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Sylvan Grove Farmer's Elevator Company

Comprehensive Investigation and Corrective Action Study

Prepared by students in the Fall 2011 and Spring 2012 Natural Resources and Environmental Sciences Capstone Course at Kansas State University

Johnny Bryant, Jacob Chapman, Noortje Crabtree, Matt DeCapo, Hilary Dees, James Ewing, Thomas Grund, Laura Kemp, Albert Maurin, David Meyer, Vishrut Patel, John Sparks, Maggie Stephens, Amy Vu, and Jeanna Walters-Fancella

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Edited by Nathan Nelson

1.0 Historical Evaluation and Site Description

The Farmer Elevator Company site is located at 129 South Main Street, Sylvan Grove, Lincoln County, Kansas 67481 in the west half of Section 13, Range 10 East, Township 12 South and the east half of Section 14, Range 10 East, Township 12 South. The geographic coordinates of the site are 39.00954º North latitude and 98.39398º West longitude. The property is on the southern side of Sylvan Grove and is divided by the Sylvan Grove Main Street (running North-south) into an eastern and western side (Figure 1). The eastern side contains 7 grain silos and a two general storage buildings. The western side contains three storage buildings (one with office space), an overhead rail car capable of storing and dispensing solid materials (like fertilizer), and a concrete dike containing several liquid storage tanks capable of storing and dispensing liquid chemicals (like liquid fertilizers).

In 1888, the railway from Salina to Plainville was completed, with Sylvan Grove being one of the stops along the way. This shipped fuel (coal), building materials, and other merchandise into remote areas of Kansas while exporting livestock and agricultural products out of these areas. It operated until the floods of 1993, when the damage to the track made it not cost effective to rebuild. This track ran along the southern border of the property (Figure 2).

According to historical Sylvan Grove city maps, grain elevators were present on the site prior to 1901. A 1901 map shows three elevators were located on the site; two on the west side of Main Street and one east of Main Street. Wood-constructed elevators burned down in the 1930's and again in 1977. A livestock sale barn was located just north of the elevator property until the 1950's. After that time it was moved farther north. In 1997, the Farmers Elevator Company used the site for grain storage, storage of dry fertilizer, and sale of chemicals and farm supplies. Dry fertilizer sales commenced in 1992 by Boettcher Enterprises. Boettcher Enterprises sold their dry fertilizer facilities to Barnard Grain in 1997. Barnard Grain Company and Miller Grain Company operated the grain storage and fertilizer storage facility from 1997 through approximately 2002. Each company operated the facility for approximately three years before filing for bankruptcy. Prior to 2002 (based on aerial imagery), a battery of liquid chemical storage tanks and a containment dike were installed on the site. After the Miller Grain Company ceased business operations on the site, the land was divided into three tracts; Kirk Meyer owned the former office building, and the Ringlers owned the land and other buildings on the site. The property is now owned solely by Ringler Farms.

Enviro Tech Services, Inc. of Salina, Kansas executed a Phase I Environmental Assessment for the Barnard Grain Company at the Farmers Elevator site in May 1996. The assessment concluded that the Farmers Elevator Company had maintained proper business practices. Enviro Tech Services, Inc. then collected seven soil samples from the site in May of 1997. These samples were tested and analyzed by Continental Analytical Services in Salina, Kansas. Results of the samples showed a maximum detection of nitrate nitrogen at 330 mg/kg. This exceeds the 85 mg/kg maximum in the upper eight inches, as set by the Risk-based Standards for Kansas.

KDHE completed a Site Reconnaissance & Evaluation in May 2008 and suggested the site be more thoroughly investigated for nitrate and pesticide contamination. Results from the 2008 KDHE Site

Evaluation found nitrate contamination in soil samples taken from the west side of the property and high nitrates in groundwater on the east side of the property. In July 2008, KDHE encouraged the current landowners to enroll their properties in the Voluntary Cleanup and Property Redevelopment Program in order to further characterize and possibly remediate the contamination. The Sylvan Grove Historical Society responded and applied to the program on August 24, 2010. Other potentially responsible parties are being researched and evaluated.

2.0 Study Area Investigation

Sylvan Grove is located in the physiogeographic province of the Smoky Hills in Kansas, which is located in the north-central region of the state. Rock outcrops throughout this region are of Cretaceous age. The sedimentary units are characteristic of deep sea environments. Sylvan Grove lies specifically in the Dakota Formation. This formation is made up of varying beds of kaolinitic claystone, mudstone, siltstone, and shale inter-fingered with sandstones. The lenticular beds are commonly cemented by iron oxide and calcite.

Groundwater within the Sylvan Grove site flows to the south-southwest. High nitrates have previously been identified in 27% of groundwater samples of Lincoln County (Berry, 1952) and high nitrates are ubiquitous in groundwater of agricultural areas in Kansas (Townsend and Young, 2000). Over 20% of groundwater samples have nitrate-N concentrations greater than 10 ppm (Townsend et al., 2003). This is due to the widespread use of nitrogen fertilizers, large concentrations of animal manure, and natural N present in soils or geologic sediments. For example, lenses of volcanic ash exist at varying depths (0-135 feet) throughout Lincoln County. The full extent of this ash has not been mapped, but there are areas of sufficient amount of volcanic ash for mining. Volcanic ash has been shown to release nitrates into the groundwater system.

According to the National Cooperative Soil Survey, the soils at the Sylvan Grove contamination site are classified as Hord silt-loam, Geary-Lancaster complex, and Roxbury silt-loam. Roxbury silt-loam is the underlying soil type to the west of the grain elevator and Hord silt-loam is found directly south. These soils are all formed from either calcareous parent material or loess. Typically, these soil types are well-draining, and readily transmit water through the soil profile.

The surface topography of the site is relatively flat. The Saline River is located approximately 2,500 feet south of the site. It is likely that the groundwater is flowing to the south or southwest at the site. Groundwater data from Feldkamp Brothers underground storage tank (UST) site located at Fourth Street and Main, indicates groundwater flowing southwest to south. Possible nitrate contamination in the underlying aquifer, both in the Pleistocene and Gulfian series, may be migrating in the direction of the groundwater flow. The properties of the underlying soils, the geological formations and location on a flood plain, provides an easy migration for nitrate to leach into an underlying aquifer, creating a concern for the extent of nitrate contamination. During KDHE's 2008 SRE of the site, groundwater was encountered at approximately 26 feet below ground surface in temporary boreholes.

3.0 Source Characterization

Ringler's were interviewed on August 25, 2011 with respect to the current operations on the property. They reported that there are not any dry or liquid fertilizers being stored on the site. They provided us with a copy of a report certifying that the liquid chemical storage tanks had been properly cleaned by an environmental consulting firm.

Site visits were conducted on November 10, 2011 and November 18, 2011. Liquid Storage tanks were empty. The rail car (that used to hold fertilizer) was being used to hold cattle feed. Based on visual inspection, there was not any storage of bulk fertilizers on site.

Jerry Boettcher was interviewed on December 1, 2011 with regards to site history. Jerry indicated that Boettcher Enterprises sold dry fertilizer on the property from 1992 to 1996. The primary fertilizer sold was diammonium phosphate (18-46-0), with some sales of monoammonium phosphate (11-52-0). Mr. Boettcher supplied us with fertilizer tonnage reports from July 1997 through December 1999, indicating potential sales of dry fertilizers (diammonium phosphate (18-46-0), monoammonium phosphate (11-52-0), and urea (46-0-0)) and liquid fertilizers (ammonium poly-phosphate (10-34-0) and urea-ammonium nitrate (28-0-0 and 32-0-0)) on the site by Sylvan Grove Agriservices Inc.

There are not currently any potential sources of nitrate contamination on the site. However, the site history shows that there have been several fertilizers stored on site which could have been the source of contamination.

4.0 Nature and Extent Characterization

A total of 36 Soil samples were collected from the site in November 2011 in accordance with the Comprehensive Investigation Plan approved by KDHE on November 7, 2011 (Appendix A). Locations were selected for additional analysis based on results from prior site evaluations. According to KDHE's Site Reconnaissance and Evaluation at the Sylvan Grove site, the soil on the eastern most side of the property contained soil nitrate concentrations well below the RSK values established for the state of Kansas (KDHE, 2008). Furthermore, nitrate concentrations in soils at P3 and P5 of KDHE's 2008 investigation were also below RSK (Figure 3). Therefore, the soil sampling was focused on defining the extent of nitrate contamination around P4 and the surface sample on the West side of the property.

4.1 Site Activities

Soil samples were collected on November 10, 2011 and November 18, 2011 with a Giddings truck-mounted direct-push probe following standard protocols listed in BER-03 and BER-07. All equipment was properly decontaminated, according to guidelines in BER-05. Samples were taken from eight locations on the western portion of the property (Figure 4, Table 1). Samples were collected at four depths from each location: 0-8 inches, 12-24 inches, 48-60 inches, and 96-108 inches. Additional samples below 108 inches were collected if soil properties permitted. Samples were collected by Dr. Nathan Nelson, Kansas State University assisted by Laura Kemp, Jeanna Walters-Fancella, Amy Vu,

Noortje Crabtree, and Arthur Fink (all students at KSU). All samples were placed in glass containers and stored at 4 °C until analysis.

Field screen tests were conducted by adding 30 mL of potassium-chloride solution to a 50-mL graduated centrifuge tube. Soil was added to bring the final volume to 40 mL, and the solution was shaken vigorously by hand for 30 seconds. Soil was allowed to settle to the bottom of the tube and a nitrate test strip was dipped in the supernatant.

An additional 24 soil samples were collected on April 1, 2012. Soil samples were collected with hand probes at 5 locations (Figure 4, Table 2). Two to three soil cores were collected within a 3-ft radius at each location. Each core was divided into 0-8 inch and 12 to 24 inch segments. Segments were placed in zip-loc bags and stored on ice until returning to the lab. Samples were collected by Thomas Grund, Albert Maurin, and Jack Sparks.

4.2 Soil Sample Analysis

Soil samples collected in November, 2011 were analyzed for nitrate and ammonium by the Soil Testing Laboratory of Kansas State University (Table 3). Additionally, four samples collected from probe site 6 were split and sent to both the KSU lab and Continental Analytical Services of Salina, Kansas, for purposes of quality assurance (Table 4). Particle size analysis was performed for two samples from probe sites 5 and 6 by the KSU soil testing laboratory (Table 5). Samples from April 2012 were analyzed for nitrate and ammonium by the Soil Testing Laboratory of Kansas State University (Table 6). Results of soil analysis are summarized in Tables 3 and 6 and complete reports from the respective laboratories are in Appendix B. Results from Continental Analytical Services agree well with results from the KSU lab (Table 4) indicating that the KSU lab results are sufficiently accurate and can be used as a basis for describing the extent of nitrogen contamination and designing remedial alternatives.

4.3 Interpretation of Soil Analysis

Analytical results indicate that NO_3-N+NH_4-N concentrations in soils on the Sylvan Grove site range from low to elevated levels of contamination (Table 3). Sites 2, 3, 7, 8, 9, 10, 11, and 13 had NO_3-N+NH_4-N [1]concentrations below or very near the RSK standards, indicating that there is little to no concern about NO_3-N+NH_4-N contamination in these soils (Table 3, Table 6, Figure 5). Soil with the elevated NO_3-N+NH_4-N concentrations were at probe sites 1, 4, 5, and 6. It should be noted that soil samples with the highest NO_3-N+NH_4-N concentrations (probe sites 4, 5, and 6) are located in the area displaying the most visual surface scarring (Figure 4). Analytical results of probe site 6 indicated nitrate levels of

[1] Ammonia (NH_3) is highly toxic to plants (and animals), however ammonium (NH_4^+) is a beneficial plant-available form of nitrogen and is not toxic to plants or animals. The data in tables 3, 4, and 6 report the amount of ammonium in the samples. Furthermore, the data in tables 3, 4, and 6 are normalized per-unit of N (i.e., mass of N present in the nitrate or ammonium forms). This is not the same as mass of ammonium or mass of nitrate per unit of water or soil because the data do not account for the oxygen or hydrogen in nitrate and ammonium. For example, 14 mg NO3-N/kg soil would be 62 mg of NO3/kg soil. In other words there are only 14 mg N in 62 mg NO3. Also, the final column in tables 3, 4, and 6 is not the total N, it is only the nitrate N and ammonium N. Total N includes organic forms of N, which would be substantial in the soil samples because of organic matter naturally present in the soil (organic N can easily be 2,000 to 10,000 mg/kg in native soils).

approximately 3,990 **mg kg^{-1}** in the upper eight inches of soil (NO_3-N+NH_4-N concentrations in excess of 4700 **mg kg^{-1}**), far greater than the risk-based standard of 85 **mg kg^{-1}** for un-vegetated soils set by the state of Kansas. Although probe sites 4 and 5 had high NO_3-N+NH_4-N concentrations in the sub-soil, the NO_3-N+NH_4-N concentrations in the surface soil were lower than the subsurface. This is likely because nitrate in the surface had already leached to the sub-surface.

NO_3-N+NH_4-N concentrations above the RSK standard were detected to a depth of 132 to 144 inches at probe sites 1 and 5. However, the NO_3-N+NH_4-N concentrations were substantially less at these depths than what was detected between 0 and 108 inches, indicating that 144 inches is near the nitrate leaching front. The majority of the NO_3-N+NH_4-N is above 108 inches (Figure 6).

NO_3-N+NH_4-N concentrations in the soils between probe sites were estimated with a nearest neighbor interpolation procedure using ESRI ArcGIS software. This was done for five soil depths corresponding to the depths of soil sample collection. These estimates are displayed in Figures 7 through 11. As shown in these figures, the majority of the contamination is located in the vicinity south west of the liquid storage tanks (Figures 7 and 8). This contamination is present in a 0.3 to 0.5 acre area (approximately 115 ft by 180 ft). The estimates show some potential contamination under and around the dry fertilizer storage area (extending 50 to 150 feet directly north of probe site 1) (Figures 9 and 10). These high predictions of NO_3-N+NH_4-N in the soil are due to the high measured concentrations at probe site 1 and the large distance between probe sites 1 and 7. This extrapolation is beyond the limits of the computer model.

NO_3-N+NH_4-N concentrations in soil layers 1 through 4 (0 to 120 inches) were used to determine the mass of N in the soil (Figure 12). Based on KDHE RSK values for NO_3-N+NH_4-N, the maximum mass of NO_3-N+NH_4-N in the profile down to 120 inches is 1550 lb N/ac for non-vegetated ground and 2600 lb N/ac for vegetated areas. Estimates in Figure 12 integrate the NO_3-N+NH_4-N contamination in multiple soil layers and defines the areas of highest contamination as the area with NO_3-N+NH_4-N mass above 2600 lb/ac. This area is approximately 0.2 ac of land. The volume of soil in this area would be approximately 3300 yd^3, or a total of 3640 tons, assuming an average soil density of 1.325 g cm^{-3}. Based on the computer interpolation, the average NO_3-N+NH_4-N concentration in the area of highest contamination is 157.6 mg kg^{-1}. Therefore, the area of highest contamination defined in Figure 12 contains a total mass of approximately 1150 lb NO_3-N+NH_4-N.

5.0 Risk Assessment

The primary risk associated with nitrate contamination in soils is nitrate leaching into groundwater followed by human or animal consumption of the groundwater. A secondary environmental risk would be nitrate leaching into groundwater and being transmitted to surface water through baseflow. Both risks start with nitrate leaching from soil to groundwater.

Soil texture will have an impact on the rate of nitrate leaching because affects percolation rates, or the downward movement of free water. Finer textured soils will have slower rates of percolation. The soil series mapped for the contaminated soils are primarily Hord silt-loam soils with hydraulic conductivity of 9 μm s^{-1}, which indicates a moderately high percolation rate. However, on-site investigations show soil

textures of loam and clay-loam (Table 5), with estimated saturated hydraulic conductivities of 1.1 to 1.5 $\mu m\ s^{-1}$, which indicates a moderate percolation rate.

Nitrate leaching is also a function of the amount of excess precipitation, which is dependent on the amount of precipitation and the actual evapotranspiration rates. The long-term average annual precipitation for Lincoln County is 28.7 inches (Kansas Weather Data Library, 2012). Therefore, it would be possible to limit water percolation through increasing evapotranspiration above the precipitation amount. The current vegetation on site is low-quality grass with areas of bare soil and weeds which would not maximize evaporative demand.

Health risks exist if nitrate contaminated groundwater is used as a drinking water source, particularly for infants. Infants exposed to high nitrate concentrations in drinking water are susceptible to methemoglobinemia. Nitrates convert to nitrite in the stomach, which further reacts with the iron present in hemoglobin of red blood cells, producing methemoglobin. Methemoglobinemia occurs when red blood cells contain greater than 1% methemoglobin. Symptoms are proportional to the concentration of methemoglobin and appear as a blue or grayish pigmentation change. This condition is also referred to as "Blue-Baby Syndrome" and can result in death (Denshaw-Burke, 2007). Methemoglobinemia is the primary health concern with high nitrates in groundwater and nitrate limits in drinking water are set to protect against methmoblobinemia.

There are other health risks with excessive nitrate consumption in adults. After ingestion, nitrate is converted to nitrite that reacts with natural and synthetic organic compounds to produce N-Nitroso compounds in the stomach of humans. N-Nitroso compounds can be carcinogenic in humans. The nitrate itself is not cancer causing, but it reacts with other chemicals to form carcinogenic compounds. Prolonged exposure to drinking water contaminated with high levels of nitrate can also lead to enlargement of the thyroid. The thyroid gland contributes to hormonal and endocrine functions. Nitrate levels in drinking water exceeding 11.3 ppm contribute to this swelling of the thyroid gland.

The Kansas Master Groundwater Well Inventory was queried to determine if any wells are located down-gradient of the contaminated soil. There are not any wells down-gradient of the contaminated soil (Figure 13). Based on the well inventory, there is a well for domestic lawn and garden use on the site. The WWC5 well ID is 36133, it is 136 ft deep, and was constructed in 1992 on the east part of the property. However, site visits have not located this well.

6.0 Identification of Corrective Action Alternatives

The goals of potential corrective actions for the contaminated site are as follows:

1. Contain the contaminant in the soil to prevent nitrate from leaching into the groundwater and moving off-site.
2. Provide a cost effective, low maintenance corrective action to increase the ease of adaption.

We recommend evaluation of the four following options for corrective action on the site:

1. No Action

2. Traditional soil excavation followed by land-filling contaminated soil
3. Use of phytoremediation to contain and remediate contaminated soil and groundwater
4. Combination of excavation (to remove the most highly contaminated soil) and phytoremediation (to contain and remediate the nitrate remaining in the soil).

7.0 CI Report

See previously presented information in section 4.

8.0 Evaluation of Corrective Actions

This section provides a description of a "no action" alternative and three corrective action alternatives to address nitrate contamination at the site. Each alternative was evaluated based on the following criteria as required by KDHE (BER-RS-20, 2005) for a corrective action study:

1. Overall protection of human health and environment
2. Compliance with Federal and State applicable, or relevant and appropriate requirements (ARARs)
3. Short and long-term effectiveness
4. Reduction of toxicity, mobility and volume of contamination through treatment
5. Implementability
6. Cost
7. Community acceptance

8.1 Alternative 1: No Action

There will be no action taken on the site. This approach relies upon natural processes to alleviate or dilute the nitrate contamination. The main concern associated with no further action is that these natural processes take a great period of time to remove the nitrate contamination from the site, during which time nitrate could be lost to the groundwater.

If no action is taken at the site, further groundwater contamination may occur due to process of leaching. Nitrate has been shown to leach at a rate of 3-8% per precipitation event (Southwick et al., 1994). While the groundwater resource down-gradient from the site is not currently being used as a water source for municipal or private wells, there is a potential for increased health risks if the groundwater resource is utilized in the future.

8.1.1 Overall Protection of Health and Environment

This alternative provides relies on natural attenuation for protection of groundwater resources. Given the site characteristics, nitrate leaching will continue. Groundwater contamination is not an immediate threat to human health as there are not any known wells down-gradient of the site. However, this alternative may lead to limitations on the future use of groundwater due to nitrate contamination. Water supply is an important matter in western and central Kansas and any loss of groundwater resources will have negative impacts on the surrounding areas.

8.1.2 Compliance

In 1974, Congress established the Safe Drinking Water Act requiring the level of contaminants to be at a level where no-adverse health effects are likely to occur. The EPA set an enforceable maximum contaminant level (MCL) for nitrate-N at 10 mg/L or 10 ppm. This standard has not only been accepted for drinking water sources, but also for well water. The state of The State of Kansas and local authorities employ the same standards established by the EPA. Standards for the maximum concentration in soils have been set by the KDHE Bureau of Environmental Remediation to protect groundwater from excess

from nitrate leaching (see below). Soils would not be in compliance with the regulations if this option were selected.

- Vegetation Present
  - 200 mg/kg (NO_3-N+NH_4-N) maximum in 0-24" of soil
  - 40 mg/kg (NO_3-N+NH_4-N) maximum in soil below 24"
- No Vegetation Present
  - 85 mg/kg (NO_3-N+NH_4-N) maximum in 0-8" of soil
  - 40 mg/kg (NO_3-N+NH_4-N) maximum in soil below 8"

8.1.3 Effectiveness

Of the 4 alternatives discussed, this is the least effective as soil and groundwater nitrate will not be removed or contained. Given the high nitrate concentrations, specifically near probe site 6 (Table 3) natural processes would not be able to alleviate the contamination in the short-term.

8.1.4 Reduction of Toxicity, Mobility, or Volume

There will be no reduction of toxicity, mobility, or volume with this alternative.

8.1.5 Implementability

This approach is simple to implement since no additional labor or inputs are required.

8.1.6 Cost

Immediate costs are low ($0.00). Because there are no efforts to contain, there is a risk of contaminant transport to adjacent properties, which could result in future unknown costs associated with civil pollution, fines and landowner claims.

However, leaving impacted soil in place above the total nitrate guideline of 40 mg/kg at depth requires an Environmental Use Control (EUC) be placed on the property. EUC costs typically range from $2,000-$10,000, depending on size, contaminant, complexity; although exact cost is not determined until after application. Because this is a small site with minimal complexity, we estimate the cost of an EUC at $2000. Furthermore, this option may require long-term monitoring of groundwater nitrate concentrations. This is estimated at a cost of $4,000 (40 samples at $100 each), over the next 20 years. Therefore, long-term costs would be approximately $6,000. Because this site is being addressed under a cooperative agreement between Kansas State and the Kansas Department of Health and Environment and many of the costs have been paid through donated services, the actual cost is difficult to estimate.

8.1.7 Community Acceptance

This option may have moderate community acceptance because there is not any threat to the community water supply and the ground water in the area may have high nitrates from other sources of contamination (see groundwater report). The primary objections may come from the dozen or so

individuals who own land down-gradient of the contaminated soils because this option may result in excess nitrate in groundwater and limit the use of groundwater.

