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February 15, 2007

Mr. Christopher C. Carey, Post-Remediation Unit
Bureau of Environmental Remediation
Kansas Department of Health and Environment
1000 SW Jackson, Suite 410
Topeka, KS 66612-1367

Subject: *Recommendations for Remedial Action at Everest, Kansas*, 2/15/07, ANL/EVS/AGEM/CHRON-1025

Dear Mr. Carey:

Attached, at the request of Caroline Roe of the CCC/USDA, is a revised version of the recommendations for remedial action at Everest, Kansas. This new version incorporates our responses to your comments of January 5, 2007, on the version we issued on November 22, 2006 (ANL/EVS/AGEM/CHRON-1009).

Also attached is a formal response to your comments of January 5, 2007. As the response indicates, thorough consideration of your request (in your Comment 4) to evaluate the use of tracers at Everest will require further investigation. We propose to submit a separate document addressing that comment more fully.

Please address comments on this document to Ms. Roe. Let us know if we can do anything to assist in your review.

Sincerely,

Lorraine M. LaFreniere

LML:rs

Attachments: *Recommendations for Remedial Action at Everest, Kansas*, 2/15/07
Response to KDHE Comments of January 5, 2007

cc: C. Roe (CCC/USDA)
G. Fremerman (CCC/USDA)
Chron 1025

bcc (with attachments): L. LaFreniere
C. Dennis
R. Sedivy
E. Yan
J. Hansen
D. Surgnier
K. Haugen
L. Culbert

Recommendations for Remedial Action at Everest, Kansas

Introduction

On September 7, 2005, the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) presented a *Scoping Memo* (Argonne 2005) for preliminary consideration by the Kansas Department of Health and Environment (KDHE). This document suggested possible remedial options for the carbon tetrachloride contamination in groundwater at Everest, Kansas. The suggested approaches were discussed by representatives of the KDHE, the CCC/USDA, and Argonne at the KDHE office in Topeka on September 8-9, 2005, along with other technical and logistic issues related to the Everest site. In response to these discussions, the KDHE recommended (KDHE 2005) evaluation of several remedial processes, either alone or in combination, as part of a Corrective Action Study (CAS) for Everest. The primary remedial processes suggested by the KDHE included the following:

- Hydraulic control by groundwater extraction with aboveground treatment
- Air sparging–soil vapor extraction (SVE) in large-diameter boreholes
- Phytoremediation

As a further outcome of the 2005 meeting and as a precursor to the proposed CAS, the CCC/USDA completed the following supplemental investigations at Everest to address several specific technical concerns discussed with the KDHE:

- Construction of interpretive cross sections at strategic locations selected by the KDHE along the main plume migration pathway, to depict the hydrogeologic characteristics affecting groundwater flow and contaminant movement (Argonne 2006a).
- A field investigation in early 2006 (Argonne 2006c), as follows:
  - Installation and testing of a production well and associated observation points, at locations approved by the KDHE, to determine the response of the Everest aquifer to groundwater extraction near the Nigh property.
  - Groundwater sampling for the analysis of volatile organic compounds (VOCs) and the installation of additional permanent monitoring points at locations selected by the KDHE, to further constrain the existing contaminant plume.
  - Resampling of all existing permanent monitoring points for VOCs and biodegradation parameter analyses, at the request of the KDHE.

On the basis of these studies (Argonne 2006a,c) and the CCC/USDA's past investigations at Everest (Argonne 2006b), the CCC/USDA concluded that groundwater extraction is not an effective remedial option for this site, and the KDHE concurred (KDHE 2006). As outlined in the next section, the CCC/USDA also believes that air sparging does not represent a viable remedial alternative. The CCC/USDA therefore proposes to collect the technical data required to evaluate the potential viability of a phytoremediation approach for this site and, if appropriate, to support the development of a remedial design.

Preliminary Assessment of the Groundwater Extraction and Air Sparging Alternatives

The CCC/USDA's investigations at Everest have demonstrated highly heterogeneous hydraulic conductivity values that can vary significantly over relatively short vertical and lateral distances. This is true throughout much of the aquifer unit along the observed contaminant migration pathway, and particularly near Prairie Road and the Nigh property. The CCC/USDA has attempted to extract groundwater from the aquifer unit at multiple locations (wells MW1, MW2, PT1, and the Nigh private well [DW06]; Figure 1) along the contaminant migration pathway. The results demonstrated sustainable flow rates to wells of approximately 1 gpm or less, generally with an effective radius of influence for each well of 100 ft or less.

Many of the demonstrated hydrogeologic and logistic concerns (outlined above) that limit the effectiveness of groundwater extraction would also apply to air sparging–SVE. The implementation of this alternative to address the carbon tetrachloride contamination along much of the plume migration pathway would require the drilling of multiple, closely spaced boreholes to depths of 50-60 ft or more. Because the contamination of concern is restricted to the saturated zone, no remedial benefit would be achieved by removing relatively large volumes of uncontaminated vadose zone soils in the upper portion of each boring. The heterogeneity of the Everest aquifer unit would restrict the vertical and lateral influence of sparging in the saturated zone beyond each borehole, in a way that is difficult to predict. Consequently, applying this technique as a containment measure along Prairie Road would have little influence on contaminant migration rates and pathways throughout most of the aquifer unit.

Representatives of the city and the county have expressed reservations regarding the need for further characterization or remediation activities at Everest, as have local private landowners. The CCC/USDA's experience indicates that the potential installation of groundwater extraction wells, air sparging wells, or other remedial facilities in the identified contaminant migration pathway northwest of the former CCC/USDA facility would be highly disruptive to current agricultural land use and might be met with strong resistance by the affected property owners and the local community.

The CCC/USDA therefore concludes that neither groundwater extraction nor air sparging coupled with SVE in large-diameter boreholes represents a practical approach for effective remediation of the groundwater contamination at Everest.

Preliminary Assessment of Risks to Human Health and the Environment

Under the present water and land use conditions at Everest, the identified carbon tetrachloride contamination in groundwater poses no unacceptable health threat to the residents of the city or to occupants of any private residences identified in the vicinity of the town that are not connected to the municipal water supply (Argonne 2006b). No carbon tetrachloride has been detected in the vadose zone soils at the former CCC/USDA facility at levels that would require remediation of the soils under the Tier 2 risk-based standards for carbon tetrachloride presented in the KDHE *Risk Based Standards for Kansas* (*RSK Manual*; KDHE 2003).

Argonne's investigations (Argonne 2006b) indicate that the migration pathway of the contaminated groundwater will turn southwestward in the vicinity of the intermittent creek west of the Nigh property, toward an area of groundwater seepage identified along the lower reach of the creek (Figure 2). The identified patterns of groundwater flow and contaminant migration

therefore indicate that the carbon tetrachloride plume could represent a *future* human health or environmental risk, as a result of contaminant discharge to the surface waters of the creek in the groundwater seepage area.

The results of periodic groundwater sampling and analyses by the CCC/USDA demonstrate that the areal extent and range of carbon tetrachloride concentrations detected in the plume at Everest have changed relatively little during the investigations at this site (2000 to present). No carbon tetrachloride has been detected in the waters of the creek. The results (as of February 2006) suggest that the dilute (carbon tetrachloride concentrations < 1 μg/L) downgradient toe of the groundwater plume lies approximately 500 ft east of the intermittent creek bed directly west of the Nigh property and approximately 3,500 ft northeast of the area of groundwater seepage to the surface identified farther downstream along the creek (Figure 2).

