NITRATE ACCUMULATION IN KANSAS SOIL AND GROUND WATER

by 1264

JAY WESLEY GOSCH

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Major Professor

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INTRODUCTION

Increased attention is being given to pollution of ground and surface waters. The quality of water may be changed in a number of ways and by various contaminants. Among these contaminants are industrial urban wastes, effluents from cities and towns and certain agricultural practices. Uncontrolled erosion resulting in excessive sediment in streams, soluble plant nutrients from fertilizers, and runoff and deep percolation of undersirable mineral and organic compounds from concentrated livestock operations may have adverse effects on water quality.

During the past few years the use of fertilizers in Kansas has increased substantially. The largest single component of this fertilizer tonnage has been nitrogen in its various forms. In addition to supplemental nitrogen supplied to the soil as commercial fertilizers, an unmeasured but significant amount of nitrogen is applied to crop land in the form of manure much which accumulates from livestock feeding operations.

Much of the nitrogen from fertilizer and manurial sources is applied to irrigated soils which in many cases are underlain by relatively shallow aquifers. Nitrogen in the form of nitrate can accumulate in the soil profile from fertilizer and manurial sources under certain conditions.

It is imperative that an attempt be made to evaluate the accumulation of nitrate in Kansas soils and the underlying aquifers and to determine the role of nitrogen fertilizations either as manure or inorganic nitrogen on such accumulations.

Nitrate or nitrite nitrogen, at high enough concentrations in water supplies, may endanger the health of both man and animals. Nitrate ingestion may lead to the developement of methemoglobinemia (15) and consequently asphyxia in the affected animal as well as other problems. Human infants are particularly susceptable to methemoglobinemia (4, 44) which is commonly referred to as cyanosis or "blue babies" disease. The tolerances of adults are greater but are not definitely established.

With increasing amounts of irrigation in the state, the use of nitrogen fertilizers will continue to increase at a rapid pace, a fact which merely increases the need for information relative to the fate of residual nitrogen.

The problem is further expanded by the rapidly growing feedlot industry in the state and the rapidly increasing problem of manure and feedlot runoff disposal.

This investigation presents data dealing with the accumulation of nitrate nitrogen in soils and ground water underlying irrigated fields receiving large amounts of inorganic nitrogen and feedlot areas subject to deposition of large and continued amounts of animal wastes.

REVIEW OF LITERATURE

Effects of Nitrate on Human and Animal Health

Medical science has shown nitrate to be a contributing factor or, perhaps, the main cause of a condition in infants known as methemoglobinemia (blue babies disease). U. S. Public Health Service (42) drinking water standards limit the nitrate content of water to a maximum of 45 parts per millon (10 ppm when expressed as nitrate-nitrogen). Domestic water with greater amounts of nitrate is potentially dangerous when used for infant feeding. The tolerances of adults are greater but have not been definitely established.

The characteristic symptoms ordinarily associated with infant methemoglobinemia are the greyish- or brownish-blue coloration, which usually is first noticeable around the lips, spreads to the fingers and toes and over the face, and may eventually cover the entire body (4). Other symptoms which may be noticed are drowsiness and an increased rate of respiration (23). Although not always present, methemoglobinemia is commonly accompained by diarrhea or other gastrointestinal disturbances (7).

The cyanosis associated with nitrate or nitrite ingestion is attributed to the anoxemia resulting from the decrease in the oxygen-transporting capacity of the blood (44). Nitrate itself is not particularly toxic but is readily converted to nitrite in the animal's digestive system. Nitrite absorbed by the blood reacts with hemoglobin to form methemoglobin. In their surveys of literature relating to infant methemoglobinemia, Walton (44); Conant (9) note that methemoglobinemia is an oxidation reaction in which the ferrous iron in hemoglobin is oxidized to ferric iron in methemoglobin. In the latter state the oxygen is so firmly bound that methemoglobin cannot function in the manner of hemoglobin in the transfer of oxygen. Thus, victims of nitrate poisoning show general symptoms of oxygen deficiency.

Ruminants, particularly cattle, are also susceptible to nitrate toxicity because of the action of rumen microorganisms that can reduce nitrate to nitrite. One of the first symptoms of the toxicity produced by the ingestion of nitrate-nitrogen is a grayish to brownish discoloration of light areas of skin and non-pigmented tissues surrounding the eyes, nose, mouth and vulva (53). As the animal continues to suffer from the affects of the ingestion, breathing becomes labored, pulse rate increases, gait becomes staggered, and frequency of urination increases. These symptoms may be followed by a coma, convulsions, and death. Also these symptoms may occur very rapidly, but some animals may collapse and then recover spontaneously and completely (53). These are the effects of the formation of methemoglobin in the blood from the normal hemoglobin via the action of nitrite-nitrogen.

Ingestion of nitrate-nitrogen may possibly produce problems in thyroid activity (3) and vitamin A metabolism (18, 29, 54). However these problems are not clearly defined. First of all, there are too many other conditions or diseases that produce symptoms which may be confused with vitamin A deficiency (51). Missouri researchers found (46) dietary nitrates capable of interferring with normal thyroid activity but the condition could be overcome by feeding iodide (46). Because of the variables, it is difficult to assess the real interrelationship of vitamin A and nitrates.

Comly (8) in 1945 reported on 2 cases of infant methemoglobinemia and concluded that methemoglobinemia may occur in an infant following ingestion of water high in nitrates, especially if the infant is suffering from gastro-intestinal disturbances. Following Comly's report of 2 proven cases from rural Iowa, Faucett and Miller reported 3 cases in Kansas, and Ferrant 2 in Belgium. Later cases were reported from rural Manitoba, Ontario, Saskatchewan, Illinois, Nebraska, Michigan, Indiana and several other states. The condition, therefore, seems widespread in the United States and Canada.

Waring (45) 1949, reported that drinking waters containing high levels of nitrate-nitrogen, 10 to 20 ppm or more, appear to be the cause of methemoglobinemia in infants, particularly when they are given the water as part of a modified milk formula. His findings indicated that the distribution of such waters appears to be confined mostly to rural wells in which a surface influence may be felt, particularly with dug wells.

During the period January 1, 1947 thru August 1, 1949, Bosch et al., (4) stated that 139 cases of methemoglobinemia, including 14 deaths, due to nitrate-nitrogen in farm well water supplies, have been reported in Minnesota. In all but 2 of these cases, the nitrate-nitrogen content of the water was in excess of 20 ppm. In the 2 exceptions mentioned the clinical histories of the suspected cases were inconclusive.

Studies of rural school wells and similarly constructed nearby farm wells by Bosch (4) et al., indicate that the nitrate content of the school well water was less than that of water from the farm wells. Bosch, et al., (4) noted that in 125 of 129 cases investigated the water came from dug wells. Bosch, et al., (4) also noted that 83 of 129 wells involved in cases of methemoglobinemia were within less than 50 feet from a barnyard, pigpen, privy, cesspool or other source of animal or human contamination.

In Walton's (44) 1951, surveys it was stated that high nitrate waters have been found most frequently in private wells serving rural homes. However, water containing in excess of 10 ppm nitrate-nitrogen has been reported for wells supplying municipal water works in Illinois, Kansas, Minnesota, Nebraska, and New York.

Mink (24) showed that mean concentrations of nitrate-nitrogen from wells in nonirrigated and irrigated regions of southern Oahu, Hawaii were 1 $\pm$ 0.22 and 8.2 $\pm$ 2.4 ppm, respectively. He attributed this difference to the percolation of nitrate added in fertilizers.

Hanway (15) et al., state that nitrates leached by percolating water tend to accumulate in the upper portion of the ground water table in the absence of rapid ground water movement and remain there an indefinite period of time. Nitrate concentration is reduced through dilution by ground water containing little or no nitrate and by ground water movement. Nitrates move with the ground water. Ground water pumped from a well may contain excess nitrates even though the decomposing waste or other nitrogen source may be located a considerable distance away from the well.

Test reports by Hanway (15) et al., show that the nitrate level may fluctuate widely in the ground water. Nitrate levels in the ground water are generally highest following wet periods and lowest, even down to zero, during dry periods of the year.

Nitrites, a more toxic form of nitrogen oxide than nitrates, (Hanway et al., 15) are less commonly found in water supplies than nitrates. However, nitrites in toxic concentrations have been found in the following circumstances: (1) close proximity of a shallow well to a place of waste disposal (the nearer to the source of pollution, the greater the probability of a high nitrite concentration); (2) small ponds collecting silo drainage (nitrites may be concentrated in silage juices); (3) shallow wells polluted by surface water (under certain conditions, bacteria may convert nitrates to nitrites); (4) in galvanized tanks or waterers used for water storage (during warm weather, zinc may serve as the reducing agent to convert nitrates to nitrites).

Navone et al., (27) 1963, reported that several domestic water sources with high levels of nitrate were found in southern California.

In Nebraska, Knudsen et al., (21) 1965 showed nitrate concentrations were higher in shallow water tables than in deeper water tables. Water samples containing more than 10 ppm of nitrate-nitrogen were collected from wells where the water table averaged 38 feed below the soil surface; samples containing less than 2 ppm came from water tables averaging 61 feet beneath the surface.

Smith (34, 35) concluded that nitrate-contaminated aquifers in Missouri were closely related to livestock feeding. He suggested that fertilizer nitrogen had little importance as a water contaminant but could become important in the future.

Stewart and co-workers (39, 40) studies in the South Platte Valley of Colorado have shown water samples from beneath several corrals to contain large amounts of organic carbon and ammonia and to possess an offensive odor. The bacterial counts under corrals were also considerably higher than under other areas, especially at the lower depths. These findings indicate some pollution of the ground water by deep percolation is occurring. Nitrate was found in most of the water samples analyzed and, in many cases, the concentration exceeded 10 ppm nitrate-nitrogen. Water from beneath corrals was not noticeably higher in nitrate than water from under irrigated fields.

Webber et al., (46) found that the movement of nitrate-nitrogen to the ground water usually occurrs during late fall, winter, or early spring in northerly latitudes. The combination of lower temperatures and a lack of decomposable organic matter in the subsoils does not lead to a high biochemical oxygen demand by the soil bacteria. Thus, when nitrate-nitrogen is leached from the surface layers, it is unlikely that significant losses of nitrogen will occur through denitrification in the sub-surface layers.

Nitrate Distribution in Soil Profiles

Wetselaar (48, 49, 50) who worked with tropical soils, found the distribution of nitrates in lateritic soils to vary with the amount of rainfall and the length of dry periods. During drying phases there was a marked accumulation of both chloride and nitrate anions near the surface accompanied by a decrease in the subsurface concentrations (48). The reverse effect, surface depletion and subsurface accumulation was caused by rain. Wetselaar (50) noted the mean movement of nitrates in lateritic soils to be 1.075 inches for each inch of rainfall and a high positive correlation of 0.946 between mean movement and rainfall.

Wagner (43) worked with nitrate distribution at different time intervals in a Putnam silt loam soil and found that nitrate moved down with rainfall and tended to accumulate in the topsoil during dry periods.

Bates and Tisdale (2) studied the movement of nitrate through columns of eight different soil materials ranging from loamy sand to coarse sand alluvium. They showed that nitrate in their leaching columns and the amount of water added to the columns. These two factors are basic for water serves as the vehicle for nitrate movement and the pores in the soil as the space through which the vehicle moves (2).

Herron, et al., (17) found a high correlation for a given soil site between amounts of nitrate-nitrogen in the surface 30 centimeters and totals of to 180 centimeters. However, the proportion found in the surface soil varied widely among years and sites.

Stewart, et al., (40) studied nitrate distribution in soil profiles under cultivated dryland fields, irrigated fields, and corrals. Under corrals, the nitrate content was extremely varied. The totals found ranged from practically none to more than 5,000 pounds per acre in a 20-foot profile. Calculations based on the average nitrate content of the irrigated fields (excluding alfalfa) and the rate water was moving through these profiles suggested that 25 to 30 pounds of nitrogen per acre were lost annually to the water table. The amount of nitrate found under cultivated dryland was very low as compared to corrals and irrigated land.

Murphy et al., (10) found high amounts of nitrate in soils from corrals. The concentration of nitrates found were greatest in the upper portion of the soil profile but decreased with depth. Their findings show that significant amounts were present at depths of 20 feet or more.

Capillary Movement

Some upward capillary movement of ions in solution has been known for sometime, but its significance in nitrate movement and its effects on nitrate accumulation in surface soil has not been known.

As early as 1928 Smith (37) in working fallow soil, also found that nitrates leached by rainfall were returned by upward movement of moisture due to surface evaporation. Further confirmation was supplied by Ohlorogee, and Scarseth (22). They found that during seasons of prolonged droughts, nitrates moved upward in the soil to accumulate at the surface. This was due to the upward movement of soil moisture; however, any moderate rainfall moved the nitrates back into the main root system (22).

Wetselaar (50) reported that during intermitten dry spells in the wet season some capillary movement upwards of the anions could have taken place in the top foot of the soil, but this apparently was not of sufficient magnitude to represent a measurable compensation of the downward movement. He also found that the upward movement in Tippera clay loam was restricted to the top 18 inches of the soil. This implies that any nitrate which has been leached below this depth cannot be recovered in topsoil by capillary movement.

In other findings in Northern Australia lateritic earth Wetselaar (48) notes that the results (for high nitrogen content in the surface one inch) could not be explained in chemical or biological terms and suspects a physical movement of nitrate (48). In another experiment, Wetselaar (49) used the chloride ion in addition to nitrate to eliminate the biological factors. He concluded that the high nitrate content generally found in the surface of tropical soils after a dry period is due to capillary movement upward of nitrates.

Bates and Tisdale (2) in working with coarse-textured soils, stated that the upward movement of ions by movement of capillary water resulting from surface evaporation could be of considerable importance.

Wagner (43) in his findings on Putman silt loam also recorded an increased nitrate content in the surface soil during the fall and spring in heavily fertilized plots. He suggests that it is not likely that nitrate moved upward during this period, since rainfall exceeded evapotranspiration. Wagner contributed this increase to biological factors.

Harmsen and Kolenbrander (16) state that upward movement of nitrogen may occur as water is evaporated from the soil surface. This upward movement may serve to supply the plant with nitrogen from subsoil waters or it may make nitrogen unavailable to the plant by carrying it to dryer layers of surface soil. However, they conceded that in most cases the quantity of mobile nitrogen in subsoil is low and that little nitrate is brought to the surface. There are instances, however, when a surface accumulation may occur.

Capillary movement of nitrates is generally considered insignificant and of little importance in most areas and soils. With certain conditions, however, this capillary movement may be of some importance in nitrate movement and plant growth.

Leaching and Factors Affecting It

Much effort has been expended studying the effects of leaching on nitrate movement. Leaching has been known to cause nitrogen loss from the soil, but it has not always been clear as to how great these losses were or what factors affected this nitrate movement.

Nitrate losses and movement from the soil were studied by Webster and Gasser (47). They found it very difficult to remove nitrate completely from any soil, even with heavy leaching. They also noted that a coarse textured soil lost nitrate more quickly than did a fine textured soil. They found the amount of nitrate removal initially greater from the coarse fraction than from the unseparated soil. The fine textured soil (less than 2 mm) fraction lost more nitrate initially than the unseparated soil but ultimately the unseparated soil lost the greatest amount of nitrate. They concluded that following dry weather the first drainage takes place through the spaces between the soil structural units and not through the soil mass.

Cunningham and Cooke (11) also reported that where nitrate fertilizers had been applied, soil nitrate remained high for several weeks and was unaffected by light rainfall. Most of the nitrate disappeared from the surface soil in a short time following heavy rains. There was significant nitrate movement downward only after persistent heavy rainfall. They found that leaching from heavy-textured soil was much less rapid than had been expected. These results suggested that nitrate may be absorbed within structural aggregates in medium and heavy textured soils, and if percolating rainfall merely passes around aggregates, nitrate may persist in the soil through periods of heavy rainfall (11).

Bates and Tisdale (2) stated also that the degree of soil aggregation would affect nitrate movement. Gasser, in earlier tests (13) while working with light soils, reported results on light soils similar to those of Cunningham and Cooke (11). However, he pointed out the degree of soil aggregation would be less likely to apply on a light soil which contained few large and stable aggregates. Gasser (13) concludes that the mechanisms of nitrate movement in light and heavy soils differ in degree rather than type.

Gasser (14) in working with nitrogen fertilization of winter wheat further confirmed earlier conclusions that prolonged and heavy rainfall is necessary to leach fertilizer nitrate to remain in the surface six inches after four to six inches of rainfall, but practically all was removed after an additional ten inches.

pH may also have an effect on leaching of nitrate. Broadbent and Tyler (5) found there was marked influence of pH on the quantity of nitrogen immobilized. As the pH decreased greater amounts of nitrate were immobilized.

Other factors affecting leaching indirectly could include soil cultivation and topography. Dyer (12) also suggested that retained water can have a major affect on the leaching process in soils.

Ayers and Doi (1) studied the influence of soil temperature on loss of nitrogen by leaching from humic ferruginous latsols under established sugar cane grown in a lysimeter. Their results demonstrate that at a soil temperature of 62^{o} F as compared to 80^{o} F, leaching may bring about extensive losses of mineral nutrients, despite the presence of a well-established root system. It would thus appear that where soil temperatures are low and where rainfall ranges as high as 200 inches per annum, losses of nitrogen by leaching might well be expected even under an established cane crop (1).

Leaching Losses

Peterson and Attoe (32) indicated that on well-drained silt loam soils with a moderate amount of rainfall the amount of nitrogen lost by leaching was small and rather insignificant. Even though the nitrogen did move some, it remained in the root zone and available to the plants. However, Wagner (43) suggests from his studies with claypan soils that leaching of heavy fertilizer applications may be significant.

Wetselaar (50) indicated, that substantial leaching losses of nitrate can occur, particularly in shallow rooted crops, such as sorghum. Such a situation is even more probable on tropical soils where more leaching is likely to occur. Danan and Pillsbury (20) stated that they found large percentages of applied nitrogen to be lost in tile drainage water, indicating significant nitrate leaching.

Harmsen and Kolenbrander (16) state that complete loss of nitrogen from sandy permeable soils may occur in humid climates during normal winters but from heavy soil only during wet winters. In heavy textured soils in humid climate, ion movement was so slow that soluble nitrate remained in the root zone throughout the winter. In sandy soils during the summer the nitrate from leaching was not significant because it always stayed within the root zone. They also stated that in semi-arid to arid regions nitrate is seldom carried down below the depths of the plant roots, except where irrigation is practiced.

Herron, et al., (17) found in his studies in Nebraska on deep, loess-derived soils that except for high nitrogen soils very heavily fertilized with nitrogen, there was little indication of appreciable movement of nitrates below the corn rooting zone.

Horizontal Translocation

Apparently little work has been done considering horizontal movement of nitrate in soils. Harmsen and Kolenbrander (16) state that horizontal translocation is seldom important except in instances where sloping soils have a parched imperivous zone. After heavy rains lateral movement in such instances may be appreciable. Lateral movement associated with furrow irrigation may also serve to concentrate the nitrate in the ridges. Lateral spreading of nitrate by diffusion from placed fertilizers has not been large.

Nielson and Banks (28) found that under certain conditions nitrate-nitrogen may accumulate in the surface 2 inches of the soil under furrow irrigation. The highest concentration of nitrates occurred in the middle of the row and little was present in the profile below the bottom of the furrow. Banded fertilizer behaved similarly to that applied broadcast, however, the movement from the band was somewhat retarded. Large amounts of nitrates were measured in the center of the row in the surface of the soil at the time the corn was harvested in September.

Stout (41) working with furrow irrigation observed a marked lateral movement of nitrate in the surface soil. He reported more than a fourfold increase in nitrate concentration in the center of the ridges where moist surface zones barely coalesced in contrast to a similar location where moisture did not traverse so far. Data also indicate a pronounced lateral movement of nitrate toward the center of the ridges below the survace. Rainfall and evaporation produced strong effects on vertical movement of nitrate.

Surface Runoff

Surface runoff of nitrate from broadcast ammonium nitrate pellets has been found to occur with intense rainfall under experimental conditions on fairly steep slopes under varying soil moisture conditions and varying crop covers (25, 26, 51).

Moe (25, 26) et al. results indicate that nitrogen losses can occur from ammonium nitrate pellets broadcast on sod and bare fields when runoff rates are high. Losses were greatest when nitrogen was applied to wet soils or soils that had a surface seal or crust. Actual measured losses by Moe and co-workers of mineral nitrogen in these studies were low even when tested under severe conditions on soils of 13 per cent slope. The greatest loss amounted to only 15 per cent of the applied fertilizer nitrogen. However, Moe and co-workers noted that to obtain more efficient crop use of nitrogen and to reduce the chances of fertilizer pollution of streams, heavy applications of nitrogen fertilizer on sloping soils should be made when the soil moisture is low and when the surface soil is not sealed.

White (51) et al., broadcast granular ammonium nitrate fertilizer at the rate of 200 pounds of nitrogen per acre on fallow and sod plots. The plots were located on sandy loam soils with a 5 per cent slope. One hour after the fertilizer application, 5 inches of rain at an intensity of 2½ inches per hour were applied with a rainfall simulator. They collected washoff samples and determined their nitrogen content. White (51) and co-workers found considerably less runoff and erosion losses from the sod plots than from the fallow plots. In addition, only 0.15 per cent of the applied fertilizer washed off the sod plots. On fallow plots, even though soil and water losses were relatively high, only 2.3 per cent of the fertilizer washed off.

Other sources of surface runoff of nitrate-nitrogen can occur from feedlots as indicated by Webber (46) et al., and Smith and Abbott (36). Runoff of this type has been known to occur for some time but the extent of the runoff of nitrate-nitrogen, from feedlots has not been fully established.