8.2 Alternative 2 - Soil Excavation

The second alternative is complete excavation of contaminated soil. Excavation at this site would consist of the removal of soil with the highest nitrate concentrations. Based on GIS analysis soil would need to be removed from an area approximately 73 by 63 feet directly above the area of highest concentration (Figure 14). The soil would be excavated to 78 inches (6.5 ft) deep, which would remove nearly all soil with nitrate concentrations above 200 ppm. Some areas with NO_3-N+NH_4-N higher than 200 ppm would remain on-site due to the under-ground utilities running through the zone of contaminated soil. This plan would require excavation and removal of approximately 1100 cubic yards of soil (95 to 110 dump-truck loads). The excavation would remove approximately 740 lb of NO_3-N+NH_4-N with the soil, for an average NO_3-N+NH_4-N concentration in excavated soil of 300 ppm. Because a large area of the proposed excavation is composed of fill dirt on top of the abandon rail road, the soil would not likely be suitable for land application. Therefore, the soil would be taken to a landfill for disposal.

8.2.1 Overall Protection of Health and Environment

If current groundwater and site use conditions remain the same, the removal of the most contaminated soil would substantially reduce the amount of nitrate that could leach into the groundwater. This plan would remove approximately 34% of the contaminated soil volume (based on soil with profile NO_3-N+NH_4-N exceeding 2600 lb N/ac) but would remove 65% of the N mass. This plan will greatly reduce the mass of nitrate that could leach into the groundwater. However, it would not address the nitrate already in the groundwater. Over time, the groundwater nitrate concentrations would decrease due to dilution with low nitrate percolate water from the site.

8.2.2 Compliance

The proposed area of excavation would clear some of the most highly contaminated areas (NO_3-N+NH_4-N > 200 mg kg^{-1}). However concerns with utilities and soil composition, make complete compliance of KDHE regulations by pure excavation very difficult.

8.2.3 Effectiveness

The excavation of the highly contaminated areas would prove effective in the short and long term but due to physical restrictions of the site, not all soils above RSK levels could be removed, reducing the overall effectiveness of excavation as the sole method of remediation.

8.2.4 Reduction or Toxicity, Mobility, or Volume

The volume of soil removed is 1100 cubic yards resulting in an overall reduction in contaminant mass by 65%.

8.2.5 Implementation

The excavation of the soil at this site may prove to be a difficult task. There are utilities running through the site creating an obstruction for excavation attempts. The utilities include an underground gas line which poses a hazard to workers and the community if complete excavation were attempted. Furthermore, there was a railroad that used to run through the site, leftover debris or railroad materials reduces the options for disposal or beneficial use of the excavated materials.

8.2.6 Cost

Excavation work for residential areas, as estimated by costowl.com, can cost anywhere from $80 to $125 an hour; or between $80 to $200 per cubic yard (including off-site transport). Using a conservative cost estimate of $80 per cubic yard, the estimated cost of the proposed excavation would be $88,000.

In addition to soil removal costs, the landowners would need to obtain an EUC and conduct long-term monitoring because soil excavation would not remove all of the contaminant. The EUC would be approximately $2000 and long-term monitoring would be $4000 (as explained in section 8.1.6). Therefore, total costs for this option would be $96,000.

8.2.7 Community Acceptance

The community would be impacted short term from the work being done during excavation. Equipment may block or slow traffic on South Main Street or Elevator Street during excavation and transportation of soil. Another impact may be loss of utility service in the event that a utility line is struck. Excavation equipment also has the potential to create a noise disturbance in the community. In short-term, the community acceptance may be low due to these impacts, but long-term acceptance would be good due to removal of the contaminated soil.

8.3 Alternative 3 - Phytoremediation

This proposal is to contain and sequester nitrate in soil and groundwater using phytoremediation. Phytohydraulics will be used to increase evapotranspiration on site, thereby reducing leaching and reducing off-site movement of groundwater. Phytosequestration will be used to uptake nitrate and convert it into more stable organic N compounds. These objectives will be accomplished by establishing deep-rooted native grasses in the areas of greatest contamination, approximately 0.4 acres (Figure 15). We recommend using the standard tall-grass mix used for the conservation reserve program in that county, which consists of the species listed in Table 7. The grasses will reduce the groundwater recharge from the contaminated area by increasing evapotranspiration. They are warm season grasses, so they will be actively growing during the summer months when there is the greatest rainfall in the region (Figure 16).

Big Bluestem is great because of its extremely long roots. Research has shown that roots may reach depths of 2 to 4 feet by the end of establishment year. The roots of well-established plants can reach depths of 7 to 8 feet and can be long lived. One test indicated 81% of big bluestem roots lived for three years (Weaver 1968). Big Bluestem also has strong, tough, dense rhizomes, a grass's innate large leaf

area index relative to plant size, drought hardiness, and overall plant vigor perfect for this site's current soil and climatic settings. Big Bluestem has also been found to be very shade tolerant compared to other warm-season grasses, so it maintain growth around the trees as well (Weaver 1968). Indian Grass is another native prairie grass that is useful for the same reasons as big bluestem. It is however more intolerant to shade, but this is not an issue because the location of the contaminant is focused on the south side of the facilities. Eastern gamagrass is especially responsive to high N environments and has higher biomass N concentrations than the other grasses (NRCS, 2006). Although seed is more expensive and the establishment time is longer, this species could assist in N uptake and may grow better in the high N conditions found on site.

The grasses will also remove some nitrogen. Nitrogen content of Big bluestem, Indian grass, and Switchgrass range from 0.5 to 0.8% while N content of Eastern gamagrass can be 1.3% N. We expect production to be between 2 and 3 ton/ac/yr (or 1.2 to 2 ton/yr from the site). This would extract 50 to 80 lb N/ac/yr from the soil in plant biomass. Once in the biomass, the nitrate is converted to organic forms of N present in amino acids, proteins, and other organic compounds. These organic forms of N are more stable than nitrate. If the biomass is left on site, the organic forms of N would be incorporated into soil organic matter and become part of the natural N cycle. Some N would mineralize and cycle back to nitrate. Removal of the biomass would remove N off site, but because the overall amount of N is relatively low compared to the quantity in the soil, we do not view harvest and removal of the biomass as a critical component.

The second component of the phytoremediation plan is to establish a linear planting of 20 cottonwoods down-gradient of the site, which will later be thinned to the best spaced and strongest 12 trees. Cottonwood trees have been selected to extract water from both the soil profile and from below groundwater. Eastern Cottonwoods have an exceptional growth rate and absorb between 100 to 200 gallons of water per day (Tsao, 2003), with reports of up to 350 gallons of water per day (Schnoor, 1997). Cottonwood's average root depth is 10 feet, but can reach over 30 feet deep in search of water, which is beyond the depth of the water table in this site. The Cottonwoods will be planted 15 feet apart from each other in a 300 ft line on the city-owned property immediately south of the site. At maturity, the trees will occupy about 0.35 ac (assuming a 50 ft diameter canopy). With 12 cottonwood trees over a 0.35 ac area, the trees would remove 7.8 inches of water per month during the growing period. This evaporative demand far exceeds the average monthly summer rainfall (Figure 16) and will pull water from below the water table thereby reducing off-site transport of nitrate that is in or may leach into the groundwater.

Cottonwood trees will also remove nitrate in the water. It is estimated that cottonwood trees take up 115 lb N/ac/yr (Fortier et al, 2010). About 40% of the N is in the leaves, with 60% in branches and stems. Although the leaves will not be removed from the site, the N will be sequestered in a form that has reduced mobility.

8.3.1 Overall Protection

The primary method of overall protection is to reduce nitrate leaching by containing the contamination with phytoremediation. Nitrate concentrations would reduce over time through plant uptake and other natural processes of immobilization and denitrification.

8.3.2 Compliance

Planting vegetation increases the allowable NO_3-N+NH_4-N levels because RSK limits are 200 ppm for vegetated areas (down to 24 inches). This method should decrease leaching and thereby decrease the nitrate concentration in the groundwater. Because phytoremediation is a long-term process, it will take many years for the soil nitrate levels to decrease to acceptable levels. Therefore, complete compliance would be many years in the future.

8.3.3 Effectiveness

Short-term effectiveness of phytoremediation is low because it takes time to establish vegetation. Fast growing native selections for the cottonwood trees will be selected to decrease the establishment time. The fast growing selections with have growth rates of 8 ft. per year and will be resistant to diseases and insects. The native grasses will take two to three years to reach full establishment. After three years, the effectiveness of the phytoremediation will increase greatly.

Establishment of vegetation is weather dependent. Tree and grass establishment will be slower if there are droughts during the establishment period. Once established, the species selected are very drought tolerant, so drought will not affect the effectiveness.

Phytoremediation is most effective for typical weather conditions. The establishment of native grass species will increase both infiltration and evapotranspiration. If there are periods of very intense rainfall, the evapotranspiration may not keep up with the rate of precipitation. Therefore, the increased infiltration could result in isolated periods of enhanced leaching. Based on weather records this area of the state does not often receive very heavy rains, therefore, the risk of excess precipitation is relatively low.

The cottonwood roots will need to intercept the water table for full effectiveness. With heavier textured soils, the roots will take longer to reach the water table and may not reach the water table at all. If cottonwood roots do not reach the water table, the trees would have reduced growth rates, would appear drought stressed, and would lose their leaves during the summer. Therefore, tree growth would need to be monitored to be assured that the trees will properly function.

Based on estimated annual N uptake from the trees (115 lb/ac) and the native grasses (65 lb/ac), the excess NO_3-N+NH_4-N on the site (1150 lbs) will be taken up by plants over a 17 year period following establishment (66 lb NO_3-N+NH_4-N removed/yr). Given a 3-yr establishment period, it will be 20 years before the site is fully remediated.

8.3.4 Reduction of toxicity, mobility and volume of contamination

The phytoremediation option will primarily reduce the mobility of the contaminant by controlling site hydrology. Over the long-term (20 years), it will also reduce toxicity (or biological reactivity) of the contaminant by converting the nitrate into organic N forms and sequestering it in plant biomass and soil organic matter.

8.3.5 Implementability

Implementability is high. Native species have been selected to facilitate establishment of vegetation. The vegetation can be established on the entire site, regardless of the underground utilities. Tree growth may interfere with Over-head utilities, therefore, trees within the utility easement will have to be pruned.

The soil structure could be a slight problem to plant growth because this area had the railroad going right through it and the soil has lots of "fill", making it a combination of clay, gravel, sand, and silt, according to the well data from the Geology team.

The high nitrate concentration in the surface soil (around the scar) could inhibit plant growth. It is not known how native species such as Indiangrass and Big Bluestem will respond to these high N concentrations. We expect that eastern gamagrass will grow better because it is adapted to high N environments.

Site maintenance during the establishment period will include mowing weeds in the native grasses and watering trees when needed. Following establishment, site maintenance will decrease until trees grow tall enough to interfere with overhead utilities, at which time tree pruning (once every 3 to 5 years) will be necessary.

8.3.6 Cost

Inexpensive to establish, however plants must be maintained during the establishment period. Costs of plant material along with maintenance and monitoring are below. Seed costs are from Prairie Moon Nursery (http://www.prairiemoon.com).

- 20 cottonwood trees@ $2.50 each ($50)
- 5 lb of eastern gamagrass seed @ $20/lb ($100)
- 3 lb of big bluestem seed @ $12/1 lb. ($36)
- 3 lb of little bluestem seed @ $20/lb ($60)
- 2 lb of indian grass seed @ $14/1 lb. ($28)
- 1 lb of switchgrass seed @ $15/lb ($15)
- Estimate of 100 hours of total labor for installation and maintenance at $20/hour = $2,000
- Monitoring the nitrate in the water: $100 / sample * 40 samples over time = $4,000
- Total cost is approximately $6,300

8.3.7 Community Acceptance

The tree and grass option should be very acceptable to the community because it will cover the existing, bare, and minimally vegetated lot with green plant life. It will reduce the risk associated with high nitrates in the soil through containment and retarding groundwater movement. Also, it will require minimal maintenance after being established and should be aesthetically pleasing.

8.4 Alternative 4: Mixed Excavation and Phytoremediation

This alternative combines excavation of the most contaminated soil and the phytoremediation actions covered in section 8.3. Probe site 6 represents the soil from the visually scared area and contains the highest NO_3-N+NH_4-N concentration detected. Furthermore, the highest concentrations of NO_3-N+NH_4-N are in the upper 8 - 12 inches of the soil at Probe site 6 (Figure 6). Based on this data, we presume that the soil with the greatest levels of contamination are in the upper 12 inches of the visually scarred area. Therefore we are proposing to excavate the top 12 inches of soil from the visually scarred area as shown in Figure 17. This proposed area of excavation includes soil above or near the probe sites with the highest levels of nitrate (1, 4, 5, and 6).

The area for proposed excavation is approximately 0.1 acre (Figure 17). The soil would be excavated to a depth of 12 inches bgs, for a total of 170 cubic yards of soil, or about 14 to 17 dump truck loads. Based on the amount of NO_3-N+NH_4-N in the upper 12 inches of soil from the interpolated data (Figure 18), the excavated soil would contain approximately 250 lb of NO_3-N+NH_4-N with an average NO_3-N+NH_4-N concentration of 680 mg kg^{-1}. As discussed in Section 4.3, complete excavation would require removal of 3300 yd^3 of soil and remove approximately 1150 lb of NO_3-N+NH_4-N. Therefore, the proposed excavation would remove only 5% of the total soil volume but would remove 22% of the excess NO_3-N+NH_4-N on the site. The NO_3-N+NH_4-N remaining on the site will be remediated through phytoremediation.

Following excavation, phytoremediation would be used to contain and remediate the remaining soil. The phytoremediation design would be exactly as described in section 8.3, native grasses would be planted over an area about 0.4 acres in size and 20 cottonwood trees would be planted down gradient of the contaminated soil. Refer to section 8.3 for details of the design.

8.4.1 Overall Protection

The excavation will immediately remove 25% of the contaminant, while only displacing about 5% of the contaminated soil volume. The contaminated soil that will remain has a substantially lower N concentration. This plan also establishes vegetation on the site which will reduce the mobility of the NO_3-N+NH_4-N that remains in the soil through N uptake and evapotranspiration. Nitrogen remaining in the soil would be reduced over time through plant uptake. Nitrates that may reach the ground water will be absorbed by tree roots, which further limits the potential for off-site migration of the contaminant.

8.4.2 Compliance

The proposed excavation will not remove all soil above the RSK levels as set by KDHE, but given the location of utilities and other obstacles, this alternative will remove much of the highly-contaminated soil and provides immediate site improvement with minimal costs. The plants will remove nitrate from the soil over time. During the period of phyto-extraction, the plants will also remove water through evapotranspiration, which will reduce the leaching potential on the site.

8.4.3 Effectiveness

The short-term effectiveness of the mixed-treatment option is improved compared to phytoremediation alone because 22% of the contaminant is immediately removed off site. This also reduces the amount of N that must be extracted by the plants and reduces the possibility for the high N concentrations to interfere with the establishment of grasses.

Long-term effectiveness is still dependent on the establishment of trees and grasses. Establishment of vegetation is weather dependent. Tree and grass establishment will be slower if there are droughts during the establishment period. Once established, the species selected are very drought tolerant, so drought will not affect the effectiveness.

As previously discussed in Section 8.3.3, phytoremediation is most effective for typical weather conditions. The establishment of native grass species will increase both infiltration and evapotranspiration. If there are periods of very intense rainfall, the evapotranspiration may not keep up with the rate of precipitation. Therefore, the increased infiltration could result in isolated periods of enhanced leaching. Based on weather records this area of the state does not often receive very heavy rains, therefore, the risk of excess precipitation is relatively low.

The cottonwood roots will need to intercept the water table for full effectiveness. With heavier textured soils, the roots will take longer to reach the water table and may not reach the water table at all. If cottonwood roots do not reach the water table, the trees would have reduced growth rates, would appear drought stressed, and would lose their leaves during the summer. Therefore, tree growth would need to be monitored to be assured that the trees will properly function.

Based on estimated annual N uptake from the trees (115 lb/ac) and the native grasses (65 lb/ac), the excess soil N remaining on the site following excavation (875 lbs) will be taken up by plants over a 13 year period following establishment (66 lb N removed/yr). Given a 3-yr establishment period, it will be 16 years before the site is fully remediated.

8.4.4 Reduction of Toxicity, Mobility, or Volume

This alternative will immediately reduce the volume of contamination, with 170 cubic yards of contaminated soil being removed. The mobility of the contaminant will also be reduced by native grass plantings and cottonwood trees planted down-gradient of the contaminated soil.

8.4.5 Implementability

Implementability is high. Soil excavation is limited to the surface 12 inches, therefore, there will not be any risk of hitting buried utilities. Furthermore, native species have been selected to facilitate establishment of vegetation. The vegetation can be established on the entire site, regardless of the underground utilities. Tree growth may interfere with Over-head utilities, therefore, trees within the utility easement will have to be pruned.

The soil structure could be a slight problem to plant growth because this area had the railroad going right through it and the soil has lots of "fill", making it a combination of clay, gravel, sand, and silt, according to the well data from the Geology team.

The high nitrate concentration in the surface soil (around the scar) could inhibit plant growth. It is not known how native species such as Indiangrass and Big Bluestem will respond to these high N concentrations. We expect that eastern gamagrass will grow better because it is adapted to high N environments.

Site maintenance during the establishment period will include mowing weeds in the native grasses and watering trees when needed. Following establishment, site maintenance will decrease until trees grow tall enough to interfere with overhead utilities, at which time tree pruning (once every 3 to 5 years) will be necessary.

8.4.6 Cost

Based on cost estimates previously cited for excavation ($80/ cubic yard, section 8.2.6), the excavation portion of the project will cost $13,600 to excavate and backfill 170 cubic yards of soil. This cost may be reduced if local equipment, material, and labor are used.

Costs for the phytoremediation portion of this option are identical to those listed in section 8.3.6, which total $6,300. This brings the total cost to $19,900.

The cost is higher than the No Action and Phytoremediation option, but it has the advantage of taking care of immediately addressing the most highly contaminated soil and thereby also decreasing the total time required for site remediation.

8.4.7 Community Acceptance

The community would be impacted short term from the work being done during excavation. Equipment may block or slow traffic on South Main Street or Elevator Street during excavation and transportation of soil. Because the soil volume is not that large, this would only occur for a short time. The addition of native grass and trees to the site will improve the visual appeal, which will also increase community support of this option.

9.0 Recommendation for Corrective Action

We recommended implementation of the Mixed excavation/phytoremediation option be implemented as an interim corrective action. This plan presents the high short-term effectiveness through excavation

of the area of highest concentration. The long-term effectiveness is also substantial as the established vegetation will continue to reduce the contaminant mobility and concentration over time. Using the phytoremediation and excavation actions will adequately address all of the corrective action goals in an environmentally friendly manner. The implementation as an interim action allows the action to be implemented in a timely manner to take advantage of the appropriate planting season.

1. Contain the contaminant plume to prevent nitrate from moving off-site.

The recommended option will remove the most contaminated soil and landfill it due to the unpredictable and undesirable materials in the soil if a farmer were to try to land apply it. The use of the phytoremediation will reduce contaminant mobility and concentration through evapotranspiration and plant uptake.

2. Reduce risk of groundwater contamination.

The risk of groundwater contamination will be reduced dramatically because there will be much less nitrate to leach down to groundwater (due to excavation). Also, the plants will control the hydrology of any remaining nitrate and prevent it from leaving the site once the plants get established. Therefore this option benefits from both short- and long-term treatment mechanisms.

3. Recommend low-maintenance alternatives for ease of adaption.

The use of native grass and tree species reduces the need for maintenance (irrigation, re-planting, pest protection, etc.) because these species are already adapted to our climate.

4. Provide a cost effective, community approved operation of removal.

The total cost will be $19,900. The cost can be reduced by using local equipment and labor rather than contracting out the work. We believe that the community will approve of the aesthetically appealing new look of the area after 2-3 years when the grass is established and the trees are getting established.

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Table 1. Geographic coordinates for the soil samples collected on November 10, 2011 and November 18, 2011.

Soil Probe ID	Latitude	Longitude
SP1	39.0094000	-98.3938167
SP2	39.0093333	-98.3936833
SP3	39.0092667	-98.3936167
SP4	39.0092500	-98.3938000
SP5	39.0092500	-98.3940667
SP6	39.0093000	-98.3937833
SP7	39.0098000	-98.3938333
SP8	39.0093667	-98.3934167

Table 2. Geographic coordinates for the points around which soil samples were collected on April 1, 2012.

Location ID	Latitude	Longitude
SP9	39.009116	-98.393383
SP10	39.009083	-98.393700
SP11	39.009083	-98.394100
SP12	39.009300	-98.393983
SP13	39.009400	-98.394330

Table 3. Nitrate and ammonium concentrations reported by the KSU laboratories for soil samples[1] collected on November 10, 2011 and November 18, 2011.

Sample ID	Probe Site	Depth(inches)	NH_4-N (mg kg^{-1})	NO_3-N (mg kg^{-1})	NO_3-N + NH_4-N (mg kg^{-1})†
1-N1-K	Site 1	0-8	43.1	43.4	*86.5*
1-N2-K		12-24	6.5	7.9	14.5
1-N3-K		48-60	4.9	151.8	***156.7***
1-N4-K		96-108	6.3	137.5	***143.8***
1-N5-K		144-150	5.5	43.0	***48.5***
2-N1-K	Site 2	0-8	14.5	11.0	25.5
2-N2-K		12-24	5.9	20.9	26.7
2-N3-K		48-60	4.1	55.6	***59.6***
2-N4-K		96-108	2.4	15.2	17.6
2-N5-K		120-156	2.8	33.9	36.7
3-N1-K	Site 3	0-8	8.1	7.2	15.4
3-N2-K		12-24	2.6	2.8	5.5
3-N3-K		48-60	2.5	9.0	11.5
3-N4-K		104-114	2.2	1.8	4.0
4-N1-K	Site 4	0-8	18.4	25.8	44.1
4-N2-K		12-24	5.0	524.4	***529.4***
4-N3-K		72-81	2.6	78.3	***80.9***
4-N4-K		96-108	1.8	36.6	38.3
4-N5-K		132-144	1.9	16.4	18.4
5-N1-K	Site 5	0-8	6.8	45.1	51.9
5-N2-K		12-24	3.5	354.0	***357.4***
5-N3-K		48-60	3.3	145.6	***148.9***
5-N4-K		96-108	1.8	49.1	***51.0***
5-N5-K		132-144	2.0	83.0	***85.0***
6-N1-K	Site 6	0-8	713.2	3991.9	***4705.1***
6-N2-K		12-24	149.6	1233.4	***1382.9***
6-N3-K		48-60	3.4	506.0	***509.4***
6-N4-K		84-96	4.4	137.6	***142.0***
7-N1-K	Site 7	0-8	6.2	2.9	9.1
7-N2-K		12-24	6.0	2.5	8.4
7-N3-K		48-60	3.9	34.1	38.0
7-N4-K		96-108	8.0	14.5	22.5
8-N1-K	Site 8	0-8	9.3	13.1	22.4
8-N2-K		12-24	2.0	2.9	5.0
8-N3-K		48-60	3.1	1.7	4.7
8-N4-K		96-108	2.2	1.3	3.5

† Values exceeding the RSK standards for NO_3-N + NH_4-N in unvegetated soil are italicized (>85 mg kg^{-1} at 0-8 inches and >40 mg kg^{-1} at depths greater than 8 inches) and values exceeding RSK standards for NO_3-N + NH_4-N in vegetated soil are in bold type (>200 mg kg^{-1} at 0-24 inches and >40 mg kg^{-1} at depths greater than 24 inches).

