
- Develop or enhance Site Monitoring and Performance Evaluation (SMPE) Plan to monitor the effectiveness of the corrective action.

As specified in the policy, work products that constitute the practice of the disciplines of geology, engineering, architecture, or surveying should be sealed, signed, and dated by a professional licensed by the Board to practice in the State of Kansas. Depending on the nature of the corrective

action, a Construction Quality Assurance Plan and a Health and Safety Plan may need to be developed. Key elements of the CAP and associated documents include:

- Summary of available site information and investigation results;
- Detailed description of the proposed corrective action;
- Remedial action objectives (RAOs) and remedial goals;
- Design specifications and drawing/schematics, including figures and site system engineering layouts (e.g., process flow diagram, piping and instrumentation diagram, etc.) and engineering design basis prepared as, for example a preliminary (10%), intermediate (30-50%) followed by a pre-final/final (90-100%) design package;
- Cost estimate; and,
- Detailed working schedule or critical path diagram.

The CAP/CA must also contain an Operations and Maintenance plan and a Site Monitoring and Performance Evaluation (SMPE) Plan. The SMPE Plan includes a monitoring component to be used for evaluating the effectiveness of the remedial action and a reporting component to keep KDHE apprised of the performance of the remedial action remedy. Key elements of a SMPE Plan include:

- RAOs and remedial goals;
- Summary of the remedial system operations that will be evaluated and identification of four criteria that will be used to evaluate system performance;
- Frequency, methods, and rationale for site monitoring;
- Description of the environmental media to be sampled (groundwater, surface water, soil, soil vapor, indoor air, etc.);

- Description of quality assurance/quality control (QA/QC) considerations;
- Identification of institutional controls that will be inspected/monitored;
- Plan for evaluating changes in land use of impacted areas that may alter the effectiveness of the corrective action;
- Description of reporting methods, format, and frequency; and,
- Description of contingency trigger criteria (e.g., asymptotic mass removal/product recovery rates, sentinel monitoring thresholds, etc.).

An outline for the SMPE Reports is included in the policy. Other Kansas action-specific TBC guidance includes several KDHE BER policies (KDHE 2001a,b; KDHE 2002; KDHE 2005b,c,d,e).

4.2.5 Waivers and Variances

Remedial alternatives that do not meet the requirements of an ARAR under CERCLA may qualify for a waiver or variance. Waivers apply only to the attainment of the ARAR; other statutory requirements (e.g., that remedies be protective of human health and the environment) cannot be waived (CERCLA §121[d][4]).

- *Interim Remedy.* An interim remedial action will not attain all ARARs; it must be followed by a complete measure that will attain all ARARs.
- *Equivalent Standard of Performance.* Equivalent or better results can be obtained by using a design or method different from that specified in the ARAR.
- *Greater Risk.* Compliance with an ARAR will cause greater risk to human health and the environment than noncompliance.
- *Technical Impracticability.* Achieving an ARAR(s) is impracticable from an engineering perspective.

- *Inconsistent Application of State Requirements.* The state has not consistently applied (or demonstrated the intention to apply consistently) a standard, requirement, criterion, or limitation in similar circumstances for other remedial actions.

- *Fund Balancing.* The costs associated with meeting an ARAR to obtain an added degree of protection or decrease in risk would jeopardize the funds for remedial actions at other sites (EPA 1990).

5 Identification and Screening of Technologies

In this section, candidate remedial technologies and practices are reviewed, along with their potential applicability to the focus area for this CAS (Section 3). A list of currently available technology types and practices suitable for the mitigation of carbon tetrachloride contamination in soils, and groundwater, was developed first. The technology types were then screened relative to site-specific conditions, in accordance with KDHE (2001a) and EPA (1988) guidance. Technology types retained after the screening were then assembled into corrective action alternatives that are outlined in Section 6 and evaluated in detail in Sections 7 and 8 (along with the no-action alternative), in accord with KDHE (2001a, 2009b) guidance.

The following types of general response actions were considered for mitigation of risk, in addition to the required no-action option:

- *Land use controls* to restrict potential future exposure to impacted groundwater.
- *Containment* to restrict contaminant migration. The containment technologies considered included engineered physical barriers to groundwater flow.
- *Removal* of the contamination or contaminated media for *ex situ* treatment (as needed) and discharge or disposal. Removal technologies for soil, groundwater, and volatile contaminants were evaluated.
- *In situ* implementation of chemically or biologically mediated processes within or downgradient from impacted areas. The *in situ* technologies examined were permeable reactive barriers and *in situ* chemical reduction (ISCR), implemented via methods other than through the use of permeable barriers.

5.1 Criteria for Identifying and Screening Technologies

Technologies identified here were screened on the basis of site-specific conditions and the current understanding of the former CCC/USDA facility. Section 121 of CERCLA identifies a strong statutory preference for remedial actions that are highly reliable and provide long-term protection.

The *primary requirements* for a selected remedy are that it

- Protects human health and the environment and
- Meets the objectives of the proposed action in a cost-effective manner.

Additional selection criteria include the following:

- Preferred remedies achieve permanent or significant reduction of the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants.
- Where practical treatment technologies are available, off-site transport and disposal without treatment is the least preferred alternative.
- Permanent solutions and innovative treatment technologies or resource recovery technologies are preferred whenever practicable.

These criteria were considered in identifying and screening technologies to determine the appropriate components of the corrective action alternatives presented in Section 6.

Potentially applicable technology types and process options were screened on the basis of effectiveness, implementability, and cost, defined as follows:

- *Effectiveness* in terms of protecting human health and the environment in both the short term and the long term. Measures of effectiveness include (1) reduction of long-term impacts to human health and the environment; (2) reduction of contaminant toxicity, mobility, or volume through treatment; (3) control of potential impacts to human health and the environment during the action period; (4) timeliness; and (5) consistency with regulatory requirements.
- *Implementability* in terms of technical and administrative feasibility and resource availability. Technical feasibility is related to the practicability of construction, the reliability of operation, and the ability to meet technology-specific regulations. Technical feasibility also addresses potential constraints

associated with the site environment. Administrative feasibility concerns the acceptability of an alternative to relevant agencies and the public, as well as the effects of limitations imposed by permits and other restrictions. Resource availability addresses physical and logistic requirements for implementing specific components.

- *Cost*, considered in a comparative manner (low, moderate, or high) for technologies of similar performance and/or implementability.

These screening criteria were applied, as discussed below, to the individual technologies and practices under consideration. Combinations of technologies to address site-specific contamination were evaluated after the technologies were assembled into alternatives, as presented in Section 6.

5.2 Screening of Remedial Technologies

The following sections document the screening of candidate remedial technologies and practices.

5.2.1 No Action

The KDHE requires evaluation of a no-action alternative as a baseline for comparison with other actions. Under this alternative, the site is left unchanged. The carbon tetrachloride contamination at Powhattan does not affect a present source of drinking water. Protective regulations for the water supply, such as the Kansas well placement and construction regulations (Section 4.2.3.1) that are already in force, will continue to preclude exposure to the contamination. As noted previously, Powhattan was ordered by the KDHE (1989) to seek a new water source because of the detection of nitrate concentrations above the MCL in local water supply wells. As a result, even with no action, the nitrate contamination is a disincentive to rely on local groundwater as a drinking water source.

The no-action alternative is discussed further in Section 6.1.

5.2.2 Kansas Environmental Use Controls

The Kansas EUC program (KDHE 2009a) was established by Kansas House Bill 2247 (Kansas 2003), which became law on April 21, 2003. An EUC is defined as an institutional or administrative control — a restriction, prohibition, or control — for one or more uses of, or activities on, a specific property. In most cases, the property owner seeking the EUC has caused or is otherwise responsible for the contamination being addressed. When residual contamination exceeds standards for unrestricted use, the property owner may request the EUC to allow for appropriate use of the property while ensuring the present and future protection of public health and the environment.

Obtaining an EUC involves completing an application that details property information, applicant information, the nature of the existing or potential contamination, requested restrictions, and a signature by the site owner or a designated representative. As part of the EUC, the applicant must agree to register an approved, notarized EUC agreement with the registrar of deeds in the county in which the property is located. The EUC can be removed if the contaminant concentration decreases below environmental standards.

As explained in KDHE (2005a) guidance, EUC sites are classified by the KDHE in one of three categories, on the basis of property size, the toxicity and mobility of residual contamination, and necessary KDHE inspection frequency. The approval of an EUC agreement involves either a one-time payment to the KDHE or a long-term care agreement with the KDHE. Category 1 sites have a one-time payment of $2,000, while Category 2 sites have a one-time payment not to exceed $10,000. The long-term care agreement required for Category 3 sites can be funded at the outset or as costs are incurred by the KDHE (KDHE 2005a, 2009a).

5.2.2.1 Effectiveness of Kansas Environmental Use Controls

Although EUCs do not actively reduce contaminant toxicity, mobility, or volume, they can be effective in reducing the potential for exposure to contaminated material. When they are implemented in a timely manner and remain in effect until contaminant concentrations reach acceptable regulatory levels, these controls can provide both short- and long-term protection of human health and the environment. In general, the effectiveness depends on monitoring and enforcement. The Kansas EUC program has a proven record of managing risk at single properties affected by contamination.

The existing Kansas well placement and construction regulations (Section 4.2.3.1) include generic restrictions comparable to those of a site-specific EUC for the protection of citizens from exposure to contaminated groundwater.

5.2.2.2 Implementability of Kansas Environmental Use Controls

To be protective, all of the landowners within the footprint of the contamination at Powhattan would need to participate in the EUC program and agree to the establishment of property-specific deed restrictions that control certain activities on their properties, such as construction of habitable structures or installation of drinking water wells. In addition, applicable EUC administrative fees, such as the EUC application fee, apply for each participating landowner.

Except for Ag Partners, none of the potentially impacted property owners has responsibility for groundwater and soil contamination that is present. Furthermore, these property owners currently have no property-specific deed restrictions to control how property is used, maintained, or developed. The deed restrictions are of no foreseeable advantage to the affected property owners. Thus, these individuals are considered unlikely to agree to the restrictions typically associated with the EUC program, and establishing EUCs for all of the approximately ten land owners involved at Powhattan is not considered implementable.

5.2.2.3 Costs of Kansas Environmental Use Controls

The KDHE determines the category of EUCs on a case-by-case basis. However, for planning purposes, the CCC/USDA assumes that the $10,000 EUC administrative fee for Category 2 properties would be required for each EUC application at Powhattan. The costs are considered to be moderate to high.

5.2.2.4 Kansas Environment Use Controls – Eliminated

On the basis of the impediments to implementation, EUCs have been eliminated from further consideration.

5.2.3 Containment by Engineered Physical Barriers to Groundwater Flow

Engineered physical barriers to contain groundwater flow can reduce contaminant mobility and the associated potential for exposure, but they do not reduce contaminant toxicity or volume. Examples of such barriers include cryogenic barriers designed to freeze moisture in a relatively limited, discrete area within the soil horizon and thus immobilize soluble contaminants; slurry walls installed by backfilling trenches or borings with an expanding material (e.g., bentonite) to form either a continuous or discrete wall; and sheet pilings constructed by driving interlocking steel or plastic sheets into the subsurface to the desired depth.

5.2.3.1 Effectiveness of Engineered Physical Barriers

Engineered physical barriers do not actively reduce contaminant toxicity or volume but can impact mobility. The potential for engineered physical barriers to achieve containment of the contamination at Powhattan is, however, extremely limited. Most notably, the existing areal extent of the contamination, in addition to the complex patterns of groundwater flow identified, make it very difficult to control contaminant migration.

The presence of cultural features (residences and utilities) across some of the area overlying the groundwater contamination limits the range of candidate physical barrier placement sites. One or more physical barriers might be employed to reduce horizontal contaminant mobility locally, in a preferred area or direction, but without additional groundwater control measures (such as groundwater extraction [Section 5.2.4]), such structures could have potentially detrimental effects, including contaminant migration around, over, or under the barrier, or localized groundwater mounding upgradient of the barrier. Any mounding effects could drive contaminated groundwater closer to the surface, conceivably increasing the potential for VI.

5.2.3.2 Implementability of Engineered Physical Barriers

The locations potentially available for implementation of subsurface barrier technologies to address the groundwater contamination are restricted logistically by the presence of cultural features, including private homes, other structures, roads, and subsurface utilities. In addition, the identified depth to the base of the contaminated interval is up to 74 ft BGL, necessitating specialized continuous trenching techniques. Construction of a physical barrier might cause only relatively short-term disruption to the daily activities of nearby residents, but it could result in

significant damage (requiring restoration) to private properties affected by the installation activities and would raise significant safety issues.

5.2.3.3 Costs of Engineered Physical Barriers

Costs for engineered physical barriers would be moderate to high.

5.2.3.4 Engineered Physical Barriers — Eliminated

Because engineered physical barriers (1) could create uncontrolled vertical and horizontal groundwater flow components, (2) do not offer added protection in the upgradient area, and (3) would significantly disrupt the community and residents' private properties, this technology is eliminated from further consideration.

5.2.4 Extraction and Treatment of Groundwater

Groundwater extraction technologies can effectively reduce the mobility and volume of contaminants by coupling groundwater and contaminant removal with the potential for hydraulic control of the contaminant migration patterns near the extraction site. Groundwater extraction is typically accomplished by using conventional vertical wells equipped with electrically operated pumps.

5.2.4.1 Effectiveness of Groundwater Extraction and Treatment

Groundwater extraction wells can be installed in a timely manner, and operation of the wells could result in permanent reduction in the mobility and volume of the dissolved carbon tetrachloride contamination. The K_h values calculated from the 2011 slug test results (Section 2.2.1.4) suggest that groundwater extraction could be effective at Powhattan. The extraction of groundwater would have multiple effects including:

- Directly addressing the area near borings T 101, 102 and 118 confirmed to be a continuing source of contamination

- Removing contaminants from both the existing more mobile, impacted groundwater as well as the saturated soils in and near the identified source area

- Facilitating intrinsic processes that may decrease carbon tetrachloride concentrations towards the chemical-specific RBSL MCL value of 5.0 µg/L.

5.2.4.2 Implementability of Groundwater Extraction and Treatment

The installation of conventional groundwater extraction wells can be accomplished readily by using conventional (or other) drilling techniques, and the installation of a vertical well at Powhattan is logistically feasible, subject to access to private property. Access is necessary for the installation of the extraction well and the pumping well monitoring points. Access is also necessary to position the treatment system. The vertical extraction well head can be flush mounted so as not to interfere with residential or Ag Partners-related agricultural truck traffic. The force main piping from a submersible pump in the extraction well to a treatment system can be installed underground using conventional trenching methods. Piping for treated effluent also could be routed underground from the treatment system to a surface or other suitable discharge point (e.g., the Powhattan stormwater system). At this time, it appears that access agreements would be needed from Ag Partners only.

Two of the most common technologies for the treatment of extracted groundwater are adsorption by granular activated charcoal (GAC) and air stripping. The use of GAC represents an effective technology for the removal of organic contaminants from groundwater. This technology requires little energy for operation; however, periodic replacement of the GAC medium is required, as it becomes depleted during the treatment process. Air stripping involves the removal of VOCs from contaminated groundwater via exposure of the water to a high-volume forced-air flow. This process is typically conducted by using a packed tower or tray aeration unit. Electric service that would be required for the operation of pump(s) and possible treatment equipment is readily accessible in and near the area of groundwater and soil contamination identified at the former CCC/USDA facility. Because of the need to periodically replace the GAC medium, air stripping is the preferred treatment technology. Of the two air stripping designs, tray aeration is preferred because it has a smaller footprint and is better suited for treating the flow rates expected from the extraction well.

5.2.4.3 Costs of Groundwater Extraction and Treatment

Costs for groundwater extraction technologies and effluent treatment technologies for carbon tetrachloride are expected to be moderate.

5.2.4.4 Groundwater Extraction and Treatment — Retained

Because it is effective in suitable locations, offers the potential to address both (saturated) soil and groundwater contamination simultaneously, is readily implementable, and has moderate costs, groundwater extraction and treatment to address volatile organic contaminants has been retained

5.2.5 Groundwater Circulation and Treatment

Groundwater can be treated either *in situ* or *ex situ* by groundwater recirculation well (GCW) technology (EPA 1998). Typically, GCWs are double-cased or single-cased wells with separated upper and lower screened intervals in the well casing. GCWs create a circulation pattern in the aquifer by drawing water in at one screen interval and then reintroducing the water back into the aquifer at the second interval. The system can be configured with either upward or downward flow. In the typical configuration, airlift pumping creates inward flow from the lower screen interval into the well casing. The water that enters the casing rises because of the airlift action and is then discharged into the vadose zone at the upper screen interval. Vapors stripped from the air-lifted, contaminated groundwater can be withdrawn from the GCW and emitted to the atmosphere, with or without treatment. Alternatively, in a configuration resembling an *in situ* technology, extracted vapors can be injected into the vadose zone, or remediation chemicals applied at the wellhead can be introduced into the aquifer via the circulation pattern created by the GCW.

5.2.5.1 Effectiveness of Groundwater Circulation and Treatment

Groundwater circulation wells can be installed in source areas and/or in the plumes emanating from the source areas. The saturated (approximately 57 ft) thicknesses at Powhattan give GCW moderate potential for success. However, GCW technology is considered to have limited to no potential for success at a site where the unsaturated thickness is 0-5 ft in extent, an unsaturated zone thickness that is close to the typical 8 ft unsaturated zone thickness at Powhattan (Table 6 in Naval Research Laboratory [1999]). With respect to aquifer characteristics, the lower,

more porous and permeable (hydraulic conductivity approximately 1 ft/day; Section 2.2.1.4) silty-sandy portion of the saturated zone suggests a moderate potential for success. However, the hydraulic characteristics of the upper silty clay deposits of the saturated zone are likely less favorable, and the ratio of horizontal to vertical hydraulic conductivity throughout the saturated sequence is unknown. Given the presence of fine grained material in the unsaturated zone, it is likely that this ratio is anisotropic. Therefore, GCW technology will have limited or no potential for success. In addition, because the radius of influence for a GCW is probably much smaller than that for a conventional extraction well, a large number of GCWs would be needed to address contamination in the northern portion of the former CCC/USDA property.

5.3.5.2 Implementability of Groundwater Circulation and Treatment

Since the design of a GCW would involve positioning a well screen within 8 ft of the ground surface, a GCW would not be in compliance with an action-specific ARAR unless a waiver could be obtained. Construction of a GCW necessitates the placement of a screen interval just above the top of the saturated zone. Kansas well installation regulations require the annulus between the casing and the boring to be grouted from the ground surface to 20 ft BGL, a construction specification that precludes the use of a GCW at the Powhattan site.

5.2.5.3 Costs of Groundwater Circulation and Treatment

Pilot tests would be needed to evaluate the applicability of GCW for the site and to establish the radius of influence for the technology. Depending on (1) the complexity and duration of the pilot test needed to determine feasibility and design parameters, and (2) the success with which pilot test results could be used to design a full-scale system, costs for groundwater treatment with GCW technologies might be moderate to high.

5.2.5.4 Groundwater Circulation and Treatment — Rejected

Because of uncertainties about the effectiveness of the technology in the geologic setting at Powhattan and because installation of a GCW would be a violation of an Action-Specific ARAR, GCW technology has been rejected.

5.2.6 Subsurface Removal and Treatment of Volatile Contaminants by Soil Vapor Extraction, Air Sparging, or a Combination

In contrast to approaches that physically remove contaminated soil or groundwater for *ex situ* treatment, removal technologies such as soil vapor extraction (SVE) and air sparging (AS) target the removal of VOCs from soil and groundwater in the subsurface environment. Employed alone, SVE is typically used to address vadose zone soil contamination in relatively permeable soils. In this application, SVE is accomplished by "pumping" vertical or horizontal wells to induce a subsurface vacuum and thus extract contaminated soil vapors. Although SVE can remove contaminant vapors arising from an underlying saturated zone, SVE alone does not represent an effective technology for remediating contaminated groundwater.

The AS technology for removal of VOCs from subsurface groundwater is typically implemented by installing one or more wells screened in the saturated zone, from which air is forced to percolate through the adjacent (contaminated) groundwater column, promoting stripping of VOCs from the groundwater. The (now contaminated) air released from an AS system either is allowed to escape naturally to the surface or is collected by a coupled SVE system.

To enhance the removal of contaminants from both groundwater and vadose zone soil in certain situations, SVE can be performed in conjunction with AS. Contaminated soil gas extracted via SVE technologies (or combined SVE-AS systems) might require treatment before release to the air. In some instances, large-diameter boreholes (LDBs) can be employed for the installation of combined SVE-AS systems, to enhance the permeability of the materials surrounding the SVE and AS well screens. When installed, singly or in combination, these remedial treatment operations have been shown to be practical and cost-effective at numerous sites. The contaminant of concern must be volatile, and the lithology of the site should allow for the installation of a reasonable number of SVE wells to capture the contaminants mobilized by the AS component. Given the volatility of carbon tetrachloride, SVE is considered an effective technology. Furthermore, LDB technology has the added advantage of the physical removal of large volumes of contaminated soil.