The potential carbon tetrachloride concentrations in the creek waters that might result from future contaminant discharge are unknown and cannot be reasonably predicted. Approximations can be made, however, of the migration times required for the plume to reach (1) the immediate area along the intermittent creek directly west of the Nigh property, which represents *the upgradient limit along the projected migration pathway* at which the contaminated groundwater might be shallow enough to effectively implement a phytoremediation treatment technology (see discussion to follow), and (2) the downstream groundwater seepage area. Simple estimates of these times made by applying Darcy's law, hydraulic property data for the aquifer unit west of the Nigh property (Argonne 2006b), and the range of hydraulic gradients for this area determined from ongoing water level monitoring (Argonne 2003, 2006b,c) are in Attachment 1. The estimates demonstrate the range of uncertainties resulting from the heterogeneity of the hydraulic conductivity distribution and the interpreted complexity of the migration pathways at Everest. Nevertheless, the results in Attachment 1 suggest that, at minimum, approximately 4 yr will be required for the carbon tetrachloride plume (in the subsurface) to reach the vicinity of the creek directly to the west, while more than 20 yr will be required to reach the identified groundwater discharge area to the southwest.

The CCC/USDA therefore concludes that *the existing plume poses no immediate danger of contamination to the surface waters of the creek.*

Recommendation of the Phytoremediation Alternative

In light of the above observations, the CCC/USDA proposes phytoremediation as a potentially viable alternative for protection of the surface waters of the creek and restoration of the Everest groundwater. The CCC/USDA recently implemented a full-scale phytoremediation program under the regulatory supervision of Region VII of the U.S. Environmental Protection Agency (EPA), to address groundwater contamination in Murdock, Nebraska, in a hydrologic setting roughly analogous to that at Everest. At Murdock, selected plant species (more than 2,000 trees, plus associated groundcover and buffer zone vegetation) are being used in conjunction with constructed wetlands to reduce initial carbon tetrachloride concentrations in excess of 300 μg/L in shallow groundwater approaching an area of surface discharge to a small creek. Initial (first-year) sampling and monitoring data for the Murdock site indicate that this remedial approach has already achieved non-detectable levels of carbon tetrachloride in the creek waters immediately downstream of the coupled phytoremediation and wetlands treatment zones (Argonne 2006d).

By employing phytoremediation and wetland technologies, the CCC/USDA was able to establish a largely self-sustaining remedial system at Murdock that is expected to function effectively for the projected lifetime (approximately 40 yr) of the groundwater cleanup. The CCC/USDA and the EPA obtained ready community acceptance of this approach, because the constructed treatment areas both enhance wildlife habitat and increase recreational opportunities for the local residents, with minimal disruption to the surrounding agricultural lands.

Figure 3 presents an estimate of the area where phytoremediation would be technically feasible at Everest, *as the projected groundwater plume approaches the creek during the next 4 yr or more*. As the figure shows, the potentially viable area for phytoremediation is along the creek trend west and downgradient of the Nigh property. Planting there would have minimal effect on agricultural use of the surrounding private lands. This estimate of the area feasible for phytoremediation was generated on the basis of recorded groundwater levels in the area characterized by the CCC/USDA, under the assumption that the limiting depth for ready use of phytoremediation (with special planting techniques to promote deep root penetration by trees where necessary) is approximately 15 ft below ground level (BGL). As the carbon tetrachloride plume progressively migrates southwestward and downgradient toward the natural groundwater discharge area, the area with shallower groundwater (suitable for conventional plantings, without the special deep-rooting techniques) will expand, therefore increasing the potential effectiveness of phytoremediation.

Proposal for Further Investigation of the Phytoremediation Alternative

The CCC/USDA believes that the phytoremediation approach outlined above represents a potentially viable and practical alternative for addressing the carbon tetrachloride contamination at Everest, in a way that will be protective of human health and the environment and acceptable to the local community. The CCC/USDA also believes, however, that the expected time frame required for the contaminant plume to reach the optimal treatment area offers an opportunity to collect additional data required to fully evaluate this remedial alternative. Therefore, the CCC/USDA seeks KDHE approval for a program of systematic groundwater sampling and monitoring at Everest. This monitoring will be a precursor to the submission of a detailed assessment of remedial alternatives, including phytoremediation, for the Everest site in the context of a CAS or other regulatory framework preferred by the KDHE.

Objectives. The specific technical objectives of the proposed monitoring activities are as follows:

- To verify the CCC/USDA's present interpretation that continued groundwater flow and contaminant migration will generally follow the trend of the intermittent creek west and southwest of the Nigh property, ultimately approaching the downstream seepage area along the creek.
- To document the contaminant migration rates and the evolution of carbon tetrachloride concentrations as the plume approaches the intermittent creek, and hence to determine the requirements and the optimal time frame for implementation of phytoremediation or other remedial alternatives to protect the quality of the creek surface waters.

- To gather additional data regarding the patterns of seasonal and longer-term groundwater and surface water level variations along the lower reaches of the intermittent creek and thus to define more precisely the areas amenable to potential phytoremediation planting.
- To generate information on the hydrologic balance among local precipitation, evapotranspiration, recharge to the aquifer, and the contributions of surface runoff and groundwater flow to the intermittent creek, which will affect the design parameters of the proposed phytoremediation treatment zone.

Monitoring Activities. To address these proposed objectives, the CCC/USDA proposes a phased program of groundwater and surface water monitoring activities. The CCC/USDA recommends that the Phase I activities be conducted at Everest for a minimum period of two years. The activities to be performed during Phase I of the program are the following:

- Annual sampling of groundwater for determination of VOCs and selected indicator parameters of possible natural biodegradation processes (dissolved oxygen, Fe^{II}, oxidation-reduction potential) at the existing permanent monitoring points shown in Figure 4. If evidence of significant natural biodegradation is found, additional indicator parameters will be selected for analysis in accord with the KDHE policy for monitoring of natural attenuation (KDHE 2001).
- Twice yearly sampling (during the first year of Phase I) and quarterly sampling (thereafter during Phase I) of groundwater for VOCs and indicator parameter analyses at the existing suite of permanent monitoring points along the presently identified lateral margins of the carbon tetrachloride plume (MW3, SB49, SB62, SB63, SB64, SB72, SB78, SB79S, SB79D, SB80), plus MW4 and SB60 near the Nigh property (Figure 5), to document the downgradient migration of the contamination over time. During each year, one of these sampling events will coincide with the annual sampling discussed above; the other(s) will be performed separately.
- Twice yearly sampling (during the first year of Phase I) and quarterly sampling (thereafter during Phase I) of surface water at five permanent locations to be established in the groundwater seepage area and along the upstream portion of the intermittent creek (Figure 6). The samples will be analyzed for VOCs to document that carbon tetrachloride at unacceptable levels has not reached the surface waters of the creek during the monitoring period. During each year, one of these sampling events will coincide with the annual sampling discussed above; the other(s) will be performed separately.
- Maintenance of the existing network of automated groundwater level monitoring points (Figure 7).

At any time during Phase I of the proposed monitoring program, if the KDHE and the CCC/USDA conclude (on the basis of the sampling results) that a more accelerated time frame is required for remedy selection at Everest, the CCC/USDA will proceed to Phase II of the program. In Phase II, the following additional monitoring activities will be

conducted (in conjunction with the annual and quarterly sampling events outlined above) for a minimum further period of one year:

- Continuous water level monitoring with automated logging equipment at permanent observation points to be established along the more downstream and perennial portions of the creek, to determine seasonal variations in surface water and groundwater levels.
- Establishment of a permanent recording weather station in the immediate vicinity of the potential phytoremediation area. This station will generate climate data for use in evaluation of the hydrologic balance at the prospective treatment site. Parameters to be monitored should include air temperature, relative humidity, precipitation, wind speeds and direction, solar and ultraviolet radiation levels, and local soil moisture.
- A one-time survey of the natural vegetation types and density along the creek trend in the vicinity of the potential phytoremediation area.
- Twice yearly sampling of natural plants at selected locations along the creek trend (locations to be determined on the basis of the survey results). The samples will be analyzed for VOCs to identify possible contaminant uptake and estimate the potential phytoremediation capability of the existing vegetation.

