Causes of Nitrate Contamination Of Ground Waters Occurring Locally In The Neepawa-Langruth Areas

A THESIS

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ABSTRACT

Investigations conducted in the Neepawa and adjacent districts show that, where sandy or coarse textured surface deposits lie as a mantle over finer textured substrata, seepage through organic refuse from human and animal habitation is the chief cause and source of excessive amounts of nitrate found locally in ground waters. Small quantities of soil nitrate, elaborated in fallow fields on sandy blackearth like soils, may be leached through the soil profile under certain conditions, but in general, these do not appreciably affect the nitrate status of the ground water. Investigations of fields under crop, point to the conclusion that little or no nitrate is leached below the depth of root penetration. Hence, it is not soil, but contamination from organic refuse that is responsible for toxic quantities of nitrate in farm and village well waters. Surface stored waters invariably were found to contain non-toxic concentrations of nitrate.

Seasonal fluctuations in nitrate content occur in both well waters and surface stored waters. The highest concentrations of nitrate in well waters occur during the summer months, whereas the lowest levels are encountered in the late winter and early spring. The nitrate content of dugout waters, though low in comparison with that in ground waters reaches its highest concentration in the winter months and is lowest during the summer.

In the affected area, to avoid methemoglobinemia in infants and nitrate poisoning in cattle, satisfactory farm and village wells can be obtained in most cases if the location of the wells are properly selected. The alternative is to use surface stored water from dugouts and ponds or streams.

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I. INTRODUCTION

Ground water in the Neepawa and adjacent areas in Manitoba is the main source of water supply for both domestic and livestock use. This water, drawn from shallow wells, often contains high concentrations of nitrate which can and has caused methemoglobinemia in infants as well as death by nitrate poisoning in ruminants.

Investigations undertaken by the Soils Department, University of Manitoba, in an attempt to ascertain the cause and source of the excessive quantities of nitrate in the water supply, gave strong indications that decomposing heavy organic matter accumulations at the soil surface such as found about barnyards, feedlots, privies, and garbage disposal lots were primarily responsible for the excessive amounts of nitrates in the subsoil water, rather than excessive nitrate elaboration in the soil profiles. Further work was necessary however, before more definite conclusions could be established.

The information recorded herein includes a portion of that obtained during the 1951 preliminary investigations together with the data gathered from subsequent work related to the problem.

II. LITERATURE REVIEW

A. NITRATE ELABORATION

Nitrate is one of the most important plant foods in the soil and has been studied from different points of view in different countries in the world. It is now generally recognized that there are certain conditions in the soil which, to a large extent, control the production of nitrate or regulate the activity of the organisms connected with the elaboration of nitrate.

The nitrogen contained in nitrogenous compounds in the soil is derived from the air. About 80 percent by volume of the air consists of free nitrogen, however, the plants are unable to avail themselves directly of this enormous supply of raw material. Before they can make use of this element it has to combine with other elements. Combination can be brought about by the intervention of influences such as lightning discharges, chemical reactions, and soil bacteria. According to Schreiner and Brown (38), 5 to 7 pounds of nitrogen per acre are added annually by lightning discharges and chemical reactions. On the other hand, the amount added by non-symbiotic bacteria is reported to average about 25 pounds per acre annually. The amount fixed by legume bacteria (symbiotic) averages about 80 pounds per acre for the same length of time.

The sequence of chemical changes taking place from the time the nitrogen is brought into the soil to the stage of conversion to nitrate anions according to Quastel (35) are as follows:-

(a) "The transformation of atmospheric nitrogen by soil micro-organisms into substances nourishing microbe and plant.

(b) "The transformation in soil of organic nitrogen compounds arising from autolysis of all forms of biological material or from the products of metabolism of living soil organisms into ammonium ions.

(c) "The conversion of ammonium cations into nitrite and nitrate anions."

The last step (soil nitrification) is brought about largely by two groups of organisms Nitrosomonas, (also Nitrocystes and Nitrosopira) which form nitrate from ammonium ions, and Nitrobacter (also Nitrocystes and Bactoderma) which converts nitrite ions into nitrate ions.

Batham and Nigam (8) carried out investigations on the production of nitrate in field soils and concluded that it appears to be influenced primarily by three factors:-

(a) Soil treatment; e.g. applications of organic matter, limestone and phosphorous.

(b) Tillage operations and kind of crops grown; e.g. fallowing, mulching, green manures and crop residues.

(c) Climatic conditions; e.g. temperature and moisture.

Batham and Nigam (8) have summarized the works of a number of authors in connection with the effects of climatic conditions on nitrate elaboration as follows:- Fraps who studied the nitrate content of plots under different crops states, "The nature of the season apparently has a marked effect on the results obtained." Vogel concluded that, "The treatment of the soil had less effect upon nitrification than the time of year." Hall, while discussing the influence of temperature and moisture upon the nitric-nitrogen content of South African soil said, "In fact, the nitrate curve on the whole, fit the rainfall diagram better than they do the one for temperature." Jensen summed up his deductions thusly, "Even when all the above factors are considered, there appears to be rhythmic periodicity of nitrifying activity during the season due to some unknown property of the bacteria." Organic matter is, therefore, the source of nearly all the nitrogen in the soil. In the later stages of decay of organic matter, nitrogen is liberated as ammonia and subsequently converted into the nitrate form.

The nature of the organic matter added, the rate and manner of application as well as the climate conditions prevailing subsequent to the addition of the organic matter, have direct bearing on the amount of nitrogenous compounds produced in the soil. Heck (23) while studying the effects of different application rates of manure under varying conditions noted that there was a decided depression in nitrate nitrogen recovery when the manure was spread on the field surface and had dried soon afterward. Barthel and Bengtsson (6) carrying on much the same work attributed this loss to the volatilization of ammonia nitrogen. The amount lost being dependent on the manner of handling the manure prior to spreading and the amount of drying which occurred thereafter. Albrecht (1) some twenty years later, while doing some research work on nitrate production as influenced by cropping and soil treatment, obtained substantial nitrate nitrogen accumulation when barnyard manure was added to field plots over a period of ten weeks. If the Azotobacter test was negative in the manure, lime was added and further increases in nitrate elaboration were noticed. Lime by its basic properties has the capacity for regulating the hydrogen-ion concentration in the soil in a manner favorable to bacterial life.

Green manures, mulches, and crop residues all add organic matter to the soil and are therefore, potentially, nitrate formers. The lapse of time required for these materials to break down into simpler constituents will depend on such factors as tillage practices (whether surface or deep), temperature of the soil, and moisture conditions prevailing therein.

Russel (36) while discussing the effects of green manures points out that they "either increase the humus content or else the supply of available nitrogen in the soil" the effect depending on the maturity of the crop when ploughed under. The humus content in the soil is increased only when material fairly resistant to decomposition is added while on the other hand the available nitrogen supply is increased only when readily decomposable material high in nitrogen is decomposed.

The kind of crop ploughed into the soil also has some bearing on the amount of available nitrogen produced. Lyon and Wilson (28) working with green manure crops consisting of hairy vetch, field peas, rye, oats and buckwheat found the greatest accumulation of nitrate to be in soil in which hairy vetch was ploughed in. Upshall, Bradt et al (40) have shown that in general, legume crops were superior to cereal crops for adding readily available nitrogen to the soil.

Influences of other forms of crop residue on nitrate elaboration in the soil were studied. Patrick (34) found that root and stubble residues of red clover and timothy in average field stands were sufficient to influence the accumulation of soil nitrate. He also noticed that the amount of dry matter in the soil in the form of red clover roots and stubble amounts to only about half the weight of timothy roots and stubble from equally good stands. Results obtained by McCalla and Russel (32) show that nitrates are produced in abundance where sweet clover residues are incorporated at the surface of the soil.

Materials possessing wide carbon-nitrogen ratios have a depressing effect on the nitrate content in soils. Murray is quoted by Fennell (20) to the effect that addition of straw to the soil reduced the concentration of nitrate nitrogen therein. Reduced yields obtained in crops following the incorporation of straw in the soil substantiate this fact.

There is evidence of nitrate accumulation under mulches. Beaumont and Crooks (7) applied 50 to 75 tons of cured hay as a mulch. They did not incorporate it with the soil in any way but left it at the surface. After three to four years concentrations of as high as 230 parts per million of nitrate nitrogen (expressed as ppm NO_3N in dry soil) were obtained. Ellis, Poyser and Leclaire (19) found concentration of well over 100 parts per million of nitrate nitrogen in the ground water underneath old straw piles and haystack bottoms.

Tests for nitrate nitrogen on the ground water in the vicinity of these organic accumulations proved that they were the source of excessive amounts of soluble nitrogen.

Where plants are not developing, some factors exert marked influences on the production of nitrate in the soil. Higher soil temperature, higher moisture conditions and better aeration are the principal factors responsible for higher nitrate nitrogen elaboration under summerfallow conditions. It was argued and rightly so, that the nitrate accumulation under the conditions being discussed was due primarily to the fact that it is not being removed by vegetation. Newton (33) working with Alberta soils found that bacterial counts as well as nitrate nitrogen concentrations were always higher in summerfallow than on cropped land. He also noticed that soluble nitrogen accumulated more rapidly in fallow following clover or alfalfa than in fallow after grasses or cereal. Baver (9) found that fallowing increased the bacterial activity in soils, which in turn speeded bacterial decomposition and mineralization of nitrogen. These results he attributed to higher temperatures, higher moisture contents, and greater aeration in the soils.

Organic matter is the raw material and soil microbes are the workers which turn the raw product into forms readily available for plants. In the soil, the efficiency of this labor force is determined or controlled by temperature and moisture conditions prevailing therein. Larson and Mitchell (29) reported that "rapid accumulation of nitrates occurs between the middle of June and the middle of August." At Saskatoon, Saskatchewan, where this work was conducted, this peak of nitrate elaboration coincided with maximum temperature for the area and also with the greatest amount of precipitation. Ellis (18) found that nitrate concentrations in the soil began to increase in May. This again coincides with increases in temperature and also decreases of excessive amounts of moisture caused by melting snow and spring rains. According to Waksman and Starkey (41), moisture conditions most favorable for nitrification are close to 50 percent of the amount of water the soil holds when saturated. The accumulation of nitrates according to Albrecht (2) follows seasonal conditions closely. "With the advent of spring the nitrate in the soil increases and shows that this process like any other biochemical soil process is subject to the moisture level and the prevailing seasonal temperature." Ellis, Poyser and Leclaire (19) state that Cook and Doughty, while working with Saskatchewan soils found, "Only a few parts per million of nitrate per week accumulated in the soil when the temperature was below 50°F. Between 50°F and 75°F the rate increased in proportion to the rise in temperature but the rate decreased at temperatures above 75°F."

B. FACTORS AFFECTING NITRATE MOVEMENT IN SOILS

Nitrates are elaborated at the surface of soils where organic accumulation occurs and proper temperature and moisture conditions prevail. They are very soluble and move freely with up and down movements of soil moisture. Heavy rainfall tends to wash nitrates into lower soil depths. According to Starkey (39), under the influence of heavy rainfall, nitrates pass into the deep region of the soil and upon such occasions the quantity of nitrates may be greater in the subsoil than in the surface soil. Because of their high solubility, the nature of the soil in which they are formed (texture, porosity) together with the amount of water entering the profile will greatly influence their distribution within the soil and substratum.

Ellis, Poyser and Leclaire (19) studied the ground water regime of four soil associations in the Neepawa area of Manitoba. These soils all have a fairly high organic content in the A or surface horizon hence, when proper conditions prevail, nitrate nitrogen will be elaborated, but not in the quantities that would be required to give the high nitrate contamination reported in some of the water of certain wells.

The dominant soil profile in the Newdale association has a clay loam to heavy clay loam texture in the upper two horizons. It is developed on clay loam till which extends from the surface to the underlying shale. The water retention capacity of this soil and substratum is about two inches per foot above the wilting point, therefore, after allowance for surface run-off the amount that penetrates through the soil and into the deep subsoil could not contribute much ground water except during excessively moist periods. Even under those conditions the water retention capacity has to be satisfied before any water will accumulate in the soil.

Nitrate nitrogen was found only in the first and upper portion of the second foot in the Newdale soils. Since the rainfall during the open season is about 13.5 inches (monthly peak of 2.5 - 3 inches in June) it was quite reasonable to find no great downward movement of the nitrates. Furthermore, there was no evidence of leaching downward by previous rains.

A second Newdale profile with a lens of coarser textured material at the fourth and fifth foot was studied. The water retention capacity of this coarser textured material is obviously less than that of the finer textured deposits. This condition was reflected when tests for nitrates were made at different levels and their presence was detected in the coarser textured layer at the four to six foot depth as well as in the upper horizon where elaboration had taken place. Downward movement of water during a moist period earlier in the season could account for the above results.

The Stockton soil and substrate were studied in a similar manner to that of the Newdale. The parent material of the Stockton soils consists of deep sand deposits (200 feet in places). The water retention capacity of this sandy soil and subsoil is only about 1/3 to 1/2 inch per foot. Their porous nature favors penetration rather than run-off. During periods of high rainfall, rapid penetration of water occurs and consequently a water table forms at about 20 feet from the surface. Below the water table a bed of saturated sand occurs, acting as a vast natural reservoir.

Nitrate was found to occur at different levels in the upper 11 feet of soil and subsoil. This occurrence of small amounts of nitrate at different layers reflects the intermittent downward movement of nitrate bearing waters that had taken place following rainy periods earlier in the season.

The Almassippi Soil Association -- typical soil found in the Lower Assiniboine Delta Area was one of the four associations studied. Here as in the Stockton, the Almasippi parent material is porous sand. It differs from the Stockton however, in that it consists of a relatively thin, sandy textured mantle resting on a highly impervious clay substratum instead of on deep sandy deposits. The high porosity and low water retention capacity of the coarse textured mantle favor rapid infiltration of water. This downward movement, however, is arrested at the point of contact between the sand and the heavy textured substratum and consequently, a perched water table occurs during wet periods.

Field work at different times during the summer and early fall showed that the water table rises after heavy rainfalls. A pit dug in a field in August, 1951, showed that the water table was 40 inches from the surface.

Frequent heavy rains fell on the area during the next month which resulted in a rise of ground water from 40 inches to 30 inches below the surface.

A few soil profiles were tested for the presence of nitrate nitrogen. Positive tests were obtained in the "A" or surface horizons (place of elaboration) and at the one and two foot levels. This indicated that the nitrate was in the process of being leached down. That it is leached into the ground water was proved when positive tests were obtained in the ground water itself. Laboratory determinations made on the ground-water sample taken on August 20 showed 30 parts per million of nitrate nitrogen, and only six parts per million in the ground-water sample taken on October 12. Since the site of testing was devoid of vegetation the decrease in concentration of nitrate nitrogen was brought about either by appreciable dilution or by lateral movement and replacement of the ground water or by both of these factors.

The fourth profile studied was in the ridge and swale topography of the Lowlands area. On the ridges, the profile is developed on relatively shallow gravel and sand beach deposits resting on water-worked clay till. Water tends to pond in the low positions in between the ridges. Ground water is commonly found in the coarse textured beach deposits and also in local sites where, as a result of water resorting, sand and gravel are occluded in the till.

The organic accumulations on the surface of this soil are usually quite low, however, where habitation occurs, decaying organic wastes can and do liberate nitrate nitrogen which later finds its way into the ground water. Since this coarse textured soil is more porous and has a lower water retention capacity than either the Stockton or the Almasippi soils, less rainfall is required to washthe nitrate nitrogen downward. Under conditions of moderate rainfall, this could mean a greater concentration of nitrate anions in the ground water due to less dilution.

Vegetation removes large quantities of nitrate nitrogen from the soil.

Starkey (39) found that "no nutrient ion in the soil solution was affected more by cropping than was nitrate. All plant nutrients as well as nitrate were lowered by cropping but nitrate more than any other."

The kind of growing crop, as well as the vigor and stage of growth, have direct bearing on the amount of nitrate that will be removed. Lyon, Bizzell and Wilson, quoted by Starkey (39), observed that grass and wheat tended to depress nitrate accumulation whereas corn favored nitrate formations during the early stages of development. Ellis, Poyser and Leclaire (19) found that deep rooted vegetation not only removes the nitrates from the soil but also removes the ground water. Good evidence of this was obtained when there was a poplar and willow grove surrounded by a field under summerfallow. The ground water in the summerfallow was at 40 inches from the surface and both soil and water showed positive tests for nitrate. On the other hand, there was no ground water under the trees and nitrate tests on the soil and substratum were negative.

Vertical distribution of nitrates is also affected by plant root development. Root systems are markedly modified by fertilizer treatment, by texture and structure of soil, and by the amount of distribution of soil moisture, so that greater or lesser quantities of nitrate nitrogen will be removed depending on whether these factors stimulate or inhibit root development.

Starkey (39) and others found that most of the removal of the nitrate ions occurs during the stage of extensive vegetative development. During the later stages, many plants show some reduction in content, and a portion of previously absorbed elements is returned to the soil.

C. THE TOXIC EFFECTS OF EXCESSIVE AMOUNTS OF NITRATE

(1) Effects Of Excess In Ground Water:

Ground water in most rural areas is the main source of water supply both for domestic and livestock use. Where there is nitrate contamination of this water it follows that humans or animals drinking it will be ingesting nitrate nitrogen as well.

The concentration of nitrate anions in the water, the age, size and kind of animal concerned, as well as the amount of water consumed are factors which determine what consequences will follow the drinking of nitrate bearing waters.

It is now recognized that in humans, usually only infants 10 weeks of age and under are seriously affected by methemoglobinemia through ingesting nitrate bearing waters. It is also accepted that concentrations of less than 10 ppm of nitrate nitrogen in the water will have no serious ill effects on the new born babies. According to Medovy (30), workers in different parts of Europe and North America have found that Methemoglobinemia (cyanosis), or the local term "Blue Baby", occurred in infants usually under 10 weeks of age who ingested well water of high nitrate content used in the prepartion of milk formulas. Bosch et al (10) working in Minnesota found that 90 percent of their cyanosed patients were under two months of age while nine percent of the affected babies were between two and five months. Bosch et al (10) quote Comby as reporting that there are a number of factors which make infants more susceptible to methemoglobinemia than older persons. In his opinion, the most important factor is that the infant has less oxidizable hemoglobin than an adult. He also suggests that there is a high fluid intake with greater turnover of water in proportion to body weight and that the intestinal flora of the infant may contain more nitrate converters.

Cornblath and Hartmann (13) claim that only younger infants become cyanosed upon ingestion of water containing nitrates because of the low gastric acidity which is characteristic of young infants. They postulate that if there is no free acid in the stomach and the pH of the gastric juice is over four, nitrate producing organisms can exist high in the gastro intestinal tract in sufficient numbers to reduce nitrate to nitrite before the former can be completely absorbed.

When one considers the conditions prevailing in the alimentary tract their theory seems sound. Under ordinary conditions, the human body reduces nitrates to nitrites and then to ammonia in which form they are excreted. When great quantities of nitrate are ingested, as is the case of the cyanosed infants, and the intestinal flora reduces nitrate to nitrite more rapidly than nitrite is reduced to ammonia, then nitrites accumulate. When this is the case, they are absorbed in the blood. One molecule of nitrite unites with two molecules of hemoglobin to form methemoglobin. The latter in itself is not toxic but it is not capable of carrying oxygen.

According to Medovy (30), cyanosis becomes clinically apparent when one third of the hemoglobin is replaced by methemoglobin. Tests of blood in those circumstances show that the latter is chocolate colored. Cases have been reported where over one half of the hemoglobin was replaced by methemoglobin.

Medical officers agree that in the affected areas there is no cyanosis in breast fed infants. However, when, for one reason or another, breast feeding is discontinued, trouble begins. The characteristic symptoms appear -- grayish blue or brownish blue cyanosis which begins around the lips, spreads to the fingers, toes, face and soon the entire body is covered. The patient becomes listless and breathes with difficulty. Bosch et al (10) list some factors which will influence the length of time required for symptoms to develop once breast feeding has been stopped and nitrate affected water is used in preparation of milk formula. The concentration of nitrate nitrogen in the water is of primary importance. The amount of water used in the formula, the amount of feeding and the amount of supplemental water feeding also have direct bearing on this matter. Physiological considerations such as the weight and general condition of the infant also come into play. The same workers while keeping data on 94 cases found that half of that number developed symptoms in one to three weeks after being on a formula requiring considerable water as a diluent. Twenty percent of the infants were on well water more than 30 days while in other cases sixty days were required before any symptoms appeared. In contaminated areas, if cows milk is available, it should be used in preference to evaporated or powdered milk. The dehydrated forms require more water in the dilution and cyanosis will likely be brought on sooner and will be more severe than if cows milk was used. In one extreme case, symptoms of methemoglobinemia appeared only one day after breast feeding had been discontinued and the infant was fed with evaporated milk diluted with well water heavily contaminated with nitrate. To make matters worse, the well water was boiled for 30 minutes before using so that the original nitrate nitrogen content of 140 parts per million was raised to 410 parts per million by the evaporation of the water.

