AN ABSTRACT OF THE THESIS OF

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Nitrate in ground water has been a concern for some time across the contiguous 48 states in the USA. It causes methemoglobinemia in infants and very young livestock and has been suspected of other adverse health effects. Several sources such as feedlots, septic tanks, and commercial fertilization have been determined to put ground water at risk of nitrate infiltration. To further investigate nitrates in ground water, this research analyzed water from three rural domestic wells in Stafford County, Kansas for three years. The wells were sampled up to 6 times a year from August 1991 to July 1994. All three wells had quantities of nitrate above natural background levels. Two of the wells had nitrate levels above the established health advisory limit of 10 mg/L as nitrogen. During the period of investigation the nitrate concentrations did not remain static. Some variances were quite large. Following a period of heavy precipitation, nitrate concentrations increased to levels greater than the EPA action limit in two of the wells.

WATER ANALYSIS

FOR NITRATES IN

STAFFORD COUNTY

KANSAS

A Thesis

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the Division of Physical Science

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by

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I. INTRODUCTION

Today, with the ever increasing human population demanding more food and space, the statement "Less must produce more" is the motto agro-technicians must take to heart. To make smaller fields produce more requires that large quantities of plant nutrient supplements such as natural and commercial nitrogen fertilizers be applied. When converted to nitrate in the soil, these large doses of nitrogen can have negative effects on the people who depend on the product reaped. One of the greatest negative impacts is that nitrate is showing up in fresh water supplies, both above and below ground. This increased concentration of nitrate has become a public health concern.

Livestock wastes are a point source of nitrate contamination in ground water resources. For instance, in the United States large quantities of beef are raised in very small spaces. The amount of space required for a town of only 100 people can contain more than 3,000 head of cattle being raised for meat. These confined animals create a great deal of waste, a source of nitrate. This is true for swine and poultry as well. With McDonald's alone having sold several billion hamburgers, it is unlikely that the demand for red meat will subside greatly anytime soon.

Another concern of nitrate contamination is human waste management systems which must be self-contained on the farm or rural residence. Many farms that exist today were established more than fifty years ago. The septic tanks installed in some cases are as old as the farms and apt to be in need of replacement or upgrading. Septic tanks and lagoons have been suspected as point sources of high nitrate concentrations in some farm water supplies.

This is a report on data gathered from three separate wells in Stafford County, Kansas over a three year period. Since crop and beef production are two of Stafford County's largest industries, crop fertilization, beef production and septic tanks are primary sources suspected to cause increased nitrate concentrations in underground water supplies. Stafford County gets 100 % of its water for municipal purposes from the Big Bend Aquifer. The data from each well will be graphed. The intent of this research and data analysis is to determine the nitrate nitrogen levels in each well. In addition, the focus is to determine how much, if any, the nitrate concentrations fluctuate in each well during the three year period and whether a cyclic pattern occurs that might indicate one of the afore mentioned causes. This paper is also designed to be a small part of the ongoing research of nitrate occurrences in subsurface water supplies.

II. OCCURRENCES OF NITRATE IN GROUND WATER

Approximately 50 % of the drinking water in the United States is drawn from underground reservoirs. Eighty-five percent of rural America obtains its drinking water from aquifers. In 1985, about 22 % or 73,300 gallons per day of all freshwater used in the United States originated from underground water reserves and nearly 40 % of the public water utilized was drawn from underground wells.¹ In some cases, these wells are the only water supply for a region. Western Kansas and a large part of Nebraska depend almost entirely on the Ogallala aquifer for water. Without question underground water is a valuable asset.

These large underground bodies of water have been determined to be vulnerable to contaminants. In isolated cases, some have become so polluted by human activities to be rendered undrinkable. Nitrate is one of a growing list of materials that are being found in increasing concentrations in aquifers. During the last two to three decades, nitrate has been a topic of much research and concern. In 1987, the United States Geological Survey (USGS) did extensive research on nitrate going back through results from samples collected during a 25 year period from the contiguous United States.² Several states have done their own research on nitrate concentrations in their aquifers.

The study by the USGS determined there are 41 aquifers in 20 states giving the United States vast quantities of potable water.² The USGS established that most of the underground water sampled is safe for human consumption. To be considered safe the samples had to contain concentrations of nitrate nitrogen below the Environmental

Protection Agency (EPA) recommended safe value of 10 mg/L of nitrate reported in the form of nitrogen or 44 mg/L nitrate reported in the form NO_3^- . All the nitrate concentrations will be reported as nitrate nitrogen in this work. The study also concluded that nitrate occurs naturally in underground water. Pristine areas (regions with little to no human influence) have nitrate nitrogen levels of up to 3 mg/L. Therefore, quantities of NO_3^- up to 3 mg/L in ground water are considered natural background levels.²

The USGS survey indicated that every state in the United States has some current problem or possible future problems with nitrate.² Each state in the survey had wells with nitrate concentrations above the background level of 3 mg/L. This indicates there are human activities that are adding nitrate to the nation's underground water supplies. Only two of the states, Hawaii and Alabama, showed 100% of the sampled wells to have nitrate levels less than 10 mg/L.

Between April 1988 and June 1989, the State of Iowa tested rural well water in every county for nitrate and other selected contaminants. The study determined that the background level of nitrate was less than 2 mg/L and often less than 1 mg/L. Although the regions with little human influence upon them were lower than the national average, Iowa does have a nitrate problem. Approximately 18% of the rural, private wells in Iowa were found to contain nitrate nitrogen in quantities exceeding the recommended health advisory level of 10 mg/L. Of the ground water sampled that was below the recommended health advisory level, about 37% had concentrations greater than the background level of 3 mg/L. Geographically the nitrate concentrations were greatest in the western region of the state. Approximately 38% of the rural wells in the northwestern region of Iowa had

concentrations exceeding the recommended 10 mg/L of nitrate nitrogen and about 31% of the sampled wells in the southwestern region had levels in excess of 10 mg/L. The northcentral area fared the best with only around 5% of the wells greater than 10 mg/L of nitrate.³ The Iowa survey found that well depth played a role in nitrate concentration. Thirty-five percent of the wells less than 15 meters (49.2 feet) in depth had quantities of nitrate higher than 10 mg/L.

Nebraska, like Iowa, is one of the top three corn producing states in the United States. Nebraska irrigates about 2.3 million hectares of crop land. It also has a high concentration of nitrate in its ground water supply. A study of 5,826 wells in Nebraska sampled between 1984 and 1988, showed that more than 20% of the wells had nitrate nitrogen levels in excess of 10 mg/L.⁴

Not all the Corn Belt States have high concentrations of nitrate. Ohio, in a statewide survey, determined that only 2.7% of the 14,478 wells sampled contained quantities of nitrate above 10 mg/L. Only 13% of the sampled wells exceeded the natural background level of 3 mg/L. The average nitrate concentration for the state was a mere 1.3 mg/L.⁵

Kansas has one of the highest recorded rates of nitrate concentrations in the United States. In the USGS survey of 1985, only the state of Rhode Island had a greater incidence of high nitrate concentrations in well water. Over 36% of the wells sampled in Rhode Island had nitrate levels above 10 mg/L. The USGS survey found that 34% of the 1,140 wells sampled in Kansas had levels of nitrate nitrogen between 3.1 and 10.0 mg/L. Twenty percent of the wells had nitrate nitrogen levels above the 10 mg/L EPA action limit.² More recent studies in Kansas place more than 25% of the private wells in the state above the 10

mg/L mark. A cooperative study by the Kansas Department of Health and Environment's Bureau of Water Protection and Kansas State University sampled 150 selected private farmstead wells in Kansas. The background level in Kansas is considered to be 4 mg/L.² Fifty-nine percent of the sampled wells had nitrate nitrogen levels above 4 mg/L. Thirtythree percent were above the EPA drinking water standard and 17% of the wells in this collaborative survey had nitrate nitrogen concentrations at or above 20 mg/L. Five percent of the wells sampled had nitrate levels of 40 mg/L and above.²

III. NITRATE HEALTH CONCERNS

A. Methemoglobinemia in Humans

Nitrate has been a public health concern since 1945 when it was first diagnosed as the cause of methemoglobinemia in two infants less than six weeks old in Iowa.⁶ The babies were being fed formula mixed with boiled well water. The wells in each case were later determined to have high concentrations of nitrate. One well had a concentration of 140 mg/L, 14 times the present EPA drinking water standard of 10 mg/L, and the other contained quantities of nitrate 9 times the present EPA action limit. When the water was boiled prior to mixing the baby formula the concentration of nitrate was increased.

Methemoglobinemia, also known as the "Blue Baby Syndrome", is the conversion of hemoglobin to methemoglobin.⁷ Hemoglobin carries oxygen to all parts of the body by way of the blood. Methemoglobin contains iron (III) and cannot combine reversibly with molecular oxygen. When methemoglobin is present in large quantities in an individual the blood's ability to transport oxygen to body cells is greatly reduced. Oxygen starvation produces cyanosis, a bluish coloring of the skin, weakness, fatigue, disorientation and in some cases even death.⁸

Nitrate itself is primarily nontoxic. When taken internally, nitrate enters the bloodstream, filtered out, and removed from the body in the urine unchanged. Nitrate becomes a concern when it is reduced to nitrite (NO_2^{-}) , the actual culprit. This conversion occurs in the digestive tract under certain conditions and in saliva.⁹ Nitrite is readily absorbed into the bloodstream. Once in the blood, it reacts with hemoglobin to form

methemoglobin. Iron (II), (Fe^{+2}) in the heme group $(C_{34}H_{32}N_4O_4Fe)$, present in red blood cells as a complex with the protein globin, is oxidized to iron (III) (Fe^{+3}) . Nitrite irreversibly bonds with iron (III) tying up the heme group so oxygen cannot be attached.¹⁰ The blood becomes chocolate-brown in color and is rendered incapable of releasing oxygen.

Infants under the age of four months are the most susceptible to methemoglobinemia. Young infants depend on bacteria to help digest food due to low concentrations of acid in their digestive tract.¹¹ Babies typically have a gastric $pH \ge 4$.⁹ These bacteria, needed for proper digestion, cause reduction of nitrate to nitrite in the digestive system and thus nitrite enters the bloodstream. The body has an enzyme in the blood for defense against nitrite inhibiting the release of oxygen. Known as NADH [reduced nicotinamide-adenine dinucleotide]-cytochrome b₅ reductase, this enzyme converts methemoglobin back to hemoglobin.⁶ Infants up to the age of six months, however, have a low activity of NADH-cytochrome b₅ reductase. Therefore, young infants' systems have only a limited ability to deal with methemoglobin in their blood. The enzyme that reduces methemoglobin can be "activated" by introducing a reducing agent like methylene blue into the bloodstream.⁶

Infants with persistent diarrhea or bacterial infections who drink water high in nitrate have a greater risk of methemoglobinemia. Pregnant women and individuals with recurring low stomach acidity are presently thought to be at higher risk.¹² People having chronic health ailments are recommended to find alternative sources of drinking water if their water is high in nitrate.¹¹

Methemoglobin is commonly found in infants and adults. When levels of methemoglobin are less than 2% of the total hemoglobin it poses no threat.⁹ Methemoglobin concentrations up to 5% usually produce no noticeable signs of methemoglobinemia. Bluing around the eyes and mouth, the first indicators of cyanosis, are noticed when there is between 5 to 10% of methemoglobin in the blood. In tests of trained subjects, it was determined impaired oxygenation of the muscles occurred at concentrations of 10 to 20% methemoglobin.⁹ When the levels of methemoglobin reach 60% of the total hemoglobin, stupor, coma, and even death occurs.¹³

Doctor Hunter H. Comly, in 1945, advised that well water containing concentrations of nitrate nitrogen above 10 mg/L not be consumed by infants. A more extensive Russian study done in the early 1960s concluded basically the same thing. Eight hundred children in day nurseries were tested in the Russian study. The study found that 90% of the children who drank water containing 20 to 40 mg/L nitrate nitrogen had increased levels of methemoglobin with 50% of these having amounts of methemoglobin above 5%.⁹ The Russian study also found that the children who consumed water with less than 9 mg/L of nitrate nitrogen had no elevated levels of methemoglobin.

Between 1945 and 1978, 2,000 cases of methemoglobinemia were reported in the United States and Europe. Seven to eight percent of the affected infants died.¹² Seventeen states responding to a survey by the American Public Health Association in 1950 reported 278 cases of infant methemoglobinemia prior to 1950. Of these cases, 39 of the infants died from the illness. Two hundred fourteen wells involved in the 2,000 cases were analyzed. All the 214 sampled wells had concentrations of nitrate in excess of 10 mg/L.¹²

Kansas reported 13 cases of methemoglobinemia in the 1950 American Public Health Association survey. Death was the result in three of the cases.¹²

The number of reported diagnosed cases of methemoglobinemia and deaths caused by it has been reduced, but the problem persists. In the 10-county Big Sioux region of eastern South Dakota, 353 physicians were surveyed in 1982. Eighty cases were reported to have been treated for methemoglobinemia by 29 physicians.¹⁴ Sixty-four of the cases were diagnosed prior to 1972 with the remaining sixteen cases treated after 1972. All of the cases with one exception involved infants. A 1988 study of Nebraska doctors at maternity wards showed that they had diagnosed 33 cases of methemoglobinemia. Neither study reported any infant deaths.