Table 4. Nitrate and ammonium concentrations reported by the Continental Analytical Services[1] laboratories for split soil samples collected on November 10, 2011 and November 18, 2011.

Sample ID	Probe Site	Depth(inches)	NH_4-N (mg kg^{-1})	NO_3-N (mg kg^{-1})	NO_3-N + NH_4-N (mg kg^{-1})†
6-N1-C	Site 6	0-8	900	3900	***4800***
6-N2-C		12-24	195	1180	***1375***
6-N3-C		48-60	12	430	***442***
6-N4-C		84-96	11	136	***147***

Table 5. Particle size analysis reported by the Kansas State University laboratory for soil samples collected on November 10, 2011 and November 18, 2011.

Sample ID	Probe Site	Depth (inches)	% Sand	% Silt	% Clay	Textural Class	Ks (mm/s)†
5-T1-K	Site 5	12-24	26	48	26	Loam	1.5
5-T2-K	Site 5	48-60	44	36	20	Loam	1.1
6-T1-K	Site 6	12-24	26	46	28	Clay loam	1.4
6-T2-K	Site 6	48-60	22	44	34	Clay loam	1.4

† Estimated saturated hydraulic conductivity based on texture using the USDA-ARS Rosetta Model.

Table 6. Nitrate and ammonium analysis for soil samples collected on April 1, 2012.[1]

Sample ID	Location ID	Replicate	Depth(inches)	NH_4-N (mg kg^{-1})	NO_3-N (mg kg^{-1})	NO_3-N + NH_4-N (mg kg^{-1})†
S9A-1	SP9	A	0-8"	7.3	5.8	13.1
S9A-2	SP9	A	12-24"	5.6	7.4	13.0
S9B-1	SP9	B	0-8"	4.9	5.0	9.9
S9B-2	SP9	B	12-24"	4.2	4.6	8.8
S9C-1	SP9	C	0-8"	5.2	2.7	8.0
S9C-2	SP9	C	12-24"	5.1	2.1	7.2
S10A-1	SP10	A	0-8"	6.8	2.6	9.4
S10A-2	SP10	A	12-24"	2.6	0.9	3.5
S10B-1	SP10	B	0-8"	5.1	1.9	7.0
S10B-2	SP10	B	12-24"	4.2	0.9	5.0
S10C-1	SP10	C	0-8"	7.8	1.1	8.8
S10C-2	SP10	C	12-24"	5.3	0.6	6.0
S11A-1‡	SP11	A	0-8"	7.3	5.0	12.3
S11B-1	SP11	B	0-8"	6.9	3.3	10.2
S11B-2	SP11	B	12-24"	5.7	1.4	7.1
S11C-1	SP11	C	0-8"	5.5	3.2	8.7
S11C-2	SP11	C	12-24"	5.0	0.9	5.9
S12A-1	SP12	A	0-8"	8.2	11.7	19.9
S12A-2	SP12	A	12-24"	7.1	48.3	*55.4*
S12B-1‡	SP12	B	0-8"	10.3	261.4	***271.7***
S13A-1	SP13	A	0-8"	7.2	5.6	12.7
S13A-2	SP13	A	12-24"	4.3	1.6	6.0
S13B-1	SP13	B	0-8"	6.4	8.6	15.0
S13B-2	SP13	B	12-24"	4.5	2.6	7.1

† Values exceeding the RSK standards for NO_3-N + NH_4-N in unvegetated soil are italicized (>85 mg kg^{-1} at 0-8 inches and >40 mg kg^{-1} at depths greater than 8 inches) and values exceeding RSK standards for NO_3-N + NH_4-N in vegetated soil are in bold type (>200 mg kg^{-1} at 0-24 inches and >40 mg kg^{-1} at depths greater than 24 inches).

‡ soil properties prohibited the collection of12-24 inch sample

Table 7. Recommended grass species and seeding rates for phytoremediation.

Common Name	Scientific Name	Planting Date	Seeding Rate (PLS/ac)	Years to establish-ment
eastern gamagrass	Tripsacum dactyloides (L.) L.	Mar. 2013	5.0	2 to 3
big bluestem	Andropogon gerardii Vitman	Feb. 2014	1.5	1 to 2
little bluestem	Schizachyrium scoparium (Michx.) Nash	Feb. 2014	0.3	1 to 2
Indiangrass	Sorghastrum nutans (L.) Nash	Feb. 2014	0.8	1 to 2
switchgrass	Panicum virgatum L.	Feb. 2014	0.2	1 to 2

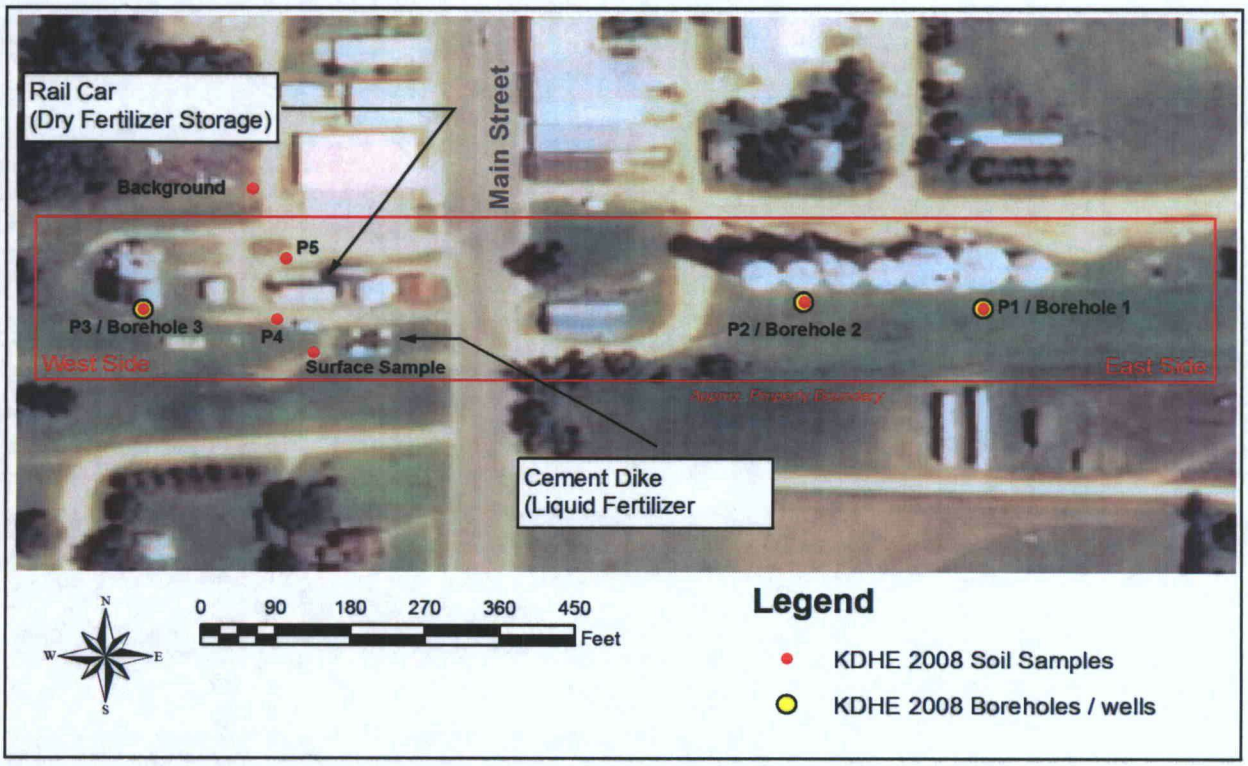


Figure 1. Map of Farmer's Elevator property including 2008 soil sample and borehole locations.

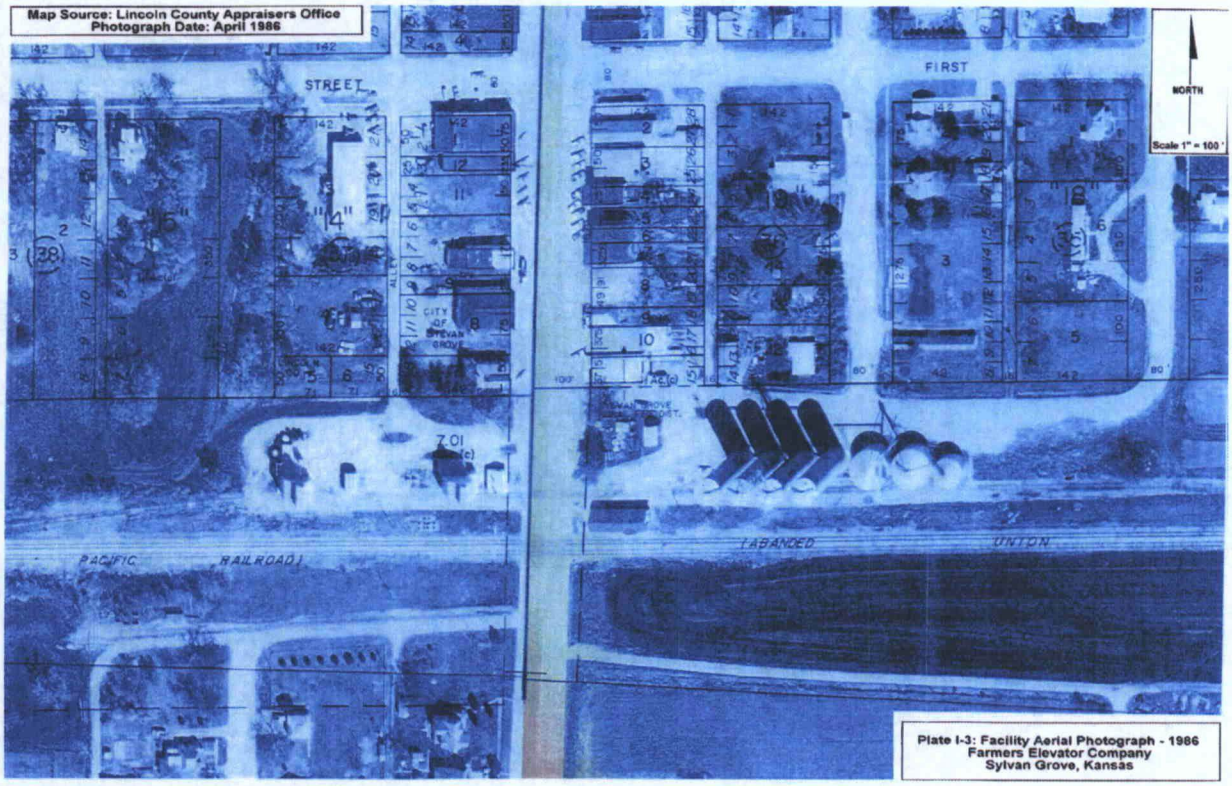


Figure 2. 1983 aerial photograph showing the abandoned railroad along the southern edge of the property (Source: Phase 1 Site Assessment).

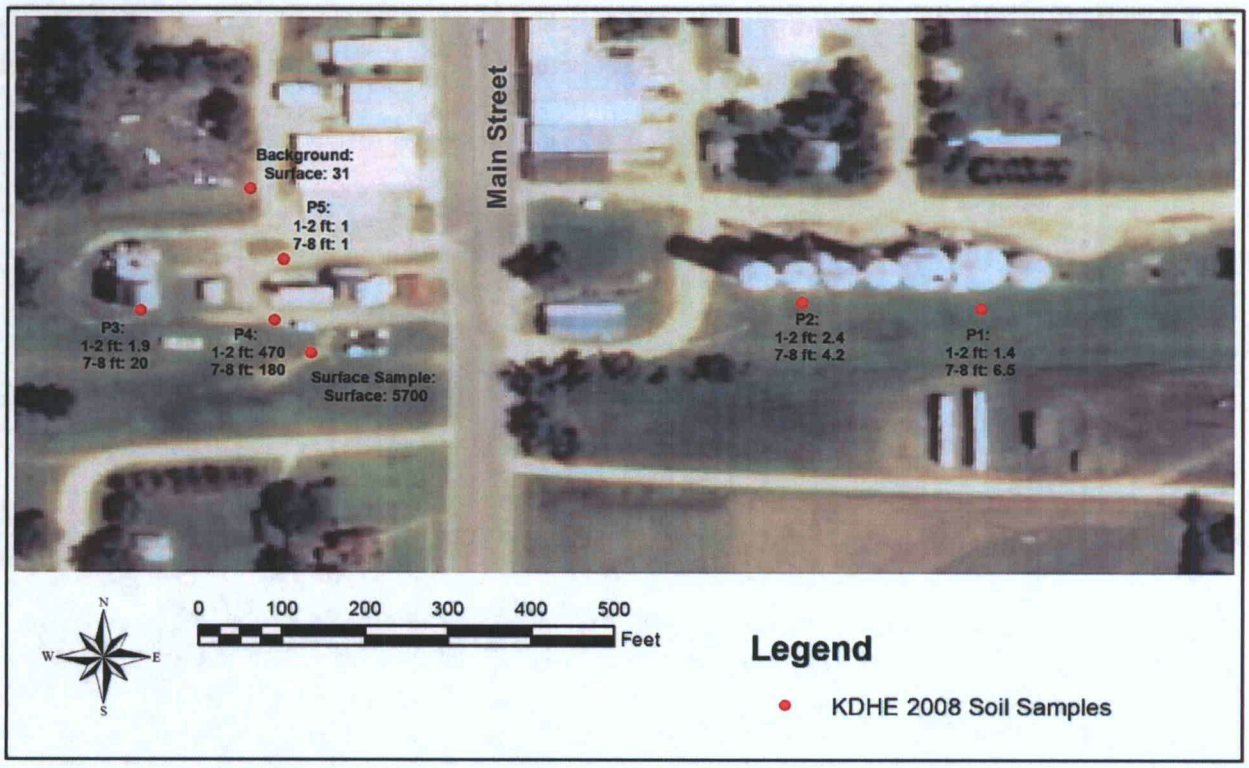


Figure 3. Soil nitrate concentrations (ppm) from the 2008 KDHE site investigation.

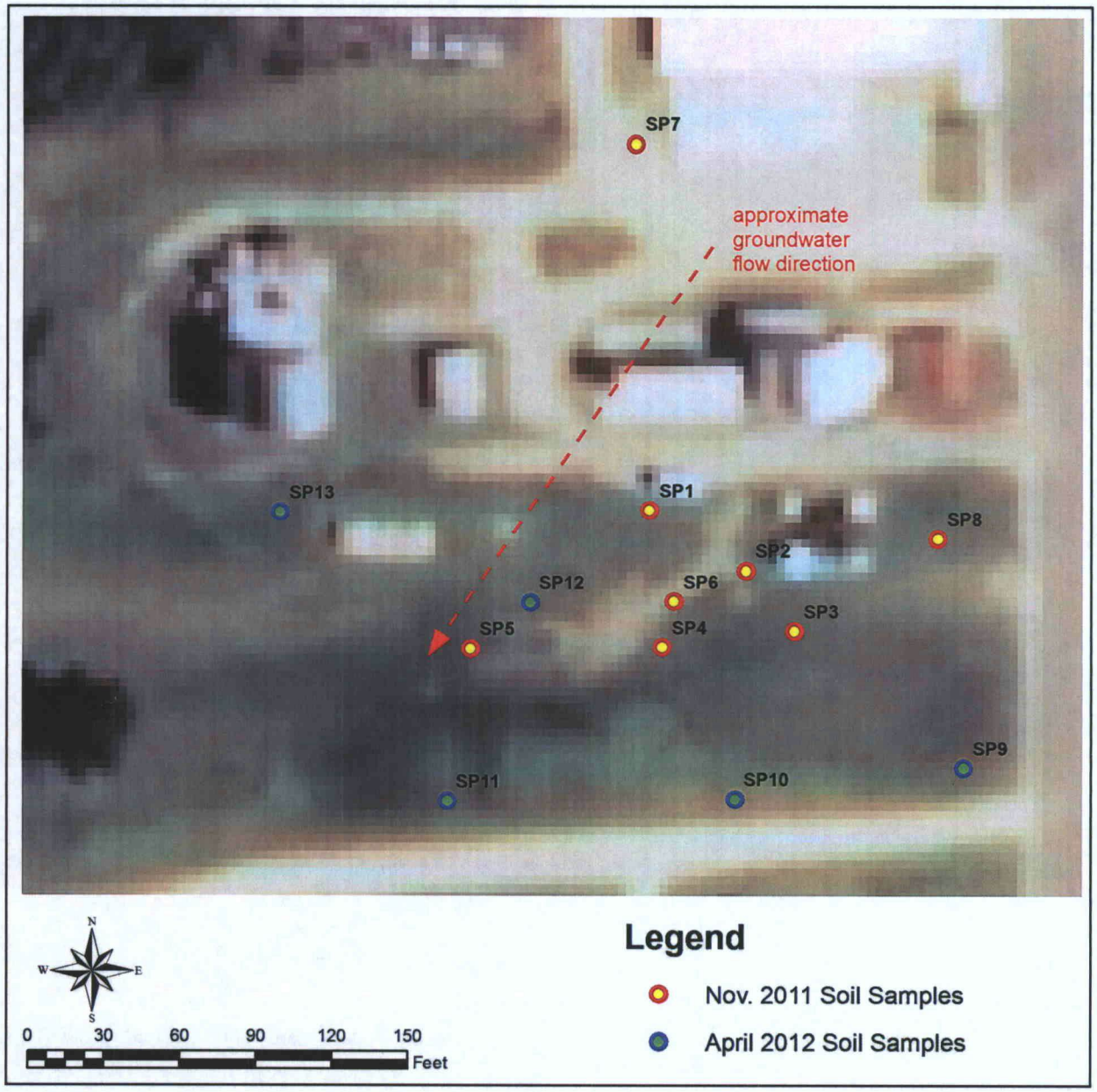


Figure 4. Locations of soil samples taken for characterization of nitrate contamination on the site.

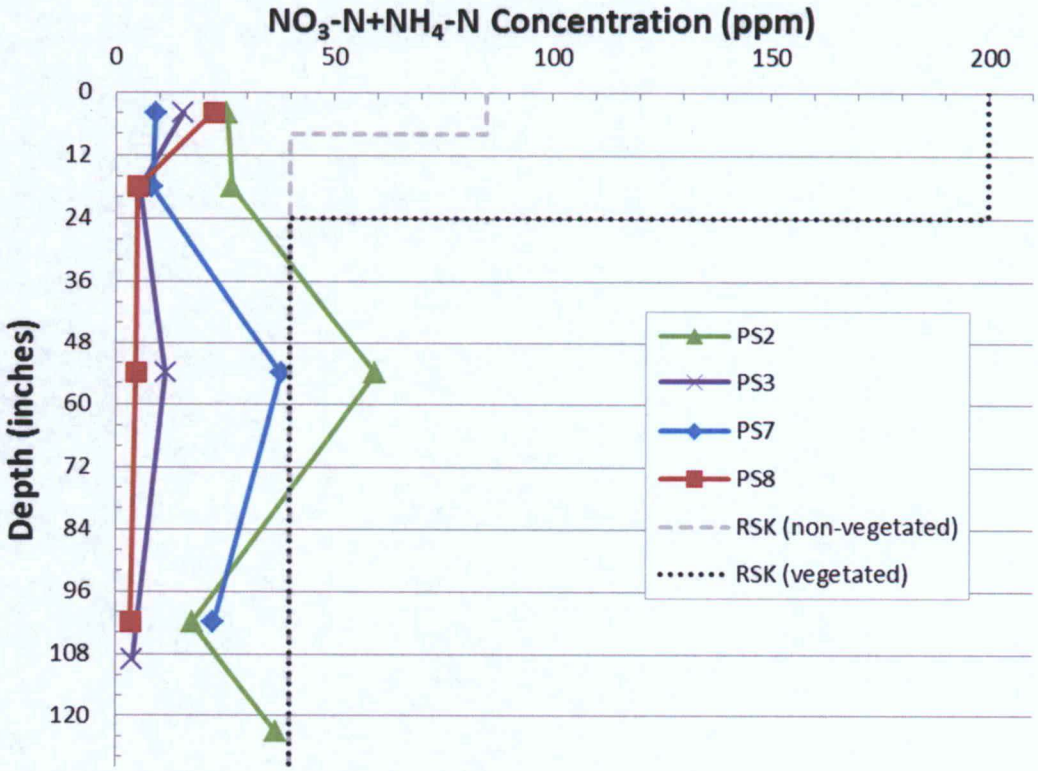
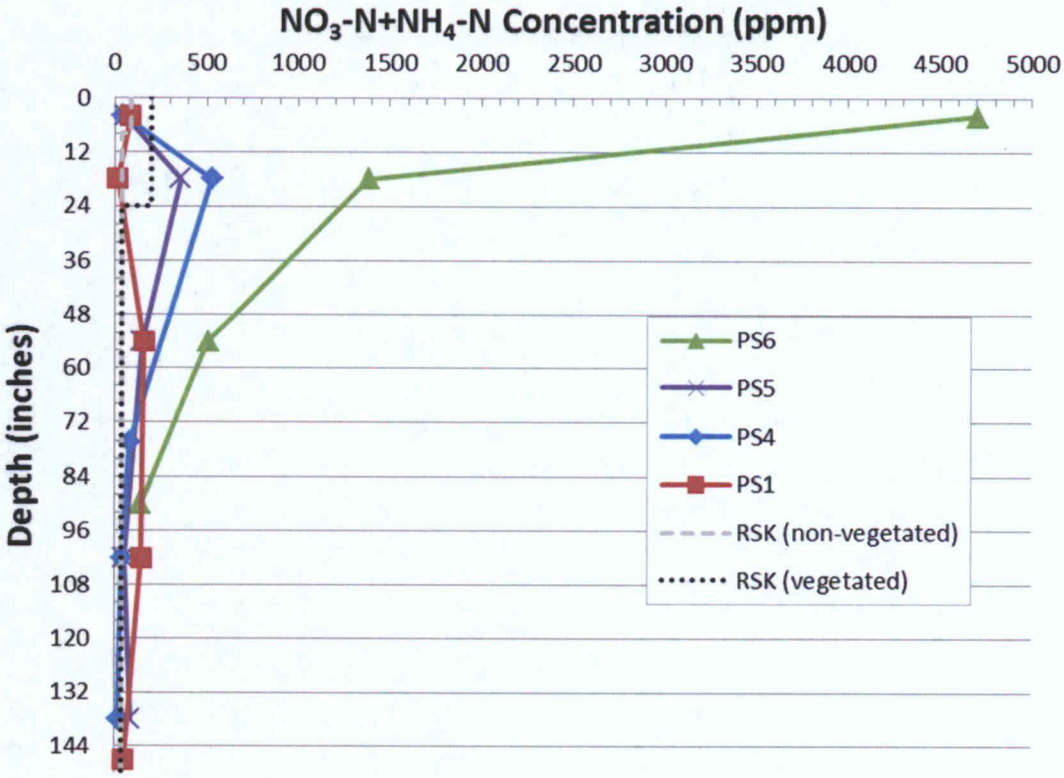


Figure 5. NO_3-N+NH_4-N concentrations in the soil profile for points 2, 3, 7, and 8.