The most important factor in treatment of cyanosis is recognition of the disease. Once detected, the subsequent use of nitrate free water for the preparation of formulas and for supplemental water feeding will be followed by spontaneous recovery. Guest, Victor and others (21) claim that such a recovery can be expected within one or two days. These same authors report that workers from Iowa, Kansas, claim the spontaneous clearing up of cyanotic symptoms within 36 to 49 hours after discontinuing the use of the contaminated well water.

In very severe cases methylene blue is given intravenously. This compound reconverts methemoglobin to hemoglobin and this happens in a very short time. Experimentally this reaction takes 10 minutes providing that the methemoglobin content has not risen to more than 40 to 50 percent of the total pigment. The recommended dose of methylene blue is one milligram per kilogram of body weight; that is, .5 c.c. of 1% methylene blue solution for an 8 pound baby would be quite satisfactory.

Aagaard (3) claims that cyanosis disappears as an infant gets older. He reports two cases where the symptoms cleared up at the age of three months with no treatment and no change in the well water used in the formulae. Medovy (30) arrives at much the same conclusions. These facts are substantiated by the Cornblath-Hartman (13) theory; namely, that gastric acidity increases in older infants. Under those conditions nitrate reduction is slowed down considerably and hence, there is no accumulation of nitrite to a dangerous level in the body.

A significant fact about the wells from which most of the nitrate bearing water is obtained is that they are nearly all dug wells and hence, relatively shallow. Also of significance is the location of these wells in relation to farmsteads or privies, etc. Aagaard et al (3) working in Minnesota found that dug wells are more frequently the source of water high in nitrate than are drilled wells. They claim that 62 percent of the wells showing nitrates in excess of 10 parts per million were less than 75 feet deep. Krasnoff (26) of Nebraska made the same observations "Shallow wells and dug wells are more apt to have water high in nitrates than are deep and cased wells." In a survey made in 1948, the average depth of high nitrate wells was

35 and 85 feet respectively. Weart (43) of Illinois also reports that shallow wells are the worst offenders.

Insofar as location of wells is concerned some interesting observations were made. In Nebraska it was noted that farm wells were the worst offenders. Municipal wells showed some improvements while wells in schoolyards were the least affected. From 258 schoolyard wells only 14 had 10 parts per million and over of nitrate nitrogen. In Minnesota 30 rural school and 64 farm wells were studied. The nitrate concentration in the school wells was lower than in the nearby farm wells in all but three instances. Ellis, Poyser and Leclaire (19) while working in the Lower Assiniboine Delta in Manitoba observed that the location of the well in relation to the highest source of organic accumulation (barn, pig pen, etc.) had direct bearing on the nitrate nitrogen content of the water. Wells east and north-east of the farm buildings had invariably higher content of nitrate in the water than those west, south and south-west of the farmstead. This can readily be explained by the fact that the fall of grade is to the east, north-east and hence, any nitrate elaborated at the building sites is washed down by rain water and tends to flow eastward.

(2) Effects Of Excess In Soils And Plants

There are three distinct deleterious effects to plants brought about by excessive amounts of nitrate in the soil. In cases of extremely high concentrations, death of plants may occur. Where the concentrations are lower but nevertheless in excess, plants are rendered susceptible to diseases because of excessive growth and consequent physiological weakness. There may also be changes in the composition and characters of the crop produced.

Headen (24) cites many instances where excessive nitrate nitrogen killed many trees in orchards. Healthy and vigorous apple trees bearing fruit one third of original size dried within a few days, leaves and fruit were still on the trees. Potato plants also are affected in much the same way. The author cautions that the ill effects are not always as evident as in the above mentioned cases.

Increases of nitrogen according to Curtis and Clark (14) bring about a decrease in relative root weight and an increase in relative top weight in sugar beets. This phenomenon has also been observed in herbaceous annuals, biennials and woody plants. Millar and Turk (31) state that nitrogen encourages above-ground vegetative growth; they add, however, that this cannot take place except in the presence of adequate quantities of available phosphorous and potassium. These same workers claim that in addition to prolonging the growing period of plants, too much available nitrogen encourages the production of soft succulent tissue which renders the latter susceptible to disease and mechanical injury. Headen (24) found that cereals growing in the presence of high nitrate concentrations had large green leaves very much darker than normal and the stems were weak. Such cereal crops lodged and were highly susceptible to rust.

In addition, to physical changes, high nitrate concentrations bring about chemical ones as well. Headen (24) working in Colorado found that the application of excessive nitrates "reduced the yield of beets, lowered the percentage of sugar and changed the composition of the ash as well as that of the juices." He also found marked changes in the composition of the wheat kernel. The nitrogen content was increased, silicon and phosphorous were decreased and the potassium increased. Changes were also noted in potato tubers. Gardner (22) reports that as a result of excessive amounts of nitrate in the soil, the canteloupe grown in the Arkanasas Valley has deteriorated both in flavor and in shipping qualities.

It has been observed that certain plants when growing in soil high in nitrate will accumulate the latter in the above-ground vegetation, the concentration being mostly in the leaves and stems. Crops treated with nitrogenous fertilizers or growing in summerfallow will have higher content of nitrate in the straw than those growing on stubble-land. Doughty and Warder (16) found that drought conditions during the heading and ripening period increased the nitrate content in oat straw. Emmert (17) found that tomato plants were affected similarly.

Nitrate accumulation does not occur in all plants nor does it accumulate to the same degree in plants which are subject to such conditions. Davidson et al (15) cite thistle, flax, millet, pig weed, wheat, straw, immature barley, native hay, corn stalks and sorghums as plants that can accumulate nitrate in toxic quantities when the right conditions prevail. Savage (37) found that under certain conditions sugar beet tops can accumulate very large quantities of nitrate nitrogen. Concentrations of as high as 7 percent potassium nitrate equivalent by weight were recorded. On a dry matter basis this figure would be much higher. Feed containing 1.5 percent of potassium nitrate (equivalent to 0.2078% nitrogen as nitrate) is taken as the lower toxic limit hence, it is not surprising that there was heavy loss of life amongst the cattle when fed on sugar beet tops containing the equivalent of 7 percent potassium nitrate.

Although the above mentioned plants can and have caused loss of life in livestock, oat straw remains as the main offender. Coupled with the fact that it is used extensively as a forage for cattle, it is also known to accumulate nitrates in high quantities. Concentrations of potassium nitrate ranging from 3.2 to 7.2 percent have been found in Colorado and Wyoming. Toxic quantities of nitrate in oat straw are suspected to have been the cause of cattle dying in the Portage and Gladstone districts of Manitoba. It is known that these animals died of nitrate poisoning but due to the fact that the water supply at times contains high nitrate, death may have been brought about by contributions of nitrate nitrogen by both the straw and the water or even by the water only.

By experiments Davidson and others (15) have found that the minimum lethal dose of nitrate for cattle was approximately 25 grams of potassium nitrate per hundred weight, (.47 lbs. for 1000 lbs.) per animal. At that rate 5.5 pounds of fodder containing 5 percent potassium nitrate would be fatal to a 500 pound animal. The same workers maintain that nitrate has little or no accumulative action in the system because sublethal quantities can be consumed daily for long periods without ill effects. Tolerance apparently is neither increased or lessened.

An interesting observation was made by Davidson and his co-workers (15). Oat hay dampened by rainfall the previous day was fed to heifers in a dry lot, and to 85 cows at pasture with access to water. The heifers which had received no water were unaffected whereas 24 of the cows died and 6 others aborted on the fourth day.

Abortion is quite common in cattle that have survived nitrate poisoning. Bradley et al (11) reports that in one instance six out of eight animals sickened, but recovered animals aborted dead calves within a few days. From Dayton, Wyoming the same investigator reports that 10 cows had aborted following the ingestion of oat hay high in nitrate. Abortion results from the lack of sufficient oxygen being furnished to the foetal circulation. The foetus is asphixiated and is subsequently expelled or discharged as foreign tissue.

The symptoms of affected animals are quite characteristic. A rapid acceleration of the pulse is first noted. This is followed by shortened quickened respirations, trembling of certain muscle groups, weakness, staggering gait and in some cases apparent blindness. The animal ceases to eat, soon sinks to the ground on its breast, or may roll over and lie quietly on its side with its mouth open. The mucous membrane and the tongue are blue or gray in color, the sclera of the eyes has a brownish tinge. Blood drawn from the animal will be a chocolate color. At this stage of the poisoning, if no treatment is undertaken death will occur and this will come about without the slightest struggle.

Treatment consists of an intravenous injection of methylene blue at a rate of two grams per 500 pounds of animal weight but not less than two grams in any case. The methylene blue is dissolved in water as a four per-cent solution. Injection of this solution is usually done in the jugular vein. Response to the treatment is almost instantaneous. The methemoglobin is quickly reduced, the symptoms disappear and the animal which was near death may begin to eat within 10 to 15 minutes following the injection.

III. INVESTIGATIONAL PROCEDURE

A. FIELD INVESTIGATIONS

(1) Landscape Areas And Ground Water In The Neepawa And Adjacent Districts

The terrain in the Neepawa and adjacent districts can be divided naturally into four main physiographic or landscape areas.

- (i) The Western Uplands Area
- (ii) The Upper Assiniboine Delta Area
- (iii) The Lower Assiniboine Delta Area
- (iv) The Lake Basin Area

The soil-water regime differs in these respective areas.

The specific features peculiar to these, and which are related to the present studies are as follows:-

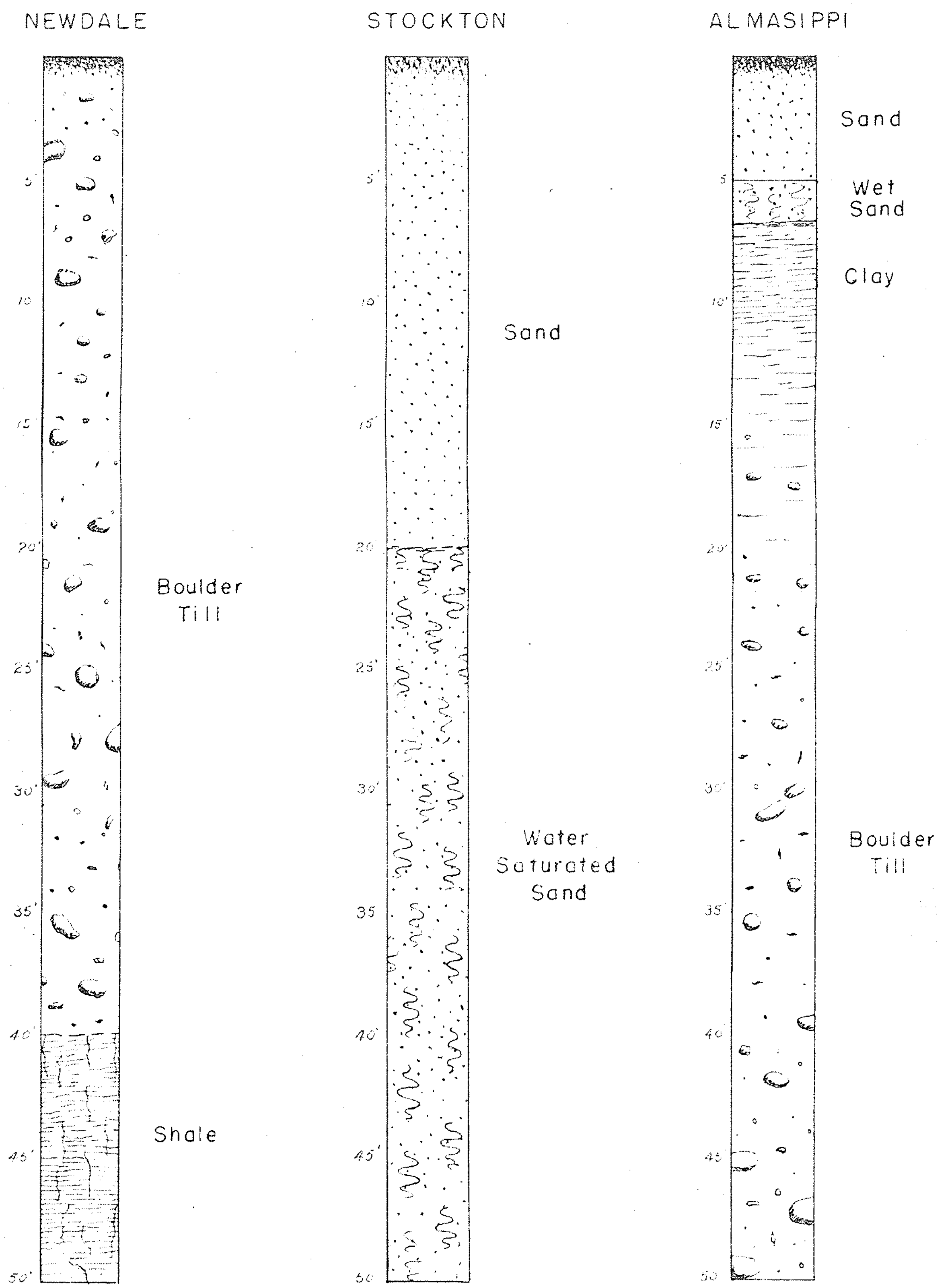
(i) The Boulder-Till Area of the Western Uplands - This area lies west and north-west of Neepawa above the level of the land inundated and modified by glacial Lake Agassiz. Physiographically it consists of an undulating plain of clay-loam boulder-till resting on shale at varying depths. The topgraphy favors run-off which is responsible for the sloughs and local hydromorphic sites in the depressions and basins. The water retention capacity of the boulder-till in this area is approximately two inches per foot, however, occluded lenses of water-worked deposits may cause local variations. It is on the upper portions of the till deposits that the profile of the soil association designated as Newdale is formed. Ground water in this area is obtained from wells dug in the till and shale. Well water appears to be derived chiefly from seepage through the till and also through fissures in the shale.

(ii) The Upper Assiniboine Delta Area - This area lies between the till area of the Western Uplands Area and the Campbell beaches of Lake Agassiz. The most prominent of those beaches is commonly referred to as the Upper Campbell Beach or the Arden Ridge. South of Neepawa the terrain consists of sand dunes interspersed with smooth areas of sandy deposits on which the soils of the Stockton Association have developed. In some places the depth of these deposits is as much as 200 feet. Due to coarse texture, these soils and their substrata have relatively low water retention capacity. Their porosity favors infiltration rather than run-off.

Ground water is obtained in those deep sandy deposits through sand points driven into what can be considered as a natural reservoir filled with sand to a depth of about 20 feet above the level of the water.

Figure I

CROSS SECTION THROUGH SOILS AND UNDERLYING GEOLOGICAL DEPOSITS



DRIFT DEPOSIT OF THE UPLAND REGION (1)

UPPER ASSINIBOINE DELTA (2)

LOWER ASSINIBOINE DELTA (3)

North of Neepawa the delta becomes ill-defined and gradually merges into gravelly and sandy beaches, alluvial fans, shale outwash and water-worked till deposits.

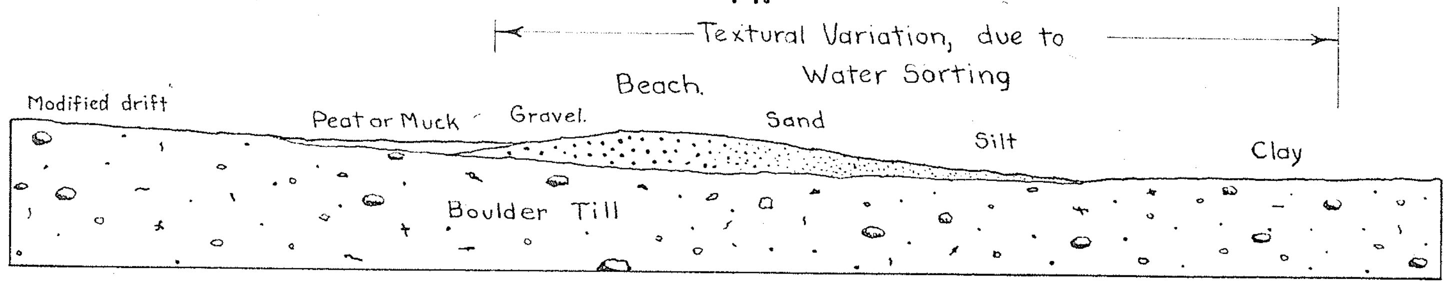
(iii) The Lower Assiniboine Delta Area - This delta extends below the Arden Ridge to Gladstone in the latitude of Neepawa and north to south it extends from Plumas to Carman. It stretches as a flat plain at a lower elevation than the upper delta, and consists of a thin mantle of sand overlying locustrine clay and water-worked clay till. It is on this sandy mantle that the soils of the Almasippi Association have developed. Despite their porous nature, these soils are poorly drained internally. The sandy mantle has a low water retention capacity but water which enters from the surface percolates rapidly downward and is arrested by the clay substrata. This results in the periodic occurrence of a perched water table above the contact between the sand and clay deposits. In periods of heavy rainfall the ground water may be within three feet from the surface. Ground water is commonly obtained from relatively shallow wells.

(iv) The Lake Basin Area - This area lies north and east of the Lower Assiniboine Delta Area and consists of a lacustrine plain quite flat in outline. The surface deposits vary considerably - they range from water-worked till in the West Lake area, to silty and clay deposits in the Red River Plain. Again, in the vicinity of streams, the lacustrine sediments may be covered by levees and flood plain overwash. North and north-east of the Lower Assiniboine Delta Area, lake action has reworked and resorted the surface till into low ridge and swale topography. These micro-ridges run from north, north-west to south, south-east. At intervals and running in the same direction, well defined ridges of gravel and sand were thrown up by Lake Agassiz during its successive stages of retreat. East of the delta, extensive lacustrine sediments

FIGURE II

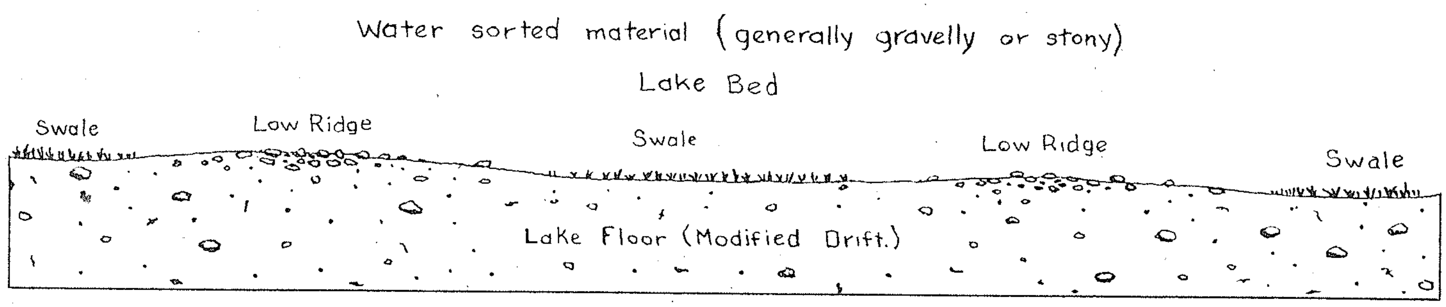
CROSS SECTION OF THE GEOLOGICAL DEPOSITS OF THE LAKE BASIN AREA
SHOWING
MODIFICATIONS OF THE PARENT MATERIAL CAUSED BY WAVE ACTION

A.



GENERALIZED CROSS-SECTION THROUGH A GRAVEL BEACH.

B.



GENERALIZED CROSS-SECTION SHOWING MICRO RELIEF
OF THE LAKE BED BETWEEN THE BEACHES

cover the Lowland plain, however, in certain areas these sediments are in turn covered by flood plain over-wash.