Infant deaths in the past ten years have been rare but still occur. In South Dakota, a female infant born on April 30, 1986 died June 28, 1986. The baby was breast-fed early on but later was given powdered formula mixed with the farm's well water. The mother reported noticing a blue color around the mouth, feet and hands of the baby to the family physician at the one-month checkup. Also the mother reported that the infant experienced difficulty in breathing, as well as instances of diarrhea and vomiting. The baby was considered healthy and sent home. The blue coloring was attributed to the temperature in the home. Approximately four weeks later, the baby was fed larger quantities of the powdered baby formula mixed with well water. About one week later, the baby died on the way to a hospital, despite efforts to revive her with oxygen. Blood extracted from the infant was chocolate-brown in color. The farm well from which the family drew drinking water was analyzed and found to contain 150 mg/L nitrate nitrogen.¹⁵

In 1981, the Kansas Department of Health reported a case of methemoglobinemia in the southwest corner of Washington County. This first case in the state in 22 years was due to an infant being fed formula mixed with well water. Two separate samples taken from the 75 foot deep well had nitrate nitrogen concentrations of 170 mg/L and 180 mg/L.¹² Methylene blue was administered. In 1986, another case of methemoglobinemia was diagnosed in Kansas, this time near Scranton in Osage County. A two and a half month old infant having blue discoloration was admitted to Stormont-Vail hospital. The formula fed to the infant had been prepared by the use of boiled well water. The well had been hand dug and was about 38 feet deep. It took approximately two to three days in the hospital before the diagnosis of methemoglobinemia was made. All the cases reported to the Kansas Department of Health were caused by infants ingesting private well water. No actual cases of public water incidence have been reported.¹² In fact, in the United States, only one case has been documented in which a public water source was even found suspect.¹⁶

Methemoglobinemia can be reversed by introducing methylene blue into the bloodstream. Methylene blue is reduced to leukomethylene blue by enzyme action. Leukomethylene then rapidly changes methemoglobin back to hemoglobin without enzymes.¹⁷ A 1% solution of methylene blue (1 to 2 mg per each kilogram of body weight) administered intravenously over a 5 to 10 minute period will bring about a rapid reduction in methemoglobin levels.¹⁸ Three to five milligrams of methylene blue per kilogram body weight or 200 to 500 mg of ascorbic acid per kilogram of body weight can be given orally following the I.V.

B. Methemoglobinemia in Livestock

Like humans, livestock are affected by the nitrite formed when nitrate is ingested. Nitrite enters the bloodstream and reduces hemoglobin to methemoglobin so that the animal is incapable of getting enough oxygen to its body tissues. If the amount of methemoglobin per total hemoglobin in the animal's blood is greater than 50%, a lack of coordination, difficulty with breathing, blue coloring of mucous membranes,¹¹ bluish tint to the whites of the eyes, blue muzzle, trembling,¹⁹ rapid heartbeat, abdominal pain, vomiting, blood chocolate-brown in color, and/or abortions may occur.²⁰

The amount of nitrate an animal can safely ingest is dependent on the type and age of the animal, the type of feed, the nitrate content of the feed, and the amount of water consumed. Ruminants such as cows and sheep are more susceptible to methemoglobinemia. These animals have a compartmentalized stomach. The first compartment of the stomach contains microorganisms that convert nitrate to nitrite. Unlike most other animals, ruminants, when healthy, rapidly convert the nitrite to ammonium that is later used in building proteins (Figure 1). Methemoglobinemia occurs in ruminants when the accumulation of nitrite exceeds the cow's or sheep's ability to convert it to ammonium. Some of the nitrite goes into the kidneys where it is excreted from the body. However, most of the unutilized nitrite is absorbed into the bloodstream and changes hemoglobin to methemoglobin in much the same way as in humans.¹⁹ The young of cows and sheep are much more susceptible to methemoglobinemia than the adults.

Figure 1. The fundamental course of nitrate in ruminants. (Modified from a Cooperative Extension Service of South Dakota University booklet.¹⁹)



Monogastric or single-stomached animals such as swine, chickens and dogs do not have a rumen for digesting. Nitrate ingested by monogastric animals is not specifically converted to nitrite for use by the body. The nitrate primarily passes through the digestive tract into the bloodstream and then into the kidneys (Figure 2) where it is expelled in the urine.²⁰ Very young monogastrics, normally less than four months of age, have digestive systems with a pH above 4. This higher pH is conducive to the production of microorganisms that can reduce nitrate to nitrite. Since monogastric animals are incapable of converting nitrite to ammonium, the nitrite enters the blood and reduces the hemoglobin to methemoglobin resulting in oxygen starvation of the tissues. Some nitrite is removed, however, from the body through solid waste excretion before it can affect the blood. Adult monogastrics have a lower pH in the stomach providing a hostile environment for the nitrate reducing bacteria. In adult swine, large doses of nitrite is required to produce toxic levels of methemoglobin.¹¹

Figure 2. The fundamental course of nitrate in monogastrics. (Modified from a Cooperative Extension Service of South Dakota State University booklet.)¹⁹



Horses are monogastric animals, like swine and chickens, but they have a large cecum that functions similar to a rumen in digesting hays and grasses.¹⁹ When the microorganisms in the cecum covert nitrate to nitrite the animal becomes susceptible to methemoglobinemia. Like the ruminants, adult horses are at risk to nitrite poisoning, but the young are at greater risk.

Livestock can safely tolerate levels of nitrate nitrogen up to 20 mg/L, twice the safe level recommended for humans, unless the feed itself has a high nitrate content. Some plants, such as corn, used for feed concentrates nitrate in the leaves. This concentration process can greatly increase an animal's nitrate intake. Concentrations of nitrate nitrogen in the water between 20 mg/L and 40 mg/L are not considered harmful as long as the feed provided has less than 1,000 parts per million (ppm) of nitrate. Water with nitrate nitrogen levels between 40 mg/L and 80 mg/L is drinkable for animals if their diet is well balanced and low in nitrate. Between 80 mg/L and 200 mg/L, symptoms of methemoglobinemia begin to occur. Death, however, is not probable. It is recommended that another source of water for the animals be located. Water containing nitrate nitrogen concentrations above 200 mg/L should not be drunk by livestock, since methemoglobinemia and some deaths are highly probable.²⁰

Treatment of methemoglobinemia in livestock involves giving a 2% methylene blue solution intravenously.²⁰ In addition, balanced diets fortified with vitamin A, C, and B complex will reduce the effects in livestock of nitrate ingestion from the water.^{20, 21}

C. Other Possible Health Effects of Nitrate

Cancer is a concern with many chemicals we use and ingest. Nitrate is no exception. Many studies have been done to determine whether or not nitrate is carcinogenic. Since nitrate is relatively harmless to humans and animals, three basic steps must occur for it to be a carcinogenic agent.

- The nitrate (NO₃) must be reduced to nitrite (NO₂). This takes place in the saliva and/or the digestive tract.
- 2. The nitrite must react with amines (secondary or tertiary) or amides found in the body to form nitrogen-nitroso compounds such as nitrosamines which are confirmed carcinogens in several kinds of animals. Over 100 nitrogen-

nitroso compounds have been tested. Nearly 80% of them have been found to cause cancer in animals.⁹ Nitrite has not been shown to be carcinogenic by itself which is the reason this step is necessary.¹⁰

3. The nitrogen-nitroso compound(s) must react with body tissue to produce a cancer.^{2, 9}

The supposed necessity of nitrate in water going through these three steps to form a carcinogen significantly complicates the designing of tests to show a correlation between nitrate in water and cancer.² On the other hand, no tests have disproven a direct link of nitrate to cancer.

Several population studies have been done to resolve what clinical studies have thus far have been unable to discern. The results of these epidemiological studies have been mixed. In the early 1970's, a study in England found that a town called Workshop had a 25% greater incidence of gastric cancer than similar towns used as controls. Some mountainous regions of Colombia in the mid-70s were discovered to have an abnormally high number of stomach cancer cases compared to the low-incidence control areas. The water of the high incidence group was found to have levels of nitrate of 110 mg/L.⁹ The state of Wisconsin between 1968 and 1982 had 5,425 people die from gastric cancer. This made for an adjusted rate of 7.1 individuals per 100,000, somewhat higher than the national average in the US. The University of Wisconsin did an epidemiological study to evaluate whether nitrate in drinking water might be a factor in causing gastric cancer. The study encompassed gastric cancer deaths of Wisconsin residents from 1982 to 1985. In

contrast to the Colombian results, this controlled study did not show any heightened gastric cancer risk due to levels of nitrate in the water.²²

An Australian study was made of babies born with central nervous system defects in Southern Australia. Pregnant women who drank water that contained nitrate nitrogen levels of 5 to 15 mg/L, were three times more likely to deliver an infant with a defect. Four times the risk was incurred if the water had levels above 15 mg/L.²³ A case study of the province of New Brunswick in eastern Canada was performed to duplicate the results of the Australian study. New Brunswick has one of the highest rates of central nervous system defects born to babies in North America. The results indicated no significant risk due to nitrate in the water. It also noted a decrease in risk of birth defects if the water was from a municipal system and a slight increase if the water source was a private well.²⁴ These studies illustrate the present lack of consistent results when evaluating the health effects of water containing nitrate.

IV. NITROGEN TRANSFORMATIONS

Once in the soil, whether by human or natural activities (see Figure 3), nitrogen undergoes a variety of transformations. Some of the changes are chemically produced while many others are catalyzed by microorganisms in the soil. These changes happen in a cyclic manner where nitrogen is transformed to one compound, modified to another and then returned to its original form. Nitrogen continues in the cycle until it is converted to nitrate where it can leach into ground water.

In dilute aqueous solutions, nitrate is chemically unreactive and very soluble. Nitrate reactions occurring in soil are catalyzed biochemically. Nitrate ions have a negative charge which is repulsed by the negative charge of most soil particles.²⁵ Thus, the unchanged nitrate ion is readily carried along with the water that percolates through the soil profile to the saturated zone. Since the concentration of the bacteria and organic matter necessary to transform nitrate within aquifers is considered to be low to nonexistent, leached nitrate remains unchanged once it reaches the water table.

The transformations of nitrogen that make up the nitrogen cycle are a complex series of chemical, physical and biological reactions. Factors, such as temperature, pH, hydraulic conductivity, soil moisture, crop type or vegetation, and precipitation play an important role in the existence and quantity of different forms of nitrogen within soils.²⁶ The primary steps of the nitrogen cycle which affect the quantity of nitrate produced in the soil are:²⁷

- \Rightarrow mineralization-immobilization
- \Rightarrow nitrification
- \Rightarrow denitrification
- \Rightarrow plant uptake and recycling

Figure 3

The Nitrogen Cycle (Modified from "Nitrate and Groundwater" *Water Quality* 1993, Kansas State University, MF-857 Revised.)¹¹



A. Mineralization-Immobilization

Mineralization is the conversion of organic nitrogen to inorganic nitrogen in the form of ammonium (NH_4^+) .¹⁰ This conversion primarily occurs when organic matter containing nitrogen (particularly plant residues) is decomposed. As the complex organic molecules are consumed by heterotrophic microorganisms, the carbon is mineralized to carbon dioxide (CO₂) and the nitrogen to ammonium. Some of the ammonium will be utilized for plant synthesis, some will be nitrified (nitrification) to nitrate (NO₃⁻), which is more readily consumed by plants than ammonium and other quantities will be returned to the atmosphere through denitrification.²⁷

Immobilization is the conversion of ammonium to organic nitrogen, the reverse of mineralization. These processes are dependent upon one another and proceed simultaneously.¹⁰ Immobilization is normally considered a microorganism process. However, nitrogen in the soil is converted to organic molecules more often by plant uptake than bacterial activity. The carbon-nitrogen compounds made are utilized to produce amino acids, amino sugars, proteins, purines, pyrimidines and nucleic acids.²⁷ Nitrogen tied up in the organic molecules is therefore, unavailable for leaching. After harvest, much of the nitrogen within plant parts and roots is left in the field. The nitrogen within the plant residue and dead bacteria is once again mineralized as the organic matter decomposes, continuing the cycle.

Normally, the rate of mineralization is greater than that of immobilization. Excluding nitrogen fertilizer application, the net rate of mineralization (rate of mineralization minus rate of immobilization) regulates the amount of nitrate within the soil. If the rate of

immobilization becomes greater than the rate of mineralization, little to no nitrogen is available in the soil for plant uptake. Mineralization and immobilization rates are influenced by soil temperatures. The net rate of mineralization in particular has been found to increase up to about 40° C. Rates are also increased when the soil is moist and the pH is neutral to slightly alkaline.¹⁰

Mineralization and immobilization of nitrogen are also affected by tillage practices employed. Agricultural activities change the bulk density, porosity and pore size distribution of soil particles.¹⁰ Along with altering the space between sediments, the water holding capacity, and aeration, it changes the depth of plant material. Some common farming practices used today put most of the plant residue within the environment of soil microorganisms below the soil surface. This places the remains within easy access of the bacteria for more rapid decomposition. However, the rate of decomposition is not necessarily improved. Recent research indicates that crop residue left on the surface by notill practices results in cooler soil temperatures thereby, increasing populations of soil microorganisms and resulting in a higher rate of decomposition of organic matter.²⁸ Tillage also tends to reduce the quantity of microbes in the soil because of the drastic change it brings upon their environment.

B. Nitrification

When soil has a pH from 7 to 8, a good population of nitrifying bacteria, and an adequate supply of oxygen (at or above 0.3 mg/L of dissolved O_2), available ammonium is transformed to nitrate. This two step oxidation of ammonium is a process known as nitrification.

The reactions involved in nitrification are:

$$2NH_4^+ + 30_2 \longrightarrow 2NO_2^- + 2H_2O + 4H^+$$
 (1)

$$2NO_2 + O_2 \longrightarrow 2NO_3$$
 (2)

Both of the reactions involved are exothermic and require microorganism activity. The oxidation of ammonium to nitrite releases 84 kilocalories per mole and the oxidation of nitrite to nitrate releases 18 kcal per mole.²⁹ Nitrification is the only natural source of nitrate in the biosphere, except for some atmospheric reactions.