Webber (46) et al., indicates that surface water pollution arises when liquid manures, silo effluents and similar discharges are allowed to flow directly or by a circuitous route into streams, ditches or other water courses that eventually discharge into a body of surface water.

Kansas has pioneered in control of water pollution by animal wastes with a law passed in 1967 that requires detention ponds at feedlots where pollution is imminent. Following the specifications of the Federal Water Quality Act of 1965, the state law requires that feedlots register with the Environmental Health Services of the Kansas State Department of Health. The law also provides penalties for noncompliance. For those feedlots which do contribute to water pollution, state law requires that a pair of detention ponds be provided to retain runoff. One collects solid wastes; below this, a second pond holds drainage from the first pond. Feedlots are also required to dispose of wastes from the ponds (36).

According to Smith and Abbott (36) Kansas State conservation engineer and state soil conservationist, respectively, a set of detention ponds were set up at Pioneer Feed Yards, Inc., of Oakley in northwest Kansas. The Pioneer feedlot, covers 100 acres with a capacity of 14,000 head, was established in 1960 near the headwaters of Hackberry Creek. Smith and Abbott noted that Pioneer's lots drained into two intermitten natural draws within the subdrainage area, so it was necessary to build two sets of detention dams. Pipes with slide gates provide controlled drainage of liquids from the solid-waste ponds into the liquid-waste ponds. As the solids settle out, the liquid is drained off the top just below the dam's emergency spillway. Smith and Abbott noted that the dams were built to state health department standards to contain up to 3 inches of runoff from the feedlot, which could be expected from about 3½ inches of rainfall at that location. Heavier rains as indicated by Smith and Abbott would greatly dilute the animal wastes in the runoff, so it would not present such a serious problem downstream.

METHODS AND MATERIALS

Design of Experiment

This investigation was organized in two parts. The first part was designed to study nitrate-nitrogen accumulation in soils and ground water underlying feedlots; the second part to study nitrate-nitrogen accumulation in soils and ground water underlying irrigated fields.

Feedlots were sampled with respect to different areas of the state to determine what effects location, soil type or texture, amount of rainfall, and age of the feedlots had on nitrate movement and accumulation in the soil. Two soil cores were taken from each lot to a depth of approximately 5 meters. The age of feedlots sampled were 0-5 years, approximately 10 years, and over 25 years of age at each location. Sampling of different age feedlots at each location under a similar soil type was instituted in an attempt to determine if nitrate-nitrogen was accumulating in greater proportions in the soil profile under the older feedlots.

Ammonium-nitrogen and phosphorus were determined in selected soil profiles to see if any downward movement of these materials had occurred.

Two observation wells were established in and near a feedlot located on an area of shallow aquifers in Reno county. One observation well was established in a lot 30 years old.

Another observation well was located 100 meters southwest of the feedlot. Additional water samples were collected from the well supplying water to the cattle. Samples were collected from these three wells during the study to obtain information of the level of nitrate-nitrogen in the ground water in the area.

Two irrigated fields were selected in areas where soils were readily permeable to water and fairly shallow aquifers existed for studies of nitrate accumulation in soils and water from applications of inorganic nitrogen. The locations included a newly leveled area at the Sandyland Irrigation Experiment Field at St. John and an area on the Ashland Agronomy Farm southwest of Manhattan in the Kansas River Valley.

Nitrate accumulation in irrigated fields with soils readily permeable to water were studied by sampling plots with different rates of applied fertilizer nitrogen under cropped conditions. Observation wells were established on some of these plots receiving different rates of fertilizer nitrogen on sandy soils at the Sandyland Experiment Station and at the Ashland Agronomy Farm.

Movement and accumulation of nitrate-nitrogen in the soil profile was evaluated by comparing nitrate analyses of cores collected before and after the growing seasons. Observation wells on these fertilized plots were sampled periodically throughout the life of the study to monitor nitrate-nitrogen movement into the ground water.

The specific objectives of this portion of the investigation were: (1) to determine the effect of varying rates of nitrogen fertilization on the accumulation of nitrate in soils of varying physical characteristics with particular emphasis on soils readily permeable to water; (2) to determine the rate of nitrate movement through soil toward underlying aquifers; (3) to determine the effects of high rates of nitrogen fertilization upon the accumulation of nitrate in aquifers underlying experimental areas.

Sampling Techniques

Core samples were collected with a truck-mounted hydraulic soil probe complete with rotary attachment, swinging mast and anchors shown in Figure 1. This probe is self powered with a 12½ horsepower Wisconsin engine with 12-volt starter. Core samples were taken with a 1 3/4 inch inside diameter 4-foot sampling tube. With the hydraulic feed, the sampling tube was pushed into the soil to a depth of 4 feet and pulled back out with soil core intact inside the sampling tube. The sampling tube was removed from the drive head and put on a channel board with a meter stick mounted on one side of the channel. The intact soil core was removed by pushing a wooden dowel rod from the bit of the sampling tube through the tube, thus pushing the soil core onto the channel board. After the soil core had been removed from the sampling tube, the core was cut up into 10 centimeter increments for the first 100 centimeters and 20 centimeter increments for the remaining

Figure 1.--A truck-mounted hydraulic soil probe complete with rotary attachment shown above was used for collecting core samples.

Figure 2.--Shown above was the method used for cutting core samples up into the desired lengths.

depth and placed in soil sample bags as seen in Figure 2. The samples were brought to the laboratory on the day of collection and stored overnight in a freezer or placed directly into a forced air oven and dried at 55°C. In cases where moisture content of the samples were to be determined, samples were weighed immediately in the laboratory then placed in a forced air oven at 55°C. After the samples were dry they were reweighed to determine the water content.

Observation Wells

To establish the observation wells a soil core was first removed by the hydraulic probe to the top of the water table. A 2-inch steel pipe with a well point and a 3 foot screen was assembled and placed in the hole to the water table and pounded into the water table by hand with a lead-headed post driver.

After the well was in place water samples were taken by means of a pitcher pump. The pump was primed with distilled water to avoid well contamination. The well was then pumped until 10 gallons of clear water was produced. At this time a water sample was collected in a 4 oz. plastic bottle. Two more water samples were collected after pumping two additional 10 gallon increments.

The samples were taken back to the laboratory and stored in a refrigerator until they could be analyzed.

Determination of Nitrate-Nitrogen in Soils

Nitrate-nitrogen extractions from the experimental soils were carried out by the method of Jackson (19). Soil nitrate was extracted from a 12.5 gram dry sample of soil by means of 50 ml of a solution of 0.0020 N $CuSO_4$ and 0.0038 N Ag_2SO_4, the silver being added to remove any possible interference of chloride ions. The soil and extracting solution were shaken together for 15 minutes. After shaking, ½ teaspoon of $Ca(OH)_2$ and ½ teaspoon of $MgCO_3$ were added to the flask to clarify the suspension by precipitating colloidal material, Cu and Ag salts. Another shaking period of 15 minutes followed, after which the suspension was gravity filtered through Whatman number 42 filter paper. A 10 ml aliquot of the filtrate was pipetted into an 8 cm evaporating dish and evaporated to dryness on a steam hotplate. Evaporating dishes were taken off the hotplate and allowed to cool prior to actual determination of nitrate-nitrogen.

The phenoldisulfonic acid method was used for determination of nitrate-nitrogen as described by Jackson (19). The phenoldisulfonic acid reagent was prepared by dissolving 25 grams of pure phenol in 150 ml of conc. H_2SO_4. Then 75 ml of fuming 20% H_2SO_4 were stirred into the phenol-sulfuric acid mixture. The solution was then heated in a boiling water bath for two hours, cooled and stored in a bottle in the dark.

After the 10 ml soil extract was evaporated to dryness, 3 ml of phenoldisulfonic acid were added rapidly to the center of the evaporating dish containing the sample residue by means of a buret. The dish was rotated in such a manner that the acid came into contact with all the residue. The acid and the residue were allowed to react for 10 minutes to effect the nitration of the phenoldisulfonic acid.

After the reaction time had elapsed, 15 ml of deionized water were added by means of a large buret to the evaporating dish and stirred with a glass rod until all residues had dissolved. During the dilution of acid with deionized water heat was given off and the evaporating dish was allowed to cool. After the evaporating dish and its contents had cooled, the solution was titrated with 1:2 NH_4OH with constant stirring. At the end-point of the titration, 6 more ml of 1:2 NH_4OH were added to insure alkalinity of the colored solution.

The yellow solution was then transferred quantitatively from the evaporating dish to a 100 ml volumetric flask and brought to volume with deionized water. Contents of the 100 ml volumetric flask were mixed well. The transmittancy was then determined by reading the solution in a spectrophotometer at 420 mu. One hundred per cent transmittancy was obtained by the use of a reagent blank. The readings of the samples were converted into ppm by means of a standard curve extending from zero to two parts per million nitrate-nitrogen. Samples which exceeded the transmittancy range of the standard curve were dilluted five fold and read again.

Determination of Nitrate-Nitrogen in Water Samples

Water samples were prepared for nitrate determination by placing a 25 ml aliquot of water into a dry 125 ml Erlenmeyer flask. Then 2.5 ml of 0.6% Ag_2SO_4 solution was added to the flask and shaken for 10 minutes. After shaking, ½ teaspoon of $Ca(OH)_2$ and ½ teaspoon of $MgCO_3$ were added to the flask. Another shaking period of 5 minutes followed, after which the solution was gravity filtered through Whatman number 42 filter paper. A 10 ml aliquot of filtrate was pipetted into a 8 cm evaporating dish and evaporated to dryness on a steam hotplate. The evaporating dishes were taken off the steam hotplate and allowed to cool. Nitrate was determined by means of the phenoldisulfonic acid procedure described earlier.

Determination of Nitrite-Nitrogen in Soil and Water Samples

Qualitative nitrate tests were run on all soil and water samples by placing 4 to 5 drops of the filtered extract (filtered solution from the nitrate-nitrogen determination) in the depression in a clean dry spot plate. To this depression 1 drop of sulfanilic acid and 1 drop N-(1-naphthyl) ethylene-diamine hydrochloride (NEDD) reagent were added then stirred with a glass rod and two minutes were allowed for the color to develop. A pink color indicated the presence of nitrite and qualified that sample for a quantitative nitrite determination.

If nitrites were observed, the sample was saved by transferring the extract to a plastic bottle and storing in a refrigerator until a quantitative nitrite determination could be carried out.

A quantitative nitrite-nitrogen was determined in extracts by means of a modified method of Snell (38) using sulfanilic acid and NEDD. Nitrites are detected in solution by the formation of a red azo dye upon the addition of sulfanilic acid as a diazotizing agent and NEDD as a coupling agent.

Sulfanilic acid as a reagent was prepared by dissolving 5.0 gram sulfanilic acid crystals in 500 ml of 1.5 N HCl. The N-(1-naphthyl) ethylenediamine hydrochloride reagent was prepared by dissolving 0.2 gram of NEDD in 1000 ml of deionized water. A 35 ppm nitrite-nitrogen standard was made by dissolving 0.1725 gram of $NaNO_2$ in 1000 ml of deionized water.

Nitrites were determined by placing a 2 ml aliquot of the solution to be tested in a spectrophotometer tube after which 1 ml of sulfanilic acid reagent and 1 ml of NEDD reagent were added. The contents of the tube were mixed and 5 minutes allowed for color development after which the samples were read at 600 mu. Nitrite-nitrogen was expressed in ppm.

Determination of Ammonium-Nitrogen

Ammonium-nitrogen determinations on experimental soils and water were carried out by the steam distillation method of Bremner (6).

Five ml of 2.0 percent boric acid-methyl purple indicator solution was added to a 50 ml Erlenmeyer flask marked to indicate a volume of 30 ml and the flask placed under the condenser of a steam distillation apparatus. A 20 ml aliquot of a water sample was pipetted into a distillation flask. In the case of soil a dry 10 gram sample was placed in a distillation flask and diluted with 20 ml of deionized water. Then 0.2 gram of dry MgO was added to the distillation flask by means of a dry funnel. After the addition of MgO, the distillation flask was attached to the distillation apparatus and distillation was allowed to proceed. After the distilate reached the 30-ml volume mark on the receiver flask, the distillation was stopped and ammonium-nitrogen in the distillate was determined by titration with 0.0052 N H_2SO_4 from a 5 ml microburet graduated at 0.01 ml intervals. The color change at the end-point is from green to a permanent, faint blue. Blanks of deionized water were run and subtracted from the sample and the results were calculated in ppm NH_4^+-N.

Determination of Cation Exchange Capacity of Soils

The cation exchange capacity of selected soils was determined by placing a 5 gram soil sample in a 250 ml Erlenmeyer flask. Then 25 ml of 1.0 N ammonium acetate were added to the flask and mixed thoroughly and allowed to stand for 30 minutes with an occasional swirling. After 30 minutes the flask contents were transferred to Whatman 42 filter paper by washing the Erlenmeyer flask with distilled H_2O. The soil and filter paper were then washed with successive portions of distilled H_2O until the filtrate was free of NH_3. Nessler's solution was used to test the filtrate for ammonia. After the filtrate was free of NH_3, the soil and filter paper were transferred to a 300 ml micro-Kjeldahl flask. Then 0.3 gram of MgO and 50 ml of distilled H_2O were added to the flask. After the addition of MgO and distilled H_2O, the flask was connected to a steam distillation apparatus. The distilate was collected in a 50 ml Erlenmeyer flask containing 10 ml of 2% boric acid-methyl purple indicator solution. After the volume reached 35 ml in the Erlenmeyer flask the contents were titrated with 0.036 N H_2SO_4. At the end-point the color change was from green to a permanent, faint blue. The results were expressed in milliequivalents of NH_4^+ per 100 grams of soil.

RESULTS AND DISCUSSION

The map of Kansas in Figure 3 shows the locations of feedlots and irrigated fields used in the investigation.

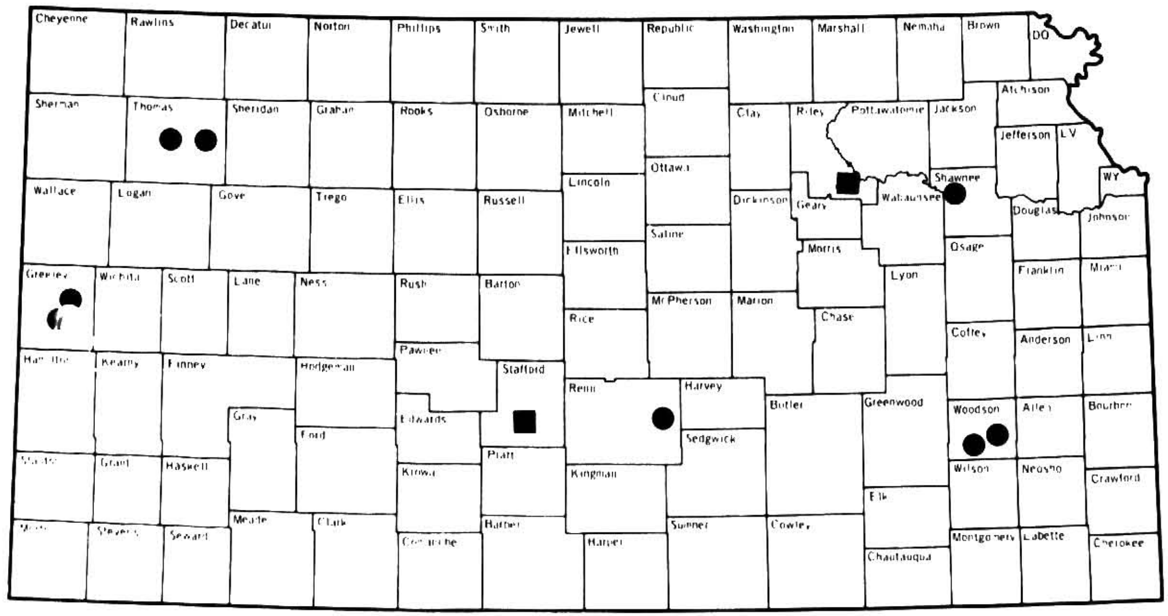
Feedlots were sampled in different areas of the state to determine effects of location, soil type or texture, amount of rainfall, and age of feedlots on nitrate-nitrogen movement and accumulation in the soil. Twenty-six soil cores ranging from 1 to 6 meters in depth were taken from the feedlots. Also 2 observation wells were established in Reno county to study nitrate-nitrogen in the ground water. All core samples were analyzed for nitrate-nitrogen and nitrite-nitrogen. In addition, core samples from Thomas, Greeley, and Reno counties were analyzed for ammonium-nitrogen and phosphorus. Selected core samples were analyzed for cation exchange capacity and percent organic matter with some cores from Riley county being subjected to moisture and texture analyses.

In Table 1 the annual precipitation for 1967 and the mean annual precipitation are shown for the locations used in these investigations.

Studies of nitrate-nitrogen movement and accumulation in irrigated soils under cropped conditions were established on sites with sandy soils, readily permeable to water. First aquifers were quite shallow at both irrigated locations. Six observation wells, three at each location, were established

FIGURE 3

LOCATION OF FEEDLOTS AND IRRIGATED FIELDS IN THE STATE OF KANSAS



■ **IRRIGATED FIELDS**

● **FEEDLOTS**

Table 1.--Precipitation in inches and centimeters for experimental sites

Location	1967 Annual Precipitation		Mean Annual Precipitation	
Yates Center	45.02 in	114.35 cm	36.00 in	91.44 cm
Topeka	50.64 in	128.63 cm	32.36 in	82.19 cm
Manhattan	37.59 in	95.48 cm	32.00 in	81.28 cm
Hutchinson	30.62 in	77.77 cm	27.60 in	70.10 cm
Pratt	20.76 in	52.73 cm	24.04 in	61.06 cm
Colby	11.17 in	28.37 cm	18.34 in	46.58 cm
Tribune	19.69 in	50.01 cm	16.26 in	41.30 cm

and sampled periodically to see if nitrate-nitrogen was accumulating in the ground water or if nitrate-nitrogen fluctuated in ground water with respect to time of year.

During the course of the investigation 24 cores were collected, 14 cores from Riley county and 10 cores from Stafford county, to monitor the nitrate-nitrogen movement in the soil.

The results of the investigation are reported on a county basis.

Thomas County

Soil cores from feedlots were collected from two locations in Thomas county on Kdith silt loam soils with 0 to 2 percent slope. One location was on the Colby Branch Experiment Station where a 40 year old feedlot was sampled. This particular lot had served as a dairy cattle holding pen for 25 years. Fifteen years ago the lot was converted to a sheep pen and was occupied by approximately 40 sheep the year around. The sheep lots were cleaned regularly. The second location was 13 miles east and 5 miles south of Colby where feedlots of 4 and 11 year ages were sampled. Approximately 100 cattle were fed in each of the lots. The lots were occupied continuously throughout the year.

The results of nitrate-nitrogen determinations on soils from the feedlots in Thomas county are presented in Figure 4. The soil cores taken from the feedlots contain fairly high concentrations of nitrate-nitrogen as indicated by Figure 4. Core samples obtained from the feedlots contained high concentrations of nitrate-nitrogen for the 1-2 meters in younger lots and up to 4 meters in the 40 year old lot. These cores were reasonably free of nitrate-nitrogen at the lower depths. The amounts of nitrate-nitrogen found in the soil cores from the corrals are quite distinct and appear to be related to the age of the feedlots. Soil of the oldest lot contained by far the highest concentration of nitrate-nitrogen. Core samples from these feedlots indicated that nitrate-nitrogen movement is occurring and nitrate-nitrogen is accumulating in the soil profile even under conditions where the average annual precipitation is 18 inches per annum.

The ranges of accumulation of nitrate-nitrogen in a 4 meter soil profile from the 4, 11, and 40 year lots were

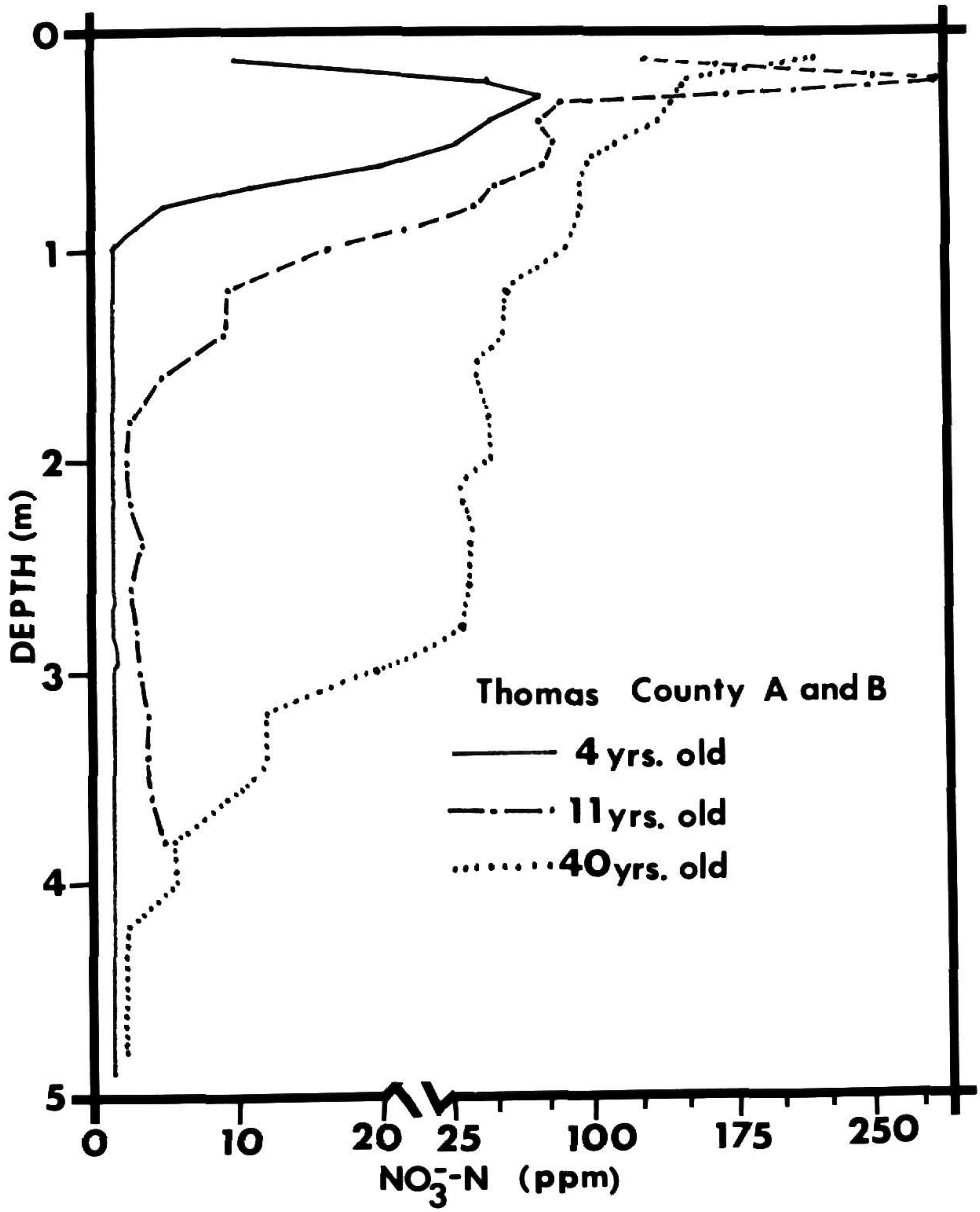


Figure 4.--Nitrate-nitrogen distribution patterns of three soil profiles from different age feedlots - Thomas County

388, 1285, and 3942 kg/ha (435, 1439, and 4415 lb/A) of nitrate-nitrogen respectively.

