

# Sylvan Grove Farmer's Elevator Company

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## Corrective Action Study

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## **1.0 Historical Evaluation and Site Description**

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 right through our area that we are studying.

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. Barnard Grain Company and Miller Grain Company operated the facility since 1997. Each company operated the facility for approximately three years before filing for bankruptcy. Prior to 2002 (based on aerial imagery), a battery of liquid fertilizer storage tanks and a containment dike were installed on the site. These tanks remain on the site to this day, but have been cleaned and are no longer used for fertilizer storage. 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. 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.

Google Earth Images show the large scar seen in Figure 1 appearing between the 2006 and 2008 photo. There was nitrate contamination before, but this is when the spot where no plants can grow any more appeared.

## **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. This groundwater, as well as agricultural areas surrounding this site, has been seen to contain high levels of nitrates. Nitrate contamination is common not only in the Corn Belt, but also in Lincoln County. 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. This is worth noting, because 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**

According to KDHE's Site Reconnaissance and Evaluation at the Sylvan Grove site, the area on the eastern most side of the property displayed soil nitrate levels below the RSK values established for the state of Kansas. At Boreholes P-3 and P-5 of KDHE's 2008 investigation, the nitrate concentrations were also below RSK. Additionally, the area immediately surrounding the dry fertilizer storage container has been excavated in the past. Because these areas have either been tested by KDHE and deemed acceptable, or have already been excavated, they were not included in this sampling and investigation.



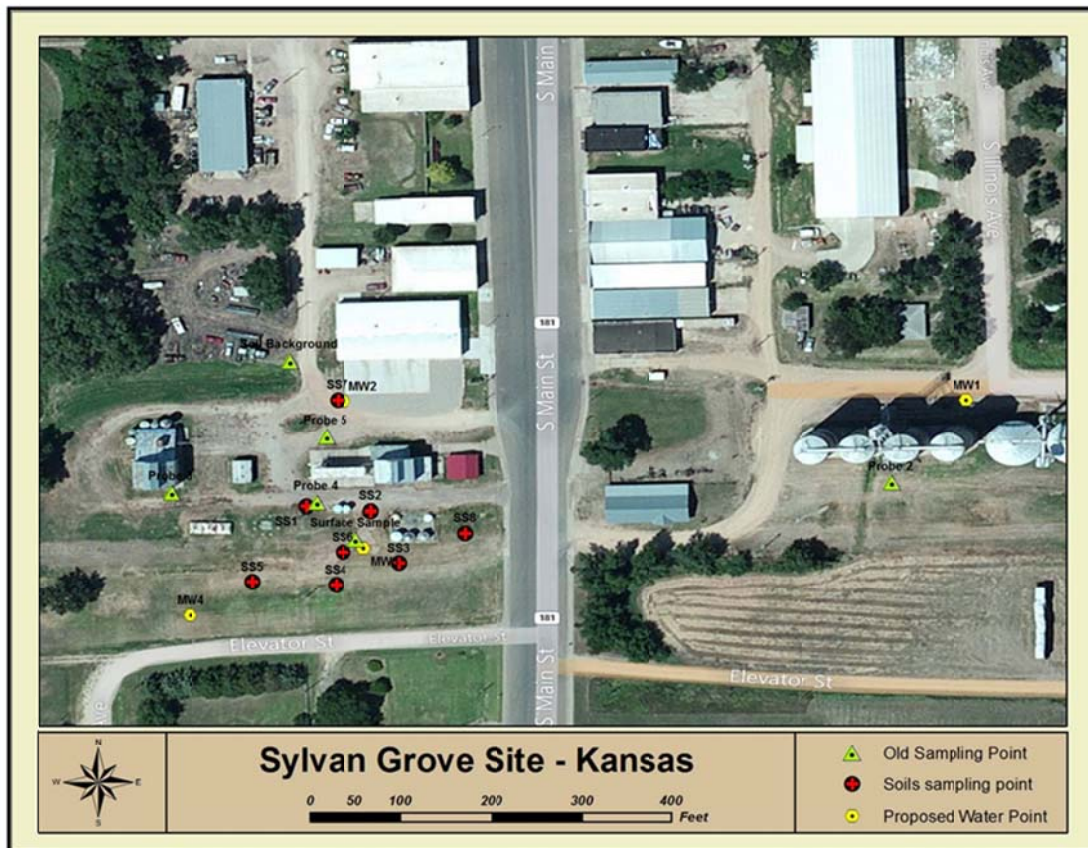
**Figure 1: Location of May 2008 Soil Samples**

This investigation's focus is the area south of the elevator and west of the sump. This general area revealed the highest nitrate contamination in the 2008 KDHE report and appears to have "scarring" typical of a synthetic nitrogen fertilizer spill. To determine the extent to which the nitrogen contamination is dispersed, a sampling plan has been devised as follows:

- A. A Giddings truck-mounted direct-push probe (properly decontaminated, according to guidelines in BER-05) was used to collect samples from suspect areas. Samples were

taken from eight identified locations on the property. Each location generated 4 subsamples; one interval sample for soil between 0-8 inches, another for 12-24 inches, a third sample for 48-60 inches, and a final for soil between 96-108 inches. Additional samples below 108 inches were collected if soil properties permitted. This allowed for development of the contamination profile both across and through the area of interest. The intention of this sampling plan was to determine both the boundaries of the contamination as well as the nitrate concentrations present at various depths through the soil profile.

- B. Probe sites 5 and 6 also had samples collected for texture analysis to help determine the hydraulic properties of the soil.



Sample collections took place in accordance to the Comprehensive Investigation Plan proposed to KDHE on November 3, 2011. A Giddings truck-mounted direct-push probe was used to

collect soil samples at the Sylvan Grove contamination site on November 10, 2011 and November 18, 2011. In attendance were: Professor Nathan Nelson, Kansas State University; undergraduate students Laura Kemp, Jeanna Walters-Fancella, Amy Vu, Noortje Crabtree, and graduate student Arthur Fink; and Kelsee Wheeler, KDHE. Exact locations of soil sample collection are listed in Table 1.