Since nitrification converts the relatively immobile ammonium ion nitrate, it has received the greatest amount of attention of all the nitrogen cycle steps.³⁰ The thrust of research has been to develop chemicals which inhibit nitrification. Nitrification inhibitors, as they are termed, are chemicals that reduce the rate of ammonium conversion to nitrite (Equation 1) by inhibiting the bacteria (nitrosomonas) that catalyze the reaction, thus lessening the amount of nitrate available for leaching. Two that have been approved for use in the United States are nitrapyrin [2-chloro-6-(trichloromethyl) pyridine], developed by Dow Chemical USA and marketed under the trade name N-Serve Nitrogen Stabilizer, and etridiazol [5-ethoxy-3-(trichloromethyl)-1, 2, 4-thiadiazole], developed by Olin Corporation and marketed under the trade name Dwell or Terrazole by Uniroyal Chemical Company.³¹ The use of inhibitors is hoped to improve the efficiency of nitrogen fertilizers decreasing the possibility of nitrate infiltration into ground water. It has been suggested that the application of nitrification inhibitors may benefit the nutrition of some crops by increasing the quantity of ammonium compared to nitrate late in the growing season. Some varieties of corn have been found to do better with a higher ammonium to nitrate concentration late in the prowing season.¹⁰

C. Denitrification

Denitrification is the biological conversion of nitrate to gaseous nitrogen molecules. This step in the nitrogen cycle is a major avenue by which nitrogen is returned to the atmosphere. Much research has been done to understand the mechanism of this bacteriadriven natural phenomenon, but as yet remains cloaked in uncertainty.³² The environmental factors that affect this process, however, are well known. When dissolved oxygen (O_2) in moist or water saturated soil becomes limited or depleted, an anaerobic condition, certain microorganisms will use nitrate as a source for oxygen. In addition, a sufficient carbon substrate, typically organic matter, must be available as an energy source and accompanied by warm soil temperatures (optimum at 60^0 to 65^0 C) and a pH at or slightly above 7.³³ The order of transformations in this process is considered to be:

$$NO_3 \rightarrow NO_2 \rightarrow NO \rightarrow N_2O_{(gas)} \rightarrow N_{2(gas)}$$
 (3)

As shown in the reaction, the nitrate is transformed to gaseous compounds of nitrous oxide (N_2O) and elemental nitrogen (N_2) .

Tillage practices have been found to influence the rate of denitrification. Reduced and no-till practices seem to increase the rate of denitrification when compared to conventional tillage methods. The soil moisture content has been found to be higher in notill systems due to the insulating effect of plant residue left on the soil's surface. In addition, the supply of organic substrate accumulates in the soil surface. It has been shown that this increased quantity of carbon-rich material increases the rate of denitrification in soil surfaces compared to the usual methods employed to place above ground plant remnants beneath the surface.³⁴ Typically, annual rates several times higher have been observed.³⁵ Traditionally denitrification has been a concern in agriculture. It releases nitrogen from the soil that might otherwise be utilized for plant growth, reducing the efficiency of nitrogen fertilizers. Losses of nitrogen within the root zone of cereal crops have been approximated to be 10 to 50 kg per hectare per year.³⁶ Often additional quantities of nitrogen fertilizers are added to compensate for this loss, thus increasing production costs to farmers. However, more recently denitrification has been viewed in a more positive light. It has been proposed that denitrification could be used to reduce the quantity of excess nitrate left in the soil once the crop is harvested. This would lessen the chance of residual nitrate leaching to ground water supplies. For example, in parts of the North Carolina Coastal Plain region, large amounts of fertilizer nitrogen are leached into the vadose zone under crop land, yet the concentration of nitrate within the aquifer is low.³⁷ Denitrification has been given much of the credit for this phenomenon and other such instances across the United States.

It has been suggested denitrification could reduce nitrate that has already infiltrated ground water. A study in Nebraska's Lower Platte Valley determined that denitrification occurred within aquifers whose water table was close to the surface. Ground water in an area between the Platte and Elkhorn rivers in Douglas County, Nebraska was found to be less than 2 meters below the surface. This irrigated land was utilized for growing corn. Despite the short distance nitrate had to traverse to reach the aquifer only 3 of 15 wells contained concentrations of nitrate nitrogen greater than 7 mg/L. The other twelve wells had levels mostly below 5 mg/L.² The results indicated that a high rate of denitrification was occurring within the aquifer.

Before denitrification can be utilized commercially, some fundamental problems must be resolved. At present, much is still not well understood about the inner workings of this process. There is a high dependence upon a carbon substrate such as organic matter, but below the root zone of most soils there is little to no organic matter for denitrification. Also the population of denitrifying bacteria is low in most aquifers that are below the vadose zone. A pitfall with denitrification is its production of nitrous oxide. Nitrous oxide is a suspected agent of atmospheric ozone destruction. Thus, dramatically increased rates of denitrification over a large region would be a cause for concern. With the resolution of these difficulties, denitrification could be a viable means of reducing residual nitrate in the soil.
V. NITRATE SOURCES

A. Septic Tanks

Farms and many other rural establishments require their own self-contained waste management systems. Septic tanks are usually employed to manage human wastes in about 30% of the rural households, resorts, motels, and restaurants in the United States. Some older cesspools, which do not use the septic tank digestion step and shallow drain fields, are still utilized.³⁸ These human waste management systems have been found to be major contributors to nitrate contamination in ground water in some areas of the US.³⁹ About 50 to 70 mg/L of nitrogen, 75% as ammonia and 25% tied up as organic nitrogen, is contained in the discharge of a typical septic tank. These nitrogen rich materials experience nitrification and move into the ground water as nitrate. The average household production of waste nitrogen is about 33 kg per liter per year.⁴⁰

In parts of the northeastern United States, it has been discovered that septic tank systems are sources of nitrate in ground water.⁴¹ A study of eleven states in the northeastern US that included 12 million people, 23% of the area's population, concluded that septic tanks released somewhere between one-half and 1 billion gallons of raw sewage into the ground each day. The study also reported the probability of high nitrate concentrations in ground water being due to independent waste disposal systems at thousands of the sites sampled.⁴¹

The septic tank is an anaerobic container that possesses no ability to remove nitrogen from the waste. The effluent is usually discharged to a gravel-filled trench 40 or more centimeters below the surface. There it diffuses into the unsaturated region often

through a restrictive layer commonly called a crust. Aerobic conditions typically exist beneath the crust where pathogens are removed and eliminated and organic nitrogens are converted to ammonium then nitrified. Since the effluent is often dispelled below the root zone, no evaporation and little plant uptake occurs. Thus, denitrification is the only means of nitrogen removal from the effluent. Conditions in the soil must be very favorable in order for denitrification to make a noticeable difference in the amount of nitrogen removed. Most studies that have monitored the aerobic unsaturated region below septic systems conclude that very little nitrogen is eliminated; therefore vertical flow of nitrate to the ground water is likely.

B. Animal Wastes

Confined feeding has become the current solution to raise enough beef and poultry to keep up with today's market demands. Large numbers of cattle, swine, and poultry are confined in buildings or outdoor pens and fed high volumes of feed for fast growth. In 1975, approximately ten million cattle were fed in feedlots containing more than 1,000 head each.⁴² In the state of Delaware alone, approximately 140 million chickens are raised annually.⁴³

These large concentrations of animals in small spaces generate great quantities of manure. The amount of waste created by chickens in Delaware, one of the largest poultry producing regions, has been considered to be greater than the quantity of solid waste produced in New York City annually. Animal wastes, particularly that of chickens, contain considerable amounts of nitrogen that are converted to nitrate in the soil. It was estimated in 1975, that 8 million tons of animal manure nitrogen were produced.⁴⁴ Wastes produced

by confined animal feeding operations are large potential sources for nitrate ground water contamination.

A study of more than 800 wells in Sussex County, Delaware, a region that raises millions of broilers annually, found high nitrate concentrations in the shallow aquifer. Nitrate levels above 10 mg/L were discovered in over 20% of the sampled wells. The average nitrate nitrogen rate was 14 mg/L in ground water sampled on the chicken farms.⁴⁵ In Missouri, 5,000 wells and springs were analyzed for nitrate. The survey determined that cattle feedlots were a primary source of nitrate contamination in the ground water of the region.⁴⁶ In Sidney, Nebraska, the municipal water supply was found to be high in nitrate. High nitrate levels were discovered under an irrigated corn field surrounding a feedlot and in adjacent soil. Residents of the area near the feedlot indicated that the manure taken from the pens over a 20 year period had been applied to the fields nearby.⁴⁷ Sidney was approximately 8 km distant and down gradient from the feedlot. Sampling of the ground water suggested that nitrate had traveled in the aquifer to the city's wells.

Some studies indicate that the area directly under the pens of a year-around active cattle feedlot have low nitrate levels, though the soil in the pens are rich with organic nitrogen from animal waste produced. It is thought the cattle pack the soil so tight that the ground becomes almost impenetrable to oxygen and water. Lacking the seepage of water through the soil, organic nitrogen in the manure has no medium in which to travel deep enough into the soil to be converted to nitrate. The ground beneath abandoned, seasonally unused or completely cleaned feedlots, on the other hand, has been found to contain high concentrations of nitrate.⁴² When cattle are removed, the soil contracts and expands in response to temperature changes and precipitation. This loosens the surface and allows

moisture to permeate the soil once more. When a pen is completely cleaned, the top soil and manure are removed and replaced with new soil. This effectively eliminates some of the hard impenetrable crust allowing water once more to leach into the soil taking with it organic nitrogen that was not removed.

There are other means in which nitrate can be leached into the soil from feedlots. Run-off during rains is a primary concern for continuous-use feedlots. Precipitation sheets off the surface of lots due to the high compaction of the soil. This transports large quantities of manure to the surrounding area. The fields and pastures near the feedlot that catch the run-off provide favorable conditions necessary for the nitrogen to percolate into the soil and the ground water. In an attempt to alleviate the run-off problem, the Kansas Department of Health and Environment (KDHE) requires operators to build ponds (often referred to as lagoons) to capture run-off. The KDHE standards require that the distance from the bottom of a lagoon and the top of the water table be greater than 3.1 meters, 10 feet. In addition, lagoons must pass a percolation test. The catch ponds do not have to be impervious to water seepage but it be slow. Recently, in some cases, the KDHE has imposed monitoring wells be drilled near the site of the lagoons to establish what, if any, impact is incurred upon the ground water.⁴⁸ However, many lagoons that are in use today were constructed before the KDHE restrictions were imposed.

Excessive manure build-up in pens becomes a problem for the animals themselves, and its disposal can result in contamination of ground water. If the amount of manure becomes great enough or the ground is not sloped, water will not run-off. Rain puddles, creating regions in the pen which cattle cannot readily traverse. Most feedlots are

periodically cleaned to reduce the manure build-up. The removal of the excess waste from the enclosures, also makes for smaller amounts of animal waste that drain into catch ponds.

Once removed, the manure has to be relocated. Most animal waste is spread onto nearby crop land for fertilizer. In some cases, particularly when there are large quantities of animal waste generated, the amount of manure applied to fields is greater than the crops can utilize. Often the manure is put on crop land that is being summer-fallowed (unplanted and primarily kept weedless for up to a year). Similarly, manure is applied during the fall and winter months when the field is idle or the crop planted is dormant. Therefore, the probability of ground water contamination from nitrate is increased because there is little or no plant growth to utilize the applied natural fertilizer.

C. Crop Land

Twenty-four percent of the 760 million hectares of land that make up the contiguous 48 states in the United States is employed as crop land. About 70 to 80 million hectares of this is utilized for growing the major row crops, corn, cotton, soybeans and wheat.⁴⁹ The farming techniques used to provide crops with maximum growing conditions also create a large nonpoint source of nitrate that can leach into ground water.

Row cropping is still the most popular method of preparing the seed bed for planting. Tillage of the soil is designed to reduce unwanted vegetation and to break up hard pan so the soil can better retain precipitation and allow penetration of plant roots. Evapotranspiration from the soil is reduced allowing excess precipitation to percolate down through the soil beyond the reach of plant roots.²⁶ While fallow, fields are kept free of weeds by herbicide application or tillage. Since there are no plants growing in fallow fields, excess nitrate in the soil is free to be leached by precipitation. Terraces made in fields over

the past three decades were designed to capture excess precipitation to reduce run-off and minimize erosion of the soil. This captured precipitation, particularly in summer-fallowed ground, permeates the soil, taking excess nitrate with it.⁵⁰

Reduced or conservation tillage is a method of farming that has become popular recently. Reduced tillage farming leaves most of the crop residue on top rather than worked into the soil. Conservation tillage boasts reduced tillage, lower incidence of erosion, a greater density of organic matter, higher moisture retention and cooler soil temperatures.⁵¹ These conditions can aid nitrate infiltration into ground water. However, it also increases nitrogen immobilization and denitrification keeping nitrogen from traveling below the root zone.⁵²

Types of soils have been determined to affect the rate of nitrate movement. Permeable soils, such as sandy loams, and sand have high nitrification rates. In addition, water percolates through these soils rather quickly in comparison to soils of finer sediment. A study of ground water contamination of nitrate in Merrick County, Nebraska showed a positive correlation between nitrate concentrations and coarse textured soils.⁵³ Sandy soils with shallow ground water tables had a rate of nitrate increase of 0.4 to 1.0 mg/L per year.⁵⁴ In addition, another study in Nebraska demonstrated that unused nitrate in sandy soils was taken deeper into the ground by normal winter and spring precipitation.