All core samples were tested for nitrite-nitrogen and were found to contain less than 1 ppm. However, the core samples contained significant amounts of ammonium-nitrogen at the surface.

Phosphorus determinations were conducted on cores from the 11 and 40 year lots. The findings show that almost all the phosphorus was concentrated at the surface. No movement of phosphorus was indicated by the data in tables 2 and 3.

Soil texture was not noticeably related to the nitrate-nitrogen content but tended to influence the nitrate-nitrogen content slightly. As the clay content decreased the nitrate-nitrogen content decreased. This was more a function of depth in the soil profile rather than soil texture because the clay content was fairly constant with depth.

Greeley County

Soil cores in Greeley county were collected from feedlots of three different ages at two locations. A 3 and a 30 year old lot were sampled at one site and a 13 year old lot at a second location. In both cases the soil was a Ulysses silt loam with a slope less than 1 percent. The 3 and 30 year old lots were located 4 miles west and 2 miles south of Tribune, and the 13 year old lot was located 3 miles north of Tribune. Approximately 100 to 150 cattle were fed in each of the corrals. The corrals were used continously in the case of the 3 and 13

Table 2.--Composition of a soil profile beneath an 11 year old feedlot - Thomas County

Depth cm	NO_3-N ppm	NH_4-N ppm	OM %	P ppm
0-10	108.0	193	5.0^{+}	1500
10-20	292.0	308	5.0	2000
20-30	308.0	18	1.5	45
30-40	228.0	25	1.3	2
40-50	88.0	43	1.1	4
50-60	35.2	22	1.8	1
60-70	14.0	12	.7	2.5
70-80	2.0	11	.6	4
80-90	1.7	16	.6	3
90-100	2.0	22	.6	4
100-120	1.7	8	.5	6.5
120-140	2.3	2	.6	17.5
140-160	0.8	0	.5	16.5
160-180	1.2	1	.9	15
180-200	1.2	6	.4	9.5
200-220	1.7	0	.4	12
220-240	1.7	5	.6	12
240-260	5.1	15	.9	27
260-280	2.3	11	.4	9.5
280-300	2.3	9	.5	9.5
300-320	2.8	8	.4	12.5
320-340	2.8	6	.5	12
340-360	3.8	4	.5	16.5
360-380	-----	---	---	------
380-400	5.4	4	.6	16.0
400-420	5.7	3	.6	14.0
420-440	6.8	6	.5	17.5

Table 3.--Composition of a soil profile beneath a 40 year old feedlot - Thomas County

Depth cm	NO_3-N ppm	NH_4^+-N ppm	OM %	P ppm
0-10	308.0	125.0	3.2	350.0
10-20	130.0	11.0	1.1	55.0
20-30	88.0	12.0	1.1	17.5
30-40	76.0	5.0	1.2	17.5
40-50	76.0	6.0	1.2	29.0
50-60	72.0	15.0	1.2	11.0
60-70	64.0	6.0	1.3	6.5
70-80	60.0	4.0	1.0	7.0
80-90	48.0	12.0	1.0	5.5
90-100	48.0	5.0	.9	10.0
100-120	44.0	16.0	.8	15.0
120-140	45.2	12.0	1.0	16.5
140-160	52.0	6.0	.6	11.5
160-180	58.0	15.0	.4	14.0
180-200	62.4	14.0	.5	12.0
200-220	62.4	14.0	.7	20.5
220-240	58.0	11.0	.6	14.0
240-260	50.0	3.0	.5	12.5
260-280	38.4	1.0	.5	9.0
280-300	28.0	2.0	.4	9.5
300-320	18.2	16.0	.5	8.0
320-340	14.0	18.0	.4	7.5
340-360	16.8	3.0	.4	9.0
360-380	6.0	2.0	.5	8.5
380-400	4.1	1.0	.3	9.5
400-420	3.2	9.0	.4	10.0
420-440	3.8	10.0	.7	9.5

year lots but the 30 year lot was used only during the winter and spring months (5 to 6 months out of the year).

The nitrate-nitrogen content found in the soil profiles from Greeley county is presented in Figure 5. The nitrate-nitrogen content of the soil profile indicated by Figure 5 and Tables 4 and 5 clearly shows that nitrate-nitrogen had accumulated in large quantities underneath the feedlots. More nitrate-nitrogen were found in the soil profile beneath the older lots than the younger lots, but cores taken from the 13 year old lot had more nitrate-nitrogen than from the 30 year old lot. The reason attributed to this apparent discrepancy was that the 13 year lot had contained cattle continously whereas the 30 year lot held cattle only 5 to 6 months of the year. From the amounts of nitrate-nitrogen deep in these profiles it can clearly be seen (Figure 5) that nitrate-nitrogen movement is occurring even in areas where mean annual precipitation is only 16 inches.

No significant amount of nitrite-nitrogen were detected in the soil profiles of the feedlots except in the manure layer in the 30 year lot.

The magnitude of nitrate-nitrogen accumulation in a 4 meter soil profile for 3, 13, and 30 year lots were 1800, 4934, and 3210 kg/ha (1016, 5526, and 3595 lb/A) respectively.

Available phosphorus was determined in soil cores from 13, and 39 year old lots. The results reported in Tables 4 and

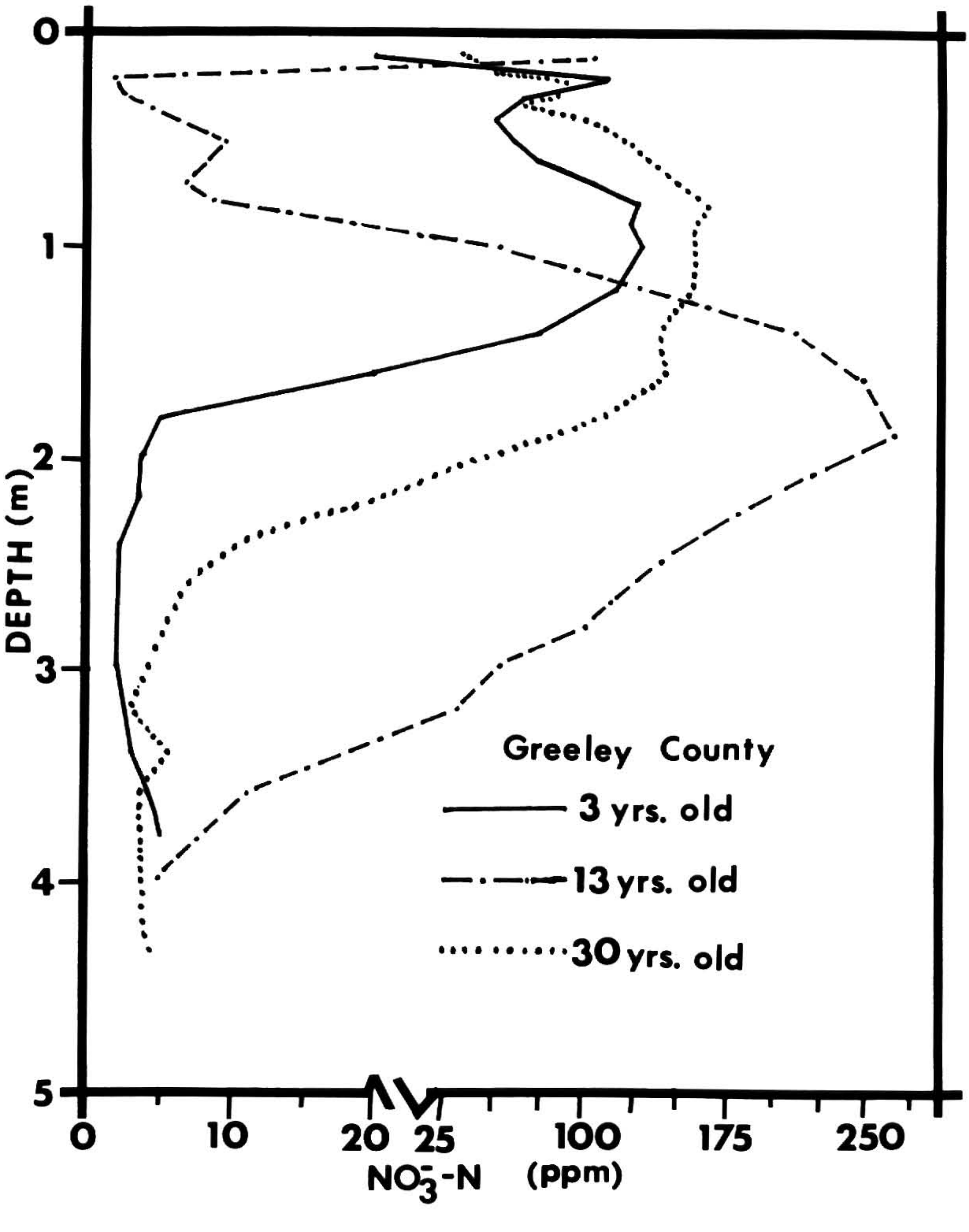


Figure 5.--Nitrate-nitrogen distribution patterns of three soil profiles from different age feedlots - Greeley County

Table 4.--Composition of a feedlot soil profile from Greeley County - 13 years old

Depth cm	NO_3-N ppm	NH_4-N ppm	OM %	P ppm
0-10	104.0	1223	5.0+	550.0
10-20	1.5	426	1.4	3.0
20-30	2.3	264	.9	1.5
30-40	6.4	99	.7	2.0
40-50	9.6	30	.9	3.0
50-60	8.4	15	.9	8.5
60-70	6.4	6	.6	3.5
70-80	9.2	14	2.0	9.5
80-90	18.8	11	.6	7.5
90-100	53.6	----	.9	12.0
100-120	130.0	7	.4	8.0
120-140	212.0	4	.7	5.5
140-160	248.0	5	.6	5.0
160-180	256.0	5	.5	5.5
180-200	240.0	11	.5	7.0
200-220	188.0	6	.3	1.0
220-240	156.0	5	.4	9.5
240-260	130.0	6	.5	13.0
260-280	100.0	4	.7	14.0
280-300	52.0	11	.6	9.0
300-320	30.0	8	.6	14.0
320-340	18.2	5	.7	18.0
340-360	12.2	7	.6	7.0
360-380	9.6	4	.8	26.0
380-400	5.7	4	.8	18.5

Table 5.--Composition of a feedlot soil profile from Greeley County - 30 years old

Depth cm	NO_3-N ppm	NH_4-N ppm	OM %	P ppm
0-10	34.4	47	5.0+	750
10-20	88.0	16	4.1	875
20-30	60.0	9	1.7	125
30-40	100.0	7	1.4	11
40-50	122.0	6	1.3	13
50-60	136.0	7	1.3	1.5
60-70	150.0	5	1.1	1.5
70-80	160.0	10	1.5	6.5
80-90	156.0	6	1.0	8.0
90-100	156.0	2	1.1	6.5
100-120	156.0	17	.7	1.5
120-140	140.0	5	.9	0.5
140-160	144.0	1	.5	1.0
160-180	108.0	5	.5	1.0
180-200	39.6	4	.6	2.0
200-220	20.4	7	.7	6.0
220-240	10.8	1	.5	8.0
240-260	6.8	0.5	.6	8.0
260-280	5.1	1	.6	8.0
280-300	4.1	3	.7	9.5
300-320	2.8	5	.8	13.0
320-340	5.4	3	.6	8.5
340-360	3.2	1	.5	9.5
360-380	3.5	0.5	.6	11.0
380-400	3.8	2	.6	10.0
400-420	3.8	1	.8	2.0
420-440	4.4	1	.7	3.0

5 indicate that phosphorus is concentrated in the upper 10 to 30 centimeters of the soil with little downward movement of phosphorus being evident.

Ammonium-nitrogen was found in significant quantities at the surface of the soils but decreased rapidly with increasing depth.

Shawnee County

One feedlot was sampled in Shawnee county on Waukesha silt loam soil with 0 to 2 percent slope. The location of the feedlot was 3 miles northwest and ½ mile south of Rossville, Kansas. Two cores were taken, one in a 12 year old feedlot and one 20 meters outside the feedlot which served as a check. The lot contained approximately 100 to 125 cattle during the winter and spring months (5 to 6 months of the year). The manure was removed in the spring and spread on nearby irrigated corn fields.

Cores from the check area and the feedlot show markedly different amounts of nitrate-nitrogen present in the soil profile as shown in Figure 6. The check core was located on a grass lawn and indicated a insignificant amount of nitrate-nitrogen in the soil profile. The core taken from the 12 year old lot showed that nitrate-nitrogen accumulation was occurring to considerable depths. Significant quantities of nitrate were found at depths in excess of 5 meters in the soil. At this particular location the water table lies at an approximate depth of 7-8 meters.

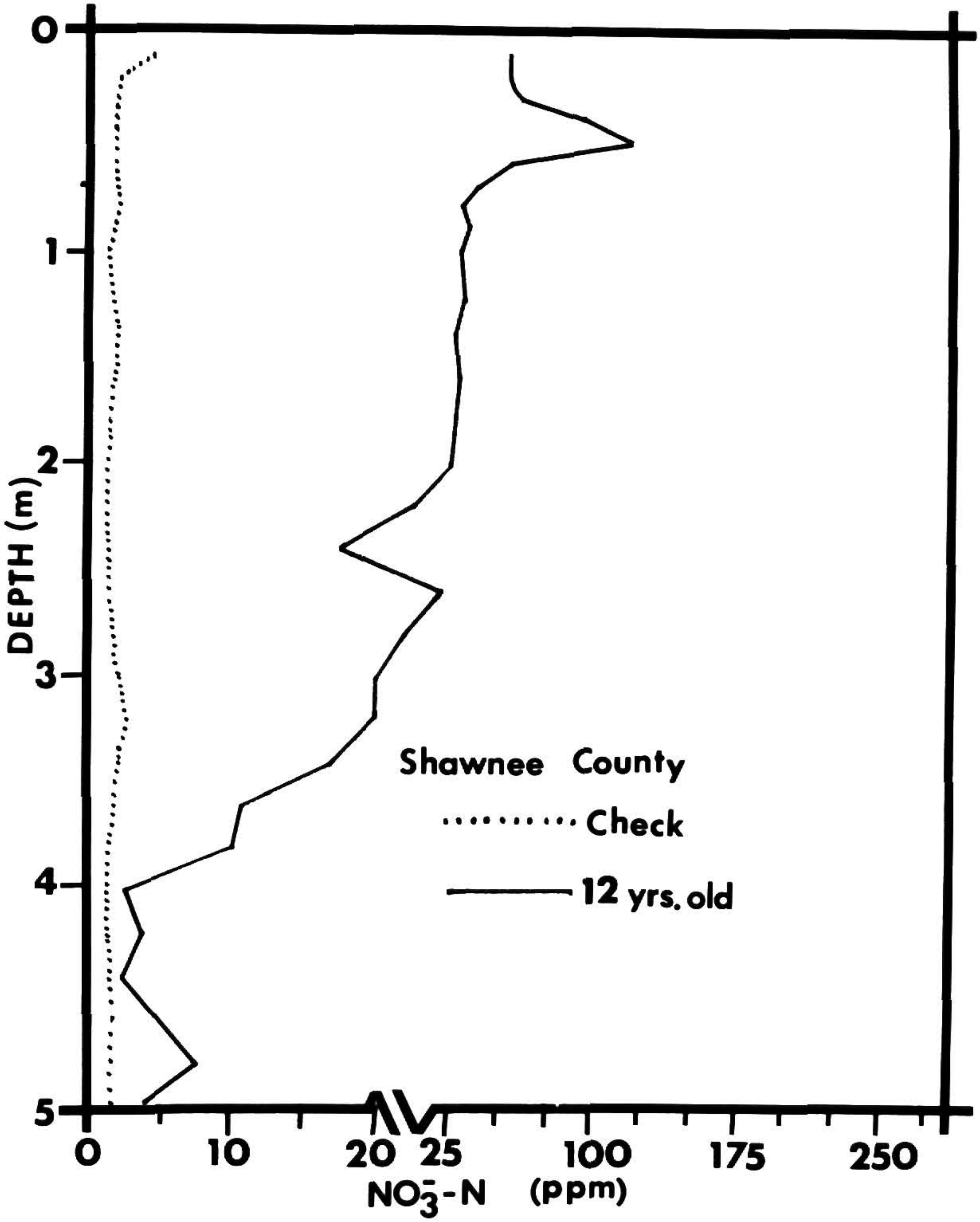


Figure 6.--Nitrate-nitrogen distribution patterns of two soil profiles from different age feedlots - Shawnee County

All core samples from this location were tested for nitrite-nitrogen and found to contain insignificant amounts of that form of nitrogen.

Woodson County

Corrals 7 and 20 years of age were sampled in Woodson county on a fine sandy loam with 4 percent slope and on a silty clay loam soil with 7 percent slope, respectively. The 7 year old corral was located on a dairy farm and was used continously during the winter months and intermittently during the summer. The lot contains on the average of 150 cows throughout the year. The 20 year lot was located on a hog farm with which an impervious layer of rock lying approximately 1 meter beneath the surface. This lot was used continously and contains 60 hogs the year around.

The soil analyses from Woodson county reveal fairly high concentrations of nitrate-nitrogen down to 2 meters in the soil on the 7 year lot as shown in Figure 7. The older lot contained high concentrations of nitrate-nitrogen at first, but the concentration decreased rapidly with depth. This was due to the extremely compact soil and the bed rock lying 80 to 100 centimeters below the surface. There was a great contrast in texture and areation of the soil between the two locations in Woodson county. Cores taken from the 7 year old lot clearly show that nitrate-nitrogen is being leached downward into soil. In the case of the older lot, bed rock is preventing the leaching of nitrate-nitrogen.

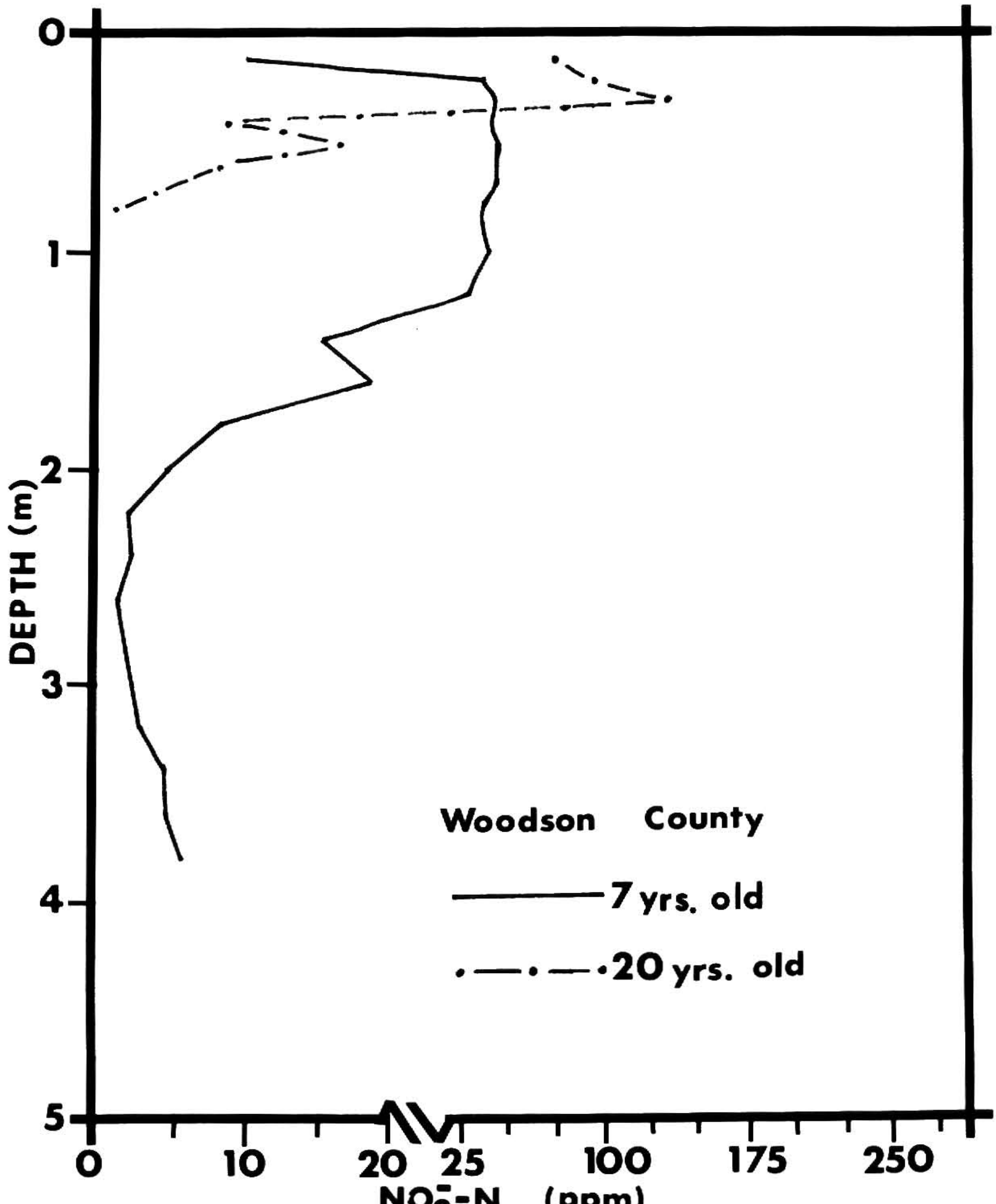


Figure 7.--Nitrate-nitrogen distribution patterns of two soil profiles from different age feedlots - Woodson County

Nitrate-nitrogen was found in quantities approaching 1 ppm in the soil immediately below the manure layer in the 7 year old lot and 1 ppm in the manure layer in the 20 year lot.