All investigators involved with the collection of soil samples used appropriate personal protective equipment including ear plugs, eye protection, closed-toe shoes, and disposable gloves. A safety radius of 16 feet from the probe was observed all those not operating the machinery. A first aid kit was available at the site

All equipment used for soil sampling was thoroughly cleaned between probe sites using a phosphate-free detergent and distilled water. After soil samples were extracted from the probe site, they were placed onto a collection trough, measured for the appropriate depth, and scooped into a plastic zip lock bag. Each sample was thoroughly blended. The soil was carefully transferred to glass jars and labeled with sample identification code, probe location, depth, and corresponding analytical laboratory. Each jar was placed in a plastic ziplock bag to protect the identification label and stored in a cooler, chilled to 4° C. Soil left over in the ziplock bag was then field tested for nitrate. Field screen tests were taken by using 30 mL of potassium-chloride solution with a soil sample added bringing the level to 40 mL measurement. A test strip was used as directed to indicate possible contaminants. Remaining soil was then transferred to a waste pile on site. This waste pile will be properly discarded after a composite nitrate analysis is made.

Any deviations from the initial comprehensive investigation plan were made either based on the results of the field screening or because, in the case of probe sites 3 and 4, the underlying media lead to difficult probe penetration and adjustments in sample collection.

Additional soil samples were collected on April 1, 2012. Hand driven soil probes were used to extract soil at locations S1 through S5 (Figure 2). Three samples at 0-8" and 12-24" depths were taken in a 1 meter radius around each location and were given values of A, B, and C. Each sample represents a single core. Thomas Grund, Albert Maurin, and Jack Sparks were in attendance. Samples were collected with hand soil corers at depths of 0 to 8 inches and 12 to 24



v

| Site ID | Probesite | Latitude  | Longitude |
|---------|-----------|-----------|-----------|
| s1      | 9         | 98.393383 | 39.009116 |
| s2      | 10        | -98.3937  | 39.009083 |
| s3      | 11        | -98.3941  | 39.009083 |
| s4      | 12        | 98.393983 | 39.00925  |
| s5      | 13        | -98.39433 | 39.0094   |

**Figure 2: Location of April 1, 2012 Soil Samples**

## **Sample Analysis**

Nitrate analyses were carried out by the Soil Testing Laboratory of Kansas State University. 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.

Analytical results indicate that nitrate contamination levels on the Sylvan Grove site range from minuscule to severe (Table 2). Highest contaminate levels were recorded at probe sites 5 and 6. It should be noted that these sites were located in the area displaying the most visual surface scarring. Analytical results of probe site 6 indicated nitrate levels of approximately 3,990 mg/kg in the upper eight inches of soil, far greater than the risk-based standard of 85 mg/kg for un-vegetated soils set by the state of Kansas. Probe site 5 is also significantly high in nitrate concentration. High nitrates were indicated during the field tests performed onsite, and an additional sample was collected from probe site 5 at a depth of 11-12 feet. The deepest samples collected at these two sites were above RSK, indicating that contamination extends beyond the scope of the plan and capability of the available equipment.

Additionally, soils below twenty-four inches have a risk-based standard (RSK) limit of 40 mg/kg nitrogen; samples from all but three of the probe sites were greater than the risk based standards for soils below twenty-four inches. Based on the soil analyses, probe site 3, located to the east of the sump, appears to be below RSK. Also, samples from probe site 7 and 8, located on the north side of the property and east side of the sump, respectively, were negligible in soil nitrogen levels.

Results from Continental Analytical Services agree well with results from the KSU lab (Table 3). Four samples collected for texture analysis are listed in Table 4.

**Table 1: GPS locations for soil sample collection**

| Soil Probe ID | Latitude |                 | Longitude |                 |
|---------------|----------|-----------------|-----------|-----------------|
|               | Degrees  | Decimal Minutes | Degrees   | Decimal Minutes |
| SP1           | 39       | 0.564           | -98       | 23.629          |
| SP2           | 39       | 0.560           | -98       | 23.625          |
| SP3           | 39       | 0.556           | -98       | 23.617          |
| SP4           | 39       | 0.555           | -98       | 23.628          |
| SP5           | 39       | 0.555           | -98       | 23.644          |
| SP6           | 39       | 0.558           | -98       | 23.627          |
| SP7           | 39       | 0.588           | -98       | 23.630          |
| SP8           | 39       | 0.562           | -98       | 23.605          |

**Table 2: Soil Testing results from KSU laboratory**

| <b>Sample ID</b> | <b>Probe Site</b> | <b>Depth(inches)</b> | <b>NH<sub>4</sub>-N (ppm)</b> | <b>N0<sub>3</sub>-N (ppm)</b> | <b>Inorganic Soil N (ppm)</b> |
|------------------|-------------------|----------------------|-------------------------------|-------------------------------|-------------------------------|
| 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                           |