Soils composed of fine grained sediments do not allow precipitation to pass through them very readily, therefore, leaching of excess nitrate is slowed. But, leaching of nitrate remains a problem. A Nebraska study found that nitrate applied to fields composed of finegrained soil over a 15 year period had seeped to a depth of more than 18 meters below the

surface. Also, ground water beneath more than 30 meters of fine-grained sediments, was found to have a nitrate nitrogen rate increase of 0.1 to 0.2 mg/L per year.⁵⁴

D. Commercial Fertilizer

As the world's population increases more food must be produced. Likewise, more space is required for such things as housing, shopping centers, and highways. This means greater volumes of food must be grown on fewer hectares. To do this each hectare planted must produce higher yields.

Today, the method employed to increase crop yields is the application of plant nutrients to enhance growth and development. Nitrogen is one of the most utilized nutrients by plants in the soil. For this reason, to increase crop yields additional nitrogen is applied, most often in the form of commercial fertilizer. The most popular forms of commercial fertilizers are anhydrous ammonia (NH₃) in liquid form, urea $[CO(NH_2)_2]$ applied as dry spherical pellets (prilled form) or in solutions, ammonium nitrate (NH₄NO₃) a white crystalline salt usually in prilled form, urea-ammonium nitrate solution, an aqueous mixture of various amounts of ammonium nitrate and urea, and ammonium sulfate $[(NH_4)_2SO_4]$, a crystalline salt used primarily for rice.

Anhydrous ammonia is the most popular nitrogen fertilizer for wheat, corn and sorghum production. It is injected under pressure approximately 7 to 16 centimeters (3 to 6 inches) below the soil surface to allow for quick incorporation, with little or no loss from wind or water erosion. And there are no granules to break down prior to plant uptake.¹⁰

From 1976 to 1977, ground water samples from Buffalo, Hall, and Merrick Counties in Nebraska were analyzed. One hundred eighty-three of the 256 samples taken contained nitrate levels above 10 mg/L. Measured nitrogen isotope values indicated that

fertilizer was the principle source of contamination in most of the well water.⁵⁵ Since 1945, the use of chemical fertilizers has grown tremendously. Consumption of fertilizer in the United States has developed from negligible, following WW II, to more than 10,000 gigagrams as nitrogen in 1981.⁵⁶ Applications to corn and wheat account for much of the fertilizer use increase. The concentration of nitrogen in fertilizers has increased as well. From 1950 to 1970 the amount of nitrogen in all fertilizers increased from 6.1 to 20.4 %.⁴²

Commercial nitrogen fertilizers are presently used more than any other kind of nitrogen source. All the livestock and poultry wastes produced in a year could only provide, about 40% of the nitrogen that is currently applied in commercial fertilizers.⁵⁷ The commercial nitrogen fertilizer applied annually during most of the 1980s was greater than estimates of all other sources of available nitrogen combined.⁵⁸

As of 1981, the annual use of nitrogen fertilizer had leveled off at between 9,000 and 10,000 gigagrams of nitrogen. In 1987, a decline in the use of fertilizer was noticed. This was primarily due to crop land acres taken out of production by the Conservation Reserve Program (CRP).⁵⁹ Land enrolled into this plan was planted to grasses. The CRP program was designed to last 10 years. Many acres that were first entered in are presently up for review. If much of the CRP ground is broken out once more for crop land, a resurgence in fertilizer use will likely occur.

Sixty-one percent of the total nitrogen fertilizers is consumed by corn, cotton, and wheat production in the US. These three crops make up approximately 64% of the total harvested area in this country.⁶⁰ Corn is one of the largest consumers of fertilizer. Only about 21% of the crop land in the United States was planted to corn in 1982, however,

nearly 40% of the nitrogen, phosphorus, and potassium fertilizers consumed were applied to fields for corn production.⁶¹ Nitrogen fertilizer application for corn in the US has grown from approximately 72 kg/hectare in 1965 to more than 150 kg/hectare in 1982.⁶²

The application of nitrogen fertilizers in and of itself is not specifically a problem. If the crops utilize all the nitrogen incorporated into the soil, there is little nitrate available to be leached into ground water. Studies in Illinois for instance, have shown that since 1965 more nitrogen has been applied to soil than is removed by harvested crops.²⁵ In Nebraska since the mid 1960s, data indicates that the nitrogen applied to crop land has been from 20 to 60% greater per year than the needs of the crops grown. The basic reason for nitrogen leaching into ground water from fertilizer, therefore, is over application. One reason for over application is that expectations are too high. A study in Nebraska found producers were applying rates of nitrogen fertilizer required for 180 bushel per acre corn, despite the fact that their land generally yielded only about 120 bushels per acre.⁶³ Another Nebraska study found growers between 1980 and 1984 had crop yield goals that averaged about 28% above the actual yields. The excess fertilizer applied to achieve the goals is available to be leached by rain or irrigation water.

Residual nitrogen not properly taken into account can lead to excessive nitrogen quantities in the soil profile. When the grain is harvested most of the plant and all the roots stay in the field. These crop remains contain much of the nitrogen absorbed by the plant during growth. Harvested grains, particularly those such as continuously cropped corn and wheat, have been found to normally contain about 35% of the plant's total nitrogen intake.⁶⁴ Much of the nitrogen in the roots and stalks is returned to the soil as they decay. A Nebraska study found residual nitrogen concentrations in fields high enough that no

additional nitrogen fertilizer was required. The study further discovered that less nitrogen fertilizer was required when residual nitrogen was taken into account. Fields that had additional nitrogen fertilizer applied did not produce any higher yields in the study than fields that had much less applied due to the consideration of nitrogen carry over.⁶⁵ A demonstration project in Hall County, Nebraska reduced nitrogen rates cooperating farmers would usually have applied by an average of 36 kilograms per year. Over the four year period of the project, no loss of yields occurred.

Cover crops such as rye, wheat, or barley can be planted to use up extra nitrogen remaining in the soil. These kinds of crops are presently planted on corn or soybean fields to reduce soil erosion during the fall and winter months. Rye, in particular, is rather tolerant to cold weather and will resume growing on warm days during the winter months using nitrogen that otherwise would be available for leaching.⁶⁶

E. Irrigation

Irrigation, which is used to supplement natural precipitation, has been an invaluable asset to many farmers. However, it has also been a factor of increased ground water nitrate contamination. In the past century, the use of irrigation has dramatically increased. Approximately 1.6 million hectares (4 million acres) of crop land were irrigated in 1890. By 1980 twenty-three million hectares, 14 times greater than in 1890, were being irrigated.⁶⁷ Most of this influx of irrigation systems in the midwest occurred during the 1970s.

In some areas, the number of irrigation systems is quite high. Merrick County, Nebraska has an irrigation well density of 2.6 wells per square kilometer (6.6 wells per square mile),⁶⁸ one of the highest concentrations in the world. Nebraska has more

sprinkler-irrigation systems than any other state in the US. This additional source of moisture has helped increase the yields grown on today's farm land. However, like nitrogen fertilizer, too much is applied in some cases. Excess water applied will percolate through the soil taking nitrogen with it. Irrigation in the central sand plain region of Wisconsin has been suspected of being the greatest cause of increased nitrate levels in their ground water.⁶⁹ Irrigation water can take nitrogen applied as fertilizer down below the root zone before developing plants can utilize it, especially in coarse soils.

Irrigation can be a major point source of contamination when chemigation is employed. Chemigation is the injecting of chemicals such as nitrogen fertilizers directly into the water applied to the crops. It is primarily used for adding additional nitrogen when crops have become too tall for conventional methods of application. If during chemigation power supplied to the pump is interrupted, back-siphoning will occur. This will draw the nitrogen fertilizer being applied, into the aquifer causing irreversible contamination.

VI. CHARACTERISTICS OF CERTAIN STAFFORD COUNTY SOILS

Stafford County is in a region called the Great Bend Prairie. This area is covered primarily by wind-blown sand heaped into dunes. It varies from fine sandy permeable soils to clay loam which drains poorly. The Soil Survey of Stafford County shows that there are about 18 different major soil types within Stafford County. The wells sampled are located in and near four different soil divisions. These specific soil types are called Attica, Carwile, Pratt and Naron. The following brief descriptions of these soils are summaries of the detailed information provided in the Stafford County Soil Survey.⁷⁰

A. Carwile Series

The A horizon, upper 18 centimeters, (7 inches) of the Carwile Series soil is a fine sandy loam consisting of a weak, fine granular structure. About 18 centimeters below the top layer, the B horizon contains particles of clay creating a sandy clay, clay, or clay loam soil, depending on the quantity of clay particulates. The deepest layer is a sandy clay loam which begins approximately 97 centimeters below the soil's surface and extends to a depth of about 152 centimeters (60 inches). Carwile soils have slow permeability to water, allowing only about 0.5 to 1.5 centimeters of precipitation to pass through in one hour, causing ponding problems in fields following rains. It is common for this soil to be moderately alkaline and calcareous (containing sufficient quantities of calcium carbonate to visibly effervesce when cold, dilute HCl is applied).

B. Attica Series

Attica soils are characterized by a fine sandy loam in the uppermost 25 centimeters (10 inches), horizon A. This becomes a friable, fine sandy loam in the B horizon. To a depth of 152 centimeters the soil characteristics change only moderately to a fine sandy loam that is not as crumbly. Attica soils have moderately rapid permeability allowing from 5 to 15 centimeters of water to pass through its layers per hour. Neither run-off nor puddling are great concerns with this soil due to its good permeability.

C. Naron Series

A Naron soil is a fine sandy loam in the upper 20 centimeters. The B horizon is more varied in its 76 centimeters than some of the other soils of Stafford County. The upper section of the B horizon is a fine sandy loam very similar to the top horizon. The soil changes to a sandy clay loam approximately midway through this layer. The 25 centimeters is a friable, fine sandy loam. The C horizon is composed of a fine sandy loam. This soil type has a moderate permeability. Five tenths to 5 centimeters of water will pass through this soil series per hour.

D. Pratt Series

The Pratt series of soils tend to be a loamy fine sand to about 20 centimeters in depth, horizon A. Horizon B extends to nearly 71 centimeters in depth, and is a heavy loam fine sand. The deepest horizon of this soil type goes to about 152 centimeters below the surface and is loamy fine sand. This soil is readily permeable to water. Approximately 15 to 51 centimeters of water can percolate through this soil in an hour. Run-off from soils of this series is not much of a problem.

Below the horizons these soil series is typically fine sand which holds the life-blood of this region, water. Within and below the soil horizons, layers of clay termed clay lenses are thought to occur. Research performed by Margaret Townsend⁷¹ determined that clay layers may impede the migration of nitrate. In this research equipment nor funds were available to ascertain whether or not clay lenses were effecting the migration of nitrate through the soil profile.

Figure 4

Map of Stafford County

The map shows the locations of each well sampled in the study and the township and range lines.



LEGEND:

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- Х
- Joel Miller's Farm Sandyland Experiment Station Jaye Dickson's Farm 0 *

SCALE:

0

10 20 miles

VII. EXPERIMENTAL

A. Experimental Design

Several wells in Stafford County were sampled based on location and accessibility. Some well owners were opposed to having their wells tested. One well had to be removed from the study because the owner no longer wished to participate. None of the wells sampled in this study were being treated with chlorine or other chemicals.

The Sandyland Experiment Station and Jaye Dickson wells were first sampled in September of 1991. Joel Miller's well was first sampled in September of 1992. The final sample from each well was taken in June 1994. The original design of this research was to sample each well about every other month. That goal was not always met due to unforeseen circumstances such as not getting to the Sandyland Experiment Station to collect a sample and well owners not being able to return samples on a timely basis. As a result, in some years only 4 samples were available for analysis. In the final year of this research project, it was possible to analyze more samples than initially intended.

The well owner would submit a filled 300 mL polyethylene sample bottle. Each participant in the study was instructed on how to take a proper specimen. The samples were taken from the tap in the house or from an outside hydrant after allowing the water to run for at least one minute prior to sampling. To minimize possible algal or bacterial growth, the samples were frozen until they could be analyzed the following summer. The water samples from the Sandyland Experiment Station were gathered personally because no one lived on the farm site.

B. Well Locations and Region Characteristics

1. Jaye Dickson

The US Bureau of Land Management system location of Jaye Dickson's homestead is NW 1/4 NW 1/4 24-T 24 S-R 11 W. The first NW 1/4 means the homestead is in the northwest corner of a section which is divided into four equal parts. The second NW 1/4 means the homestead is in the northwest quarter of the section of concern. The number 24 is the number of the section, in township 24 south (T 24 S), range 11 west (R 11 W). By way of travel, Jaye Dickson's well is located about 1/4 mile east of the Zenith road along US Highway 50 (see Figure 4). The house is in a two acre region of trees on top of a hill less than 1/4 of a mile south of US Highway 50. The well is contained in an out building located on the northwest corner and about 4.6 meters (5 yards) from the west side of the house.

No exact information on the construction of the well could be obtained. The Dicksons purchased the property directly from the previous tenants so no water testing was required for the sale. A new well pump was installed a few years ago by Joe's Electric of St. John and it was determined that the well was 37 meters (120 feet) deep. The new pump was positioned 27.7 meters (90 feet) down, and it was thought that the well was screened at a depth of 23 meters (75 feet), and the casing was metal. The previous owners, who had lived on the property for many years, were contacted but they were unable to contribute any additional information.

Southwest of the well house, about 12 meters distant, is the septic tank for the residence. The septic tank is located on the hill and has not been disturbed during the six years that Mr. Dickson has been a resident on the farmstead. Approximately 15 meters to

the west of the well, the ground slopes away rapidly to the bottom of the rise. The ground falls away about 9 meters. This area at the bottom of the rise has been used to hold cattle during the winter for many years. Mr. Dickson removed the pens about two years prior.