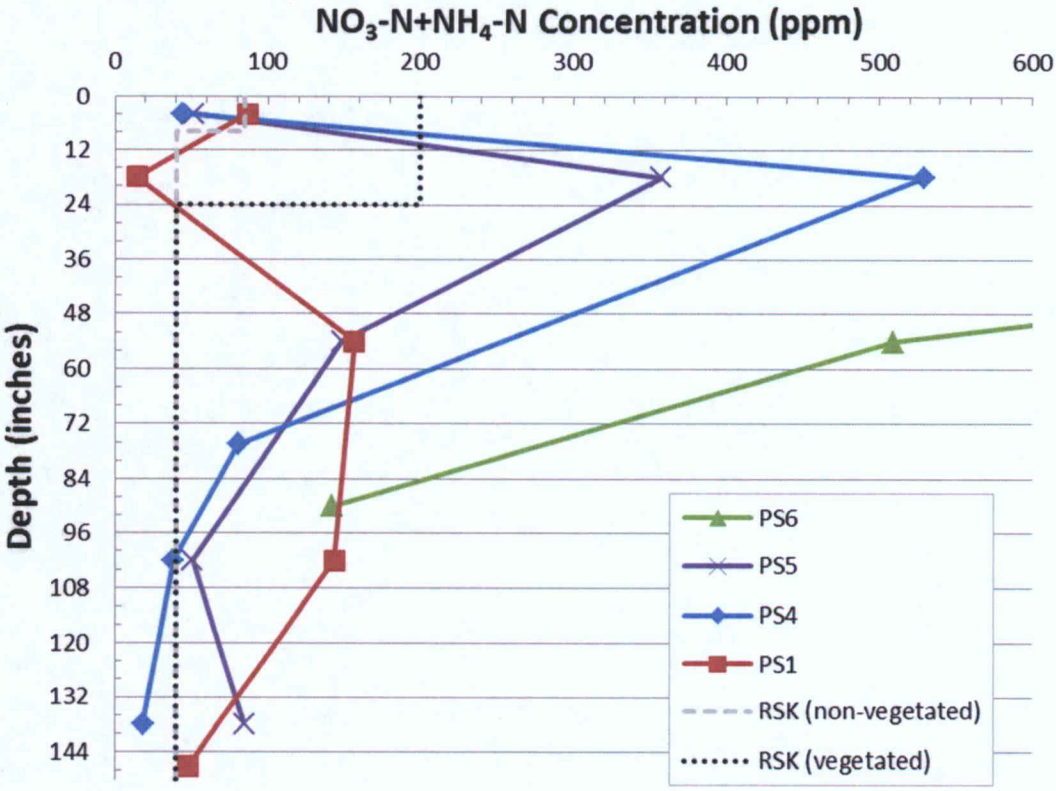


Figure 6. NO_3-N+NH_4-N concentrations in the soil profile for points 1, 4, 5, and 6.

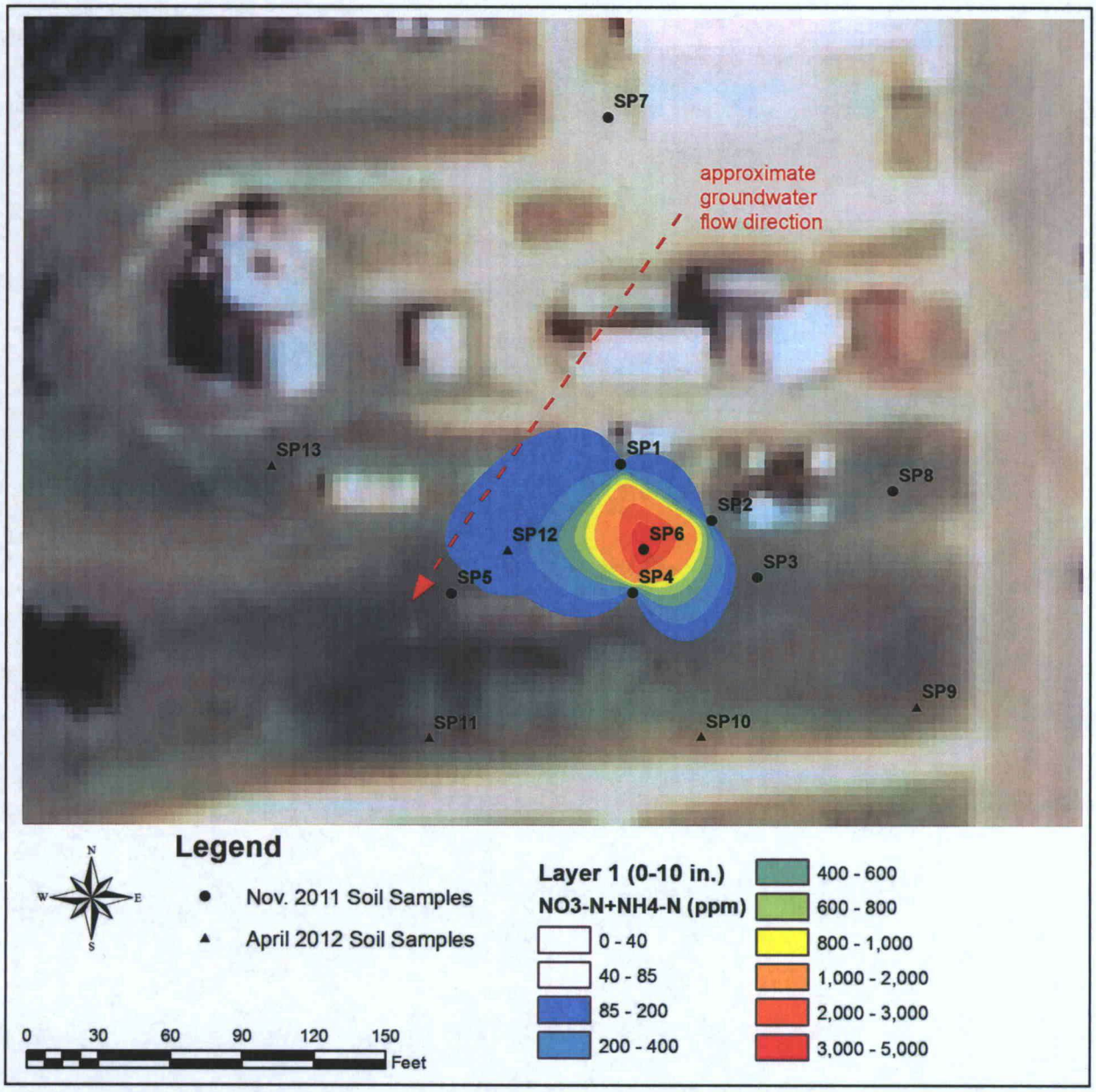


Figure 7. Interpolated NO_3-N+NH_4-N concentrations in the 0 to 10 inch soil layer.

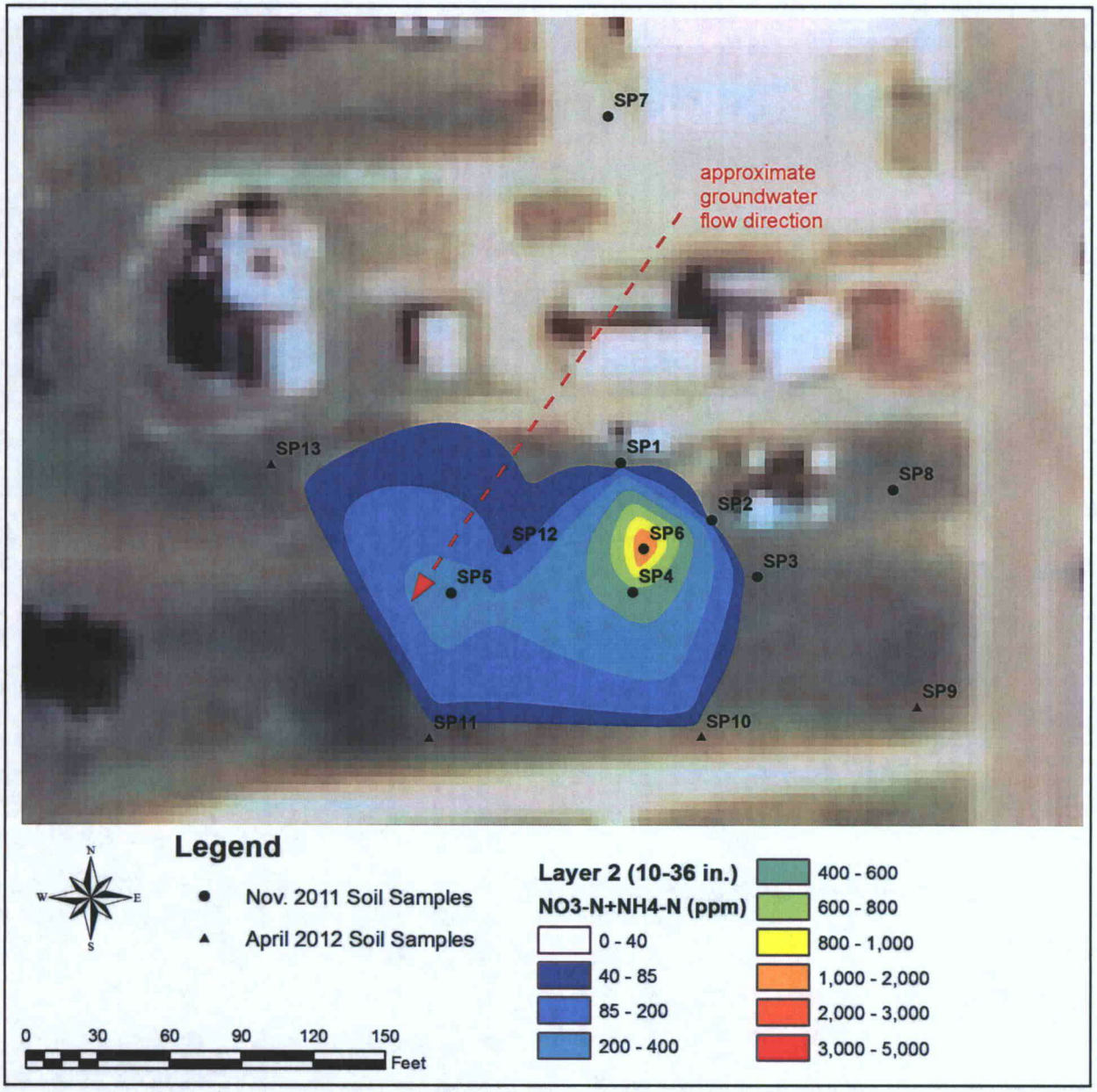


Figure 8. Interpolated NO_3-N+NH_4-N concentrations in the 10 to 36 inch soil layer.

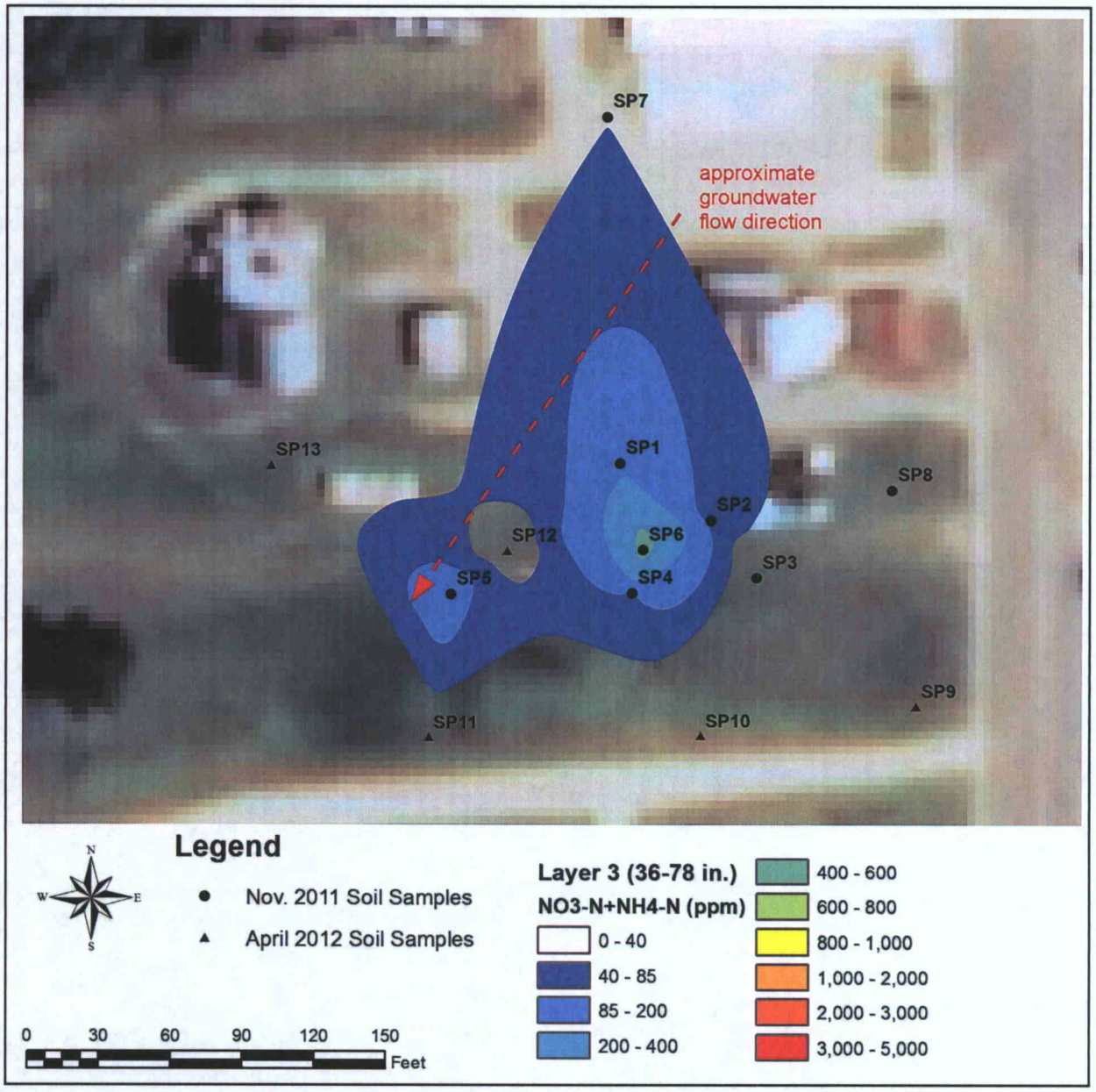


Figure 9. Interpolated NO_3-N+NH_4-N concentrations in the 36 to 78 inch soil layer.

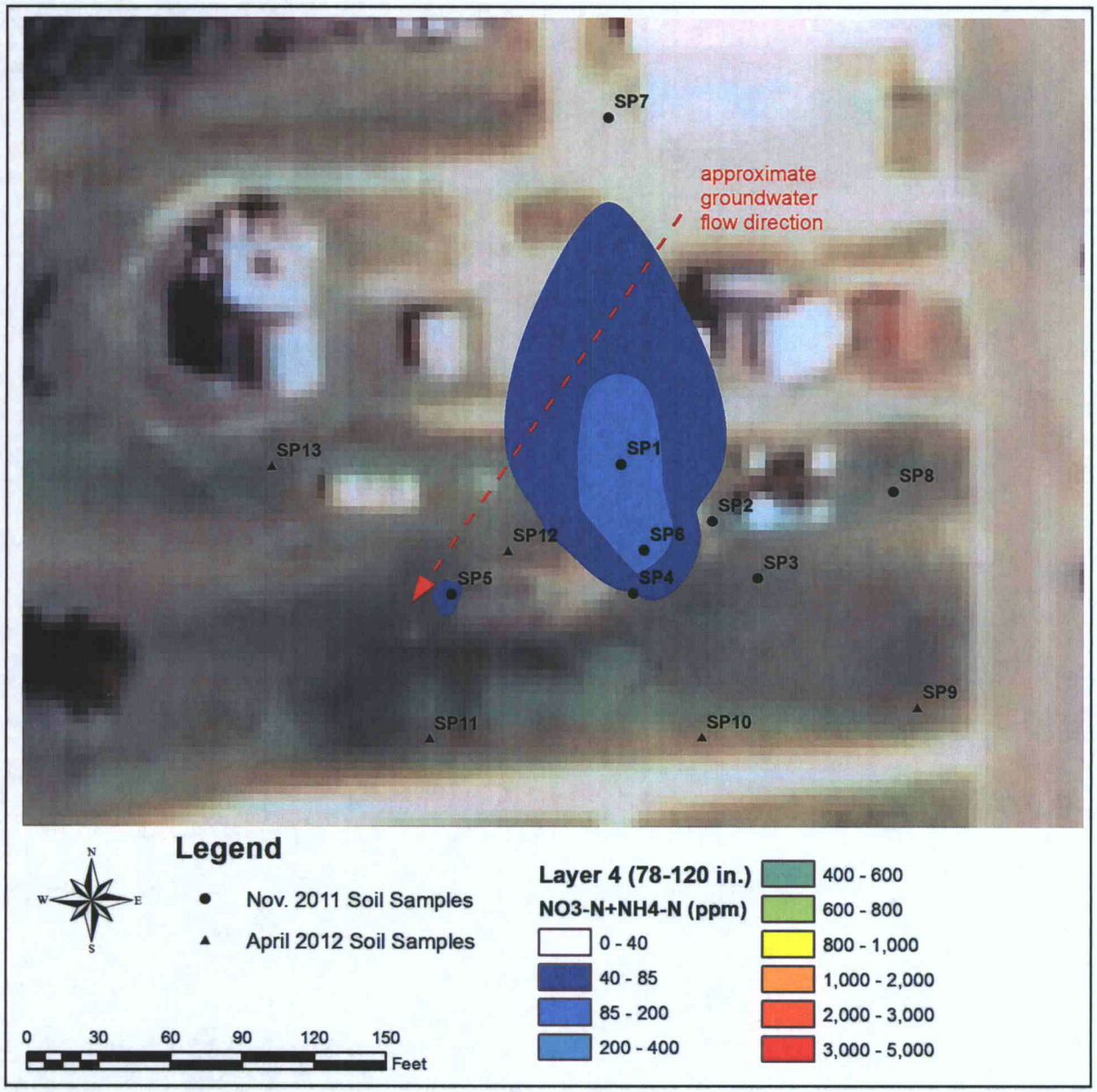


Figure 10. Interpolated NO_3-N+NH_4-N concentrations in the 78 to 120 inch soil layer.

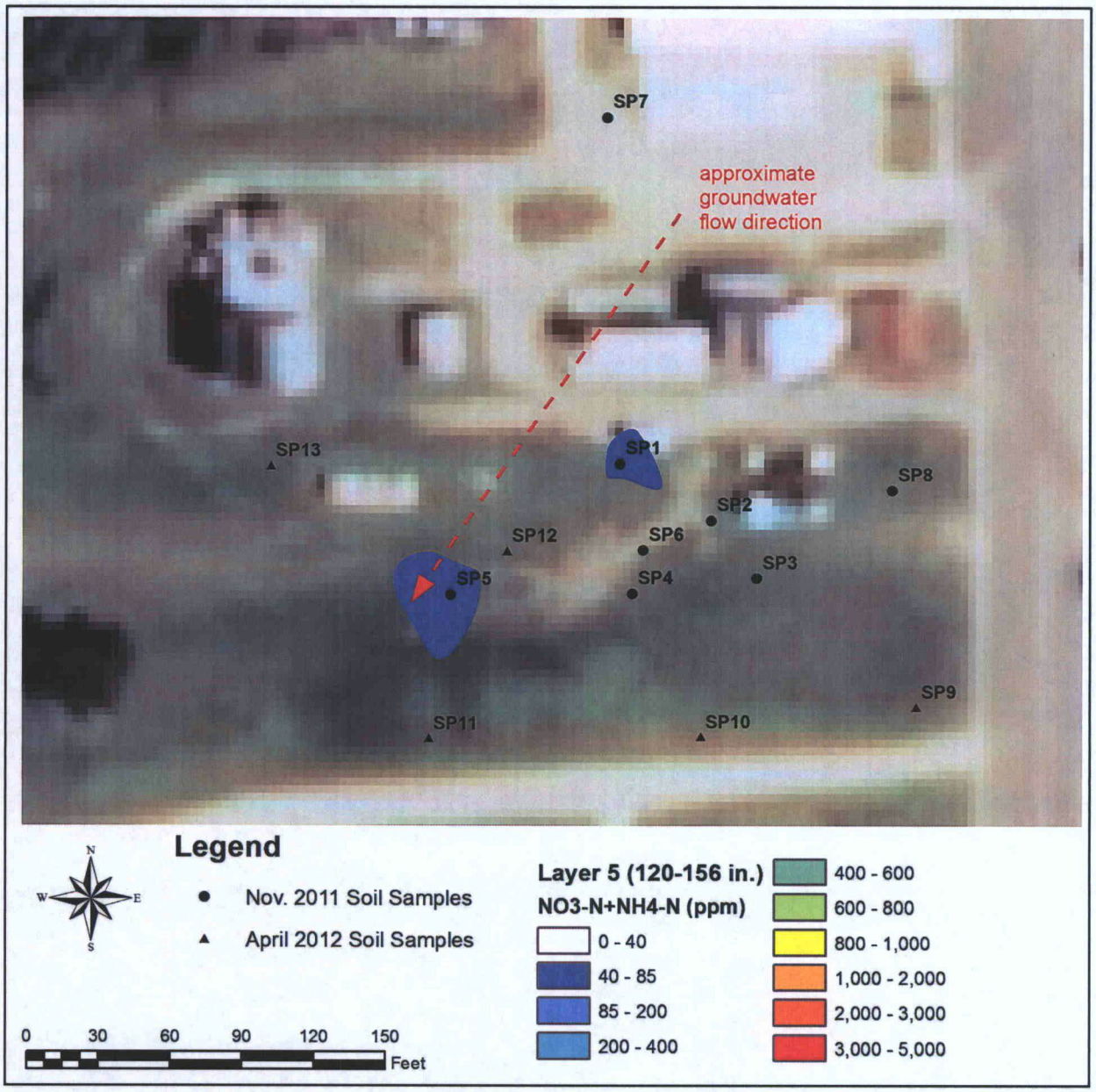


Figure 11. Interpolated NO_3-N+NH_4-N concentrations in the 120 to 156 inch soil layer.