Reno County

Feedlots with ages of 3 months, 18 years, 30 years, and 60 years old were sampled in Reno county on a fine sandy loam soil with 0 to 2 percent slope. The location of the feedlots was 6 miles north and one mile west of Haven, Kansas. A soil core was taken 100 meters southwest of the feedlots to serve as a check. The lots contained approximately 60 to 100 cattle per lot continously the year around. The manure was removed in the spring and fall and spread on nearby fields.

Observation wells were established in the 30 year lot and at the check location (100 meters southwest of the feedlots) to monitor the nitrate-nitrogen content of the ground water throughout the year. The water table existed at 2.6 and 3.0 meters below the surface soil at the check location and 30 year lot, respectively. Samples were also collected from the farmer's well supplying the water for the cattle.

The soil analysis data from Reno county site are shown in Figures 8 and 9. The nitrate-nitrogen content of the feedlot cores was much lower than expected but ammonium-nitrogen was detected in significant quantities throughout the profile, especially in the 30 year lot. This is in direct opposition to the distribution of nitrogen species in cores taken from other feedlot locations.

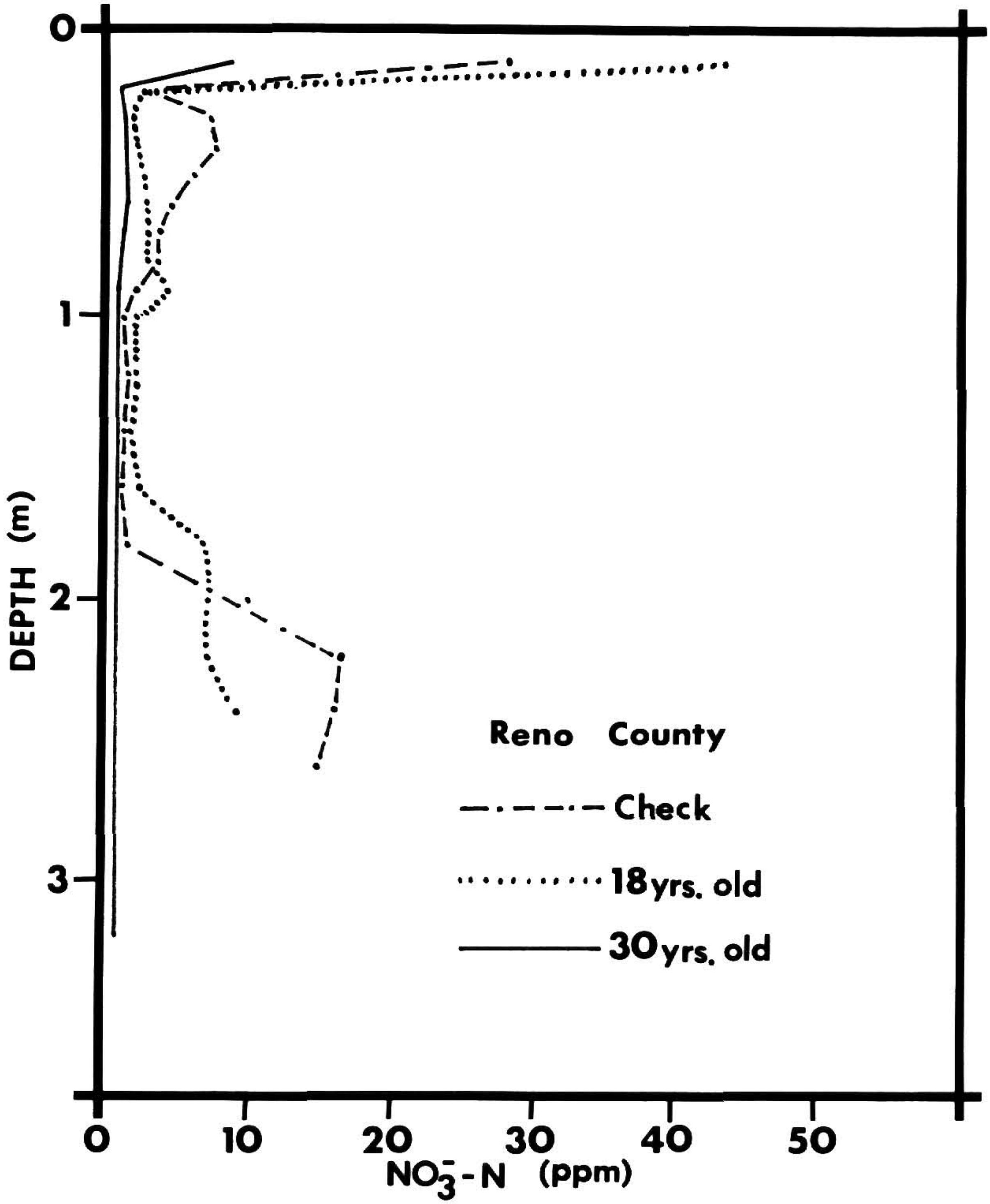


Figure 8.--Nitrate-nitrogen distribution patterns of three soil profiles from different age feedlots - Reno County

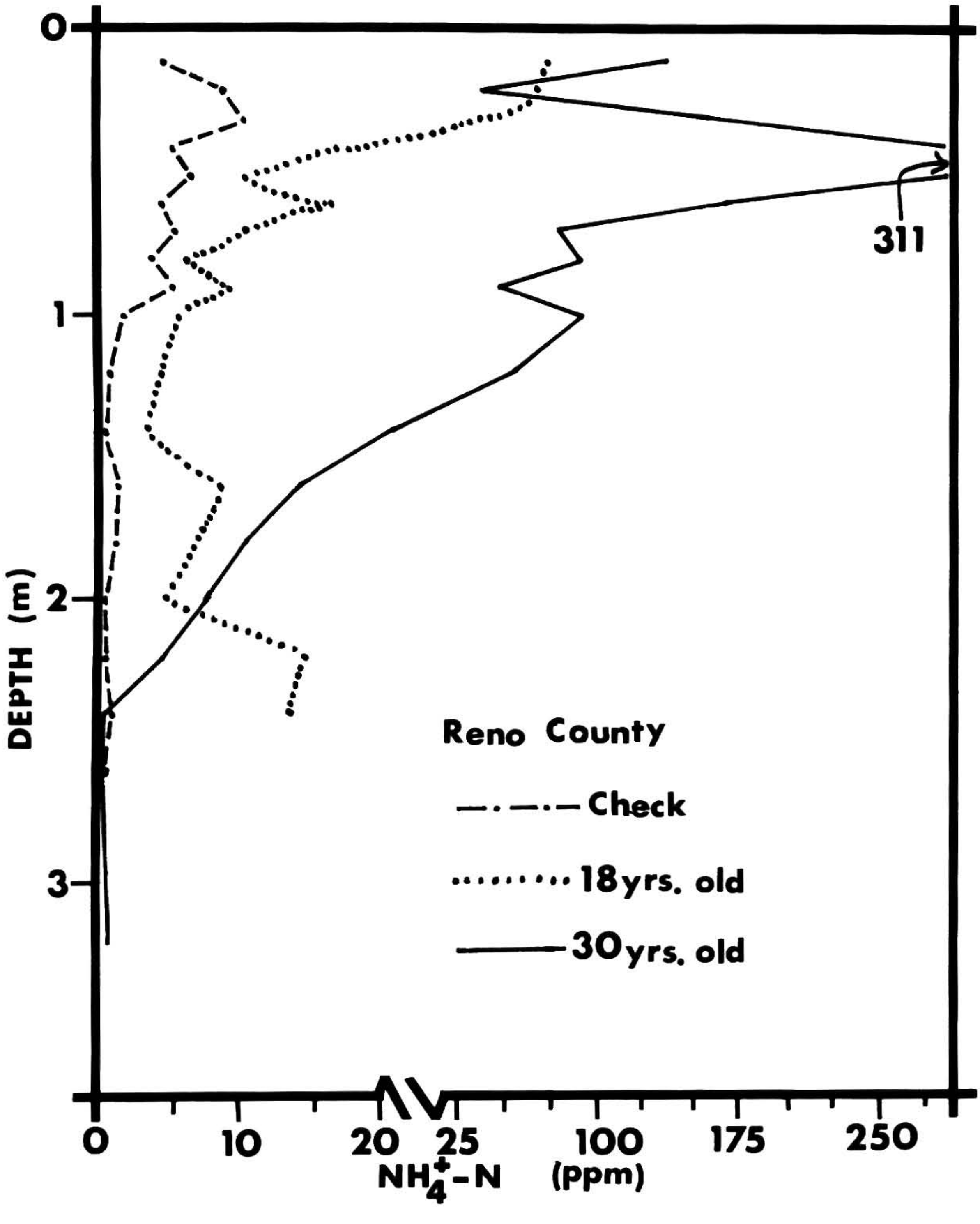


Figure 9.--Ammonium-nitrogen distribution patterns of three soil profiles from different age feedlots - Reno County

Stewart and co-workers (40) reported similar low nitrate-high ammonium distributions in soil profiles underlying corrals in northeastern Colorado. They attributed the low nitrate-nitrogen level as probably due to a low oxygen status in the soil as indicated by the low Eh values in their data. Previous studies (31) have shown that nitrate-nitrogen is generally unstable in soil systems when the Eh value is lower than about 320 to 340 mv. Other workers (30) have shown that low redox potentials develop with increased soil moisture content and under submerged soil. This might be due to partial or complete displacement of oxygen from soil and rapid consumption of oxygen by soil microbes. The findings of Savant and Ellis (33) show that fresh organic matter in a submerged soil accelerates the rate of decrease of redox potential of the soil. It is interesting to note that in both situations where high ammonium-nitrogen concentrations existed throughout the soil profile, a shallow aquifer existed. The presence of a high water table would contribute to a lowering of the oxygen status of the soil.

Ammonium-nitrogen accumulation in the sandy soil of the Reno county site was also favored by the soils low cation exchange capacity (Appendix Table 13). The low soil exchange capacity apparently allowed a large amount of leaching of cations through the profile. The relatively unhindered leaching may also account for the relatively small amount of nitrate-nitrogen in the profile.

The results of analyses on water samples taken from wells at the Reno county site are presented in the following Table 6. The analysis of variance of nitrate-nitrogen data from these wells indicated highly significant differences between wells and between sampling dates. These differences indicate that the nitrate-nitrogen content of the ground water fluctuates during the year. The highly significant differences between wells were due to the specific location of each well. The well supplying water to the cattle was located on the north side of the lots. The Arkansas river is located 2 miles south of the lots and the gradient of the ground water flow is in a southerly direction. Therefore the well supplying the water to the cattle would not be contaiminated by lateral movement of ground water containing nitrate-nitrogen.

Table 6.--Nitrate-nitrogen content of water from observation wells - Reno County

		Analysis of Variance		
Source	df	SS	MS	F
Total	35	15,940.59		
Wells	2	11,539.92	5,764.96	60.31*
Dates	3	1,543.08	514.36	5.38*
Error	30	2,867.59	95.59	

*A significant difference at 0.05 level

In the case of the check well, high concentrations of nitrate-nitrogen were found in the water. Some factors which might have attributed to this condition were: (1) high amounts of manure applied to fields near the site of the check well; (2) the check well location on the south side of the feedlots was conductive to movement of nitrate-nitrogen in ground water from beneath the lots to the position of the well; (3) large amounts of inorganic fertilizer applied next to the check well area for forage corn. These three factors may have served to concentrate the nitrate-nitrogen at the check well.

The amount of nitrate-nitrogen found in the observation well inside the 30 year lot was not as high as expected. The low nitrate-nitrogen content of water from the observation well agreed well with the data from the 30 year lot soil core analysis shown in Appendix Table 8 where a low content of nitrate-nitrogen was found in the soil profile.

Nitrite-nitrogen was determined on all water samples and all samples were found to contain less than 1 ppm nitrite-nitrogen. Ammonium-nitrogen in quantities up to 0.9 ppm was detected in the water samples collected from the observation well in the 30 year lot.

Accumulation of Nitrate-Nitrogen under Inorganic Nitrogen Fertilization

Riley County

Unit one of the Ashland Agronomy Farm in Riley county, 6 miles southwest of Manhattan was the location of an irrigated corn study on a sandy loam soil where nitrate-nitrogen accumulation in the soil profile and in ground water was studied. The corn produced on this area was irrigated by furrow irrigation. The entire study area received 354 kg of nitrogen per ha annually as 316.00 kg of nitrogen per ha as anhydrous ammonia in split applications of preplant and sidedressing and 18 kg of nitrogen per ha as a starter. Plots I-4, II-5, III-6, and IV-7 received anhydrous ammonia at the rates of 56kg N per ha preplant and 280 kg N per ha sidedressed, 336 kg preplant and 0 sidedressed, 224 kg preplant and 112 kg sidedressed, and 112 kg preplant and 224 kg sidedressed, respectively. Soil cores were collected to depths of approximately 5 meters from these plots.

This irrigated site possessed the unique facilities required by this study in that the soils were readily permeable to water and a shallow water table exists at a depth of approximately 6 meters. Three observation wells were established on the irrigated field, one serving as a check well and located 30 meters west of the study, the other two wells located on plots II-5 and IV-7. These wells provided a means of sampling the ground water at a specified depth over the period of the investigation. The fact that these observation wells were located in the areas used for experimental purposes allowed a simultaneous monitoring of nitrate-nitrogen movement through the soil by means of soil cores and a monitoring of the nitrate content of the ground water beneath the plot area.

The nitrate-nitrogen distribution patterns in the soil cores taken from this site are presented in Figures 10, 11, 12, 13 and 14. There is evidence that nitrate-nitrogen movement has occurred in the soil as indicated by downward movement of three distinct nitrate-nitrogen peaks for the three sampling dates which are shown in Figure 12 for plott II-5.

The level of total nitrate-nitrogen had increased in the soil profile during the study as indicated by all plots with the exception of plot IV-7 and the check location as shown in the following table.

Table 7.--Soil NO_3^--N kg/ha to a depth of 4 meters - Riley county site

	1967	1968	1969
Check	517	---	381
Plot I-4	320	186	391
Plot II-5	127	200	232
Plot III-6	112	242	173
Plot IV-7	315	523	159

The amount of nitrate-nitrogen in 4 meters of soil profile increased for plot II-5 from 127 to 200 to 232 for the years 1967, 1968, and 1969, respectively. The nitrate-nitrogen levels in 4 meters of soil profile on the other plots were quite varied from one sampling period to the next.

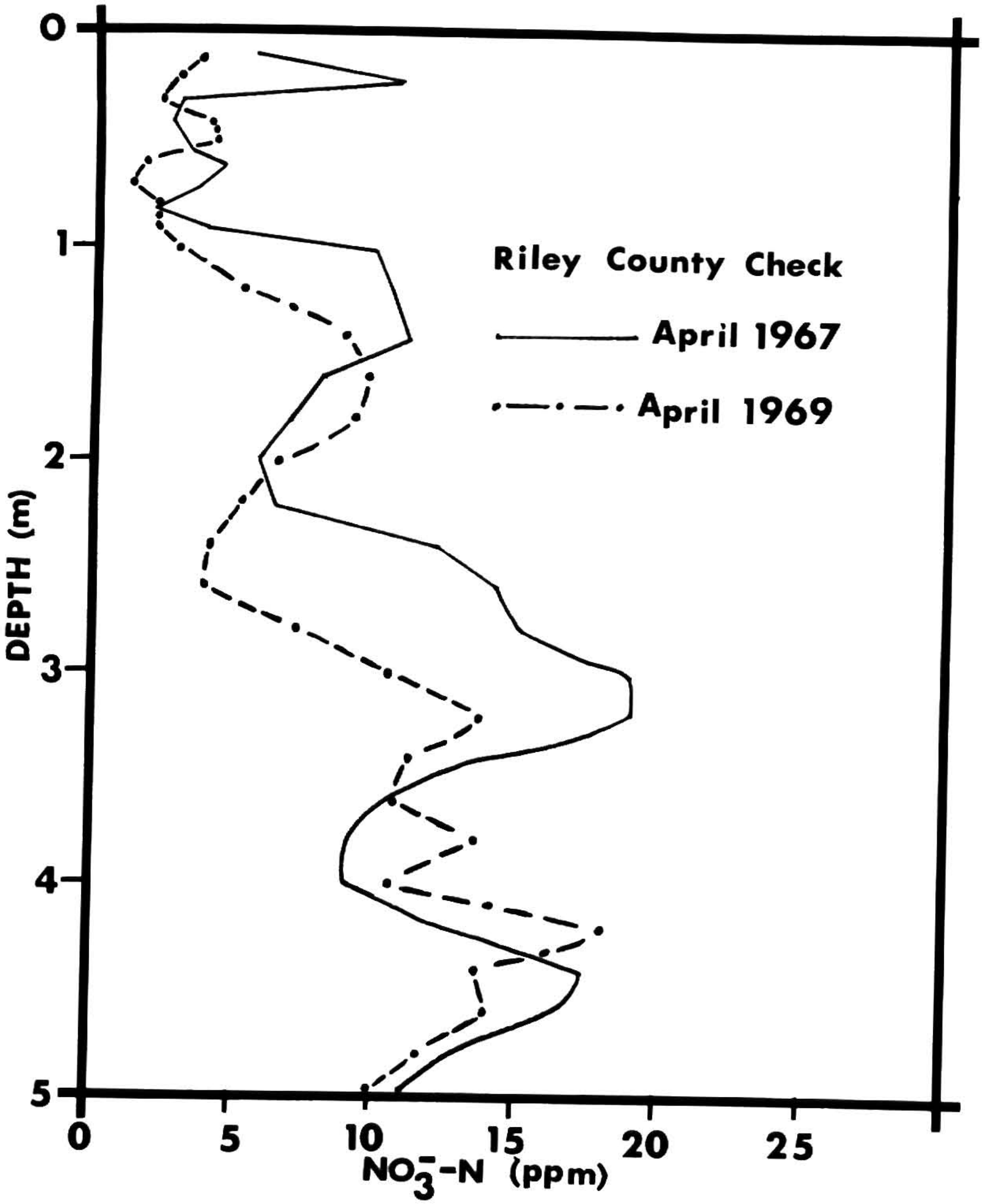


Figure 10.--Nitrate-nitrogen distribution patterns in the soil cores from the check site, Riley County