North to US Highway 50 and just east of the house is pasture which is grazed by a small number of cattle. East of the farm site and beyond the small strip of pasture is farm ground. South of the house about 92 meters and west about 185 meters are fields planted to wheat.

The soil making up the farmstead is Attica surrounded predominately by Carwile. A narrow band of Naron extending beyond the Attica to the southwest and an area of Pratt soil extending northwest from the Attica breaks up the Carwile into two large sections.

2. Sandyland Experiment Station

The Sandyland Experiment Station is located 3 miles south of St. John and 1/2 mile west of the intersection of US Highway 281 and US 50. The US Bureau of Land Management system lists Sandyland Experiment Station as being located W 1/4 SE 1/4 16-T 24 S - R 13 W.

The site contains several out buildings, an abandoned house, and an office building north of the house. The tested well is near the house. This well is the primary source for drinking water at the experiment station. The water for this research was drawn from a hydrant about 74 meters distant down hill from the well.

The well is old and said to be hand dug. No other specific information about its construction could be obtained. It was thought by the former superintendent of the experiment station to be approximately 14 meters (45 feet) deep. Vic Martin, the present

superintendent, indicated this well is also being tested by the US Geological Survey for pesticide residues.

There are two septic tanks on site, the original and a new one. The original is located on the south side of the house, about 15 meters southwest of the well. It was utilized by former residents of the house. The house has not been occupied for over 5 years and its facilities have been used minimally by personnel at the station. The newer septic system is nearly 92 meters north of the well. It utilized by the new office building which was put in during the last 10 years.

South and east of the station is pasture land. North of the site, about 185 meters away, is farm land tended by the experiment station for a variety of crops. Approximately 37 meters west of the well is a field containing a center-pivot irrigation system which has been planted to corn for the past three years.

The Sandyland Experiment Station is constructed on a small area of Naron soil. Carwile soil dominates the region surrounding the Naron. This station does not do any work with domesticated animals. Its primary function is growing various crops using a variety of farming and fertilizing techniques.

3. Joel Miller

The legal position of Mr. Miller's farmstead is NW 1/4 NW 1/4 11 - T 23 S - R 14 W. The site is located along an aged asphalt Stafford County road called the Eden Valley Road. This road is two miles east of St. John. Mr. Miller's residence is 1 and 7/8 miles north of the Eden Valley Church on the east side of the Eden Valley road. The house is only about 15 meters from the road.

The farmstead consists of the house, a barn, and a couple of small out buildings. The well is located 15 meters east of the house or about 30 meters west and south of the barn. It is 21.5 meters deep and screened at a depth of nearly 20 meters below the ground surface. It is packed with gravel above the perforation to the top of the well.

The septic tank is located about 9 meters south and west of the well. The barn has a corral where two horses and a small number of cattle come for water. North, east and west of the house is at least a half-mile of pasture. To the south, about 92 meters from the well, a field is being strip farmed. It is alternated between summer-fallow, wheat, and sorghum. This year, wheat was planted. All the soils in this area are different types of Pratt series. The soil in which most of the crops are planted is a Pratt loamy fine sand, hummocky and the soil upon which the farm rests is Pratt loamy fine sand, undulating. The soils have the same basic characteristics of the Pratt series to which they belong. However, they are not as readily permeable to water.

C. Apparatus

All samples were analyzed using a reverse-phase high performance liquid chromatography (HPLC) technique developed by Dr. D. C. Schroeder⁷² at Emporia State University. The HPLC system used was a Varian 2010 pump/2210 system mated with a model 2050 variable-wavelength UV detector. A reverse-phase column and a Rheodyne 7125 injector with a 10 micro meter (μ m) loop completed the apparatus.

A strip-chart recorder connected to the detector was employed to record the peak heights as the nitrate was dispelled. The recorder was set at a chart speed of 1 centimeter per minute. The graph paper was 25 cm wide, which is where the number 25 comes from in the calculations of absorbance from peak heights.

Overall, this equipment performed well. Things did not always go as hoped though. During the summer of 1992, when the first well samples were analyzed, a full day's work came to naught because a leak was noticed in the back of the HPLC's loop late in the day. Not knowing when the leak first occurred it could not be determined what data were good so none of the data was used. The septum where the syringe is inserted leaked and it became necessary to leave the syringe in longer to obtain reproducible peaks. At times a peak would appear that had a very broad base and it would take up to ten minutes for the detector return to its operating range. Some errors during the first several days of this summer were due primarily to lack of experience in working with the apparatus. July 23, 1992 data was obtained that produced a very good calibration curve and thus was used for this project (see Figure 7 on page 75).

D. Solution Preparations

1. Mobile-Phase, Buffer and Stock Solution

The mobile phase, which carried the sample through the HPLC system, was prepared by adding 6.80 grams of KH_2PO_4 and 400 microliters (µL) of reagent grade concentrated H_3PO_4 to a 1,000-mL volumetric flask. It was then diluted with distilleddeionized water, and filtered through a 0.45 µm membrane to degas it.

The buffer solution was made from the same materials as the mobile phase, however, in greater concentration so that, after mixing with the sample, the composition would be nearly identical with the mobile phase. The buffer was added to all analyzed samples to suppress ions (lower the pH) of organic compounds which may have been present. These ions would have caused added noise in the baseline and/or broader nitrate

peaks. The buffer consisted of 8.50 grams KH_2PO_4 , 500 μ L of concentrated H_3PO_4 diluted with deionized water in a 250-mL volumetric flask and not filtered.

A stock solution was made by diluting 1.81 grams KNO₃ to mark, in a 250-mL volumetric flask with distilled-deionized water. This yielded a 1.00 g/L concentration of nitrogen. Dilutions from the stock solution were made to prepare standards for analysis.

2. Standards and Samples

Standards of various concentrations were made. The standards were needed as a comparison in order to calculate the concentration of nitrate in the well samples. Standard A was made by diluting 500 μ L of the stock solution with distilled-deionized water in a 100-mL volumetric flask. This yielded a concentration of 5.00 mg/L of nitrogen. In the summer of 1992, eight standards having concentrations of 7.50, 6.0, 5.0, 3.0, 2.5, 2.0, 1.0, and 0.0 mg/L were made because the HPLC was not giving reproducible results due to leaks in the system. The analysis completed in the summer of 1993 required only three standards. All standards were made up the day they were to be analyzed every summer.

The final concentration of all samples analyzed, both well water and standards, had to be diluted so that the nitrate concentration was less than 3.0 mg/L. At concentrations above 3.0 mg/L results were less reliable. For analysis, 5.0 mL of each standard 5.0 mL of buffer solution were added together in a 25-mL volumetric flask and diluted to mark with distilled-deionized water. The blank standards (nitrate concentration 0.0 mg/L) were made by diluting 5.0 mL of buffer to mark in a 25-mL volumetric flask with distilled-deionized water. Well water samples were prepared by adding 5.0 mL of the sample or less if the nitrate concentration was too high, to 5.0 mL of buffer and diluting to mark with distilled-deionized water in a 25-mL volumetric flask. This final dilution allowed for well water

sample nitrate concentrations of up to 15 mg/L to be analyzed without further dilution. Several times, less than 5.0 mL of well samples were analyzed so the detector could be set at 0.64 or below which was thought to be a more sensitive range. The chemicals used were considered to be in good condition so as to produce reliable results. It was determined that the deionized water used for all dilutions contained traces of nitrate, however, the blank standards were mixed to account for the nitrate that might have been added from possible sources such as the deionized water.

Contamination of reagents was suspected of causing the skewness of the data collected in August of 1994. The dilemma was first noticed on August 3 when the first standards and samples were run. The results from the HPLC had good precision, but the values calculated were inconsistent, very high, and the calibration curve made from the data was a curve rather than a straight line. In the interest of time and accuracy, fresh mobile phase and new standards were made and run August 4. In addition, all well water samples were reanalyzed using the new mobile phase and standards. Therefore, none of the August 3 data was used in this report. A possible cause for the problems with the data may have come from the filter used to degas the mobile phase. A white precipitate was found under the filter in the vacuum apparatus (after all analyses had been performed on August 4) indicating something besides air was being removed from the mobile phase. Due to time constraints and circumstances, fresh mobile phase could not once again be made and new samples run so other means were pursued.

E. Analysis Procedure

The pump of the HPLC was set at a flow rate of 1.0 mL/min, the detector was set at 205 nanometers, and all analyses were performed at room temperature, about 22° C. The

pressure could not be set but remained within acceptable parameters during the process. The range setting on the detector was adjusted to produce a maximum peak height with minimal base line interference.

A 1.0-mL injection syringe was employed to draw 0.20 mL of sample from the 25mL volumetric flask and inject it into the loop. The syringe was rinsed at least twice before a new sample was analyzed. Trapped air bubbles were removed by holding the syringe upright and tapping its sides to dislodge the bubbles. The air was ejected from the syringe along with excess sample to yield a 0.20 mL injected sample. The amount of sample injected into the HPLC from the loop was 0.1 mL. After injection of the sample from the loop into the HPLC it would take on the average just under 3 minutes for the nitrate peak to appear.

A minimum of two trials were performed on each sample. Three or more runs were made if there was a noticeable variance in the peak heights of the first two. After all analyses were complete for a day, each peak height was measured using a 30 centimeter ruler. Each peak height was measured to the nearest hundredth of a centimeter.

A calibration curve of absorbance vs. concentration of the standards was made each summer. This was to determine the linearity of the absorbances for the standards and reliability of the data. The calibration curve constructed from the July 23, 1992 data (Figure 7) showed no signs of skewness even in the higher concentrations, so no dilutions were made to the well samples. The calibration curves constructed during the 1993 and 1994 summers became nonlinear for standards having a nitrate concentration above 5.0 mg/L. Therefore, less than 5.0 mL of water were analyzed from well samples with predicted nitrate concentrations above 5.0 mg/L as seen in Table IV.

The reason the amount of water analyzed from well samples are not all whole numbers is some of the pipets used were inaccurate. The 1.772 mL sample size, for instance, in Table IV is the amount the 2 mL pipet employed dispensed. To determine the accuracy of a pipet, distilled water was pipetted to mark and then dispensed into a preweighted beaker. The beaker and the volume of pipetted water was then weighed. By dividing the mass of the water by 0.997 g/L, density of water at 25^o C, the actual volume of water pipetted was calculated. In contrast, the micropipets employed were found to be accurate.

F. Calculations

The absorbance for each sample is the result of multiplying the peak height by the range setting of the detector and dividing by 25 centimeters (the width of the chart paper). The value of absorbance has no units because the units of the peak height and the paper width cancel out and range has no units. The range of the detector, the height of each peak and other pertinent data (see Appendices A thru H) was entered into a spreadsheet. The spreadsheet software performed the calculations for absorbance, concentrations shown in the appendices. The software was instructed to report the values gleaned from the calculations in proper significant digits. The significant digits recorded was limited by the number of digits in the values for well sample and standard volumes, standard concentrations, and peak heights.

The spreadsheet likewise calculated the mean values and standard deviations for the absorbance of the standards and the concentrations of the well samples. The number of significant digits reported for the calculated average values (see Tables III, IV, V, and VI) were determined by each average's standard deviation. The average values were rounded

to one less decimal place than the decimal place in the standard deviation value having the greatest uncertainty. For example, the average absorbance value for the July 23, 1992 blank standard in Table III of 0.00228 was rounded to 0.002 because the 3 in the ten-thousandths place has a greater uncertainty than the 5 in the hundred-thousandths place in the standard deviation value 0.000<u>3</u>5. Exceptions to this rounding technique were made when the remaining rounded value left of the decimal would contain only one digit.

The regression (best fit) line for the July 23, 1992 calibration curve (Figure 7) is straight. The concentrations of the well water samples analyzed during the summer of 1992 were calculated using the slope and y-intercept values of this graph. The slope intercept formula for a straight line is:

$$\mathbf{y} = \mathbf{m}\mathbf{x} + \mathbf{b} \tag{4}$$

where y represents the vertical value of a point on the line (absorbance), x is the horizontal value of the same point (concentration), m is the slope (absorbance/concentration) and b is the value of y when x = 0, better known as the y-intercept value. The slope and y-intercept were calculated by the advanced math function of the spreadsheet.

When the calibration curve yields a straight line, as was the case of the data gathered in the summer of 1993, the concentration of the well water samples can be determined without the values for the slope and y-intercept. The formula

$$C_{x} = [C_{s} * V_{s} * (A_{x} - A_{b})] / [V_{x} * (A_{s} - A_{b})]$$
(5)

was employed to calculate the nitrate concentration of each well water sample analyzed in the summer of 1993. C_x and C_s represent the nitrate concentrations of the well water and standard samples respectively in units of mg/L. V_x and V_s are the volumes of the well water and stock respectively pipetted to make the samples that were analyzed. A_x , A_s , and A_b represent the absorbance values of the well water, standards and blank respectively.

A software program called "Curve Fitter" and an Apple IIe computer were employed to help evaluate the concentrations of the analyses made August 4, 1994. The data from the standards prepared in 1994 did not fit a straight line on a calibration curve and the calculations of the well sample concentrations were highly variable. The program was authored by Paul K. Warme and copyrighted 1980. It was distributed by Interactive Microwave Inc. P. O. Box 771, State College, PA 16801.