The proposed supplemental activities in Phase II will provide critical data required for subsequent remedial design evaluation of phytoremediation in the context of a CAS or under the regulatory framework the KDHE prefers.

The above activities are summarized in Table 1.

At the request of the KDHE, the CCC/USDA and Argonne will investigate the possible use of tracers to monitor the migration and fate of the carbon tetrachloride contamination in groundwater as it approaches the area(s) targeted for possible phytoremediation. In particular, the viability of using inorganic, isotopic, or other geochemical species to track groundwater uptake by the natural vegetation (as well as by possible phytoremediation plantings) near the intermittent creek will be evaluated. If indicator species and analysis methods suitable for use in this manner can be identified, the CCC/USDA will present recommendations to the KDHE for possible tracer use as part of the present monitoring program or in conjunction with a phytoremediation remedy.

Reporting. Data from each of the proposed monitoring events will be submitted to the KDHE for review within 60 days of the completion of field activities. The reporting activities will be as follows:

- Twice yearly reporting during the first year of Phase I — and quarterly reporting thereafter — of analytical results for each sampling event to the KDHE as a brief data report.
- Annual summary reporting, with interpretation, of the results of all sampling and monitoring activities during the preceding calendar year. These annual

performance reports will be submitted for KDHE review and approval throughout the monitoring program.

Consultation between the KDHE and CCC/USDA project managers is recommended as each new report is released, to determine the merits of continuing the current phase of the monitoring program or to discuss modifications that may be required to address additional data needs.

TABLE 1 Summary of sampling and monitoring requirements proposed for Everest, for a minimum total period of approximately 3 yr (Phase I and Phase II).

Sampling or Monitoring Activity	Locations	Frequency	Phase(s)
Groundwater sampling from permanent monitoring points, for VOCs analyses and selected biodegradation indicators	Figure 4	Annually	I and II
Groundwater sampling at wells on the plume margins, plus MW4 and SB60	Figure 5	Twice annually (once in coincidence with the annual event, plus one additional event)	I (1st year)
		Four times annually (once in coincidence with the annual event, plus three additional events)	I (2nd year) and II
Surface water sampling in the groundwater seepage and upstream creek areas, for VOCs analyses only	Figure 6	Twice annually	I (1st year)
		Four times annually	I (2nd year) and II
Groundwater level monitoring at existing permanent monitoring points	Figure 7	Continuously (water level recorders)	I and II
Groundwater and surface water level monitoring in new locations	Locations to be determined in the downstream and perennial parts of the creek	Continuously (water level recorders)	II
Establishment of weather station	In proposed phytoremediation area	Continuously (automated data logging)	II
Survey of natural vegetation types and density	Along creek trend	One time	II
Sampling of natural plants for VOCs analyses	Locations to be selected along creek trend	Twice annually	II

References

Argonne, 2003, *Final Phase II Report: QuickSite® Investigation, Everest, Kansas*, ANL/ER/TR-03/003, prepared for the Commodity Credit Corporation. U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, September.

Argonne, 2005, *Scoping Memo for the Discussion of Potential Remedial Options for the Groundwater Contamination Site at Everest, Kansas*, ANL/ER/AGEM/CHRON-883, prepared for the Commodity Credit Corporation. U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, September 6.

Argonne, 2006a, *2005 Cross Section Analysis and Recommendations for Further Studies at Everest, Kansas*, ANL/EVS/AGEM/TR-05-02, prepared for the Commodity Credit Corporation. U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, January.

Argonne, 2006b, *Final Report: Phase III Targeted Investigation, Everest, Kansas*, ANL/ER/TR-04/004, prepared for the Commodity Credit Corporation. U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, January.

Argonne, 2006c, *Final Report: Results of Aquifer Pumping and Groundwater Sampling at Everest, Kansas, in January-March 2006*, ANL/EVS/AGEM/TR-06-05, prepared for the Commodity Credit Corporation. U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, September.

Argonne, 2006d, *Murdock, Nebraska, Removal Action: Initial Report of Quarterly Monitoring Activities for Reporting Period August 2005-June 2006*, ANL/EVS/AGEM/CHRON-980, prepared for the Commodity Credit Corporation. U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, August 31.

KDHE, 2001, *Monitored Natural Attenuation*, Policy #BER-RS-042, Kansas Department of Health and Environment, Bureau of Environmental Remediation, Topeka, Kansas, March 30.

KDHE, 2003, *Risk-Based Standards for Kansas: RSK Manual — 3rd Version*, Kansas Department of Health and Environment, Bureau of Environmental Remediation, Topeka, Kansas, March 1, online at http://www.kdhe.state.ks.us/remedial/rsk_manual_page.htm.

KDHE, 2005, letter from C. Carey (Bureau of Environmental Remediation, Kansas Department of Health and Environment) to C. Roe (Commodity Credit Corporation. U.S. Department of Agriculture), regarding *Scoping Memo* and attached table of candidate response actions, remedial technologies, and process options for restoration of the Everest aquifer unit, October 3.

KDHE 2006, letter from C. Carey (Bureau of Environmental Remediation, Kansas Department of Health and Environment) to C. Roe (Commodity Credit Corporation. U.S. Department of Agriculture), regarding *Draft Report: Results of Aquifer Pumping and Groundwater Sampling at Everest, Kansas, in January-March 2006*, August 11.

Attachment 1:
Estimation of Groundwater and Carbon Tetrachloride Migration Rates

Introduction

The basic Darcy equation can be used to calculate the *volumetric flow rate*, Q, of water passing through a given cross sectional area of a permeable material, as follows:

$$Q = A \times I \times K \,. \tag{1}$$

In Equation 1,

Q = volumetric flow rate (volume/time),

A = cross sectional area (length^2),

I = hydraulic gradient (length/length; dimensionless), and

K = hydraulic conductivity (length/time).

The *average linear velocity of water*, V_{wl}, can be calculated as follows:

$$V_{wl} = Q \div (A \times n_e) = (I \times K) \div n_e \,. \tag{2}$$

In Equation 2,

V_{wl} = average linear velocity of water (length/time),

Q = volumetric flow rate (volume/time),

A = cross sectional area (length^2),

n_e = effective porosity (dimensionless),

I = hydraulic gradient (length/length; dimensionless), and

K = hydraulic conductivity (length/time).

For dissolved contaminants that are affected by retardation due to sorption onto the permeable material, *the average linear velocity of the contaminant*, V_{cl}, can be calculated from the average linear velocity of water, V_{wl}, and the *retardation factor*, R_c, for the specific contaminant relative to the medium, as follows:

$$V_{cl} = V_{wl} \div R_c \,. \tag{3}$$

In Equation 3,

V_{cl} = average linear velocity of contaminant (length/time),

V_{wl} = average linear velocity of water (length/time), and

R_c = retardation factor (velocity/velocity; dimensionless).

Experimental Parameters Used for the Everest Migration Calculations

To estimate the migration of groundwater and carbon tetrachloride toward the intermittent creek, the migration is assumed to be controlled by the hydraulic properties of the Everest aquifer unit west of Prairie Road and upgradient of the creek.