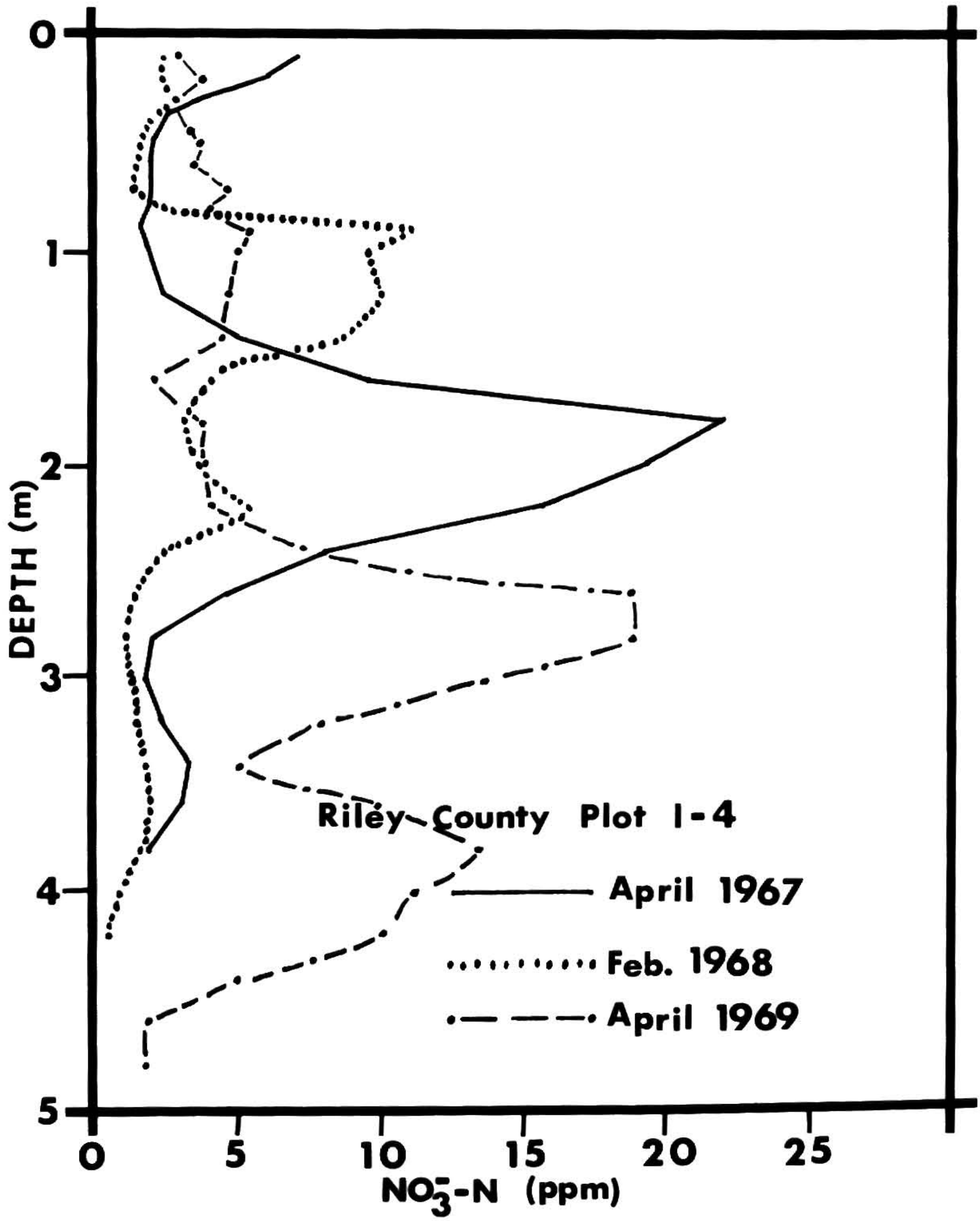


Figure 11.--Nitrate-nitrogen distribution patterns in soil cores from plot I-4. - Riley County

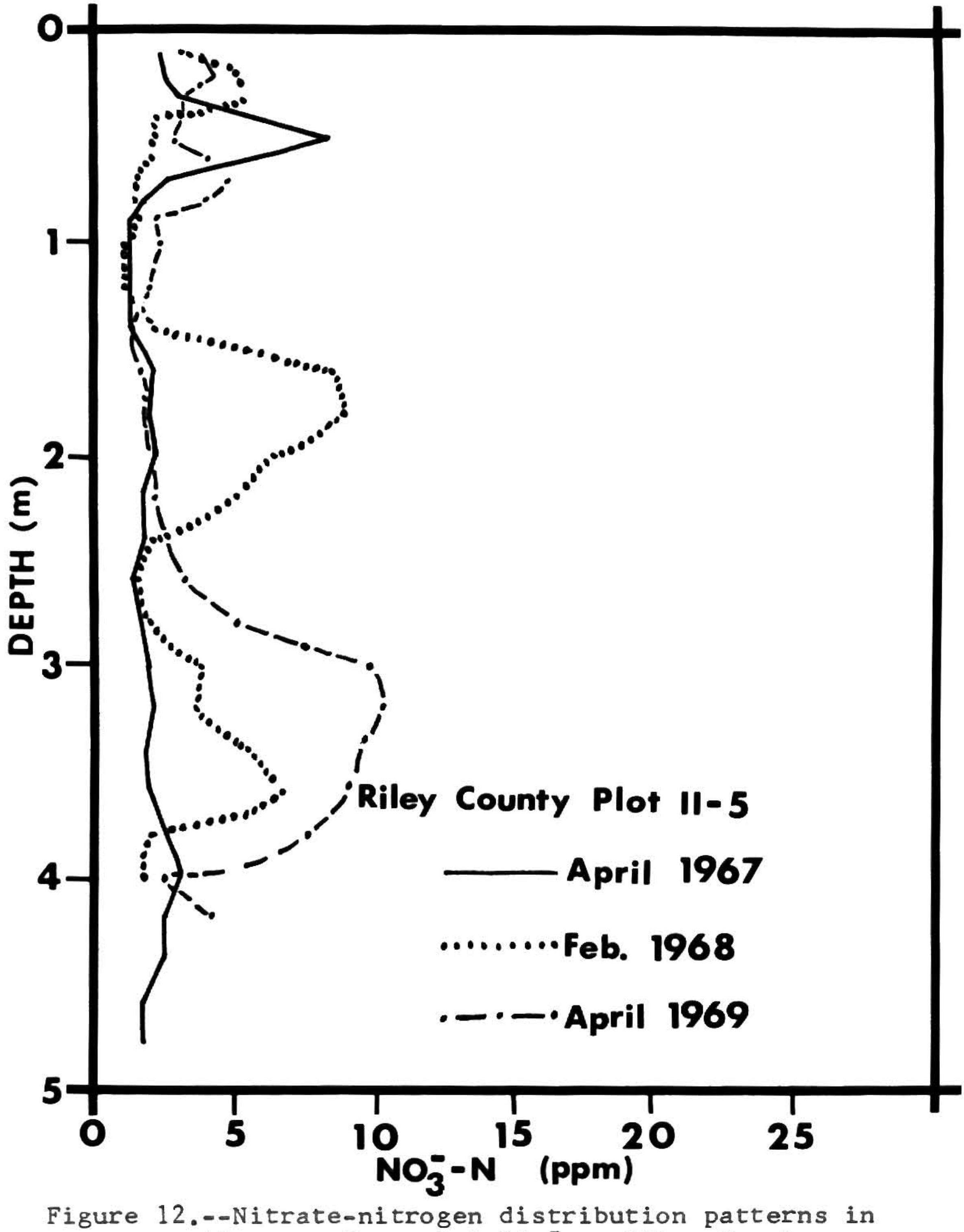


Figure 12.--Nitrate-nitrogen distribution patterns in soil cores from plot II-5. - Riley County

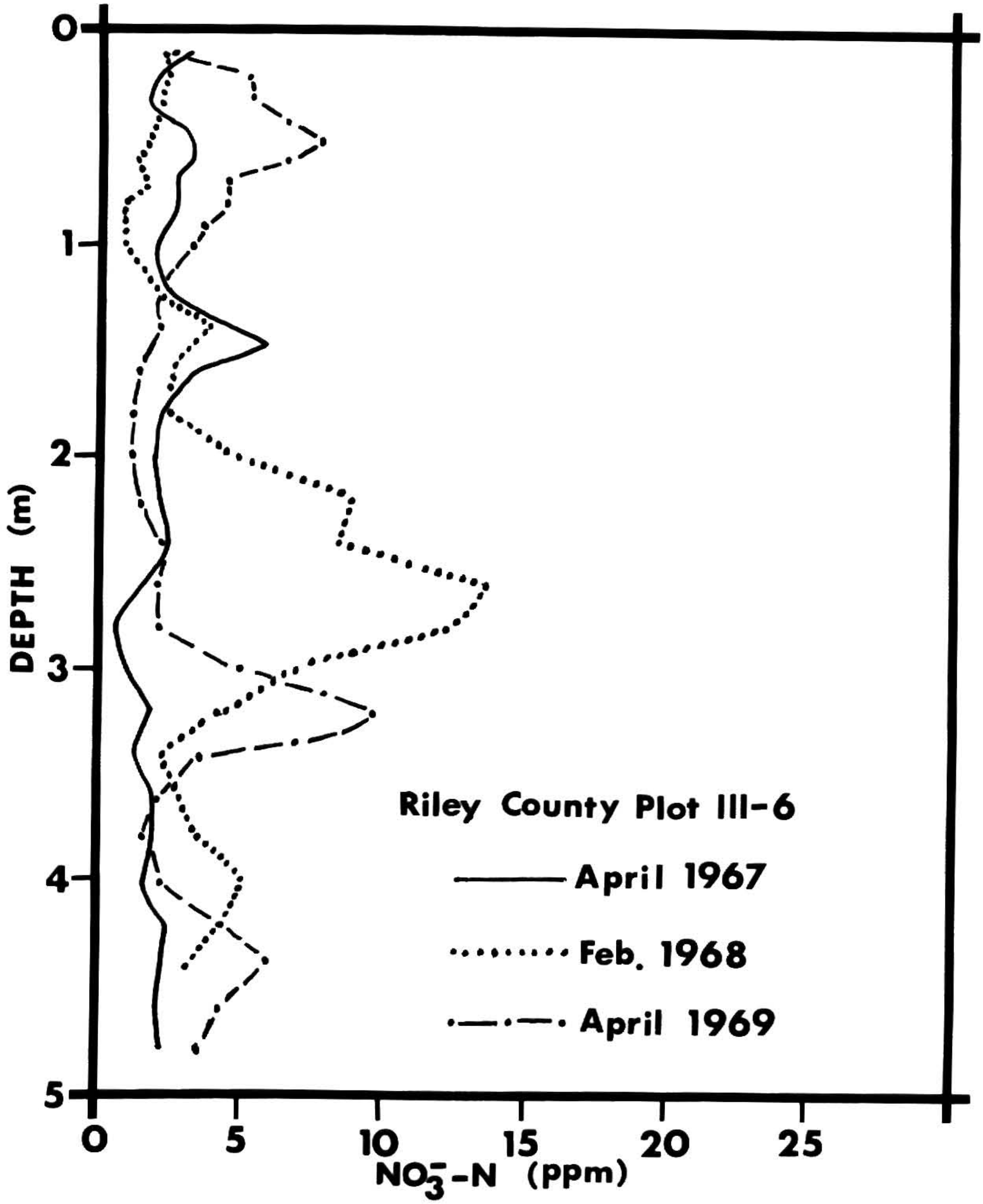


Figure 13.--Nitrate-nitrogen distribution patterns in soil cores from plot III-6. - Riley County

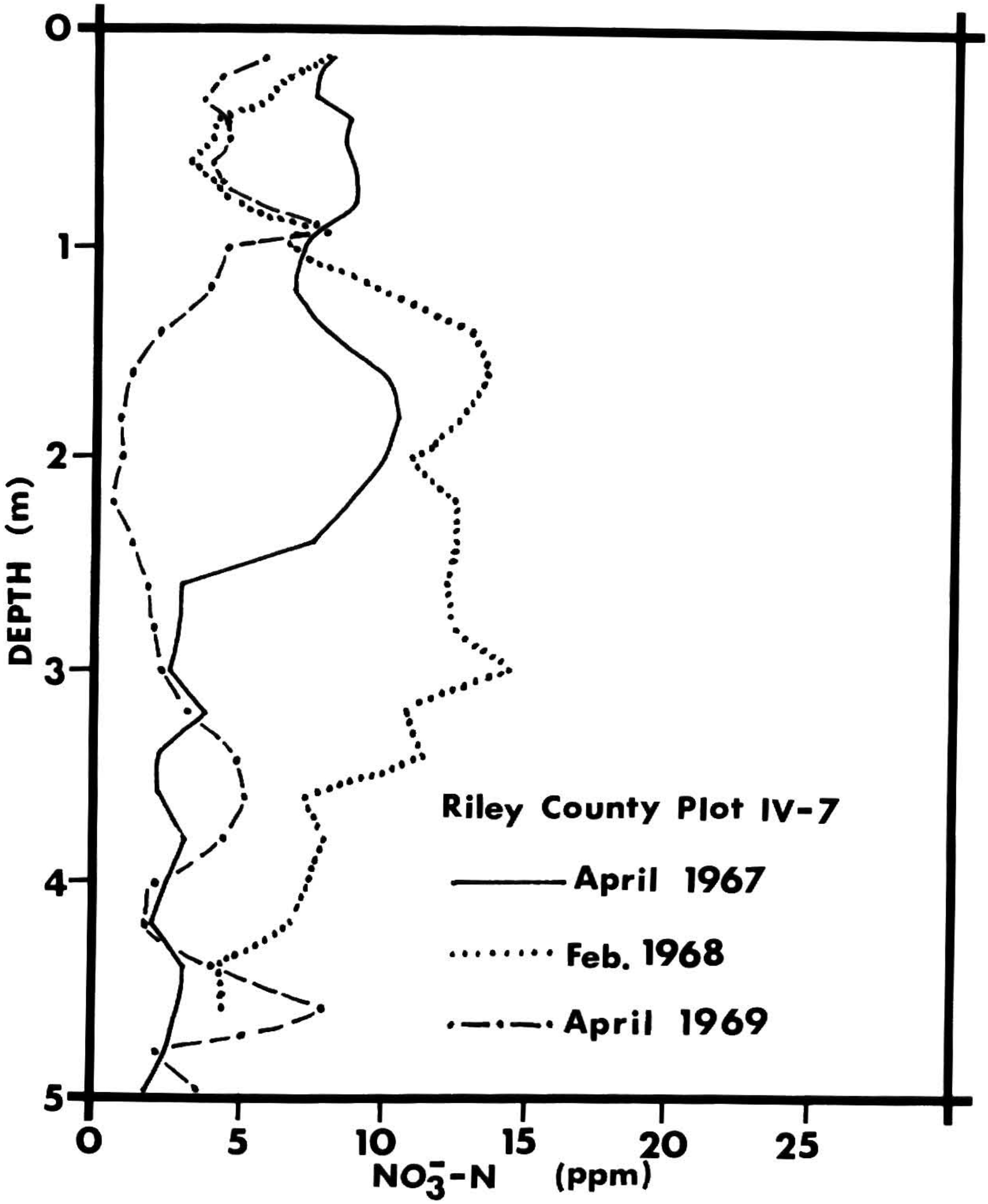


Figure 14.--Nitrate-nitrogen distribution patterns in soil cores from plot IV-7. - Riley County

The time of application of nitrogen as preplant and sidedressed applications of anhydrous ammonia had little effect on the amount of nitrate-nitrogen accumulated in the soil.

All core samples were tested for nitrite-nitrogen and were found to contain less than one ppm nitrite-nitrogen.

Nitrate-nitrogen movement in this soil was affected by soil texture as indicated in Tables 8 and 9 for plots I-4 and II-5. The data clearly show that as the clay content increases the nitrate-nitrogen content also increases. As the clay content increased the moisture content increased also. This was expected since water serves as the vehicle for nitrate-nitrogen movement and the clay content serves to restrict water movement. Thus, in varied soil profiles, as those in plots I-4 and II-5, it was noted that as the clay content increased the moisture content increased and points of nitrate-nitrogen accumulation tended to coincide with points of high water content.

The nitrate-nitrogen content of the water samples taken from the observation wells during the study are shown in Figure 15.

The results of an analysis of variance of the water sample nitrate-nitrogen data from Table 10 indicate significant differences between sampling dates. This signifies that the amount of nitrate-nitrogen in the ground water fluctuates considerably throughout the year. Also nitrate-nitrogen in the ground water seem to be a little higher in the fall and winter months than during the summer months.

Table 8.--Composition of soil profile from Riley County - plot I-4

Depth cm	Texture	NO_3-N ppm	% H_2O	%Sand	%Clay	%Silt
0-10	Silt loam	3.20	11.39	28.4	16.8	54.8
10-20	Silt loam	3.80	20.76	32.4	16.2	51.4
20-30	Loam	3.20	21.43	42.0	14.8	43.2
30-40	Silt loam	2.80	21.29	36.4	13.2	50.4
40-50	Loam	3.80	21.73	42.0	10.2	47.8
50-60	Sandy loam	3.48	15.07	46.0	8.2	45.8
60-70	"	4.80	15.55	62.4	8.8	28.8
70-80	"	4.12	11.16	66.4	6.8	26.8
80-90	"	5.40	15.74	56.4	8.8	34.8
90-100	"	5.08	13.36	70.4	7.8	21.8
100-120	"	4.80	15.58	70.4	9.8	19.8
120-140	"	4.12	17.78	70.4	9.8	19.8
140-160	"	2.28	13.42	72.6	9.2	18.2
160-180	"	3.80	17.16	62.0	12.2	25.8
180-200	Loam	3.80	21.41	51.6	14.2	34.3
200-220	"	4.12	21.00	47.6	13.6	38.8
220-240	"	8.00	21.08	45.6	14.6	39.8
240-260	"	18.80	21.01	47.6	13.6	38.8
260-280	"	18.80	24.57	33.8	17.8	48.4
280-300	Silt loam	13.60	23.80	29.6	18.8	51.6
300-320	Loam	8.00	19.00	45.8	13.4	40.8
320-340	"	5.08	16.23	48.8	9.4	41.8
340-360	"	10.00	24.79	46.8	12.4	40.8
360-380	Silt loam	13.60	27.57	29.4	13.6	57.0
380-400	"	11.20	28.80	35.4	10.6	54.0
400-420	Loam	10.40	28.32	42.0	9.6	48.4
420-440	Loamy sand	5.08	13.55	77.2	5.0	17.8
440-460	Sand	2.00	2.99	94.6	4.0	1.4
460-480	"	2.00	4.52	94.2	3.0	2.8

Table 9.--Composition of soil profile from Riley County - plot II-5

Depth cm	Texture	CEC me/100g	NO_3-N ppm	% H_2O	%Sand	%Clay	%Silt
0-10	Loam	10.15	3.80	16.80	38.4	17.0	44.6
10-20	"	8.21	4.12	21.03	36.8	17.0	46.2
20-30	"	10.15	3.20	22.89	32.4	20.0	47.2
30-40	"		3.20	21.32	37.8	17.0	45.2
40-50	"	8.57	2.80	17.47	44.4	12.0	43.6
50-60	Silt loam		4.12	16.59	39.4	10.0	50.6
60-70	"	7.00	4.80	21.65	35.6	10.0	54.4
70-80	Loam		3.48	20.30	45.6	11.0	43.4
80-90	Sandy loam	4.54	2.28	13.60	68.6	8.0	23.4
90-100	"		2.28	19.72	55.2	10.4	34.4
100-120	Loamy sand	2.66	2.00	11.25	83.8	5.4	10.8
120-140	Sandy loam		1.48	19.88	68.2	8.0	23.8
140-160	"	5.04	1.20	18.23	65.8	10.4	23.8
160-180	Loamy sand		1.20	9.72	82.8	8.0	9.2
180-200	Sandy loam	9.94	2.00	18.69	54.6	16.8	28.6
200-220	Loam		2.00	19.15	47.6	14.8	37.6
220-240	"	4.68	2.28	19.09	47.2	12.8	40.0
240-260	"		2.52	19.53	49.2	11.8	39.0
260-280	"	7.42	2.80	24.83	32.2	19.2	48.6
280-300	"		5.08	23.70	30.2	20.2	49.6
300-320	"	5.40	10.00	20.68	43.6	14.8	41.6
320-340	"		10.40	22.33	51.6	9.8	38.6
340-360	"	4.90	9.60	26.96	46.2	10.8	43.0
360-380	Sandy loam		9.20	26.53	48.8	6.2	45.0
380-400	Loamy sand	2.30	7.60	19.20	79.8	5.2	15.0
400-420	Sand		2.52	5.82	96.8	0.8	2.4
420-440	"	0.72	4.12	6.58	97.0	0.8	2.2

Figure 15.--Level of Nitrate-nitrogen in the ground water throughout the life of the study - Riley County

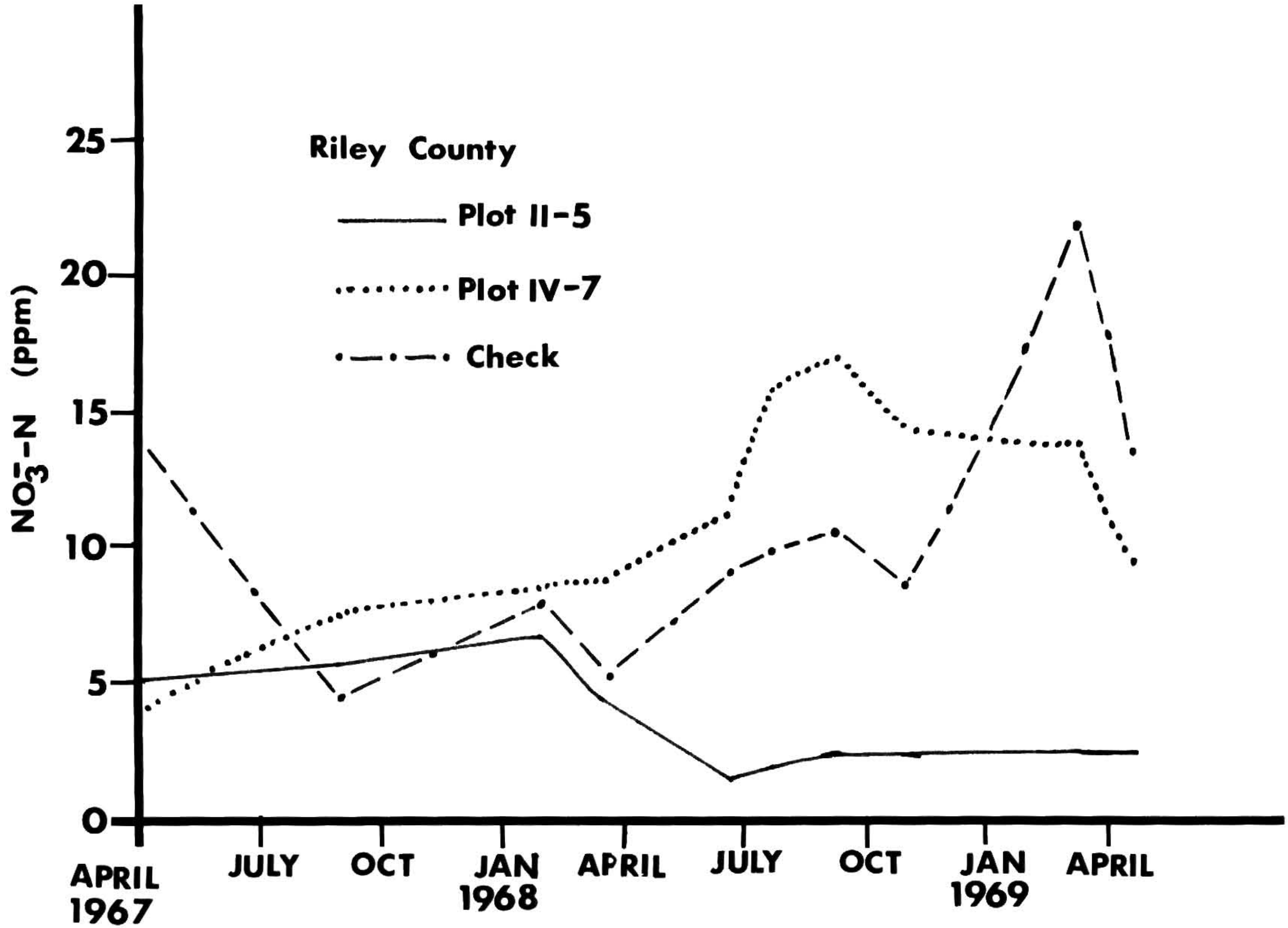


Table 10.--Nitrate-nitrogen content of water from observation wells - Riley County

Source	df	Analysis of Variance SS	MS	F
Total	89	2,288.30		
Wells	2	1,060.64	530.32	46.28*
Dates	9	334.04	37.12	3.24*
Error	78	893.62	11.46	

*A significant difference at 0.05 level

All samples were tested for nitrite-nitrogen and found to contain insignificant amounts in all cases. Selected water samples from plots II-5 and IV-7 were analyzed for ammonium-nitrogen and found to contain only nonsignificant amounts. However, amounts up to one ppm ammonium-nitrogen were found in the water samples from the check observation well.