The Curve Fitter program calculated the slope of the curve (coefficient of the polynomial) that fit each data point entered. First, the absorbance values for each standard were entered, from which the computer determined the coefficients for each degree of the polynomial. It determined the standards fit a second degree polynomial with three terms (see Appendices I, J, and K). The coefficient of determination was 0.999692103, the coefficient of correlation equaled 0.9984604 and the standard error of estimate was 2.26384263E-3. Next, the absorbance of each well sample was entered into the program. The value (multiplier, as the software considered it) was put into the formula

$$C_{x} = Curve^{*} V_{s} / V_{x}$$
(6)

 C_x represents the calculated value of the well water nitrate concentration, Curve is the value of the multiplier determined by the Curve Fitter program and V_x and V_s are the volumes of well water and stock used to make the well samples and standards respectively for analysis.

VIII. RESULTS AND DISCUSSION

A. Rainfall Data

The monthly rainfall totals for the duration of the research are shown in Table I. All the rainfall measurements were made at the Sandyland Experiment Station. They are the official precipitation totals for Stafford County and are kept at the Soil Conservation Office in St. John, KS. No measurements of precipitation were available at the other two sites.

Figure 5 is a graph of this data as precipitation vs. month and year. The monthly totals for all four years were put on one graph to better show the variance from month to month. The graph illustrates the variable moisture patterns Stafford County experienced during this project. It illustrates that 1991 was a rather dry year. June being the wettest month with just under 4 inches of rain. Five months in 1991 received less than an inch of precipitation. The total precipitation for this first year of the study, was 19 inches, about 6 inches below the 50 year average of 25.65 inches for Stafford County.⁴⁸

There was a dramatic increase in precipitation amounts in 1992. Except for the months of April and December, each monthly rainfall total was higher in 1992 than in 1991. In some cases the increase was quite large. The rainfall total for 1992 was more than 29 inches, over 3 inches above the 50 year average and more than 10 inches greater than the recorded amount for 1991.

The year of 1992 began a trend that extended into the first half of 1993. Particularly in late spring to early summer of 1993, precipitation amounts were very high. It was during this period that many lakes, ponds, and farm fields were filled by the heavy

rains. The months of May, June, and July in 1993 each received more rain than any other month in the past 15 years with the exception of June 1992. The total for the year of 1993 was likewise wetter than any other year in the past 15. The rainfall accumulation for 1993 was more than 36 inches, about 17 inches above that which fell in 1991 and greater than 10 and one-half inches above the 50 year average.⁴⁸ After July 1993, the precipitation amounts for each month throughout the rest of the year were normal.

The weather was much drier in 1994. By the end of June, only 5.42 inches of precipitation had been recorded for the year, over 6 inches less than the amount received during the same period in 1991. The yearly total for 1994 was more than 2 inches below that of 1991.

Figure 5 and Table I also show that each year during the project the greatest overall precipitation occurred in late spring through the middle of summer. January and February were usually the driest months and precipitation amounts of about an inch per month fell in the fall.

B. Depth to Water

The values for the depth of the water table in Stafford County shown in Table II were taken at the Sandyland Experiment Station. The official location of the well used is NC NE*16 13W 02 n or 1/4 mile east and 1/2 mile north of the experiment station farm site. The water depth of the well was measured in the last week of December each year after the time, it was presumed, the draw down from the year's irrigation had equalized with the surrounding level of the aquifer.⁷³

Figure 6 is a graph of the aquifer's measured height or depth to water. The graph should be viewed carefully. The title properly states that the values graphed are the

distances to water below the surface of the soil. The distance from the soil surface to the top of the aquifer in 1993 was only 18.8 feet. This is over 6 feet more water than the level recorded in December 1991. The increased height of the water table in December 1993 directly corresponds to the large amounts of precipitation received during the year.

The water table level did not change much after the rains that fell in 1992. Possibly, this was due to the previously dry conditions. A good share of the first precipitation in 1992 was probably utilized by dry crops, trees, grasses, and for rehydration of the vadose zone. This also indicates that it takes time for precipitation to reach the aquifer. As the rains continued in 1993, the excess moisture percolated through the vadose zone reaching the aquifer and subsequently reducing the distance to water.

C. Nitrate Standards Analysis Averages and Calibration Curve

The average values of the results from the standards are found in Table III. The raw data from which these averages are gleaned are found in the appendix of this report. Standard deviations of the absorbances were calculated from all the samples of each standard analyzed for that year. The percent variance of the standard deviation of the absorbance from the average absorbance value was 2% or less for all standards except the blanks, which had very low levels of nitrate.

The horizontal lines in Table III separate the values of standards run in different years. As the table shows, more standards were used in the first year than in the following, with the analysis in the summer of 1993 requiring only four separate standards be made. There are two different values for standards A and B for the 1993 analyses because the same standards were run on two consecutive days, each with a slightly different value. The

standard value which corresponds to the well water sample analysis date was used to calculate the well water nitrate concentrations.

The absorbance values shown in Table III for 1994 were much lower than the same concentration of standards analyzed during the previous summers. This was a definite indicator something went awry. As mentioned in the experimental chapter, a white precipitate was found under the filter used to degas the mobile phase. However, it is not known if this was the cause or whether there was another source of error. The Curve Fitter program was employed on this data in hopes the values it calculated would be reasonably accurate. Though the data appears to have come out fairly well, at present there is no way of knowing for certain if these recorded values are accurate, or inaccurate for that matter.

The calibration curve shown in Figure 7 was made using all the data shown in Appendix A, not the average of the absorbances for each standard found in Table III. This is the reason some of the points in Figure 7 vary in size. The size difference is because there were notable variances in the absorbance values for some of the standards. One such example was standard C which has a concentration of 5.00 mg/L.

D. Jaye Dickson Well Water Analysis Averages

Table IV contains the average water sample values for the well owned by Jaye Dickson. The standard deviation of the concentrations shows good precision. Most of the values used to calculate the average varied less than 1% from the mean.

The nitrate levels in the well water were rather high the first year. Three of the five samples taken had nitrate concentrations above the health advisory limit of 10 mg/L. Over half of the samples analyzed each year had nitrate levels greater than 10 mg/L. This water

had not been sampled since the farm had been purchased by Mr. Dickson, so it could not be determined if the nitrate levels had always been this high.

In the first year of analysis, the nitrate concentration went from a high of 11 mg/L down to just under 7 mg/L, a drop of about 4 mg/L in two months time. Considering the small amount by which ground water is thought to move or change within a year, it would seem that this much change in nitrate concentrations in a two month period would be quite notable.

As mentioned, the nitrate levels within this well fluctuated quite a bit throughout the period of this study. This is interesting since most of the soil making up the area around the farm is Carwile. This type of soil has a slow permeability to water. However, the soil upon which the house and out buildings are built is Attica. Attica soil allows water to percolate through its layers rather rapidly making it possible for precipitation to reach the aquifer in a shorter period of time. The large variances seen in Figure 8 over relatively short periods of time suggests that a primary source of nitrate in this well is likely located on the farm site.

Figure 8 shows the nitrate levels in the late summer to winter, in the first year of analysis are high, then a significant drop occurs in early spfing. In May of the same year, the concentration is on the rise. The nitrate concentrations in the late summer and winter months of 1992 are high again, higher than the previous year. April of 1993 has a much lower concentration than the winter months sampled. The last year of sampling has a fluctuation pattern similar to the prior 2 years, but this time, the lowest concentration is in the month of February, the last full month of winter. The months in which the concentrations are lowest are after the times of the year when soil is frozen to its greatest depth. This indicates that the frost in the soil impeded the migration of nitrate. Then in the spring

months when soil was free from frost the nitrate once again was able to infiltrate the well. This also indicates that water percolates through the soil that makes up this farm site rather quickly because not much time transpires before the nitrate levels are on the rise again. The area that once held the cattle pens could be the major reason for the occurrence of the pattern. By the time of this study, the compaction of the soil would have been greatly reduced by grass, tree roots, and time. Much of the manure nitrified to nitrate would likely be above the frost line. In addition, the soil making up the former cattle pens is Attica and this area is just west of the well. In fact, the cattle pen area, being at the bottom of the hill, is about 9 meters below the top of the well. Therefore, this area is less than 15 meters above where the well is screened. Thus, nitrate from the manure does not have far to travel to reach the well water.

The fields located near this well site were alternately fallow or planted to wheat throughout the study. When a field is to be planted to wheat, it is fertilized, usually with anhydrous ammonia, in middle to late August and left idle until September, or later if soil moisture is low. The nitrogen incorporated into the soil remains unutilized until the wheat starts to sprout, approximately two weeks after planting. Once the fertilizer is nitrified it is free to be leached by precipitation. This could account for some of the nitrate levels for this well in the early to mid-winter months.

The septic tank for the house was located rather close to the well which would be a cause for high nitrate levels. It would seem though, that the rate of nitrate infiltration from the septic tank would be rather constant throughout the year since the septic tank was in constant use. In addition, it was buried below the frost line so winter freezes would have little effect on the rate of nitrate migration.

E. Sandyland Experiment Station Well Water Analysis Averages

Overall, the data in Table V from the Sandyland Experiment Station well had good precision based on the standard deviations of the concentrations. The values taken during the summer of 1993 were the least precise. The data with the greatest percentage of variance in the other two wells was also gathered during the summer of 1993. Even so, the precision is considered to be within an acceptable range, less than 5%.

This well had been tested several times for nitrate concentrations prior to this research project. In many of the tests, the nitrate levels were said to be greater than 10 mg/L,⁷³ as was the case in this study. No certain cause for the high nitrate concentrations had been determined by the earlier studies.

Figure 9 readily shows that the nitrate levels of the Sandyland Experiment Station well are high, but over half the samples contain less than the health advisory limit. It also illustrates that the amount of nitrate fluctuated throughout the study. The lowest concentration of 8.32 mg/L was in the sample taken June 2, 1993 and the highest reading of 10.9 mg/L occurred in the Mar 20, 1994 well water sample. This is a variance of over 2 and-a-half mg/L. In several instances though, it is shown in the graph that the nitrate concentration remained pretty much unchanged. The overall variance of this well was less than the nitrate fluctuations of Mr. Dickson's well.

The field closest to the well was just west across a gravel road from the experiment station and was privately owned and farmed. Part of the west half of this field, next to the gravel road, is Naron soil which is moderately permeable to water. Corn was planted in

this field each spring over the duration of this study. Therefore, it was usually fertilized in the early spring and then likely side-dressed in late May or June.

Table V shows the greatest nitrate levels occurred in the samples taken following the summer of increased precipitation amounts, 1993. This indicates that excess nitrogen fertilizer, very possibly from the field west of the experiment station, may have percolated into the aquifer as nitrate with the precipitation. All of the well samples following the summer of 1993, with the exception of one, had nitrate levels greater than 10 mg/L.

The old septic tank on the farm that is not far from the well site could be influencing the well. It has been at least 5 years since any one has lived in or used the farm house that the septic tank served. It would seem this old septic tank would not add much nitrate to the ground water since it has been out of service for at least 5 years. Most of the nitrate left from prior use would most likely have been leached out by now. There is a second, more recent septic tank on the farm site that services the office building. This system was put in when the office was built less than 10 years ago. The newer septic system is farther from the well but could still be a point source. However, there are only two full time employees at the experiment station, so the amount of nitrate generated would be small.

At present, there are no confined animal operations within a mile radius of the well location. This station was designed for crop experimentation, so no livestock are kept on the premises. Thus, animal waste as a point source is ruled out.

Figure 9 suggests that a rather constant source of nitrate is the culprit. The levels do not follow a pattern similar to Mr. Dickson's well that would indicate a nitrate source close to the soil surface that could be impeded by frost. Neither do nitrate levels show a cyclic
pattern that would point a finger at agricultural activities. The data indicates that a source below the frost line in the soil is the cause of the high nitrate values.

F. Joel Miller Well Water Analysis Averages

The standard deviation of Mr. Miller's well data shown in Table VI had good precision similar to the other two wells. The concentrations calculated, using the 1993 summer data, had up to 4% variance from the mean.

Figure 10, a graph of Mr. Miller's average well concentrations, shows that the amount of nitrate in this well is much lower than the other two wells. The highest value shown in Table VI is just under 6.5 mg/L which is almost half that of the other wells sampled. Though, the nitrate concentrations are much lower for Mr. Miller's well, they are above background levels for nitrate concentrations. This indicates that the water in this well is too influenced by human activity. Figuer 10 further illustrates that the levels of nitrate varied, though not by much. The difference between the highest value of 6.5 mg/L and the lowest concentration of 4.77 mg/L is only about 1.75 mg/L.

The septic tank, which is within close proximity to the well, is likely causing the above background levels of nitrate. Also the soil it is embedded in is a Pratt series that are rather permeable to water. The nitrate levels did not fluctuate much throughout this research, which would be consistent with the rather constant rate of effluent from a septic system that is in use year round and below the frost line.

The barn and stock pen where horses and cattle come to water would not be a strong point source of nitrate. Mr. Miller and his family have lived on this farm about half a dozen years and the number of animals kept in the pen at any one time has been small and

the well is a fair distance away. Most often they are allowed to roam from the pen into the adjoining pasture, not being confined to a small area.

There is some agriculture activity close to the farm as mentioned in Chapter VII, but this farm is primarily surrounded by pasture. No pattern can be ascertained that shows an increase of nitrate following nitrogen fertilizer application to the field south of the farm. This well should have been the most susceptible to agricultural activities since all the soil in this area are types of Pratt series. The field closest to this well was more than 92 meters south of the well. The apparent lack of influence from the field may be due to the direction of flow of the aquifer. Since only one side of the farm has active agriculture, it is possible the flow of the underground water current carries possible nitrate contamination from crop fertilization away from the well draw-down.

This well does indicate indirectly that agricultural activities affect well water when compared to the other two. Mr. Miller's well has the least amount of farm land near it and the lowest nitrate levels of the three wells sampled. Also, Mr. Miller's well has the least amount of variance of nitrate concentrations between samples.