Hydraulic Conductivity (K)

Hydraulic conductivity (K) values were determined for the area west of Prairie Road on the basis of slug tests performed at permanent and temporary monitoring points SB49, SB60, SB62, SB64, SB66, SB67, and SB68 (Argonne 2006b). The K values ranged fairly consistently from 0.84 to 2.30 ft/d (average, 1.41 ft/d) for the aquifer materials near and to the west of the Nigh property. A value of 10.6 ft/d was determined for a thin sandy interval penetrated at SB64 only.

Hydraulic Gradient (I)

Groundwater monitoring results for the area west of Prairie Road (Argonne 2003, 2006b,c) have demonstrated a relatively consistent pattern of groundwater flow from the vicinity of the Nigh property toward the intermittent creek, yielding estimated hydraulic gradient values (calculated as the observed head change [length] divided by the linear distance between the Nigh private well and monitoring point SB63 [length]) ranging from 0.0067 to 0.0079 (length/length; dimensionless).

Effective Porosity (n_e)

Total porosity values measured for Everest aquifer sediment samples collected in the vicinity of the Nigh property and at the former CCC/USDA facility ranged from 0.235 to 0.327 (dimensionless). The *effective* porosity represents only the portion of the *total* porosity that is sufficiently interconnected and of adequate pore size to allow the passage of groundwater through the aquifer material. Hence, in some materials effective porosity can be significantly less than total porosity. For this exercise, however, the measured values are assumed to reflect the range of effective porosity values, n_e, in the aquifer.

Retardation Factor (R_c)

Additional soil property data (bulk density and organic carbon content) were also measured for the sediment samples used to determine the porosity values described above, in order to estimate retardation factors for the Everest aquifer materials (Argonne 2006b). The calculated R_c values ranged from 2.42 to 3.28 (volume/volume; dimensionless) for most of the samples analyzed. One sample of calcareous, cemented sand collected beneath the former CCC/USDA property had an R_c value of and 4.43 (volume/volume; dimensionless).

As an additional limiting case, no retardation of carbon tetrachloride is assumed to occur within the aquifer materials. Under this scenario, $R_c = 1$ (volume/volume; dimensionless), while the assumed contaminant linear velocity, V_{cl} (length/time), is equal to the groundwater velocity, V_{wl} (length/time).

The effective movement of dissolved species near the migration front of a moving plume will also be influenced by both dispersion and diffusion processes within the aquifer material; however, these factors are typically relatively minor for groundwater systems that are advection-dominated (dominated by horizontal flow). For simplicity, this is assumed to be the case for Everest.

Values Selected for Parameters

On the basis of the above information, the values in Table A.1 were selected to reflect potential maximum and minimum levels for the parameters necessary to estimate groundwater (V_{wl}) and contaminant (V_{cl}) linear migration velocities for the Everest aquifer unit and the carbon tetrachloride plume (where I, n_e, and R_c are dimensionless):

TABLE A.1 Selected parameter values.

	K (ft/d)	I	n_e	R_c
Maximum	10.6	0.0079	0.33	3.3
Minimum	1.4	0.0067	0.24	2.4

Results of the Migration Calculations

The aquifer parameter values defined above were used to estimate the potential maximum and minimum time frames that might be required for the downgradient toe of the Everest carbon tetrachloride plume to reach (1) the immediate vicinity of the creek trend directly west of the Nigh property (~ 500 ft downgradient from the present plume location) and (2) the identified area of groundwater discharge along the downstream portion of the creek trend (~ 3,500 ft southwest from the present plume location). The results of the calculations are shown in Table A.2 and Table A.3:

TABLE A.2 Results of migration velocity calculations.

	Groundwater velocity, V_{wl} (ft/d)	Contaminant velocity, V_{cl} (ft/d)
Maximum	0.34	0.14
Minimum	0.03	0.01

TABLE A.3 Calculated minimum and maximum migration times.

	(1) Time to reach the creek trend west of the Nigh property (yr)		(2) Time to reach the identified groundwater discharge area (yr)	
	With No Retardation	With Retardation	With No Retardation	With Retardation
Maximum	45.6	137	320	959
Minimum	4.0	9.8	28.2	68.5

These calculations indicate that, under the natural groundwater flow conditions at the site,

1. A *minimum* of approximately 4 yr to 10 yr is estimated to be required for the present downgradient toe of the carbon tetrachloride plume to reach the vicinity of the intermittent creek directly west of the Nigh property, and
2. More than 20 yr is estimated to be required for the contaminant plume to reach the groundwater discharge area identified along the downstream portion of the creek southwest of Everest.

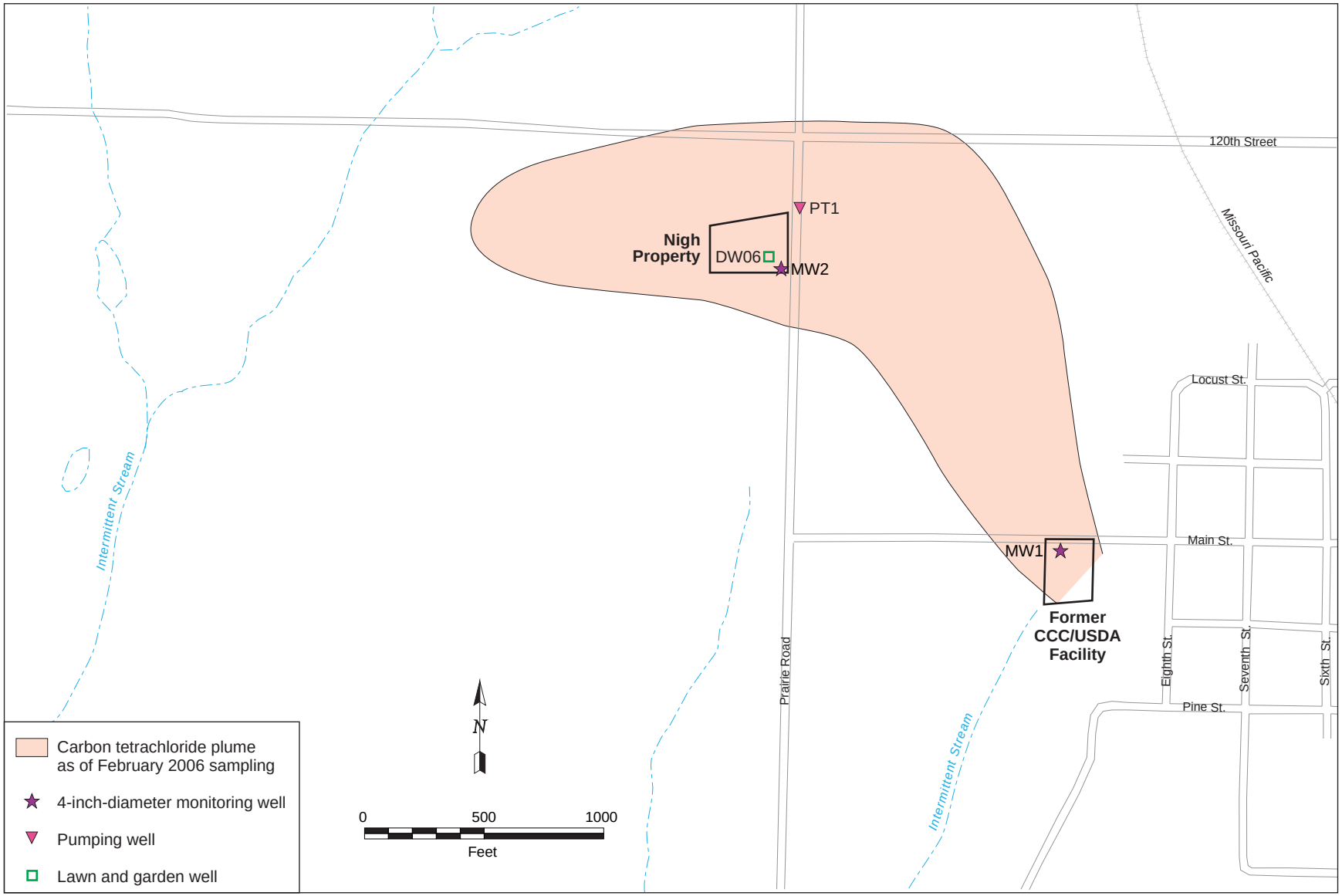

FIGURE 1 Locations of wells at Everest that have been pumped to test the groundwater production capability of the aquifer unit.