5.2.6.1 Effectiveness of Soil Vapor Extraction and Air Sparging

Discrete zones where soil is contaminated above the soil-to-groundwater RBSL have been identified in the northern portion of the former CCC/USDA property. This zone could be targeted

for treatment by SVE-AS. However, groundwater levels documented in monitoring wells (completed in the lower silty-sandy interval) variably occur at 5-15 ft BGL, suggesting that locally saturated conditions extend into the shallower, contaminated portions of the soil profile. Under these possible conditions, conventional SVE would not be effective in removing contamination from the saturated intervals of soil.

Air sparging can be an effective technology for the remediation of groundwater; however, if used alone, it could exacerbate the migration of contaminated soil vapor from groundwater into the vadose zone and then into multiple residences. In addition, AS is typically not a suitable remediation technology at sites like Powhattan, with hydraulic conductivity values $< 10^{-3}$ cm/s (about 3 ft/day; NAVFAC 2001).

5.2.6.2 Implementability of Soil Vapor Extraction and Air Sparging

Installation of the facilities and equipment required for a combined SVE-AS system in the northern portion of the former CCC/USDA property might be technically and logistically feasible; however, as noted above, the design of such a system would require very careful, location-specific consideration of the site's geologic and hydrologic conditions. The installation of LDBs, if warranted, requires the use of large and relatively specialized equipment. Installation of any such system at Powhattan would be predicated on the construction and operation of a groundwater extraction (dewatering) system that could lower the water table, thus optimizing the functioning of the SVE-AS system. The extracted, contaminated groundwater would also require treatment. Under such circumstances, a groundwater extraction system would already be remediating the contaminated groundwater and saturated soils, so installing and operating an additional SVE-AS system (or LDB-SVE-AS system) would be redundant.

5.2.6.3 Costs of Soil Vapor Extraction and Air Sparging

Costs for the SVE-AS technologies coupled with a groundwater extraction system would be moderate to high.

5.2.6.4 Soil Vapor Extraction and Air Sparging — Eliminated

The presence of unacceptable concentrations of carbon tetrachloride in soil, the mass excavation benefit of LDB technology, and the anticipated radius of influence make LDB

technology suitable for addressing the soil and groundwater contamination at Powhattan. The LDB technology helps overcome the poor hydraulic conductivity impediment that makes conventional SVE and AS impractical. In order to function, however, this technology would need to be paired with a groundwater extraction (dewatering) and treatment component that would create an expanded vadose zone more amenable to SVE treatment. Since groundwater extraction and treatment alone would address the same contaminants to be targeted by a coupled GWPT and SVE-AS technologies, the SVE-AS technology has been eliminated from further consideration. Conventional AS technology has also been eliminated because of the poor hydraulic conductivity of the impacted aquifer and because AS technology could exacerbate the migration of contaminated soil vapor from groundwater into the vadose zone and then into multiple residences.

5.2.7 *In Situ* Treatment by Permeable Reactive Barriers

Permeable reactive barrier (PRB) technology has been used to treat both organic (including carbon tetrachloride) and inorganic contaminants. A permeable "wall" or barrier containing a chemically and/or biologically active treatment medium capable of interacting with the target groundwater contaminant(s) is constructed in the subsurface, across the groundwater migration pathway. The technology is passive, in that the design relies on natural hydraulic gradients to carry groundwater through the PRB, where the treatment occurs. The thickness of the PRB must be sufficient so that groundwater passes through with adequate residence time for treatment or removal of the contaminants (EPA 2002).

Construction methods used to install PRBs include conventional excavation, continuous trenching, and slurry wall techniques; deep soil mixing; horizontal or large-diameter boring; hydraulic fracturing; and injection. The depth limit for conventional excavation and trenching techniques is typically about 40 ft BGL (Hocking 2004).

Reactive constituents (such as zero-valent iron) are frequently used in barrier construction for the treatment of VOCs. The reactive constituents are often mixed with materials such as guar gum, sand, gravel, or native soil to increase barrier permeability, or in some cases to help promote biological activity. Other potentially reactive media include edible oil, mulch, and hydrogen- or oxygen-releasing compounds. These materials can negatively affect the potability of groundwater in the treatment area.

5.2.7.1 Effectiveness of Permeable Reactive Barriers

Where applicable, PRB technology is capable of reducing the toxicity, mobility, and volume of contaminants in groundwater. The identified areal extent of the contamination, plus the multiple groundwater flow directions affecting contaminant migration, could make the effective use of this technology difficult at Powhattan on a sitewide basis. In addition, the presence of cultural features (residences and utilities) limits the range of candidate PRB placement sites. One or more PRBs might possibly be employed locally to intercept the contamination in groundwater at a restricted number of locations, subject to property access. Since the PRB technology relies, however, on natural groundwater flow to transport contaminants toward and through the subsurface PRB, the identified predominance of silty clays in the stratigraphic section and the relatively low permeabilities of the lower silty-sandy interval would result in a prolonged remediation time frame. Since contaminant reduction takes place only within the PRB itself, this passive remedial approach would have no effect on groundwater contamination remaining upgradient of any constructed PRB.

5.2.7.2 Implementability of Permeable Reactive Barriers

The depth to the bottom of the (contaminated) lower silty-sandy groundwater interval ranges up to approximately 74 ft BGL, which is deeper than braced construction techniques or continuous trenching equipment can achieve, indicating that more specialized construction methods would be required (see also Section 5.2.4). Construction of a PRB would cause relatively short-term disruption to the daily activities of nearby residents, but it could result in significant damage to private properties and a requirement for restoration. Long-term access to any constructed PRB location(s) would be required for periodic renewal of the subsurface treatment medium as it became depleted over time.

5.2.7.3 Costs of Permeable Reactive Barriers

The costs for placement of multiple PRBs are expected to be moderate to high.

5.2.7.4 Permeable Reactive Barriers — Eliminated

On the basis of its limited effectiveness, difficulty in implementation, and high cost, PRB technology is eliminated from further consideration.

5.2.8 *In Situ* Chemical Reduction Treatment

For contaminants such as carbon tetrachloride that are amenable to abiotic and anaerobic biodegradation processes, the introduction into the subsurface (by means other than the construction of a PRB) of materials that promote either abiotic or biologically mediated ISCR can be a viable remedial approach. Existing or newly installed semi-permanent injection wells, or (in some cases) direct-push technologies, can be used to deliver the treatment chemicals to the impacted zone via pressure injection or by passive placement within a borehole or casing. The applicability of ISCR is determined primarily by the nature of the contaminant(s) and the availability of suitable treatment media. Successful implementation is also strongly influenced, however, by the site-specific geologic and hydrologic characteristics of the target treatment zone, as these parameters largely determine the potential for effective emplacement and dispersion of the treatment material.

5.2.8.1 Effectiveness of *In Situ* Chemical Reduction Treatment

Where applicable, ISCR technology can reduce the toxicity, mobility, and volume of contaminants in groundwater and soil. Vendors produce a variety of additives capable of addressing chlorinated organic contamination. Additives can be introduced singly or in combination. In some cases, additives need to be introduced in phases, because the initial additive creates the geochemical environment needed for the follow-on additive to function effectively.

One possible application strategy for ISCR would be targeted to address the most highly contaminated parts of the site. In this approach, ISCR additive(s) would be delivered actively, by injection, throughout the northern portion of the former CCC/USDA facility (Figure 5.1).This application of the ISCR technology could be effective for treatment of the discrete contaminated soil intervals and the high levels of groundwater contamination that have been identified in this area. The other possible application strategy would address a wider area of the site where groundwater is contaminated. In this approach, the ISCR material would be placed in linear zones to effectively create ISCR treatment barriers that would intercept the primary contaminant migration pathways emanating from each source area, similar to the placement of PRBs (Section 5.2.8). This approach would require a prohibitively large number of densely distributed application points along a north-south transect east of the northern portion of the former CCC/USDA facility and along an east-west transect southwest of the former CCC/USDA facility to achieve sitewide interception of the contaminated groundwater. In addition, this linear-zone

approach faces many of the site-specific limitations to effectiveness that are outlined in Section 5.2.8.1 for the PRB technology. Specifically, because the ISCR treatment is effectively passive in that it relies on the natural movement of groundwater to the treatment area, its implementation in linear zones would be expected to result in a prolonged remediation time frame and only localized effects in the downgradient margins of the plumes. ISCR implementation in linear zones would also have little to no influence on groundwater contaminant levels at locations upgradient of the implementation areas throughout the lifetime of the projected remediation effort.

5.2.8.2 Implementability of *In Situ* Chemical Reduction Treatment

The ISCR technology can be implemented with available equipment and materials. Direct-push technology can readily be used to inject ISCR materials into the silty clay layer, where much of the contamination resides in the northern portion of the former CCC/USDA facility, as well as into the underlying, more permeable, groundwater-producing silty-sandy interval. Pressurized injection of the ISCR materials with specialized equipment will be required because of the thickness and generally low permeability of both of these intervals. These ISCR placement operations are likely to cause minimal disruption to the daily activities of nearby residents and business activities at the Ag Partners facilities, but they might result in damage to private property that requires restoration. Long-term access to the ISCR placement locations might be required for renewal of the subsurface treatment medium as it becomes depleted over time.

With the approval of the KDHE, the CCC/USDA and Argonne pilot-tested the use of the EHC® material developed by the Adventus Group 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 PeroxyChem (http://www.peroxychem.com). The EHC® material is available in forms suitable for injection or for passive placement in boreholes and wells. The experience at Centralia indicated that effective removal of carbon tetrachloride requires close spacing of 15 ft or less between application points. Introduction of the ISCR chemicals can, however, result in persistent fouling of the groundwater being treated, making it unsuitable for domestic use.

5.2.8.3 Costs of *In Situ* Chemical Reduction Treatment

Expected costs for the ISCR treatment technology would be moderate for targeted treatment of highly contaminated area and moderate to high for linear-zone treatment of a wider

area. Costs for the ISCR technology will be high if semi-permanent injection points are required to allow the introduction of additives periodically over time.

5.2.8.4 *In Situ* Chemical Reduction Treatment — Eliminated for the Area-Wide Groundwater Contamination but Retained for Hot-Spot Treatment

On the basis of very limited radius of effectiveness and significant implementability issues and cost, the ISCR treatment technology is eliminated from further consideration for linear treatment of the groundwater contamination. However, ISCR treatment technology is retained for consideration for the targeted treatment of the soil/groundwater hot spot in the northern portion of the former CCC/USDA property.

5.3 Potentially Applicable Technologies

The screening process for potentially applicable methods for addressing the contaminated soil, groundwater, at Powhattan resulted in retention of the following technologies and practices for further consideration:

- Groundwater extraction and treatment
- ISCR hot-spot treatment

The technologies and practices retained through the screening analysis were used to develop the corrective action alternatives for the site that are identified and discussed in Section 6.

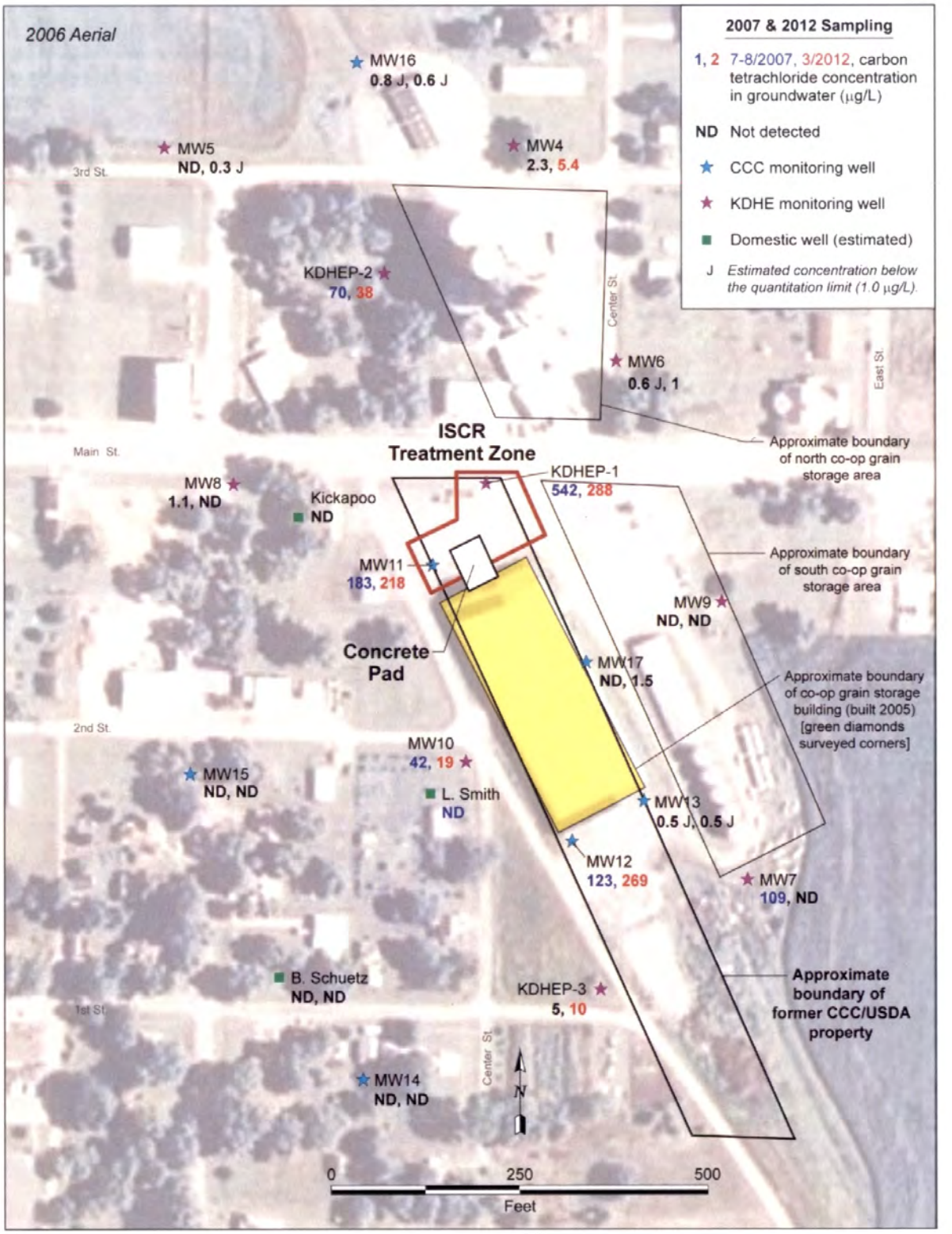

FIGURE 5.1 Proposed ISCR injection area.

6 Description of Alternatives

Corrective action alternatives for the former CCC/USDA facility at Powhattan were developed on the basis of the remedial technologies retained after the initial screening process described in Section 5, conducted in accordance with EPA (1988) and KDHE (2001a, 2009b) guidance. The resulting candidate technologies for addressing the carbon tetrachloride contamination in groundwater and soil on the former CCC/USDA property were combined to create two remedial alternatives, in addition to the no-action alternative, for further consideration. This section describes the three alternatives that were evaluated in detail. The alternatives are summarized in Table 6.1.

Although the focus of Alternative 3 is the treatment of carbon tetrachloride, treatment of nitrate in groundwater may also occur as a byproduct of the ISCR geochemical processes. The focus of Alternative 2 is also the treatment of carbon tetrachloride; however, this alternative will not result in the treatment of nitrate. Water containing small concentrations of nitrate may be discharged along with the treated effluent. *The CCC/USDA accepts no responsibility for the identified nitrate contamination at Powhattan.* Alternatives 2 and 3 are therefore presented under the specific assumption that the KDHE will work with both the CCC/USDA and Ag Partners to ensure that Ag Partners accepts responsibility for the treatment of nitrogen compounds in groundwater, including extracted groundwater that is treated for VOC content only and that, when discharged, could contain a de minimus concentration of nitrates.

6.1 Alternative 1: No Action

The no-action response is a required component of the CAS evaluation under KDHE (2001a) guidance, to provide a baseline for comparison. The no-action response is evaluated as Alternative 1 in Sections 7 and 8.

Under Alternative 1, no action will be taken at the former CCC/USDA facility, and the contaminated soils and groundwater will remain in place. The former CCC/USDA property will continue to be an active grain handling area for Ag Partners operations.

Under the no-action alternative, all existing water supply protective measures are assumed to remain in effect. These include the KDHE regulations governing the location and construction

of water supply wells (Section 4.2.3.1) and observance of the KDHE (1989) order not to use local groundwater as a water supply because of nitrate contamination.

6.2 Alternative 2: GWPT and Discharge, and Groundwater Monitoring

Alternative 2 will involve the installation, operation, and monitoring of a groundwater extraction system to reduce carbon tetrachloride contamination to the extent practicable (mass removal to asymptotic levels in monitoring wells or for eight years, whichever occurs sooner). The basis for the eight year period of operation is provided in Appendix C (Estimation of the Operation Time Period for Groundwater Extraction in Alternative 2). Alternative 2 has the following components:

- Installation and testing of an extraction well near the northern limit of the former CCC/USDA property.

- Installation of two pump test observation wells near the extraction well to serve as monitoring points during initial production testing and for long-term performance monitoring of the extraction well;

- Preparation of a CAP including, but not limited to, a pre-final and final (90% to 100%) design and cost estimate; operation and maintenance (O&M) Plan, and SMPE Plan;

- Installation of a groundwater treatment system and a discharge line to route treated water to the Powhattan stormwater system and operation of the groundwater extraction and treatment system for an anticipated period of up to eight years.

- A SMPE monitoring and reporting program to include (1) baseline groundwater monitoring, (2) sampling and analysis of a National Pollutant Discharge Elimination System (NPDES) -permitted, treated discharge, (3) initial annual and longer-term, bi-annual sampling and analysis and continuous water level measurements of monitoring wells, and (4) the recording of groundwater extraction volume and flow rates pursuant to requirements of the groundwater appropriation regulations.

6.2.1 Extraction Well and Observation Wells Installation and Production Testing

Full-scale implementation of Alternative 2 will be preceded by an information-gathering phase that will involve the installation of a vertical extraction well and two observation wells. The well will be used to gather design parameters during a pumping test and as the extraction well for the remedial alternative. The pump test/extraction well will consist of an 8 in. well that will be installed to a depth of 70 ft at the location shown in Figure 6.1.The well will be constructed with a 10 ft, #10 slot high-flow stainless steel screen from 60-70 ft BGL. The well will be finished with an 8 in. cover and lock.

Two 2-in. pump test observation wells will also be installed to evaluate the performance of the extraction well during test pumping and subsequently during the implementation of the remedy. The monitoring points will be completed at the surface with a 12-in. flush-mount well cover and a 2 ft by 2 in. concrete pad.

6.2.2 Preparation of a Corrective Action Plan

The CAP will describe the design, construction, and implementation of remedial actions. It will also include details associated with the design, O&M, and performance evaluation for the groundwater extraction and treatment system. The CCC/USDA would submit a pre-final/final (90-100%) design package for approval by KDHE that would document pre-final/final design specifications/drawings and the design basis. The CAP package would also address O&M requirements and SMPE-related activities.

6.2.3 Installation and Operation of a GWPT and Discharge Pipeline

The major components of the GWPT system would include electrical service, a submersible pump, force main piping to a tray aerator, control system, and treated effluent discharge line to the Powhattan storm water system.

Either a treatment building will be constructed or an existing treatment building will be moved to the Powhattan site. Electrical service from the existing electric power infrastructure at Powhattan will be dropped to the treatment building and to the extraction well. Influent/effluent pipe transects will be excavated. An SDR 11 high-density polyethylene (HDPE) 2-in. pipe or similar will be used from the extraction well to the treatment building and from the treatment

building to the discharge point. Electrical and communication service will be routed via the excavated pipe transects or additional trenching as needed. A submersible pump (such as a Grundfos RediFlo 3 or similar) and electric service/communication cable will be installed in the extraction well. The 2-in. force main and communication cable will be routed through a pitless adaptor and pipe trench to the treatment building. A control box, such as the Grundfos CU 300, will be mounted in the treatment building to control, monitor, and display the performance of the pump. Meters will be installed to measure flow rate and total flow as required by short term groundwater withdrawal regulations.

Extracted groundwater would be treated by an aeration system installed within the treatment building and sized to accommodate the long-term flow rate(s) determined from the extraction well test pumping. The use of a NEEP Shallow tray aerator, Model 2600 or similar, is anticipated. Treated effluent will be pumped to the Powhattan storm water management system by a pipeline to be installed in a trench between the treatment building and a storm sewer manhole or surface access point.

During informal discussions with Argonne, both Ag Partners staff and the Chief of the Powhattan Fire Department expressed an interest in using treated effluent from the GWPT. Ag Partners expressed an interest in using treated effluent versus Powhattan City water supply as mixing water for agricultural products. The Chief of the Powhattan Fire Department expressed an interest in being able to use water from a treated effluent storage tank for fire suppression. In keeping with KDHE NPR guidance, this CAS has incorporated a treated effluent storage tank into the conceptual design for Alternative 2 in order to provide for such beneficial uses at Powhattan. The tank would be installed downstream from the aerator with a plumbing configuration that would allow overflow from the tank to discharge to the permitted outfall. Valves for the tank would be installed to be compatible with the needs of Ag Partners and the Powhattan Fire Department.