**Table 3 Soil Samples Collected April 1, 2012.**

**(analysis performed by Kansas State University Soil Testing Lab)**

|  | Site ID | Probesite | Latitude   | longitude | NH4-N (ppm) | NO3-N (ppm) | depth (in.) |  |  |  |
|--|---------|-----------|------------|-----------|-------------|-------------|-------------|--|--|--|
|  | S1A     | 9         | -98.393383 | 39.009116 | 7.3         | 5.8         | 0-8         |  |  |  |
|  | S1A     | 9         | -98.393383 | 39.009116 | 5.6         | 7.4         | 12-24       |  |  |  |
|  | S2A     | 10        | -98.3937   | 39.009083 | 6.8         | 2.6         | 0-8         |  |  |  |
|  | S2A     | 10        | -98.3937   | 39.009083 | 2.6         | 0.9         | 12-24       |  |  |  |
|  | S3A     | 11        | -98.3941   | 39.009083 | 7.3         | 5.0         | 0-8         |  |  |  |
|  | S4A     | 12        | -98.393983 | 39.00925  | 8.2         | 11.7        | 0-8         |  |  |  |
|  | S4A     | 12        | -98.393983 | 39.00925  | 7.1         | 48.3        | 12-24       |  |  |  |
|  | S5A     | 13        | -98.39433  | 39.0094   | 7.2         | 5.6         | 0-8         |  |  |  |
|  | S5A     | 13        | -98.39433  | 39.0094   | 4.3         | 1.6         | 12-24"      |  |  |  |
|  | S1B     | 9         | -98.393383 | 39.009116 | 4.9         | 5.0         | 0-8         |  |  |  |
|  | S1B     | 9         | -98.393383 | 39.009116 | 4.2         | 4.6         | 12-24       |  |  |  |
|  | S2B     | 10        | -98.3937   | 39.009083 | 5.1         | 1.9         | 0-8         |  |  |  |
|  | S2B     | 10        | -98.3937   | 39.009083 | 4.2         | 0.9         | 12-24       |  |  |  |
|  | S3B     | 11        | -98.3941   | 39.009083 | 6.9         | 3.3         | 0-8         |  |  |  |
|  | S3B     | 11        | -98.3941   | 39.009083 | 5.7         | 1.4         | 12-24       |  |  |  |
|  | S5B     | 13        | -98.39433  | 39.0094   | 6.4         | 8.6         | 0-8         |  |  |  |
|  | S5B     | 13        | -98.393983 | 39.0094   | 4.5         | 2.6         | 12-24       |  |  |  |
|  | S1C     | 9         | -98.393383 | 39.009116 | 5.2         | 2.7         | 0-8         |  |  |  |
|  | S1C     | 9         | -98.393383 | 39.009116 | 5.1         | 2.1         | 12-24       |  |  |  |
|  | S2C     | 10        | -98.3937   | 39.009083 | 7.8         | 1.1         | 0-8         |  |  |  |
|  | S2C     | 10        | -98.3937   | 39.009083 | 5.3         | 0.6         | 12-24       |  |  |  |
|  | S3C     | 11        | -98.3941   | 39.009083 | 5.5         | 3.2         | 0-8         |  |  |  |
|  | S3C     | 11        | -98.3941   | 39.009083 | 5.0         | 0.9         | 12-24       |  |  |  |
|  |         |           |            |           |             |             |             |  |  |  |
|  |         |           |            |           |             |             |             |  |  |  |
|  |         |           |            |           |             |             |             |  |  |  |
|  |         |           |            |           |             |             |             |  |  |  |



## **4.0 Nature and Extent Characterization**

Four monitoring wells were installed at the field site by Geocore Geotechnical Services Inc. 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 out in the Work Plan.

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 first day, and MW-1 was completed the second day. Geocore Geotechnical Services Inc. from Salina, Kansas, provided the drilling services. An air rotary drill rig with a hollow stem auger and split spoon sampler was used to advance the boreholes for MW-1 through MW-4. Soil cores were collected as the auger was advanced. Wells were completed using a 2 inch PVC casing, with 10 feet 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 the borehole was filled with bentonite grout. Wells were completed with a locking cap and flush mount vault with concrete pad.

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 Teflon 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 to be developed after the above amounts were purged and visual observation indicated a reduction in turbidity. The samples were taken using disposable bailers, taking care to minimize any disturbance of the water column to prevent outgassing or degassing during collection. Collected groundwater samples from each well were containerized for transport to the laboratories in the following:

- 1) a 125ml plastic Nalgene HDPE bottle,
- 2) 50ml polypropylene centrifuge tube,
- 3) 60ml clear glass bottle,

- 4) 125 ml amber Nealgene HDPE bottle
- 5) 2 litre HDPE bottle
- 6) 1 1/2 litre amber glass bottle
- 7) 250ml 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. Two litre (HDPE bottles) samples are used for N-15 analysis. One 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 (and also preserved in a cooler under ice in field). Analysis of nitrate and ammonium was conducted by the KSU Soils Lab 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. Results from water analysis are summarized in Table 4.

**Table 6: Nitrate, ammonium, and atrazine analysis of well water**

**(samples conducted by the Kansas State University Analytical Services Laboratory and Continental Analytical Services Laboratory)**

| Well ID | KSU Laboratory     |                    |          |  | CAS Laboratory     |                    |          |
|---------|--------------------|--------------------|----------|--|--------------------|--------------------|----------|
|         | NH <sub>4</sub> -N | NO <sub>3</sub> -N | Atrazine |  | NH <sub>4</sub> -N | NO <sub>3</sub> -N | Atrazine |
|         | ppm                | ppm                | ppb      |  | ppm                | ppm                | ppb      |
| MW-1    | 0.05               | 45.75              | ND       |  | ND                 | 45                 | ND       |
| MW-2    | 0.03               | 7.13               | 0.18     |  | --                 | --                 | --       |
| MW-3    | 0.01               | 19.4               | 0.06     |  | --                 | --                 | --       |
| MW-4    | 0.06               | 45.05              | ND       |  | ND                 | 37                 | ND       |

## 5.0 Goals

The goals of the corrective action are as follows:

1. Contain the contaminant plume to prevent nitrate from moving off-site.
2. Reduce risk of groundwater contamination.

3. Recommend low-maintenance alternatives for ease of adaption.
4. Provide a cost effective, community approved operation of removal.

## **6.0 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:

- Overall protection of human health and environment
- Compliance with Federal and State applicable, or relevant and appropriate requirements (ARARs)
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility and volume of contamination through treatment
- Short-term effectiveness
- Implementability
- Cost
- Community acceptance

The four options presented are:

1. No Action
2. Excavation
3. Phytoremediation
4. Mixed Excavation and Phytoremediation

### **6.1 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 will. 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.

#### **6.1.1 Exposure Pathways/Health Hazards**

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 (9). While this groundwater resource 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.

Infants exposed to high nitrate concentrations in drinking water are susceptible to methemoglobinemia. This 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” (Denshaw-Burke, 2007).

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 (EWG, 2007).

Prolonged exposure to drinking water contaminated with high levels of nitrate can 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 (EWG, 2007).

### **6.1.2 Overall Protection of Health and Environment**

This alternative provides no additional protection of human health and environment. The current use conditions of the site and groundwater limit the potential exposure pathways and health hazards. This alternative may lead to the loss of this resource for future use. 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.

### **6.1.3 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 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 to protect groundwater from excess nitrate inputs from nitrate leaching.

## Soil Maximum Contaminant Level (Bureau of Environmental Remediation)

- Vegetation Present
  - 0-24" of soil = 200 mg/kg (nitrate + ammonia N)
  - 24"+ of soil = 40 mg/kg (nitrate + ammonia N)
- No Vegetation Present
  - 0-8" of soil = 85 mg/kg (nitrate + ammonia N)
  - 8"+ of soil = 40 mg/kg (nitrate + ammonia N)

### **6.1.4 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 soil sample 6 (Table 4) natural processes would not be able to alleviate the contamination in the short-term or long-term.