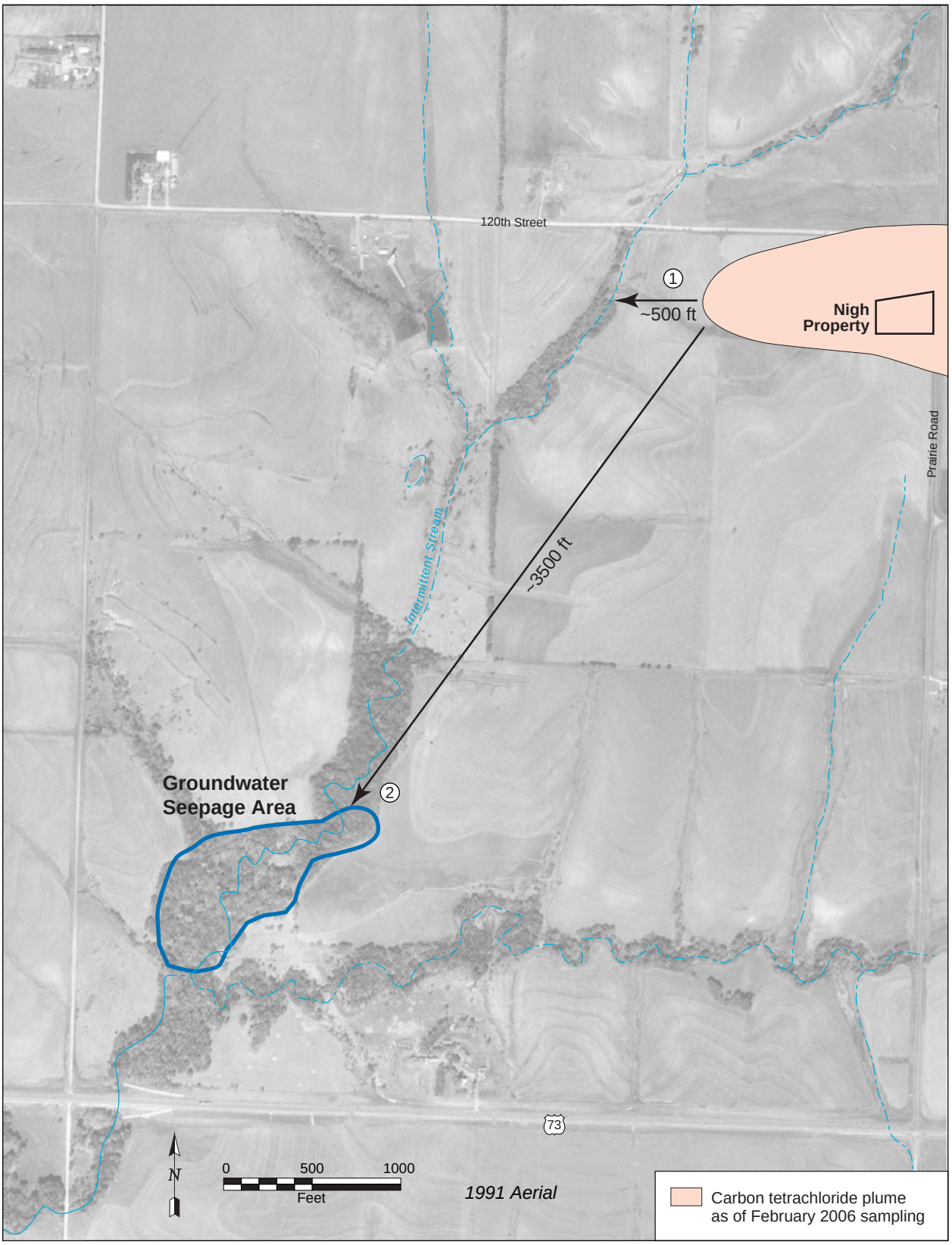

FIGURE 2 Interpreted location of the toe of the existing (February 2006) carbon tetrachloride plume relative to (1) the intermittent creek bed directly to the west and (2) the identified downgradient area of groundwater seepage to the creek.

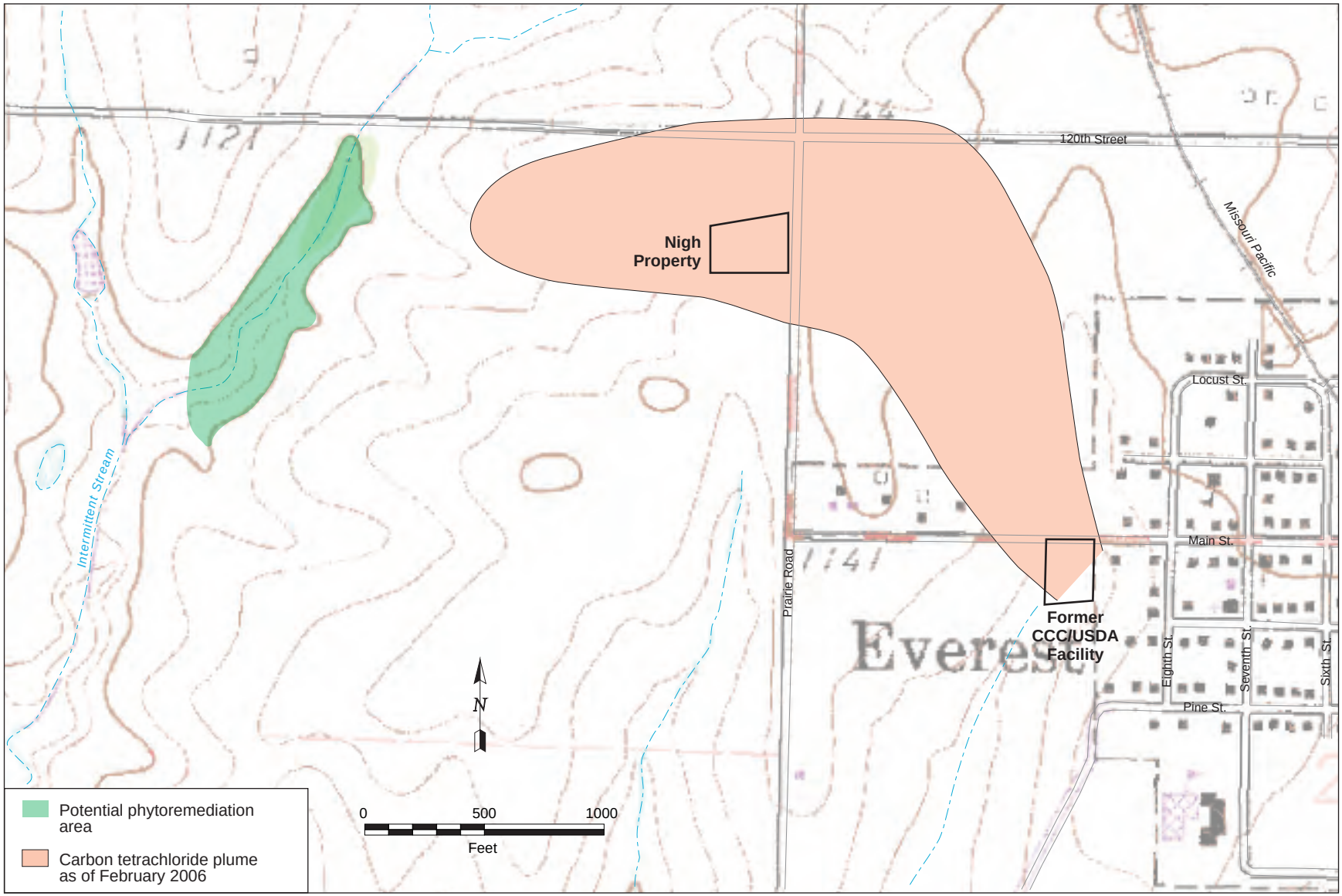

FIGURE 3 Area near the intermittent creek west of Everest where phytoremediation is interpreted as being realistically feasible, with depths to groundwater of 15 ft or less.