Stafford County

Nitrate-nitrogen in soil profiles and ground water were studied on a newly leveled irrigated field at the Sandyland Experiment Field located 3 miles south of St. John in Stafford county. Nitrogen was applied to plots on the experimental area at rates up to 448 kg/ha (499 lb/A). Grain sorghum was grown on the sandy site under furrow irrigation. Slope of the experimental area varied from 0-1 percent.

The status of the newly leveled Sandyland Experiment Field provided the unique facilities required by this study in that the soils were readily permeable to water and the water table was situated at a depth of approximately 6 meters. Three observation wells were established on the site, one serving as a check well at the edge of the plot area, the other two located on plots I-4 and II-6. Plots I-4 and II-6 received annual rates of 112 and 448 kg of nitrogen per ha as ammonium-nitrate, respectively. These wells provided a means of sampling the ground water at a specified depth over a period of time. The fact these observation wells were located in the actual areas used for experimental purposes allowed a simultaneous monitoring of nitrate-nitrogen movement through the soil by means of soil cores and a monitoring of the nitrate-nitrogen content of the ground water beneath the plot area.

At the start of investigations in Stafford county significant amounts of nitrate-nitrogen were found throughout the soil profile in all plots sampled. All core samples that were taken after the crop had been harvested showed insignificant amounts of nitrate-nitrogen in the soil profile. All subsequent sampling periods following the initiation of the study revealed insignificant amounts of nitrate-nitrogen in the soil profile as compared with the amount present at the start of the investigations. Table 11 gives the levels of nitrate-nitrogen in kg/ha for 4.2 meters of soil profile. The soil of plot II-6 contained higher amounts of nitrate-nitrogen in the profile than did plot I-4 and the check area throughout the study. This was probably due in part to a higher application rate of nitrogen for plot II-6 (448 kg of N per ha) than for

Table 11.--Soil nitrate-nitrogen kg/ha to a depth of 4.2 meters - Stafford County

	6-67	2-68	5-68	4-69
Check	710	---	---	48
Plot I-4	294	57	116	55
Plot II-6	805	73	157	111

plot I-4 which received 112 kg of N per ha and the check area which received no nitrogen. However, the general trends of the nitrate-nitrogen content of the soil was to decline even on the check plot. This would suggest that the advent of irrigation had leached nitrate-nitrogen from the soil into the ground water. Another possibility is the incorporation of large amounts of nitrogen into plant residues but it is rather unlikely that this plus grain removal could account for almost 1600 kg/ha in the case of plot II-6.

Furrow irrigation was used for irrigating the grain sorghum on the experimental area. Under this type of irrigation larger applications of water may have been used than needed and excessive leaching may have occurred. After the first cropping season, insignificant amounts of nitrate-nitrogen found in the soil profile. The rooting depth of grain sorghum extends down approximately 2 meters in the soil and the crop would use nitrate-nitrogen from the soil in this range. Below this range nitrate-nitrogen would not be available for absorption.

Figures 16, 17 and 18 show the nitrate-nitrogen distribution patterns in the soil profile at the start of the experiment and for the last sampling date. Data for other sampling dates for this site are included in the tabular data in Appendix Tables 21, 22 and 23.

Water samples from the observation wells contained relatively low amounts of nitrate-nitrogen at the begining of the study and increased throughout the sampling period. The largest increases of nitrate-nitrogen in the ground water occurred after the crop was harvested and during the winter months. This trend can be observed in Figure 19.

Table 12.--Nitrate-nitrogen content of water from observation wells - Stafford County

		Analysis of Variance		
Source	df	SS	MS	F
Total	80	1,418.30		
Wells	2	138.66	69.33	7.52*
Dates	8	634.36	79.28	8.60*
Error	70	645.38	9.22	

*A significant difference at 0.05 level

The analysis of variance of the Stafford county water sample data indicated the pressence of significant differences between wells and between dates of sampling. The significant difference between dates of sampling indicates that the nitrate-nitrogen content in the water fluctuated considerably during

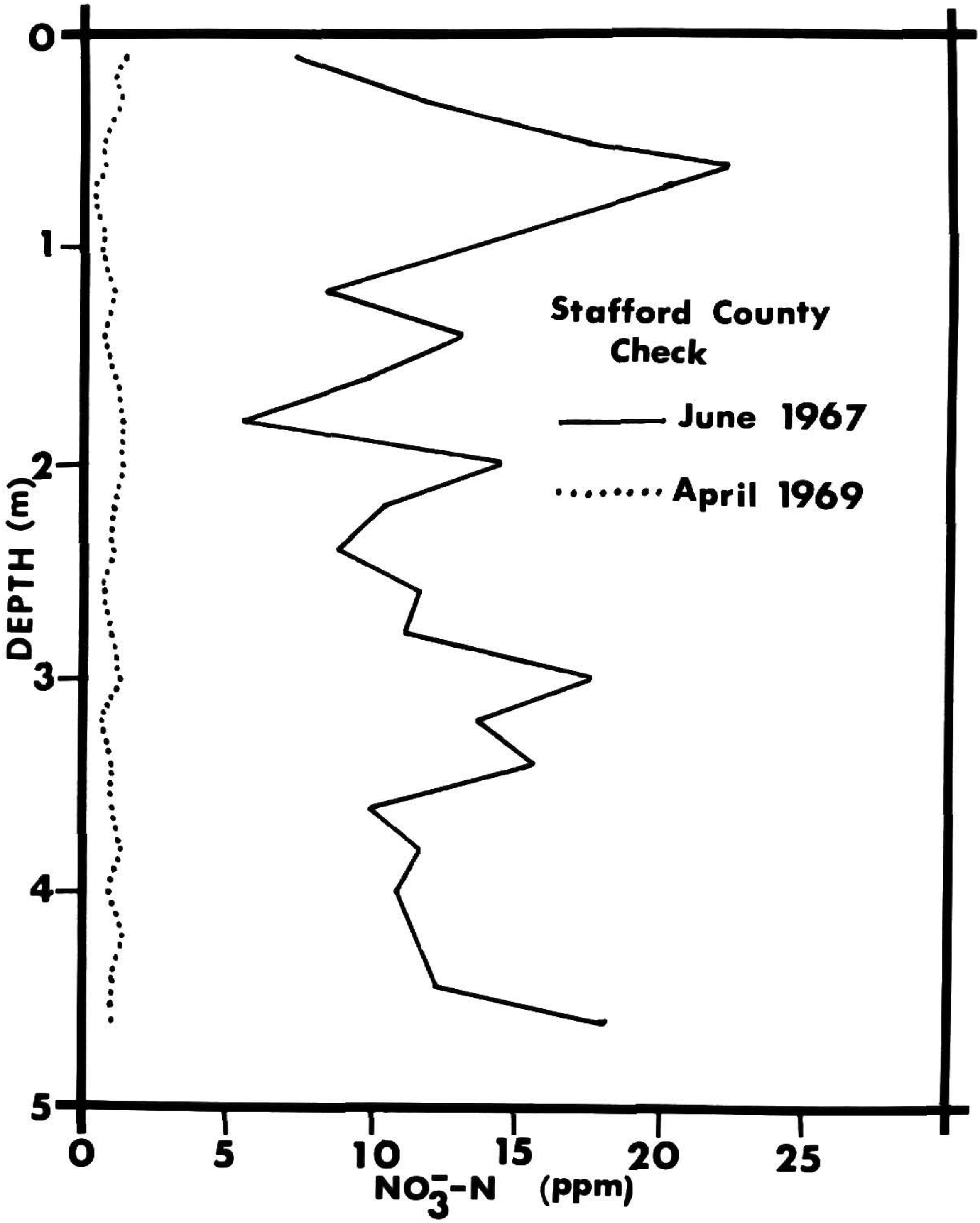


Figure 16.--Nitrate-nitrogen distribution patterns in soil cores from check site - Stafford County

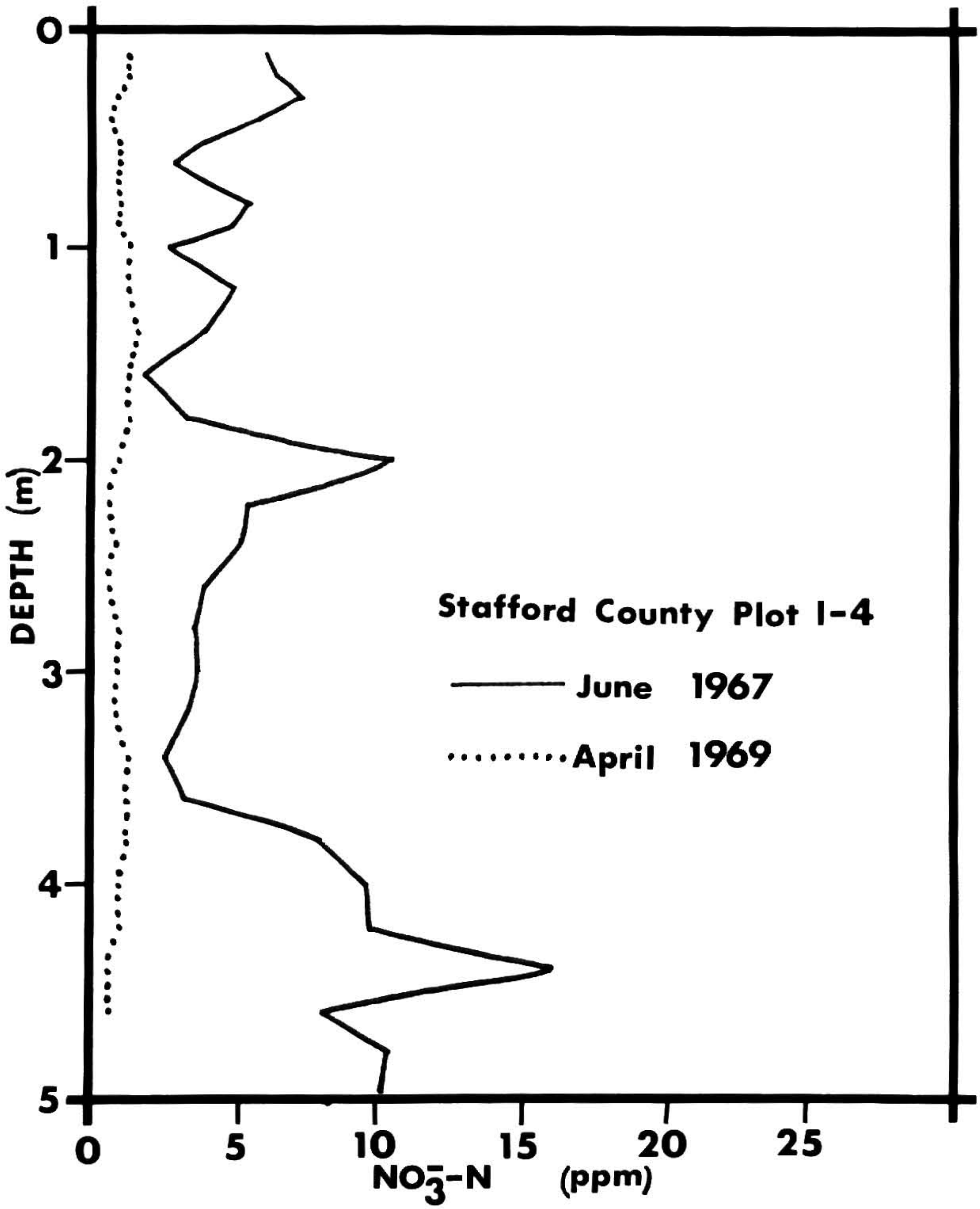


Figure 17.--Nitrate-nitrogen distribution patterns in soil cores from plot I-4. - Stafford County

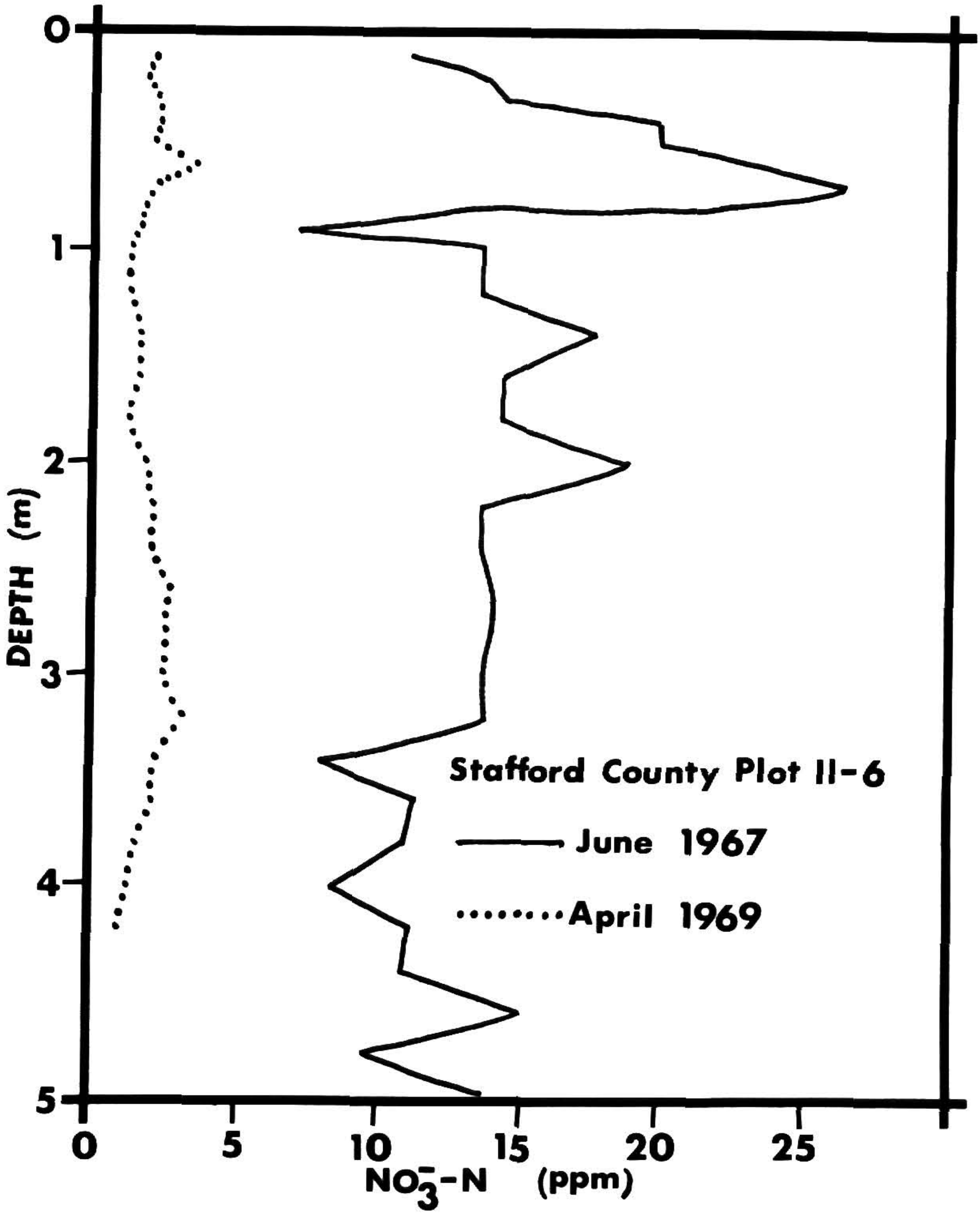
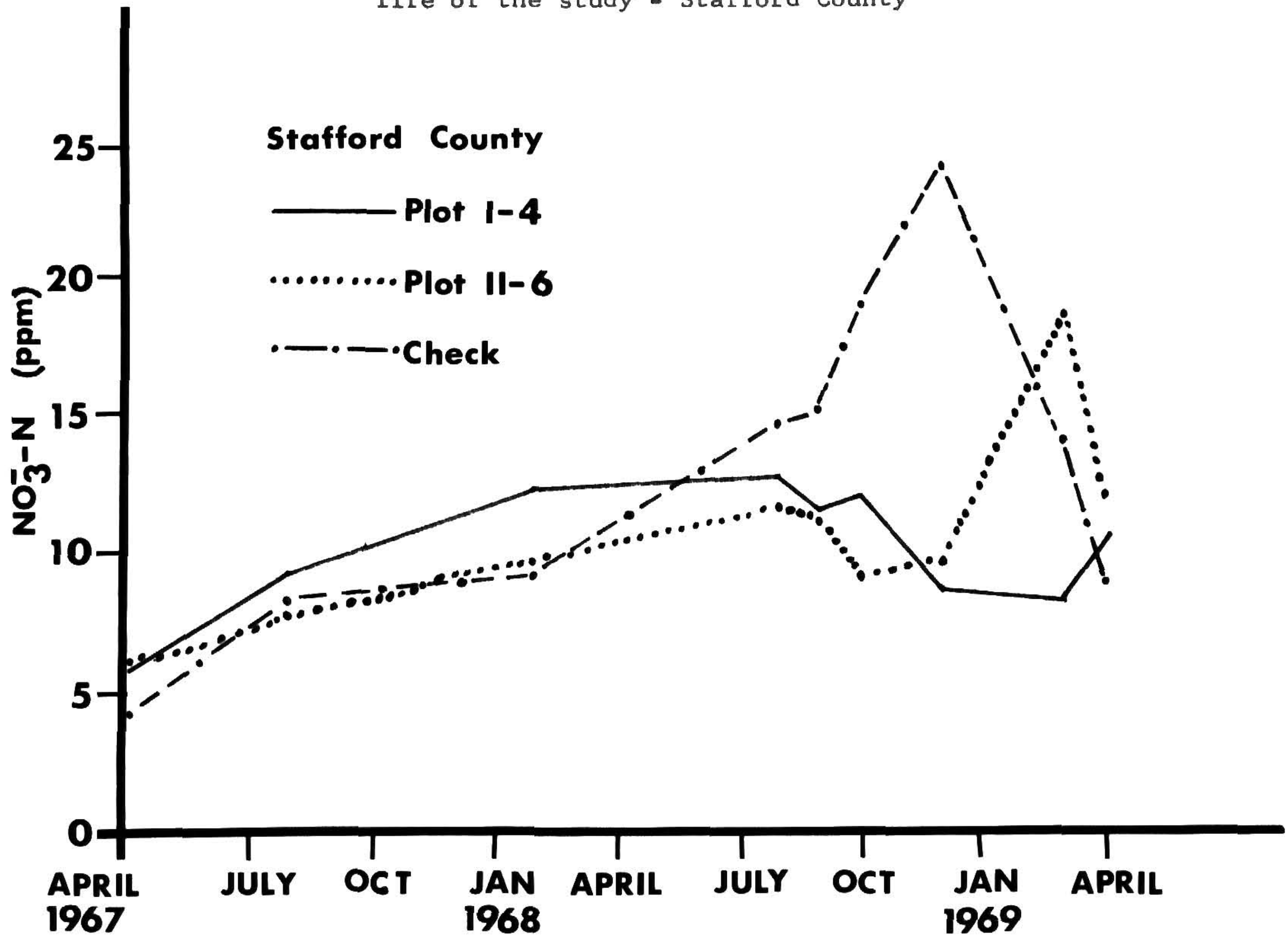


Figure 18.--Nitrate-nitrogen distribution patterns in soil cores from plot II-6. - Stafford County

Figure 19.--Level of nitrate-nitrogen in the gound water throughout the life of the study - Stafford County



the year and at the same time nitrate-nitrogen was increasing in the ground water. Nitrate-nitrogen was noted to increase mostly in the fall and winter months.

All core samples and water samples were analyzed for nitrite-nitrogen and all samples were found to contain less than 1 ppm nitrite-nitrogen. Ammonium-nitrogen analyses were conducted on selected water samples. No ammonium-nitrogen was detected in the water.