The GWPT system is expected to operate for a period of eight years or until carbon tetrachloride concentrations reach asymptotic levels in monitoring wells, whichever happens sooner. The basis for the operating time of the groundwater extraction system is discussed further in Appendix C.

6.2.4 SMPE-Related Monitoring and Reporting

This alternative will include a groundwater monitoring component and a groundwater treatment system monitoring component. The alternative will also require periodic reporting of the monitoring results on either an annual basis or as part of the content of 5-yr reviews.

6.2.4.1 Groundwater Monitoring

A comprehensive groundwater monitoring program will be implemented at and near the former CCC/USDA facility to evaluate groundwater quality. The monitoring will include a baseline monitoring component followed by groundwater monitoring to assess the performance of the remedy, followed by post-remedy groundwater monitoring. During Year 1, the 18 wells sampled in April 2012 (Table 2.4 and Figure 6.1) will be sampled before initiation of the pump test as part of a baseline sampling event. A subset of the 18 wells, in this case 12 wells, will be sampled annually (Years 2 to 11) following the baseline sampling event. The 12 wells will be sampled for eight years during pumping (Years 2 to 9) and for two years of confirmation sampling (Years 10 and 11). The selection basis for the wells is summarized in Table 6.2, and the wells are shown in Figure 6.1. The well sampling program will be evaluated continuously throughout the duration of the remedy.

The groundwater monitoring program will involve collection of groundwater samples, laboratory analysis for selected VOCs, data evaluation, and reporting. The samples will be analyzed for field parameters (dissolved oxygen, oxidation-reduction potential, pH, temperature, and conductivity) at the wellhead, and for carbon tetrachloride, chloroform, and methylene chloride by a qualified laboratory.

6.2.4.2 Groundwater Treatment Operations and System Monitoring

Operating conditions of the groundwater treatment system will be monitored during periodic visual inspections and remotely via cellular or land line communication with the well pump and aerator system control boxes. In compliance with Kansas water appropriation regulations, flow rates and total flow will be tracked and recorded. In compliance with Kansas NPDES requirements, the discharge to surface waters will be sampled and analyzed as specified in the permit. (Frequency to be determined; assumed quarterly [every three months] for planning purposes).

6.2.4.3 SMPE-Related Reporting

As part of the SMPE Plan reporting, a summary of the amounts of water withdrawn for treatment will be sent to the Kansas Department of Agriculture on a monthly basis. A summary of the results of groundwater monitoring, and NPDES discharge monitoring results, will be sent to the KDHE for each yearly groundwater well sampling event. Data analyses, evaluations, and interpretations will be delivered to the KDHE every five years as a component of the 5-yr reviews.

For sites like Powhattan where contamination is expected to remain at levels that do not allow for unrestricted residential use until the remedy is complete, the KDHE suggests reviews at least every five years to ensure that remedial actions remain protective of human health and the environment. The 5-yr reviews for Powhattan will include document review, a site inspection, and a report. Documents to be reviewed by the CCC/USDA and Argonne include the SPME Plan and CAD, groundwater monitoring results, and any records generated during the review period pertaining to groundwater use or distribution or to the investigation of contamination in groundwater or soils in the impacted area. The report is expected to include a discussion of the remedial action objectives established by the CAD, a summary of the site visit, a summary of groundwater monitoring, any areas of noncompliance, and a summary of the protectiveness of the established corrective action.

The 5-yr reviews will serve as a project management mechanism. The first 5-yr review will include a recommendation regarding the potential need for continued operation of the groundwater extraction well to (or beyond) the initially planned eight years, on the basis of documented system performance and the concentrations attained in the monitoring well network. Similarly, the potential for ultimate site reclassification pursuant to policy BER-RS-024 (KDHE 2001b) will be evaluated in conjunction with the ongoing 5-yr review process, on the basis of concentrations observed in the site monitoring wells.

6.3 Alternative 3: ISCR, and Groundwater Monitoring

Alternative 3 has the following components:

- Preparation and approval of a CAP.

- An ISCR treatment of the contaminated soils and groundwater in the northern source area.

- Sitewide groundwater monitoring.

- Five-year reviews, as described in Section 6.2.4.3.

6.3.1 Preparation of a Corrective Action Plan

The CAP will describe the design, construction, and implementation of the ISCR remedial actions. It will also include details associated with the design, implementation, and performance evaluation for the ISCR treatment program. The CCC/USDA would submit a pre-final/final (90-100%) design package for approval by KDHE that would document pre-final/final design specifications/drawings and the design basis. The CAP package would also address SMPE-related activities.

6.3.2 Injection of Amendments

Under Alternative 3, ISCR amendments will be injected into the subsurface to cover an area of approximately 15,700 ft^2 (Figure 6.2). The ISCR chemicals will be introduced via approximately 100 injection points with eight discrete treatment intervals 15-17 ft BGL, 21-23 ft BGL, 27-29 ft BGL, 33-35 ft BGL, 40-42 ft BGL, 46-50 ft BGL, 54-56 ft BGL, and 58-60 ft BGL. A product similar or identical to that employed at the Centralia site (Section 5.2.9) will be used. The material will be injected from the top of the boring and downward, from about 15 ft to 60 ft BGL, to address soil contaminated with carbon tetrachloride above the soil-to-groundwater RBSL guideline, as well as groundwater contamination. The top-downward method of injection is recommended on the basis of recent successful application by this method by the CCC/USDA at Montgomery City, Missouri, with the concurrence of the Missouri Department of Natural Resources. Changes can be made, if technically warranted, during the actual injection process given the specific subsurface conditions encountered. Modifications to the injection methodology will be made in consultation with the CCC/USDA and KDHE program managers, on the basis of recommendations of the contractor's technical specialists.

6.3.3 SMPE-Related Monitoring and Reporting

A comprehensive monitoring program will be implemented at and near the former CCC/USDA facility to evaluate groundwater quality. The monitoring will include baseline and post-remedy monitoring components.

6.3.3.1 Groundwater Monitoring

During Year 1, the 18 wells sampled in April 2012 (Table 2.4 and Figure 6.2) will be sampled before initiation of the ISCR program as part of a baseline sampling event. Results from the baseline sampling event will be compared to results from subsequent sampling events (Section 6.3.3.2) to assess the impact of the ISCR remedy on contaminants in groundwater.

The ten wells identified in Table 6.2 and illustrated in Figure 6.2 will be sampled annually in Years 2 to 11. If an evaluation of the monitoring results from the monitoring network indicates that groundwater contaminant concentrations are not decreasing, the CCC/USDA will review the current site conditions and historical data to determine the most appropriate approach for addressing the contamination, including consideration of a second round of ISCR injection. Additional contingency plans will be evaluated in conjunction with the KDHE if such plans become necessary

6.3.3.2 SMPE Related Reporting

A summary of groundwater monitoring results will be sent to the KDHE for each sampling event. Data analyses, evaluations, and interpretations will be delivered to the KDHE every five years as a component of the 5-yr reviews (Section 6.2.4). The 5-yr reviews will serve as a project management mechanism. The first 5-yr review will include a recommendation regarding the potential need to inject additional ISCR amendment(s) in the treatment area. Similarly, the potential for ultimate site reclassification pursuant to policy BER-RS-024 (KDHE 2001b) will be evaluated in conjunction with the ongoing 5-yr review process, on the basis of concentrations observed with time in the site monitoring wells.

TABLE 6.1 Summary of remediation alternatives.

Item	Alternative 1: No Action	Alternative 2: GWPT	Alternative 3: Treatment with ISCR Technology
Remedial Action Construction	–	Vertical extraction well, two pump test monitoring wells, aerator, piping from well to aerator, treatment building, discharge line to surface water	Injection of EHC® at 100 points in northern portion of the former CCC/USDA property
Source Treatment	–	Saturated soils in source area will be within capture zone of extraction well.	ISCR injection in northern portion of the former CCC/USDA property (15-55 ft BGL) to treat soil and groundwater.
Groundwater Treatment	–	Extraction well operation for eight years will decrease concentrations within radius of influence and minimize contaminant migration from northern portion of former CCC/USDA property.	ISCR injection treats groundwater using 8 discrete treatment intervals of 15-17 ft BGS, 21-23 ft BGS, 27-29 ft BGS, 33-35 ft BGS, 40-42 ft BGS, 46-50 ft BGS, 54- 56 ft BGS, and 58-60 ft BGS
Monitoring	–	Baseline monitoring of 18 wells in Year 1. Annual monitoring of 12 wells, Years 2 to 9; quarterly monitoring of NPDES discharge, Years 2 to 9; confirmation monitoring of 12 wells, Years 10 and 11; 5-yr reviews and reporting.	Baseline monitoring of 18 wells in Year 1. Annual monitoring of 10 wells, Years 2 to 11; 5-yr reviews and reporting.
Cost (current year dollars with 15% contingency)	$0	$728,300 (NPV: $637,000)	$1,212,000 (NPV: $1,117,000)

TABLE 6.2 Proposed monitoring well networks for Alternatives 2 and 3.

		Monitoring Wells to Assess Performance of Remedial Alternatives	
Well	Selection Basis	Alternative 2	Alternative 3
KDHEP-1	Proximity to zone of influence of Alternative	X	X
MW11	Proximity to zone of influence of Alternative	X	X
Pump test well 1 – to be installed (for Alternative 2)	Proximity to zone of influence of Alternative		
PTMP-1 (to be installed)		X	
PTMP-2 (to be installed)		X	
MW 10	Proximity to zone of influence of Alternative	X	X
KDHEP-2	Northern contaminant migration boundary	X	X
KDHEP-3	Southern contaminant migration boundary	X	X
MW4	Northern contaminant migration boundary	X	X
MW6	Northeast contaminant migration boundary	X	X
MW12	Southernmost groundwater migration boundary	X	X
MW14	Southwest groundwater migration boundary	X	X
MW16	Northern contaminant migration boundary	X	X

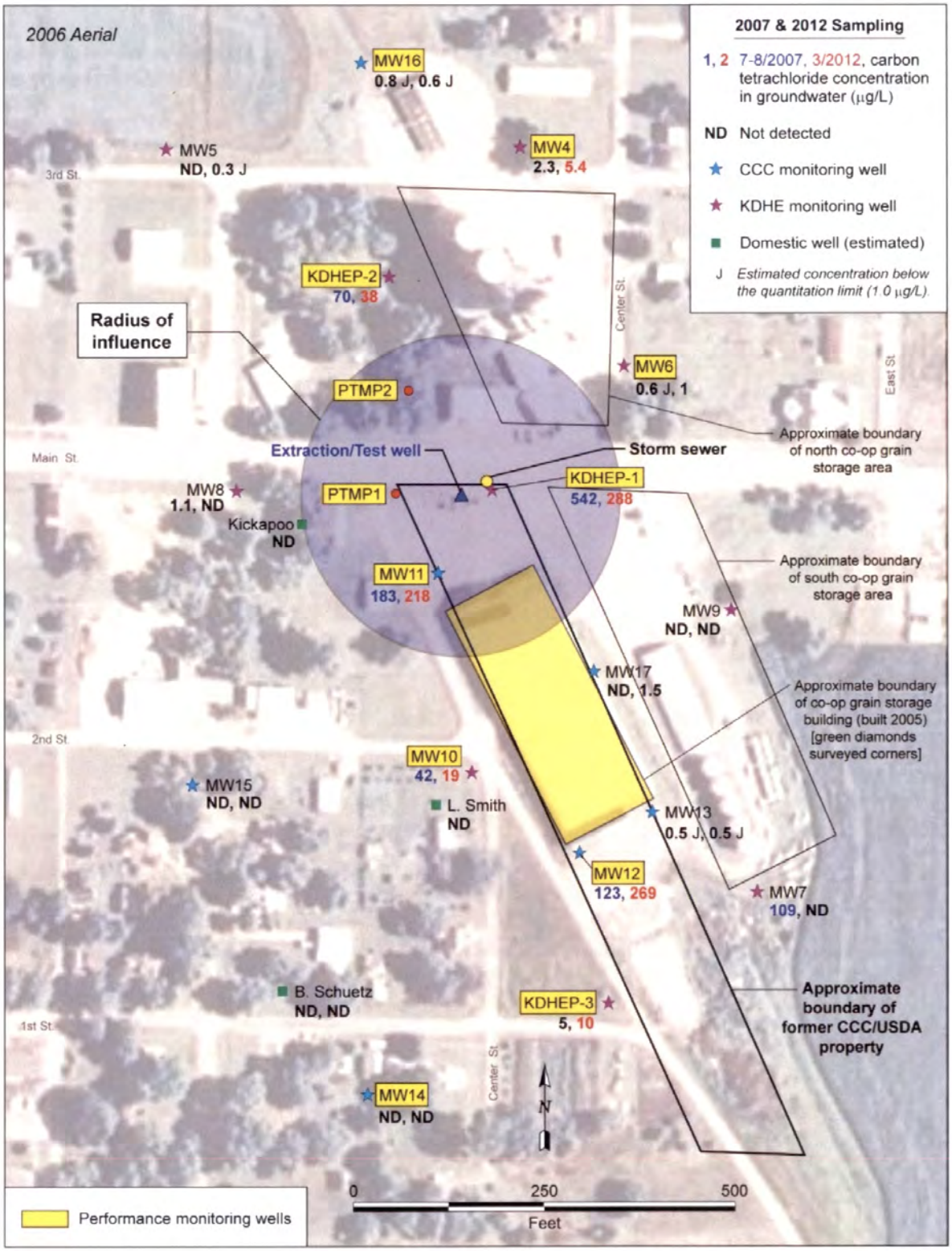

FIGURE 6.1 Conceptual diagram of the location of a groundwater extraction well, pump test monitoring wells, project-related monitoring wells, and the modeled ROI.

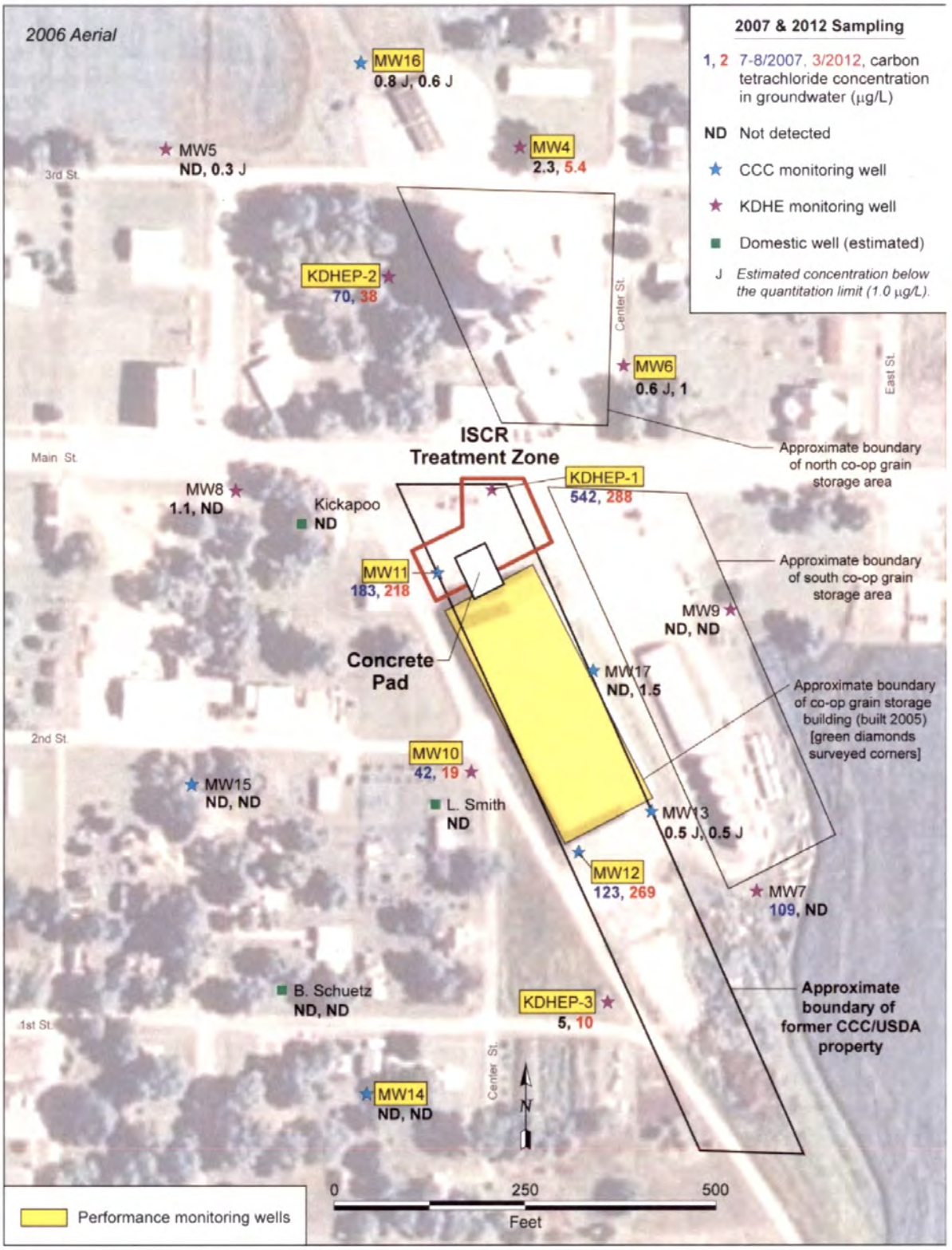

FIGURE 6.2 Conceptual diagram of an ISCR treatment zone plus monitoring wells and additional wells for baseline sampling.

7 Detailed Analysis of the Corrective Action Alternatives

The KDHE (2001a) CAS guidance adopts by reference nine EPA-defined criteria. The criteria are as follows:

1. *Overall protection of human health and the environment*, which addresses protection from unacceptable risks in both the short term and the long term by minimizing exposures, in accordance with the purpose and objectives of the proposed actions. Because of its broad scope, this criterion also reflects the focus of Criteria 2-5.

2. *Compliance with ARARs*, which addresses the attainment of federal and state environmental requirements determined to be either applicable or relevant and appropriate to the alternative, on the basis of site-specific considerations. Potential ARARs and TBCs are listed in Appendix B.

3. *Long-term effectiveness and permanence*, which addresses residual risks remaining after completion of a remedial action. The EPA (1991) guidance states that it is usually sufficient to indicate whether an alternative has the potential to achieve the preliminary cleanup levels and not necessary to quantify the risk that would remain after implementation.

4. *Reduction of contaminant toxicity, mobility, or volume*, which addresses the degree to which treatment addresses the principal threat(s) at the site; the amount of material treated; the magnitude, significance, and reversibility of the given reduction; and the nature and quantity of treatment residuals.

5. *Short-term effectiveness*, which addresses the potential impacts to site workers, the general public, and the environment from implementing the alternative; the effectiveness and reliability of mitigation measures; and the time required to achieve protectiveness.

6. *Implementability*, which addresses technical feasibility, including the availability and reliability of required resources (such as specific technologies, materials and equipment, facility capacities, and skilled workers); ease of

implementation; and the ability to monitor effectiveness. This criterion also addresses administrative feasibility. The actual determination of administrative feasibility would not be made until after the CAS is completed.

7. *Cost*, which addresses both capital and annual O&M costs. Costs for the individual components of the alternatives are also considered.

8. *State acceptance*, which addresses KDHE comments on the alternatives being considered. State acceptance is deferred pending issuance of this document.

9. *Community acceptance*, which addresses the comments made by the community on the alternatives being considered. Because these comments will not be received until this report has been issued for public review, the community acceptance criterion is deferred.

In the following sections, each of the alternatives outlined in Section 6 is evaluated in detail on the basis of Criteria 1-7 above. The comparative analysis is summarized in Table 7.1.

Costs presented for the alternatives were estimated by using a combination of actual costs, costs from similar projects, and the Remedial Action Cost Engineering and Requirements (RACER) cost estimation model (AECOM 2009).

7.1 Alternative 1: No Action

In compliance with the CAS requirements, the no-action alternative is included to provide a baseline for comparison with the other alternatives. Under this alternative, no action would be taken to remediate, or otherwise prevent potential exposure to, the contaminated soils and groundwater on the former CCC/USDA property.

7.1.1 Overall Protection of Human Health and the Environment

Under the current use conditions, Alternative 1 is considered protective of human health and the environment. No private (or public) wells are known to be in present use for domestic water supply in Powhattan. Residences are connected to the RWD 2 public supply, which is free of carbon tetrachloride contamination. Existing water supply protective measures, including the

KDHE regulations governing the location and construction of water supply wells (Section 4.2.3.1) and observance of the KDHE (1989) order not to use local groundwater as a drinking water supply (because of nitrate contamination), provide long-term mitigation of potential health risks associated with the contaminated groundwater. As a result, under current and future use conditions, residents will not be exposed to groundwater containing carbon tetrachloride above regulatory thresholds.