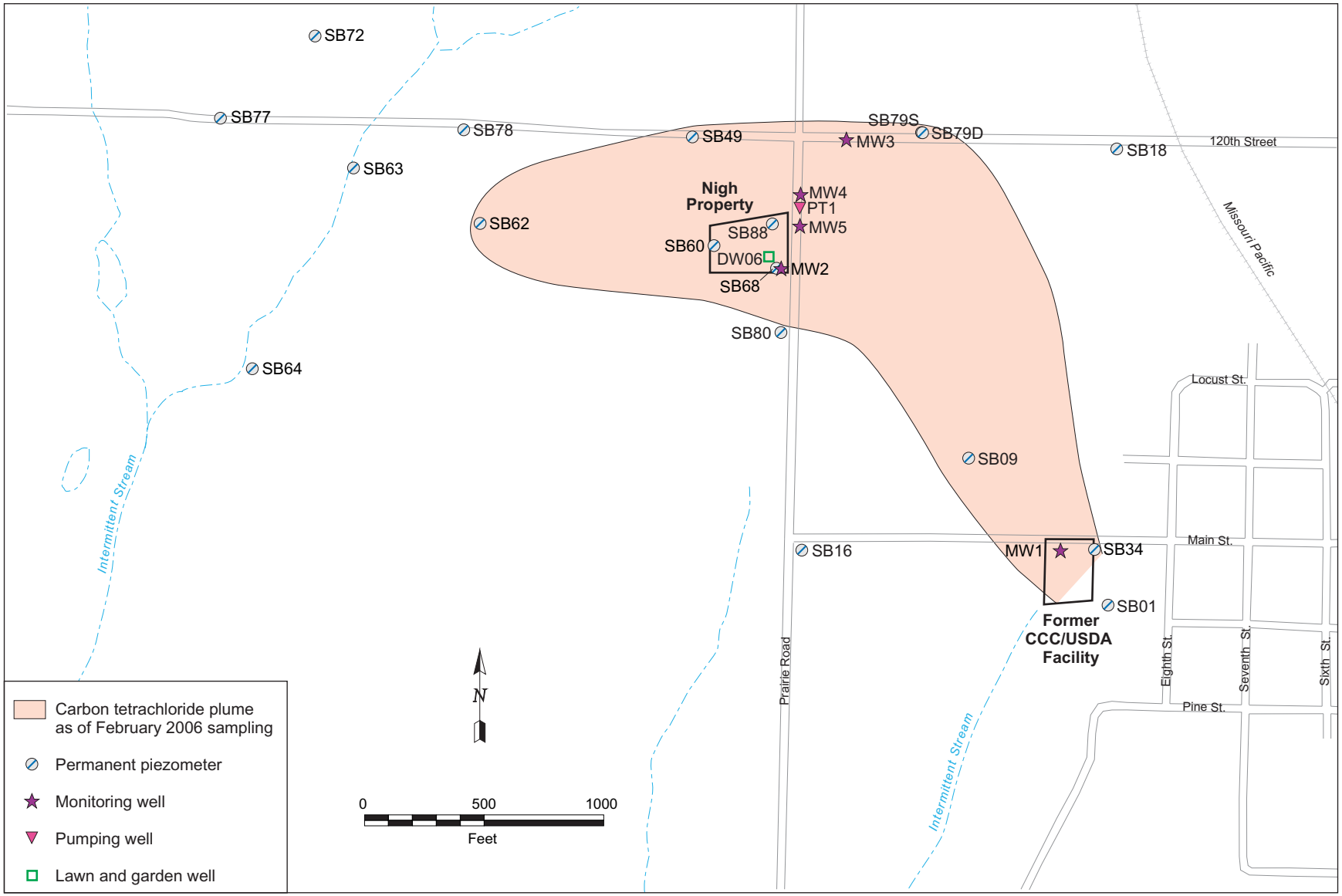

FIGURE 4 Locations of existing permanent monitoring points at Everest, proposed for annual sampling and analysis for VOCs and for selected parameters (dissolved oxygen, oxidation-reduction potential, Fe^{II}) indicative of possible natural biodegradation processes.