SUMMARY AND CONCLUSIONS

Nitrate in Feedlot Soils and Associated Aquifers

Nitrate-nitrogen accumulations in soils underyling feedlots were somewhat varied. The range of nitrate-nitrogen accumulation in a 4 meter soil profile underlying feedlots was from nearly essentially nothing to as much as 5,000 kg/ha. Frequently the variation of nitrate-nitrogen found in soils was due to the age of the feedlot. In many cases the data showed that the older lots had accumulated more nitrate-nitrogen in the soil profile than had the younger lots.

The situation at the Shawnee county site exemplified the effects of age of lot by showing the difference between a check core with insignificant amounts of nitrate-nitrogen in the soil profile and the adjoining 12 year old feedlot with significant amounts of nitrate-nitrogen accumulated to 6 meters in the soil profile.

Nitrate-nitrogen movement in soil apparently has occurred and is occurring beneath feedlots even in areas of low rainfall. In the western part of the state, Kansas mean annual precipitation is 40 to 45 cm (16 to 18 in.) and nitrate movement was detected to depths of 4 meters in the soil underlying the older lots. In areas of higher rainfall as in eastern Kansas where the mean annual precipitation is 80 cm (32 in.) per year, nitrate-nitrogen had accumulated to depths greater than 6 meters in the soil. These results clearly point out the effects of amount of rainfall on nitrate-nitrogen movement in the soil. In general, areas which received higher rainfall will have more nitrate-nitrogen movement to greater depths in the soil than in low rainfall areas. Exceptions to the rule due exist in areas such as those with bedrock near the surface which would prevent nitrate-nitrogen movement to greater depths as was the case in Woodson county. Many management factors can affect the amount of nitrates in the soil such as how often manure is removed from the lots, type of feed used, type of livestock fed, length of time livestock are fed, and length of time during the year in which cattle occupy the lot.

Soil texture did not markedly affect nitrate-nitrogen distribution patterns beneath feedlots in western Kansas on soils of fairly constant composition. However, in varied soil profiles it was found that as the clay content increased, moisture and nitrate-nitrogen content increased. This was as expected since water serves as the vehicle for nitrate-nitrogen movement and the clay content of the soil serves to retain moisture. Thus nitrate-nitrogen was found in the high moisture clay layers.

Under certain conditions a considerably different situation may develop and ammonium-nitrogen may accumulate throughout the soil profile instead of nitrate-nitrogen. This phenomenon was encountered in Reno county. These findings agreed with work reported from Colorado (40) where researchers encountered a similar situation. They attributed the low nitrate-nitrogen level as possibly due to the low oxygen status of the soil. Other workers (30) have also shown that low redox potentials develop with increased soil moisture content and under submerged soil conditions. This is due to a partial or complete displacement of oxygen from soil and rapid consumption of oxygen by soil microbes. Savant and Ellis (33) from Kansas have shown that fresh organic matter in submerged soil accelerates the rate of decrease of redox potential of soil.

It is interesting to note that ammonium-nitrogen accumulated where a shallow aquifer was present both in this study and in the work reported by Stewart and co-workers (40) (2.6 and 3.0 meter depths, respectively). Ammonium-nitrogen may have accumulated due to the large amount of ammonical nitrogen present as manure and the possible lack of oxygen necessary to support nitrification. Ammonium-nitrogen movement through the profile was possibly enhanced due to the organic form of the ammonium-nitrogen and the low cation exchange capacity of the soil.

Qualitative nitrite-nitrogen determinations conducted on over 2,000 soil samples revealed concentrations as high as 1 ppm in only 5 total samples. These isolated occurrences were found to be relegated to the manure layer in some feedlots.

Soil phosphorus analyses from feedlots indicated little if any movement of P. The P was found to be concentrated in the top 10 to 30 cm or manure layer. However, some phosphorus movement was detected in the feedlots in Reno county on soils with extremely low exchange capacity. This was the only location that exhibited any noticeable phosphorus movement of any kind.

Nitrate-nitrogen content of ground water underlying feedlots at the Reno county site was found to be quite varied. The nitrate-nitrogen content in the ground water was higher in the winter months than during the other sampling periods. Concentrations up to 78.3 ppm nitrate-nitrogen were found in the water from Reno county site. All water samples were found to be essentially free from nitrite-nitrogen. Ammonium-nitrogen concentrations up to 0.9 ppm were found in the ground water underlying the feedlots from Reno county suggesting that some movement of organic materials was occurring in these soils of extremely low exchange capacity.

Nitrate Accumulation in Soils and Aquifers Underlying Irrigated Fields

Nitrate-nitrogen accumulation in soils and ground water of irrigated fields were examined at two locations. The investigations were conducted on fairly sandy soils that were readily permeable to water. Under irrigated conditions, this would assure some water movement in the soil.

Under high rates of applied nitrogen, movement of nitrate-nitrogen downward in the soil was detected by the movement of nitrate-nitrogen peaks in the soil from one sampling period to the next as shown in Figure 12. Even though nitrate-nitrogen movement was detected in some plots there was much variation in the amount of nitrate-nitrogen found in the soil profile from one sampling date to the next. At the Riley county site three of four plots receiving nitrogen exhibited an increased amount of nitrate-nitrogen in the soil profile over the sampling period. At the Stafford county location the opposite was true. All plots exhibited decreases in the amount of nitrate-nitrogen found in the soil profile from the first sampling date to the last. However, at the last sampling date in Stafford county relatively more nitrate-nitrogen was present in the soil of those plots which had received 448 kg N/ha (400 lb N/A) as compared to the plots receiving 112 kg N/ha (100 lb N/A).

Nitrite-nitrogen was detectable only in trace amounts in the core samples from both feedlots and irrigated fields.

Soil texture affected the moisture and nitrate-nitrogen content of the soil cores. As the clay content increased the moisture and nitrate-nitrogen content also increased. The findings of this study indicate that nitrate-nitrogen in the soil profile is often associated with high moisture clay layers.

Investigation of nitrate-nitrogen accumulation in ground water has shown that nitrate-nitrogen in the ground water fluctuated greatly throughout the year. The highest levels of nitrate-nitrogen in test wells on the experimental plots were noted during the months after harvest (winter and spring months). This indicates that nitrate-nitrogen was apparently moving through the soil into the ground water during the months when plants were not growing on the area.

Nitrate-nitrogen content of the ground water at both locations had increased over the life of the study but considerable variation did exist in the amount of nitrate-nitrogen present from one sampling date to the next.

During the investigation some relationship was noted between the amount of nitrate-nitrogen in the soil profile and the amount of nitrate-nitrogen in the ground water. In general, the soils containing the highest amount of nitrate-nitrogen in the soil profile throughout the study had the highest concentration of nitrate-nitrogen in the ground water.

All water samples were tested for nitrite-nitrogen. A few contained trace amounts. Selected water samples were analyzed for ammonium-nitrogen and found to be devoid of this form of nitrogen. One exception was the check well from Riley county which ranged up to 1.0 ppm ammonium-nitrogen.

Results of these investigations indicate that accumulation of nitrate-nitrogen in soils and ground water under heavily fertilized, irrigated areas is at most a slow process. Much more nitrate-nitrogen was found to have accumulated in the vicinity of feedlots and this, in the opinion of the author, poses a more serious threat to ground water pollution than does inorganic fertilization. As expected and in agreement with work in adjacent states, the longer the period of feedlot existence, the greater the amount of nitrate-nitrogen in the soil profile.

This work points to the need for continued efforts in evaluating the long term effects of high fertilization with inorganic nitrogen on the nitrogen status of soils and ground water. More intensive sampling of ground water at a greater number of points in the vicinity of the experimental area should be included in future research. Continued sampling of feedlots used in this study would be valuable in determining the rate of nitrogen accumulation in the soils' profiles with a given stocking rate.

Those who champion the return to organic forms of nitrogen in an attempt to eliminate the accumulation of nitrate in soil and possibly ground water should familiarize themselves with the fact that nitrogen once in contact with the soil, whether from an organic or inorganic source, acts in exactly the same manner and poses the same pollution threat regardless of source.

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APPENDIX

Table 1.--Distribution of nitrate-nitrogen in soil profiles from different age feedlots - Thomas County

	4 yrs old		11 yrs old		40 yrs old	
Depth cm	ppm	ppm	ppm	ppm	ppm	ppm
0-10	10.8	12.2	130.0	108.0	308.0	220.0
10-20	48.0	18.2	292.0	292.0	130.0	156.0
20-30	72.0	44.0	88.0	308.0	88.0	150.0
30-40	48.0	40.0	72.0	228.0	76.0	136.0
40-50	30.8	29.2	80.0	88.0	76.0	116.0
50-60	20.0	18.8	76.0	35.2	72.0	100.0
60-70	11.2	12.2	50.0	14.0	64.0	96.0
70-80	5.7	6.4	37.2	2.0	60.0	96.0
80-90	3.2	4.1	22.0	1.7	48.0	92.0
90-100	1.5	3.5	16.8	2.0	48.0	88.0
100-120	1.5	1.5	9.6	1.7	44.0	58.0
120-140	1.5	1.5	9.2	2.3	45.2	52.0
140-160	1.5	1.5	4.8	0.8	52.0	39.6
160-180	1.7	1.5	2.5	1.2	58.0	45.2
180-200	1.7	1.5	2.5	1.2	62.4	46.4
200-220	1.5	1.7	3.5	1.7	62.4	31.2
220-240	1.5	2.0	2.5	1.7	58.0	37.2
240-260	1.7	2.0	2.8	5.1	50.0	35.2
260-280	1.7	1.5	3.2	2.3	38.4	31.2
280-300	1.5	1.2	3.8	2.3	28.0	20.0
300-320	1.5	1.5	3.5	2.8	18.2	12.2
320-340	1.7	1.2	3.8	2.8	14.0	12.6
340-360	1.7	1.2	4.8	3.8	16.8	9.6
360-380	1.7	1.5	5.4	6.4	6.0	5.4
380-400	1.5	1.7		5.4	4.1	5.4
400-420		1.5		5.7	3.2	2.0
420-440		1.2		6.8	3.8	1.7
440-460		1.2				2.0
460-480						2.0

Table 2.--Distribution of ammonium-nitrogen in soil profiles from different age feedlots - Thomas County

	4 yrs old		11 yrs old		40 yrs old	
Depth cm	ppm	ppm	ppm	ppm	ppm	ppm
0-10	1023	721	277	193	125	118
10-20	572	323	66	308	11	42
20-30	50	26	23	18	12	9
30-40	35	12	24	25	5	7
40-50	25	13	33	43	6	9
50-60	17	4	19	22	15	14
60-70	9	2	19	12	6	4
70-80	22	7	9	11	4	5
80-90	18	12	13	16	12	9
90-100	47	6	6	22	5	4
100-120	11	17	6	8	16	10
120-140	19	7	8	2	12	7
140-160	2	5	4	0	6	6
160-180	8	2	5	1	15	15
180-200	9	2	7	6	14	8
200-220	1	3	18	0	14	4
220-240	6	6	10	5	11	8
240-260	10	0	1	15	3	1
260-280	8	2	3	11	1	3
280-300	13	4	10	9	2	5
300-320	----	5	4	8	16	2
320-240	1	11	1	6	18	3
340-360	7	7	5	4	3	6
360-380	----	3	1	---	2	1
380-400	12	8		4	1	5
400-420		7		3	9	5
420-440		5		6	10	2
440-460						2
460-480						3

Table 3.--Composition of a soil profile beneath a 40 year old feedlot - Thomas County

Depth cm	Texture	NO_3^--N ppm	NH_4^+-N ppm	%Clay	%Silt	%Sand
0-10	Manure	220.0	118.0	31.8	50.2	18.4
10-20	Clay loam	156.0	42.0	34.8	44.4	20.8
20-30	Silty clay loam	150.0	9.0	33.4	46.8	19.8
30-40	Clay loam	136.0	7.0	28.4	44.4	27.2
40-50	"	116.0	9.0	28.4	50.4	21.2
50-60	"	100.0	14.0	30.4	42.2	27.4
60-70	"	96.0	4.0	22.4	48.2	22.4
70-80	"	96.0	5.0	25.4	47.2	25.4
80-90	Loam	92.0	9.0	26.4	49.2	26.4
90-100	"	88.0	4.0	27.4	48.2	27.4
100-120	Silt loam	58.0	10.0	26.4	50.2	26.4
120-140	"	52.0	7.0	26.8	51.0	26.8
140-160	"	39.6	6.0	26.8	51.0	26.8
160-180	"	45.2	15.0	26.2	52.6	26.2
180-200	"	46.4	8.0	27.2	54.0	27.2
200-220	"	31.2	4.0	28.8	54.4	28.8
220-240	"	37.2	8.0	26.0	56.2	26.0
240-260	"	35.2	1.0	26.0	56.5	26.0
260-280	"	31.2	3.0	25.0	56.6	25.0
280-300	"	20.0	5.0	25.0	58.2	25.0
300-320	"	12.2	2.0	25.6	57.6	25.6
320-340	"	12.6	3.0	24.6	57.6	24.6
340-360	"	9.6	6.0	24.8	58.0	24.8
360-380	"	5.4	1.0	27.0	56.0	27.0
380-400	"	5.4	5.0	27.0	55.4	27.0
400-420	"	2.0	5.0	24.6	59.6	24.6
420-440	"	1.7	2.0	26.2	57.0	26.2
440-460	"	2.0	2.0	27.6	55.6	27.6
460-480	"	2.0	3.0	27.6	55.6	27.6

Table 4.--Distribution of nitrate-nitrogen in soil profiles from different age feedlots - Greeley County

	3 yrs old		13 yrs old		30 yrs old	
Depth cm	ppm	ppm	ppm	ppm	ppm	ppm
0-10	20.3	31.2	88.0	104.0	34.4	28.0
10-20	116.0	104.0	18.2	1.5	88.0	39.6
20-30	64.0	50.8	53.6	2.3	60.0	48.0
30-40	50.8	41.2	43.2	6.4	100.0	43.6
40-50	60.0	41.2	27.6	9.6	122.0	52.0
50-60	76.0	38.0	17.2	8.4	136.0	76.0
60-70	104.0	16.0	10.4	6.4	150.0	100.0
70-80	130.0	24.8	8.4	9.2	160.0	104.0
80-90	126.0	60.0	6.4	18.8	156.0	100.0
90-100	130.0	80.0	4.8	53.6	156.0	104.0
100-120	116.0	112.0	3.8	130.0	156.0	116.0
120-140	76.0	100.0	3.2	212.0	140.0	122.0
140-160	20.4	48.4	10.0	248.0	144.0	112.0
160-180	5.7	22.0	26.4	156.0	108.0	72.0
180-200	3.8	8.0	48.4	240.0	39.6	35.2
200-220	3.5	1.7	104.0	188.0	20.4	22.0
220-240	2.0	0.8	122.0	156.0	10.8	14.0
240-260	1.7	0.8	122.0	130.0	6.8	7.2
260-280	1.7	6.8	122.0	100.0	5.1	5.7
280-300	2.3	0.5	112.0	52.0	4.1	3.8
300-320	3.2	0.8	104.0	30.0	2.8	4.1
320-340	2.8	0.5	108.0	18.2	5.4	4.4
340-360	4.4	6.0	108.0	12.2	3.2	3.8
360-380	5.1	0.5	100.0	9.6	3.5	3.5
380-400	5.1	1.2	84.0	5.7	3.8	3.8
400-420		1.2	52.0		3.8	4.4
420-440			45.2		4.4	
440-460						
460-480						

Table 5.--Distribution of ammonium-nitrogen in soil profiles from different age feedlots - Greeley County

	3 yrs old		13 yrs old		30 yrs old	
Depth cm	ppm	ppm	ppm	ppm	ppm	ppm
0-10	451	357	1030	1223	47	56
10-20	67	48	95	426	16	22
20-30	6	54	11	264	9	10
30-40	5	34	11	99	7	10
40-50	3	22	7	30	6	7
50-60	19	19	8	15	7	12
60-70	35	27	10	6	5	14
70-80	12	9	11	14	10	13
80-90	5	14	7	11	6	4
90-100	---	2	13	----	2	7
100-120	6	10	3	7	17	3
120-140	6	4	6	4	5	5
140-160	0	10	6	5	1	4
160-180	7	0	14	5	5	2
180-200	7	5	3	11	4	5
200-220	6	4	10	6	7	4
220-240	7	6	14	5	1	4
240-260	3	6	3	6	0.5	3
260-280	6	8	6	4	1	3
280-300	4	1	5	11	3	2
300-320	5	1	5	8	5	3
320-340	4	1	5	5	3	4
340-360	0	---	10	7	1	1
360-380	4	2	10	4	0.5	1
380-400	4	0	5	4	2	1
400-420		0	6		1	0.3
420-440			12		1	

Table 6.--Distribution of nitrate-nitrogen in soil profiles from different age feedlots - Shawnee County

Depth cm	Ck ppm	12 years ppm
0-10	4.4	53.6
10-20	2.0	53.6
20-30	2.0	58.0
30-40	2.0	96.0
40-50	1.7	122.0
50-60	2.3	53.6
60-70	2.0	40.8
70-80	2.0	30.0
80-90	1.5	34.0
90-100	1.2	31.0
100-120	1.5	30.0
120-140	2.0	27.4
140-160	1.7	28.2
160-180	1.5	27.4
180-200	1.5	25.6
200-220	1.2	22.6
220-240	1.2	17.6
240-260	1.7	24.8
260-280	2.0	22.0
280-300	2.0	20.6
300-320	2.5	20.6
320-340	2.0	16.8
340-360	1.7	10.8
360-380	1.5	10.0
380-400	1.2	2.3
400-420	1.2	3.8
420-440	1.5	2.5
440-460	1.5	2.0
460-480	1.5	7.6
480-500	1.7	4.1
500-520	1.5	5.4
520-540	1.2	5.4
540-560	2.3	1.5
560-580	1.7	8.4
580-600		7.2

Table 7.--Distribution of nitrate-nitrogen in soil profiles from different age feedlots - Woodson County

	7 yrs old		20 yrs old	
Depth cm	ppm	ppm	ppm	ppm
0-10	17.6	10.4	76.0	16.8
10-20	48.2	36.0	96.0	17.6
20-30	100.0	43.6	144.0	3.2
30-40	172.0	40.8	9.2	4.8
40-50	200.0	45.2	17.2	14.0
50-60	182.0	43.6	8.4	20.6
60-70	116.0	43.6	4.1	20.6
70-80	46.8	39.6	0.8	18.8
80-90	22.6	39.6		21.2
90-100	12.6	40.8		32.0
100-120	18.2	28.2		
120-140	5.7	16.0		
140-160	7.2	19.4		
160-180	7.2	8.8		
180-200	7.2	5.1		
200-220	8.8	2.5		
220-240	7.2	2.5		
240-260	12.6	1.7		
260-280	16.8	2.0		
280-300	32.0	2.8		
300-320	24.8	4.1		
320-340	6.8	5.1		
340-360	4.4	5.1		
360-380		6.0		

Table 8.--Distribution of nitrate-nitrogen in soil profiles from different age feedlots - Reno County

	3 mos old		18 yrs old		30 yr	60 yrs old		Ck
Depth cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0-10	1.7	30.0	18.8	43.6	8.8	7.6	3.8	28.2
10-20	1.5	20.0	1.7	2.3	0.8	2.5	12.2	3.2
20-30	1.7	13.0	2.3	1.7	1.2	2.0	1.2	7.2
30-40	2.0	18.8	2.3	2.0	1.2	1.7	1.5	7.6
40-50	2.8	16.0	2.3	2.5	1.2	1.7	1.7	6.0
50-60	14.0	14.4	2.0	2.8	1.5	1.2	2.0	5.7
60-70	21.2	15.6	2.0	2.8	1.2	1.2	1.7	3.8
70-80	39.6	17.6	2.0	2.8	0.8	1.5	1.7	3.5
80-90	43.6	16.0	2.0	4.1	---	1.7	1.5	2.0
90-100	43.6	16.0	2.3	2.0	1.2	1.7	1.5	1.2
100-120	26.4	15.6	2.3	2.0	1.5	1.5	1.2	1.5
120-140	10.4	15.6	2.0	1.7	1.2	1.2	2.0	17.6
140-160	2.8	18.8	2.0	2.3	0.8	1.5	1.7	34.0
160-180	3.2	39.6	0.5	6.8	0.8	1.7	1.5	----
180-200	5.4	24.8	1.7	10.0	0.5	1.7	1.5	39.6
200-220		14.4	2.0	9.2	0.8	1.5	1.5	16.8
220-240		8.0	2.0		5.4	1.5		16.0
240-260					3.8			15.0
260-280					0.8			
280-300					0.5			
300-320					0.8			

Table 9.--Distribution of ammonium-nitrogen in soil profiles from different age feedlots - Reno County

Depth cm	Ck ppm	3 mo ppm	18 yr ppm	30 yr ppm	60 yr ppm
0-10	4.4	29.9	71.3	140.5	248.3
10-20	8.7	10.2	66.4	41.5	110.7
20-30	10.1	6.6	34.7	160.6	22.4
30-40	5.0	8.7	16.9	288.7	10.4
40-50	6.4	10.2	10.4	311.4	12.4
50-60	4.4	9.5	16.6	168.3	12.2
60-70	5.2	8.0	11.7	78.8	9.0
70-80	3.7	6.4	6.1	88.4	9.2
80-90	5.1	4.7	9.5	-----	7.7
90-100	1.9	2.0	5.7	91.9	6.4
100-120	0.9	3.5	4.2	60.9	9.2
120-140	0.3	----	3.5	21.0	5.1
140-160	1.3	5.3	8.3	14.3	6.8
160-180	1.2	3.4	7.2	10.8	-----
180-200	0.9	----	4.4	7.4	6.3
200-220	0.3	4.2	14.5	4.5	7.4
220-240	0.7	----	13.5	0.3	7.4
240-260	0.2			0.0	
260-280				0.0	
280-300				0.0	
300-320				0.2	