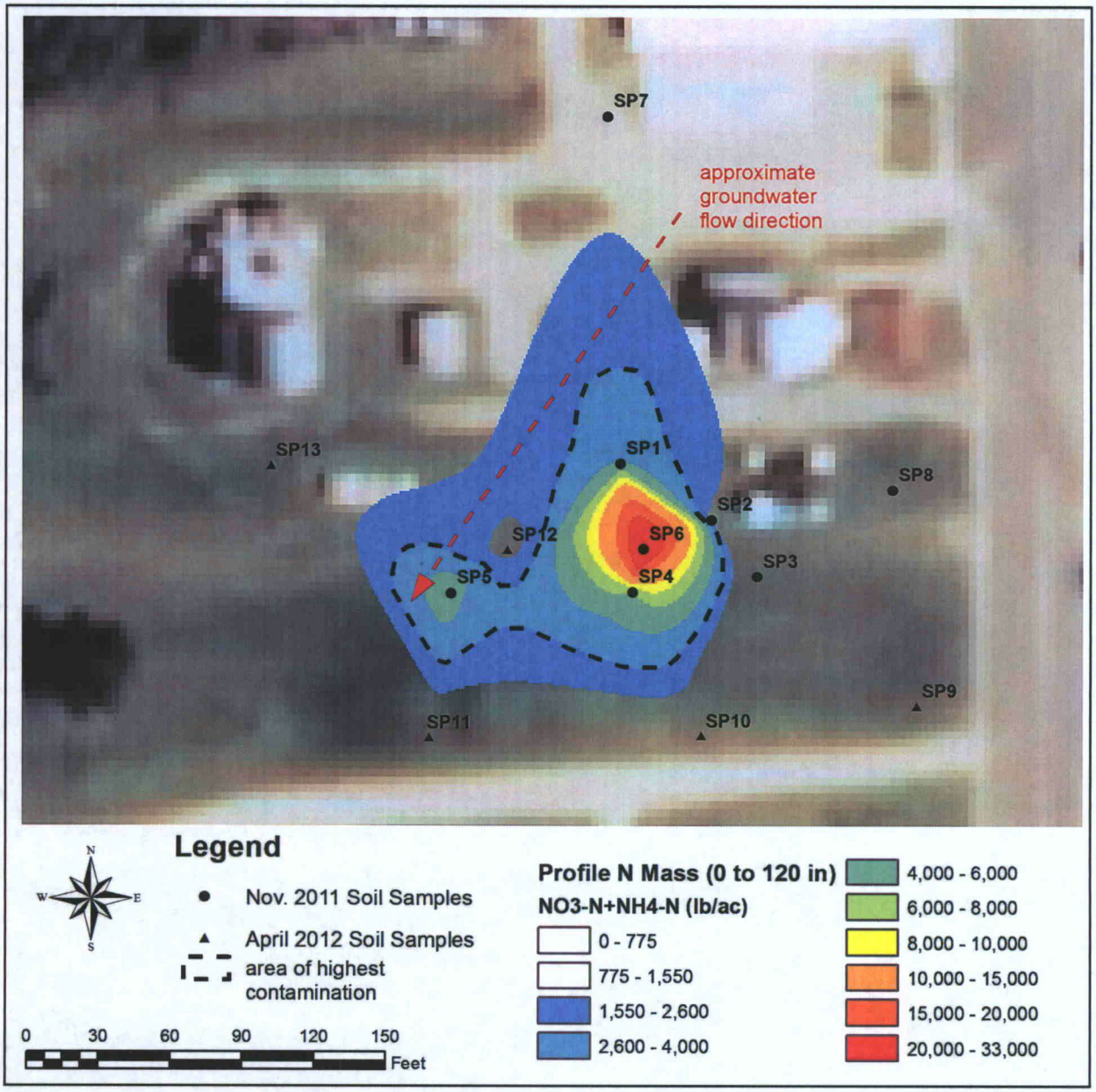


Figure 12 Estimated NO_3-N+NH_4-N mass in the soil profile (0 to 120 inches). Based on KDHE RSK limits for NO_3-N+NH_4-N, a 120 inch profile would have a maximum of 1550 lb NO_3-N+NH_4-N/ac for un-vegetated areas and 2600 lb NO_3-N+NH_4-N/ac for vegetated areas.

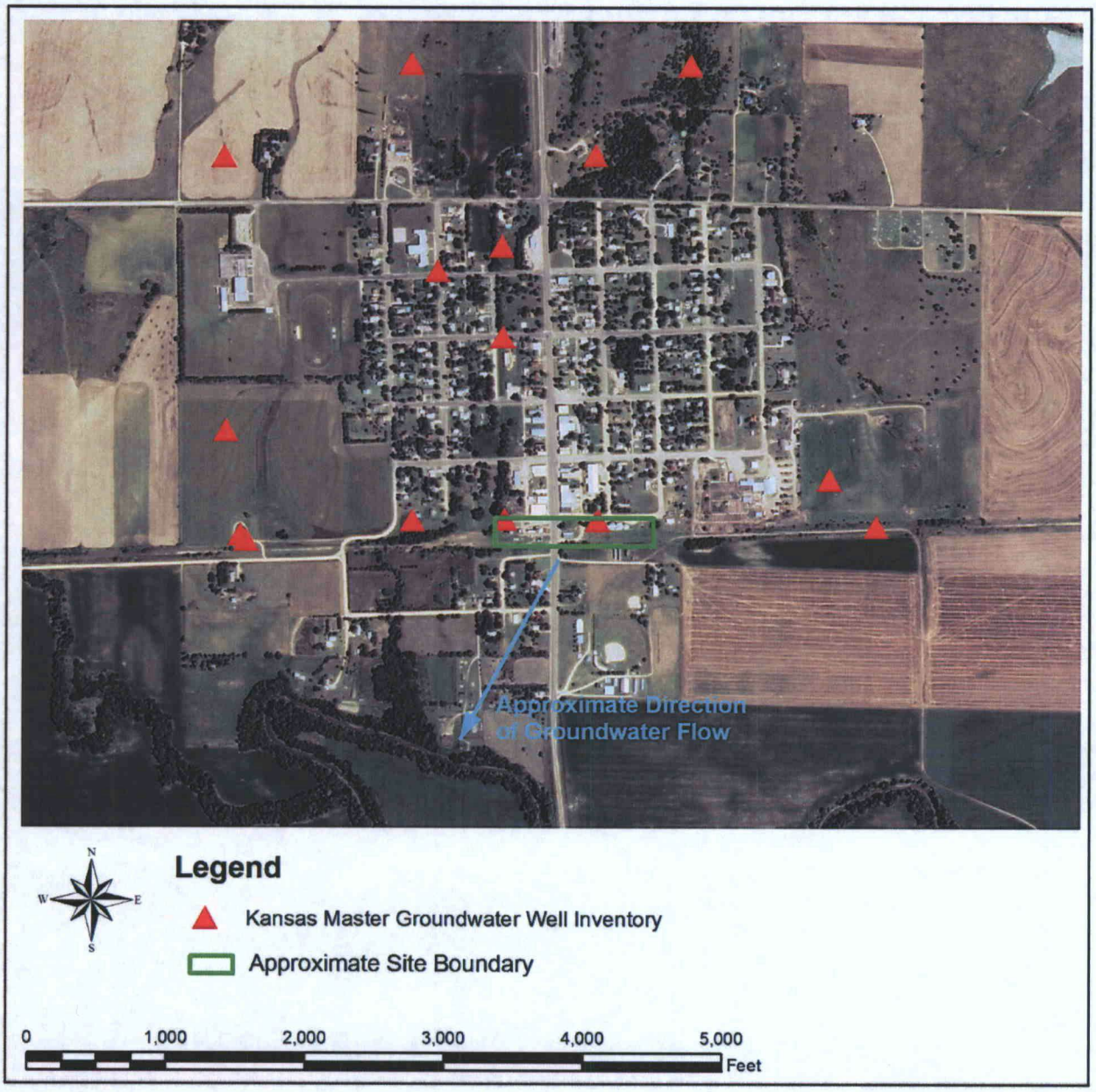


Figure 13. Registered groundwater wells in the Sylvan Grove area based on the Kansas Master Groundwater Well Inventory (Kansas Geological Survey).

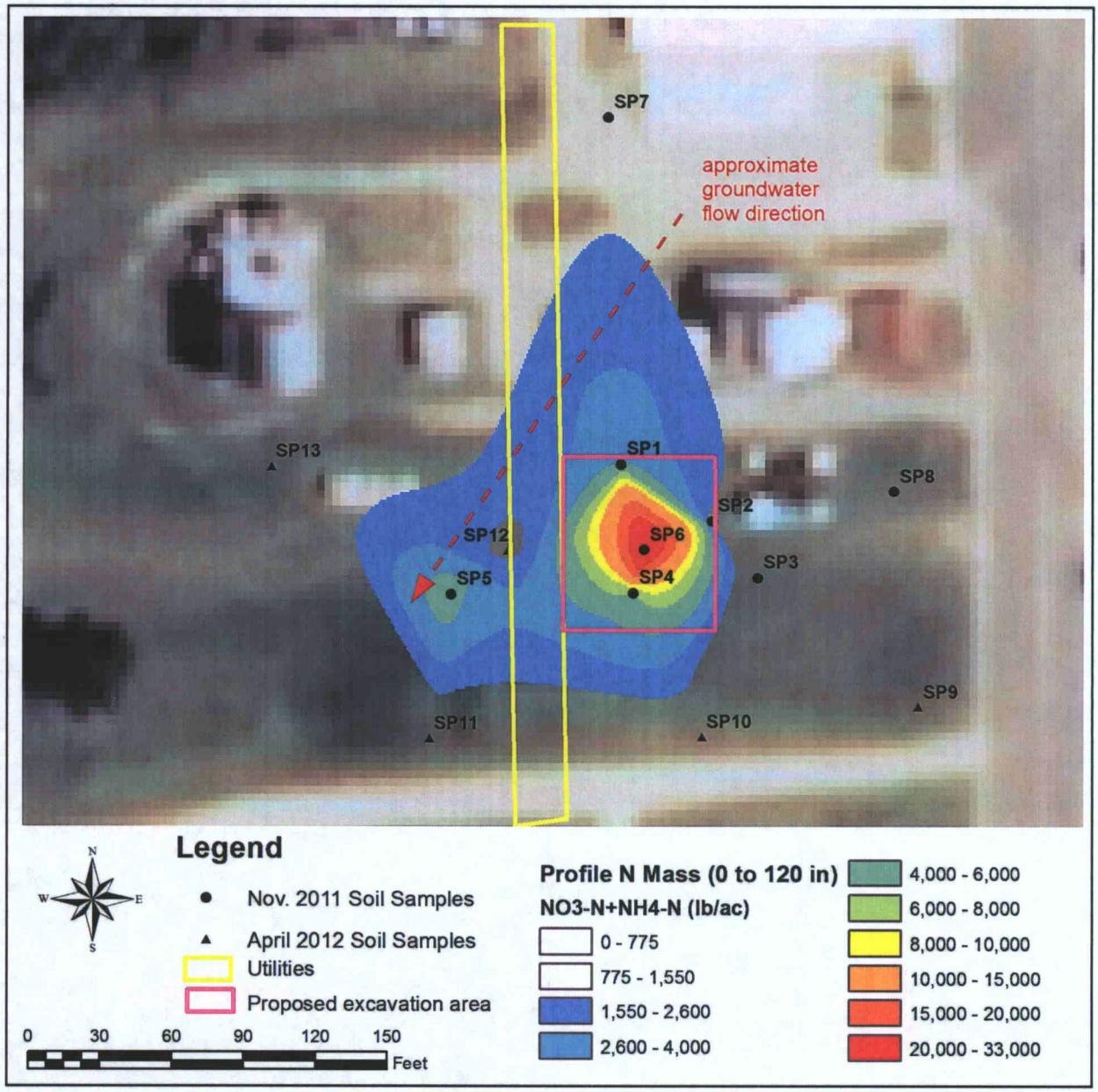


Figure 14. Location of the proposed area for excavation in remedial alternative 2.

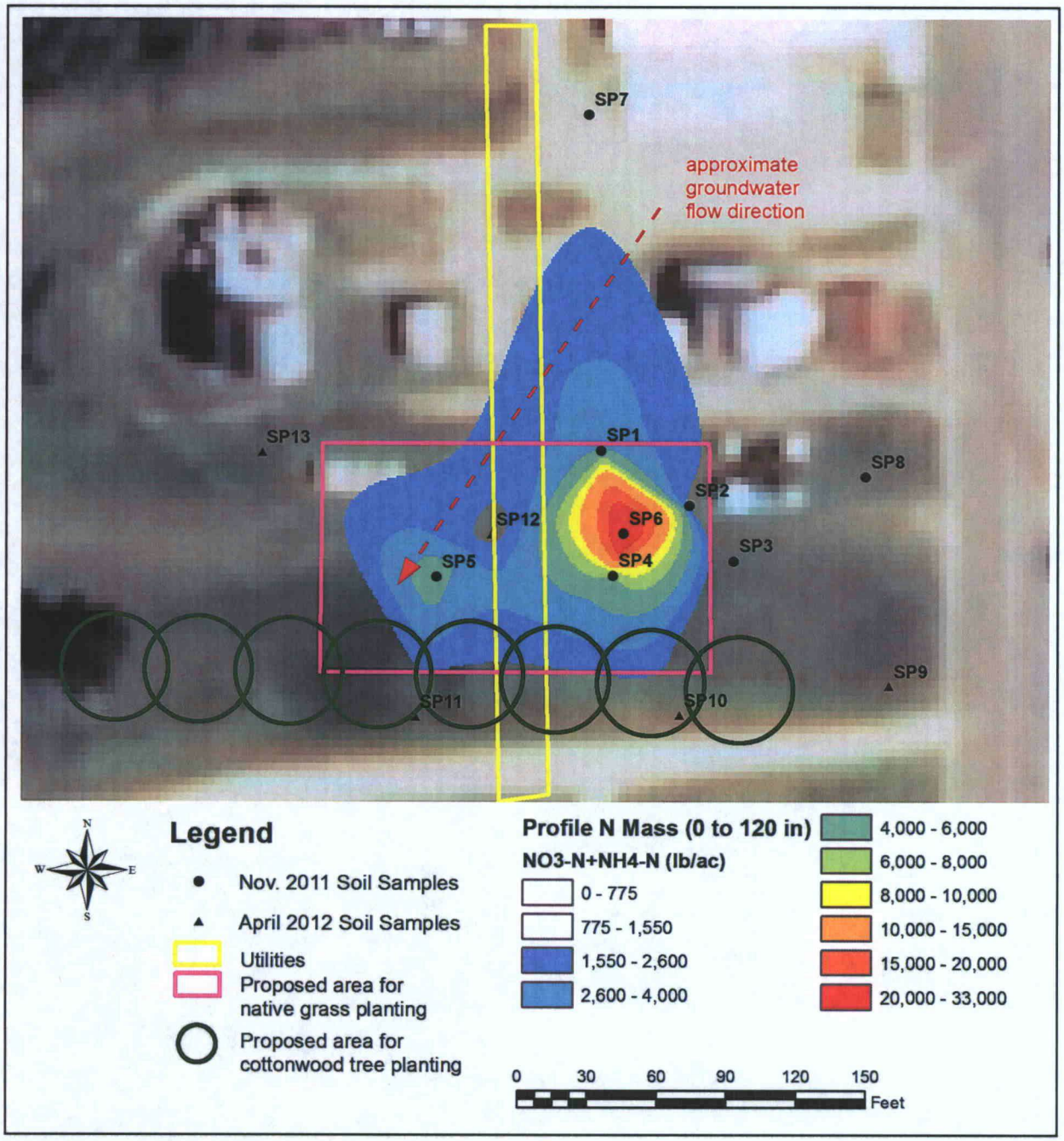


Figure 15. Location of plantings for the phytoremediation option

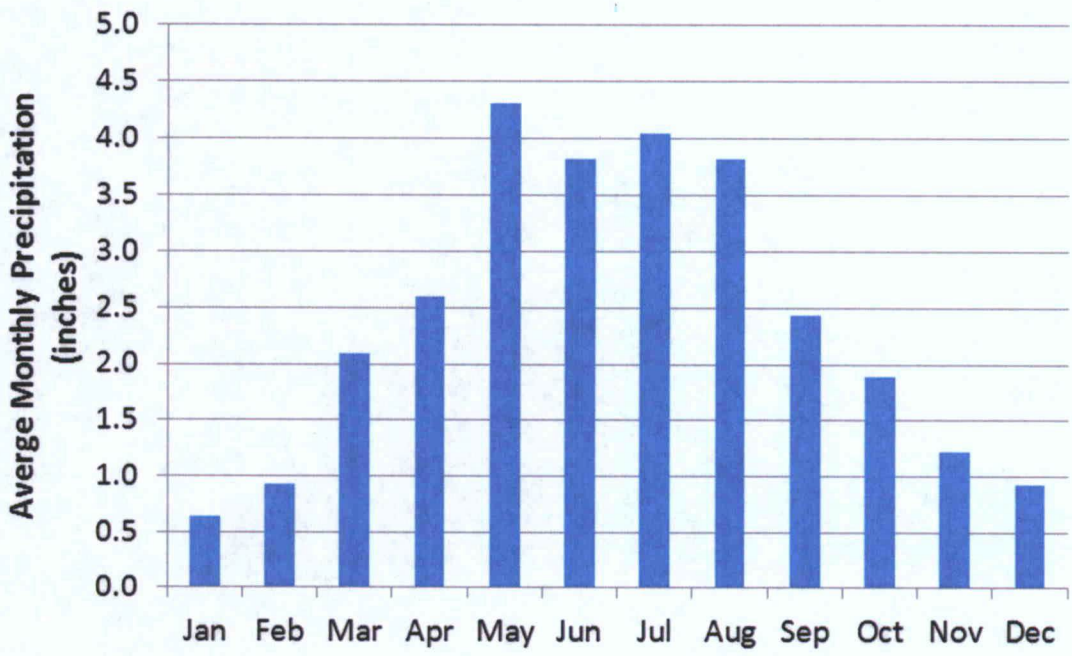


Figure 16. Average monthly rainfall for Lincoln County, KS (source: Kansas Weather Data Library).

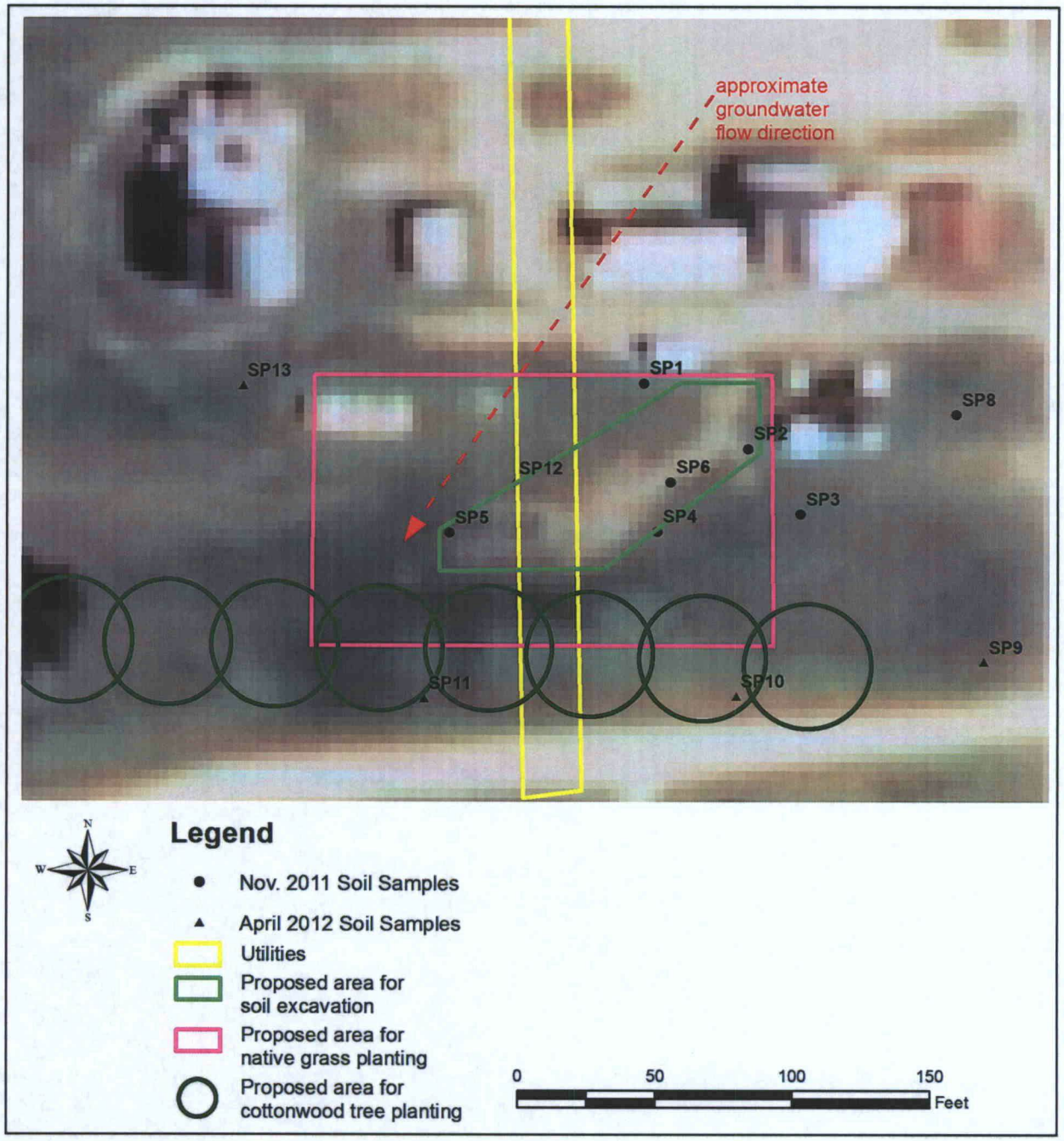


Figure 17. Location of soil excavation, grass planting, and tree planting for the mixed excavation-phytoremediation option.