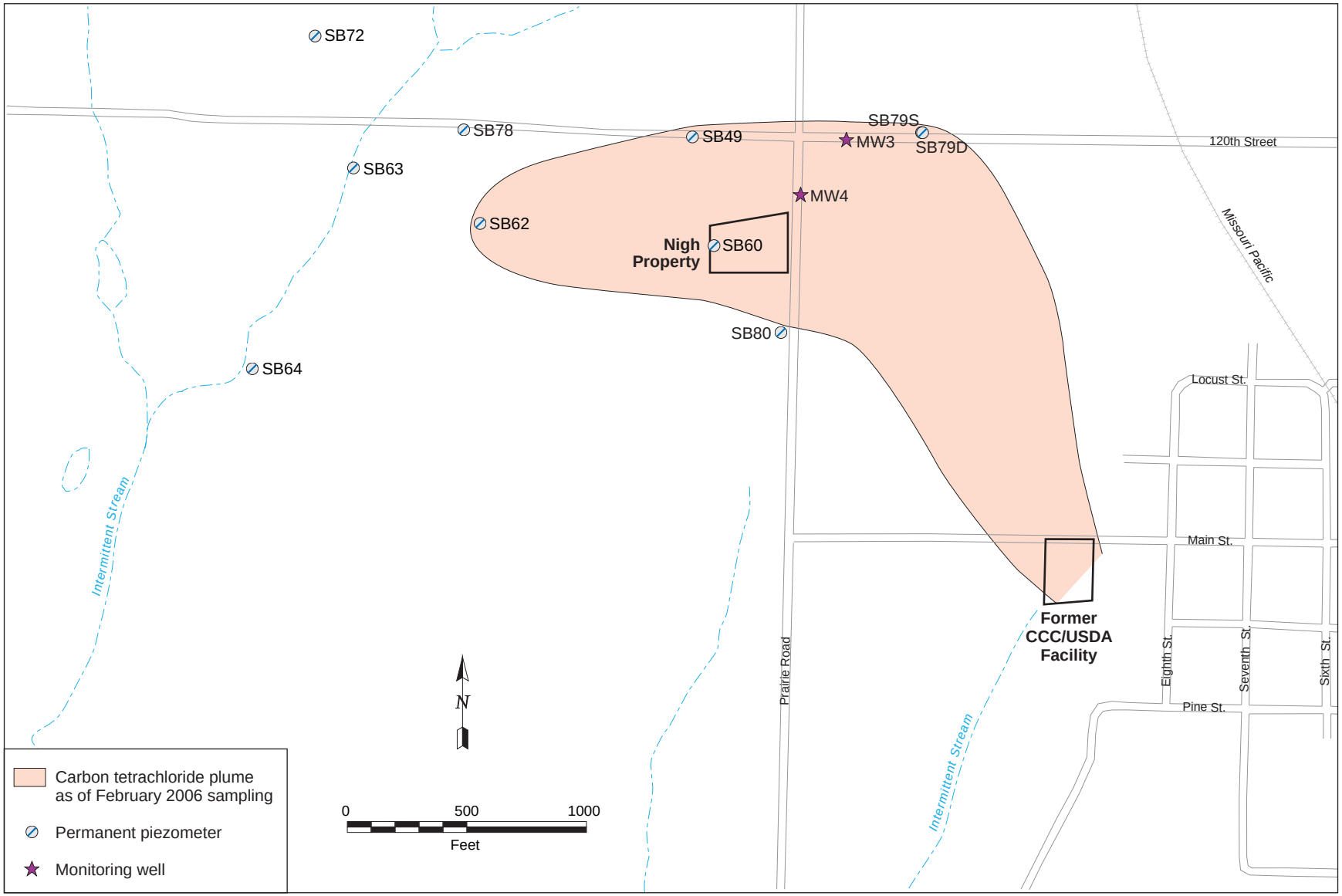

FIGURE 5 Locations of existing permanent monitoring points at Everest selected for twice yearly (first year of Phase I) or quarterly (second year of Phase I and Phase II) groundwater sampling and analyses for VOCs and selected parameters (dissolved oxygen, oxidation-reduction potential, Fe^{II}) indicative of possible natural biodegradation processes.

EV05.ai 02/09/2007

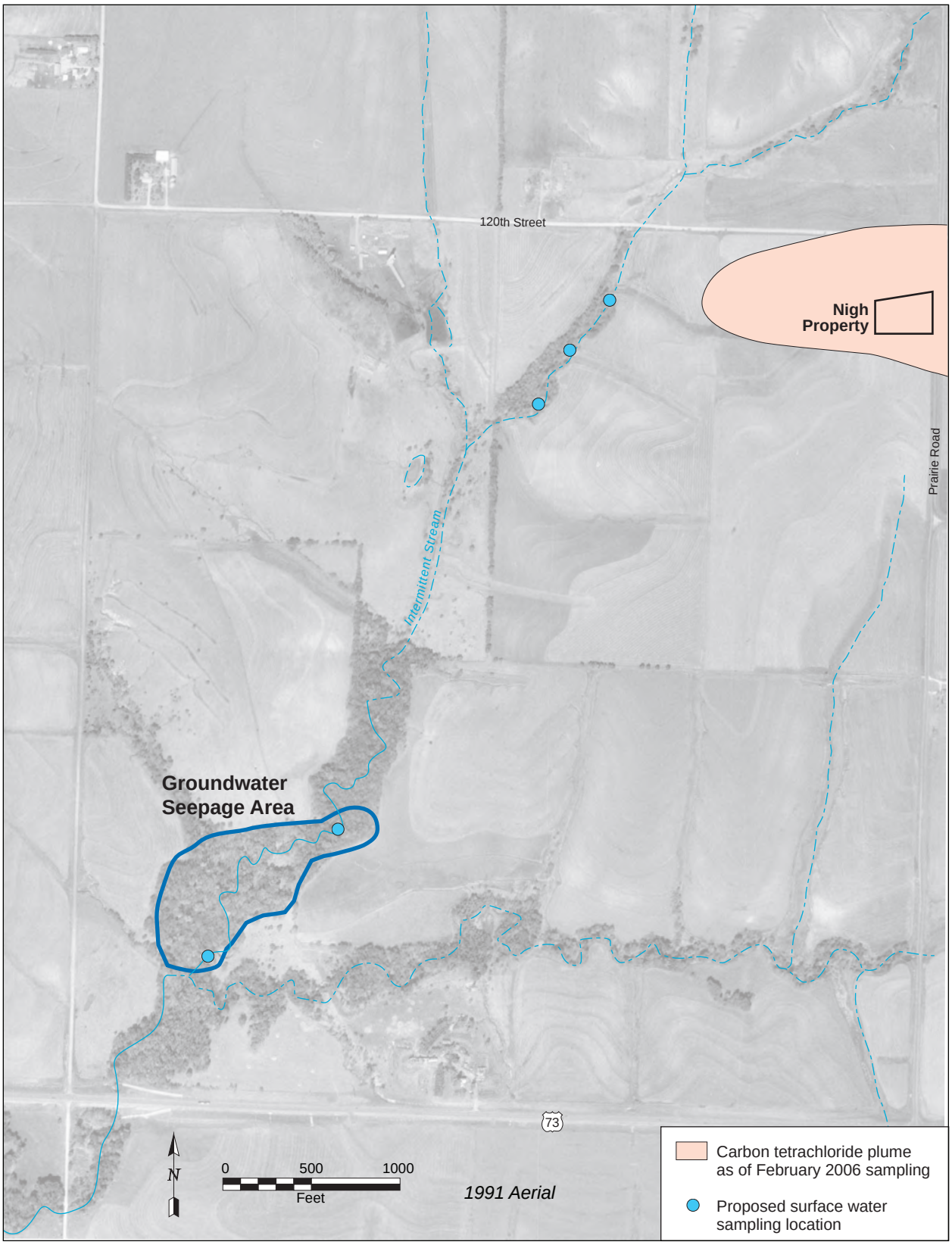

FIGURE 6 Locations along the intermittent creek west and downgradient of the Nigh property proposed for twice yearly (first year of Phase I) or quarterly (second year of Phase I and Phase II) surface water sampling and analysis for VOCs.