Table 10.--Composition of soil profile beneath the check area - Reno County

Depth cm	NO_3^--N ppm	NH_4^+-N ppm	P ppm
0-10	28.2	4.4	14.0
10-20	3.2	8.7	30.0
20-30	7.2	10.1	8.5
30-40	7.6	5.0	4.5
40-50	6.0	6.4	8.0
50-60	5.7	4.4	5.5
60-70	3.8	5.2	7.0
70-80	3.5	3.7	4.0
80-90	2.0	5.1	2.5
90-100	1.2	1.9	2.5
100-120	1.5	0.9	4.0
120-140	17.6	0.3	3.0
140-160	34.0	1.3	7.0
160-180	----	1.2	6.0
180-200	39.6	0.9	2.0
200-220	16.8	0.3	3.0
220-240	16.0	0.7	6.0
240-260	15.0	0.2	3.5

Table 11.--Composition of a soil profile beneath a 3 month old feedlot - Reno County

Depth cm	NO_3^--N ppm	NH_4^+-N ppm	P ppm
0-10	30.0	29.9	75.0
10-20	20.0	10.2	18.0
20-30	13.0	6.6	27.0
30-40	18.8	8.7	60.0
40-50	16.0	10.2	65.0
50-60	14.4	9.5	64.0
60-70	15.6	8.0	36.0
70-80	17.6	6.4	13.0
80-90	16.0	4.7	10.0
90-100	16.0	2.0	8.0
100-120	15.6	3.5	5.5
120-140	15.6	----	11.5
140-160	18.8	5.3	----
160-180	39.6	3.4	----
180-200	24.8	----	2.5
200-220	14.4	4.2	----
220-240	8.0	----	----

Table 12.--Composition of a soil profile beneath a 18 year old feedlot - Reno County

Depth cm	NO_3^--N ppm	NH_4^+-N ppm	P ppm
0-10	18.8	71.3	500+
10-20	1.7	66.4	55.0
20-30	2.3	34.7	8.0
30-40	2.3	16.9	7.0
40-50	2.3	10.4	8.5
50-60	2.0	16.6	6.5
60-70	2.0	11.7	6.0
70-80	2.0	6.1	6.5
80-90	2.0	9.5	16.5
90-100	2.3	5.7	11.5
100-120	2.3	4.2	6.5
120-140	2.0	3.5	7.0
140-160	2.0	8.3	-----
160-180	0.5	7.2	-----
180-200	1.7	4.4	25.0
200-220	2.0	14.5	-----
220-240	2.0	13.5	-----

Table 13.--Composition of a soil profile beneath a 30 year old feedlot - Reno County

Depth cm	CEC me/100g	NO_3-N ppm	NH_4-N ppm	P ppm
0-10	5.18	8.8	140.5	500+
10-20	----	0.8	41.5	2.5
20-30	----	1.2	160.6	100.0
30-40	4.16	1.2	288.7	500+
40-50	5.11	1.2	311.4	500+
50-60	4.46	1.5	168.3	207.5
60-70	4.17	1.2	78.8	142.5
70-80	5.40	0.8	88.4	245.0
80-90	----	---	-----	-----
90-100	6.48	1.2	91.9	85.0
100-120	3.60	1.5	60.9	125.0
120-140	----	1.2	21.0	99.5
140-160	3.17	0.8	14.3	85.0
160-180	----	0.8	10.8	25.0
180-200	0.65	0.5	7.4	33.0
200-220	0.96	0.8	4.5	12.5
220-240	----	5.4	0.3	4.0
240-260	----	3.8	0.0	4.0
260-280	0.86	0.8	0.0	62.5
280-300	1.10	0.5	0.0	23.5
300-320	0.94	0.8	0.2	5.5

Table 14.--Composition of a soil profile beneath a 60 year old feedlot - Reno County

Depth cm	NO_3^--N ppm	NH_4^+-N ppm	P ppm
0-10	7.6	248.3	500+
10-20	2.5	110.7	320
20-30	2.0	22.4	287.5
30-40	1.7	10.4	217.5
40-50	1.7	12.4	187.5
50-60	1.2	12.2	140.0
60-70	1.2	9.0	130.0
70-80	1.5	9.2	112.5
80-90	1.7	7.7	85.0
90-100	1.7	6.4	20.0
100-120	1.5	9.2	4.5
120-140	1.2	5.1	3.0
140-160	1.5	6.8	2.0
160-180	1.7	-----	-----
180-200	1.7	6.3	21.0
200-220	1.5	7.4	19.0
220-240	1.5	7.4	-----

Table 15.--Composition of a soil profile beneath a check area - Riley County

Depth cm	4-67 NO_3^--N ppm	4-21-69 NO_3^--N ppm	4-21-69 % H_2O
0-10	5.72	3.48	19.67
10-20	10.80	2.80	18.52
20-30	2.80	2.28	19.48
30-40	2.52	3.80	21.40
40-50	3.20	4.12	19.00
50-60	4.40	1.48	9.12
60-70	3.48	1.20	8.03
70-80	2.00	2.28	13.53
80-90	3.80	2.00	16.15
90-100	9.60	2.80	16.98
100-120	10.40	5.08	16.23
120-140	10.80	8.80	15.10
140-160	8.00	9.60	13.23
160-180	6.80	9.20	11.97
180-200	5.72	6.40	10.24
200-220	6.40	5.08	10.23
220-240	12.20	4.12	10.88
240-260	14.40	3.80	6.89
260-280	15.00	7.20	8.47
280-300	18.80	10.40	10.61
300-320	18.80	13.60	19.15
320-340	13.60	11.20	16.60
340-360	10.40	10.40	17.53
360-380	8.80	13.60	21.47
380-400	8.80	10.40	14.77
400-420	12.20	18.20	24.15
420-440	17.60	13.60	18.03
440-460	16.00	14.00	21.04
460-480	12.60	11.60	25.25
480-500	11.20	9.60	24.67
500-520	16.00		
520-540	6.40		

Table 16.--Composition of a soil profile beneath plot I-4 - Riley County

Depth cm	4-67 NO_3^--N ppm	2-3-68 NO_3^--N ppm	4-21-69 NO_3^--N ppm	4-21-69 % H_2O
0-10	7.20	2.52	3.20	11.39
10-20	6.00	2.52	3.80	10.76
20-30	3.48	2.80	3.20	21.43
30-40	2.52	2.00	2.80	21.29
40-50	2.28	2.28	3.80	21.73
50-60	2.00	2.00	3.48	15.07
60-70	2.00	1.48	4.80	15.55
70-80	2.00	2.80	4.12	11.16
80-90	1.73	11.20	5.40	15.74
90-100	2.00	9.20	5.08	13.36
100-120	2.52	9.60	4.80	15.58
120-140	5.08	8.80	4.12	17.78
140-160	9.60	4.12	2.28	13.42
160-180	22.00	3.20	3.80	17.16
180-200	19.40	4.38	3.80	21.41
200-220	15.60	5.40	4.12	21.00
220-240	8.00	2.50	8.00	21.08
240-260	4.80	1.48	18.80	21.01
260-280	2.28	1.20	18.80	24.57
280-300	2.00	1.48	13.60	23.80
300-320	2.52	1.48	8.00	19.00
320-340	3.48	1.72	5.08	16.23
340-360	3.20	2.00	10.00	24.79
360-380	2.00	2.00	13.60	27.57
380-400		0.80	11.20	28.80
400-420		0.80	10.40	28.32
420-440			5.08	13.55
440-460			2.00	2.99
460-480			2.00	4.52

Table 17.--Ccmposition of a soil profile beneath plot II-5 - Riley County

Depth cm	4-67 NO_3^--N ppm	1-29-68 NO_3-N ppm	4-21-69 NO_3-N ppm	4-21-69 % H_2O
0-10	2.28	3.20	3.80	16.80
10-20	2.52	4.80	4.12	21.03
20-30	2.80	2.80	3.20	22.89
30-40	5.40	2.28	3.20	21.32
40-50	8.40	2.28	2.80	17.47
50-60	5.72	2.00	4.12	16.59
60-70	2.52	1.48	4.80	21.65
70-80	2.28	1.48	3.48	20.30
80-90	1.20	1.20	2.28	13.60
90-100	1.20	1.20	2.28	19.72
100-120	1.20	1.20	2.00	11.25
120-140	1.48	2.28	1.48	19.88
140-160	2.28	8.40	1.20	18.23
160-180	2.00	8.80	1.20	9.72
180-200	2.28	6.40	2.00	18.69
200-220	1.72	5.08	2.00	19.15
220-240	1.72	2.52	2.28	19.09
240-260	1.48	2.00	2.52	19.53
260-280	1.72	2.52	2.80	24.83
280-300	2.00	3.80	5.08	23.70
300-320	2.28	3.48	10.00	20.68
320-340	1.72	5.40	10.40	22.33
340-360	2.00	6.80	9.60	26.96
360-380	2.80	2.00	9.20	26.53
380-400	3.20	1.72	7.60	19.20
400-420	2.52		2.52	5.82
420-440	2.52		4.12	6.58
440-460	1.72			
460-480	1.72			

Table 18.--Composition of soil profile beneath plot III-6 - Riley County

Depth cm	4-67 NO_3^--N ppm	2-14-68 NO_3^--N ppm	4-21-69 NO_3^--N ppm	4-21-69 % H_2O
0-10	2.28	2.00	2.28	22.63
10-20	1.72	2.28	5.08	22.36
20-30	1.48	2.00	5.08	23.34
30-40	2.28	1.72	6.40	21.72
40-50	2.80	1.48	7.60	22.64
50-60	3.32	1.20	6.40	21.45
60-70	2.52	1.48	4.40	16.93
70-80	2.52	0.80	4.40	17.99
80-90	2.28	0.80	3.48	22.90
90-100	1.72	0.80	3.20	15.89
100-120	2.28	1.72	2.28	14.02
120-140	5.72	3.80	2.00	18.93
140-160	3.20	2.52	1.48	13.55
160-180	2.00	2.28	1.20	11.05
180-200	1.72	4.80	1.20	18.62
200-220	2.00	8.80	1.72	19.89
220-240	2.52	8.40	2.28	19.12
240-260	1.48	13.60	2.00	18.35
260-280	0.52	12.20	2.00	22.32
280-300	1.20	6.80	5.08	19.14
300-320	1.72	4.40	9.60	22.20
320-340	1.20	2.28	3.48	15.01
340-360	1.72	2.80	2.00	10.96
360-380	1.72	3.48	1.72	12.32
380-400	1.48	5.08	2.28	14.47
400-420	2.28	4.40	4.40	27.90
420-440	2.28	3.20	5.72	30.15
440-460	2.00		4.12	16.69
460-480	2.28		3.48	17.41

Table 19.--Composition of a soil profile beneath plot IV-7 - Riley County

Depth cm	4-67 NO_3^--N ppm	2-7-68 NO_3^--N ppm	4-21-69 NO_3^-N ppm	4-21-69 % H_2O
0-10	8.00	8.00	5.72	17.62
10-20	7.60	6.40	4.12	19.98
20-30	7.60	5.08	3.48	20.62
30-40	8.80	4.12	4.40	19.80
40-50	8.40	3.80	4.40	16.23
50-60	8.80	3.20	3.80	11.11
60-70	8.80	3.80	4.12	12.24
70-80	8.80	4.80	4.80	15.21
80-90	7.60	7.20	8.00	22.24
90-100	7.20	6.00	4.40	23.33
100-120	6.80	9.60	3.80	18.44
120-140	8.00	13.00	2.00	16.55
140-160	10.00	13.60	1.20	-----
160-180	10.40	-----	0.80	20.34
180-200	10.00	10.80	0.80	21.44
200-220	7.60	12.60	0.52	14.16
220-240	2.80	12.60	1.20	20.15
240-260	2.80	12.20	1.72	21.91
260-280	2.52	12.60	2.00	22.86
280-300	3.80	14.40	2.28	22.86
300-320	2.28	10.80	3.20	24.27
320-340	2.28	11.60	4.80	25.60
340-360	3.20	7.20	5.08	21.10
360-380	2.40	8.00	4.40	22.86
380-400	2.00	7.60	2.00	12.97
400-420	3.20	6.80	1.72	12.30
420-440	2.80	4.40	4.12	26.90
440-460	2.52	4.40	8.00	29.18
460-480	1.72		2.80	19.97
480-500	2.00		3.48	13.73
500-520	2.28			
520-540	2.00			

Table 20.--Level of nitrate-nitrogen in water samples from observation wells - Riley County

Date	Check Well ppm	Plot II-5 ppm	Plot IV-7 ppm
4- -67	14.4	5.1	3.6
	12.8	5.1	3.9
	13.1	5.1	3.8
11-21-67	4.3	5.2	7.2
	4.8	5.5	7.2
	4.6	5.0	8.0
2-9-68	7.2	6.0	8.7
	8.4	6.6	8.4
	8.4	7.2	8.4
3-15-68	5.2	4.4	8.3
	5.0	4.4	9.4
	5.3	5.0	8.5
6-25-68	8.5	1.5	11.6
	9.7	1.3	11.2
	9.0	1.6	10.7
7-23-68	9.9	1.9	15.3
	9.7	2.1	16.0
	10.2	2.1	15.3
9-11-68	10.2	2.4	16.3
	10.9	2.5	17.2
	10.2	2.5	17.2
11-11-68	7.5	2.3	13.8
	8.9	2.5	14.6
	9.4	2.5	15.1
3-16-69	21.3	2.3	13.8
	22.0	2.4	14.6
	22.0	2.3	24.6
4-21-69	11.8	2.3	9.6
	13.8	2.4	9.4
	14.6	2.8	9.6

Table 21.--Distribution of nitrate-nitrogen in soil profile from check area - Stafford County

Depth cm	6-67 ppm	4-23-69 ppm
0-10	-----	1.20
10-20	7.20	0.80
20-30	9.20	1.20
30-40	11.60	0.80
40-50	12.60	0.52
50-60	17.60	0.52
60-70	22.40	0.28
70-80	20.80	0.28
80-90	-----	0.52
90-100	-----	0.52
100-120	8.40	0.80
120-140	13.00	0.52
140-160	9.80	0.80
160-180	5.40	1.20
180-200	14.40	1.20
200-220	10.40	0.80
220-240	8.80	0.80
240-260	11.60	0.52
260-280	11.20	0.80
280-300	17.60	1.20
300-320	13.60	0.52
320-340	15.60	0.80
340-360	10.00	0.80
360-380	12.60	1.20
380-400	10.80	0.80
400-420	11.50	1.20
420-440	12.20	0.80
440-460	18.20	0.80

Table 22.--Distribution of nitrate-nitrogen in soil profile from plot I-4 - Stafford County

Depth cm	6-67 ppm	2-10-68 ppm	5-28-68 ppm	4-23-69 ppm
0-10	6.00	1.20	3.48	1.20
10-20	6.40	1.20	2.28	1.20
20-30	7.20	1.20	2.00	0.80
30-40	5.72	1.48	2.00	0.52
40-50	3.80	1.72	1.72	0.80
50-60	2.80	1.20	1.72	0.80
60-70	3.80	1.20	1.72	0.80
70-80	5.40	1.20	1.72	0.80
80-90	4.80	0.80	1.72	0.80
90-100	2.52	1.72	1.48	1.20
100-120	4.40	1.48	2.00	1.20
120-140	3.80	1.20	2.00	1.48
140-160	1.72	1.20	2.00	1.20
160-180	3.20	1.20	1.72	1.20
180-200	10.40	0.80	1.72	0.80
200-220	5.40	0.52	1.72	0.52
220-240	5.08	0.28	2.00	0.80
240-260	3.80	2.00	1.72	0.52
260-280	3.48	0.52	1.72	0.80
280-300	3.48	0.28	2.28	0.80
300-320	3.20	0.80	2.28	0.80
320-340	2.52	0.52	2.28	1.20
340-360	3.20	0.28		1.20
360-380	8.00	0.52		1.20
380-400	9.60	1.72		0.80
400-420	9.60	0.52		0.80
420-440	16.00			0.52
440-460	8.00			0.52
460-480	10.40			
480-500	10.00			

Table 23.--Distribution of nitrate-nitrogen in soil profile from plot II-6 - Stafford County

Depth cm	6-67 ppm	2-10-68 ppm	5-28-68 ppm	4-23-69 ppm
0-10	11.00	0.80	2.00	2.00
10-20	13.60	1.20	2.00	1.72
20-30	14.40	1.48	2.28	2.00
30-40	19.40	1.48	2.28	2.28
40-50	19.40	1.20	1.20	2.00
50-60	15.00	1.20	1.72	3.48
60-70	26.40	0.80	2.28	2.28
70-80	13.00	1.20	2.00	1.72
80-90	7.20	0.80	1.72	1.48
90-100	13.60	0.80	2.52	1.20
100-120	13.60	0.80	2.80	1.20
120-140	17.60	1.48	2.80	1.48
140-160	14.40	0.52	3.80	1.48
160-180	14.40	0.52	2.52	1.20
180-200	18.80	1.48	1.80	1.72
200-220	13.60	1.20	2.52	2.00
220-240	13.60	1.72	2.28	2.00
240-260	14.00	1.20	3.20	2.52
260-280	14.00	1.48	3.20	2.52
280-300	13.60	1.72	2.80	2.52
300-320	13.60	1.48	3.20	3.20
320-340	8.00	1.48		2.28
340-360	11.40	1.48		2.00
360-380	10.80	1.48		1.48
380-400	8.40	1.20		1.20
400-420	11.20	1.20		0.80
420-440	10.80	1.48		
440-460	15.00			
460-480	9.60			
480-500	13.60			
500-520	11.20			

Table 24.--Level of nitrate-nitrogen in water samples from observation wells - Stafford County

Date	Check Well	Plot II-6	Plot I-4
6-10-67	1.8	6.6	5.8
	5.3	5.7	5.2
	5.8	5.5	5.5
8-2-67	7.8	8.3	9.9
	8.8	7.5	9.0
	8.3	7.9	9.5
2-10-68	9.9	9.8	12.5
	9.4	9.8	12.5
	9.0	9.8	12.5
8-5-68	14.3	11.2	13.2
	15.6	12.0	12.9
	14.7	12.0	12.9
9-6-68	15.3	10.9	11.6
	15.3	11.6	11.6
	15.3	11.6	11.6
9-28-68	20.6	8.8	12.9
	16.3	8.8	12.4
	20.6	8.5	11.6
11-10-68	23.4	10.0	8.8
	24.8	9.7	8.8
	24.8	10.0	8.8
3-16-69	13.8	18.7	7.7
	14.6	18.7	8.6
	14.6	18.7	8.6
4-23-69	8.7	12.1	11.0
	9.0	12.5	11.0
	9.4	12.1	10.7

Table 25.--Level of nitrate-nitrogen in water samples from observation wells - Reno County

Date	Tank ppm	Check ppm	30 year lot ppm
9-28-68	4.8	19.4	12.9
	5.0	39.9	14.6
	4.9	35.8	14.2
11-10-68	5.0	78.3	13.8
	5.0	76.0	15.1
	5.0	78.3	15.1
3-16-69	4.7	43.3	12.5
	5.2	41.6	12.5
	5.0	43.3	11.8
4-23-69	5.0	33.0	10.7
	5.0	33.0	10.3
	5.0	33.0	10.3

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NITRATE ACCUMULATION IN KANSAS SOIL AND GROUND WATER

by

JAY WESLEY GOSCH

B. S., Kansas State University, 1968

AN ABSTRACT OF A MASTER'S THESIS

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An investigation was set up in two parts to evaluate nitrate-nitrogen accumulation in Kansas soil and ground water. The first portion of the investigation involved sampling of feedlots in different areas of the state to determine effects of location, soil type or texture, amount of rainfall, and age of feedlots on nitrate-nitrogen movement and accumulation in the soil and ground water. The second part of the investigation included studies of nitrate-nitrogen movement and accumulation in irrigated soils under high rates of nitrogen fertilization.

Nitrate-nitrogen accumulations in soils underlying feedlots were varied. The range of nitrate-nitrogen accumulation in a 4 meter soil profile underlying feedlots was from essentially zero to as much as 5,000 kg/ha. The longer the lots had been in existence the greater the amount of nitrate-nitrogen that had accumulated in the soil.

Nitrate-nitrogen movement in soil apparently has occurred beneath feedlots even in areas of low rainfall. Despite a mean annual precipitation is 40 to 45 cm (16 to 18 in), nitrate-nitrogen was detected to depths of 4 meters in the soil underlying some older lots. In areas of higher rainfall, nitrate-nitrogen had accumulated to depths greater than 6 meters.

Soil texture affected the moisture and nitrate-nitrogen content of the soil cores. As the clay content increased the moisture and nitrate-nitrogen content also increased. The findings indicate that nitrate-nitrogen in the soil profile is often associated with high moisture, clay layers. Such conditions were noted both in feedlots and irrigated soils.

Soil phosphorus in feedlot soils indicated little if any movement of P. The P was found to be concentrated in the top 10 to 30 cm or manure layer.

Under high rates of applied inorganic nitrogen, movement of nitrate-nitrogen downward in the soil was detected by movement of nitrate-nitrogen peaks from one sampling period to the next. Even though nitrate-nitrogen movement was detected in some plots there was much variation in the amount of nitrate-nitrogen found in the soil profile from one sampling date to the next.

Nitrite-nitrogen was detectable only in trace amounts in the core samples from both feedlots and irrigated fields.

Investigation of nitrate-nitrogen accumulation in ground water has shown that nitrate-nitrogen in the ground water fluctuated greatly throughout the year. The highest levels of nitrate-nitrogen in test wells on experimental plots were noted during the months after harvest (winter and spring months).