### **6.1.5 Reduction of Toxicity, Mobility, or Volume**

There will be minimal reduction of toxicity, mobility, or volume with this alternative. Denitrification may reduce the contaminant over time, but this process is very slow and requires anaerobic soil conditions.

### **6.1.6 Implementability**

The "Do-Nothing" approach is the simplest remedial action since no additional labor or inputs are required for implementation

### **6.1.7 Cost**

There is no immediate cost associated with a do nothing approach. However, because there are no efforts to contain, there is a risk of contaminant transport to adjacent properties, which can result in civil pollution, fines and landowner claims in the future.

### **6.1.8 Community Acceptance**

The benefit of no action for site remediation is that it causes no disruption of the site and surrounding areas. Other approaches exercise the use of large, noisy, industrial equipment that can introduce noise pollution as well as traffic hazards during their operation. No action will not employ these undesirable procedures and will leave the site undisturbed. The location of the site is in the downtown area of Sylvan Grove that is exposed to moderate traffic levels that would have to be adjusted if any other remedial action is accepted.

## **6.2 Alternative 2**

Excavation at this site would consist of the removal of soil in the areas determined to be of the highest concentration, as shown in figure 4. Using GIS analysis we estimate the area to be cleared is 75 by 60 feet directly above the area of highest concentration. The plot would be excavated to 2 feet deep, resulting in a total of 9000 cubic feet of soil needing to be removed. 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) If the \$80 a cubic yard estimate the cost of the proposed excavation would cost \$26,600. The removed soil will be taken to a landfill due the high gravel content and other undesirable contents of the soil. <sup>t</sup>

### **6.2.1 Overall Protection of Health and Environment**

If current groundwater and site use conditions remain the same, the removal of contaminated soil above RSK levels would provide complete protection from future nitrate leaching on-site. Health hazards may be present at the soil disposal site, however. Soil brought to a landfill has the potential to leach into groundwater in the event of an absent or torn landfill liner

### **6.2.2 Compliance**

The proposed area of excavation would clear some of the highly contaminated areas, but concerns with utilities and soil composition, make complete compliance of KDHE regulations by pure excavation very difficult.

### **6.2.3 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, making this method not effective in the long run. Proper plants should still be established to absorb whatever nitrate remains after excavation.

### **6.2.4 Reduction or Toxicity, Mobility, or Volume**

The volume of soil removed is 333 cubic yards resulting in a reduction in the toxicity of the site but as shown total reduction will be very difficult to achieve. The removal of the soil may also contribute to lowering the probability of contamination mobilization across the site.

### **6.2.5 Implementation**

The excavation of the soil at this site may prove to be a difficult task. The utilities were requested to be marked before the last site visit but were not. Based on the site history we know that there are utilities running through the plot creating an obstruction for excavation attempts. These utility lines must be located before excavation. Along with utilities, there was a railroad that used to run through the site, leftover debris or railroad materials could pose a threat to excavation equipment.

### **6.2.6 Cost**

The cost for excavating 333 cubic yards of soil was calculated to cost around \$26,600. This was determined from an estimate obtained from costowl.com

### **6.2.7 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. Overall community acceptance may be low due to short term impacts, but may increase after the contaminated soil has been removed and replaced.

## **6.3 Alternative 3: Phytoremediation**

### **6.3.1 Description**

This proposal is to implement a two-tier system where area of land near the scar is native grasses and the further away land is cottonwoods and grasses to ensure containment of nitrate contamination. First, the vegetative grass cover on and surrounding the contaminated soils will be established and will help slow the groundwater flow while removing some nitrogen. This could potentially be harvested and removed if remedial action is favored over containment only. Next in the path of the groundwater flow will be an initial linear planting of ten cottonwoods in the drainage ditch just downhill of the site, which will later be thinned to the best spaced and strongest four trees. The plants have been selected to best prevent movement of nitrate off site by selecting species that evapotranspire more than the 22" average rainfall, greatly reducing the ability of the nitrates to leach out of the soil, and species with deep, extensive root systems. The roots will uptake nitrogen from soil and groundwater, bringing it to the surface and converting it into a more stable organic form. If removal of nitrate is desired, the grass could be harvested giving the resource of high nitrogen organic that could then be spread as green fertilizer on agricultural fields at proper application rates, or it could be blended with less nitrogen dense feed and fed to live stock. If nitrate removal is not a priority, the nitrogen dense material can be left in place to naturally decay and feed the soil biome where it will be converted to a much more stable soil component called humus. Our analysis is based on multiple factors including cost, effectiveness, amount of maintenance required, aesthetics, and other factors listed in greater detail below.

This will be less expensive than excavation alone, but without excavation of surface soil having more than 200ppm Nitrogen, it is unlikely that the desired native plant species will be

able to grow directly in the most contaminated soils, due to excessive nitrate levels leading to potential toxicity to plants.

### **6.3.2 Exposure pathways/Health hazards**

The plants will be able to phytohydraulically slow the movement of nitrate to the river and to other water sources. Due to existing riparian buffer (4) in place between the site and river, during normal weather conditions surface and groundwater will be highly filtered through roughly half of a mile of roots and soil before reaching the river and flowing past Sylvan Grove eventually reaching the Gulf of Mexico. The natural filtering ability of vegetation and soil greatly buffer and slow the movement of nitrates down the hydraulic gradient. Along with that species we have chosen use more water than what is coming into the area, making it so that water and nitrates are not leaving their root zone (contamination site) reducing the potential of the nitrate contamination reaching outside of the groundwater under the site. Further reduction of risk can be accomplished with the implementation of the second part of the suggested phytoremediation strategy, by placing the cottonwoods, or stronger second wall of phytohydraulic defense, directly in the path of the ground water downhill from the site, insuring that any ground water potentially carrying nitrates that made it through the grass will then be pulled up through the soil by the evapotranspirational pull of the tree and then be converted into stable organic forms. Due to the location of Sylvan Grove's wells away from the path of the groundwater flow, the drinking water supply would not be contaminated.

#### **Consequences**

The native plants species to be installed will phytohydraulically slow nitrate movement as well as take up nitrates over time reducing overall nitrogen concentrations. The legal risks of the nitrate moving off site associated with no action will be reduced to negligible amounts. Some maintenance such as watering and mowing or harvesting will be required to maximize nitrate uptake, and minimize time of remediation and the movement of contaminated groundwater.