EV06.ai 02/09/07

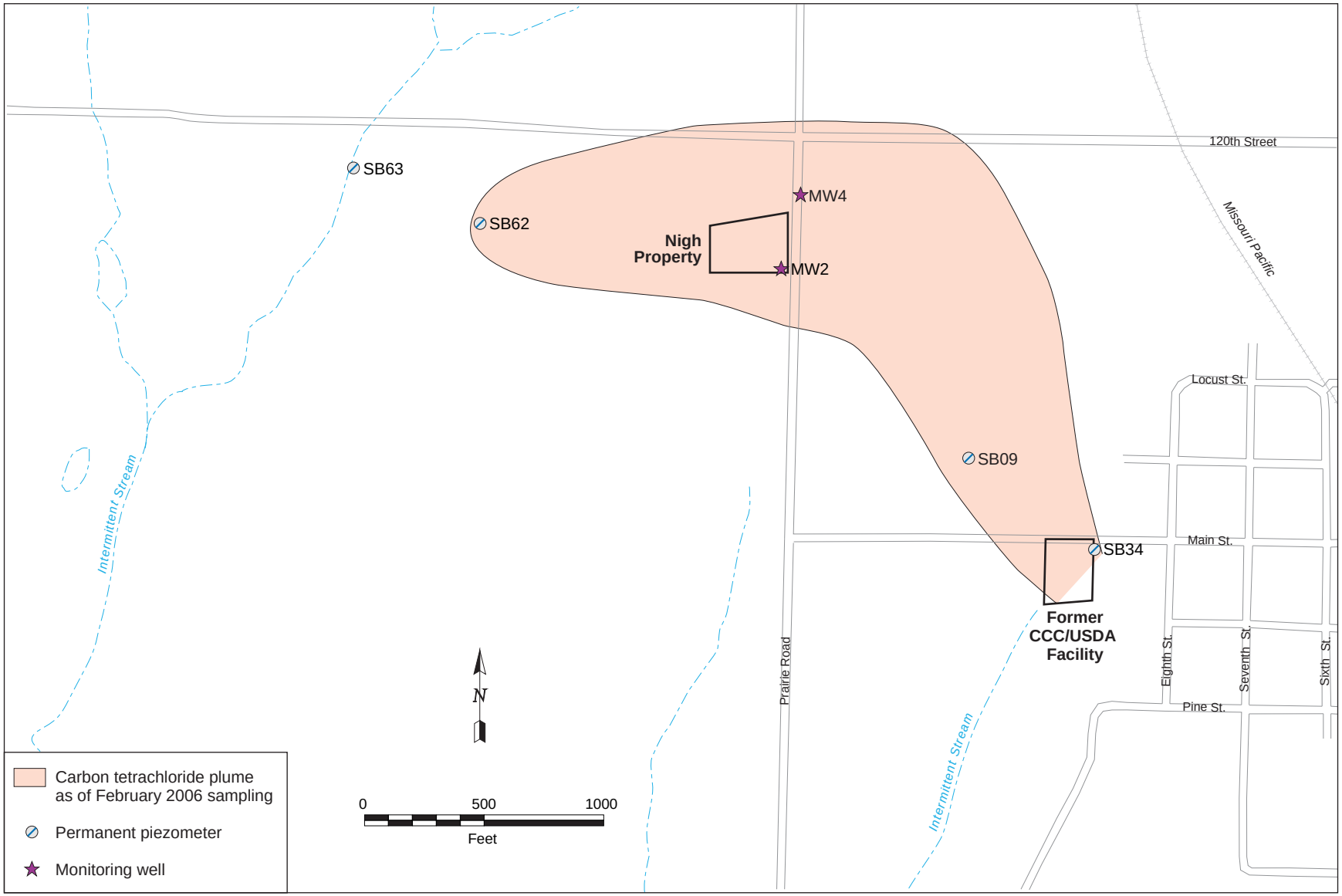

FIGURE 7 Permanent locations presently being monitored with automatic water level recorders at Everest.

Responses to KDHE Comments of January 5, 2007, on
Recommendations for Remedial Action at Everest, Kansas,
(Dated 11/22/06)

Comment 1 — KDHE maintains that the lack of quarterly monitoring data for VOCs and geochemical parameters represents a data need that must be addressed prior to the completion of a corrective action study or the implementation of any remedial actions at the site. KDHE recognizes that quarterly data may be more useful to evaluate the potential effectiveness of phytoremediation later in the monitoring program and, therefore, will allow for one year of semi-annual monitoring to be completed prior to initiating the quarterly monitoring program. Notwithstanding this determination, KDHE reiterates its recommendation to begin quarterly monitoring immediately for a period of one year to evaluate short-term seasonal fluctuations in VOC concentrations and geochemical properties; this may allow CCC/USDA to move forward with other data collection activities to support remedial actions and could potentially reduce costs associated with groundwater monitoring at the site. Please revise the document as appropriate.

> **Response 1** — The CCC/USDA accepts KDHE's position, and will revise the original monitoring proposal to include an initial period (as part of Phase I) of semi-annual sampling, to be followed (during the remainder of Phase I and Phase II) by quarterly sampling.

Comment 2 — KDHE does not agree that the two surface water sample locations will support CCC/USDA's goal to "document that carbon tetrachloride at unacceptable levels has not reached the surface waters of the creek during the monitoring period." As described by Argonne and KDHE staff during the December 19, 2006 call, standing water and consistently moist soil has been observed in the intermittent creek bed directly west of the Nigh Property during times of limited precipitation; therefore, KDHE recommends the collection of additional surface water samples near this location. Please revise the document accordingly.

> **Response 2** — The CCC/USDA's original surface sampling recommendation was more correctly intended to monitor for the potential appearance of unacceptable levels of carbon tetrachloride in the identified downstream, perennial portion of the creek. As noted during the December 19, 2006, call, the CCC/USDA acknowledges KDHE's concerns regarding the observed occurrences of surface moisture in the more upstream reaches of the intermittent creek channel west of the Nigh property. Continued monitoring by Argonne of the groundwater levels at existing wells SB63 and SB64 and periodic observations of the surface water conditions along this portion of the creek suggests that the potential for groundwater seepage from the contaminated aquifer unit into the creek in this area is minimal. The CCC/USDA agrees, however, that additional surface water monitoring points along the upstream portion of the intermittent creek are prudent (subject to the availability of water for sampling). The draft report will be revised to include recommendations for additional surface water sampling locations along the portion of the intermittent creek west of the Nigh property.

Comment 3 — In general, KDHE approves the proposed groundwater monitoring locations; however, KDHE requests that CCC/USDA collect groundwater samples from locations MW4 and SB60 at a frequency not less than semi-annually to evaluate concentrations of carbon tetrachloride in the body of the plume. Please revise the document accordingly.

> **Response 3** — Permanent monitoring points MW4 and SB60 will be added to the revised monitoring schedule discussed in the Response 1, as requested by the KDHE.

Comment 4 — KDHE encourages CCC/USDA and Argonne to evaluate potential geochemical tracers which could be used to determine whether existing vegetation in the "proposed phytoremediation area" draws water from surface water or groundwater; these data could be used in preliminary evaluations of phytoremediation technologies at the site. Please revise the document to include a discussion of the applicability of using geochemical tracers to evaluate vegetation uptake.

> **Response 4** — KDHE's recommendation for the possible use of tracers in the investigation of groundwater and contaminant movement at the Everest site were discussed by Mr. Chris Carey of the KDHE and members of the Argonne technical staff in a conference call on February 5, 2007. As noted during the conference, the CCC/USDA and Argonne are presently unaware of any naturally occurring dissolved species that might be both (1) unique to *eithe*r the groundwater *or* the local precipitation/surface water at Everest, and (2) utilized by the existing vegetation in a form that can be conclusively detected by analyses of the plant materials, and that hence might serve to trace the uptake of deep-versus-surface waters as suggested by the KDHE. The CCC/USDA and Argonne will investigate the potential use of tracers, as requested by the KDHE, in conjunction with the revised monitoring program. Both naturally occurring and "artificial" alternatives will be investigated. If indicator species and analysis methods suitable for use in this manner can be identified, the CCC/USDA will present recommendations to the KDHE in a separate document for possible tracer use as part of the present monitoring program or in conjunction with a phytoremediation remedy.

Closing Comments — It is important to note that the KDHE will require CCC/USDA to evaluate contingent remedies to be implemented in the event that the phytoremediation remedy fails. KDHE encourages CCC/USDA to collect any data necessary to properly evaluate other remedial technologies during the proposed monitoring period. KDHE conditionally approves the "Recommendations for Remedial Action at Everest, Kansas" upon satisfactory resolution of the comments listed above. Please submit a revised document for our consideration within 30 days of the date of this letter.

> **Response to Closing Comments** — The CCC/USDA acknowledges the KDHE's recommendations and will continue to seek potentially viable remedial options for this site. The CCC/USDA previously suggested several restoration approaches in conjunction with the *Phase III Targeted Investigation* and *Scoping Memo* documents submitted to the KDHE for Everest, however, and has reviewed and discussed these and other possible alternatives with the KDHE. The CCC/USDA has also examined two candidate technologies in greater detail

at the specific request of the KDHE; these are (1) groundwater extraction and (2) air sparging with soil vapor extraction in large-diameter boreholes. The results of these activities have suggested that a majority of the presently available remedial methodologies (with the anticipated exception of the phytoremediation approach now under consideration) appear hydrogeologically ill-suited, or technologically or logistically impractical, for implementation at Everest.

The CCC/USDA is committed to providing revised *Recommendations for Remedial Action at Everest*, as outlined above, within the timeframe requested by the KDHE.