7.1.2 Compliance with ARARs and TBCs

Alternative 1 would not address chemical-specific ARARs for carbon tetrachloride in drinking water (the MCL and RBSL). However, the presence of nitrate contamination identified by the KDHE renders the local groundwater unsuitable for use as a potable water source. The nitrate contamination is unrelated to former CCC/USDA activities. The KDHE (1989) directed Powhattan to discontinue use of the local groundwater for domestic water supply, because of persistent levels of nitrate contamination above acceptable standards.

Carbon tetrachloride concentrations exceeding the KDHE RBSL guideline for protection of the soil-to-groundwater pathway are present in a limited interval of soils in the northern source area. No actions would be taken under Alternative 1 to address this TBC.

Because no active measures are associated with Alternative 1, there are no location- or action-specific ARARs.

7.1.3 Long-Term Effectiveness and Permanence

Alternative 1 involves no treatment of contaminated soils or groundwater and thus is not considered permanent. However, carbon tetrachloride levels will decrease through intrinsic processes. The identification of low levels of chloroform in groundwater at multiple locations indicates that some degradation of carbon tetrachloride is occurring locally through reductive dechlorination under inferred anaerobic conditions (Argonne 2008).

Under Alternative 1, the level of contamination and risks to terrestrial biota over the long term are similar to current levels. These risks are considered insignificant, because there would be no exposure to the impacted groundwater.

7.1.4 Reduction of Toxicity, Mobility, or Volume

The implementation of Alternative 1 would not directly address the toxicity, mobility, or volume of carbon tetrachloride at the site; however, intrinsic remediation would result in a long-term decrease in the toxicity and volume of the contaminants present.

7.1.5 Short-Term Effectiveness

Implementation of Alternative 1 would not impact the general public or the environment. No mitigation measures would be required.

7.1.6 Implementability

The property formerly occupied by the CCC/USDA facility would continue to be used for agricultural business purposes by the Ag Partners.

7.1.7 Cost

No costs are associated with Alternative 1.

7.2 Alternative 2: GWPT and Discharge, and Groundwater Monitoring

7.2.1 Overall Protection of Human Health and the Environment

Under the current use conditions, Alternative 2 is considered protective of human health and the environment. No private (or public) wells are known to be in present use for domestic water supply in Powhattan. Residences are connected to the RWD 2 public supply, which is free of carbon tetrachloride contamination. Existing water supply protective measures, including the constraints established under the KDHE regulations governing the location and construction of water supply wells (Section 4.2.3.1) and observance of the KDHE (1989) order not to use local groundwater as a drinking water supply (because of nitrate contamination), provide long-term mitigation of potential health risks associated with the carbon tetrachloride contamination in groundwater. As a result, under current and future use conditions, residents will not be exposed to groundwater containing carbon tetrachloride above regulatory thresholds.

The GWPT component of Alternative 2 would result in significant carbon tetrachloride mass removal from groundwater that was likely impacted by the confirmed contamination in (predominantly saturated) soils located in the northern portion of the former CCC/USDA facility. Treatment would mitigate potential risk associated with the carbon tetrachloride in the groundwater and saturated soils. The sitewide groundwater monitoring and treatment-specific performance and compliance monitoring aspects of this alternative would verify the successful operation of the proposed treatment. In addition, intrinsic processes will continue to decrease carbon tetrachloride concentrations within and beyond the zones directly influenced by GWPT.

7.2.2 Compliance with ARARs and TBCs

Under Alternative 2, the chemical-specific RBSL MCL value of 5.0 µg/L for carbon tetrachloride in drinking water is an ARAR that would be addressed within and beyond the radius-of-influence (ROI) of the extraction well. Interception (by pumping) and treatment of the groundwater from the targeted area of the (saturated) soils and groundwater will reduce the concentrations, mobility, and volume of carbon tetrachloride throughout the capture zone developed during the period of active pumping. In addition, existing intrinsic processes will continue to decrease carbon tetrachloride concentrations toward the RBSL-MCL value within and beyond the zones directly influenced by the extraction and treatment.

Carbon tetrachloride concentrations exceeding the KDHE RBSL guideline for protection of the soil-to-groundwater pathway are present in a limited interval of soils in the northern portion of the former CCC/USDA facility. Alternative 2 would specifically address this contamination since the soil horizon with contaminants that exceed the KDHE RBSL guideline would be within the ROI of the extraction well. Removal of groundwater by the extraction well will accelerate the downward migration and capture of contaminants from the (predominantly saturated) impacted soil horizon within the ROI. Documentation prepared to support Alternative 2 such as the CAP, SMPE Plan, O&M Plan, etc. would comply with the CAP/CA TBC.

7.2.3 Long-Term Effectiveness and Permanence

The groundwater extraction and treatment component of Alternative 2 would be protective of human health and the environment. The extraction and treatment would bring the concentrations of carbon tetrachloride down in soil and in groundwater.

7.2.4 Reduction of Toxicity, Mobility, or Volume

Under Alternative 2, carbon tetrachloride contamination would be actively removed from soil and groundwater resulting in a continuous reduction of contaminant toxicity, mobility and volume. Continued intrinsic remediation would contribute to a long-term decrease in the toxicity and volume of any residual contaminants present.

7.2.5 Short-Term Effectiveness

No short-term mitigation measures are required under Alternative 2. Implementation of Alternative 2 would pose no short-term risks to the general public or the environment. Site workers involved in the construction of the groundwater extraction wells and treatment system and subsequent monitoring would be protected by adherence to a site specific health and safety plan. Installation of the required well and underground piping and construction of the tray aerator facility are expected to have a short-term impact. There may be a short-term disruption of normal community activities in areas where the groundwater extraction and treatment system is installed.

7.2.6 Implementability

Implementation of Alternative 2 is feasible. Resources and well-established construction methods are available to perform the needed installation of the extraction well and related facilities. Installation of the 8-in. groundwater extraction well will involve the use of conventional techniques that are well within the scope of industry practice. The submersible pump and pump controller are commercial, off-the-shelf technologies that can be readily purchased and installed. A tray aerator can be manufactured or an existing tray aerator meeting the required design specifications can be installed to treat the expected volume and quality of extracted groundwater.

The implementability of Alternative 2 is contingent on access to private property for the installation of the extraction well, treatment system, and underground piping for the force main and the effluent line. The CCC/USDA will not assume responsibility for the nitrate contamination in groundwater caused by third parties. As a result, the implementability of Alternative 2 is predicated on effluent treatment for VOCs only.

Under Alternative 2, residents would experience a short-term disruption while the extraction well and treatment facilities are installed. The former CCC/USDA facility would

continue to be used by Ag Partners for agricultural business. Monitoring and reporting would be performed with readily available resources.

7.2.7 Cost

The estimated cost for Alternative 2 in current-year dollars is $728,300 (including a 15% contingency). The net present value (NPV) cost is $637,000 (Table 7.2). The estimate includes the costs to perform the recommended pumping test, preceding the final design and installation of the full groundwater treatment and related piping facilities.

7.3 Alternative 3: ISCR and Groundwater Monitoring

7.3.1 Overall Protection of Human Health and the Environment

Alternative 3 is protective of human health and the environment under current and future use conditions. No private (or public) wells are known to be in use for domestic water supply in Powhattan. Residences are connected to the RWD 2 water supply, which is free of carbon tetrachloride contamination.

Active treatment of contaminated soils and groundwater in the northern portion of the former CCC/USDA facility would permanently mitigate potential risks associated with the soil-to-groundwater pathway and would eliminate the source of groundwater contamination. Groundwater monitoring would verify the successful operation of the proposed treatment program.

7.3.2 Compliance with ARARs and TBCs

Under Alternative 3, the chemical-specific RBSL MCL value of 5.0 µg/L for carbon tetrachloride in drinking water is an ARAR that would be addressed within and beyond the treatment zone. In portions of the groundwater impacted by ISCR, the treatment approach would have the additional benefit of addressing the nitrate contamination in groundwater (unrelated to CCC/USDA activities). In addition, existing intrinsic processes will continue to decrease carbon tetrachloride concentrations beyond the zone influenced by the ISCR approach. The KDHE RBSL for carbon tetrachloride in soils (73.4 µg/kg for protection of the soil-to-groundwater pathway) is a TBC that would be actively addressed by treatment under Alternative 3 and is expected to be met over time.

Alternative 3 would comply with other pertinent ARARs and TBCs as appropriate.

7.3.3 Long-Term Effectiveness and Permanence

Alternative 3 involves treatment of contaminated groundwater and soil. The ISCR treatment would bring the concentrations of carbon tetrachloride down in soil and in groundwater.

7.3.4 Reduction of Toxicity, Mobility, or Volume

Alternative 3 directly addresses the toxicity, mobility, and volume of carbon tetrachloride in soil and groundwater. Intrinsic remediation will also result in a long-term decrease in the toxicity and volume of this contaminant.

7.3.5 Short-Term Effectiveness

Any short-term impacts associated with remedy implementation can be addressed easily. Site workers monitoring and placing the ISCR injection points and residents in the vicinity will be protected by adherence to requirements associated with workplace health and safety plans. Over the short term, Alternative 3 might adversely affect water quality to the point of non-compliance with secondary MCLs.

7.3.6 Implementability

Implementation of Alternative 3 would be straightforward, subject to the agreement of property owners. Experience with the use of this technology at the former CCC/USDA facilities in Centralia, Kansas, and Montgomery City, Missouri, has demonstrated, however, that successful injection of the ISCR amendment(s) into fine-grained soils can be locally difficult, requiring that special measures be employed to minimize return of the materials to the surface ("daylighting") during injection. The specific injection techniques and equipment required for use at Powhattan would be determined on-site, as needed.

Residents will experience short-term disruption while the ISCR injection points are installed. The property formerly occupied by the CCC/USDA facility will continue to be used by Ag Partners for agricultural business. Monitoring and reporting can be performed with readily available resources.

7.3.7 Cost

The estimated cost for Alternative 3 in current-year dollars is $1,212,000 (including a 15% contingency). The NPV cost is $1,117,000 (Table 7.2).

TABLE 7.1. Comparative analysis of Powhattan CAS alternatives.

Evaluation Criterion	Alternative 1 — No Action	Alternative 2 — Groundwater Extraction and Treatment	Alternative 3 — Soil and Groundwater Treatment with *In Situ* Chemical Reduction Technology
Overall protection of human health and the environment	Protective under current use. All residences within the delineated footprint of the contaminated groundwater are connected to the RWD 2 system. Water supply protective regulations (the state well location and construction regulations) are meant to preclude exposure to contaminated groundwater. This alternative is not protective in the absence of compliance with water supply protective regulations.	Protective under current use. All residences within the delineated footprint of the contaminated groundwater are connected to the RWD #2 system. Water supply protective regulations (the state well location and construction regulations) are meant to preclude exposure to contaminated groundwater. This alternative is not protective in the absence of compliance with water supply protective regulations. Active treatment would reduce the carbon tetrachloride concentration.	Protective under current use. All residences within the delineated footprint of the contaminated groundwater are connected to the RWD #2 system. Water supply protective regulations (the state well location and construction regulations) are meant to preclude exposure to contaminated groundwater. Active ISCR treatment would reduce the carbon tetrachloride concentration, though it could compromise water quality in the aquifer for a time.
Compliance with federal and state ARARs	Local groundwater is non-potable. Because of nitrate contamination, the KDHE ordered the city to obtain a new water source in 1989. Carbon tetrachloride in groundwater remains above the Kansas Tier 2 RBSL and the EPA MCL of 5 µg/L. Carbon tetrachloride in soil remains above the Tier 2 RBSL soil-to-groundwater protective level (73.4 µg/kg). An alternate water supply is provided by RWD 2. This alternative complies with all other ARARs and TBCs.	Local groundwater is non-potable. Because of nitrate contamination, the KDHE ordered the city to obtain a new water source in 1989. Groundwater extraction and treatment has the potential to bring carbon tetrachloride concentrations within the ROI of the extraction well below the MCL. Carbon tetrachloride in soil will also be addressed by the downward migration of meteoric water through the soil horizon contaminated above the 73.4-µg/kg TBC guideline. An alternate water supply is provided by RWD 2. This alternative complies with all other ARARs and TBCs.	Local groundwater is non-potable. Because of nitrate contamination, the KDHE ordered the city to obtain a new water source in 1989. An alternate water supply is provided by RWD 2. ISCR technology would be expected to bring carbon tetrachloride concentrations below the RBSL and the MCL values of 5 µg/L and the Tier 2 RBSL soil-to-groundwater protective level of 73.4 µg/kg. This alternative complies with all other ARARs and TBCs.
Long-term effectiveness and permanence	The long-term effectiveness of this alternative depends on community compliance with water supply protective regulations. Intrinsic remediation will eventually bring carbon tetrachloride concentrations permanently below regulatory thresholds (5 µg/L in groundwater and 73.4 µg/kg for soil).	Subject to the design parameters gathered during a preliminary pump test, this alternative has the potential to be effective, and bring carbon tetrachloride concentrations permanently below regulatory thresholds. The long-term effectiveness of this alternative depends on community compliance with water supply protective regulations. Intrinsic remediation will also eventually bring carbon tetrachloride concentrations permanently below regulatory thresholds (5 µg/L for groundwater and 73.4 µg/kg for soil).	The long-term effectiveness of this alternative depends on community compliance with water supply protective regulations. ISCR coupled with intrinsic remediation will eventually bring carbon tetrachloride concentrations permanently below regulatory thresholds (5 µg/L for groundwater and 73.4 µg/kg for soil).
Reduction of toxicity, mobility, and volume through treatment	No reduction of toxicity, mobility, and volume (TMV) occurs in this alternative, except through intrinsic remediation.	Within the capture zone of the extraction well, reduction of carbon tetrachloride TMV occurs via active treatment under this alternative, as well as via intrinsic remediation.	Within the area of ISCR treatment. Alternative 3 will actively reduce carbon tetrachloride TMV.
Short-term effectiveness	Implementation can be accomplished with no additional risk to workers, the community, or the environment.	Implementation can be accomplished with no additional risk to workers, the community, or the environment.	Implementation can be accomplished with no additional risk to workers, the community, or the environment. The ISCR treatment could negatively impact water quality in the aquifer for a time.
Implementability	This alternative can be implemented readily; acceptance by KDHE might be unlikely, because no active measures are taken.	Implementation is predicated on the performance of a pump test to gather needed design parameters and the treatment of extracted groundwater for volatile constituents only. Alternative 2 can be implemented by using standard, readily available technologies and vendors. Contingent on access to privately owned property.	Alternative 3 can be implemented by using standard, readily available technologies and vendors. Contingent on access to privately owned property to install the ISCR injection points.
Preliminary cost estimate (with 15% contingency)	$0	$728,300	$1,212,000
NPV cost	$0	$637,000	$1,117,000

TABLE 7.2 Cost Basis for Alternatives 1-3.

	Total ($)	NPV ($)
Alternative 1: No Action		
Subtotal	0	
Total cost	0	
Alternative 2: Groundwater Extraction and Treatment		
Third party permitting (CAP, NPDES, groundwater withdrawal) and design	107,520	
Argonne permitting design effort	57,600	
One year of baseline monitoring (18 wells)[2]	18,000	
Yearly sampling of 12 performance monitoring wells for eight years and quarterly monitoring of NPDES discharge[2]	97,360	
Five-year review costs (two reviews)[1,2]	72,000	
Confirmation sampling of performance monitoring wells (12 wells) for two years[2]	24,000	
Construction of GWPT system:		
Cascade drilling of extraction well and piezometers	49,028	
Professional labor management (PLM) during drilling	9,907	
Perform pump test[1]	0	
Argonne PLM and reporting results	24,000	
Submersible pump	1,655	
Pump cable (8.5 per ft=150 ft)	2,036	
Pump controller	1,500	
Overhead electrical distribution (gratis)	–	
Pitless adapter	1,146	
Excavating effluent and force main trenching	28,511	
2-in. HDPE	3,386	
Move and set up existing aerator	3,818	
Startup plumbing, power connection, groundwater extraction, and controller setup[1]	8,847	
Argonne PLM during set up[1]	14,400	
Concrete pad for aerator shed and 10,000-gal tank	2,262	
10,000-gal tank	7,157	
Electric charge	800	
Sample/analyze NPDES discharge for three quarters (yearly); one quarter occurs during well sampling events[2]	60,000	
Reporting as specified in the SMPE Plan	38,400	
Subtotal	633,333	553,915
Contingency (15%)	95,000	83,087
Total cost	*728,333*	*637,002*
Alternative 3: Soil and Groundwater Treatment with ISCR Technology (Northern Source Area)		
Third party permitting (CAP, NPDES, groundwater withdrawal) and design	107,520	
Argonne permitting design effort	57,600	
One year baseline monitoring (18 wells)[2]	18,000	

TABLE 7.2 (Cont.)

	Total ($)	NPV ($)
Confirmation sampling of performance monitoring wells (10 wells) for 10 years[2]	100,000	
Five-year review (five reviews)[1,2]	72,000	
Remedial action ISCR points:		
Material costs for EHC® in the ISCR zone	431,734	
Dedicated trucks for delivery	19,092	
IET injection services	152,103	
Hole block	10,182	
Argonne PLM for ISCR	19,200	
Vendor oversight during ISCR	27,648	
Reporting as specified in the SMPE	38,400	
Subtotal	1,053,480	971,002
Contingency (15%)	158,022	145,650
Total cost	*1,211,502*	*1,116,652*

[1] Cost is an internal programmatic cost.

[2] As specified in the SMPE Plan.

8 Comparative Analysis of Alternatives

This section evaluates the relative performance of the alternatives with respect to criteria 1-7, as described at the beginning of Section 7.

8.1 Overall Protection of Human Health and the Environment

Under the realistic current-day scenario, Alternatives 1, 2, and 3 are all protective. Although carbon tetrachloride was detected in soil above the soil-to-groundwater RBSL guideline and in groundwater above the MCL, residents are served by a public water supply that obtains water from Brown County RWD 2.

Under future use scenarios, Alternative 1 places no constraint beyond those already established in the existing water supply protective measures on the installation of a water supply well in an area with impacted groundwater. However, local groundwater has been designated by the KDHE as not acceptable for potable use because of elevated nitrate levels.

The implementation of groundwater extraction and treatment would reduce the carbon tetrachloride concentration in (predominantly saturated) soils and groundwater in the identified source area, decrease the potential for contaminant migration in groundwater beyond this area, and reduce carbon tetrachloride concentrations in groundwater surrounding (within the capture zone of the extraction well) the northern portion of the former CCC/USDA facility. Alternative 3 would potentially reduce carbon tetrachloride concentrations in soil to below the soil-to-groundwater RBSL guideline within the proposed injection area, but might have a more limited areal influence on the reduction of concentrations in the surrounding groundwater relative to Alternative 2.

8.2 Compliance with ARARs and TBCs

Alternative 1 would not actively reduce carbon tetrachloride concentrations and thus would not achieve concentration-related ARARs, but intrinsic remediation processes will continue to reduce contaminant levels. Alternative 3 and Alternative 2 would actively remove and/or decrease the carbon tetrachloride concentrations in groundwater beneath and migrating away from the northern portion of the former CCC/USDA facility. Under Alternatives 2 and 3, all measures implemented will be conducted in accordance with applicable location- and action-specific ARARs.

8.3 Long-Term Effectiveness and Permanence

Alternatives 1, 2, and 3 would effectively protect human health and the environment over the long term, because impacted groundwater is unlikely to be used as a water supply source. Furthermore, the absence of carbon tetrachloride in surficial soil and surface water discharges of groundwater eliminates potential risks to ecological resources. Alternative 2 would be effective in directly addressing the carbon tetrachloride contamination in groundwater and in reducing the levels of contamination in the soil. Alternative 3 would effectively address the carbon tetrachloride concentrations in both soil and groundwater, but possibly to a lesser areal extent in groundwater than Alternative 2. Removal of carbon tetrachloride from the affected media under both Alternatives 2 and 3 would be permanent.

8.4 Reduction of Toxicity, Mobility, or Volume

Alternative 1 does not involve active treatment to decrease the toxicity, mobility, or volume of groundwater or soil contaminated with carbon tetrachloride, though intrinsic process will reduce concentrations in time. Alternatives 2 and 3 would reduce both the volume of contaminated groundwater and the mass of soil contaminated above the soil-to-groundwater RBSL guideline.

8.5 Short-Term Effectiveness

Alternatives 1, 2, and 3 would not adversely affect the general public or the environment. During injection of the ISCR materials or construction of the extraction well and treatment system workers would be protected by site- and task-specific health and safety plans. The construction activities associated with Alternative 2 and Alternative 3 might cause some short-term disruptions in Ag Partners operations. In addition, over the short term, Alternative 3 might adversely affect water quality to the point of non-compliance with secondary MCLs.

8.6 Implementability

Alternative 1 requires no implementation actions; however, the potential for administrative acceptance of this alternative is low, because no active measures would be taken to mitigate site risks.

The monitoring components of Alternatives 2 and 3 can be implemented with available techniques, materials, and equipment, subject to continued property access.

The ISCR treatment component of Alternative 3 can be implemented with readily available equipment, materials, and techniques. Implementation of the ISCR component of Alternative 3 can be accomplished by vendors with a proven track record at Kansas, national, and international sites. Specialized techniques might be required, however, to control injection of the ISCR amendments into the fine-grained deposits at Powhattan.