(2) Variations In Ground Water Regime

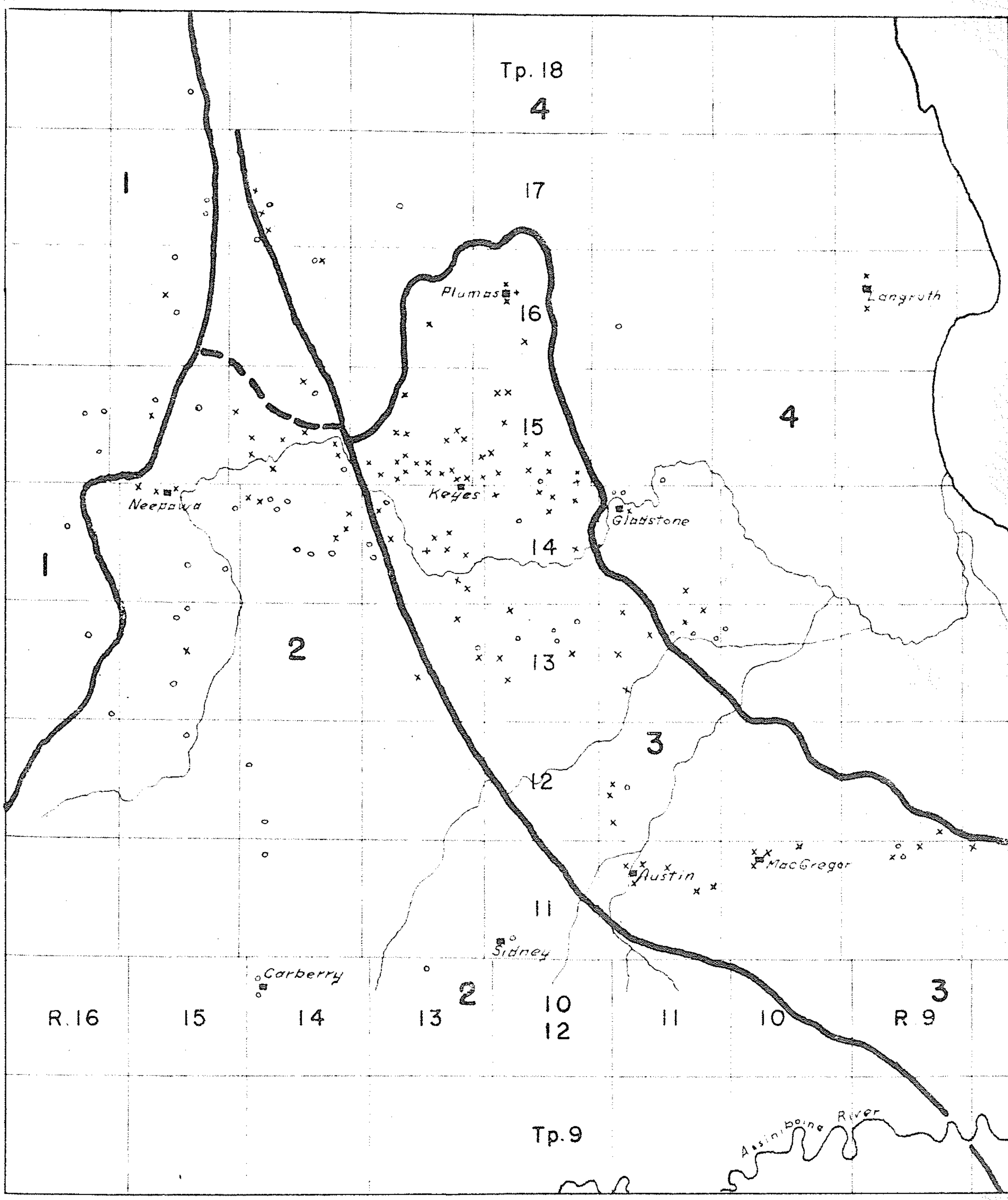
Different water regimes occur under the various surface deposits in the Lake Basin Area. On the Agassiz beaches and in the shallow lacustrine sediments, water is obtained readily, in moist seasons, from shallow wells. On the other hand, the deep lacustrine clay deposits do not favor easy percolation and ground water storage. Therefore, dugouts here are used quite extensively for storage of water. In the more porous sediments, wells of shallow to medium depth are the common source of water supply.

The preliminary field work in this investigation consisted of making traverses through the Neepawa and adjacent physiographic areas. Along these lines of traverse random samples of water were obtained from wells and dugouts and tests for the presence of nitrate nitrogen were made in the field at the site of sampling. By the use of appropriate symbols, all the information obtained was plotted on a district map as shown in Figure III, and from observations made of the physical features of the region, a definite lead was obtained. It became apparent, on the one hand, that nitrate contaminated well waters were of common occurrence in the Lower Assiniboine Delta Area, in the mixed deposits at Neepawa and in the coarse textured beach deposits of the Lake Basin Area. On the other hand, well waters tested in the till plain of the Western Uplands Area and in the deep sand deposits of the Upper Assiniboine Delta Area showed nitrate contamination to be only of casual and widely scattered occurrence.

Once the distribution of nitrate-contaminated wells was ascertained, and a general picture of the ground-water regime in the surface deposits of the physiographic regions under study was obtained, an attempt was made to

FIGURE III

SKETCH MAP OF NEEPAWA AREA AND ADJACENT DISTRICTS



LEGEND

NITRATE STATUS

× Location of wells with water containing > 10 P.P.M. of nitrate nitrogen.

∘ Location of wells with water containing < 10 P.P.M. of nitrate nitrogen.

PHYSIOGRAPHIC AREAS

1. Western Uplands. 2. Upper Assiniboine Delta.
3. Lower Assiniboine Delta. 4. Lake Basin or Lowlands.

determine the source of nitrate nitrogen in the contaminated well waters. The preliminary survey showed that nitrate contaminated ground waters were most common in areas where ground water occurred at relatively shallow depths or where a perched water table below the soil profile was present. Consequently, subsequent studies were centered on the ridged areas of the Lowland Basin and in the Lower Assiniboine Delta where the above respective conditions are encountered.

(3) Determinations Of Nitrate In Ground Waters

Tests for the presence of nitrate nitrogen were made on soil profiles throughout the affected area. These profiles were selected from fields having different types of crop and also from areas supporting poplar and willow. Tests were run on the different horizons in the soil profiles as well as on the underlying ground water. During the month of August 1951, when this phase of the survey was conducted, ground water was not present in any of the tested sites under groves of trees, native grass, alfalfa grass mixtures, or in some sites under crop. However, under fallow, row crops such as corn and sunflowers, and under cereal crops in most sites, it was encountered at about four feet from the surface. A few profiles investigated in fallow fields showed the ground water to be at about 30 inches from the surface.

The tests made on the different horizons in the fallow profiles revealed the presence of nitrate nitrogen therein. (See Table No. I) The surface horizon or zone of elaboration invariably had the highest concentration. From there, as one progressed downward the concentration of nitrate decreased. In the ground water, however, there proved to be an accumulation since the quantity there was greater than at any place within the profile. At on specific site tests made at intervals from August 20th to the 12th of October on a profile in a summerfallow field showed that the above mentioned pattern held true, i.e.

nitrate nitrogen is elaborated in the surface horizon and is subsequently washed down through the profile by rains. From the time that the first pit was opened in August to the date of the last testing, the ground water had risen from 40 inches to 30 inches from the surface. This was brought about by 3.2 inches of rain which fell on the area during that time. Accompanying the rise of the ground water was a reduction of concentration of nitrate from 30 parts per million to six parts per million. This reduction could have been brought about by the appreciable dilution caused by excessive precipitation or by lateral movement and replacement of the ground water or by both of these factors.

TABLE NO. I

NITRATE NITROGEN IN FALLOW FIELD N.W. 1/4 27-14-13 AT SUCCESSIVE DATES 1951

Depth	Aug. 20	Depth	Sept. 18	Depth	Oct. 12
0 - 6"	++	0 - 6"	10 ppm	0 -10"	3 ppm *
7 -12"	+	7 -12"	10 ppm		
12 -20"	trace	12 -20"	8 ppm	10-20"	5 ppm *
20 -30"	trace	20 -30"	trace		2.5 ppm *
30 -40"	trace				
	Water at 40"		Water at 30"		Water at 32"
	30 ppm *		(+)		6.0 ppm *

* Determinations made in laboratory; other figures are estimates made by spot plate comparisons in the field.

++ = Very high, and + = positive presence of nitrate on August 20, but not measured quantitatively.

The results of similar tests made in fields under crops showed an absence of nitrate or, if present, trace amounts only. Negative results were obtained in all horizons of the soil profiles under crop as well as in the ground water occasionally found under row crops. (See Table II)

TABLE NO. II

NITRATE NITROGEN STATUS OF ALMASIPPI SOIL, AND OF GROUND WATER, WHERE PRESENT, AT TIME OF OBSERVATION, (1951), UNDER DIFFERENT VEGETATIVE COVER.

Depth In Feet	Fallow Aug. 27	Corn Aug. 30	Sunflowers Aug. 27	Oats Aug. 28	Grass-Alfalfa Aug. 28	Native Vegetation: Grass (Hydro-morphic site) Aug. 31	Native Vegetation: Bush Aug. 22
0-1	positive	negative	negative	negative	negative	negative	negative
1-2	positive	trace	negative	negative	negative	negative	negative
2-3	negative	negative	negative	negative	negative	negative	negative
3-4	negative	negative	negative	negative	negative	negative	negative
4-5	trace	negative	negative	negative	negative	negative	negative
	water at 55 inches positive	water at 54 inches negative	water at 55 inches trace	- - - - - - (NO GROUND WATER PRESENT) - - - - - clay at 45 inches	glacial drift at 44 inches	glacial drift at 40 inches	glacial drift at 60 inches

Having completed that phase of study and being reasonably sure that the quantity of nitrate nitrogen contributed by the soil to the well waters, at the very most was in very small quantities only, it is imperative to look for other causes of nitrate contamination. Nitrate nitrogen is an end product of organic decay - to produce the concentrations of nitrate found in some well waters would require quantities of organic matter far exceeding those present in soils under ordinary field conditions. In seeking for organic accumulations, attention was directed to farmsteads. Here were found organic accumulations of all descriptions - manure piles, pig pens, chicken coops, corrals, stack bottoms in feed lots, seepage of liquid excreta from barns etc.

On a specific farm (N.E. 1/4 26-11-11) in the Almasippi Soil Association nitrate tests were made on the ground water under the farm fields. The concentration of nitrate was relatively low. On the other hand, tests on water from wells located about the farm buildings contained large quantities of nitrate. This striking difference of levels of nitrate in the ground water below the farm fields and of that in the well water in the farm yards led to a detailed study of the ground waters below the specific farmstead and adjacent fields. A detailed plane table survey map was made of the farm unit (farmstead and surrounding fields). Borings at selected points down to ground water were made with a three inch soil auger. At every foot depth, soil was taken and leached with distilled water and the leachate was then tested for nitrate. When the ground water was reached, a rubber tube fitted with a glass end was inserted in the hole and by suction, ground water was drawn up, filtered and tested. The results obtained at every boring site were recorded on the map by appropriate symbols. As the boring progressed, a definite pattern became apparent. Invariably the heaviest concentrations of nitrate in the ground water were obtained in water from holes bored in the immediate vicinity of heavy accumulation of organic matter. The usual accumulation of manure about the barn, in addition to the liquid excreta seeping through the barn floor and into the soil, supplied the ground water under it with an abundant supply of nitrate. The organic accumulations under and around the privy, chicken pen, pig pen, manure pile and the feed lot also were other sites where excessively high accumulations occurred. Holes bored in the garden showed the ground water to be nitrate contaminated although not to the extent as that found immediately below the farmstead. As the borings progressed further away from the farmstead and garden, the concentration of nitrate in the ground water was observed to be less and less until a point was reached where trace amounts or negative results were obtained.

A copy of the plane table map of this farm is shown as Figure IV. The locations of the respective bore holes are shown by numbers and the respective concentrations of nitrate nitrogen in the ground waters are given in Table III. The contaminated area as shown on the farm map is delineated by the dotted line. All holes bored within that area showed that the ground water contained nitrate in excess of 10 parts per million, (minimum toxic quantity recognized by medical authorities) whereas holes bored outside that area showed the ground water to be negative, or to contain nitrate in non-toxic quantities.

The line of delineation indicates that contamination stops short west and north of the farmstead, but on the other hand to the east and north-east, it carries well into the adjacent fields for a distance of nearly one tenth of mile.

A second farm unit (N.W. 1/4 34-13-12) in the same soil association was studied in a similar detailed manner, and the farmstead plan is here submitted as Figure No. V. The notations of the nitrate studies of ground water

FIGURE NO. IV

NITRATE STATUS OF GROUND WATER

ALMASIPPI SOIL ASSOCIATION

NE 1/4 SEC. 26 TP. 11 R. 11

SEPT. 1951

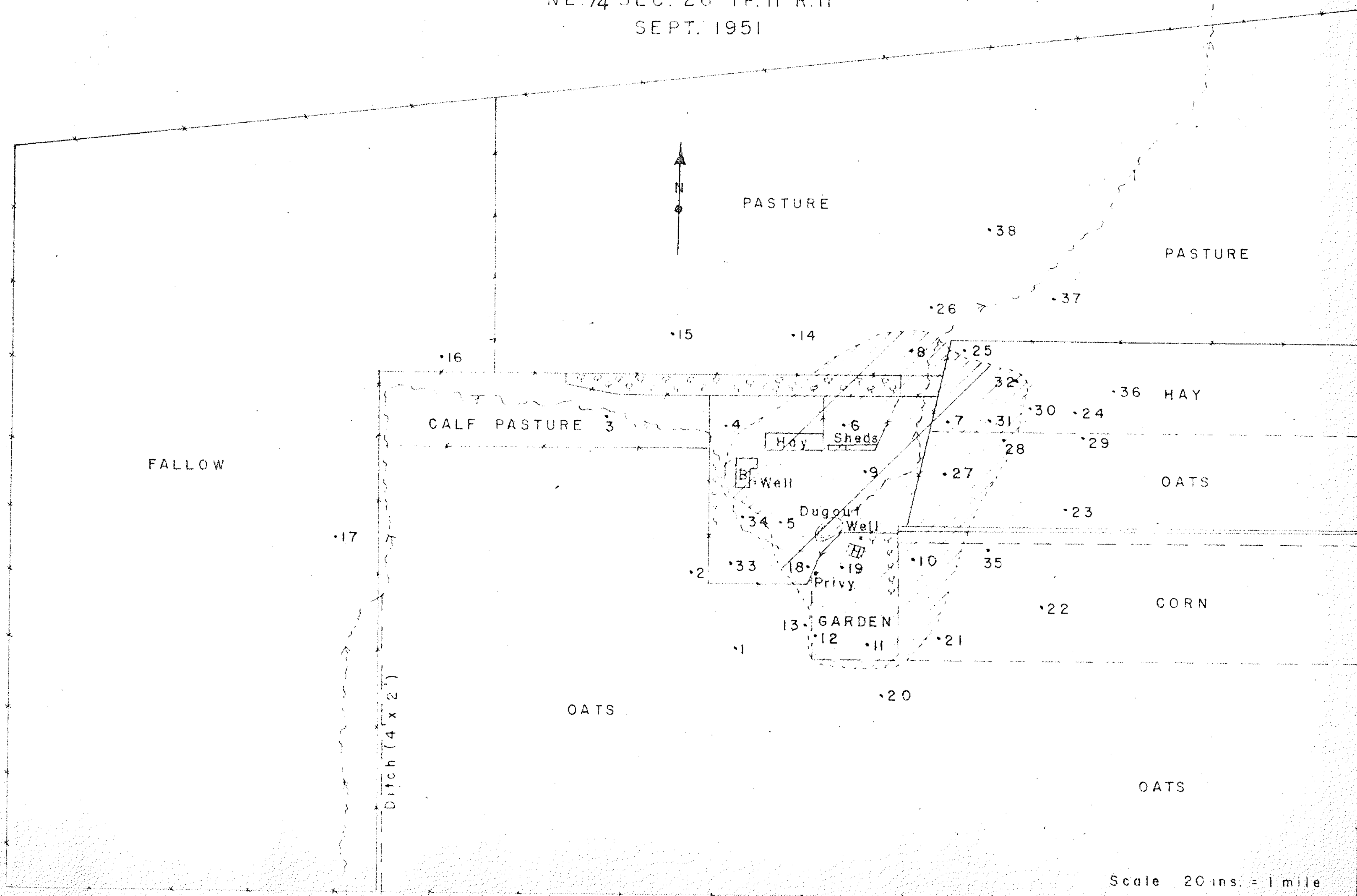


TABLE NO. III

DEPTH TO GROUND WATER AND NITRATE NITROGEN CONTENT

OF GROUND WATER FOUND IN BORE HOLES NUMBERED AND RECORDED IN FIGURE IV

N.E. 26-11-11 Almasippi Soil Association September, 1951

Bore-hole No.	Depth to ground water in feet	Estimated Nitrate Nitrogen content in ppm of ground water drawn from bore hole	Remarks
18	6.5	100++ [1]	Four feet from privy
6	6.0	100++	Chicken yard
9	5.5	100+ [2]	In front of hen house
5	5.0	90-100	Between house and barn
11	4.5	60-75	Garden
19	6.0	60-70	Between house and privy
27	6.8	60-70	Field close to and east of farmstead
28	6.0	40-50	Field close to and east of farmstead
31	6.0	40-50	Field close to and east of farmstead
10	5.5	40-50	Field close to and east of farmstead
8	5.5	20-30	Field close to and north of farmstead
3	4.5	10-15	Near draw in calf pasture
7	4.5	10-15	Field close to and north-east of farmstead
21	5.0	10-15	Field close to and east of farmstead
Barn Well No. 1		100++	
House Well No. 2		60-70	
13	5.5	trace [3]	Very close to garden
32	5.9	trace	Field close to and north-east of farmstead
12	*	High surface concentration	Garden
20	5.0	trace	Oat field
22	6.0	trace	Corn field
24	6.5	trace	Hay field
29	6.0	trace	Oat field
1	4.5	Nil	Oat field
2	4.2	Nil	Oat field
4	6.5	Nil	Yard north-west of farmstead
33	6.0	Nil	Yard west of buildings
34	4.0	Nil	Yard south of barn
14	5.5	Nil	Grass pasture field
15	5.5	Nil	Grass pasture field
16	4.5	Nil	Fallow
17	*	Nil	Fallow
23	6.0	Nil	Oat field
25	6.5	Nil	Hay field (alfalfa)
26	6.3	Nil	Grass pasture
30	7.0	Nil	Hay pasture (alfalfa)
35	5.0	Nil	Corn field
36	6.0	Nil	Hay field (alfalfa)
37	6.0	Nil	Grass pasture
38	6.0	Nil	Grass pasture