IX. SUMMARY

The results of this research show that nitrate nitrogen concentrations in all three wells are above background levels, and in some instances higher than the EPA action limit of 10 mg/L. Each of these wells is thus influenced by human activity. The septic tanks in use on each farm site are nitrate point sources. For Mr. Dickson's well, the septic tank and the area where the cattle pens once were, likely account for the majority if the nitrate found in the well. In the case of Mr. Miller's well, nearly all the nitrate isolated in this research is probably from the septic tank effluent. It would seem the septic tank used at the Sandyland Experiment Station imparted far less influence upon the well than the other septic systems since it is not used much.

Mr. Dickson's well had the greatest nitrate concentrations. In two separate instances, the level of nitrate was greater than 12 mg/L. This could be due to the old cattle pens. If this is the case the level of nitrate should diminish in the next several years if no more animals are confined in this area of the farm. About half or more of the Dickson and the Sandyland Experiment Station well samples showed nitrate quantities above 10 mg/L. Each of these well sites have farm land on several sides. The highest nitrate concentration from Mr. Miller's well was below 6.5 mg/L. This well is mostly surrounded by pasture. The septic tank for Mr. Miller's household is as close to the well as the other two and has not been upgraded. This indicates that agriculture is playing a role in the nitrate amounts found in Mr. Dickson's and Sandyland's wells. The data does not show a cyclic pattern that specifically points to agriculture, however.

The nitrate levels were not static over the three-year period of this study. In Mr. Dickson's well, the amount of variance was surprising. This well had levels over 12 mg/L and less than 8 mg/L. The Sandyland and Dickson wells had the largest variance and the greatest nitrate concentrations with the nitrate levels fluctuating from below the EPA action limit to above it.

Mr. Miller's well, along with having the least amount of nitrate, had the least variance in the samples. As mentioned earlier in this work, the difference between the highest and lowest nitrate values recorded for this well was less than 2 mg/L. This again indicates that agricultural activities may be influencing Mr. Dickson's and Sandyland's well water.

All three wells are located on at least moderately permeable soils. Figure 6 shows just how well water can penetrate these soils, at least at the Sandyland Experiment Station. The water table rose 6 feet in one year, which is a large rise. The well where the water table measurements were made at the experiment station is located in Naron soil which has a moderate permeability to water. The soil around Mr. Dickson's well is less permeable than the Naron. The soil surrounding Mr. Miller's well was the most permeable implying that it should have had the greatest fluctuation of nitrate levels of the three wells due to how readily water can pass through this soil type. During the heavy rains of 1993, it would seem that this well would have had more variance than it did. Mr. Miller's well, surrounded mostly by pasture, has the best showing , i.e. lowest nitrate nitrogen levels, despite its having the most porous soil type. The comparisons made between these three wells show strong indications that agricultural activities are influencing the concentrations of nitrate in the Dickson and Sandyland wells. These same comparisons show an unexpected correlation

between soil type and nitrate levels. Mr. Dickson's well, which is surrounded by the least permeable soil, had the greatest variance of the three wells. I would have thought that Sandyland's well would have shown more variance due its close proximity to a corn field with permeable soil.

This work leaves unanswered questions such as what percentage of nitrate in the wells is from the septic tanks, how much of a factor is soil porosity, and does well construction influence the nitrate concentrations. Future projects that better isolate the variables involved could help answer these questions. One method that could be employed would be the use of the nitrogen-15 isotope that can be specifically identified in analysis. For instance, at Mr. Dickson's well site, where the cattle pens were located, a solution containing the nitrogen isotope 15 could be poured into the soil. This nitrogen isotope will show up in well water analyses if the cattle pens are actually a point source. In addition a time frame could be established for how long it took for the nitrogen isotope to show up in analysis. Another method would be to drill a new well a sufficient distance from the septic tank system's influence. This would make it possible to ascertain how much of a nitrate contributor the waste management system has been upon the well. The depth at which the pump of the new well draws water should be equal to the depth water is drawn from the present well so as not to introduce another variable. Continuing the research of this study using the new well could better show whether and how much of a factor agricultural activities are in ground water contamination.

Education of both rural residents and agro-technicians should be pursued to reduce nitrate as a possible hazard in ground water. Farmers could have more soil testing done prior to fertilizer application to calculate rather than "guesstimate" the concentration of

nitrogen needed for proper crop growth and development. This would reduce fertilizer costs and the amount of nitrate available for leaching.

Rural residents need to be made better aware of how waste management systems, whether domestic animal or human, can contaminate drinking water if the system is in close proximity to the well. Also, rural residents need to be informed that though, water looks, smells and tastes okay, does not mean it's safe to drink. Nitrate is not detectable by the human senses. Only through proper testing can water be determined potable. Furthermore, rural residents need to be made aware that well water nitrate concentrations can vary, and testing should be done about once a year. If nitrate concentrations are high, they should investigate the purchase of a reverse-osmosis purifying system which can reduce nitrate concentrations to safe levels.

Table I

Rainfall Totals

measured at Sandyland Experiment Field Dryland Guage : measurements in inches.

	YEAR					
MONTH	1991	1992	1993	1994		
January	0.36	0.95	1.11	0.67		
February	0.00	0.19	2.63	0.53		
March	1.76	2.13	2.64	0.19		
April	3.64	1.17	1.16	2.78		
Мау	1.94	4.01	6.88	0.51		
June	3.98	7.24	8.67	0.74		
July	0.71	1.65	7.81	4.18		
August	1.38	4.57	1.55	0.97		
September	0.87	1.20	1.25	0.52		
October	0.98	1.80	0.80	3.15		
November	1.73	3.00	1.05	0.93		
December	1.65	1.54	0.68	1.51		
Total Precipitation	19.00	29.45	36.18	16.68		

Table II

Depth to Water

Measured at Sandyland Ex. Field Readings taken from well NC NE*16 13W 02 n

(1/4 east and 1/2 mile north of the farm site)

F	Date the Reading was Taken	Depth to Water (feet)	
)ec 28 1990	23.3	
)ec 31, 1991	25.0	
C	ec 31, 1992	24.9	
C	ec 30, 1993	18.8	

Table III

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Nitrate Standards Analysis Averages from Summer 1992 to 1994.

			Blank		
	SAMPLE		adjusted		Absorbance
Standard	SIZE		Concen.	Absor-	Standard
Name	(mL)	RANGE	_(mg/L)	bance	Devialtion
Stds run July 2	3, 1992				
Blank	5.0	0.02	0.00	0.002	0.00035
Α	5.0	1.28	7.50	0.65	0.0046
В	5.0	0.64	6.00	0.508	0.00059
С	5.0	0.64	5.00	0.43	0.010
D	5.0	0.32	3.00	0.260	0.00084
E	5.0	0.32	2.50	0.23	0.00160
G	5.0	0.08	1.00	0.076	0.00027
н	5.0	0.08	0.50	0.05	0.0010
Stds run June 3	30, 1993				
Blank	0.000	0.04	0.00	0.004	0.00037
Α	4.954	0.64	5.00	0.39	0.0017
В	4.954	0.16	1.00	0.081	0.00058
Stds run July 1	, 1993				
А	4.954	0.64	5.00	0,121	0.00091
B	4.954	0.16	1.00	0.079	0.00069
Stds run Augus	t, 1994				
Blank	0.0	0.04	0.00	-0.014	0.00088
Α	5.0	0.64	5.00	0.288	0.00090
В	5.0	80.0	1.00	0.05	0.0024
С	5.0	0.32	3.50	0.20	0.0034

Table IV

Jaye Dickson Well Water Analysis Averages for Nitrate Concentrations from Fall 1991 to Summer 1994.

			Blank	Standard
	SAMPLE		adjusted	Deviation
SAMPLE	SIZE	Absor-	Concen.	of Conc.
Date	(mL)	bance	(mg/L)	(mg/L)
Aug 30, 1991	5.00	0.9126	10.7	0.038
Nov 10, 1991	5.00	0.9290	10.9	0.038
Jan 22, 1992	5.00	0.9357	11.0	0.038
Mar 15, 1992	5.00	0.5921	7.0	0.0 69
<u>May 1</u> 9, 1992	5.00	0. <u>7150</u>	8.4	0.084
Sept 28, 1992	1.772	0.3258	12	0.11
Dec 23, 1992	1.772	0.3343	12.0	80.0
Feb 26, 1993	1.772	0.3213	11.9	0.04
Apr 23, 1993	1.772	0.2134	7.6	0.32
Aug 23, 1993	0.985	0.140	12.67	0.00
Nov 12, 1993	0.985	0.117	11.1	0.01
Feb 1, 1994	0.985	0.085	8.4	0.0 9
June/11/94	0.985	0.126	11.8	0.01

Table V Sandyland Well Water Analysis Averages for Nitrate Concentrations from Fall 1991 to Summer 1994.

			Blank	Standard
	SAMPLE		adjusted	Deviation
SAMPLE	SIZE	Absor-	Concen.	of Conc.
Date	(m <u>L)</u>	bance	<u>(mg/L)</u>	(mg/L)
Nov 16, 1991	5.00	0.7816	9.2	0.038
Jan 11, 1992	5.00	0.7818	9.2	0.045
Mar 28, 1992	5.00	0.7368	8.7	0.042
May 9, 1992	5.00	0.7813	9.2	0.014
Nov 3, 1992	2.00	0.2729	8.6	0.37
Dec 30, 1992	2.00	0.2736	8.7	0.35
Mar 14, 1993	2.00	0.2761	8.7	0.35
June 2, 1993	2.00	0.2627	8.3	0.34
Sept 5, 1993	0.985	0.1087	10.20	0.000
Nov 21, 1993	0.985	0.1108	10.6	0.083
Dec 18, 1993	0.985	0.0933	8.9	0.015
Jan 19, 1994	0.985	0.1125	10.7	0.012
Mar 20, 1994	0.985	0.1143	10.85	0.0061
Apr 30, 1994	0.985	0.1120	10.50	0.000
June 6, 1994	0,985	0.1085	10.4	0.074

Table VI

Joel Miller Well Water Analysis Averages for Nitrate Concentrations from Fall 1991 to Summer 1994.

			Blank	Standard
	SAMPLE		adjusted	Deviation
SAMPLE	SIZE	Absor-	Concen.	of Conc.
Date	(mL)	bance	(mg/L)	(mg/L)
Sept 25, 1992	2.967	0.2739	5.9	0.24
Dec 22, 1992	2.967	0.2886	6.2	0.25
Feb 28, 1993	2.967	0.3025	6.5	0.26
Apr 13, 1993	2.967	0.2874	6.1	0.25
July 28, 1993	1.964	0.1317	6.16	0.000
Oct 6, 1993	1.964	0.1236	5.8	0.042
Nov 11, 1993	1.964	0.1270	6.0	0.040
Feb 4, 1994	1.964	0.1249	5.9	0.026
Mar 17, 1994	1.964	0.1041	5.0	0.027
May 11, 1994	1.964	0.1251	5.9	0.18
June 11, 1994	1.964	0.0989	4.8	0.028

Rainfall Amounts from 1991 to 1994 measured at Sandyland Experiment Station.



Depth to Water from 1990 to 1993 measured at Sandyland Experiment Station.



Nitrate Calibration Curve constructed from Summer of 1992 Standard Analysis Data.



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Figure 8 Jaye Dickson 1991 to 1994 Average Nitrate Concentrations in Well Water.

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Sandyland 1991 to 1994 Average Nitrate Concentrations in Well Water.



Figure 10 Joel Miller 1992 to 1994 Average Nitrate Concentrations in Well Water.

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Appendix A

Nitrate Standards Analysis taken July 23, 1992.

					ABS MINU	LINEAR
STAND-	CONC.		PEAK HT.	ABSOR-	BLANK	REG. ABS
ARD	(mg/L)	RANGE	(CM)	BANCE	AVG	of STDs
BLANK	0.00	0.04	1.04	0.0017		
BLANK	0.00	0.04	1.56	0.0025		
BLANK	0.00	0.02	2.96	0.0024		
BLANK	0.00	0.02	3.04	0.0024		
BLANK	0.00	0.02	3.08	0.0025	0.0023	-0.0062
E1	2.50	0.32	17.04	0.2181	0.2243	0.2079
E2	2.50	0.32	17.27	0.2211	0.2272	0.2079
E3	2.50_	0.32	17.07	0.2185	0.2247	0.2079
H1	0.50	0.08	13.09	0.0419	0.0481	0.0366
H2	0.50	0.08	13.74	0.0440	0.0501	0.0366
НЗ	0.50	0.08	13.24	0.0424	0.0485	0.0366
H4	0.50	0.08	13.82	0.0442	0.0504	0.0366
H5	0.50	0.08	13.64	0.0436	0.0498	0.0366
G1	1.00	0.08	21.80	0.0698	0.0759	0.0794
G2	1.00	0.08	21.96	0.0703	0.0764	0.0794
G3	1.00	0.08	21.84	0.0699	0.0761	0.0794
B1	6.00	0.64	19.56	0.5007	0.5069	0.5075
B2	6.00	0.64	19.60	0.5018	0.5079	0.5075
B3	6.00	0.64	19.60	0.5018	0.5079	0.5075
D1	3.00	0.32	19.84	0.2540	0.2601	0.2507
D2	3.00	0.32	19.79	0.2533	0.2595	0.2507
D3	3.00	0.32	19.92	0.2550	0.2611	0.2507
C1	5.00	0.64	16.02	0.4101	0.4163	0.4219
C2	5.00	0.64	16.44	0.4209	0.4270	0.4219
C3	5.00	0.64	16.96	0.4342	0.4403	0.4219
C4	5.00	0.64	16.33	0.4180	0.4242	0.4219
A1	7.50	1.28	12.70	0.6502	0.6564	0.6360
A2	7.50	1.28	12.61	0.6456	0.6518	0.6360
A3	7.50	1.28	12.52	0.6410	0.6472	0.6360

Regression Output:

Constant	-0.0062	= y-inter.	R Squared	0.9985
X Coefficient(s)	0.0856	= slope	No. of Observation	24
Std Err of Y Est	0.0083		Degrees of Freedo	22
			Std Err of Coef.	0.0007

Appendix B

Jaye Dickson Water Analysis from Fall 1991 to Summer 1992 for Nitrate Concentrations.