### **6.3.3 Implementability**

A combination of cottonwoods (poplar) and native grasses such as Yellow Indian grass or Big Bluestem would be best to minimize irrigation and maintenance needs while easing

implementability. The plan would also provide: the desired ET rates needed to phytohydraulically contain nitrates onsite slowing nitrate movement throughout the soil profile, an extensive root systems with adequate ability to reach and filter mobile nitrates that have already leached in groundwater, as well as adding vegetative protection to the currently barren area of soil from any farther significant surface erosion. Several factors have been considered for the final plant selection and design including but not limited to; climate, weather, required tools, ET rates of many plant species, Nutrient up take rates of varying species, Soil quality factors, contaminant location/depth, plant growth requirements and limitations, Root/contamination depths/area, legal restrictions, physical restrictions such as utilities/facilities/. /. Our sketch of where the plants will be planted in this remediation option is shown below. An analysis of the plant types is presented next.



Figure 1: Placement of Cottonwood trees and Big Bluestem and Indian Grass for phytoremediation option

Willow trees have a very widespread and aggressive root system that seeks out moisture, resulting in high evapotranspirational pull. This could be a good addition to have the aggressive root system near the very high concentrations of nitrate.

Eastern Cottonwoods have an exceptional growth rate and (2) can absorb up to 350 gallons of water per day. (8) Cottonwood's average root depth is 10 feet, but can reach over 30 feet deep in search of water. The combination of these characteristics, along with accounting for average rain fall rates of 22"/year, would best provide the capability to inexpensively hinder the movement of the contaminated groundwater away from the site. The Cottonwoods will be planted 15 feet apart from each other. (cheyennecity.org Cottonwood Trees: Facts and Informaion) ET Rates for cottonwoods in the area average a hydraulic pull of 0-200+ gallons water per day (NELSON, 2011) which far exceeds the inflow of 22 inches per year average rainfall, therefore creating a phytohydraulic barrier the mobile nitrates will not be able to translocate beyond under average weather conditions. (12).

Big Bluestems 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. Combining these traits with trees in a tiered system would confine the contamination very well and not require nearly as much maintenance as a non-native species. Big Bluestem has also been found to be very shade tolerant compared to other warm-season grasses, so this would be planted 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.

Potential problems - Environmental conditions that reduce/stop plant growth

- Summer drought – this would make the grass and trees better option.
- Alfalfa will take lots of maintenance and watering
- Persistent cloudiness or plants growing in shade
- Unseasonal hot or cold weather
- Research – Root shields for deeper water table,

#### **6.3.4 Overall Protection**

The proposed method of using trees with native grasses will contain the nitrate exceptionally well with less maintenance and implementation costs than other options, besides no action. The nitrate could be removed over time, but the containment of the phytohydraulic pull would protect the residents from risk under all normal weather conditions.

### 6.3.5 Compliance

For this site to comply with the requirements for maximum nitrate levels, then specific details about the site must be known, as the requirements are different in different cases. First, we must know that the water table is less than 50ft. deep in our whole site. Water table depth is important because nitrates travel via free water molecules not bound to any soil. The ground water is a perfect example of a large body of that with large potential to move nitrates.

The next nitrate limit that applies to our site is the limit for no vegetation. This applies to the big scar in the middle of our site. The policy with no vegetation is in the first 0-8" of soil, the Total N limit is 85ppm N, and for 8" one, then the total N limit is 40ppm.

The Lower acceptable concentrations are due to the higher potential of leaching/surface erosion associated with barren soil. A vegetative cover helps protect soil surface as well as allowing evapotranspiration of water up and out of the soil. This reduces the amount of water that leaches through the profile potentially carrying mobile nitrates with it and is why it is very important that we establish vegetative cover in areas that are currently barren soil.

If vegetation is present, then the first 24" of soil have a total N limit of 200ppm N, and deeper than 24" has a total N limit of 40ppm N. This applies to areas at the site outside of the barren zone where grass is growing.

The higher acceptable value when vegetative cover is present is due not only to the evaporative pull all living plants have, which will reduce the amount of water and potential nitrates that leach through the soil system, but also the cover protecting the soil from surface erosion. The roots not only help hold the plant in place but also keep the soil and its contents together.

The estimates for number of years it will take to lower nitrogen to correct levels with best option selected (grass and trees) were difficult because no studies were found with concentrations of nitrate as high as our site. There is no data on nitrogen uptake by cottonwoods in high nitrogen environment, so they will be classified as containment only for this basic calculation. If the grass

species average (20lbs n/ac/yr) for this area, cleanup of hotter spots (where concentrations are close to 5000ppm N) could take up to 240 years to lower the highest concentrations to 200ppm, the legal limit with vegetation. This calculation also assumes that the grass is being harvested and removed. If no OM is withdrawn from the site, the nitrate will be pulled up to the surface and converted to organic forms. These will eventually break down, mineralize, and once again be in the soil as ammonium and nitrates. The cycle will continue as the nutrients will be once again contained through phytohydraulics and assimilated by plants. Less leaching should occur as the nitrogen will get immobilized and incorporated into plant matter and the biotic community. The reduction of nitrogen concentration would be minimal and from denitrification in the anaerobic portions of the lower soil profile near or below the water table. However, the nitrates converted by plants would be turned into very stable organic forms without potential to leach and leave the site.

If cost is a primary concern and immediate removal of the nitrate is not prioritized, this option will get the job done over a much longer time period, but at a lower cost than the excavation and phytoremediation option.

Knowing these policies can help this sit move towards compliance because if we are able to get plants to grow on the scar eventually, then we can have higher nitrate concentrations in top 24” of soil. The nitrate will be more locked up with plant cover and is less likely to be leached into the groundwater.

#### **6.3.6 Effectiveness**

The time frame will be longer for the tree grass mix remediation than with excavation, and potentially little remediation could occur if organic materials are not removed from site. With the evaporative/transpirational pull on site of the grass and downhill from eastern cottonwoods, the nitrate will be hydraulically retained except for the rare leaching of minimal amounts of nitrates into adjacent ground water during abnormally strong storm surges. This option will work well for all parties involved to achieve the desired outcome

### **6.3.7 Implementability**

Utilities above and below ground may interfere with plant selection further away from the high nitrate scar. A good portion of the surface scar covers an area where utilities are known to be buried. It is important to contact the utility company to mark buried cables and lines prior to any excavation operation.