* Water extract - no ground water obtained

1 Very high concentrations - well over 100 ppm

2 High concentrations - above 100 ppm

3 Below 10 ppm - hence non toxic concentrations

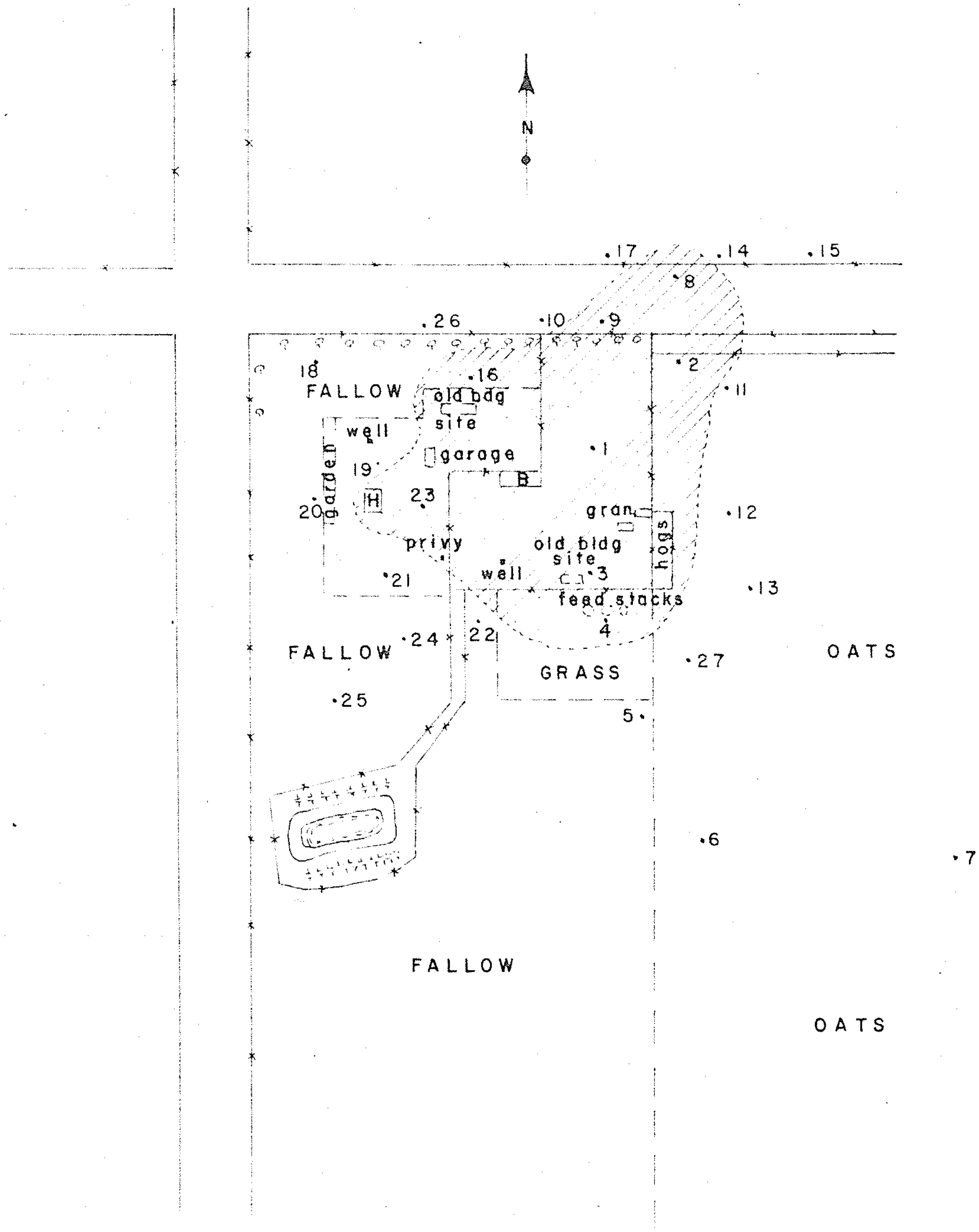
FIGURE NO. V

NITRATE STATUS OF GROUND WATER

ALMASIPPI SOIL ASSOCIATION

N.W.1/4 SEC. 34 TP. 13 R. 12

SEPT. 1951



Scale 20" = 1 mile

TABLE NO. IV

DEPTH TO GROUND WATER AND NITRATE NITROGEN CONTENT OF GROUND WATER FOUND IN BORE HOLES NUMBERED AND RECORDED IN FIGURE V

Bore-hole No.	Depth to ground water in feet	Estimated Nitrate Nitrogen content in ppm of ground water drawn from bore hole	Remarks
1	6.5	100+ [2]	Farmyard - 75 feet east of barn
3	6.5	100+	Old building site
23	6.0	40-50	50 feet east of house
4	5.0	20-30	Stockyard
8	6.5*	20-30	Road allowance north-east of farmstead
16	5.5	10-15	Thirty feet north of old building site
2	6.5	10-15	Oat field north-east of farmstead
9	5.5*	10-15	Road allowance north-east of farmstead
24	5.0	10-15	Fallow, clean and free from couch grass
Well No. 2		10-15	
Well No. 1		Nil	
5	5.0	trace [3]	Fallow field
6	5.0	trace	Oat field near fallow
27	5.0	trace	Oat field near fallow
11	5.5	trace	Oat field
12	5.5	trace	Oat field
25	5.0*	trace	Fallow, couch grass in festation
26	5.0*	trace	Road allowance north of farmstead
10	5.0	Nil	Road allowance north of farmstead
13	5.5	Nil	Oat field
7	6.3*	Nil	Oat field
14	5.5*	Nil	Field north-east of farmstead and road
15	5.5*	Nil	Field north-east of farmstead and road
19	5.5*	Nil	North-west corner of farmstead
20	5.5*	Nil	West of garden and farmstead
21	5.5*	Nil	South-west corner of farmstead
22	5.5*	Nil	Fallow

FIGURE NO. VI

NITRATE STATUS OF GROUND WATER

ALMASIPPI SOIL ASSOCIATION

N.E. 1/4 SEC. 26 TP. 11 R. 11

JUNE 1953

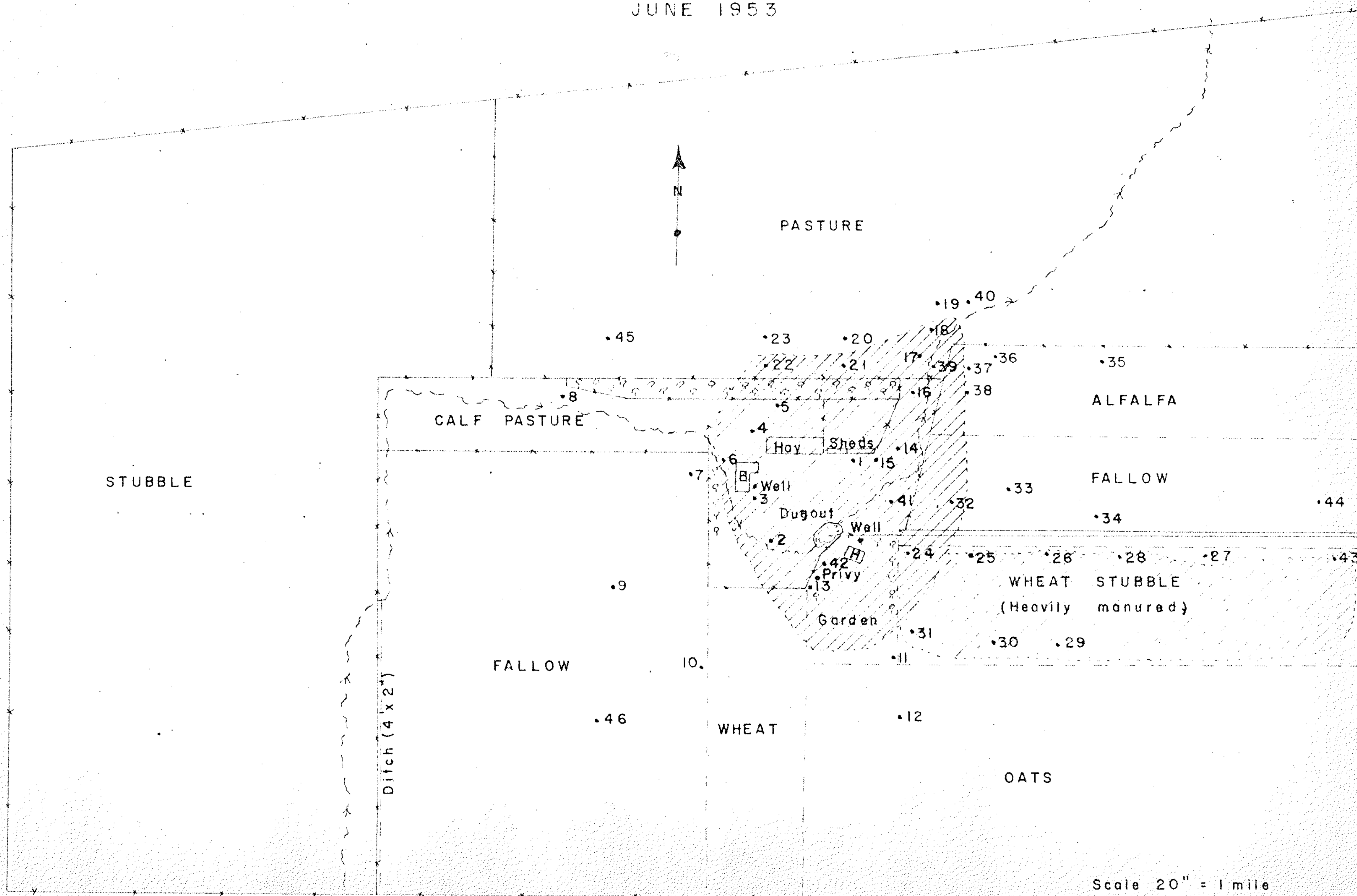


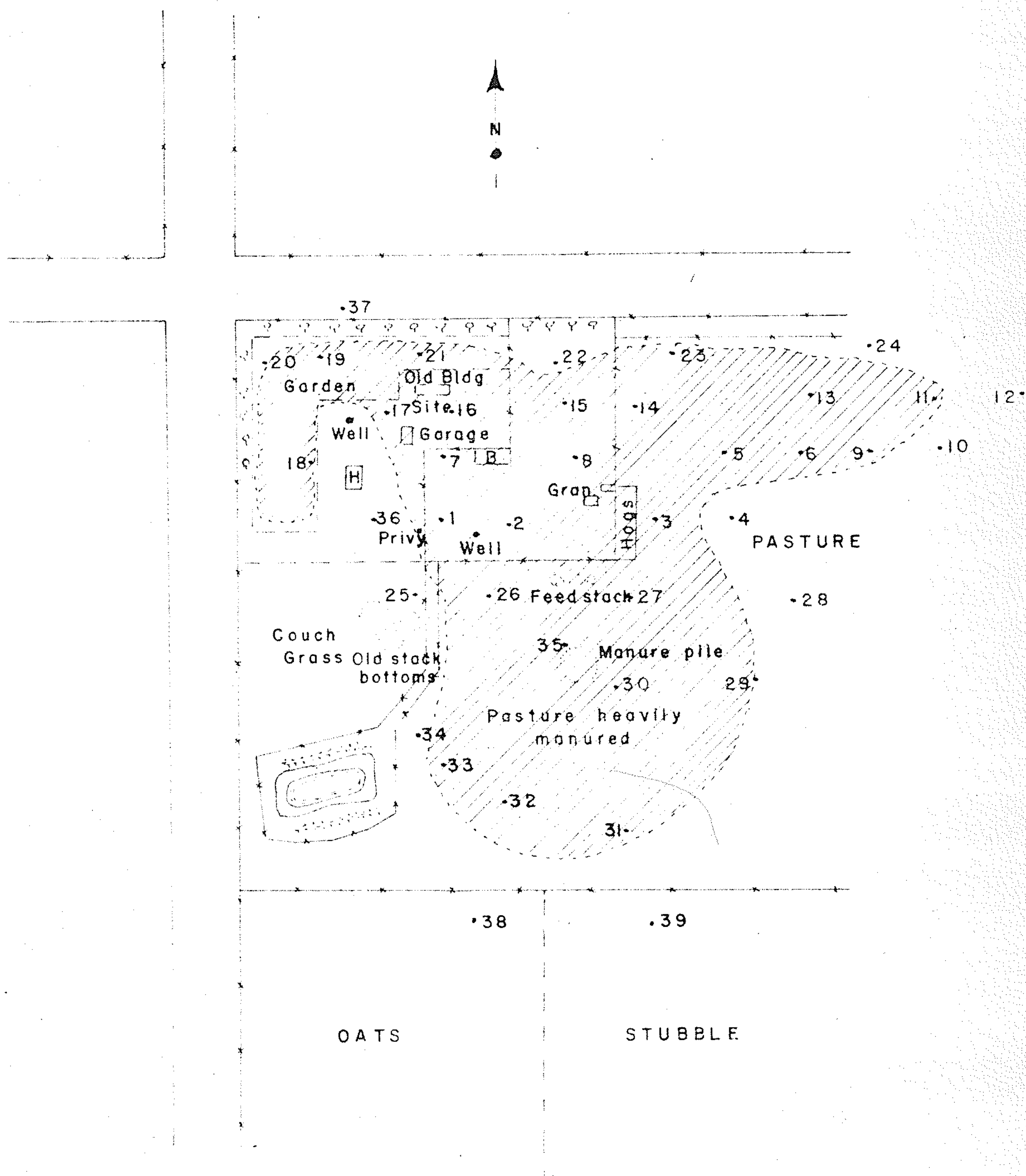
TABLE NO. V

DEPTH TO GROUND WATER AND NITRATE NITROGEN CONTENT OF GROUND WATER FOUND IN BORE HOLES NUMBERED AND RECORDED IN FIGURE VI

Bore-hole No.	Depth to ground water in feet	Estimated Nitrate Nitrogen content in ppm of ground water drawn from bore hole	Remarks
1	7.0	100++[1]	In barnyard close to chicken house
3	8.0	100++	About 12 feet east of barn
4	6.0	100++	50 feet north of barn close to haystacks
5	6.0	100++	In chicken pen north, north-east of barn
15	6.0	100++	About 50 feet east of chicken house (bareground
16	6.0	100++	At east end of shelter belt
17	6.0	100++	In pasture north-east of shelter belt
18	6.0	100++	Pasture 12 ft. north of ravine and north-east of farmstead
41	3.5	100++	East of barn north-east of privy house to garden
32	4.0	100+[2]	Fallow field near yard fence
42	5.0	100+	About 15 ft. north-east of privy
21	5.5	100+	Close to shelter belt north-east of farmstead
29	2.0	100+	In heavily manured field
24	5.0	100	Heavily manured field
26	3.0	100	Heavily manured field
22	5.5	75	Due north of barn 100 ft. north of shelter belt
28	3.5	75	Heavily manured field
25	3.0	50-60	Heavily manured field
39	4.0	50	Pasture near ravine north-east of farmstead
14	6.0	30-40	Close to and east of chicken house
43	3.0	20-40	Eastern extremity of heavily manured field
11	6.0	25-35	Garden
6	6.0	15	West of barn about 20 feet away from corner
31	3.0	15	Heavily manured field
2	5.0	10-15	About 40 feet south-east of barn
8	5.0	10	Pasture west of barn
20	6.0	10	Pasture north of farmstead some distance from latter
30	3.5	10	Heavily manured field
40	4.0	trace[3]	In pasture north-east of barnyard
34	4.5	trace	Fallow after corn
33	4.0	trace	Fallow after corn
19	5.5	trace	North-east of farmstead some distance in field
27	2.5	trace	Heavily manured field
46	5.0	trace	Fallow sown to oats
23	5.5	trace	North of farmstead beyond shelter belt
9	5.0	trace	In oat field
10	4.5	nil	Wheat field - grain about 3 inches long
12	6.0	nil	Oat field
13	6.0	nil	4 ft. east of privy at foot of cottonwood caragana (belt
35	4.0*	nil	Brome - alfalfa mixture
36	4.0	nil	Brome - alfalfa mixture
37	5.0*	nil	Fenceline west end of alfalfa field
38	5.0	nil	Fenceline - heavy grass growth
45	5.5	nil	Pasture
Creek west of barn		nil	

FIGURE NO. VII

NITRATE STATUS OF GROUND WATER
ALMASIPPI SOIL ASSOCIATION
N.W. 1/4 SEC. 34 TP. 13 R. 12
JUNE 1953



Scale 20" = 1 mile

TABLE NO. VI

DEPTH TO GROUND WATER AND NITRATE NITROGEN CONTENT OF GROUND WATER FOUND IN BORE HOLES NUMBERED AND RECORDED IN FIGURE VII

N.W. 34-13-12 Almasippi Soil Association June - 1953

Bore hole No.	Depth to ground water in feet	Estimated Nitrate Nitrogen content in ppm of ground water drawn from bore hole	Remarks
1	6	100++[1]	About 10 feet east of privy and in barnyard
2	6	100++	In barnyard
8	4	100++	East of barn (about 50 feet away)
15	5	100++	North-east of barn (60 feet away)
26	5	100++	Feed lot (bare ground)
30	5	100++	In heavily manured pasture adjacent to manure pile
35	4.5	100++	Near manure pile in pasture
5	5	100++[2]	Pasture (grass) east of barnyard
16	5	100+	10 feet north of hen house
19	5	100+	Pasture east of farmstead
21	5	100+	Garden
6	6	100+	Pasture (grass) east, north-east of farmstead
27	5*	100+	Pasture near feed lot and manure pile
11	4.5	100	Due east of barnyard in pasture
13	5	100	Pasture east of barnyard (close to latter)
31	5	80-100	Heavily manured pasture south of farmstead
18	5	80-90	East half of garden
33	5	75	Heavily manured pasture south of farmstead
9	4.5	75	Pasture east of barn, close to latter
17	5	60-75	Short distance east of garden
32	5	50-60	Heavily manured pasture south of farmstead
3	5.5	25-35	Close to and east of pig pen and old bldg. site
29	5	10	Pasture east of manured area
34	5.5	10	Lane near dugout
Well No. 2		100++	Close to barn and privy
7	5	Trace[3]	About 40 feet west of barn-grassed
22	5	Trace	About 150 ft. north, north-east of farmstead at foot of tree belt
12	5	nil	Pasture due east of farmstead
14	5	nil	Pasture north-east of farmstead
20	4	nil	Grassed road allowance west of garden
24	5	nil	North-east of farmstead quite some distance in field
25	5	nil	Grassed area south of house to west of farmstead
28	5	nil	South-east of farmstead some distance in field
4	5	nil	Pasture south-east of farmstead
10	5	nil	Pasture due east of farmstead
12	5	nil	Pasture due east of farmstead
36	5	nil	Grassed yard south of house
37	5	nil	Grassed road allowance north of farmstead
38	5	nil	Grain field
39	5	nil	Stubble
Well No. 1			North of house and in heavily grassed area

are recorded on Table No. IV. As in the first farm studies, nitrate contamination of ground water was centered about the farmstead. As before, contamination stopped short of the buildings and organic refuse to the west, south-west and north-west. To the east and north-east the contaminated ground water area drifted out into the fields in a more definite tongue than was noticed on the first farmstead.

During the latter part of June, 1953, the ground water of the same two farm units was again tested for the presence of nitrate nitrogen. The striking similarity of pattern of the contaminated areas about the respective farmstead between that obtained in the fall of 1951 and in June, 1953, can best be noticed by comparing the plane table maps of the farm units under study made at those respective dates, (Figures IV, V, VI, VII). The nitrate contaminated tongued area protruding north-east away from the farmstead and into the adjacent fields is in evidence on all the maps. Contamination is also seen to stop short of the farm buildings and organic refuse to the west, south and south-west.

During the winter of 1952 - 1953 the farm operator on the N.E. 1/4 26-11-11, heavily manured (at least 25 tons per acre) one of the fields adjacent to his garden. This specific field is shown on Figure VI. The ground water tested under this field was positive from one end to the other with the concentrations of nitrate ranging from trace quantities to over 100 parts per million. Tests on the ground water under the fields flanking this heavily manured patch showed that nitrate was either absent or present only in non toxic quantities.

Ground water under a pasture located south of the farmstead on the N.W. 1/4 34-13-12, as shown on Figure VII was found to be positive. This particular portion of the pasture in addition to being heavily strewn with manure as a result of litter dropped from the manure wagon and stone-boat, contained a manure pile, old feed-stack bottoms, and served also as a corral for about 35 head of cattle. A flock of some 250 turkeys also roamed this area during the season. (The area under discussion is situated immediately east of the dugout and south of the farmstead.

During early October, 1953, the third and final detailed study of the ground water under the same two farms was conducted. In the immediate vicinity of the farmsteads and gardens of both farms the pattern found in the two previous investigations still persisted. The field on the N.E. 1/4 26-11-11 which had been heavily manured during the previous winter, had supported a heavy stand of corn during the summer. Ground water under this field now was free of nitrate. On the other hand the pasture on N.W. 1/4 34-13-12 as shown in figure IX was still harboring an abundance of organic matter at its surface and the ground water was still laden with nitrate.