			Peak		Nitrate
Run	Sample		Height	Absor-	Conc.
Number	_ Date	Range	(cm)	bance	(mg/l)
48	5/19/92	1.28	13.76	0.7045	8.30
49		1.28	14.08	0.7209	8.49
50		1.28	14.00	0.7168	8.44
51		1.28	14.02	0.7178	8.46
58	3/15/92	1.28	11.52	0.5898	6.96
59		0.64	23.31	0.5967	7.04
60		0.64	22.84	0.5847	6.90
61		0.64	23.32	0.5970	7.04
67	1/22/92	1.28	18.32	0.9380	11.03
68		1.28	18.23	0.9334	10.97
75	11/10/91	1.28	18.19	0.9313	10.95
76		1.28	18.10	0.9267	10.90
85	8/30/91	1.28	17.87	0.9149	10.76
86		1.28	17.78	0.9103	10.70

Appendix C Sandyland Experiment Station Water Analysis from Fall 1991 to Summer 1992 for Nitrate Concentrations.

		Peak Nitra			
Run	Sample		Height	Absor-	Conc.
Number	Date	Range	(cm)	ance	(mg/L)
31	5/9/92	1.28	15.24	0.7803	9.19
32		1.28	15.24	0.7803	9.19
33		1.28	15.28	0.7823	9.21
34		1.28	15.28	0.7823	9.21
62	3/28/92	1.28	14.34	0.7342	8.65
63		1.28	14.44	0.7393	8.71
72	1/11/92	1.28	15.34	0.7854	9.25
73		1.28	15.19	0.7777	9.16
74		1.28	15.28	0.7823	9.21
80	11/16/91	1.28	15.31	0.7839	9.23
81		1.28	15.22	0.7793	9.17
87	7/13/92	1.28	15.26	0.7813	9.20
88		1.28	15.39	0. 788 0	9.28

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Appendix D

Nitrate Standards Analysis

taken June 30 and July 1, 1993.

		SAMPLE		PEAK		Conc. of
RUN	SAMPLE	SIZE		HEIGHT	Absor-	standard
No.	DATE	(mL)	RANGE	(cm)	bance	(mg/L)
9	Blank	0.000	0.04	2.89	0.00462	0.00
10	Blank	0.000	0.04	2.56	0.00410	0.00
	blank avg.	0.000	0.04	2.73	0.00 436	0.00
2	Std A 6/30/93	4.954	0.64	15.26	0.3907	5.00
З	Std A 6/30/93	4.954	0.64	15.17	0.3884	5.00
4	Std A 6/30/93	4.954	0.64	15.13	0.3873	5.00
	avg A 6/30/93	4.954	0.64	15.19	0.3888	5.00
5	Std B 6/30/93	4.954	0.16	12.60	0.08064	1.00
6	Std B 6/30/93	4.954	0.16	12.53	0.08019	1.00
7	Std B 6/30/93	4.954	0.16	12.71	0.08134	1.00
	avg B 6/30/93	4.954	0.16	12.61	0.08073	1.00
1	Std A 7/1/93	4.954	0.64	15.7 9	0.4042	5.00
2	Std A 7/1/93	4,954	0.64	15.74	0.4029	5.00
	avg A 7/1/93	4.954	0.64	15.77	0.4036	5.00
3	Std B 7/1/93	4.954	0.16	12.15	0.07776	1.00
4	Std B 7/1/93	4.954	0.16	12.35	0.07904	1.00
5	Std B 7/1/93	4.954	0.16	12.32	0.07885	1.00
	avg B 7/1/93	4.954	0,16	12.27	0.07855	1.00
Appendix E

Jaye Dickson Water Analysis from Fall 1992 to Summer 1993 for Nitrate Concentrations.

						Blank ad	Blank ad
		SAMPLE		PEAK		Conc. wit	Conc. wit
RUN	SAMPLE	SIZE		HEIGHT	Absor-	Std A	Std B
No.	DATE	(mL)	RANGE	(cm)	bance	(mg/L)	(mg/L)
		June 30,	1993 ana	lysis data	for nitrate	es	
28	9/28/92	1.772	0.64	12.58	0.3220	11.55	11.63
29	9/28/92	1.772	0.64	12.81	0.3279	11.77	11.85
30	9/28/92	1.772	0.64	12.79	0.3274	11.75	11.83
31	12/23/92	1.772	0.64	13.00	0.3328	11.94	12.02
32	12/23/92	1.772	0. 64	13.12	0.3359	12.05	12.14
		July 1, 19	993 analy	sis data fo	or nitrates		
6	2/26/93	1.772	0.64	12.58	0.3220	11.12	11.97
7	2/26/93	1.772	0.64	12.52	0.3205	11.07	11.91
8	4/23/93	1.772	0.64	8.31	0.21274	7.30	7.85
9	4/23/93	1.772	0.64	8.36	0.21402	7.34	7.90

Appendix F

Sandyland Experiment Station Water Analysis from Fall 1992 to Summer 1993 for Nitrate Concentrations.

						Blank adj.	Blank adj.
		SAMPLE	Ξ	PEAK		Conc. with	Conc. with
RUN	SAMPLE	SIZE		HEIGH	Absor-	Std A	Std B
No.	DATE	(mL)	RANGE	(cm)	bance	(mg/L)	(mg/L)
			· · · · ·				
10	11/3/92	2.00	0.64	10.70	0.2739	8.36	9.00
11	11/3/92	2.00	0.64	10.62	0.2719	8.30	8.93
12	12/30/92	2.00	0.64	10.70	0.2739	8.36	9.00
13	12/30/92	2.00	0.32	21.31	0.2728	8.33	8.96
14	12/30/92	2.00	0.32	21.42	0.2742	8.37	9.01
15	3/14/93	2.00	0.64	10.85	0.2778	8.48	9.13
16	3/14/93	2.00	0.32	21.50	0.2752	8.40	9.04
17	3/14/93	2.00	0.32	21.50	0.2752	8.40	9.04
18	6/2/93	2.00	0.64	10.34	0.26470	8.08	8.69
19	6/2/93	2.00	0.32	20.48	0.26214	8.00	8.61
20	6/2/93	2.00	0.32	20.42	0.26138	7.97	8.58

Appendix G

Joel Miller Water Analysis from Fall 1992 to Summer 1993 for Nitrate Concentrations.

						Blank adj.	Blank adj.
		SAMPLE		PEAK		Conc. with	Conc. with
RUN	SAMPLE	SIZE		HEIGH	Absor-	Std A	* Std B
No.	DATE	SIZE (ml)	RANGE	_ (cm)	bance	(mg/L)	(mg/L)
23	9/25/92	2.967	0.64	10.77	0.2757	5.67	6.11
24	9/25/92	2.967	0.32	21.22	0.2716	5.59	6.01
25	9/25/92	2.967	0.32	21.43	0.2743	5.65	6.08
26	12/22/92	2.967	0.64	11.27	0.2885	5. 9 4	6.40
27	12/22/92	2.967	0.32	22.48	0.2877	5.93	6.38
28	12/22/92	2.967	0.32	22.61	0.2894	5.96	6.42
29	2/28/93	2,967	0.64	11.79	0.3018	6.22	6.69
30	2/28/93	2.967	0.32	23.68	0.3031	6.25	6.72
31	2/28/93	2.967	0.32	23.64	0.30259	6.24	6.71
32	4/13/93	2.967	0.64	11.10	0.28416	5.85	6.30
33	4/13/93	2.967	0.32	22.54	0.28851	5.94	6.40
34	4/13/93	2.967	0.32	22.61	0.2894	5.96	6.42

Appendix H Nitrate Standards Analysis taken August 1994.

				ABS	
			PEAK	PK*	
RUN	SAMPLE		HEIGHT	RANGE/	CONC.
NO.	NAME	RANGE	PK (cm)	25 cm	mg/L
1	STD A1, 8/2	0.64	11.2 9	0.2890	5.00
2	STD A1, 8/2	0.64	11.25	0.2880	5.00
4	STD A2, 8/2	0.64	11.22	0.2872	5.00
3	STD C, 8/3	0.32	15.41	0.1972	3.50
2	STD C, 8/3	0.32	15.40	0.1971	3.50
53	STD C, 8/3	0.32	15.63	0.2001	3.50
25	STD C, 8/3	0.32	15.05	0.1926	3.50
24	STD C, 8/3	0.32	15.01	0.1921	3 .50
5	STD B, 8/2	0.16	7.21	0.0461	1.00
6	STD B, 8/2	0.08	15.10	0.0483	1.00
7	STD B, 8/2	0.08	14.80	0.0474	1.00
8	STD B, 8/3	0.08	13.39	0.0428	1.00
7	STD B, 8/3	0.08	13.29	0.0425	1.00
54	STD B, 8/3	0.08	13.9 3	0.0446	1.00
9	BLANK 1	0.04	-8.08	-0.013	0.00
10	BLANK 1	0.04	-8.53	-0.014	0.00
11	BLANK 2	0.04	-9.41	-0.015	0.00
5	BLANK 3	0.04	-9.00	-0.014	0.00
4	BALNK 3	0.04	-9.10	-0.015	0.00
55	BLANK 3	0.04	-8.12	-0.013	0.00

Appendix I

Jaye Dickson Water Analysis from Fall 1993 to Summer 1994 for Nitrate Concentrations.

	CURVE		CURVE	VOLUME	CONCEN.
	FITTER		FITTER	OF SAMPL	(mg/L)
RUN	POINT	SAMPLE	PROGRAM	PIPETED	FIT VALUE *
<u>No.</u>	NUMBE	DATE	VALUE	(mL)	5 mL/Vol pipeted
9	1	3/16/94	Out of Range	1.970	
10	2	3/16/94	Out of Range	1. 97 0	
11	2	3/16/94	Out of Range	1.970	
16	6	6/11/94	2.3209	0.985	11.78
17	7	6/11/94	2.3242	0.985	11.80
41	28	11/12/93	2.1883	0.985	11.11
42	29	11/12/93	2.1849	0.985	11.09
43	30	8/23/93	2.4952	0.985	12.67
44	30	8/23/93	2.4952	0.985	12.67
58	31	2/1/94	1.6735	0.985	8.49
59	32	2/1/94	1.6438	0.985	8.34
62	43	2/1/94	1.6395	0.985	8.32

Appendix J Sandyland Experiment Station Water Analysis from Fall 1993 to Summer 1994

for Nitrate Concentrations.

	CURVE		CURVE	VOLUME	CONCEN.
	FITTER		FITTER	OF SAMPLE	(mg/L)
RUN	POINT	SAMPLE	PROGRAM	PIPETED	FIT VALUE *
No	NUMBER	DATE	VALUE	(mL)	5 mL/Vol pipeted
12	3	4/30/94	2.0987	0.985	10.7
13	3	4/30/94	2.0987	0.985	10.7
32	19	6/6/94	2.024	0.985	10.3
33	20	6/6/94	2.0472	0.985	10.4
34	21	6/6/94	2.051	0.985	10.4
35	22	11/21/93	2.0672	0.985	10.5
36	23	11/21/93	2.0904	0.985	10.6
39	26	1/19/94	2.1086	0.985	10.7
40	27	1/19/94	2.1053	0.985	10.7
47	33	3/20/94	2.1368	0.985	10.8
48	34	3/20/94	2.1385	0.985	10.9
49	35	9/5/93	2.0439	0.985	10.4
					•
51	36	12/18/93	1.7862	1	8.9
52	37	12/18/93	1.7905	1	9.0

Appendix K

Joel Miller Well Water Analysis from Fall 1992 to Summer 1993 for Nitrate Concentrations.

	CURVE		CURVE	VOLUME	CONCEN.
	FITTER		FITTER	OF SAMPLE	(mg/L)
RUN	POINT	SAMPLE	PROGRAM	PIPETED	FIT VALUE *
No.	NUMBER	DATE	VALUE	(mL)	5 mL/Vol pipete
14	4	6/11/94	1.8929	1.970	4.8
15	5	6/11/94	1.8796	1.970	4.8
18	8	6/11/94	1.871	1.970	4.7
19	9	5/11/94	2.354	1.970	6.0
20	10	5/11/94	2.3557	1.970	6.0
21	11	5/11/94	2.2115	1.970	5.6
23	12	5/11/94	2.3408	1.970	5.9
26	13	11/11/93	2.364	1.970	6.0
27	14	11/11/93	2.3325	1.97 0	5.9
28	15	11/11/93	2.344	1.970	5.9
29	16	2/4/94	2.3043	1.97 0	5.8
30	17	2/4/94	2.3242	1.970	5.9
31	18	2/4/94	2.3109	1.970	5.9
37	24	10/6/93	2.2795	1.970	5.8
38	25	10/6/93	2.3027	1.970	5.8
56	38	3/17/94	1.9759	1. 97 0	5.0
57	39	3/17/94	1.9609	1.970	5.0
			•		
60	42	7/28/93	2.4255	1.970	6.2
61	42	7/28/93	2.4255	1.97 0	6.2

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