The installation of a groundwater extraction well and treatment system can be implemented with standard equipment and construction techniques.

The implementability of Alternative 2 and Alternative 3 is predicated on having site access in order to install the components of each remedial Alternative. In the case of Alternative 2, site access will be required for the term of remedial operation in order to operate and maintain the groundwater extraction/treatment system. Access requirements for Alternative 3 would be limited to the one time injection of ISCR treatment chemicals. Every attempt will be made to limit site access requirements to a single property owner; in this case: Ag Partners property

8.7 Cost

Alternative 1 (no action) has no costs. Alternative 2 would be less costly than Alternative 3. Alternative 3 would have the same 5-yr review, monitoring, and costs as Alternative 2, but Alternative 3 would be more costly overall.

8.8 Stakeholder and State Acceptance

State acceptance will be reflected in the KDHE comments on this CAS and in the final corrective action selected. Community acceptance will be affected by the content of this CAS. As a result, stakeholder and state acceptance cannot be determined at this time.

8.9 Summary and Recommended Corrective Action

The CCC/USDA recommends Alternative 2 for the former CCC/USDA facility at Powhattan.

At the present time, when the former CCC/USDA and surrounding properties are occupied by residences and the Ag Partners agribusiness, Alternative 2 is protective of human health and the environment. Alternative 2 addresses carbon tetrachloride contamination in soil and groundwater in the northern portion of the former CCC/USDA property.

Alternative 2 will achieve compliance with regulatory requirements over time (because of both active groundwater and soil treatment and continuing intrinsic remediation). Alternative 2 also will decrease the toxicity, mobility, and volume of carbon tetrachloride in both groundwater and in soil and thus offers long-term protectiveness and permanence.

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Appendix A:

KDHE Order, Case 89-E-8 – February 13, 1989

Powhattan 1.0

BEFORE THE KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

In the Matter of Violation of
Kansas Statutes and Regulations
by City of Powhattan
City Hall
Powhattan, Kansas 66527

Case No. 89-E-8

ORDER

The Secretary of the Kansas Department of Health and Environment (KDHE), after reviewing the administrative files in this matter and being fully and duly advised, makes the following findings of fact and law:

FINDINGS OF FACT AND CONCLUSIONS OF LAW

1. The City of Powhattan, a municipality, owns and operates a public water supply system as defined by K.S.A. 65-162a(b) and K.A.R. 28-15-11(a) and a community public water supply system as defined by K.A.R. 28-15-11(b) located in Brown County, Kansas.

2. The City of Powhattan is a supplier of water as defined by K.S.A. 65-162a(d).

3. The public water supply system owned and operated by the City of Powhattan utilizes a groundwater source.

4. The City of Powhattan is participating in a feasibility study for the formation of Rural Water District No. 2, Brown County. The feasibility study is being prepared by Bartlett and West Engineers, Inc. Topeka, Kansas.

5. K.S.A. 65-171m authorizes the Secretary to adopt rules and regulations for public water supply systems and drinking water standards. K.A.R. 28-15-13, adopted under K.S.A. 65-171m, sets the maximum contaminant level for nitrate in public water supply systems.

6. The City of Powhattan is required by K.A.R. 28-15-14(b)(2) to monitor the water in the public water supply distribution system once every three years to determine the concentration of the chemical constituents listed in K.A.R. 28-15-13(b). This includes a determination of the nitrate concentration.

7. A maximum contaminant level (MCL) for nitrate in public water systems in established under K.A.R. 28-15-13(b) at 10 milligrams per liter (mg/l) expressed as nitrogen.

8. The results of the analyses of annual compliance samples required by K.A.R. 28-15-14(b)(2), and special samples show the water in the City of Powhattan's public water supply system consistently exceeds a nitrate level of 10 mg/l (as N).

Date	Result mg/l (as N)	Where Sampled
March 28, 1977	19	Well No. 1
September 21, 1978	22	Billy Lowe residence
March 19, 1979	23	Billy Lowe residence
May 2, 1979	25	Well No. 1
May 2, 1979	26	Well No. 2
December 8, 1980	17	Billy Lowe residence
May 26, 1982	28	Brown County Co-op
October 28, 1982	24	Brown County Co-op
January 23, 1984	26	Billy Lowe residence
April 1, 1985	22	Brown County Co-op
November 5, 1985	19.00	Brown County Co-op
September 12, 1986	25.00	Well No. 1
September 12, 1986	19.00	Well No. 2
March 23, 1987	19.00	Brown County Co-op
March 30, 1987	21.00	Mary Manley residence
June 23, 1987	21.00	Brown County Co-op
September 14, 1987	22.27	Jerry Hirsch residence
December 21, 1987	24.40	Jerry Hirsch residence
April 11, 1988	23.35	Billy Lowe residence
April 11, 1988	21.00	Terry Hirsch residence
July 7, 1988	24.05	Ralph Kniesel residence
September 27, 1988	25.10	R. Gartner residence
October 6, 1988	19.98	Well No. 1
October 6, 1988	25.20	Well No. 2

9. It is a violation of K.S.A. 65-171r(e) for a supplier of water to fail to "comply with a primary drinking water standard established under K.S.A. 65-171m and rules and regulations adopted pursuant thereto unless a variance or exception has been granted." No such variance or exception has been granted to the City of Powhattan.

10. The City of Powhattan, as a result of its failure to meet the maximum contaminant level for nitrate, is required to issue public notification in accordance with K.A.R. 28-15-15. Public notification was done for violations in April 1986, March and September 1987; April, July and October 1988.

11. Based on the above, the Secretary of the Kansas Department of Health and Environment finds that City of Powhattan has violated K.S.A. 65-171r(e) by failing to comply with K.A.R. 28-15-13(b).

12. K.S.A. 1988 Supp. 65-171s authorizes the Secretary to assess a civil penalty in an amount of up to and including $5,000 per day for each violation of K.S.A. 65-171r.

13. K.S.A. 1988 Supp. 65-163(b)(2) states:

> "Whenever an investigation of any public water supply system is undertaken by the secretary, it shall be the duty of the supplier of water under investigation to furnish to the secretary information to determine the sanitary quality of the water supplied to the public and to determine compliance with the applicable state laws and rules and regulations. The secretary may issue an order requiring changes in the source or sources of the public water supply system or in the manner of storage, purification or treatment utilized by the public water supply system before delivery to consumers, or distribution facilities, collectively or individually, as may in the secretary's judgment be necessary to safeguard the sanitary quality of the water and bring about compliance with applicable state law and rules and regulations. The supplier of water shall comply with the order of the secretary."

ORDER

1. IT IS THEREBY ORDERED pursuant to K.S.A. 1988 Supp. 65-163(b)(2), that the City of Powhattan comply with the following schedule to bring about the required compliance with applicable state law, rules and regulations affecting public water supply systems:

By September 1, 1989:	Provide the Kansas Department of Health and Environment a copy of the contract between the City of Powhattan and RWD #2, Brown County, for the purchase of water.
By December 31, 1990:	Purchase water from Rural Water District No. 2, Brown County.

In the event Rural Water District No. 2, Brown County, is not formed, or does not obtain financing, or if the City and Rural Water District No. 2, Brown County cannot agree on contract terms, the following schedule shall apply:

By December 1, 1989:	Submit an engineering report to the Kansas Department of Health and Environment. The report should study all feasible means of correcting the nitrate problem. A written statement outlining the means of correction selected must accompany the report.
By March 1, 1990:	Submit construction plans to the Kansas Department of Health and Environment for approval.
By May 1, 1990:	Advertise and award bids for construction of KDHE approved public water supply improvements.
By December 31, 1990:	Complete construction of water supply improvements. Provide water in full compliance with all maximum contaminant levels.

Failure to take KDHE approved corrective action in a timely manner will result in the imposition of a civil penalty pursuant to K.S.A. 1988 Supp. 65-171s.

2. IT IS FURTHER ORDERED pursuant to K.S.A. 65-163b(2) that the City of Powhattan provide public notification, as required by K.A.R. 28-15-15-(a) and (c), of maximum contaminant level violation for nitrate to all users on a quarterly basis so long as the MCL violation continues. The public notice shall state that a schedule for correction of the nitrate problem has been established for the city in an administrative order. Proof of compliance with the public notification requirements shall be supplied to the Kansas Department of Health and Environment not later than 45 days after the date the

supplier of water is required to issue the public notice as specified in K.A.R. 28-15-15(d).

APPEAL RIGHTS

If the City of Powhattan is of the opinion that this order is unlawful or unreasonable it may appeal this Order by filing a written Notice of Appeal and a request for a hearing stating the specific legal and factual grounds upon which relief is requested. Said written Notice of Appeal and request for hearing must be directed to and received by Stanley C. Grant, Ph.D., Secretary, Department of Health and Environment, Forbes Field, Building 740, Topeka, Kansas 66620-0001 within 20 days of the City's receipt of this Order.

It is so ordered by the Secretary of the Kansas Department of Health and Environment on the 13th day of Feb, 1989.

Stanley C. Grant, Ph.D., Secretary
Kansas Department of Health and Environment

CERTIFICATE OF MAILING

The undersigned hereby certifies that a copy of the above and foregoing order was placed in the U.S. Mail on the 14th day of Feb, 1989, addressed to the City of Powhattan, City Hall, Powhattan, Kansas 66527 by certified mail, return receipt requested, postage prepaid.

Joanne G. Woodard
Staff Member

291 116 428
Certified Mail Number

S/2

Appendix B:

Potential Federal and State ARARs and State Guidance Documents "To Be Considered"

TABLE B.1 Potential federal applicable or relevant and appropriate requirements (ARARs) and guidance to be considered for former CCC/USDA facilities.

Title	Citation[a]	Description	Comment	Type[b]	Determination
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	42 USC 9601 *et seq.*			A	Relevant and appropriate
National Oil and Hazardous Substances Pollution Contingency Plan (NCP)	40 CFR Part 300	Provides the federal government's blueprint for responding to both oil spills and hazardous substance releases.	Applicable to releases into the environment of hazardous substances and pollutants or contaminants that may present an imminent and substantial danger to public health or the national welfare.	A	Relevant and appropriate
Off-Site Rule	40 CFR 300.440	Establishes procedures for planning and implementing off-site response actions.	Applicable to response actions involving off-site transfers of hazardous substances, pollutants, or contaminants.	A	Relevant and appropriate
Emergency Planning and Community Right-to-Know Regulations	49 CFR 350, 355 and 372	Allows state and local planning for chemical emergencies, provides for notification of emergency releases of chemicals, and addresses communities' right to information about toxic and hazardous chemicals.	Applicable if hazardous chemicals are stored or otherwise used as part of the corrective action.	A	Relevant and appropriate
Safe Drinking Water Act (SDWA) (Public Health Service Act)	42 USC 300(f) *et seq.*				
National Primary Drinking Water Standards	40 CFR Part 141, Subparts B and G	Establishes maximum contaminant levels (MCLs), which are health-based standards for public water systems. The MCL for carbon tetrachloride is 5 μg/L. The MCL for chloroform (total trihalomethanes) is 80 μg/L.	Applicable to organic groundwater contamination in a sole-source aquifer.		

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Safe Drinking Water Act (cont.)					
National Secondary Drinking Water Regulations (NSDWRs)	40 CFR Part 143	Establishes secondary maximum contaminant levels (SMCLs) for public water systems to protect the aesthetic quality of the water. The SMCLs are not federally enforceable but are intended as guidelines for the states.	Applicable if groundwater is a source of drinking water and if the NSDWRs have been adopted as enforceable standards by the state.	A, C	Relevant and appropriate
Maximum Contaminant Level Goals (MCLGs)	40 CFR Part 141, Subpart F	Establishes non-enforceable drinking water quality goals at levels of no known or anticipated adverse health effects, with an adequate margin of safety. The MCLG for carbon tetrachloride is zero.	May be relevant and appropriate if a more stringent standard is required to protect human health and the environment.	C	Relevant and appropriate
Standards for Owners and Operators of Public Water Supply Systems	40 CFR Part 141	Provides treatment requirements for public water supply systems (i.e., systems that serve at least 25 people or have at least 15 connections).	Relevant and appropriate in the establishment of cleanup goals for groundwater contamination.	A	Relevant and appropriate
Underground Injection Control Regulations	40 CFR Parts 144-148	Provides for protection of underground sources of drinking water.	Applicable if a response alternative involves underground injection.	A	Relevant and appropriate
Sole-Source Aquifers	40 CFR Part 149	Prohibits activities, including drilling, in an area designated a sole-source aquifer without special permission of the U.S. Environmental Protection Agency (EPA).	Applicable if the aquifer in the area is a sole-source aquifer.	A, L	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Clean Water Act (CWA) (Federal Water Pollution Control Act)	33 USC 1251 *et seq.*			A, C	Applicable
Ambient Water Quality Criteria	40 CFR Part 131	Establishes ambient water quality criteria (AWQCs) reflecting "the latest scientific knowledge . . . on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life . . . which may be expected from the presence of pollutants in any body of water. . . ." Water quality criteria are based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects. These recommended criteria provide guidance for states and tribes in adopting water quality standards under Section 303(c) of the CWA [33 USC 1313(c)].	Developed for some organic constituents in groundwater; may be relevant and appropriate.	C	Applicable
National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122-125	Establishes NPDES permit procedures, criteria, and standards governing the discharge of pollutants from any point source into U.S. waters [Sections 318, 402, and 405 of the CWA (33 USC 1328, 1342, 1345)]. Most storm water discharges require coverage by an NPDES permit.	Discharge limits will be established if effluent is discharged to a surface water body. No permit is required for on-site response actions under CERCLA, but the substantive requirements apply if a response alternative involves discharge into a creek or other surface water on-site. A permit is required if the discharge is to a creek or other surface water off-site.	A, C	Applicable

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Clean Water Act (cont.)					
Storm Water Discharge Requirements	40 CFR 122.26	Establishes requirements to obtain a permit to discharge storm water under the NPDES program.	Applicable to surface water discharges of storm water.	A	Relevant and appropriate
Water Quality Standards	40 CFR Part 131	Defines goals for a water body by designating the water body's uses, setting criteria to protect those uses, and establishing provisions to protect water bodies from pollutants. Forms the foundation of the water-quality-based pollution control program mandated by the CWA.	Applicable to surface water discharges.	C	Applicable
National Pretreatment Standards	40 CFR Part 403	Provides general pretreatment standards and regulations for existing and new sources of pollution; establishes standards to control pollutants that pass through or interfere with treatment processes in publicly owned treatment works (POTWs) or that may contaminate sewage sludge.	Applicable if a response alternative involves discharge to POTWs.	A, C	Relevant and appropriate
Dredge or Fill Requirements	40 CFR Parts 230-233 [40 CFR Part 6.302(a)]	Requires permits for discharge of dredged or fill material into navigable waters.	Applicable if a response alternative requires discharge of dredged or fill material into navigable waters.	A	Not an ARAR
Executive Order (EO) on Protection of Wetlands	EO 11990 [40 CFR Part 6.302(a)]	Requires federal agencies to avoid, to the extent possible, adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists.	Applicable if a response alternative has a negative effect on wetlands.	A, L	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Rivers and Harbors Act of 1899	33 USC 401 *et seq.*			A	Not an ARAR
Section 10 Permit	33 USC 403 33 CFR Parts 320-330 [40 CFR Part 6.302(a)]	Requires a permit for structures for work in or affecting navigable waters.	Applicable if a response alternative affects a navigable waterway.	A, L	Not an ARAR
Executive Order on Floodplain Management	EO 11988 [40 CFR Part 6.302(b)]	Requires federal agencies to evaluate the potential effects of actions in a floodplain to avoid, to the extent possible, the adverse impacts associated with direct and indirect development of a floodplain.	Applicable if activities are located in a 100-yr floodplain.	A, L	Not an ARAR
National Environmental Policy Act of 1969 (NEPA)	42 U.S.C. 4321-4370(c)	Requires federal agencies to consider significant environmental impacts arising from projects under agency jurisdiction and to establish a procedure giving members of the public an opportunity for meaningful participation in consideration of the proposed action.	Applicable for major federal actions. The CERCLA-like procedures in the CAS process — including public participation, the development of corrective action alternatives, and the corrective action alternative evaluation process — are equivalent to the NEPA process.	A	Relevant and appropriate
Clean Air Act (CAA)	42 USC 7401 *et seq.*			A	Applicable
Standards of Performance for New Stationary Sources	40 CFR 60	Describes standards for the performance of new stationary sources of air emissions.	Applicable if emissions thresholds are exceeded.	A, C	Applicable

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Clean Air Act (cont.)					
National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Establishes national primary and secondary ambient air quality standards under Section 109 of the Clean Air Act (42 USC 7409) to protect public health and welfare.	Applicable if contaminants are discharged to the air during treatment.	A, C	Applicable
National Emissions Standards for Hazardous Air Pollutants (NESHAPs)	40 CFR Parts 61 and 63	Implements the federal control program for hazardous air pollutants (HAPs). Identifies emission standards for HAPs that originate from specific categories of sources, including site remediation. NESHAPs are technology based and are issued to limit the release of specified HAPs from specific industrial sectors. *Federal Register* notices published for carbon tetrachloride [50 FR 32621 (August 13, 1985)] and chloroform [50 FR 39626 (September 27, 1985)] included consideration of serious health effects, such as cancer, due to ambient exposures.	Applicable if the identified HAPs are emitted from a specific source category at amounts regulated by the program (for example, if on-site treatment units with emissions are part of response actions).	A, C	Relevant and appropriate
Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA), the Hazardous and Solid Waste Amendments of 1984, the Federal Facility Compliance Act of 1992, and the Land Disposal Program Flexibility Act of 1996	40 USC 6901 *et seq.*	Regulates the characterization, generation, transportation, treatment, storage, and disposal of hazardous waste and establishes a framework for the management of nonhazardous waste.		A	Applicable

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Solid Waste Disposal Act (cont.)					
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	Establishes classification criteria for sanitary landfills and prohibits open dumps. At a minimum, facilities meet the sanitary landfill classification "only if there is no reasonable probability of adverse effects on health or the environment . . ." [Section 4004(a) of RCRA (42 USC 6944(a))].	Applicable if a response alternative involves land disposal of solid waste on-site.	A	Not an ARAR
		Provides for protection of surface water and groundwater at solid waste disposal facilities (40 CFR 257.3-3 and -4).	Applicable if a response action includes provisions for an on-site landfill.		
Criteria for Municipal Solid Waste Landfills	40 CFR Part 258	Establishes minimum national criteria for municipal solid waste landfill units.	Applicable if municipal solid waste is placed in a municipal solid waste landfill.	A	Not an ARAR
Identification and Listing of Hazardous Wastes	40 CFR Part 261	Identifies solid wastes that are subject to regulation as hazardous wastes under 40 CFR Parts 124, 262-265, 268, 270, and 271.	Applicable if a material at the site is defined as a solid and hazardous waste; requires handling as a hazardous waste.	A, C	Applicable
Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262	Establishes standards for generators of hazardous waste.	Applicable if hazardous wastes are generated as a result of on-site activities.	A	Applicable
Standards Applicable to Transporters of Hazardous Waste	40 CFR Part 263	Establishes standards that apply to transporters of hazardous waste within the United States if the transportation requires a manifest under 40 CFR Part 262.	Applicable if a response alternative involves off-site transportation of hazardous wastes.	A	Applicable

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Solid Waste Disposal Act (cont.)					
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 264	Establishes minimum national standards that define the acceptable management of hazardous wastes for owners and operators of facilities that treat, store, or dispose of hazardous waste.	Applicable or relevant and appropriate if hazardous waste is disposed of on-site.	A	Applicable
		Provides for groundwater protection standards, general monitoring requirements, corrective action requirements, and technical requirements.	RCRA standards can be relevant and appropriate for groundwater at a site if an on-site landfill is constructed.		
Standards for Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities	40 CFR Part 266	Establishes requirements that apply to recyclable materials.	No substances are expected to be present at CCC/USDA sites in quantities to warrant recycling.	A	Applicable
Land Disposal Restrictions	40 CFR Part 268	Identifies hazardous wastes that are restricted from land disposal; defines limited circumstances under which an otherwise prohibited waste may continue to be land disposed.	Applicable or relevant and appropriate if hazardous waste is disposed of on-site.	A, C	Applicable
Hazardous Waste Permit Program	40 CFR Part 270	Establishes provisions covering basic EPA permitting requirements.	No permit is required for on-site CERCLA response actions. Substantive requirements are addressed in 40 CFR Part 264.	A	Applicable
Universal Wastes	40 CFR Part 273	Establishes requirements governing universal wastes (hazardous waste batteries, hazardous waste pesticides that are either recalled or collected in waste pesticide collection programs, hazardous waste thermostats, and hazardous waste lamps).	Applicable if universal wastes are generated or managed on-site in the course of investigation or response operations.	A	Applicable