During preliminary investigations it had been found that many wells situated in little towns and villages that were located in the Lower Assiniboine Delta Area, or on gravel ridges of the Eastern Lowlands supplied water that contained toxic concentrations of nitrate nitrogen. Tests of different horizons of the soil profiles and of the ground water showed that the greatest concentration of nitrate nitrogen were invariably encountered near privies or in gardens. However, when one bears in mind that each and every lot in these little towns or villages has garbage receptacles in addition to one or both of the above mentioned items behind the house and that the well is usually in the vicinity of these supplies of organic refuse it is not surprising to find the well water to be laden with nitrate. Furthermore, most of these local sites have been habitated for well over a half century and consequently the profile and subsoil are well supplied with organic matter

FIGURE VIII

NITRATE STATUS OF GROUND WATER

ALMASIPPI SOIL ASSOCIATION

N.E. 1/4 SEC. 26 TP. 11 R. 11

OCT. 1953

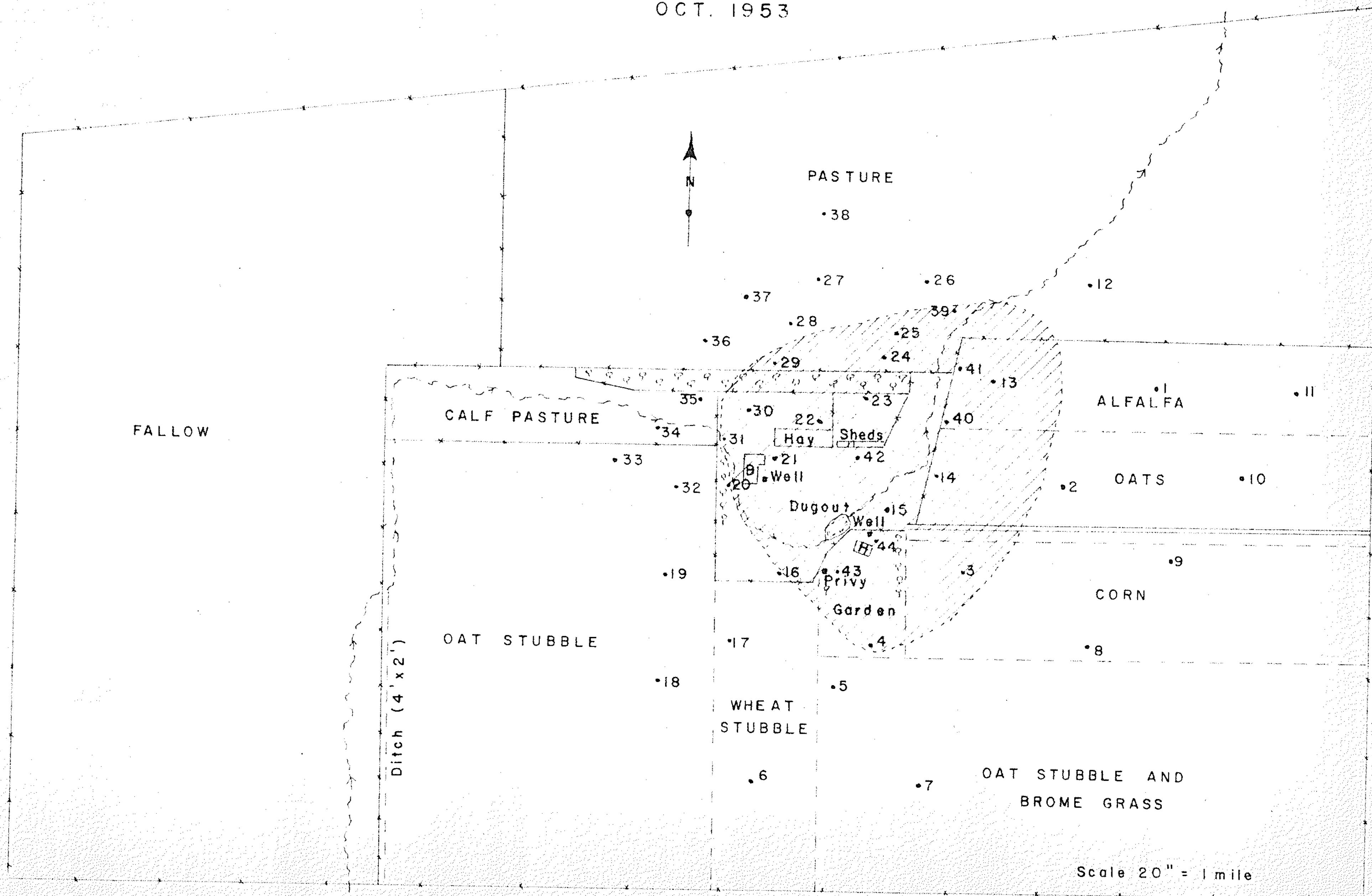


TABLE NO. VII

DEPTH TO GROUND WATER AND NITRATE NITROGEN CONTENT

OF GROUND WATER FOUND IN BORE HOLES NUMBERED AND RECORDED IN FIGURE VIII

N.E. 26-11-11 Almasippi Soil Association October - 1953

Bore hole No.	Depth to ground water in feet	Estimated Nitrate Nitrogen content in ppm of ground water drawn from bore hole	Remarks
21	6.0	100++	40 feet north-east of barn
22	6.5	100++	Behind haystacks
23	7.0	100++	Chicken pen
24	7.5	100++	North-east and close to shelter belt & farmstead
29	7.0	100++	North, north-east of barn about 200 ft. away
13	8.5	100	Alfalfa field north-east of farmstead
42	6.5	100	Close to chicken house
14	7.0	75	Grain stubble
41	8.5	75	Alfalfa field
44	6.0	40-50	10 feet south of house well
30	6.5	30-40	75 feet north of barn
3	6.0	25	Cornfield heavily manured previous winter
15	5.0	25	Close to house
25	7.5	25	Pasture north, north-east of barn
43	6.0	10-20	About 15 feet east of privy
4	6.0	15	Garden
31	6.5	15	About 30 feet north-west of barn
35	6.5	10	Corral north-west of barn
Housewell		100++	About 40 feet north-east of house
Barnwell		100++	15 feet east of barn
1	7	nil	Alfalfa
2	7	nil	Oat stubble
5	8	nil	Oat stubble and grass
6	5.5	nil	Wheat stubble
7	6.5	nil	Oat stubble and grass
8	7	nil	Cornfield
9	7	nil	Cornfield
10	5	nil	Oat stubble
11	6.5	nil	Alfalfa field
12	7.5	nil	Pasture north-east of farmstead quite removed
16	6.0	nil	Blue grass mixture west of house (from latter
17	6.0	nil	Wheat stubble
18	7.0	nil	Oat field stubble
19	8.0	nil	Oat field stubble
20	6.0	nil	15 feet south-west of barn
26	7.0	nil	Pasture north-east of farmstead
27	6.5	nil	Pasture
28	7.5	nil	Pasture
32	7.0	nil	Oatfield stubble
33	6.5	nil	Oatfield stubble
34	3.5	nil	In creek west of barn
36	6.5	nil	Pasture
37	7.0	nil	Pasture
38	7.5	nil	Pasture
39	7.0	nil	Pasture
40	6.5	nil	About 150 feet east of chicken house on heavy grassed fenced line

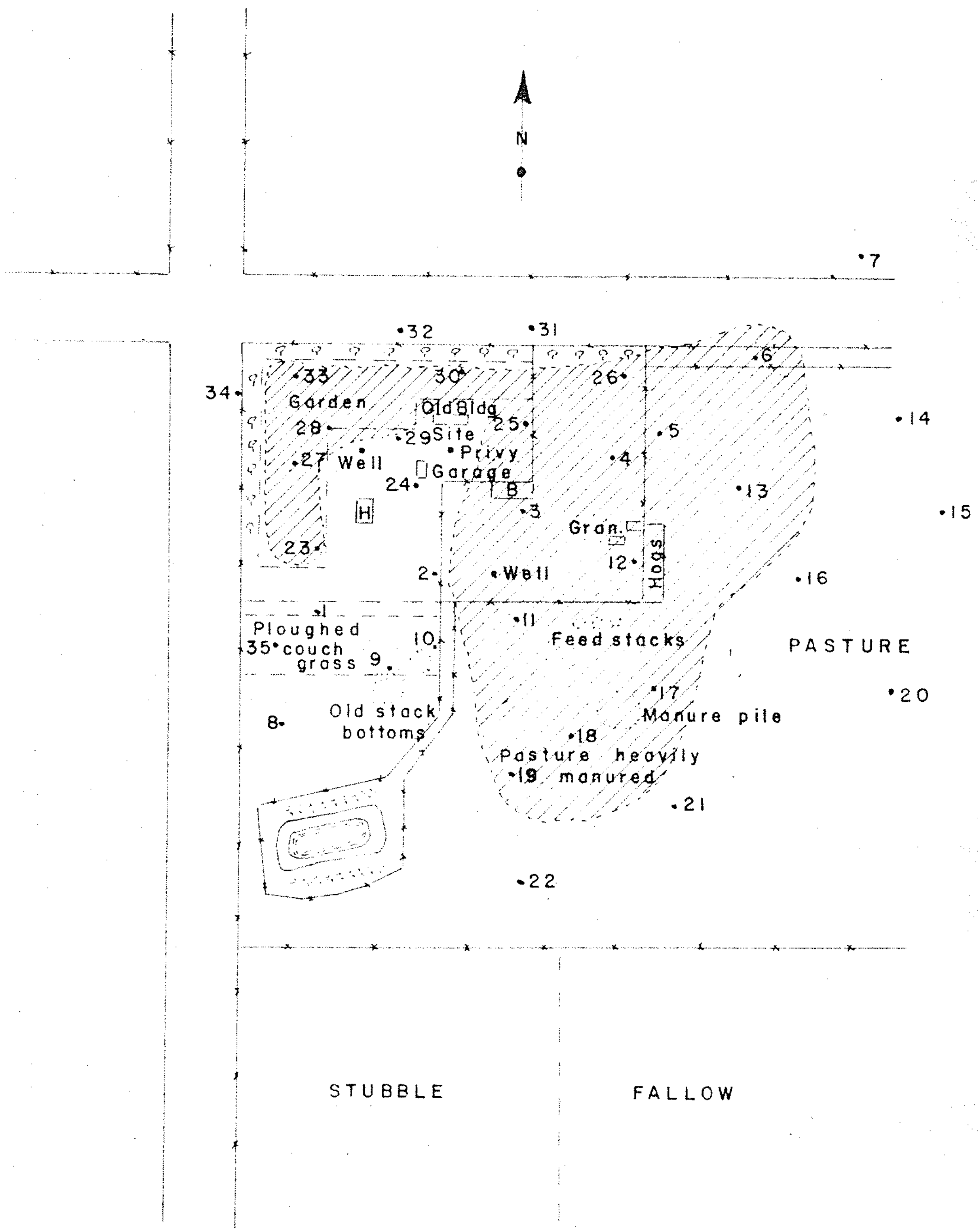
FIGURE NO. IX

NITRATE STATUS OF GROUND WATER

ALMASIPPI SOIL ASSOCIATION

N.W. 1/4 SEC. 34 TP. 13 R. 12

OCT. 1953



Scale 20" = 1 mile

TABLE NO. VIII

DEPTH TO GROUND WATER AND NITRATE NITROGEN CONTENT

OF GROUND WATER FOUND IN BORE HOLES NUMBERED AND RECORDED IN FIGURE IX

N.W. 34-13-12 Almasippi Soil Association October, 1953

Bore-hole No.	Depth to ground water in feet	Estimated Nitrate Nitrogen content in ppm of ground water drawn from bore hole	Remarks
4	7	100++ [1]	100 feet north-east of barn
5	6.5	100+ [2]	100 yards north-east of barn
9	6.0	100	Old stack bottom site south of house
11	6.5	100	Manured pasture
12	7.0	75	Barnyard 4 feet west of pig pen
28	6.5	75	Garden (bare surface)
6	7.0	50-60	North-east of farmstead near road allowance
13	6.5	50	Pasture east of farmstead
17	6.5	50	Matured pasture south of farmstead
30	7.0	50	Garden
18	7.0	40-50	Manured pasture
29	6.5	40-50	East edge of garden
27	6.5	30-40	Garden
33	6.8	30-40	Garden
3	6.8	25	15 feet south of barn
19	6.5	15-25	200 yeards north-east of dugout
23	7.0	15	Garden
Barn Well		Trace	Close to barn and hog house
1	7.0	trace [3]	Couch grass south of house
21	7.0	trace	Pasture
25	7.0	trace	100 feet north of barn
2	6.5	Nil	5 feet south of old privy site
7	6.5	Nil	North-east of farmstead across road
8	6.0	Nil	Couch grass north of dugout
10	6.0	Nil	Couch grass south of house
14	6.5	Nil	Pasture some distance east of farmstead
15	6.5	Nil	Pasture east of farmstead
16	6.0	Nil	Pasture east of farmstead
20	7.0	Nil	Pasture south-east of farmstead quite removed from latter
22	6.5	Nil	Pasture east of dugout
24	7.0	Nil	30 feet north-east of house
26	8.5	Nil	At foot of shelter belt eastern extremity
31	6.5	Nil	Road allowance dense brome north of farmstead
32	6.0	Nil	Road allowance
34	6.0	Nil	Road allowance west of farmstead
35	6.5	Nil	Ploughed couch grass south of house
House Well		Nil	North of house and in heavily grassed area

in varying stages of decay. These two factors; namely, the length of time of habitation and the large amounts of organic wastes decaying with their end products being washed through the soil and into the ground water, account for high concentrations of nitrate in the water supply of these habitation sites.

(4) Determinations Of Nitrate In Surface Waters

It has previously been stated that samples of surface water along with well water samples were tested for nitrate during the initial traverses made throughout the Neepawa and adjacent areas. In 1951, surface water from roadside ditches, creeks, rivers, sloughs, natural ponds and dugouts was tested for the presence or absence of nitrate nitrogen. Of all the bodies of surface water mentioned, only an occasional dugout was found to contain nitrate and where the test was positive, the quantity of nitrate was only in trace or non-toxic concentration. Natural ponds and dugouts even in the most unsanitary sites were found to be free of nitrate. Such a case is well illustrated where, on one particular farm there is a natural pond in the centre of the farmstead. Here run-off carries pollution into this depression from every corner of the manure besprinkled yard. In many other instances cattle and flocks of ducks and geese had access to both natural ponds and dugouts - excreta from these animals could be seen at the waters edge, yet the tests for nitrate were negative.

From data supplied by the Department of Health, the comparable records of nitrate in dugout waters and the nitrate in well-waters on the same farms were tabulated and are presented here in tabular form as Table No. IX.

The negative or very low levels of nitrate in dugout waters shown on this table (Table No. IX) are in striking contrast to the nitrate levels in the adjacent located well waters. It also may be of some interest to note that in three of the comparisons shown on this table, the waters from stable wells show higher concentrations of nitrate than waters from house wells.

For a time during this particular phase of the investigation it was thought that an exception to the rule had been encountered. At Langruth there is a large dugout which serves as the village water supply. As can be seen on Figure X, the village itself is situated on a gravel ridge while the dugout is at the foot of this ridge. From all appearances, the best of sanitary conditions have been put into practice here. A high fence was built around the dugout to keep animals from wandering into the water supply and which also (for a time only) kept the investigators out. Initially water for the nitrate test was obtained from a tap protruding from the pumphouse which encloses a pressure system. This water obtained, contained nitrate in toxic concentrations. It was assumed from tests of the water from this well that dugout water was contaminated with nitrate. Another dugout situated at the foot of the same ridge but some five miles south of the village, had water that was nitrate free and it was therefore decided to go back and take a sample directly from the dugout itself. The test showed that this dugout water also was free of nitrate nitrogen and therefore the water that had previously been tested was not all pumped directly from the dugout, but was contaminated by ground water seepage from below the village.

(5) Determination of Nitrate Leached From Soils

In the initial stages of the investigation, random tests on the soil profile throughout different fields had shown that the quantities of nitrate nitrogen elaborated in fields under crop were too low to appreciably affect the nitrate status of the ground water. At any rate it soon became evident some source other than, or in addition to the soil was responsible for the excessively high concentrations of nitrate encountered in certain local wells.

TABLE NO. IX

COMPARISON OF NITRATE NITROGEN IN WELL AND DUGOUT WATERS

DATA OBTAINED FROM DEPARTMENT OF HEALTH

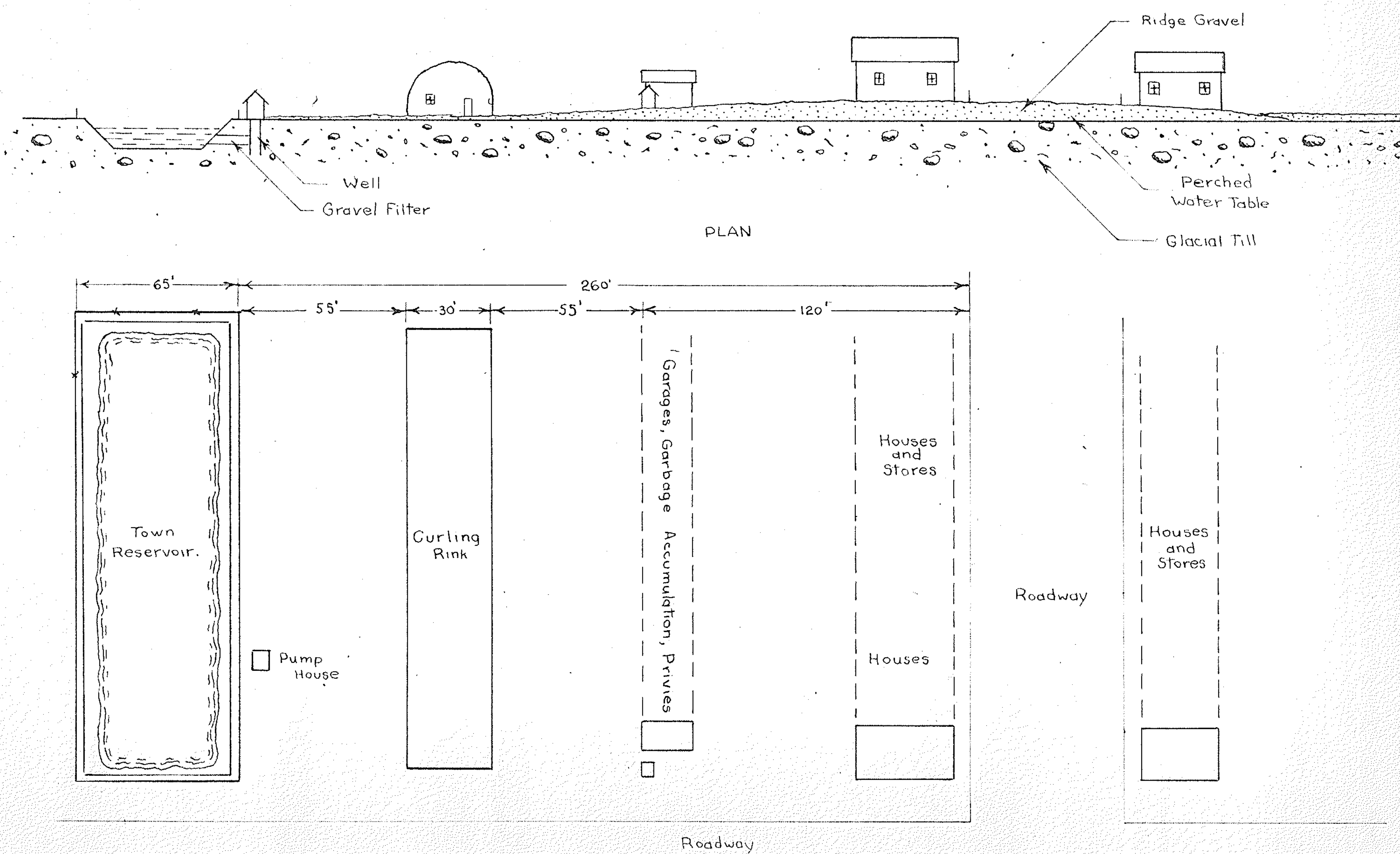
Location	Soil Association	NITRATE NITROGEN IN PPM IN			
		Dugout-Stored Water	Well Water		
			House Well	Stable Well	Not Specified
NE 34-14-12	Almasippi	Negative	200	-	-
SW 1-15-12)	Almasippi	Negative	-	-	350)
SW 1-15-12)	Almasippi	-	-	-	300)
SW 1-15-12)	Almasippi	-	-	-	150)
NW 8-15-13	Almasippi*	Negative	Trace	-	-
NE 10-15-12)	Almasippi*	Negative (N)	10	75	-)
NE 10-15-12)	Almasippi*	Negative (S)	-	-	-)
NW 34-14-13	Almasippi	5 ppm	300	350	-
13-15-13	Almasippi*	Negative	-	50	-
NE 2-15-13	Almasippi	Negative	250	-	-
NE 4-15-13)	Almasippi	Negative	100	-	75)
NE 4-15-13)	Almasippi	-	-	-	Neg.)
NE 9-15-13	Almasippi*	Negative	20	200	-
SW 8-15-13)	Almasippi*	Trace	-	-	-
N 8-15-13)	Almasippi*	-	10	-	-
SW 4-15-13	Almasippi*	Negative	50	-	-
SW 16-13-13	Firdale	Negative	100	100	-
NW 28-15-13	Not Mapped	Negative	-	-	-
SE 34-15-14	Not Mapped	Negative	150	-	-
SW 27-13-11	Overwash/Sand	Negative**	Negative	-	-
SW 20-14-13	Almasippi-Agassiz	Negative**	150	-	-
SE 19-14-13	Almasippi-Agassiz	Negative**	Negative	-	-

* Presumed to be Almasippi Soil Association because of geographical position in Lower Assiniboine Delta Area, but not verified as this township has not been covered by Soil Survey.