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.

Another obstacle to plant establishment is the large nitrate scar that currently has no plants growing in it. The best bet to address this is to plant the Indiangrass and Big Bluestem as near as possible to the scar in the direction of the groundwater flow. The deep roots will filter the water and absorb some nitrate, allowing the plants to extend their boundary into the scar and eventually overtake it as the plants do their work to clean up the contamination.

Initially, installation and maintenance until the plants get established will be required. This will include watering the plants when they need it, taking out the weeds, and harvesting the Big Bluestem and Indiangrass when they are established and nitrate removal is required.

### **6.3.8 Cost**

Inexpensive to establish, however plants must be maintained through irrigation.

Costs of plant material along with maintenance and harvesting.

\$24 for 10 cottonwood trees\* 1 = \$24 (14)

\$12 for 1 lb. of big bluestem seeds \* 5 = \$60 (15)

\$14 for 1 lb. of Indian Grass seeds\*5 = \$70 (16)

Estimate of 100 hours of total labor for installation and maintenance at \$20/hour = \$2,000

Monitoring the nitrate in the water: \$200 / sample \* 10 samples over time = \$2,000

Total cost = \$4,154

### **6.3.9 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 take care of most of the risk associated with this contamination by containment and retarding groundwater movement.

Also, it will require minimal maintenance after being established and should be aesthetically pleasing.

## **6.4 Alternative 4: Mixed Excavation and Phytoremediation**

### **6.4.1 Description**

This alternative combines the excavation of the most contaminated soil and the phytoremediation actions covered in section 6.3. The contaminant model in Appendix A shows the proposed area of excavation for this alternative. The area is approximately 20 yards by 25 yards in size. The area that is proposed for excavation in this alternative is the main area of the scar, an area of 5 yards by 10 yards. This area is to be excavated to a depth of 24 inches. This value is conservative due to the location of utilities in relation to the highest concentrations. At this area and depth approximately 100 cubic yards of soil need to be excavated and backfilled. The excavated soil is to be brought to a landfill, as land application is unfeasible due to debris and gravel within the soil.

In the areas right near the scar where we know the contamination runs deeper than 2 feet and we know the utilities are not nearby, we suggest extracting deeper than 2 feet. The 100 cubic yards is an estimate for the total removed.

This alternative still uses the same plant design as presented in the phytoremediation section. The grasses will grow much better in the new replaced soil over the heavily nitrate contaminated soil before. The cottonwood growth should be unaffected except due to some unintended soil compaction from the heavy excavation equipment. The grasses will be established with proper maintenance after 2-3 years, and the cottonwood should be established after 10 years. The cottonwoods have lives of around 100 years, so once they are established, the flow of the nitrate in the groundwater should be contained.

This option has the best short and long term remediation, at a much lower cost than just excavation. The phytoremediation option is cheaper, but will not have much of an instant impact on the nitrate levels. If overall removal and containment of the contamination as well as restoration of the area's biota and aesthetics is desired, then this is the best option.

#### **6.4.2 Overall Protection**

Combining excavation and phytoremediation techniques will provide sufficient protection of the subsurface groundwater. With the areas of greatest nitrate concentration removed from the site, the cottonwoods and grass will be able to grow without impedance. The roots of the cottonwood tree have the potential to reach the water table and directly remove nitrate through absorption. Tree roots will also retard the downward infiltration of water as they absorb water moving through the soil profile. Through evapotranspiration the water absorbed by the tree roots will ultimately end up being released into to atmosphere. The grass will stabilize the surface layer of the soil profile by taking up water and reducing the effects of leaching. The denser the grass cover is planted, the more water can be removed through transpiration.

#### **6.4.3 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 most nitrate contaminated soil in the short-term. The plants will clean up the nitrate over time. We expect the whole plant system to be established after 10 year, the contamination should be lower than the maximum in about 20-30 years, versus the 240 years calculated for phytoremediation alone.

#### **6.4.4 Effectiveness**

The short-term effectiveness is high due to the mechanical removal of highly concentrated soil. After plants have been established the nitrate levels will continue to decrease as the plants take up the nitrogen, establishing long-term effectiveness on the site. The plants should also contain the nitrate until it is absorbed over time.

#### **6.4.5 Reduction of Toxicity, Mobility, or Volume**

This alternative will immediately reduce the volume of contamination, with 100cubic yards of contaminated soil being removed. The mobility of the contaminant will also be reduced by cottonwood trees planted down-gradient of the contaminant plume.

#### **6.4.6 Implementability**

The location of utilities across the site makes for difficult excavation and limits the available locations to plant vegetation. Soil conditions and debris beneath the site may also make excavation difficult, as the bed of an abandoned railroad runs through the site. The subsurface compaction pan may prove to be an obstacle for planting trees, but the grass can be planted with no additional effort.

#### **6.4.7 Cost**

Sweet's 2002 Unit Cost Guide provides a cost of \$25.19 per cubic yard of earth that is excavated and backfilled. This cost includes labor, materials, and overhead. . In the excavation section, a much higher estimate is given that includes the offsite transport and disposal. We took a cost that was in the middle, \$80 / yard<sup>3</sup>. This alternative would add an additional cost of approximately \$8,000 to the project. This cost may be reduced if local equipment, material, and labor are used.

If similar costs are kept from the phytoremediation option, then the plants and labor to install, maintain, and monitor will cost \$4,154. This brings the total cost to \$12,154.

The cost is higher than the No Action and Phytoremediation option, but it has the advantage of taking care of the nitrate much quicker and solving the problem in decades rather than centuries.

#### **6.4.8 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. Overall community acceptance may be low due to short term impacts, but may increase after the contaminated soil has been removed and replaced. Once plants are growing in the area that was the barren scar, we believe that the community will be much more accepting of

the project. Also, when the cottonwoods are growing along the road and protecting the citizens of the community from nitrate movement into the groundwater, then we feel that they will be glad that the contamination problem is on its way to being solved.

## **7.0 Recommendation for Corrective Action**

The recommended remedial action will implement the phytoremediation/excavation combination. This plan presents the highest short-term effectiveness through excavation of the area of highest concentration. The long-term effectiveness is also substantial as the implemented vegetation will continue to reduce the contaminant levels over time. Using the phytoremediation and excavation actions will adequately address all of the corrective action goals in an environmentally friendly manner.