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Solid Waste Disposal Act (cont.)					
Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks	40 CFR Part 280	Establishes regulations related to underground storage tanks.	Applicable if a response alternative involves use of underground storage tanks.	A	Not an ARAR
Occupational Safety and Health Act (OSHA)	29 USC 651 *et seq.*			A	Applicable
Occupational Safety and Health Standards	29 CFR Part 1910	Establishes safety and health standards for workers. OSHA has set a limit of 10 ppm for carbon tetrachloride in workplace air for an 8-hr time-weighted average (29 CFR 1910.1000 Table Z-2).	Under 40 CFR Section 300.150, response actions under the NCP will comply with OSHA requirements for the safety and health of response action workers.	A	Applicable
Regulations for Construction	29 CFR 1926	Provides standards for work practices, safety equipment, fall protection, equipment operation, excavation, use of power tools, and other activities related to construction.	Applicable if construction activities are required for a corrective action.	A	Applicable
Noise Control Act of 1972	42 USC Sect. 4901 *et seq.*	Prohibits federal activities resulting in noise that would jeopardize the health or welfare of the public.	Applicable for activities such as drilling near a public access point.	A	Applicable
Hazardous Materials Transportation Act	49 USC 5101 *et seq.*			A	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Hazardous Materials Transportation Act (cont.)					
Hazardous Materials Transportation Regulations	49 CFR Parts 106-180	Protects against the risks to life and property inherent in the transportation of hazardous material by listing the materials deemed hazardous and describing required labeling, placarding, and training. Hazardous materials are chemicals that the U.S. Department of Transportation has determined pose unreasonable risks to health, safety, and property during transportation activities.	Applicable if an alternative involves transportation of hazardous materials. Does not apply to on-site response operations.	A	Not an ARAR
National Historic Preservation Act of 1966	16 USC 470 *et seq.*	Establishes criteria for the creation and management of a National Registry of Historic Places composed of districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, engineering, and culture.	Applicable if an alternative involves a site on the National Registry of Historic Places.	L	Not an ARAR
Protection of Historic Properties	36 CFR Parts 800 [40 CFR 6.301(b)]	Defines the way federal agencies meet the statutory responsibilities. Requires federal agencies to consider the effects of any federally assisted undertaking (including those carried out with federal financial assistance and those requiring a federal permit, license, or approval) on any district, site, building, structure, or object that is listed in the National Register of Historic Places or eligible for such listing; requires agencies to give the Advisory Council on Historic Preservation a reasonable opportunity to comment on those undertakings.	Applicable if a district, site, building, structure, or object listed on or eligible for the National Register is on or adjacent to the site.	A, L	Not an ARAR
Executive Order on Protection and Enhancement of Cultural Environments	EO 11593	Requires federal agencies to preserve, restore, and maintain the nation's historic and cultural environment in their activities.	Applicable if an alternative involves the disturbance of significant cultural resources.	A, L	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
National Historic Preservation Act of 1966 (cont.)					
Executive Order on Preserve America	EO 13287	Formulates policy to promote intergovernmental cooperation and partnerships for the preservation and use of historic properties.	Applicable if an alternative involves a historic property.	A, L	Not an ARAR
Historic Sites, Buildings and Antiquities Act (Historic Sites Act) and Regulations	16 USC 461 *et seq.* [40 CFR 6.301(a)]	Establishes a national policy to preserve historic sites and objects of national significance, including those located on refuges. Provides procedures for designation, acquisition, administration, and protection of such sites. Requires federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks and avoid undesirable impacts to such landmarks.	Applicable if an entity on the National Register of National Landmarks is on or adjacent to the site.	A, L	Not an ARAR
Archaeological and Historic Preservation Act of 1974 and Regulations	16 USC 469 *et seq.* [40 CFR 6.301(c)]	Carries out policy established by the Historic Sites Act. Establishes procedures for preservation of historical and archaeological data that might be lost or destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program. Directs federal agencies to notify the Secretary of the Interior whenever they find that a federal or federally assisted, licensed, or permitted project may cause loss or destruction of significant scientific, prehistoric, or archaeological data.	Applicable if historical or archaeological data are on or adjacent to the site and if construction projects or alteration of terrain at the site could destroy historical or archaeological materials.	A, L	Not an ARAR
Antiquities Act	16 USC 431 *et seq.*	Authorizes the President to designate as national monuments objects or areas of historic or scientific interest on lands owned or controlled by the United States. Requires a permit for examination of ruins, excavation of archaeological sites, and the gathering of objects of antiquity on lands under the jurisdiction of the Secretaries of Interior, Agriculture, and Army. Provides penalties for violations.	Applicable if an alternative involves the gathering of objects of antiquity on lands under the jurisdiction of the federal agencies noted	A, L	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Antiquities Act (cont.)					
Preservation of American Antiquities	43 CFR 3 [40 CFR Sect. 6.301(b)] Executive Order 11593	Protects all historic and prehistoric sites on federal lands and prohibits excavation or destruction of such antiquities without the permission (Antiquities Permit) of the secretary of the department that has the jurisdiction over those lands; authorizes the President to declare areas of public lands as national monuments and to reserve or accept private lands for that purpose.	Applicable if site operations affect antiquities on federal lands.	A, L	Not an ARAR
Archaeological Resources Protection Act	16 USC 470aa *et seq.*	Supplements the provisions of the Antiquities Act of 1906. Establishes detailed requirements for issuance of permits for any excavation or for removal of archaeological resources from federal or Indian lands. Also establishes civil and criminal penalties for the unauthorized excavation, removal, or damage of such resources.		A, L	Not an ARAR
Protection of Archaeological Resources	43 CFR Part 7, 36 CFR Part 296 [40 CFR 6.301(b)]	Establishes uniform definitions, standards, and procedures to be followed by all federal land managers in providing protection for archaeological resources located on public or Indian lands.	Applicable if site operations affect archaeological resources on public or Indian lands.	A, L	Not an ARAR
American Indian Religious Freedom Act	42 USC 1996 *et seq.*	Protects and preserves the right of American Indians to have access to their sacred places; directs federal agencies to consult with Indian religious practitioners if a place of religious importance to American Indians may be affected by an undertaking.	Applicable if site operations affect access to sacred Indian sites.	A, L	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
American Indian Religious Freedom Act (cont.)					
Executive Order on Indian Sacred Sites	EO 13007	Requires agencies managing federal lands to accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners and to avoid adversely affecting the physical integrity of such sacred sites; also requires agencies to develop procedures for reasonable notification of proposed actions.	Applicable if site operations affect access to sacred Indian sites.	A, L	Not an ARAR
Native American Grave Protection and Repatriation Act	25 USC 3001 *et seq.*	Establishes the priority for ownership or control of Native American cultural items excavated or discovered on federal or tribal lands after 1990 and the procedures for repatriation of items in federal possession; allows the intentional removal or excavation of Native American cultural items from federal or tribal lands only with a permit or upon consultation with the appropriate tribe.	Applicable if site operations involve excavation or discovery of Native American cultural items on federal or tribal lands.	A, L	Not an ARAR
Native American Graves Protection and Repatriation Regulations	43 CFR Part 10	Develops a systematic process for determining the rights of linear descendants and Indian tribes to certain Native American human remains, funerary objects, sacred objects, or objects of cultural patrimony. Defines items included under the Native American Grave Protection and Repatriation Act. Describes the consultation procedure applicable to intentional excavation or inadvertent discovery of remains or objects covered.	Applicable if actions involve intentional excavation or inadvertent discovery of remains or objects subject to the regulations.	A, L	Not an ARAR
Endangered Species Act	16 USC 1531 *et seq.*	Provides for the conservation of threatened and endangered plants and animals and the habitats in which they are found.	Applicable if actions involve threatened and endangered species.	A	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Endangered Species Act (cont.)					
Interagency Cooperation	50 CFR Part 402 [40 CFR 6.302(h)]	Requires action to conserve threatened and endangered species within critical habits upon which endangered species depend, including consultation and conferencing with the Department of the Interior (U.S. Fisheries and Wildlife Service or U.S. National Marine Fisheries Service).	Applicable if threatened or endangered species or critical habitats are identified at the site.	A	Not an ARAR
Migratory Bird Treaty Act	16 USC 703 *et seq.*			A	Not an ARAR
Migratory Bird Permits	50 CFR Parts 10 and 21	Requires a permit from the U.S. Fisheries and Wildlife Service for the taking of protected migratory birds.	Applicable if a response alternative will affect a migratory pathway.	A	Not an ARAR
Executive Order on Responsibilities of Federal Agencies to Protect Migratory Birds	EO 13186	Directs federal agencies taking actions having or likely to have a negative effect on migratory bird populations to work with the U.S. Fisheries and Wildlife Service to develop an agreement to conserve those birds.		A	Not an ARAR
Bald and Golden Eagle Protection Act	16 USC 668 *et seq.*			A	Not an ARAR
Eagle Permits	50 CFR Parts 10 and 22	Requires a permit from the U.S. Fisheries and Wildlife Service to move nests because of construction or operation of project facilities.	Applicable if project activities affect bald and golden eagle populations, including construction or operation of facilities that call for the moving of nests.	A, L	Not an ARAR
Fish and Wildlife Conservation Act	16 USC 2901 *et seq.*	Encourages states to develop conservation plans for nongame fish and wildlife of ecological, educational, aesthetic, cultural, recreational, economic, or scientific value.	Applicable if significant populations are present at a site or are affected by site response activities.	A	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Fish and Wildlife Coordination Act	16 USC 661 *et seq.* [40 CFR 6.302(g)]	Requires consultation with the U.S. Fish and Wildlife Service when a federal department or agency proposes, authorizes, permits, or licenses any modification of any stream or other water body. Requires adequate provision for protection of fish and wildlife resources.	Applicable if a response alternative will cause damage to or loss of wildlife by modifying a stream or body of water.	A	Not an ARAR
Wilderness Act	16 USC 1311 *et seq.*			A	Not an ARAR
Wilderness Preservation and Management	50 CFR Part 35	Describes the activities allowed and banned in wilderness areas and uses requiring authorization.	Applicable if a wilderness area exists on-site or adjacent to the site.	A	Not an ARAR
Management of Designated Wilderness Areas	43 CFR Part 6300		Applicable if actions involve a Designated Wilderness Area.	A	Not an ARAR
National Wildlife Refuge System Administration Act	16 USC 668dd		Applicable if actions involve a National Wildlife Refuge.	A	Not an ARAR
Executive Order on Management and General Public Use of the National Wildlife Refuge System	EO 12996	Directs preservation of a national network of lands and waters for the conservation and management of fish, wildlife, and plant resources for the benefit of present and future generations. Recognizes compatible uses, while ensuring maintenance of biological integrity and environmental health.	Applicable if a wildlife refuge area exists on-site or adjacent to the site.	A, L	Not an ARAR
Wild and Scenic Rivers Act	16 USC 1271 *et seq.*	States that a federal agency may not assist, through grant, loan, license, or otherwise, the construction of a water resources project that would have a direct and adverse effect on the values for which a river in the National Wild and Scenic Rivers System or a study river on the National Rivers Inventory was established.		A, L	Not an ARAR

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Wild and Scenic Rivers Act (cont.)					
Wild and Scenic Rivers	36 CFR Part 297 (40 CFR 6.302(e))	Requires a notification process for federally assisted water resource projects in any portion of a designated river.	Applicable to on-site water resource projects located within, above, below, or outside a wild and scenic river or study river.	A, L	Not an ARAR
Federal Insecticide, Fungicide and Rodenticide Act of 1972	16 USC 2901-2911	Establishes a pesticide regulatory program.		A	Not an ARAR
Pesticide Management Program Regulations	40 CFR 150-189	Creates a federal program for the registration, control, distribution, and use of pesticides.	Applicable if pesticides will be used as part of corrective action activities.	A	Not an ARAR
Toxic Substances Control Act (TSCA) of 1976	15 USC 2601	Authorizes the EPA to track, screen, and require reporting or testing of chemicals that might pose an environmental or human health risk.	Applicable if site activities involve substances regulated under TSCA, such as polychlorinated biphenyls.	A	Not an ARAR
Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, EPA 540-G-89-004, October 1988		Describes the procedures used to characterize the nature and extent of contamination and risk posed by the release of chemical constituents at a site. Also describes the procedures for evaluating potential remedial alternatives.		A	TBC
Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion)	67 FR 71169 (Nov. 29, 2002)	Serves as a screening tool to aid in determining whether a vapor intrusion pathway is complete and, if so, whether the complete pathway poses an unacceptable risk to human health at cleanup sites. For sites with a complete pathway, guidance is provided to evaluate whether the pathway poses a potential significant risk to human health.	Suggested for use at NPL and Superfund Alternative Sites.	A, C	TBC

TABLE B.1 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Guidance for Quality Assurance Project Plans, EPA 240-R-02-009, December 2002		Describes the form and content of a Quality Assurance Project Plan.		A	TBC
Use of Monitored Natural Attenuation Remedies for VOCs in Groundwater, April 2004		Describes the procedures for performing and evaluating monitored natural attenuation (MNA).		A	TBC
Technical Protocol for Evaluating Chlorinated Solvents in Groundwater, October 1998		Describes protocols that can be used to evaluate whether MNA is occurring in groundwater.		A	TBC
Guide to Discharging CERCLA Aqueous Wastes to Publicly Owned Treatment Works, EPA OSWER Directive 9330.2-13 FS, March 1991		Describes the process of discharging CERCLA wastes to a publicly owned treatment works (POTW).	Applicable to the discharge of CERCLA wastes to a POTW.	A, C	TBC

[a] Abbreviations for citations:
CFR, Code of Federal Regulations
FR, Federal Register
Sect., Section
USC, United States Code
TBC, To be considered

[b] Types:
A, Action specific
C, Chemical specific
L, Location specific

TABLE B.2 Potential state applicable or relevant and appropriate requirements (ARARs) and guidance to be considered for former CCC/USDA facilities in Kansas.

Title	Citation[a]	Description	Comment	Type[b]	Determination
Radiation	KAR 28-35-1 to 28-35-363	Addresses the registration of radiation-producing devices and the licensing of sources of radiation.	Applicable if radiation-producing devices are used as part of a corrective action.	A, C	Not an ARAR
Spill Reporting	KAR 28-48-1 to 28-48-2	Addresses reporting requirements for the accidental releases of unpermitted discharges.	Applicable if an unpermitted discharge occurs during the performance of a corrective action.	A, C	Applicable
Emergency Planning and Right-to-Know Regulations	KAR 28-65-1 to 28-65-4	Requires facilities storing hazardous substances above threshold quantities to report the presence of the materials and any releases of the materials. Creates emergency planning and response procedures.	Applicable if regulated hazardous chemicals are stored as part of the corrective action.	A, C, L	Applicable
Kansas Air Quality Control Act; Kansas Air Quality Regulations	KSA, Chapter 65, Article 30; KAR, Title 28, Article 19	Requires permitting and preconstruction notices for air contaminant sources. Provides for reporting and inspections. Establishes state emission standards for listed hazardous air pollutants (HAPs) and state air quality standards. HAPs include carbon tetrachloride and chloroform emitted above a threshold (e.g., 10 tons/yr of a single HAP or 25 tons/yr of any combination of HAPs). Specifically requires the following: • For emissions above threshold amounts, (1) construction permits (e.g., for 25 tons/yr of particulate matter [PM], 15 tons/yr of PM 10, 100 tons/yr of carbon monoxide, 40 tons/yr of volatile organic compounds [VOCs]) or (2) preconstruction approval (e.g., for 5 lb/hr of PM, 2 lb/hr of PM 10, 50 lb of carbon monoxide per 24-hr period, or 50 lb of VOCs per 24-hr period — alternatively, in a nonattainment area, either 15 lb per 24-hr period or 3 lb/hr) (KAR 28-19-300). • Operating permits for certain stationary sources (28-19-500 *et seq.*).	Applicable if any listed pollutants are discharged to the air during investigation or response through air stripping, thermal destruction, handling of contaminated soil, gaseous waste treatment, aeration, or disposal in a municipal solid waste landfill.	A	Applicable

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Kansas Air Quality Control Act; Kansas Air Quality Regulations (cont.)		Prohibits open burning (28-19-645 *et seq.*). Establishes emission standards for major source HAPs (28-19-750 *et seq.*).			
Underground Storage, Disposal Wells and Surface Ponds	KSA, Chapter 65, Article 1; KAR, Title 28, Article 13	Regulates the construction and use of underground storage reservoirs, disposal wells, and surface ponds for the confinement, storage, and disposal of industrial fluids. Establishes approval and permitting requirements.	Applicable if a response alternative involves the need for underground storage reservoirs, disposal wells, or surface ponds.	L, A	Relevant and appropriate
Washington County RWD #1 Cross-Connection Regulations	Section 3 (*Requirements*, Item 4. Individual Water Supplies) (RWD 2009b)	Precludes a landowner from cross-connecting a private water supply with an RWD public supply.	Applicable if a residence connected to the RWD supply also has a private water supply.	A	Applicable
Drinking Water Regulations	KSA, Chapter 65, Article 33; KAR, Title 28, Article 15	Establishes maximum contaminant levels (MCLs) pertaining to public water supplies. The MCLs for carbon tetrachloride, total trihalomethanes (including chloroform), nitrate, and nitrite are 0.005 mg/L, 0.1 mg/L, 10 mg/L, and 1 mg/L, respectively (KAR 28-15a-61 and 28-15a-62).	Applicable if waste derived from an investigation or response enters a public water system. Not applicable to investigative wells, as such, that are not used for drinking water supply; however, relevant for establishing sampling and analysis parameters and analytical detection limits during investigation activities.	C	Relevant and appropriate

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Water Pollution Control Regulations	KSA, Chapter 65, Article 33; KAR, Title 28, Article 16	Protects public health and welfare and the use of surface water for aquatic life; for agricultural, domestic, and industrial water supply; and for recreation. Controls surface water use designation. Establishes surface water quality standards (KAR 28-16-28 *et seq.*). MCL is defined as "any of the enforceable standards for finished drinking water promulgated by the U.S. Environmental Protection Agency [KAR 28-16-28b(hh)]." When the KDHE finds that these criteria are underprotective or overprotective for a given surface water segment, the KDHE may, in accordance with KAR 28-16-28f(f), make appropriate site-specific determinations [KAR 28-16-28e(a)]. Surface water must be free from the harmful effects of substances that produce any public health hazard; hazardous substances must not occur in surface water at concentrations that jeopardize public health and other protected life [KAR 28-16-28e(b)].	Applicable if contaminated effluent from investigative or response operations is discharged into surface water; also possibly applicable to alluvial aquifers demonstrated to be hydraulically connected to surface water bodies.	C	Applicable

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Water Pollution Control Regulations (cont.)		Provides numeric criteria by use category for different parameters [KAR 28-16-28e(d)]. For chloroform the values are 28,900 μg/L for aquatic life-acute, 1,240 μg/L for aquatic life-chronic, 470 μg/L for public health-food procurement, and 100 μg/L for public health-domestic water supply. (No values are specified for agriculture-livestock and agriculture-irrigation.) For carbon tetrachloride the values are 35,200 μg/L for aquatic life-acute, 6.94 μg/L for public health-food procurement, and 5 μg/L for public health-domestic water supply. (No values are specified for aquatic life-chronic, agriculture-livestock, and agriculture-irrigation.) The State's overall water quality program also implements an anti-degradation policy to limit discharges and other activities that will negatively impact water quality. Establishes procedures relating to the discharge of wastewaters under the NPDES program (KAR 28-16-57 *et seq.*). National effluent standards are adopted by reference. Provides for the establishment and administration of critical water quality management areas (KAR 28-16-69 *et seq.*). Limits the types of wastes that can be discharged to publicly owned treatment works (POTWs) and governs pollutants from nondomestic sources that are subject to one or more pretreatment standards and that are indirectly discharged into POTWs or are otherwise introduced by any means (KAR 28-16-83 *et seq.*).	Applicable if the following result from an investigation or response: • Discharges into "waters of the state." • Discharges into a designated critical water quality management area. • Discharges of contaminated groundwater to POTWs. • Discharges into a designated critical water quality management area.	C	Applicable
Groundwater Management Districts	KSA, Chapter 82a, Article 10	Establishes requirements for the creation of special districts for the proper management of the groundwater resources of the state.		L	Relevant and appropriate

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Kansas Drycleaner Environmental Response Act	KSA 65-34, 141	Authorizes creation of a drycleaner site management program; funds assessment and corrective action activities at former and existing drycleaner facilities.		L	Relevant and appropriate
Kansas Drycleaner Environmental Response Regulations	KAR 28-68-1 to 28-68-9	Regulations created pursuant to the Kansas Drycleaner Environmental Response Act.	May be applicable if a drycleaner operated at the site of the former CCC/USDA facility.	A, C	Relevant and appropriate
Kansas Environmental Use Controls	KSA, chapter 65-1221 to 65-1235	Defines the Environmental Use Control (EUC) as a legal mechanism for applying restrictions, prohibitions, and conditions on land use for a property that has environmental contamination at levels prohibiting unrestricted use (i.e., exceeding residential standards). An EUC can be voluntarily applied to a property by the landowner as part of a corrective action to assure adequate protection of public health and the environment from contamination on the subject property. The protection offered by an EUC can provide a landowner relief from environmental liability concerns, making property more attractive for redevelopment or to prospective buyers.	Applicable if corrective action includes an EUC.	L	Applicable
Kansas Water Well Contractor's License Regulations; Water Well Construction and Abandonment Regulations	KSA, Chapter 82a, Article 12; KAR, Title 28, Article 30	Establishes requirements for licensing of well drillers and standards for construction, operation, and abandonment of wells (KAR 28-30-3 *et seq.*).	Applicable if investigation or response involves drilling and installing wells that intercept the water table.	A	Applicable
Underground Injection Control Regulations	KSA, Chapter 65, Article 1; KAR, Title 28, Article 46	Governs discharges into underground injection wells (KAR 28-46-1 *et seq.*). In general, federal Safe Drinking Water Act regulations are adopted by reference.	Applicable if investigative or response wastes are introduced into wells for discharge or disposal.	A, C	Relevant and appropriate