** Creek water

FIGURE NO. X

DIAGRAM OF LANGRUTH TOWN RESERVOIR AND ADJACENT BUILDINGS LANGRUTH MAN.



Whether it was only at the time of examination that small quantities of nitrate were elaborated under field conditions was not known. Some means of ascertaining the quantities and pattern of nitrate elaboration and the subsequent downward movement to ground water had to be found. Such a project to be of any value, would have to be in operation from the onset of soil microbial activity in the spring to the time such biological action was inhibited by low temperatures in the fall.

An experiment therefore, was planned under field conditions so that leachate from the surface soil horizon or zone of nitrate elaboration could be collected following rains that would supply moisture in excess of field capacity. Analyses subsequently were made to determine the nitrate content of this leachate and thus ascertain the amount of nitrate added to the ground water from the soil under the various conditions. The most common field crops and cultural practices in the affected area are alfalfa and sweet clover, grasses, cereals and fallow, hence a set of catchment pans were installed in a representative field under each such treatment. For purposes of comparison, a fifth installation was made at a high organic matter refuse site on the Agassiz gravel ridge at Arden.

Pits a yard square and 30 inches deep were dug in each of the five locations. Wood cribbing was installed to prevent cave-in. Slits were opened through this cribbing and flat metal troughs 30 inches long and 12 inches wide were inserted horizontally under the dark colored surface horizon. Each trough was on a slope of three inches and protruded six inches inside the pit, hence, leaving two square feet of metal surface for arresting the percolating soil solution on its downward movement. A small pipe welded to the trough served as an outlet, and an attached piece of a rubber tubing connected the latter to a Winchester flask below. A triplicate installment of these leachate "Catchment Units" was made at each pit.

No leachate was obtained from the field units in the summer and fall of 1953. At that time this was attributed to the failure of the seasonal rains to provide soil moisture in excess of field capacity. On the gravel ridge where entirely different conditions prevailed, some leachate was collected. The high porosity and relatively low moisture retention capacity of that surface horizon combined to make ideal conditions for percolation of the soil solution.

In the spring of 1954 heavy rains fell over the area and again no results were obtained under field conditions. Close observations following one such downpour showed that only a fraction of the water that fell penetrated into the soil. Furthermore, the amount of water in excessof field capacity that did enter the soil was prevented from flowing to the outlet by adhesion forces at the contact point of metal and sand. To overcome this adverse condition, a gravel lense about one inch thick was placed on the pans thus breaking the direct contact between sand and metal. To prevent surface runoff, a tin enclosure of equal area to that of the pan was placed directly above the latter at the soil surface. This tin enclosure penetrated two inches below the surface and protruded four inches above. Water falling within this area could not run into the nearby micro depressions or drop over the end and into the pit and hence, it had to penetrate into the soil.

Subsequent to these alterations, rains supplying moisture in excess of field capacity produced results. A close check-up was maintained on the amount of precipitation falling over the area, and whenever it was thought there had been sufficient rainfall to supply moisture in excess of the retention capacity, (depending on the moisture conditions in the soil before the rain) a trip was made to the experimental sites. Whenever leachate was present in the containers, the volume was measured and recorded. Aliquots were then brought into the laboratory and were either analysed immediately upon arrival or else placed in a refrigerator and the determination made the following day. Jackson's method (24) was used for making this quantitative nitrate determination. Table No. X records the monthly mean volumes of leachate obtained per two square feet of surface from the different sites together with the concentration of nitrate nitrogen in the respective leachates. The amount of nitrate nitrogen removed from the surface soil at the respective study sites, during the months of June to October, 1954, was calculated as pounds per acre and recorded in Table No. XI.

B. LABORATORY DETERMINATIONS OF SOILS USED IN "CATCHMENT" STUDIES

When the leachate "catchment units" were installed, samples from the entire "A" or surface horizon were taken from each site and brought into the laboratory. Here, analyses to determine total nitrogen, organic matter content, texture and moisture retention capacity were carried out because the amount of nitrate elaborated and subsequently washed through the soil profile and into ground water is affected by these various components.

A composite surface horizon sample was taken at each "catchment unit" hence three samples were obtained from each experimental site. These samples were air dried, passed through a two millimeter sieve and thoroughly mixed. The following methods were used for making the respective determinations.

Nitrogen - Total nitrogen was determined by the Kjeldahl - Gunning - Arnold method as outlined in "Methods of Analyses" - A.O.A.C. fifth edition 1940.

Organic Matter - Organic carbon x 1.724. The organic carbon was determined by wet combustion. The method used was a modification of the methods given by Adams (4) and Waynick (42) 1934.

TABLE NO. X

MONTHLY MEAN VOLUMES OF LEACHATE (C.C.) OBTAINED PER REPLICATED TWO SQUARE FEET OF SOIL UNDER DIFFERENT CROPS, AND MONTHLY MEAN CONCENTRATIONS (PPM) OF NITRATE NITROGEN IN THE LEACHATE

(JUNE TO OCTOBER, 1954)

Month	Soil Under									
	Grain		Fallow		Alfalfa-Grass		Brome		Old Refuse Site	
	c.c. leachate	ppm NO_3N	c.c. leachate	ppm NO_3N	c.c. leachate	ppm NO_3N	c.c. leachate	ppm NO_3N	c.c. leachate	ppm NO_3N
June	2554	1.0	1850	3.9	2025	1.0	324	1.1	2275	59.2
July	960	2.4	125	10.1	95	4.4	62	2.3	270	43.0
August	89	11.8	16	13.6	17	4.2	73	0.0	1397	69.3
September	877	0.3	4420	17.4	3515	0.9	365	0.4	2632	117.2
October	980	0.7	649	22.3	2500	3.0	965	0.7	415	118.3

TABLE NO. XI

NITRATE NITROGEN IN POUNDS PER ACRE, REMOVED FROM SURFACE SOIL AT THE RESPECTIVE STUDY SITES. CALCULATED FROM THE VOLUMES OF LEACHATE OBTAINED JUNE TO OCTOBER 1954

Month	Soil Under				
	Grain	Fallow	Alfalfa-Grass	Brome	Old Refuse Site
June	0.12	0.36	0.100	0.020	8.2
July	0.12	0.06	0.020	0.007	0.6
August	0.05	0.01	0.003	0.000	4.8
September	0.01	3.85	0.160	0.007	15.4
October	0.03	0.72	0.030	0.030	2.5

TABLE NO. XII

TOTAL NITROGEN, ORGANIC CARBON, CARBON-NITROGEN RATIO, ORGANIC MATTER, MOISTURE EQUIVALENT, AND MOISTURE RETENTION CAPACITY OF SOIL FROM THE DIFFERENT EXPERIMENTAL SITES

Crop or Site	Percent Total Nitrogen	Percent Organic Carbon	Carbon-Nitrogen Ratio	Percent Organic Matter	Moisture Equivalent	Moisture Retention Capacity in Inches Per Foot
Grain	0.20	1.90	9.46	3.30	11.80	1.15
Brome	0.12	1.12	9.10	1.90	6.96	0.67
Alfalfa-Grass	0.12	1.25	10.70	2.20	6.36	0.62
Fallow	0.11	0.95	8.73	1.60	8.80	0.85
Old Refuse Site	0.79	8.52	10.90	14.70	24.96	1.35

* Figures are a mean of 3 replicates

TABLE NO. XIII

MECHANICAL ANALYSES OF SOILS FROM THE DIFFERENT FIELDS OR EXPERIMENTAL SITES

Crop or Site	Percent of Various Sand Fractions					Percent Sand	Percent Silt	Percent Clay	Texture
	Very Coarse	Coarse	Medium	Fine	Very Fine				
Grain	0.06	0.14	0.68	45.34	39.64	85.86	4.78	9.36	Fine sand
Brome	0.30	0.71	8.67	73.97	4.57	88.22	3.87	7.91	Fine sand
Alfalfa-Grass	0.42	0.86	3.41	85.03	1.82	91.74	2.18	6.08	Fine sand
Fallow	0.13	0.63	1.61	59.84	24.67	86.88	4.01	9.11	Fine sand
Old Refuse Site	12.27	11.20	10.71	17.26	15.95	72.13	22.30	5.57	*Fine sandy Loam

* Analysis on fractions of 2 m.m. and less only

Mechanical Analyses percentages are based on oven-dry weight of sand, silt and clay.

Moisture Retention Capacity - The moisture retention capacity of the soils were arbitrarily determined by factors based on the moisture equivalent values. The method used for moisture equivalent determinations was that of Briggs and McLane (12).

Mechanical Analysis - The percentages of sand silt and clay in the respective soil samples were determined by the method outlined by Kilmer and Alexander (27) with minor variations. The results of the various analyses are presented in Tables No. XII and XIII.

C. BIOLOGICAL STUDIES

In the early fall of 1953, a representative sample of water (composite of different depths) was taken from a dugout adjacent to the cemetery south of Langruth, and brought into the laboratory in order to make a microscopic study, and thus identify the different forms of life contained.

Water from the dugout was brought in on two separate occasions (Sept. 26 and October 16) and until identification had been carried out, these samples were kept in separate containers. Prior to, and including the time of the first sampling, the temperature had remained 10 - 12 degrees above frost (even during the night) and consequently many forms of life that one would encounter during the summer months (except the most highly sensitive to lower temperatures) would be found. Furthermore, the green masses of floating organisms seen on the surface of the water in these dugouts during the summer months were still present, adding further evidence that no great changes in the forms of life had yet occurred. Between the time of the first and second sampling dates, temperatures had dropped considerably and frost had been reported on several occasions. The green "floating masses" were no longer present, but had been replaced by swarms of Cladocera (fresh water fleas) which could be seen swimming about in the upper 12 - 15 inches of the water.

The following forms of life were identified in the water sample taken on September 26th, 1953.

PLANT LIFE

Blue-Green Algae

- Anabaena flos-aquae
- Nostoc commune
- Coelosphaerium kutyingianum
- Microcystis
- Phormidium subfuscum

Green Algae

- Scenedesmus quadricanda
- Selenastrum gracile
- Kirchneriella obesa
- Botryoccoccus braunii
- Pediastrum boryanum
- Pleurococcus vulgaris
- Schizochlamys gelatinosa

ANIMAL LIFE

Amoeboid Protozoa

- Amoeba radiosa
- Actinophrys sol

Ciliate Protozoa

- Paramoecium caudatum
- Colpidium striatum
- Frontonia leucas
- Onychodromus grandis
- Halophrya sp.
- Condylostoma patens

Flagellate Protozoa

- Ceratium hirudinella

Rotifera

- Diglena
- Salpina spinigera

Crustacea

- Daphnia pulex (very few)
- Cyclops spp.

The following forms of life were identified in the water sample taken on October 16th, 1953.

Amoeboid Protozoa

Actinophrys sol

Ciliate Protozoa

Paramoecium caudatum

Frontonia leucas

Holophrya sp.

Onychodromus grandis

Stylonychia notophora

Rotifera

Diruella sulcata

Rotifer spp.

Notholca longispina

Salpina spp.

Crustacea

Daphnia pulex (very numerous)

Winter eggs of that species were also present.

An experiment was set up in an attempt to find out how much nitrate nitrogen was taken up by the biological life in dugout water and also the quantities of this compound liberated upon the decay of the bodies of those organisms.

Nitrate free dugout water with all its forms of life was subjected to five different treatments under laboratory conditions, each treatment being carried out in triplicate.

(i) Dugout water was filtered, boiled for three minutes and re-aerated by bubbling air through it. Three separate volumes of 720 c.c. were measured out and put in different containers, and to each of these volumes were added 80 c.c. of 750 parts per million nitrate nitrogen solution thus making three 800 c.c. volumes containing 75 parts per million of nitrate nitrogen.

(ii) Three 800 c.c. volumes of dugout water, not altered in any way, were put in three separate containers.

(iii) Three 800 c.c. volumes of dugout water, also not altered, but in this case the containers were placed in complete darkness.

(iv) Three 720 c.c. separate volumes of dugout water were measured and to each one of these, 80 c.c. of 750 parts per million nitrate nitrogen solution were added, thus making three 800 c.c. volumes with a concentration of 75 parts per million of nitrate nitrogen.

(v) Three volumes of 800 c.c. each were given identical treatment, but in this case the samples were placed in complete darkness.

The containers used in this experiment were rectangular pyrex dishes 8 3/4 inches long, five inches wide and 2 1/4 inches deep, hence the 800 c.c. volume brought the level of the liquid to approximately 1/4 inch from the upper edge. A glass covering was placed over each container to prevent foreign material from falling in, and also to keep evaporation losses down to a minimum. The entire experiment was carried out in a greenhouse, with adequate lighting facilities. The danger of too much variation in temperature was eliminated because a rigid control was exercised over this factor at all times with the thermometer hovering at about 72 degrees, F. from the time the project was set up to the date of the last sampling. Where complete darkness was required it was obtained by placing a cover designed for this specific purpose over the container thus excluding light and at the same time allowing a normal air supply to circulate within the enclosure.

The fifteen containers were put in place in the greenhouse on October 27th and on the same day a 25 c.c. aliquot was removed from each dish for nitrate determination by the phenoldisulphonic acid method and the concentration of nitrate nitrogen ascertained. Further aliquots for nitrate determination were subsequently removed on the following dates, i.e. November 3rd, 12th, 18th, December 4th, 28th and January 21st. To maintain the level of the liquid in the containers at approximately 800 c.c.'s after each sampling, a volume of solution equal to that removed and also of equal nitrate concentration was added to each container as required. It was also necessary on two occasions to add nitrate free water to replenish losses in volume caused by evaporation.

From time to time a survey of the bioligical life in each treatment was carried out and on such occasions the various forms of life present were identified and are here presented as Table No. XIV.

TABLE NO. XIV

ORGANISMS IDENTIFIED IN DUGOUT WATER, WITH AND WITHOUT ADDED NITRATE AND KEPT IN THE LIGHT AND IN THE DARK UNDER GREENHOUSE CONDITIONS

Treatment	Date	Forms of Life Identified	Relative Population
Dugout water with nitrate kept in the light	Nov. 3	Green Algae	
		Scenedesmus quadricaudata	Very numerous
		Botryococcus braunii	Very numerous
		Protozoa	
		Frontonia leucas, Colpidium striatum, Paramoecium caudatum, Onychodromus grandis, Holophrya sp. Condylostoma patens	Few
		Rotifer	
		Diruella sulcata, Rotifer spp., Salpina spinigera	Few
		Crustacea	
		Daphnia pulex	Sparse
Dugout water with nitrate kept in the dark	Nov. 3	Green Algae	
		Botryococcus braunii, Scenedesmus quadricaudata	Quite sparse and brownish in color
		Protozoa	
		Paramoecium caudatum	Very few
		Rotifer	
		Salpina spinigera	Very few
		Crustacea	
		Daphnia pulex	Quite a few
Dugout water without nitrate kept in the light	Nov. 3	Green Algae	
		Scenedesmus quadricaudata	Very few, living masses of dead algae floating about.
		Crustacea	
		Daphnia pulex	Rather sparse
		Daphnia winter eggs	Quite numerous

(cont'd)

Treatment	Date	Forms of Life Identified	Relative Population
Water from dug-out without nitrate and kept in the dark	Nov. 3	Green Algae *Botryococcus braunii* Rotifer *Salpina spinigera* Crustacea *Daphnia pulex* *Daphnia* winter eggs	 Very few (Only one seen) Sparse Numerous
Dugout water with nitrate kept in the light	Nov. 12	Green Algae *Scenedesmus quadricaudata* *Botryococcus braunii* Crustacea *Daphnia pulex* *Daphnia* winter eggs	 Very very numerous Numerous Rather numerous Scarce
Dugout water with nitrate kept in the dark	Nov. 12	Green Algae *Scenedesmus quadricaudata* *Botryococcus braunii* Crustacea *Daphnia pulex* *Daphnia* winter eggs	 Numerous, brown in color Quite a few Quite numerous Rather numerous
Dugout water without nitrate kept in the light	Nov. 12	Green Algae *Scenedesmus quadricaudata* *Botryococcus braunii* Crustacea *Daphnia pulex* *Daphnia* winter eggs	 Sparse (light yellow in Sparse color) Rather scarce Quite numerous
Dugout water without nitrate kept in the dark	Nov. 12	Green Algae *Scenedesmus quadricaudata* *Botryococcus braunii* Crustacea *Daphnia pulex* *Daphnia* winter eggs	 Few brown in color Few brown in color Few Numerous

(cont'd)

Treatment	Date	Forms of Life Identified	Relative Population
Dugout water with Nitrate kept in the light	Jan. 21	Green Algae	
		Scenedesmus quadricaudata	Very numerous
		Botryococcus braunii	Very numerous
		Crustacea	
		Daphnia pulex	Few
		Daphnia winter eggs	Quite numerous
Dugout water with nitrate kept in the dark	Jan. 21	Green Algae	
		Scenedesmus quadricaudata	Very few (Masses of dead algae floating about)
		Crustacea	
		Daphnia winter eggs	Quite numerous
Dugout water without nitrate kept in the light	Jan. 21	Crustacea	
		Daphnia winter eggs	Numerous
Dugout water without nitrate kept in the dark	Jan. 21	Crustacea	
		Daphnia winter eggs	Numerous

On January 21st, the last determination for nitrate nitrogen concentration was carried out and the results of tests made from the beginning to the end of the experiment are presented here in tabular form as Table No. XV.

TABLE NO. XV

PERIODIC NITRATE NITROGEN DETERMINATIONS ON DUGOUT WATER KEPT UNDER GREENHOUSE CONDITIONS AND SUBJECTED TO FIVE DIFFERENT TREATMENTS

Kind of Treatment	Date	Concentration in ppm
Dugout water boiled and filtered having been made to a solution containing 75 ppm nitrate nitrogen	October 27	73.3*
	November 2	69.3
	November 12	70.6
	November 18	69.3
	December 4	72.6
	December 28	71.6
	January 21	
Dugout water with biological life without nitrate nitrogen and exposed to light	October 27	0.00
	November 2	0.26
	November 12	0.10
	November 18	0.20
	December 4	0.37
	December 28	0.11
	January 21	0.12
Dugout water with biological life without nitrate nitrogen and in complete darkness	October 27	0.00
	November 2	0.26
	November 12	1.76
	November 18	2.10
	December 4	3.10
	December 28	3.26
	January 21	
Dugout water with biological life the solution containing 75 ppm nitrate nitrogen and exposed to the light	October 27	70.0
	November 2	90.6
	November 12	66.0
	November 18	65.3
	December 4	71.0
	December 28	72.0
	January 21	71.1
Dugout water with biological life, the solution containing 75 ppm of nitrate nitrogen in complete darkness	October 27	69.3
	November 2	89.6
	November 12	68.6
	November 18	68.0
	December 4	66.0
	December 28	71.0
	January 21	71.3

* Figures are the mean of 3 replicates.

D. SEASONAL VARIATION OF NITRATE IN DUGOUT AND WELL WATERS

An investigation was conducted to determine the nitrate status in dugout and well waters. This sub-project was carried out in cooperation with the Department of Health and Public Welfare and of the Neepawa Health Unit. Wells and dugouts representing average conditions both about farmyards and fields, and in small towns were selected throughout the affected area by members of the Manitoba Soil Survey Staff and plane table maps were made of the environs of each of these wells and dugouts. These maps are shown herein as Figures XI,XII, XIII, XIV, XV and XVI.