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. This option will move the main contamination offsite and will contain the rest through the use of the phytoremediation.

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. Also, the plants will control the hydrology of any remaining nitrate and prevent it from leaving the site once the plants get established. The option we recommend is the best at addressing this specific concern.

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

To reduce the amount of maintenance and save money, less monitoring of the wells could be done. Also, the residents of Sylvan Grove could let other grass species invade into our area and go for a less labor intensive, more bio-diverse approach.

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

The total cost will be \$12,154. The cost can be reduced by using local equipment and labor rather than contracting out the work. Also, if one of the residents can make his or her own cuttings of cottonwood or has the Big Bluestem and Indian Grass seeds, this will save money as well. 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. The main aspect that the community may not like about this option is that it costs more than the other options.

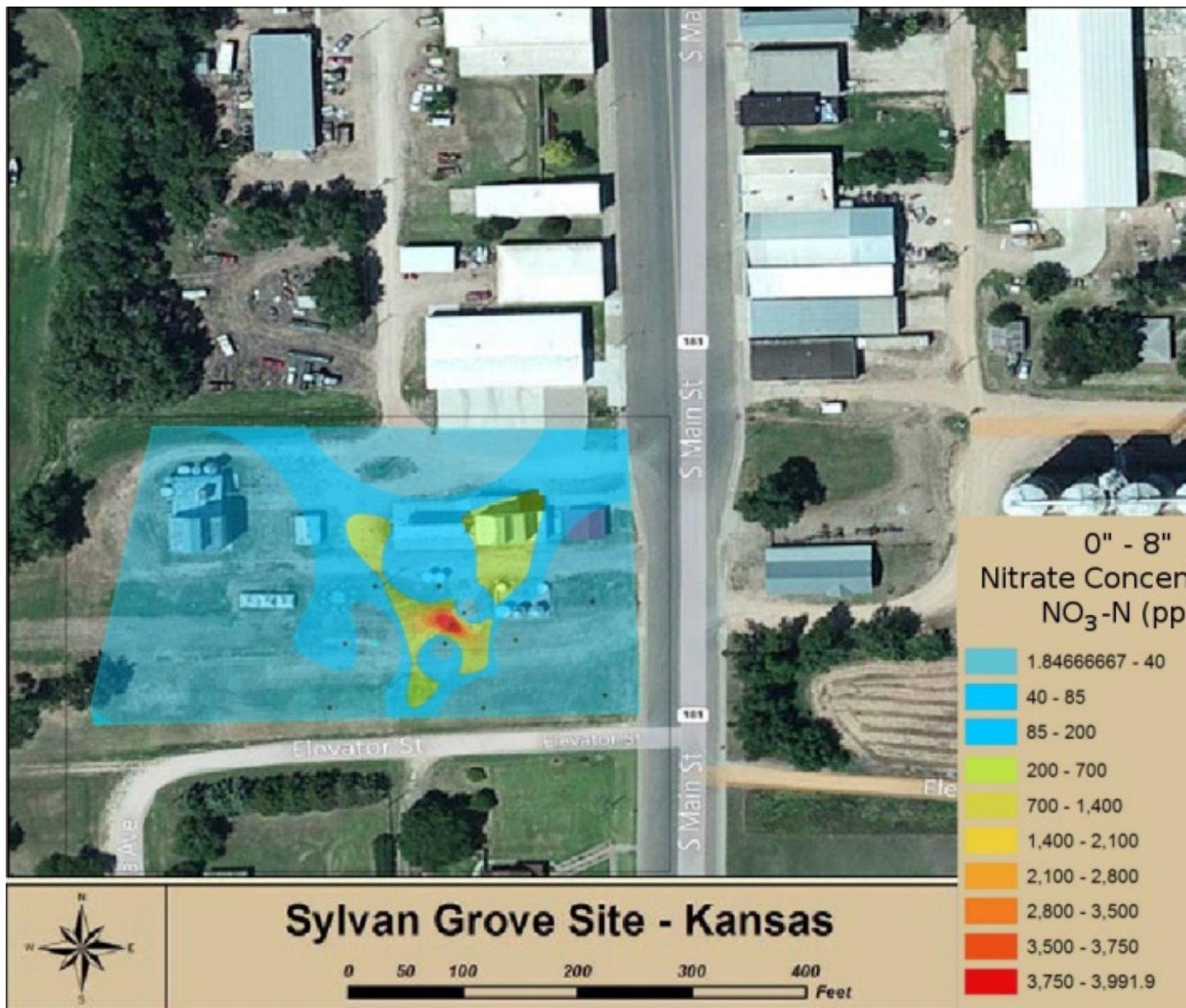
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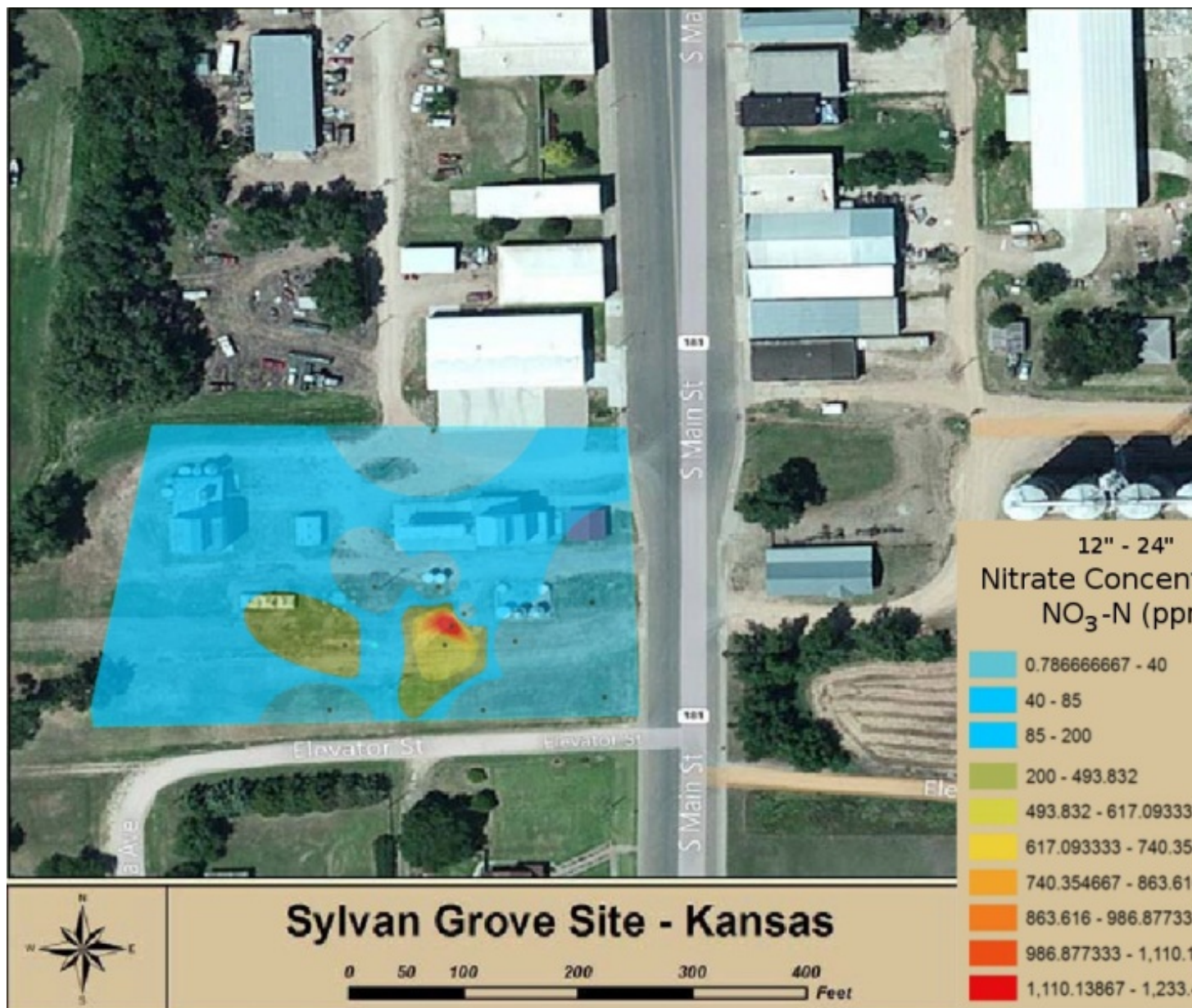
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Appendix A: Graphical Representation of Contaminant Plume