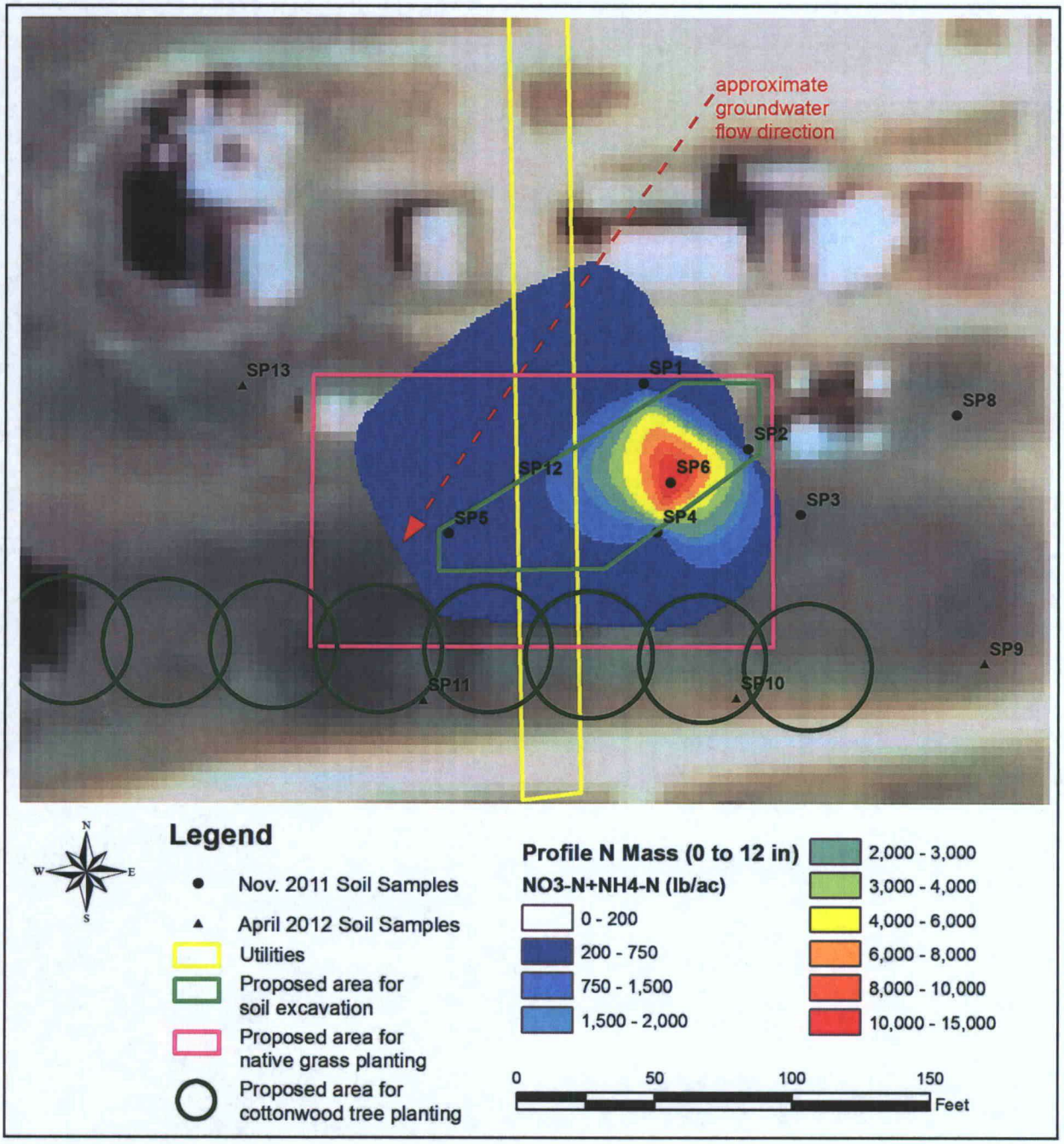
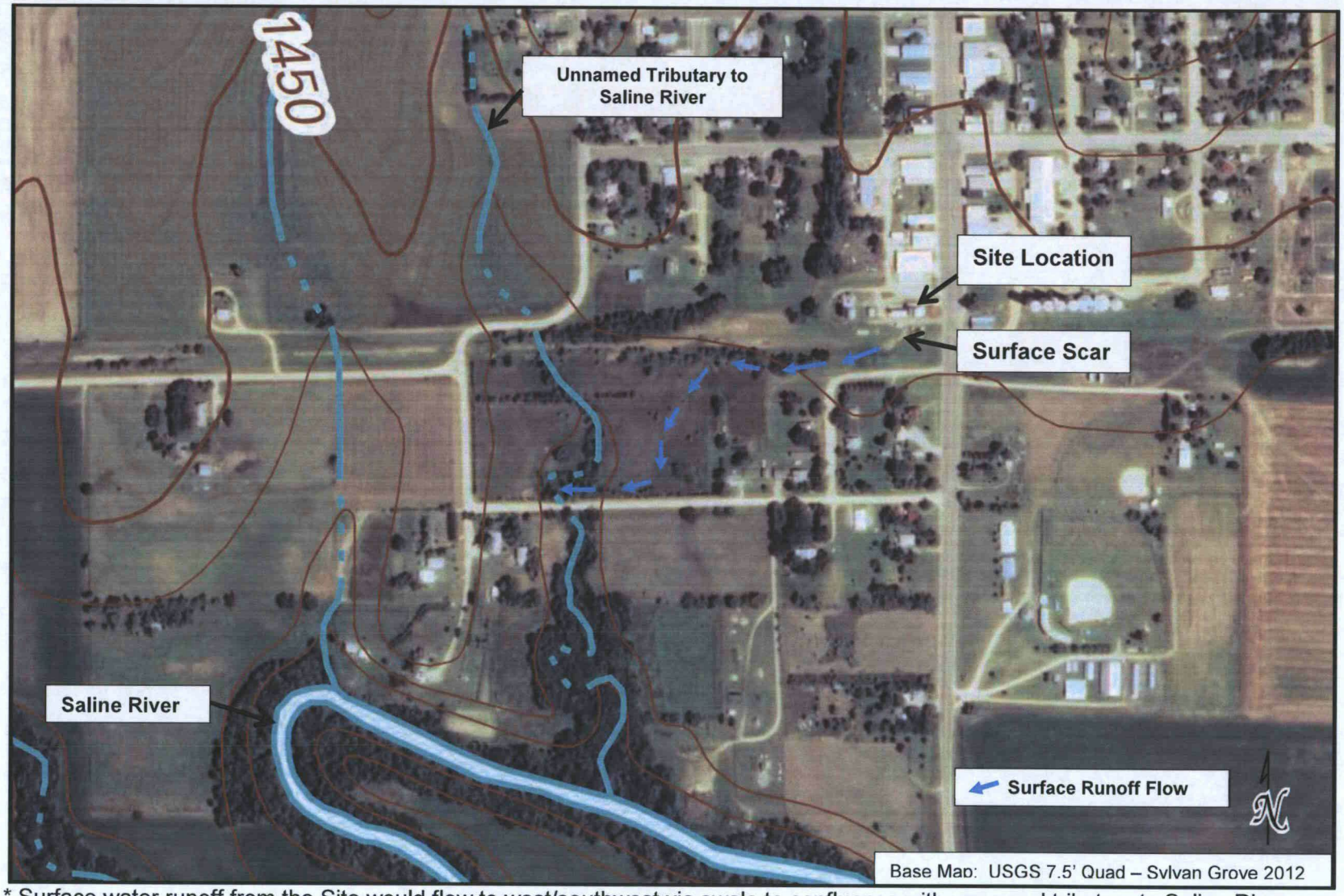


Figure 18. Location of soil excavation, grass planting, and tree planting for the mixed excavation-phytoremediation option.

FIGURE SHOWING ROUTE FOR SURFACE RUNOFF, OVERLAND FLOW



* Surface water runoff from the Site would flow to west/southwest via swale to confluence with unnamed tributary to Saline River.

THE FARMERS ELEVATOR COMPANY SITE INVESTIGATION REPORT

Former Nitrogen Fertilizer Distribution Center and Current Grain Elevator
Sylvan Grove, KS

Sophia Ford, Chad Hobson, Guilherme Sonntag Hoerlle, Sankar M.S, Clint Rose, Chris Sanders, Ali Mahdi, David Meyer, Daniel Ramirez, Casey Bulen, Mathew Crawford, Arthur Fink, Charles Loughman and Nate Wold

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Completed: April 30, 2012

CI/CAS: Students of Introduction to Geochemistry Course Spring 2013

Department of Geology, Kansas State University, Thompson Hall, Manhattan, KS, 66506

1.0 Executive Summary

This document is a report detailing the site activities that have taken place since the Kansas Department of Health and Environment Bureau of Environmental Remediation (KDHE BER) approved the previous report titled "The Farmers Elevator Company Investigation Work Plan, November 1, 2011". That work plan included proposed drilling locations, soil sampling methods, groundwater sampling methods, and the laboratory methods. This document includes sampling methods used in the field, procedures used, laboratory analyses of the samples, results, and recommendations. The major concern of the Farmers Elevator Company site located in Sylvan Grove, Kansas is nitrate contamination of soil and groundwater. Groundwater at the site was analyzed for the presence of nitrates, ammonia, and atrazine, and tested for the sources of such nitrates and the results of the analyses are presented in this document.

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2.0 Introduction

1. Nitrate contamination is a problem that affects groundwater in many agricultural areas of Kansas. KDHE BER has performed an initial reconnaissance of the former Farmers Elevator Company site. Their findings indicate nitrate in the groundwater upto 35 mg/L (2). A maximum contaminant level (MCL) has been set by the United States Environmental Protection Agency (US-EPA) for nitrate at 10 mg/L (1). During this investigation, soil sampling of the area also indicated nitrate enrichment. KDHE's Risk-based Standards for Kansas (RSK) establish action levels for nitrates at are set at 85 mg/kg for nitrates plus ammonia in the upper 8 inches of soil where no surface vegetation is present, and 200 mg/kg in the upper 24 inches when vegetation is present; soil surface samples collected on site indicated contamination levels of up to 5,700 mg/kg.

2.1 Property Location and Demographics

The Farmers Elevator Company is located at 129 S Main St. Sylvan Grove, KS, in the west half of Section 13, Township 12 South, Range 10 West and the east half of Section 14, Township 12 South, Range 10 West. The geographic coordinates of the site are 39.00954° North latitude and 98.39398° West longitude. A former sale barn was located to the north adjacent to the site. Land use around the Sylvan Grove area is shown in Fig. 1.

2.2 Property History

The use of the facility as an elevator has been reported as early as 1901. Other historical activities conducted on the property have included grain milling, coal storage, a retail lumber store, a rail depot, a park and a well and water storage system for locomotives (3). In 2003, Glenn P. Ringler and Gregory J. Ringler purchased the property. 3 to 5 years prior to the purchase of the property, 150 to 200 truckloads of soil in the fertilizer loading area was removed and replaced. This activity was performed without KDHE oversight and so according to the reference, the November 8, 2007 phone converstation, the location, size, and depth of this excavation is not documented (2). The site is now used by the owners for grain storage.

2.3 Previous Investigations

In May 1996, Enviro Tech Services, Inc., Salina, Kansas performed Phase 1 Environmental Assessment of Farmers Elevator Company site for the Barnard Grain Company. Reports indicate Farmers Elevator Company appeared to have good housekeeping and no bulk chemicals or liquids were stored at the facility. Previously a fumigant known as 80/20 was used at the facility. This fumigant is a mixture of 80% carbon tetrachloride and 20% carbon disulfide. No direct evidence was determined to indicate that the soil or groundwater underlying the property had been negatively impacted as a result of this Phase 1 Assessment (3).

In May 1997, Enviro Tech Services, collected 7 soil and 2 groundwater samples and had them analyzed by Continental Analytical Services, Inc. in Salina, Kansas. Results indicated a maximum detection of nitrate as nitrogen at 330 mg/kg in soil and 62 mg/L in groundwater. Total Nitrate plus Ammonia'sRisk-based Standards for Kansas (RSK) is of 85 mg/kg in the upper 8", 40 mg/kg in the lower 8", where no vegetation is present, and 10 mg/L for groundwater pathway (2).

The City of Sylvan Grove obtains its drinking water from 2 wells that are located within one half mile west of the site. The city routinely samples their water supply system. Sometime between April 10, 2000 and April 30, 2007, 10 samples were analyzed for nitrate; 3 samples were analyzed on annual basis and 7 samples were analyzed for bacteriological content. Nitrate was detected at less than 5 mg/L as nitrogen. Between August 21, 1996 and August 1, 2005, atrazine was not detected above 0.1 μg/L for 4 samples (2).

In May 2008, a report for KDHE was prepared A Site Reconnaissance and Evaluation for Farmers Elevator Company. Their results detected neither carbon tetrachloride nor chloroform. Nitrate was detected in soil and groundwater at levels exceeding RSK values. Elevated levels of ammonia were detected in the water collected from the sump. It was recommended that a potentially responsible party (PRP) search be conducted to identify past operations at the site (2).

Kansas State University Departments of Agronomy and Geology began investigating Farmers Elevator Company during fourth quarter of 2011.

3.0 Site Investigation Activities

Four monitoring wells were installed at the field site by Geotechnical Services, Inc. (GSI) on November 10 and 11, 2011. The monitoring wells were developed and water samples were collected by the KSU Water Resource Geochemistry group on November 11, 2011 according to the methods identified in the Work Plan.

3.1 Groundwater Monitoring Well Installation

Groundwater monitoring well installation activities began on November 10, 2011, and were completed on November 11. Monitoring wells MW-2, 3, and 4 were completed the 1st day, and MW-1 was completed the 2nd day. Geotechnical Services, Inc. provided the drilling services. An rotary drill rig with approximately 8-inch outside diameter and 4.25-inch inside diameter hollow stem augers and split spoon sampler was used to advance the boreholes for MW-1 through MW-4. Soil cores were collected every five feet as the augers were advanced. Wells were completed using 2" PVC casing, with 10' of screen placed at the bottom of the borehole. A silica sand pack was placed around the screen, and the remainder of the annular space between casing and borehole was filled with bentonite grout. Wells were completed with a locking cap and flush mount vault with concrete pad.

3.1.1 Monitoring Well Borehole Logging

Soil cores that were collected as the auger advanced through the boreholes were described and logged as they were generated. The Geology Department staff and students, as well as the environmental consultant for the site Mr. Frank Arnwine of Blackstone Environmental, Inc., conducted the soil core logging. The information collected during the logging was used to develop the well completion logs seen in Table 1, and the resulting monitoring well borehole diagrams with well completion information are included as Fig. 2.

3.1.2 Monitoring Well Location Surveying

A Leica Rugby 55 Laser Level 4 Total Station was used to survey the site. The laser level was setup at a control point that had the ability to achieve clear line of sight to all four monitoring wells and height above ground was recorded. A street sign, in the alley way near MW-3, had a nail drilled in it that is the same elevation as the floor of the Sylvan Grove Fire Station to the northeast of the site. The floor level of the fire station can be found through blue prints or other city documents and will help to reference and compare the elevation of all monitoring wells on the site. Therefore, the elevation of the nail was referenced with the use of the total station and a sensor that was slid up and down a measuring pole. When the sensor reached the same height as the laser level, the height from the sensor to the ground was recorded. Next, each monitoring well height from ground surface was found and recorded using the laser level total station at control point and sensor at each monitoring well. Recorded elevation data from laser level measurements is presented in Table 2.

Spatial monitoring well locations were recorded using a handheld Global Positioning System (GPS) device. The GPS device was held directly over each monitoring well to obtain longitude and latitude measurements and then recorded. These GPS latitude and longitude measurements were tested and recorded several times for comparison and accuracy. For additional comparison, a measuring wheel was used to determine north-south and east-west distances from reference points to monitoring wells. Recorded longitude and latitude data from GPS measurements is also presented in Table 2.

3.2 Groundwater Elevation Measurement

The groundwater elevation measurement was completed on November 11, 2011. Measurements were taken 24 hours after well installation completion to allow the sediment in the well water to settle. These measurements were handled by Matt Crawford, Frank Arnwine, Charles Loughman, and Sophie Ford, using an electronic water level indicator. The data for the measurements can be seen in Table 2.

3.3 Groundwater Sampling

Groundwater sampling at the site was conducted on November 11, 2011. The groundwater sampling team consisted of Charles Loughman, Sophie Ford, Ali Mahdi, Mathew Crawford, Arthur Fink, Sankar M.S., Dr. Saugata Datta and Frank Arnwine.

Sampling was conducted using the disposable polyethylene bailers. The wells were purged before the sampling was initiated. The purging volumes were as follows: 20 gallons for MW-1, 20 gallons for MW-2, 20 gallons for MW-3, and 30 gallons for MW-4. Wells were considered developed after the above amounts were purged and visual observation indicated a reduction in turbidity. The samples were then taken using disposable bailers, taking care to minimize any disturbance of the water column to prevent outgassing during collection. Collected groundwater samples from each well were containerized for transport to the laboratories in the following:

1) 500 ml plastic Nalgene HDPE bottle,
2) 50 ml polypropylene centrifuge tube,
3) 60 ml clear glass bottle,
4) 125 ml amber Nalgene HDPE bottle,
5) 2 litre HDPE bottle,
6) 1 litre amber glass bottle, and
7) 250 ml glass bottle (provided by Continental labs).

The first 4 samples are preserved in the hydrogeochemistry lab at the Department of Geology at Kansas State University. 2 litre HDPE bottle samples are used for N-15 analysis. 1 litre amber glass bottle sample for atrazine analysis and 250 ml glass bottle was used to collect water sample for total nitrate

analysis. All the bottles were filled leaving no head space in the bottle. Samples were stored in sealed sample bottles and stored at 4°C.

Analysis of nitrate and ammonium was conducted by the KSU Soils Laboratory in the Department of Agronomy for MW-1 through 4, and Continental Analytical Services, Inc., for MW-1 and MW-4 according to EPA Methods 352.2 and 350.1, respectively. Atrazine analysis was conducted by KSU Department of Biological and Agricultural Engineering for MW1-4 and Continental Analytical Services, Inc., for MW-1 and MW-4 according to EPA Method 8141.

3.4 Aquifer Slug Test

A slug test was performed by Frank Arnwine, Arthur Fink, Charles Loughman, Sophie Ford, and Saugata Datta following EPA Method 2046. A 6' by 1.25" solid PVC slug was used. The data was plotted but found to be insufficient to calculate hydraulic conductivity. The data is included in Table 3, and a graphical summary of the data is included as Fig. 3. Estimated Hydraulic Conductivity values are in range of 10^{-5} cm/sec

3.5 Soil Characterization and Sampling

Soil characterization and sampling was completed by the KSU NRES group under the guidance of Dr. Nathan Nelson, KSU Department of Agronomy.

4.0 Property Physical Characteristics

KDHE BER thoroughly identified the physical characteristics of the site during their 2008 site investigation. The current site investigation activities, guided by the November 2011 Work Plan, confirms the original KDHE BER characterization.

4.1 Characterization of Soils

According to the National Cooperative Soil Survey, the soils at the Sylvan Grove contamination site are classified as Hord silt-loam, Geary-Lancaster complex, and Roxbury silt-loam. Typically, these soil types are well-draining, and readily transmit water through the soil profile.

Rock outcrops throughout this region are of Cretaceous age. Sylvan Grove lies specifically in the Dakota Formation (4). This formation is made up of varying beds of kaolinitic claystone, mudstone, siltstone, and shale inter-fingered with sandstones. Lenses of volcanic ash exist at varying depths (0" - 135") throughout Lincoln County. The full extent of this ash has not been mapped. Volcanic ash is worth noting, because ash has been shown to both store and release inorganic nitrates into the groundwater, depending on the sediment's overall ionic/charge and adsorption characters at the time (5). We did not find any traces of volcanic ash from our well logs, contribution from the ash cannot be certain.

4.2 Characterization of Groundwater

In the previous study by KDHE, nitrate was found in all wells. However, only one location had nitrate levels above the RSK. The one well that was above RSK was to the east/north-east of the site. Background literature indicates that background levels of nitrate are to be expected because this is an agricultural region. It is also important to note that groundwater flow is approximately south/southwest, indicating that a contamination detected on the north-east corner would travel throughout the rest of the site. The groundwater flow was determined after the development of new piezometers used to sample groundwater in this study. By measuring the water level in the wells after they were developed, it was possible to use a three-point problem approach to determine a flow direction and possible potentiometric surface (Fig. 4a & 4b). After analyzing the groundwater it was discovered that all but 1 well indicated nitrate levels above the RSK (Table 5). The 2 highest areas are again, on the northeast corner and the well on the southwest corner of the study area (Fig. 5). It should be noted that the highest values of nitrate are 10 ppm higher than the previous investigation and the lower levels are higher than the previously recorded values by a significant amount. Measurements on groundwater quality (Table 4) were made during sampling and pH values have a little variation, being the lowest value 6.3 at MW-4 and 6.5 on MW-1, the highest. It may indicate that pH values are decreasing on the direction of groundwater flow (southwest). The water conductivity ranges from 1536 µS/cm on MW-1 reaching 2056.3 µS/cm at MW-4. It probably indicates that TDS values are increasing southwest. Correlation between NO_3 distribution, pH and conductivity are shown on Fig. 7. Considering that the highest and lowest values of pH and conductivity

are located at same place as the highest values of nitrate, it is possible to affirm that there is no correlation between nitrate distribution and pH or conductivity.

5.0 Nature and Extent of Contamination

This section focuses on the laboratory analytical results from the groundwater sampling described in Section 3.0. This section also compares this current data to that of the 2008 KDHE BER investigation.

5.1 Nitrate and Ammonium in Groundwater

Nitrate was found to be above the MCL (10 mg/L) in 3 of the 4 wells sampled (Table 5). The wells that were found to have the highest concentrations were MW-1 with 45.38 +/- 0.53 mg/L and MW-4 with 41.03 +/- 5.69 mg/L. MW-3 was the 3rd well over MCL with a concentration of 19.4 mg/L. Though not over the MCL MW-2 was found to have 7.13 mg/L which itself is close enough to be of concern. The results from KSU Soils Laboratory matched well with those from Continental Labs. For MW-1 the standard deviation was 0.5 mg/L and for MW-4 it was 5.7 mg/L.

Ammonium concentrations for all 4 wells were below 1-ppm (Table 6). The concentrations ranged from a high of 0.06 mg/L in MW-4 to a low of 0.01 mg/L in MW-4. The duplicate samples sent to Continental Labs came up below the detection limit, which is in accordance with the low results from KSU Soils Laboratory.

5.2 Atrazine in Groundwater

Atrazine was analyzed by KSU Department of Biological and Agricultural Engineering and Continental Analytical Services Inc. using EPA Method 8141. All 4 wells were found to have below MCL (3 μg/L) concentrations of atrazine (Table 7). MW-1 and MW-4 were both found to have below detection concentrations which match with the duplicates sent to Continental Labs. MW-2 showed a concentration of 0.18 μg/L and MW-3 0.06 μg/L. Atrazine at these concentrations pose no threat in this particular study area.

5.3 Nitrogen Isotope Analysis of Groundwater

The 2 isotopes of nitrogen have a slightly different atomic mass and are preferentially used by different chemical and physical processes. These results in a relative enrichment of that isotope in the product and an enrichment of the other in the reactants (9). Because of this, different sources of NO_3 - nitrogen have shown to have different isotope signatures. Analyzing a sample for its isotope ratio can be useful in determining the potential source of the NO_3 since it should have a value representative of the

source. Rolston et al. found that using $\delta^{15}N$ values gives various ranges for the different sources of the NO_3. Many of these ranges overlap, and they found that separating the soil organic nitrogen from fertilizer input cannot be done. However, $\delta^{15}N$ is useful in determining if the source is from animal waste or fertilizers. Stable isotope analysis is widely used by researchers to elucidate the source of NO_3 contamination in groundwater (10).