By previous arrangement, it was agreed that a staff member of the Neepawa Health Unit would assume the responsibility of collecting water samples from the chosen wells and dugouts at two week intervals, and would forward these to the Department of Health and Public Welfare where the nitrate determinations would be made.

The first samples of water from the respective dugouts and wells were taken in November, 1952. Sampling was continued throughout the year, until termination of the sub-project in November, 1953.

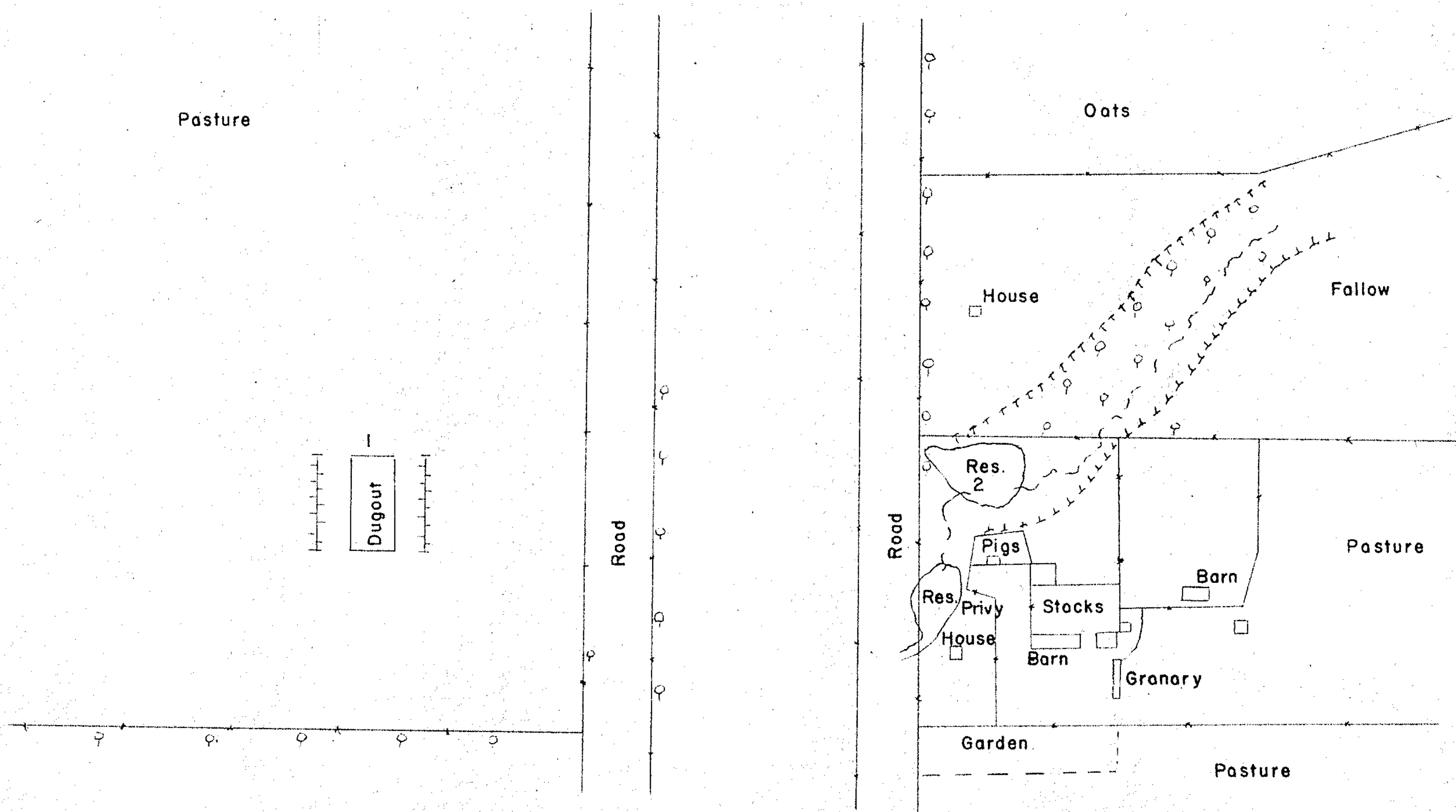
For various reasons, samples from some sites were not taken at the regular two week intervals. As a result, complete data are available for only 10 of the 17 wells, and five of the seven dugouts. Some valuable information can be obtained from the remaining sites where sampling was not regularly carried on, however, the irregular samplings cannot be used to show seasonal trends and variations in nitrate content. This is unfortunate because some of the well waters which were not sampled regularly show the greatest extremes in nitrate nitrogen concentration.

In compiling the data for presentation it was necessary therefore to separate the complete and incomplete records into two sets of data. In Table

FIGURE NO. XI

Dugout No. 1
S.E. Corner N.E. 1/4 Sec. 6 Tp. 14 Rge. 11
Geology - 12 to 14 Feet of Sand Over Heavy Substrata

Dugout No. 2
Centre W. Side Sec. 5 Tp. 14 Rge. 11
Geology - 12 to 14 Feet of Sand Over Heavy Substrata



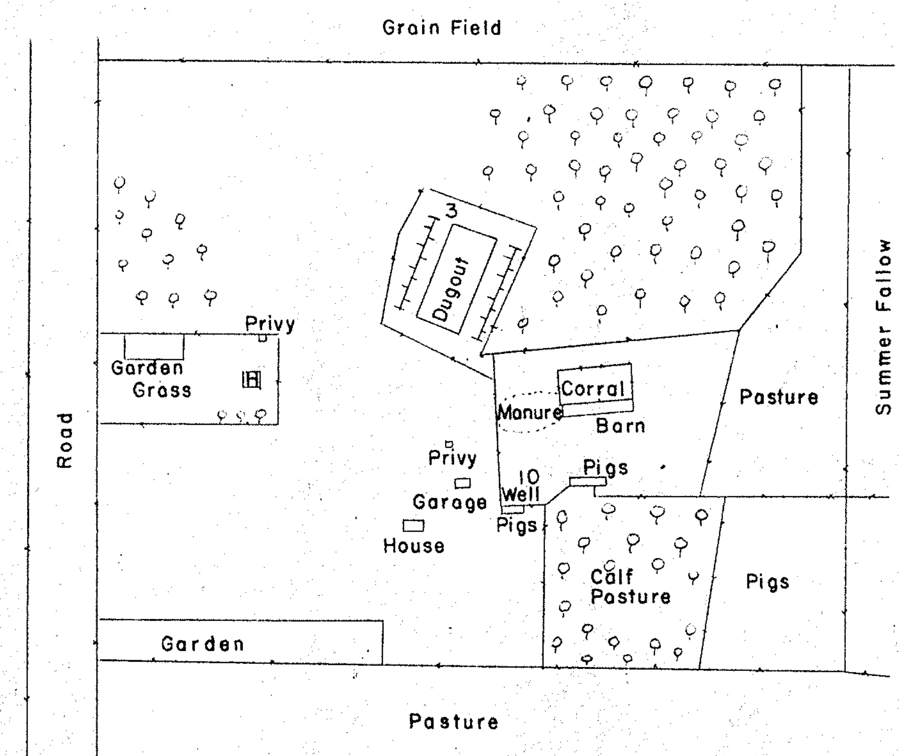
Water From Dugout Nitrate Free Aug. 1952

Water From Reservoirs Nitrate Free Aug. 1952

Scale 1" = 264 Feet

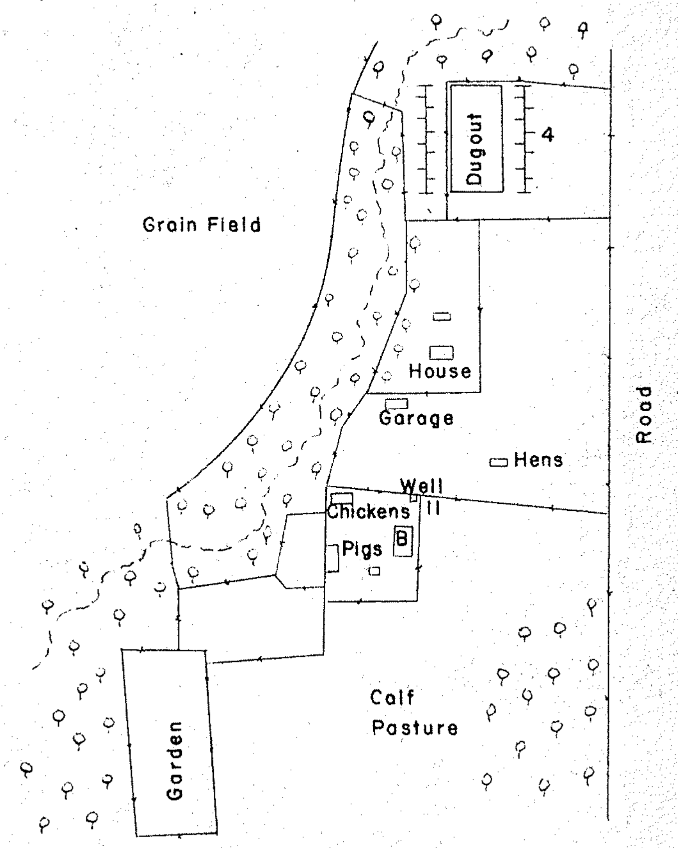
FIGURE NO. XII

Dugout No. 3 and Well No. 10
N.W. 1/4 Sec. 32 Tp.13 Rge.11
Geology-10 to 12 Feet of Sand Over Heavy Substrata



Water From Well 30 to 40 P.P.M. Aug. 1952
Water From Dugout Nitrate Free Aug. 1952

Dugout No. 4 and Well No. 11
Centre E. Side S.E. 1/4 Sec.6 Tp. 14 Rge. 11
Geology- 12 to 16 Feet of Sand Over Heavy Substrata

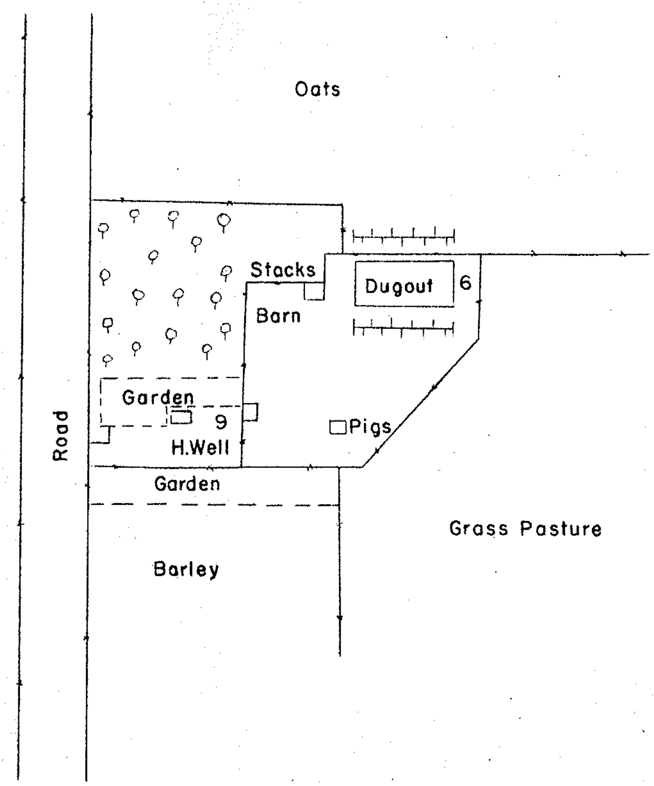


Water From Well 30 P.P.M. Aug. 1952
Water From Dugout Nitrate Free Aug. 1952

Scale 1" = 264 Feet

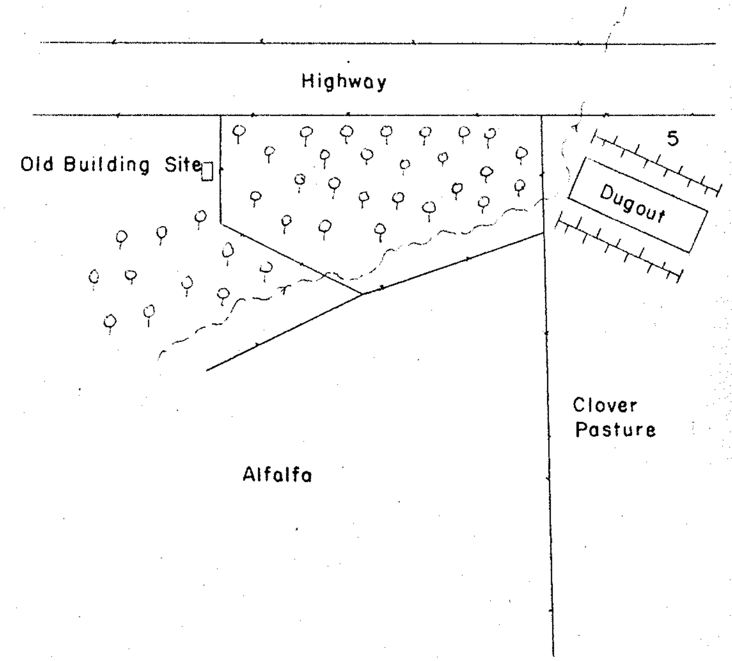
FIGURE NO. XIII

Dugout NO. 6 and Well NO. 9
Centre W. Side N.W. 1/4 Sec. 28 Tp. 14 Rge. 12
Geology-5 to 6 Feet of Sand Over Heavy Substrata



Water From New Dugout 5P.P.M. Aug. 1952
Water From Well 15 P.P.M. Of Nitrate N. Aug. 1952

Dugout NO. 5
N.W. Corner N.E. 1/4 Sec. 30 Tp. 14 Rge. 12
Geology-5 to 6 Feet of Sand Over Heavy Substrata

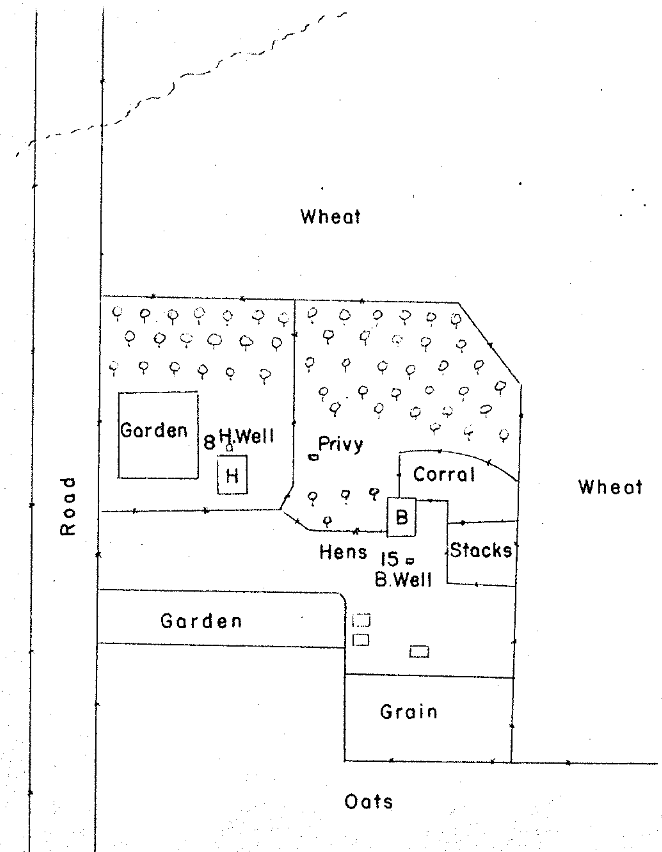


Dugout Excavated During The Summer Of 1952
Water Contained 5 P.P.M Of Nitrate N. Aug. 1952

Scale 1" = 264 Feet

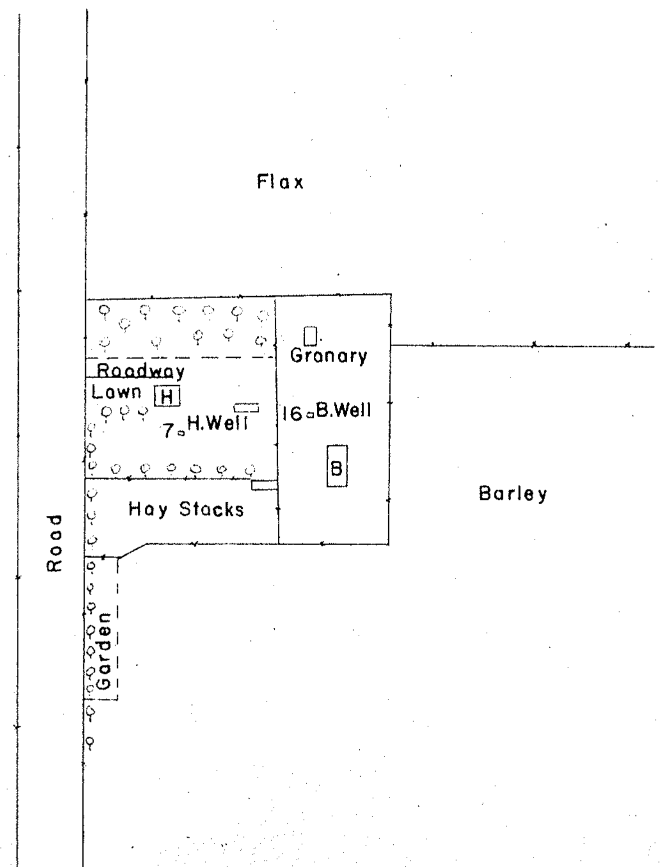
FIGURE NO. XIV

Wells NO. 8 and 15
Centre W. Side Sec. 33 Tp. 15 Rge. 12
Geology- 8 to 10 Feet of Sand Over Heavy Substrata



Water From House Well 15 P.P.M Aug. 1952
Water From Barn Well Positive Aug. 1952

Wells NO 7 and 16
Centre W. Side S.W. 1/4 Sec. 9 Tp. 16 Rge. 12
Geology- 8 to 10 Feet of Sand Over Heavy Substrata



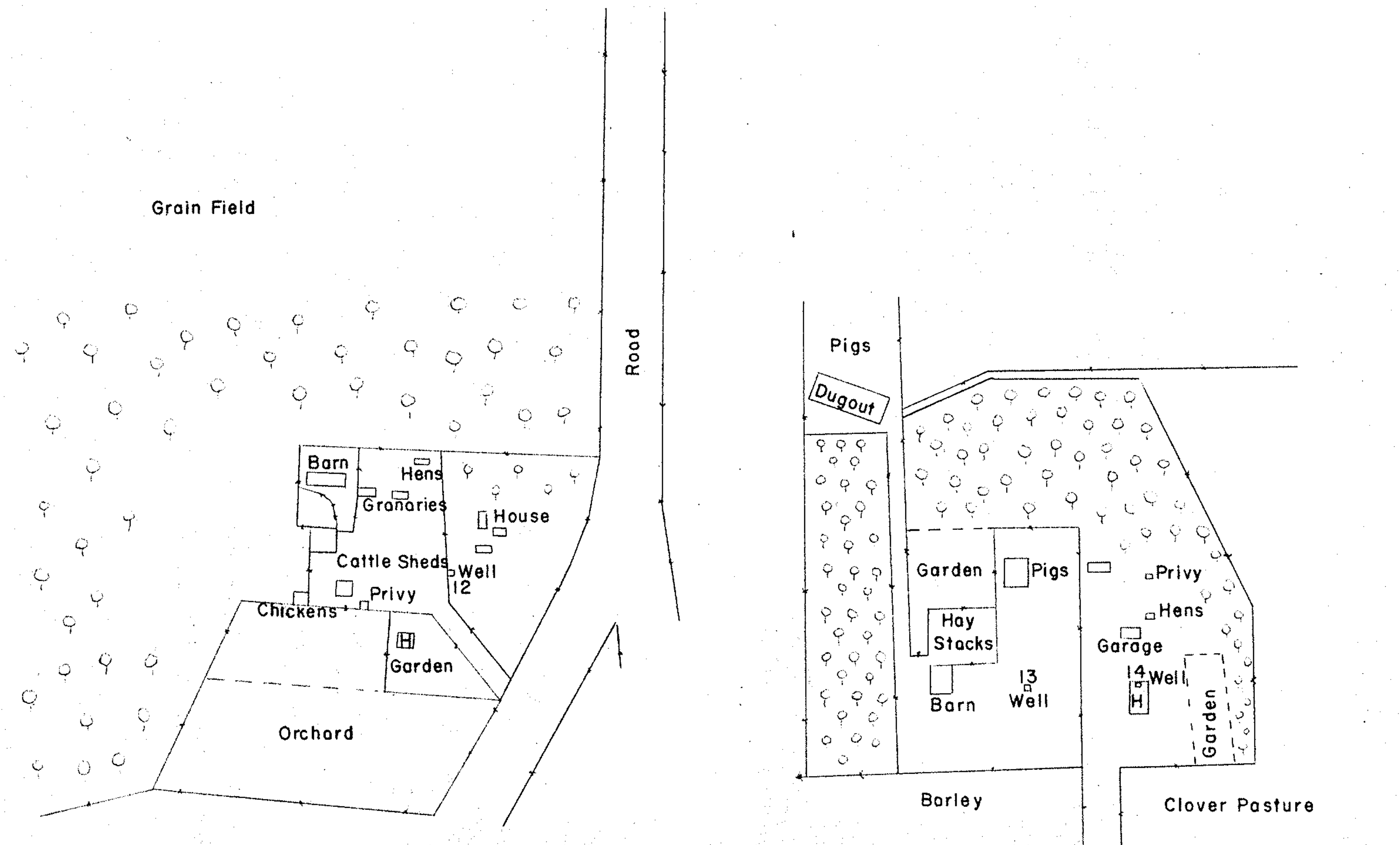
Water From House Well Nitrate Free Aug. 1952
Water From Barn Well Positive Aug. 1952