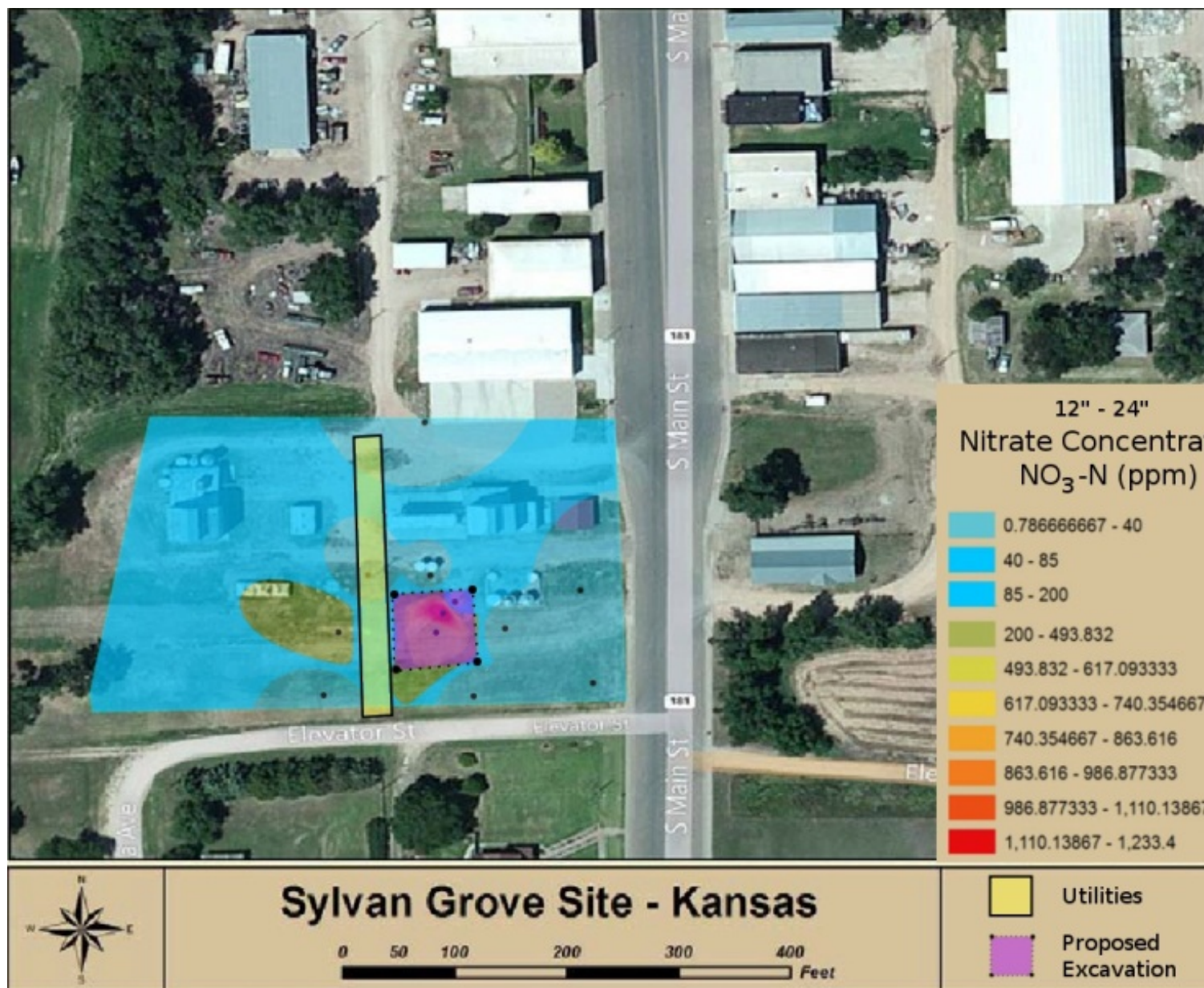


figure 4