Nitrogen has 2 stable isotopes, ^{14}N and ^{15}N, and its isotopic composition is expressed relative to air. The ratio of ^{14}N and ^{15}N is measured relative to the ratio of a standard of known isotopic composition, such as atmospheric air ($^{15}N/^{14}N$ = 0.0036765). The stable isotopic compositions of low-mass (light) elements such as oxygen, hydrogen, carbon, nitrogen, and sulfur are normally reported as "delta" (δ), values in parts per thousand (denoted as ‰) enrichments or depletions relative to a standard of known composition, in this case, atmospheric air. δ values are calculated by:

$$‰\delta^{15}N = \frac{{}^{15}N/_{14}N\ sample - {}^{15}N/_{14}N\ standard}{{}^{15}N/_{14}N\ standard} \times 1000$$

Groundwater samples from the Sylvan Grove site were first analysed by Water Resources Geochemistry (Geol 611) students from Fall 2011, at the Department of Biology, Stable Isotope Mass Spectrometry Laboratory at KState and later for confirmatory purposes sent to Activation Laboratories Ltd. in Ontario, Canada for analysis. $\delta^{15}N$ from groundwater samples is determined on an inorganic nitrate derivative using automated, continuous-flow elemental analyzer/isotope ratio mass spectrometry (EA/IRMS). Nitrate is extracted and concentrated based on a recently published ion-exchange resin method (8). Freeze-dried $AgNO_3$ is packed in silver-foil cups and combusted within the reactor of an elemental analyzer using its existing reaction scheme for nitrogen and carbon analysis. $\delta^{15}N$ is determined using an isotope ratio mass spectrometer. Results are drift-corrected to an $AgNO_3$ working standard that has been calibrated against known $AgNO_3$. Despite high concentrations of carbonate, the precision for all runs is better than 0.10% (8). For precision, analysis of $\delta^{15}N$ was repeated on 50% of samples. Results from testing are in Table 8.

Variations of $\delta^{15}N$ values in groundwater are associated with different sources of nitrate. Three references were selected to compare the range of $\delta^{15}N$ values as either inorganic or organic sources. Kendall & McDonnell concluded that stable isotope values of fertilizers have $\delta^{15}N$ values generally in the range of -4 to +4‰. However, some fertilizer samples have shown a total range of -8 to +7‰. Values of $\delta^{15}N$ generally in the range of +10 to +20‰ are recognized as animal waste (7). Nitrogen from commercial fertilizers sources has $\delta^{15}N$ values from -2 to +8‰ (6). Fig. 6 displays a range of values as potential sources of nitrate. In accordance with the previous sources, animal waste is generally characterized with a $\delta^{15}N$ value of +10‰, which is why we suggest that MW-1, MW-2 and MW-3 are values closest to that of an organic source. The stable isotope values of $\delta^{15}N$ did suggest organic sources of nitrates with possible

overlap of inorganic fractions (fertilizer induced) for MW-4. A map of $\delta^{15}N$ values with respect to site location is seen in Fig. 5.

5.4 Nitrate in Soil

Soil analysis was completed by Dr. Nelson's Natural Resources and Environmental Science group.

6.0 Conclusion

Nitrate was the primary contaminant of concern at this site. Nitrate concentrations exceeding the MCL were found in the eastern and western edges of the property. Ammonium concentrations were at or below the detection limit, which is in accordance with the tendency of ammonium to be oxidized during nitrification. Trace concentrations of atrazine were also detected but were found to be well below MCL. The general groundwater flow is to the southwest indicating that the nitrates could be moving via advection to the south-southwest of the property. Conversely it could be deduced that the source of the nitrates may be northeast of the monitoring wells. Though this data allows for some degree of characterization of fate and transport, further data is required to justify firm conclusions. The addition of monitoring wells up-gradient and down-gradient from the current wells could shed greater light onto the source and extent of the nitrate plume. The data from the $\delta^{15}N$ stable isotope analysis indicates MW-1, MW-2 and MW-3, are probably from an organic source such as animal waste. The presence of the sale barn immediately upgradient of the MW-1 where concentrated animal activities may give an indication of possible organic nitrate source in the property. However, the contribution of the inorganic source is higher in MW-4 than in the others. . We can even postulate that the whole property may be divided into two zones. The eastern zone of this site, where KDHE previously detected elevated nitrates in the groundwater does appear to have an upgradient source from the sale barn. The western zone of this site does appear to have nitrate impact to soil and groundwater from apparent fertilizer handling operations. Data comparison showed evidence of two different sources of nitrate contamination.

7.0 Monitoring Plans for the area

Seasonal sampling and testing groundwaters for both contents of NO_3 and NH_4 are absolutely necessary in this study area. This study proposes that possible two sampling times should be designated: late October-early November during dry winter months, and later mid-late April during wet spring months. This could set some variation in the nitrate levels in the aquifer as it changes with the recharge processes.

8.0 References

1. EPA, 2009. Nitrates and Nitrites TEACH Chemical Summary. U.S. EPA, Toxicity and Exposure Assessment for Children's Health.

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TABLES

MW-1		
Depth (ft)	Amount Recovered (ft)	Description
0-0.5	0.5	topsoil
0.5-2.5	NA	Dark Brown Clay (very dry), Fill-cinders, gravel
5-7.5	1.4	brown clay (dry)- trace of calcareous nodules
10-11	1.5	yellow-orange sandy clay
11-15.5		yellow-orange calcareous sand, medium grading to fine with depth
15-17.5	1.0	poorly sorted yellow-orange calcareous unconsolidated sand with angular limestone gravel: weathered
20-22.5	1.8	hard, dry reddish-brown clay in upper and lower with clay clasts, includes gray mottling with very small non-calcareous crystals (sparkle in sun)
25-27.5	0.5	orange very fine non-calcareous sand with trace of silt, 2 in layer with same lithology but very dark gray color: wet at ~ 27 ft
30-32.5	1.5	upper 0.8 ft orange-brown slightly calcareaous wet clayey sand; lower 0.7 ft light gray dry clay
TD 30	NA	set 10ft of screen from 30-20ft; 10/20 sand pack then bentonite to surface

MW-2		
Depth (ft)	Amount Recovered (ft)	Description
3ft	NA	auger cuttings; orange clay-gravel mix
5-7.5	NA	tan-gray clayey sand with trace of gravel
10-11	0.9	sand with trace of silty caly; calcareous nodules
11	NA	hit rock
15-17.5	1.0	calcareous pooly sorted sand and limestone gravel
20-22.5	0.2	rusty brown poorly sorted sandstone with conglomerate and clacit cement
23ft	NA	end of Hord Formation
25-27.5	0.5	very oxidized sand with traces of silt; 6 in of water in borehole
30-32.5	0.5	very fine tan sand with silt and small amount of orange-tan gravel; saturated towards bottom
35-37.5	0.5	rusty clear brown silt with very fine sand; saturated
TD 33	NA	set 10ft screen from 33-23ft; 10/20 sand pack then enviroplug bentonite to surface

MW-3		
Depth (ft)	Amount Recovered (ft)	Description
0.5-3	2.5	0.5 ft brown clay with gravel, brownish-tan clay with silt (possible fill)
5-7.5	2.5	brownish-tan clay with silt, white calcareous nodules
10-12.5	1.5	light brown very fine sand with clay that decreases with depth
15-17.5	1.3	sand with traces of clay,3 in silty zone atop 3in of porly sorted weatherd rock at bottom
20-22.5	0.33	brown-tan calcite cemented conglomerate with broken fragmented limestone and sand intermix
25-27.5	0.1	fragmented limestone with small amount of clay
30-32.5	0.6	gray-brown sand with clay; saturated
TD 30	NA	set 10ft screen from 30-20 ft; 10/20 sand pack from 30-15ft then enviroplug bentonite to 2ft

MW-4		
Depth (ft)	Amount Recovered (ft)	Description
0-0.5	NA	topsoil, dark brown clay with rock and brick fragments (fill)
0.5-2.5	2	clay, light brown with sand and gravel (fill)
5-7.5	2.5	brown silty clay with nodules
10-12.5	2.5	yellow-brown to tan sandy clay with calcareous noduals, 3 in cleaner sand zone at ~ 12ft
15-17.5	1.2	yellow-orange moist sand with trace of silt and clay (cleaner with depth0
16-22	NA	rock: hard drilling, split spoon atempted at 20ft with small amount of calcarewous cemented poorly sorted sandstone and conglomerate with angular grains recovered. out of rock at 22 ft
25-27.5	1.4	gray and light brown-yellow mottled sandy silt with trace of clay
30-32.5	1.5	wet gray and tan mottled sandy silt with trace of clay: water encounterd at ~ 29-30 ft
35-37	1.2	yellow-brown fine sand with silt: saturated
TD 35	NA	set 10ft screen from 35-25 ft; 10/20 sand pack then enviroplug bentonite to surface

Table 1: Monitoring Well Borehole Soil Logging Data

Well Data						
Well ID	Latitude	Longitude	Survey (ft.)	Well Elevation (ft.)	Depth to GW (ft.)	GW Elevation (ft.)
MW-1	39.0097	-98.3911	2.44	102.96	23.11	79.85
MW-2	39.0098	-98.3938	5.3	100.1	22.85	77.25
MW-3	39.0093	-98.3938	5.59	99.81	23.8	76.01
MW-4	39.0092	-98.3941	6.35	98.87	24.75	74.12
Central Pt			5.4	100		

Table 2: Monitoring well location survey data and November 2011 groundwater elevation measurement. Note the nail elevation was 95.9 ft.

Slug Test: 6' long 1.25" diameter solid pvc			
Assigned Well elevation (ft)			200
Initial Depth (ft)			25.48
$Depth_0$ (ft)			24.4
H_0 = (well elevation - $depth_0$) - (well elevation - initail depth)			1.08
H_t = - (well elevation - $depth_t$) - (well elevation - initial depth)			
$Depth_t$	**t (s)**	**H_t (Ft)**	**$H_t/H_{0\,(Ft)}$**
24.4	0	1.08	1.00
24.45	10	1.03	0.95
24.5	20	0.98	0.91
24.57	30	0.91	0.84
24.55	40	0.93	0.86
24.58	57	0.9	0.83
24.6	64	0.88	0.81
24.62	79	0.86	0.80
24.65	95	0.83	0.77
24.67	118	0.81	0.75
24.7	149	0.78	0.72
24.73	183	0.75	0.69
24.75	200	0.73	0.68
24.77	233	0.71	0.66
24.8	267	0.68	0.63
24.81	298	0.67	0.62
24.83	320	0.65	0.60
24.84	346	0.64	0.59
24.85	357	0.63	0.58
24.86	384	0.62	0.57
24.88	416	0.6	0.56
24.89	448	0.59	0.55
24.9	480	0.58	0.54
24.91	504	0.57	0.53
24.92	537	0.56	0.52
24.93	600	0.55	0.51
24.94	654	0.54	0.50
24.95	733	0.53	0.49
24.96	800	0.52	0.48
24.97	931	0.51	0.47

Table 3: Data from aquifer slug test on MW-4

Well ID	pH	ORP (mV)	Sp. Cond. (µS/cm)	Temp. (°C)	TDS (mg/L)	LDO (mg/L)
MW-1	6.54	414	1536	16.44	0.98	7.71
MW-2	6.44	420	1720	17.33	1.1	9.2
MW-3	6.48	404	1930.6	18.98	1.23	8.11
MW-4	6.3	418	2056.3	16.33	1.32	8.19

Table 4: Water quality data

NO_3-N Results (mg/L)					
Sample ID	KSU BAE Labs	Continental Lab	Mean	Standard Deviation	RSK Values
MW-1	45.75	45	45.38	0.53	10
MW-2	7.13	NA	NA	NA	10
MW-3	19.4	NA	NA	NA	10
MW-4	45.05	37	41.03	5.69	10

Table 5: Groundwater nitrate laboratory analytical results

NH_4-N Results (mg/L)		
Sample ID	KSU BAE Labs	Continental Lab
MW-1	0.05	BDL
MW-2	0.03	NA
MW-3	0.01	NA
MW-4	0.06	BDL

Table 6: Groundwater ammonium laboratory analytical results

Atrazine Results (µg/L)			
Sample ID	KSU BAE Labs	Continental Lab	RSK Values
MW-1	BDL	BDL	3
MW-2	0.18	NA	3
MW-3	0.06	NA	3
MW-4	BDL	BDL	3
MW-3 Dup	0.09	NA	3

Table 7: Groundwater atrazine laboratory analytical results

Sample Name	$\delta^{15}N$	Result	Repeat
	NO3	AIR	
MW-1 (A12-03614-1)	X	13.13	13.14
MW-2 (A12-03614-2)	X	11.58	
MW-3 (A12-03614-3)	X	10.50	
MW-4 (A12-03614-4)	X	8.91	8.98

Table 8: Nitrogen Isotope Analysis of Groundwater from Activation Laboratories

FIGURES

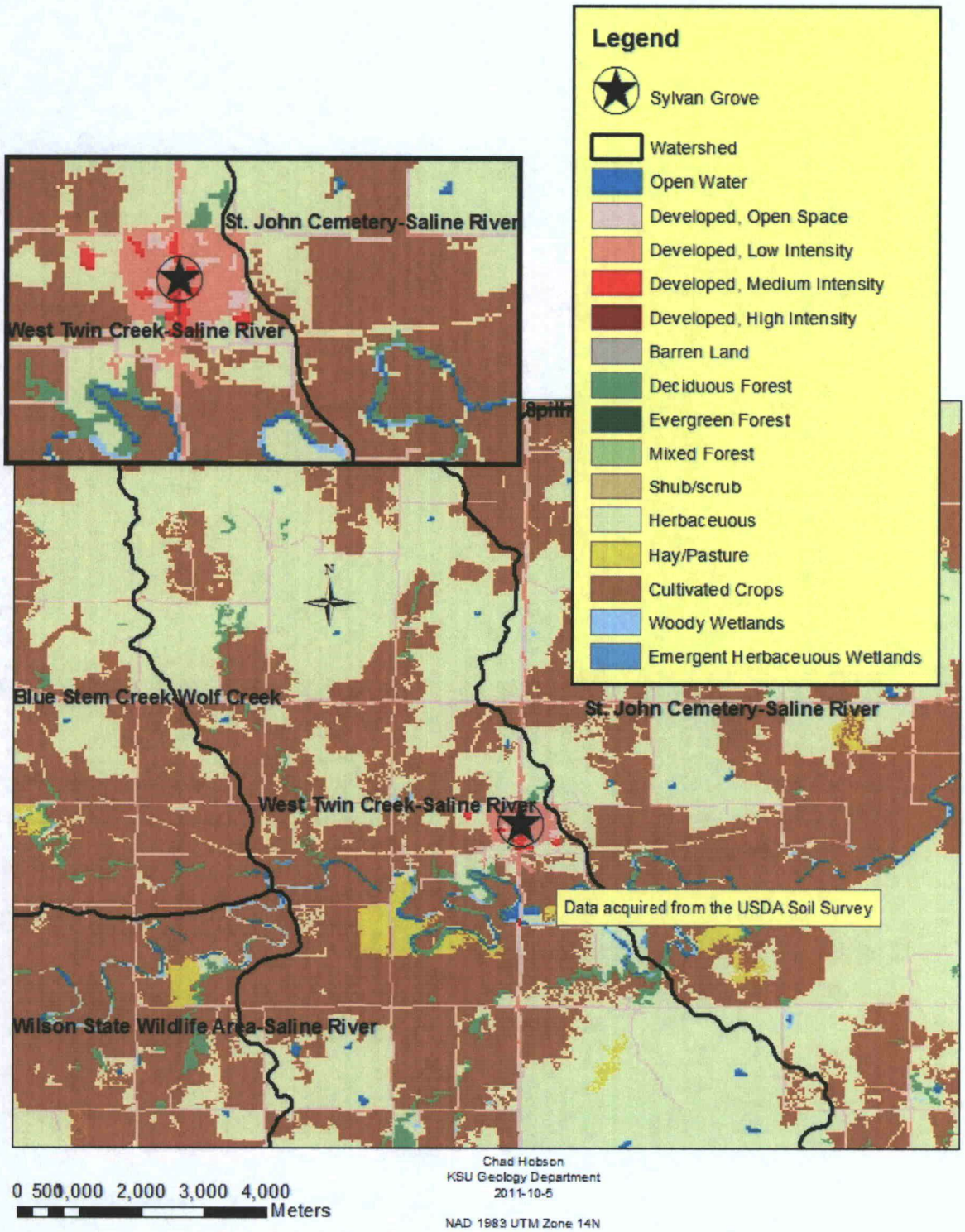
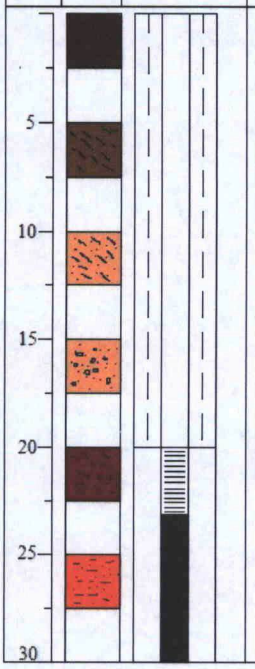


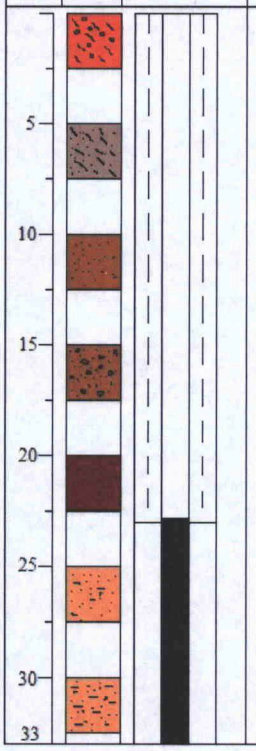
Fig. 1: Land use of area surrounding Sylvan Grove

MW-1



SEDIMENT DESCRIPTION	WELL CONSTRUCTION DESCRIPTION
TOPSOIL: Dark brown very dry clay and gravel (fill)	
	2" OD Schedule 40 Casing 0'-20'
CLAY: Brown dry clay with traces of calcareous nodules	0.010" Schedule 40 PVC Screen 2" OD 20'-30'
SAND AND CLAY: Yellow-orange calcareous sandy clay medium grading to fine with depth	
SAND AND GRAVEL: Pooryl sorted yellow-orange calcareous sand with angular limestone gravel; weathered	
CLAY: Hard dry reddish-brown clay with clay clasts; includes gray mottling with very small non-calcareous crystals (sparkle in sun)	
	Static Water Level 23.11'
SAND AND SILT: Orange very fine sand with trace of silt, 2" layer with same lithology but very dark gray color	
	Total Depth 30'

MW-2



SEDIMENT DESCRIPTION	WELL CONSTRUCTION DESCRIPTION
CLAY AND GRAVEL: Orange clay-gravel mix (fill)	
	2" Schedule 40 Casing 0'-23'
CLAY AND SAND: Tan-gray clayey sand with trace of gravel	0.010" Schedule 40 PVC Screen 2" OD 23'-33'
SAND: Sand with trace of silty clay and calcareous nodules	
SAND AND GRAVEL: Poorly sorted calcareous sand and limestone gravel	
SANDSTONE: Rusty brown poorly sorted sandstone with conglomerate and clacite cement	
	Static Water Level 22.85'
SAND: Very oxidized sand with traces of silt	
SAND AND SILT: Very fine tan sand with silt and small amount of orange-tan gravel	
	Total Depth 33'