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Solid Waste Act and Regulations	KSA, Chapter 65, Article 34; KAR, Title 28, Article 29	Establishes standards for management activities and facilities relative to solid wastes (KAR 28-29-1 *et seq.*).	Applicable if nonhazardous materials discarded as a result of an investigation or response are landfilled on-site.	A, C, L	Not an ARAR
		Establishes location restrictions, design standards, operating standards, groundwater monitoring, corrective action, and financial assurance for municipal solid waste landfill units, during and after closure (KAR 28-29-100 *et seq.*).	Applicable if a municipal solid waste landfill is used.		
Hazardous Waste Management Standards and Regulations	KSA, Chapter 65, Article 34; KAR, Title 28, Article 31	Requires generators of solid waste to make a hazardous waste determination. For a waste that is not excluded from hazardous waste regulations and not listed as a hazardous waste, the determination is generally made through testing by a laboratory certified for such analyses by the KDHE [KAR 28-31-4(b)].	Applicable if investigation or response operations generate solid wastes.	A, C	Relevant and appropriate
		Establishes standards for hazardous waste generators and transporters and for facilities that treat, store, or dispose of hazardous waste (KAR 28-31-4 *et seq.*)	Applicable to response-generated wastes that are determined to be hazardous and that are managed on-site through treatment, storage, and disposal or are transported.		
		Adopts by reference federal regulations governing universal wastes (KAR 28-31-15).	Applicable if universal wastes are generated or managed on-site in the course of an investigation or response operation.		
Kansas Board of Technical Professions	KAR 66-6-1 through 66-14-12	Establishes requirements for the licensing of surveyors, geologists, and architects.	Applicable if these professionals are required for implementation of the selected corrective action.	A	Applicable
Kansas Storage Tanks Act	KSA Chapter 65, Article 34	Establishes standards for the registration and permitting of nonexempt aboveground tanks used to store a regulated substance (KAR 28-44-29).	Applicable if a response alternative involves use of storage tanks to contain an accumulation of regulated substances, associated piping and ancillary equipment, and a containment system.	A, L	Not an ARAR

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Kansas Storage Tanks Act (cont.)					
Petroleum Products Storage Tanks	KAR 28-44-1 to 28-44-29	Provides requirements for permitting, installing and testing underground storage tanks and for licensing installation contractors.		A, L	Not an ARAR
Kansas Water Appropriations Act	KSA 82a-701 *et seq.*	Addresses the appropriation and distribution of water.		A, L	Not an ARAR
Kansas Water Appropriations Act Rules and Regulations	K.A.R. 5-1-1 through 5-10-6 and KAR 5-50-1 through 5-50-8	Establishes a framework for the control, conservation, regulation, allotment, and distribution of water resources.	Applicable if water appropriations are required for a corrective action.	A, L	Not an ARAR
Kansas Nongame and Endangered Species Conservation Act; Kansas Nongame and Endangered Species Conservation Regulations	KSA, Chapter 32, Article 9; KAR, Title 115, Article 15	Designates endangered and threatened species, as well as nongame species in need of conservation. Requires consultation with the Kansas Department of Wildlife and Parks pertaining to actions that might affect listed species and their critical habitats. Projects that affect listed species or their habitats and that are publicly funded, state or federally assisted, or require a permit from another state or federal agency require review and action permits (KSA 32-957 through -963, 32-1009 through 32-1012, and 32-1033; KAR 115-15-1, -2, -3, and -4).	Applicable if threatened or endangered species are identified at or near the site.	A	Not an ARAR
Kansas Levee Law and Regulations	KSA, Chapter 24, Article 1; KAR, Title 5, Article 45	Requires prior approval of chief engineer before construction of floodplain fills and levees (KSA 24-126). "Floodplain fill" means material, usually soil, rock, or rubble, placed in a floodplain to an average height of more than 1 ft above the existing ground, which has the effect of diverting, restricting, or raising the level of floodwaters on a stream (KAR 5-45-1).	Applicable if site activities involve construction of floodplain fills.	A	Not an ARAR

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Kansas Historic Preservation Act and Regulations	KSA, Chapter 75, Article 27; KAR, Title 118, Article 3	Provides for protection and preservation of sites and buildings listed on state or federal historic registries (KSA 75-2715 through 75-2726; KAR 118-3-1 through 118-3-16).	Applicable if the investigation or response site is a listed state or federal historic site or is adjacent to such a site and if activities requiring permitting are initiated at the site.	A	Not an ARAR
Kansas Unmarked Burial Sites Preservation Act	KSA Chapter 75, Article 27; KAR Title 126, Article 1	Establishes the Burial Sites Preservation Board; prohibits unauthorized disturbance; requires permits for excavation of any unmarked burial site, registered or unregistered (KSA 75-2741 through 75-2754; KAR 126-1-1 through 126-1-2).	Applicable if investigation or remediation activities encounter a burial site.	L,A	Not an ARAR
Agricultural and Specialty Remediation Act	KSA Chapter 2, Article 37 KAR Title 124, Article 1	Provides for the reimbursement of corrective action costs resulting from an incident involving a rupture, leak, spill, emission, discharge, disposal, or any other event that releases an agricultural or specialty chemical accidentally or otherwise into the environment. Releases resulting from the normal use of a product or practice in accordance with the law are not covered.	Applicable if remediation activities involve the release of an agricultural or specialty chemical. Costs to the federal government are considered ineligible.	C,A	Relevant and appropriate
Guidelines for Obtaining an Alternative Public Drinking Water Source	BER-032	–	Formerly BER-RS-032. 2005.	A	TBC[c]
Kansas Vapor Intrusion Guidance Chemical Vapor Intrusion and Residential Indoor Air		–	No number provided. 2007.	A	TBC
Public Information Program	BER-RS-002	–	Adopted 1993.	A	TBC

TBC

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Characterization and Management of Contaminated Soil Cuttings	BER-RS-003	–	Revised 1996.	A, C	
Cost Recovery of EPA's Past Costs	BER-RS-004	–	Revised 2005.	A	Not a TBC
Evaluating Future Land Use	BER-RS-005	–	Revised 2005.	A	TBC
Final Guidance for Verification Sampling of Non-Hazardous Industrial Wastewater Ponds	BER-RS-006	–	Revised 1996.	A, C	Not a TBC
Minimum Standards for Model Use	BER-RS-007	–	Revised 2005.	A	TBC
Development of Draft CADs	BER-RS-009	–	Revised 2005.	A	TBC
Utilization of Funding Through the State Water Plan	BER-RS-011	–	Revised 2001.	A	TBC
Investigation and Remediation of Salt (Chloride)-Impacted Soil and Groundwater	BER-RS-013A	–	Revised 2005.	A, C	TBC
Potential Applicable or Relevant and Appropriate Requirements ARARs	BER-RS-015	–	Revised 2005.	A	TBC

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Scope of Work (SOW) for a Preliminary Investigation	BER-RS-017	–	Revised 2005.	A	TBC
Scope of Work (SOW) for a Comprehensive Investigation	BER-RS-018	–	Revised 2005.	A	TBC
Scope of Work (SOW) for a Corrective Action Study	BER-RS-019	–	Revised 3-29-01	A	TBC
Scope of Work (SOW) for a Comprehensive Investigation (CI)/Corrective Action Study (CAS)	BER-RS-020	–	Revised 12/29/2005.	A	TBC
Scope of Work (SOW) for a Corrective Action Plan (CAP)/Corrective Action (CA)	BER-RS-023	–	Revised 2005.	A	TBC
Reclassification Plan	BER-RS-024	–	Revised 2001.	A	TBC
Scope of Work (SOW) for a Remedial Investigation (RI)/Feasibility Study (FS)	BER-RS-025	–	Revised 2005.	A	TBC

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Scope of Work (SOW) for a Remedial Design (RD)/Remedial Action (RA)	BER-RS-026	–	Revised 12/2005.	A	TBC
Reimbursement of Costs for use of KDHE Direct-Push and Mobile Laboratory	BER-RS-027	–	Revised 2005.	A	TBC
Consideration for Hydraulic Containment	BER-RS-028	–	Revised 2005.	A	TBC
Policy and Scope of Work (SOW) for Interim Measures	BER-RS-029	–	Revised 10/26/2006	A	TBC
Removal Site Evaluation (RSE)/Removal Action Design (RAD)/Removal Action (RA)	BER-RS-031	–	Revised 1996.	A	TBC
Guidelines for Obtaining an Alternative Public Drinking Water Source (changed to BER-032, 2005)	BER-RS-032	–	Adopted 1995.	A	TBC
Considerations for Remedial Standards	BER-RS-033	–	Revised 2005.	A, C	TBC
Mercury Contamination Characterization at Gas Pipeline Sites	BER-RS-034	–	Revised 2005.	A, C	Not a TBC

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Mercury Contamination Remediation at Gas Pipeline Sites	BER-RS-035	–	Revised 2005.	A, C	Not a TBC
Scope of Work for Site Monitoring	BER-RS-036	–	Revised 2005.	A	TBC
Scope of Work for a Qualitative Risk Assessment	BER-RS-039	–	Revised 2005.	A	TBC
Clean-up Levels for Total Petroleum Hydrocarbons	BER-RS-041	–	Adopted 2000.	A, C	TBC
Addendum	BER-RS-041	–	Adopted 2001.	A, C	TBC
Monitored Natural Attenuation	BER-RS-042	–	Revised 2005.	A, C	TBC
Considerations for Groundwater Potability and Use Determinations	BER-RS-045	–	April 2016.	A, C	TBC
Filtering Water Samples Collected for Metal Analysis	BER-RS-046	–	Adopted 2006.	A	TBC
Presumptive Remedy Policy Investigation and Cleanup of Nitrogen at Agricultural-Related Sites in Kansas	BER-RS-047	–	December 1, 2014.	A, C	TBC

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Consideration and Selection of Borrow Sites	BER-RS-048	–	Adopted 2007.	A	TBC
Cost Recovery Guidance for KDHE/BER Activities at Sites Determined to have Responsible Parties	BER-RS-049	–	Adopted 2007.	A	TBC
VCPRP Initial Deposits For Grouped Properties	BER-RS-VCP-001	–	Adopted 2004.	A	TBC
Eligibility Determinations Concerning Public or Private Drinking Water Well Situations	BER-RS-VCP-002	–	Adopted 2000.	A	TBC
Standards for Property Identification For Issuance of NFA Determinations	BER-RS-VCP-003	–	Adopted 2002.	A	TBC
Transfer of Contaminated Sites From the State Cooperative Program to the Voluntary Cleanup and Property Redevelopment Program	BER-RS-VCP-004	–	Adopted 2003.	A	TBC

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination
Property Eligibility for Assessments Conducted by the Brownfields Program	BER-RS-BF-001	–	Adopted 2004.	A	TBC
Natural Resource Damage Assessments	BER-ARS-044	–	Adopted 2002.	A	TBC
Sediment Policy	BER-ARS-045	–	Adopted 2004.	A	TBC
Kansas Petroleum Storage Tank Release Trust Fund Policy and Procedures Manual	–	–	–	A	Not a TBC
Kansas Storage Tank Program Aboveground Storage Tank Overview	–	–	–	A	Not a TBC
Updated Policy and Procedures Manual for the Preventative/UST Unit Storage Tank Section	–	–	–	A	TBC
Kansas Geological Survey Public Information Circular 23 — Drilling a Water Well on Your Land; What You Should Know	Suchy et al. 2011	Includes a primer on groundwater systems; describes how to evaluate the potential for a water well; advises that a yield of 4-5 gpm is considered the minimum amount necessary for domestic household use; references the need to select a reputable and responsible driller, and points out the need to check with local and state regulatory agencies for permitting and construction regulations.	Adopted in 2005; amended in 2011	A	TBC

TABLE B.2 (Cont.)

Title	Citation[a]	Description	Comment	Type[b]	Determination

[a] Abbreviations for citations:
KAR, Kansas Administrative Regulations
KSA, Kansas Statutes Annotated

[b] Types:
A, action specific
C, chemical specific
L, location specific

[c] TBC, To be considered.

Appendix C:

Estimation of the Operation Time Period for Groundwater Extraction in Alternative 2

Appendix C:

Estimation of the Operation Time Period for Groundwater Extraction in Alternative 2

C.1 Estimation Method

A component of Alternative 2 is groundwater extraction by a conventional well, to be completed in the sandy-silty interval at the base of the saturated zone. Removal of contaminated groundwater from the saturated zone via the pumping of this well is expected to result in a reduction in the carbon tetrachloride concentrations in groundwater within the zone of capture of the well, to asymptotic levels after the contaminated water-bearing unit has been flushed with several pore volumes[1] of water. For purposes of cost estimation, a simplified volumetric method (described here) was used to estimate the extraction well operation time required for the carbon tetrachloride concentration to reach asymptotic levels. Estimation by numerical modeling was not attempted. The numerical modeling approach requires a number of parameters, which at Powhattan have relatively high uncertainty because of the variable hydrogeologic properties of the saturated sediments, and the heterogeneous vertical and lateral distribution of the carbon tetrachloride contamination in the targeted extraction area.

The groundwater extraction component of Alternative 2 involves installing a conventional well in the most contaminated area, associated with the source area identified in the northern portion of the former CCC/USDA facility. Pumping of the well will induce a cone of depression[2] within the radius-of-influence (ROI)[3] of the well, and will remove a significant amount of carbon tetrachloride from the groundwater (and saturated soils) in this portion of the contaminated area.

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1 Pore volume is the aggregate volume of the air spaces between soil grains.

2 Cone of depression is the natural depression in the water table around a well during pumping.

3 For remedial alternatives involving pumping, the ROI is the radial distance from the center of a wellbore to the point where no lowering of the water table or potentiometric surface occurs (i.e., the edge of the cone of depression). For other alternatives, the ROI is the area influenced by the treatment.

C.2 Aquifer Characteristics and Anticipated Response to Groundwater Pumping

The operating time for the extraction well is in part based on (1) the well's anticipated long-term pumping rate, and (2) its ROI, and hence the volume of the cone of depression induced by pumping of the well.

The expected rate of pumping and ROI of the extraction well are influenced by the thickness and hydraulic conductivity of the basal sandy-silty interval, as well as the anticipated response of the overlying, more silty-clayey deposits to the extraction of groundwater. Extended monitoring of the natural groundwater levels at Powhattan, together with the observed distribution of groundwater (and locally carbon tetrachloride contamination) in the silty-clayey deposits, suggest that the groundwater-producing interval is not strictly confined, but that the silty-clayey materials may function as a "leaky" confining layer, permitting limited vertical transmittal of groundwater to the producing zone through the finer-grained deposits. Under these conditions, the silty-clayey materials may simply restrict the vertical movement of groundwater, or may also provide transient storage of groundwater that can be released to the underlying deposits as the pumping occurs.

To consider these alternatives, theoretical calculations (Hantush and Jacob 1955; Hantush 1960) have been used to estimate the rates of groundwater withdrawal, and resulting ROI, anticipated for the Powhattan extraction well and saturated sediments, based (to the extent possible) on the site-specific characteristics of these units. The critical inputs employed for these calculations area are shown in Table C.1.

TABLE C.1 Hydraulic properties of the groundwater-producing and confining layers.

Saturated Interval	Thickness (ft)	Hydraulic Conductivity (ft/d)		Storativity
		Horizontal	Vertical	
Sandy-silty	10	1.0		0.001
Silty-clayey	40	0.1	0.01	0.1

The results of these calculations are summarized in Figures C.1 and C.2. Under both aquifer scenarios (leaky-confined with and without groundwater storage in the confining layer),

effectively steady-state drawdown conditions are anticipated to occur within approximately 90 days of pumping. The estimated sustainable pumping rates under both conditions are similar, ranging from 2.0-2.3 gpm; however, a much broader, and somewhat less well-defined, cone of depression is suggested under the assumption of no groundwater storage in the confining layer. On the basis of these findings, a conservative ROI of approximately 200 ft is estimated for the proposed extraction well at Powhattan, yielding an estimated pore volume within the associated cone of depression of approximately 251,300-377,000 ft^3 (or 1,880,000-2,820,000 gallons, assuming effective porosities of 20% -30%; Table C.2).

C.3 Estimated Operating Time for the Extraction Well

In general, the performance of groundwater extraction in removing contaminants from an aquifer is influenced by known factors, such as non-aqueous phase liquid (NAPL) dissolution, contaminant sorption and desorption, matrix diffusion, and variations in groundwater velocity (Cohen et al. 1994). These factors typically contribute to a "tailing" effect (Boulding 1996) that results in persistent low-level (asymptotic) concentrations of the target contaminants. The operation time required to reach an asymptotic concentration of carbon tetrachloride at Powhattan was estimated through the following evaluation:

- The results from the KDHE, CCC/USDA, and Ag Partners investigations (see Section 2) indicate that no carbon tetrachloride is present in the form of NAPL.

- Palmer and Fish (1992) found that, in the absence of free product (NAPL), the number of pore volumes required to *remove* an organic contaminant from a homogeneous aquifer is approximately equal to the retardation factor.[4] The retardation factor reflects the overall processes by which contaminants from groundwater tend to be adsorbed onto the solid phase of the water-bearing unit, thus retarding contaminant migration.

- In work conducted in 2003, Argonne estimated carbon tetrachloride retardation factors ranging from 1.5 to 1.8 for soil samples collected from sites in Nebraska and Kansas. In another study, Pacific Northwest National Laboratory identified

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[4] Retardation factor: The ratio of the groundwater flow rate to the contaminant migration rate, which is an indicator of sorption of groundwater contaminants onto the solid phase of the water-bearing unit.

a carbon tetrachloride retardation factor of 1.71-3.44 for soil samples collected from the aquifer unit at the U.S. Department of Energy Hanford site (Riley et al. 2005).

- Variations in migration time along different path lines will delay contaminant removal (Cohen et al. 1994). Groundwater flowing along path lines at the edge of the capture zone travels a greater distance and has a longer migration time than groundwater that flows along the center of the capture zone.

- A "tailing" effect is typically observed after initial flushing in laboratory soil column tests and field studies (Boulding 1996), even when initial flushing of the contaminated water-bearing unit with a number of pore volumes equal to the retardation factor reduces contamination significantly.

- The persistent low level (asymptotic level) of contamination remaining after a reasonable period of flushing appears to result from (1) diffusion and desorption from less permeable porous media and/or dead spots and (2) variations in groundwater velocities due to variable permeability of the porous matrix (Keely 1989; Palmer and Fish 1992; Cohen et al. 1994), in the absence of NAPL.

On the basis of the highest reported carbon tetrachloride retardation factor of 3.44 for Hanover soils (Riley et al. 2005) and the finding of Palmer and Fish (1992) that the retardation factor is approximately equal to the number of pore volumes required to *remove* an organic compound from a homogeneous aquifer, extraction of approximately 3.4 pore volumes is suggested as a plausible estimate for the volume of pumping required for the carbon tetrachloride concentrations in groundwater at Powhattan to approach an *asymptotic level*. Upon reaching this condition, the effectiveness of continued groundwater extraction on the residual carbon tetrachloride concentrations in the surrounding groundwater is expected to significantly diminish.

On the basis of the findings and analysis outlined above, the estimates of operation time for the proposed extraction well at Powhattan are shown in Table C.2.

TABLE C.2 Estimated pore volumes and pumping durations for Powhattan single extraction well.

Assumed Effective Porosity	Estimated Pumping Rate, gpm[1]	Estimated Radius of Influence[1]	Estimated Pore Volume		Time to Pump (yr)	
			Cubic feet	Gallons	1 pore vol	3.44 pore vol
0.2	2.3	200	251,327	1,879,939	1.6	5.4
0.3	2.3	200	376,991	2,819,894	2.3	8.0

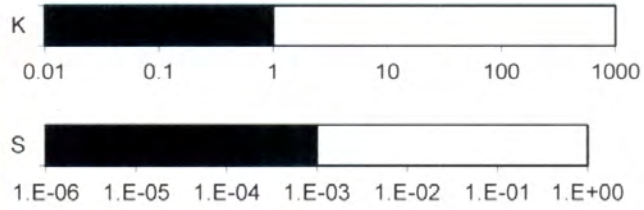
[1] Results of calculations summarized in Figures C.1 and C.2.

The results suggest that operation of the proposed extraction well at Powhattan for a period of 5-8 years may be sufficient for the concentrations of carbon tetrachloride in the basal sandy-silty interval to approach *asymptotic levels*.

Drawdown Prediction for Leaky Confined Aquifers, Hantush-Jacob (1960)

Input Data for prediction of drawdown

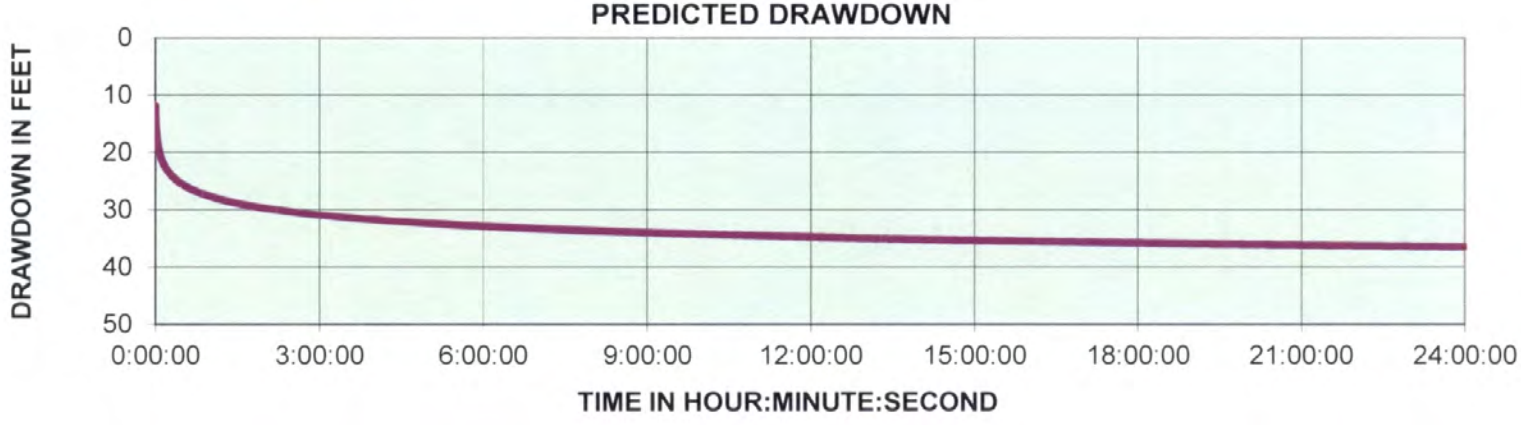
Hydraulic conductivity, K, ft/day	1
Aquifer Thickness, b, ft	10
Storage Coefficient, S	0.001
Pumping Rate, GPM	2
Distance from well, ft	0.333
Ratio of K_z to K	0.01
Confining Layer Thickness, b', ft	40



Equation used in prediction

$$s = \frac{Q(H(u, r/B))}{4\pi T} \qquad u = \frac{r^2 S}{4Tt} \qquad B = \sqrt{\frac{T}{K_z/b'}}$$

s is drawdown, H(u, r/B) is the well function



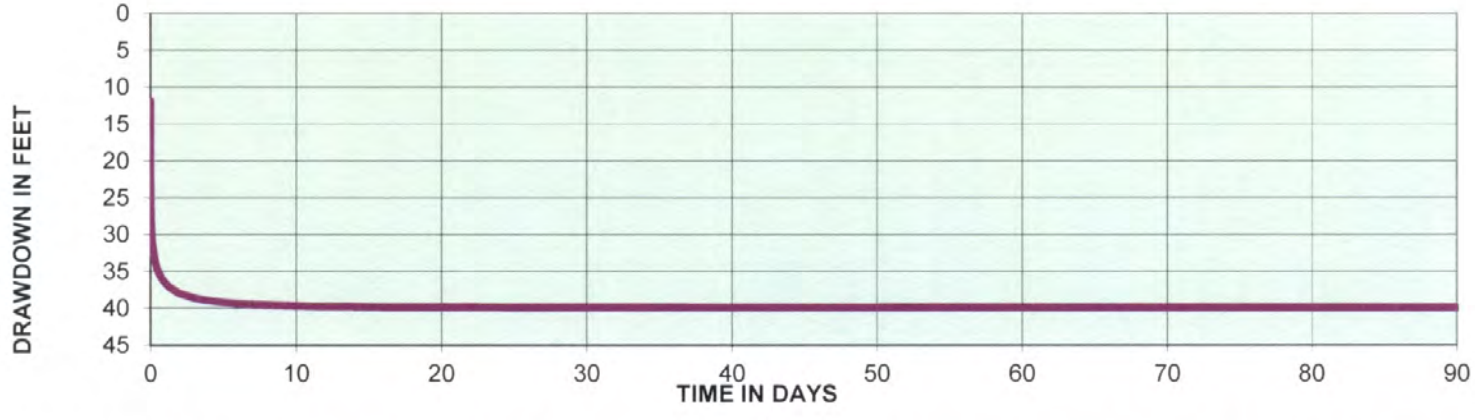
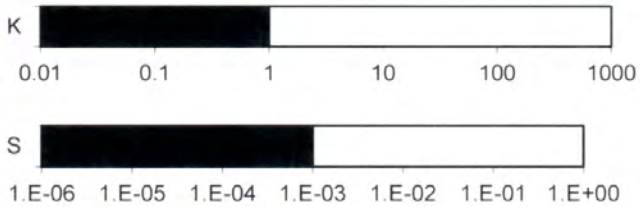


Figure C.1a Predicted drawdown with time at the pumping well, for leaky-confined case with no storage in the confining layer.

Drawdown Prediction for Leaky Confined Aquifers, Hantush-Jacob (1960)

Input Data for prediction of drawdown

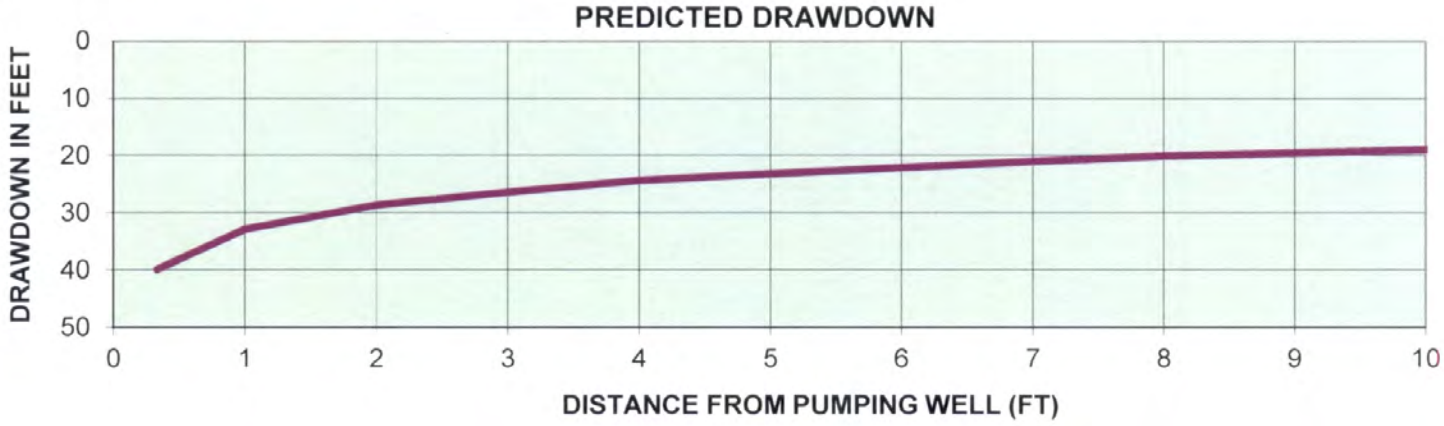
Hydraulic conductivity, K, ft/day	1
Aquifer Thickness, b, ft	10
Storage Coefficient, S	0.001
Pumping Rate, GPM	2
Time since pumping, day	90
Ratio of K_z to K	0.01
Confining Layer Thickness, b', ft	40



Equation used in prediction

$$s = \frac{Q(H(u, r/B))}{4\pi T} \qquad u = \frac{r^2 S}{4Tt} \qquad B = \sqrt{\frac{T}{K_z/b'}}$$

s is drawdown, H(u, r/B) is the well function



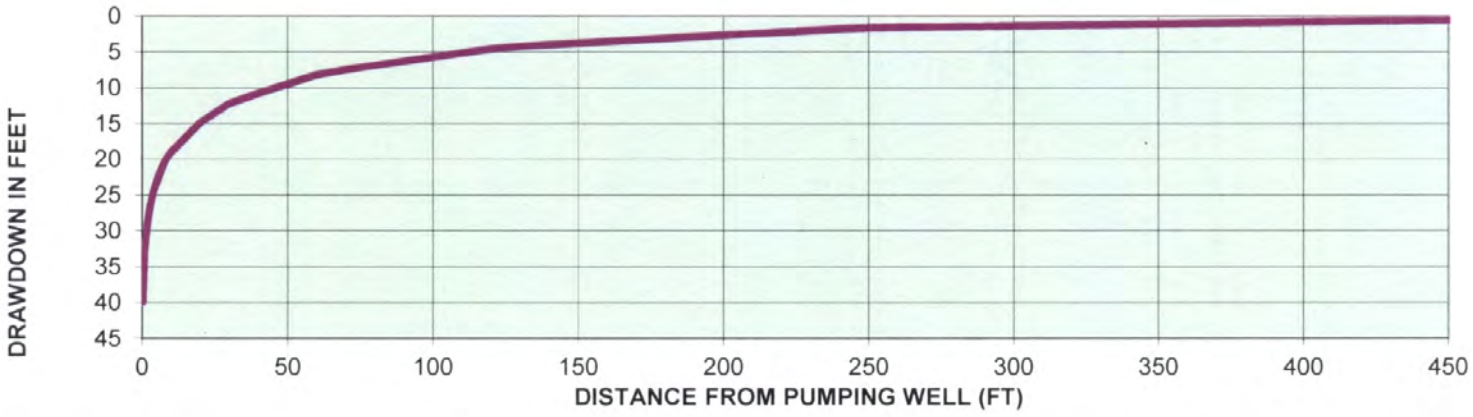
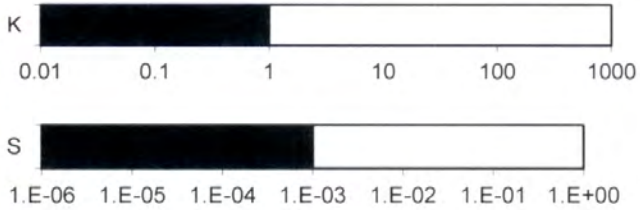


Figure C.1b Predicted drawdown with distance from the pumping well, for leaky-confined case with no storage in the confining layer.

Drawdown Prediction for Leaky Confined Aquifers, Hantush-Jacob (1960)
(with Storage in the Leaky Confining Layer)

Input Data for prediction of drawdown

Hydraulic conductivity, K, ft/day	1
Aquifer Thickness, b, ft	10
Storage Coefficient, S	0.001
Pumping Rate, GPM	2.3
Distance from well, ft	0.333
Ratio of K_z to K	0.01
Confining Layer Thickness, b', ft	40
Storage Coefficient in CL, S'	0.1

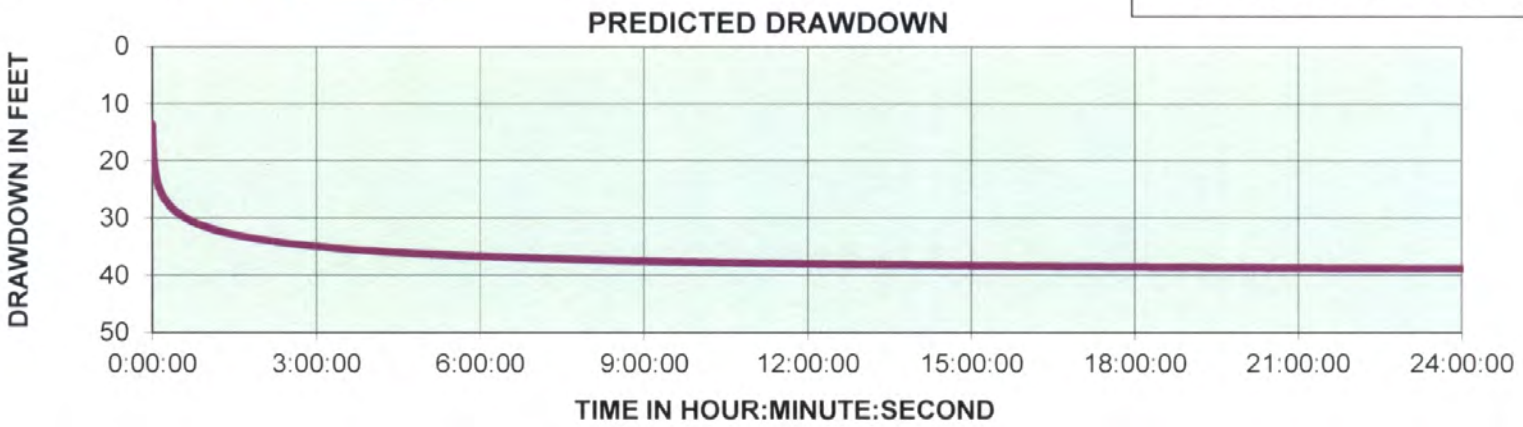


Equation used in prediction

$$s = \frac{Q\,(H\,(u,\beta))}{4\pi T}$$

$$u = \frac{r^2 S}{4Tt} \quad B = \sqrt{\frac{T}{K_z/B}} \quad \beta = \frac{r}{4B}\sqrt{\frac{S'}{S}}$$

s is drawdown, H(u, β) is the well function



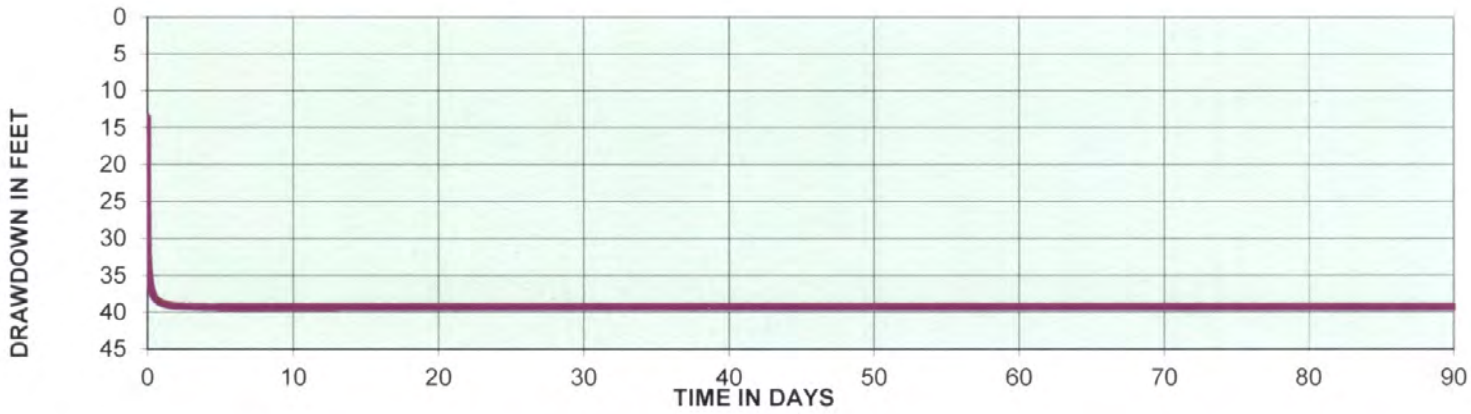
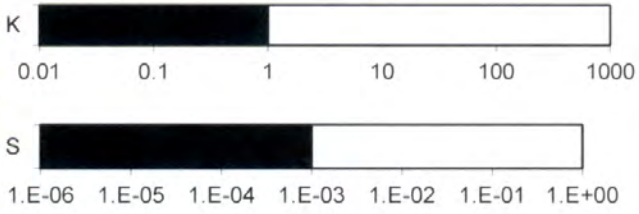


Figure C.2a Predicted drawdown with time at the pumping well, for leaky-confined case with storage in the confining layer.

Drawdown Prediction for Leaky Confined Aquifers, Hantush-Jacob (1960)
(with Storage in the Leaky Confining Layer)

Input Data for prediction of drawdown

Hydraulic conductivity, K, ft/day	1
Aquifer Thickness, b, ft	10
Storage Coefficient, S	0.001
Pumping Rate, GPM	2.3
Time since pumping, day	90
Ratio of K_z to K	0.01
Confining Layer Thickness, b', ft	40
Storage Coefficient in CL, S'	0.1

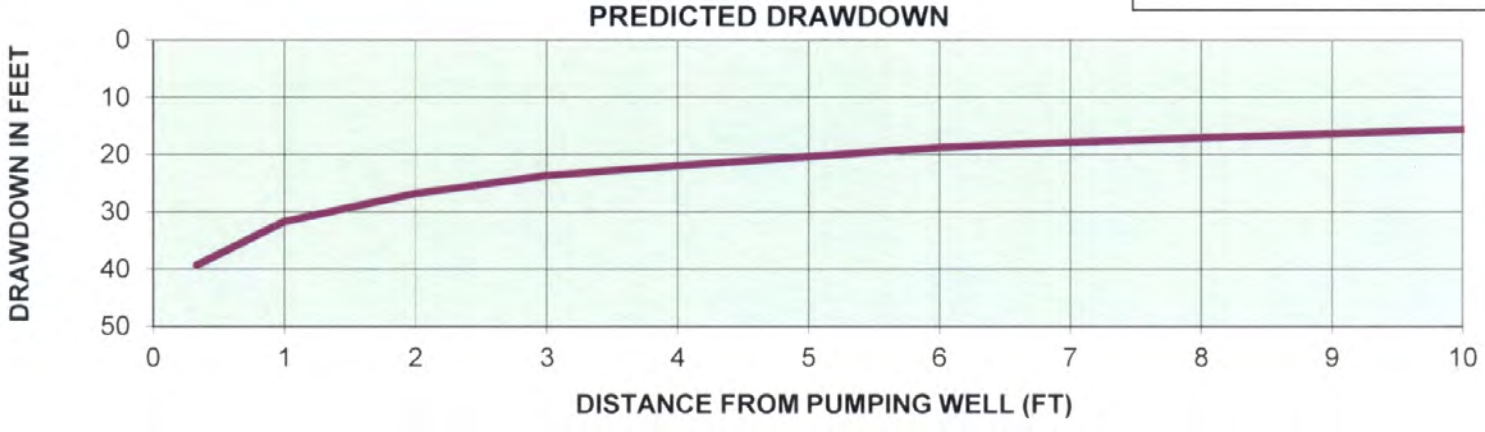


Equation used in prediction

$$s = \frac{Q\,(H\,(u,\beta))}{4\pi T}$$

$$u = \frac{r^2 S}{4Tt} \quad B = \sqrt{\frac{T}{K_z/B}} \quad \beta = \frac{r}{4B}\sqrt{\frac{S}{S'}}$$

s is drawdown, H(u, β) is the well function



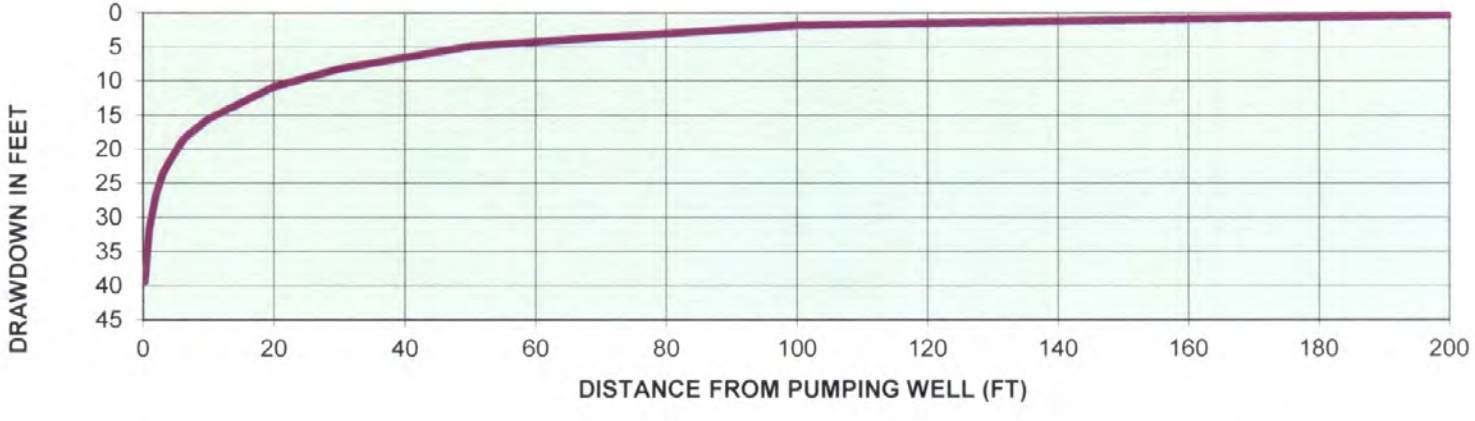


Figure C.2b Predicted drawdown with distance from the pumping well, for leaky-confined case with storage in the confining layer.

C.4 References

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