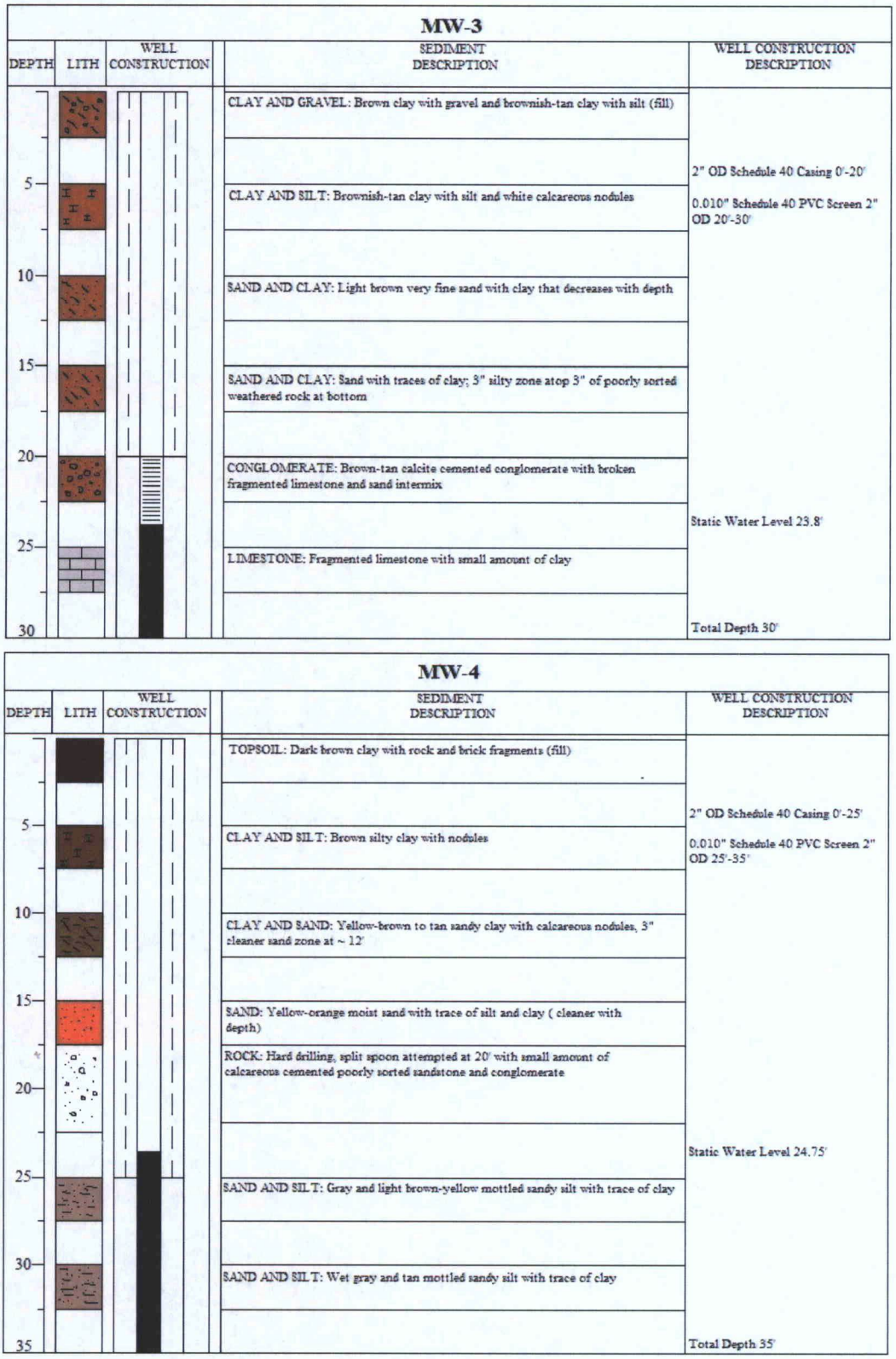
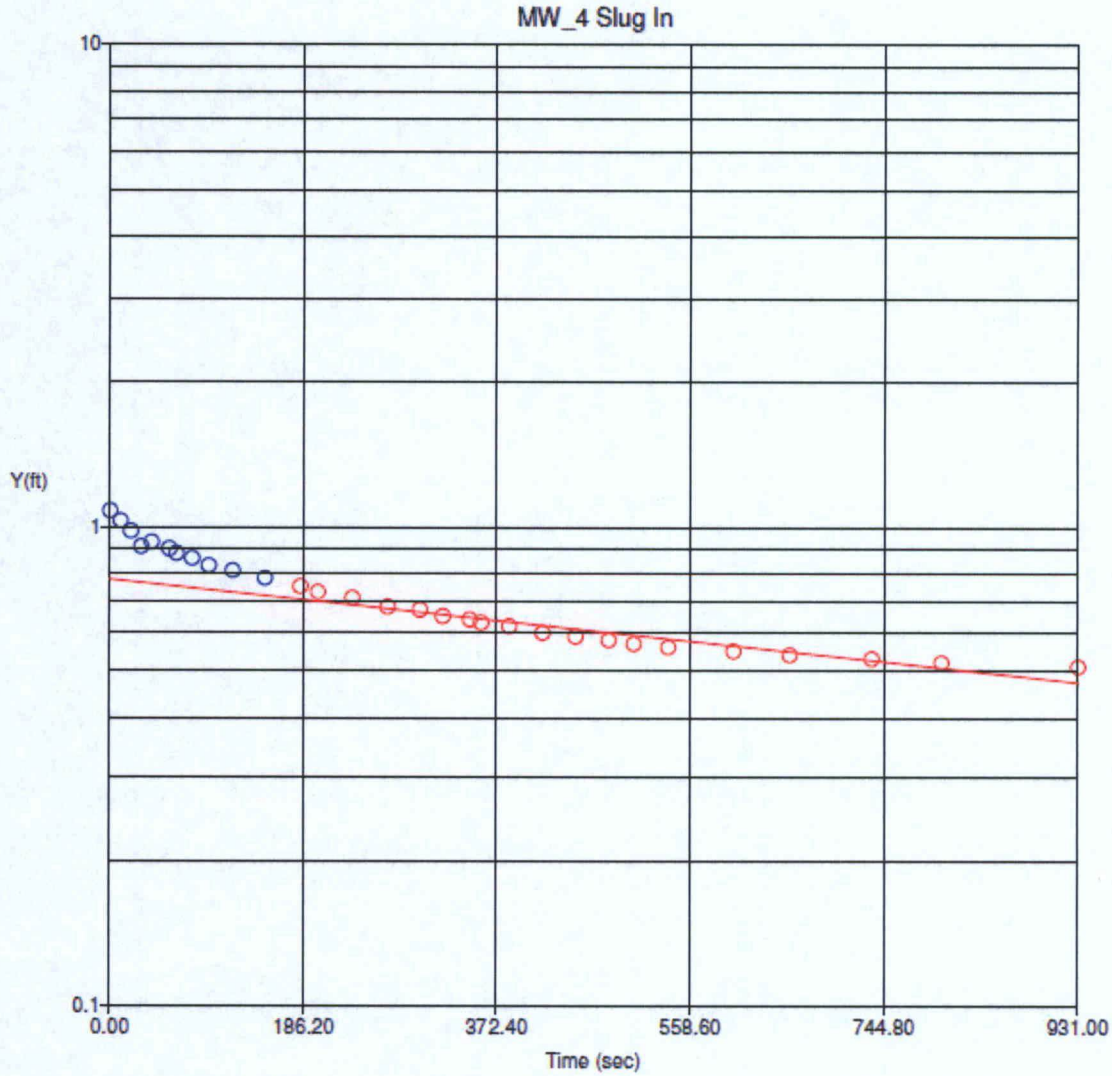


Fig. 2: Monitoring well borehole diagrams with well completion information



LUST No.:	Site Name: Farmers Elevator Company	
Hydraulic Conductivity: 7.50e-05 cm/sec	Well: MW-4 Slug Test	Slug Test Date: 11/11/11
	CGWP:	

Fig. 3: Graph of MW-4 aquifer slug test data

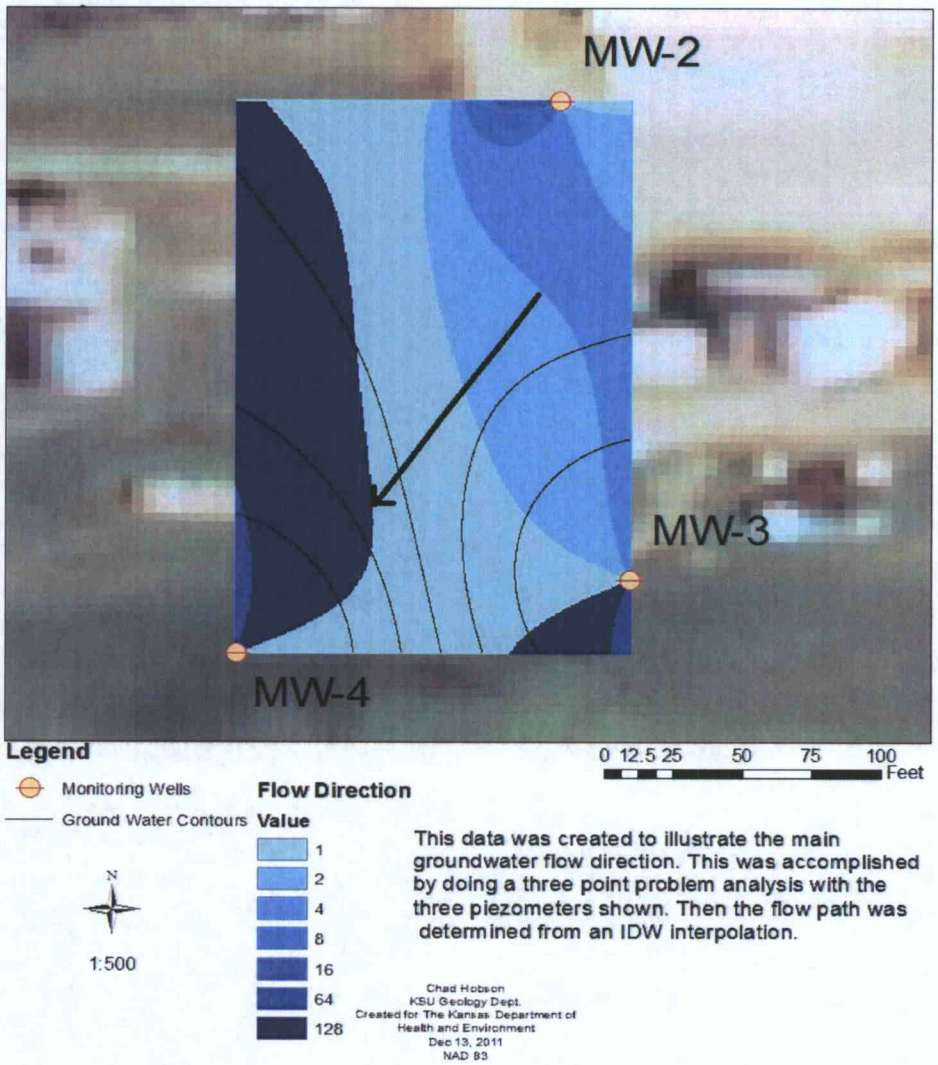


Fig. 4a: Hydrogeology of Farmer's Elevator Company, Sylvan Grove, KS, by three point calculation computer generated groundwater flow and potentiometric surface.

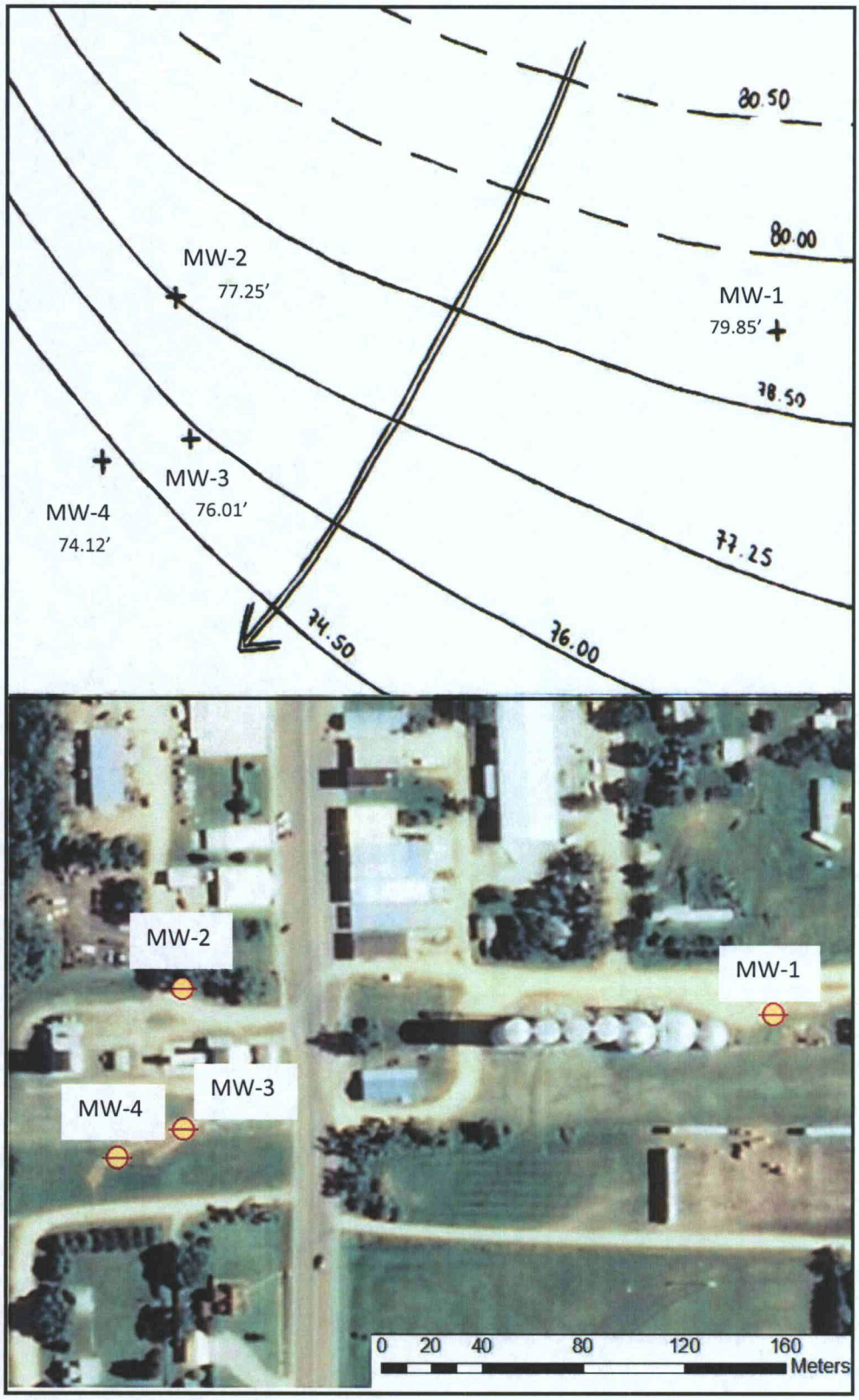


Fig. 4b: Hydrogeology of Farmer's Elevator Company, Sylvan Grove, KS, by three point calculation drawn by hand including well MW-1. Consult Fig. 5 for more detailed GW elevation etc. parameters.

Fig. 5: Wellhead elevation, nitrate values and $\delta^{15}N$ values at the monitoring wells

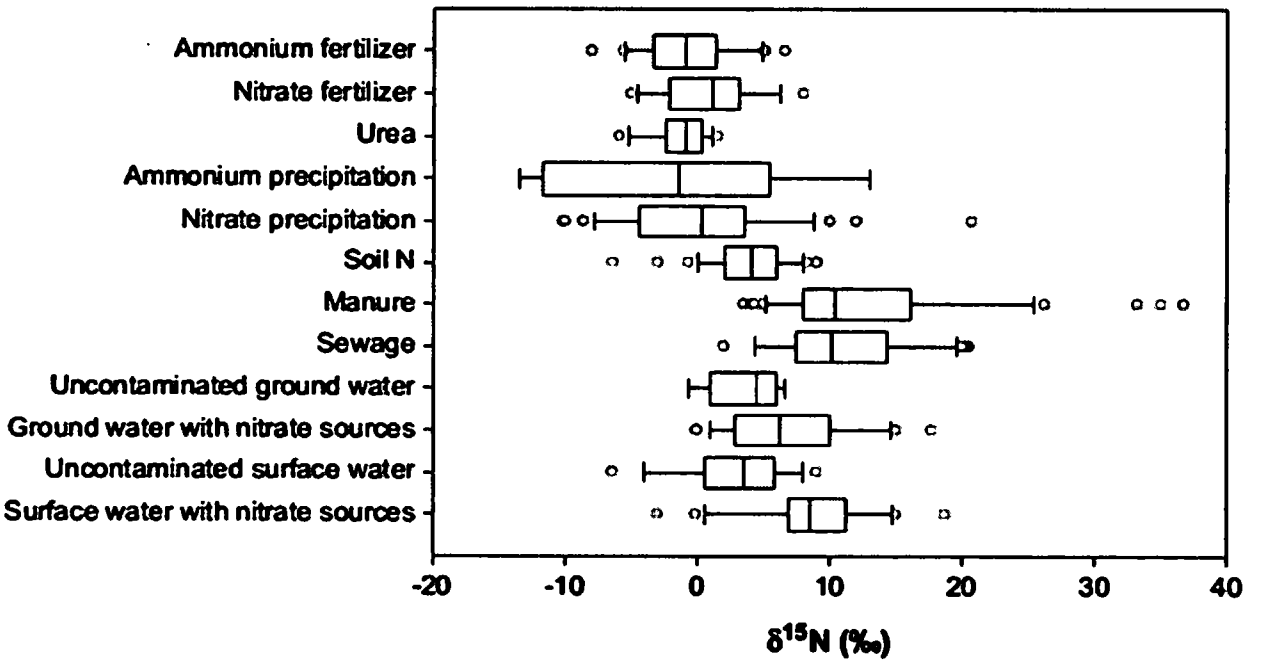


Fig. 6: $\delta^{15}N$ values of nitrates from various sources and sinks. Box plots showing 25th, 50th and 75th percentiles for $\delta^{15}N$ values of nitrates from various sources and sinks. The whiskers show the 10th and 90th percentiles, and the circles represent outliers (11).

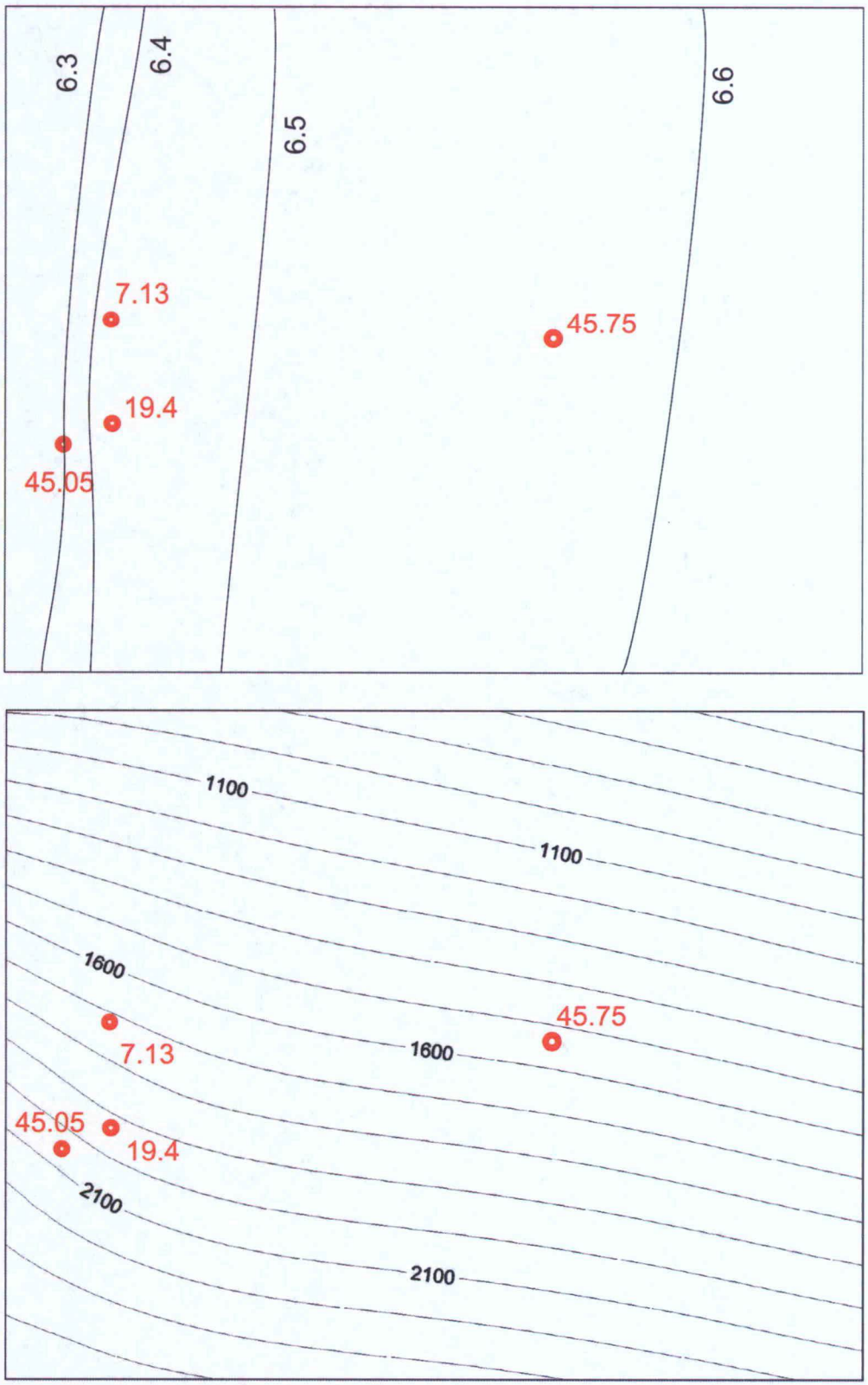


Fig. 7: Correlation of NO_3 (mg/l) distribution vs pH (upper) and conductivity(lower).

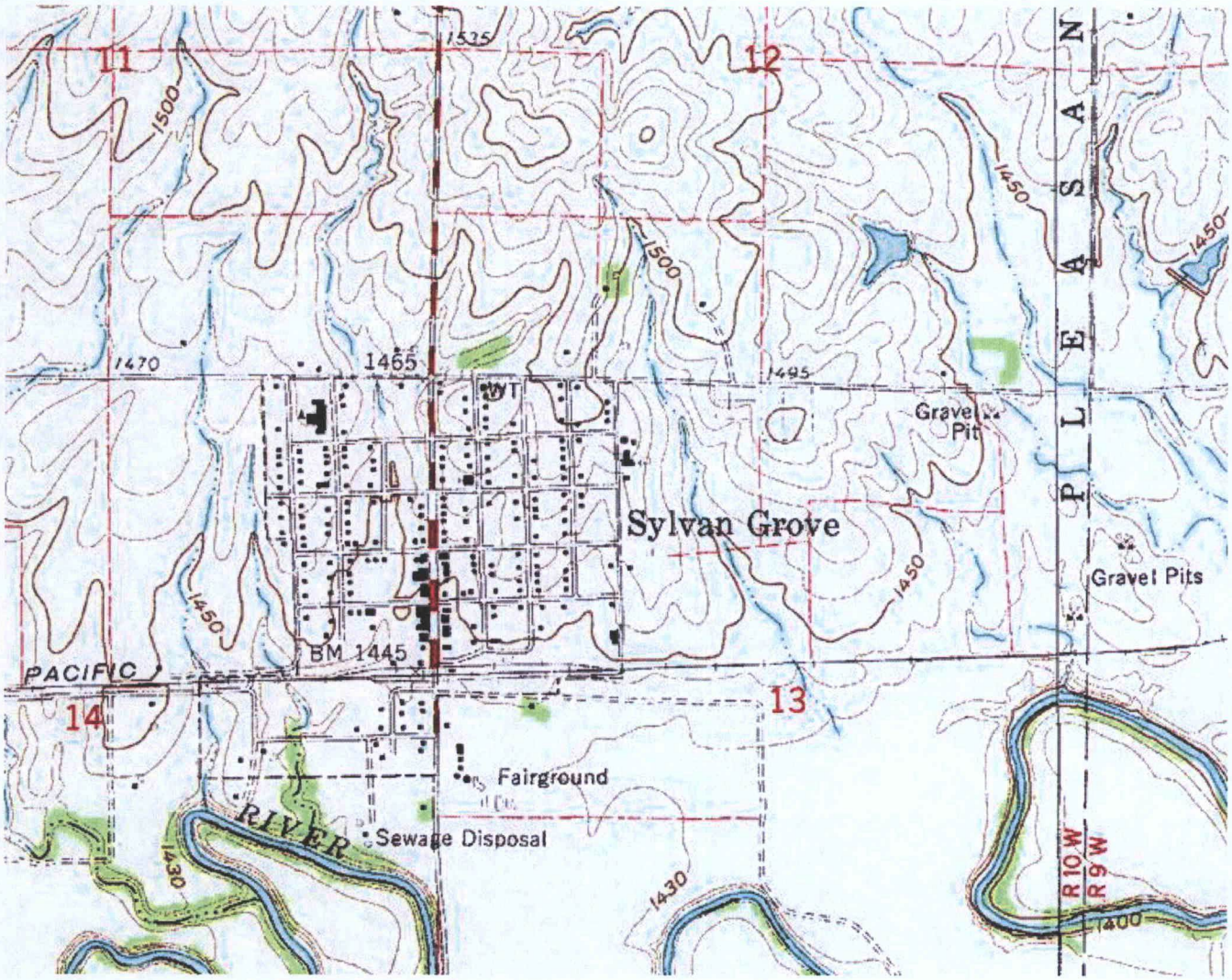


Fig. 8 Topographic profile of the Sylvan Grove Area