Scale 1" = 264 Feet

FIGURE NO. XV

Well No. 12
S.E. 1/4 Sec. 6 Tp. 13 Rge. 11
Geology-10 to 12 Feet of Sand Over Heavy Substrata

Wells No. 13 and 14
S.E. 1/4 Sec. 35 Tp. 14 Rge. 12
Geology- 6 to 8 Feet of Sand Over Heavy Substrata



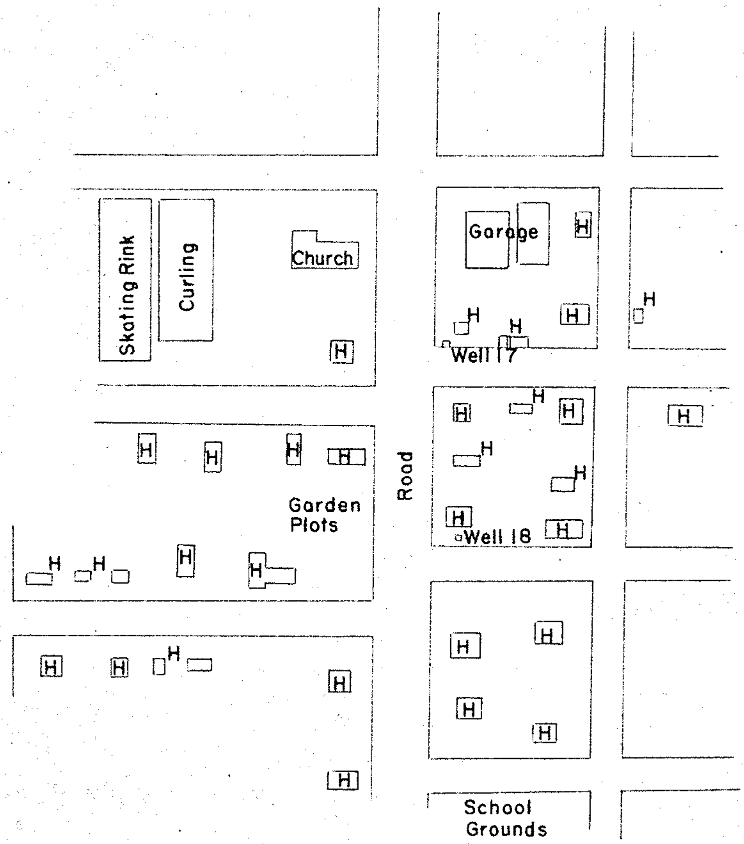
Water From Well Positive Aug. 1952

Water From Barn Well Positive Aug. 1952
Water From House Well Positive Aug. 1952

Scale 1" = 264 Feet

FIGURE NO. XVI

Plan of a Section of the Town of Gladstone
Geology- 4 Feet of Silty Clay Over Wide Laminae of Sand to Clay-Loam Underlain at 16 Feet by Lacustrine Clay



Well No. 17 Positive Aug. 1952
Well No. 18 Positive Aug. 1952

Scale 1" = 264 Feet

TABLE NO. XVI

MONTHLY MEAN OF BI-MONTHLY TESTS OF DUGOUT WATER FOR THE PRESENCE OF NITRATE NITROGEN IN THE GLADSTONE-NEEPAWA-LANGRUTH AREAS, 1952 - 1953

CONCENTRATION OF NITRATE NITROGEN EXPRESSED AS PARTS PER MILLION

Time of Sampling	Designation Number and Site Description of Dugouts					Total	Mean
	1 Situated in a pasture, cattle having free access to dugout	3 Northwest of farmyard livestock have access during evenings	4 North of house along shelter belt not used by livestock	5 In a field, water runway cuts across corner of dugout and carries pollution from old building site nearby	6 About 65 ft. east of barn and feed stacks livestock have free access to dugout		
1952							
November	0.45	0.30	0.20	6.00	1.20	8.15	1.63
December	0.50	0.50	0.18	5.50	3.00	9.68	1.94
1953							
January	0.45	0.40	0.30	5.50	2.00	8.65	1.73
February	0.60	0.40	0.40	5.00	2.00	8.40	1.68
March	0.40	0.33	0.20	5.00	2.33	8.26	1.65
April	1.15	0.40	0.20	4.00	1.00	6.75	1.35
May	0.60	0.30	0.30	0.60	1.00	2.80	0.56
June	0.66	0.20	0.16	0.20	1.53	2.75	0.55
July	0.20	0.30	0.20	0.20	0.40	1.30	0.26
August	0.25	0.30	0.20	0.25	0.45	1.45	0.29
September	1.10	0.25	0.35	0.20	0.35	2.25	0.45
October	1.05	0.30	0.15	0.20	0.20	1.90	0.38
November	2.00	6.00	3.00	0.40	0.90	12.30	2.46
Total	9.41	9.98	5.84	33.05	16.36		
Mean	0.72	0.76	0.45	2.45	1.26		

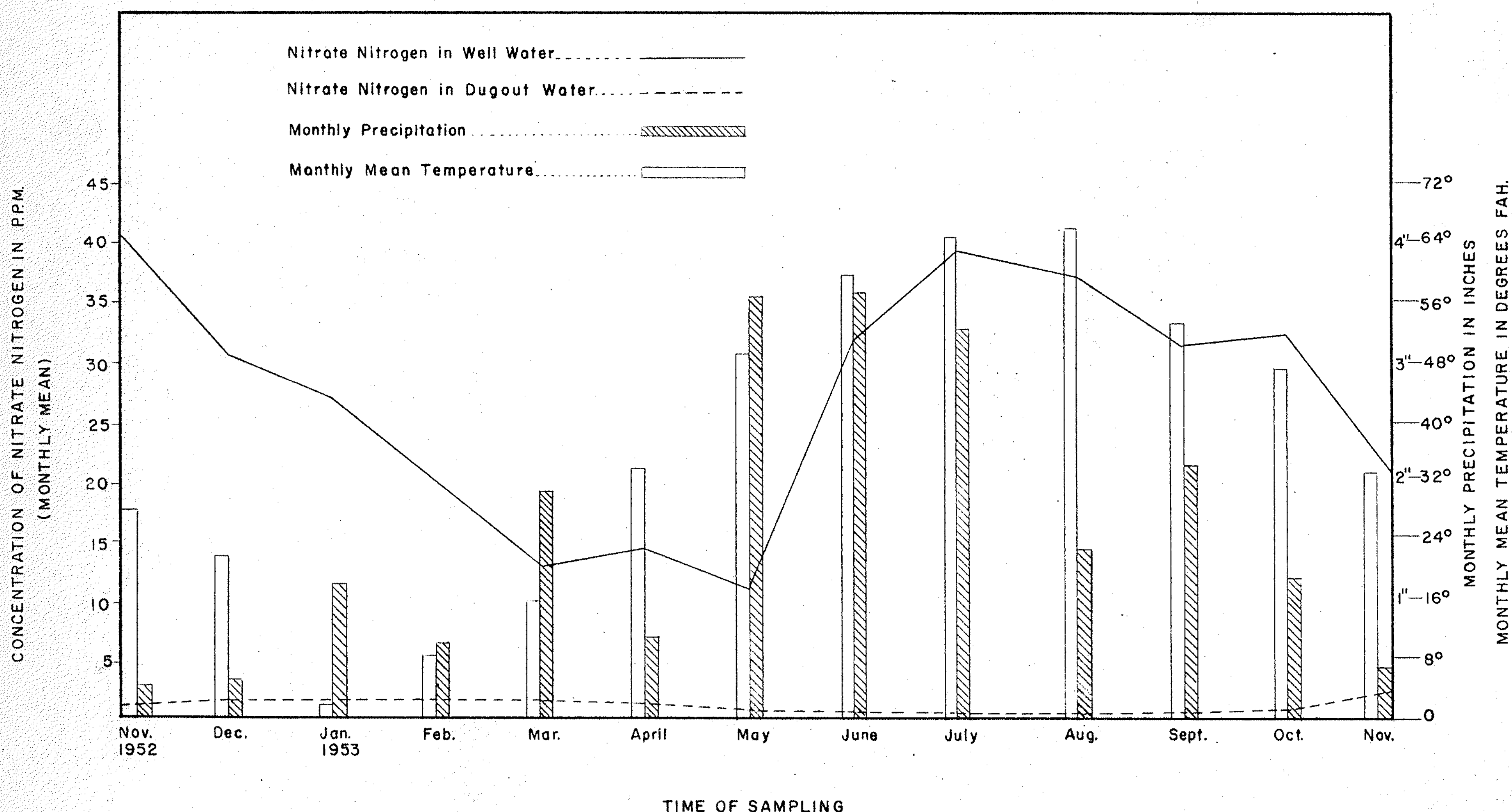
16, data from the five dugouts that were regularly sampled are presented. These cover the period November, 1952 to November, 1953. The figures for each month are the monthly means of the results of two tests conducted each month.

The figures in Table XVI show that throughout the year and at all sites the maximum nitrate nitrogen content was considerably below the non-toxic level of 10 parts per million. The water in dugouts, designated as three and five, reached a concentration of six parts per million and at both of these sites, exceptionally favorable conditions for biological life prevailed. At the site designated number three, the dugout is within a fenced area which connects with a barn and corral, with the result that the relatively large herd of cattle spend a considerable amount of time in the immediate vicinity of the dugout. Much organic wastes from the cattle finds its way into the water and provides an abundance of food for aquatic life. Much the same situation occurs at dugout number five, however, in addition to the organic wastes being discharged directly into or near the water by cattle, a water runway cuts across the corner of the dugout and carries into it, the end products of organic decay from an old building site nearby. This was verified by tests conducted in the summer of 1952.

The mean concentration of nitrate nitrogen for the five different dugout waters for each month shows that definite seasonal trends occur. In Figure No. XVII, these mean monthly concentrations are expressed in graphic form. The lowest curve shows a rather steady level from the months of November to March inclusively. A progressive decline occurs during the months of April, May and June. During July and August the curve shows its lowest level followed by a slight rise for the month of September. This level was maintained till October when there was a rather sharp rise to the

FIGURE NO. XVII

RELATIONSHIP OF TEMPERATURE AND PRECIPITATION TO NITRATE NITROGEN IN WELL AND DUGOUT WATERS FROM NOV. 1952 TO NOV. 1953



winter level.

Two distinct levels of nitrate nitrogen in dugout water therefore occur during a year or 12 month period. The peak concentration occurs during the winter months while the lowest nitrate content is found in summer. Nitrate level gradients towards these two extremes are found in the spring and fall. Optimum conditions for the growth and propagation of aquatic life occur during the summer months. Because nitrate anions are assimilated very rapidly by many of these forms of life, it is reasonable to expect that the nitrate content in the water will be kept low in the summer season. A large supply of nitrate will result in a greater aquatic population, therefore, little or no nitrate should be expected to occur in ponds and pot holes which act as catch basins in barnyards and other unsanitary places. With the advent of lower temperatures in the fall, many species of nitrate assimilators either go into the spore stage or die. As the temperature lowers further, the aquatic life gets more and more sparse, and before temperatures are low enough to prevent nitrate elaboration at the source of contamination, there is a period of nitrate accumulation due to less nitrate uptake. In addition, there is the decomposition of the bodies of dead organisms and the consequent liberation of nitrate in the water. This is probably the chief factor responsible for maintaining the nitrate content at a relatively high level during the cold period. Based on the above assumption, long fall periods with above normal temperatures followed by a sudden break of this warm weather could result in a sudden rise of nitrate content in the water of dugouts.

The monthly means of nitrate nitrogen obtained for the 10 wells regularly sampled are presented in Table No. XVII. Three features distinguish these from the dugout results.

(1) Much higher concentrations of nitrate are encountered in the well water in most cases.

TABLE NO. XVII

MONTHLY MEAN OF BI-MONTHLY TESTS OF WELL WATER FOR THE PRESENCE OF NITRATE NITROGEN IN THE GLADSTONE-NEEPAWA-LANGRUTH AREAS

1952 - 1953

CONCENTRATION OF NITRATE NITROGEN EXPRESSED AS PARTS PER MILLION

Time of Sampling	Designation Number and Site Description or Location of Wells											
	7 At centre of grassed house yard west of barnyard	10 In barnyard about 110 ft. south of barn and manure pile	11 On east side of a ravine and about 90 ft. north of a barn	15 At centre of barnyard and about 50 ft. south of barn and corral	16 In barn-yard and about 65 ft. north-west of barn	17 Well in Glad-stone	18 Well in Glad-stone	22 At Arden on east flank of gravel ridge	23 Situated east of gravel ridge at Arden	24 On gravel ridge at Arden	Total	Mean
1952												
November	0.10	90.00	9.00	90.00	0.80	9.00	30.00	150.00	20.00	8.00	406.90	40.69
December	0.14	55.00	9.00	55.00	0.22	6.00	14.00	145.00	15.00	8.50	307.86	30.78
1953												
January	0.12	35.00	6.50	35.00	0.15	5.00	20.00	150.00	15.00	7.50	274.27	27.42
February	0.10	50.00	4.00	20.00	1.00	6.00	20.00	80.00	10.00	7.00	198.10	19.81
March	0.00	28.33	2.33	20.00	5.33	6.00	16.66	35.33	10.00	6.33	130.31	13.03
April	0.00	25.00	2.00	20.00	6.50	6.00	20.00	50.00	10.00	8.00	147.50	14.75
May	1.00	15.50	5.50	15.00	11.00	7.00	20.00	12.50	15.00	8.50	111.00	11.10
June	0.03	60.00	23.00	43.33	4.33	8.33	23.33	133.33	13.33	7.00	316.01	31.60
July	0.10	60.00	20.00	50.00	3.00	10.00	20.00	200.00	20.00	10.00	393.10	39.31
August	0.10	50.00	20.00	30.00	2.00	7.50	35.00	200.00	20.00	8.50	373.10	37.31
September	0.10	30.00	35.00	30.00	2.00	7.00	30.00	150.00	20.00	10.00	314.10	31.41
October	0.05	30.00	20.00	25.00	0.60	5.00	25.00	200.00	15.00	6.00	326.65	32.66
November	0.00	30.00	8.00	20.00	3.00	9.00	20.00	100.00	10.00	8.00	208.00	20.80
Total	1.84	558.83	164.33	453.33	39.93	91.83	293.99	1606.16	193.33	103.33		
Mean	0.14	42.98	12.64	34.87	3.07	7.06	22.61	123.55	14.87	7.94		

(2) There is considerable variation in nitrate content of well water from site to site, in contrast to relatively uniform levels of water from the dugouts.

(3) The nitrate level of well waters fluctuates considerably from month to month, and this is particularly true where high concentrations are encountered.

Water from the wells with designation numbers seven, 16, 17 and 24 contains relatively low amounts of nitrate nitrogen throughout the year, and of these, number seven has by far the lowest level. It is a farm well, and its position in relation to the various farmyard establishments is shown on Figure No. XIV. This well is located west of the buildings and in a grassed houseyard. The nitrate in the ground water here follows the pattern revealed by previous investigations, and again repeated in the results of well designated as number 16. The latter is only about 65 feet from the barn which is a common source of contamination, but because this well lies north-west of the barn, the nitrate level is relatively low. Well numbers 17 and 24 are both small town wells, the latter is located in the gravel ridge at Arden.

Toxic concentrations of nitrate are encountered throughout the year in the water from wells numbered 10 and 15. Figures 12 and 14 show that these wells are located within the farmyard contamination orbit, and both are south of barns and corrals etc. However, other sources of excessive nitrate such as privies, pig pens and gardens are present nearby. A rather striking observation may be noted in Figure No. XII. Water from the well (No. 11) in this farmyard contained nitrate nitrogen below the toxic level throughout most of the year, inspite of the fact that it is located close to, and north-east of the chicken pen, hog house and barn. The probable reason for this is the presence of the creek immediately west of this farmyard. The surface drainage of this particular yeard is towards this creek. Most of the organic matter which normally accumulates about such places is swept into the creek by run-off and carried away in the stream flow, so that relatively low amounts of nitrate find their way in the ground water.

The three remaining wells, designated as 18, 22 and 23 are situated in small towns or villages. Two of these, (i.e. 18 and 23) one in Gladstone and the other east of the gravel ridge at Arden, have water containing concentrations of nitrate nitrogen ranging from 10 to 35 parts per million throughout the year. The third one of this group, i.e. 22, is situated on the east flank of the gravel ridge at Arden. The nitrate nitrogen content in the water of this well was very high during most of the year, with concentrations up to 200 parts per million encountered on several occasions. No plane table map of the environs of this well is available as this particular site was chosen by the Neepawa Health Unit Staff and added to the list submitted by the Manitoba Soil Survey. However, the high nitrate content in the water of this well indicates that a heavy accumulation of organic matter is present in its immedia te vicinity.

The mean concentration of nitrate nitrogen of the water from the 10 wells as shown in Figure No. XVII presents a sharp contrast with that of the dugouts. For the period of time this study was conducted, the concentration dropped gradually from the November peak of slightly above 40 parts per million to a low of 12 parts per million in May. A sharp rise occurred in June and this rise continued till July where a nitrate content slightly under 40 parts per million was again attained. A slight and progressive decline followed this peak and the trend was maintained up to October when the drop became rather sharp. From October to November the concentration fell from 33 to 21 parts per million.

TABLE NO. XVIII

MONTHLY MEAN TEMPERATURE AT NEEPAWA, AND PRECIPITATION AT NEEPAWA AND THE KATRIME ILLUSTRATION STATION FOR THE PERIOD NOVEMBER 1952 TO NOVEMBER 1953 INCLUSIVE

Month	Temperature in degrees Fahrenheit	Precipitation in Inches		Mean Precipitation of the two places
		Neepawa	Katrime	
1952				
November	28	0.34	0.27	0.30
December	14	0.59	0.15	0.37
1953				
January	2	1.40	0.97	1.16
February	8	0.70	0.61	0.65
March	16	1.80	2.08	1.94
April	34	0.40	1.04	0.72
May	49	3.70	3.39	3.54
June	60	3.30	3.85	3.57
July	65	2.50	4.03	3.26
August	66	1.10	1.73	1.41
September	53	2.20	2.02	2.11
October	47	1.20	1.13	1.16
November	33	Trace	0.40	0.20

Histograms showing the monthly precipitation and the monthly mean temperature for the duration of the water-testing period have been superimposed over the nitrate nitrogen curves of the well and dugout water on Figure No. XVII. This graph was prepared to show the relationships existing between the various factors. The general trend of the nitrate curve shows the influences of the closed and open seasons. Optimum conditions for the nitrate elaboration at contamination sites occur during the summer months. With increase of temperatures in late spring and summer, there is a progressive increase in nitrate elaboration which continues until optimum conditions are reached. This optimum level of elaboration is maintained as long as favorable conditions prevail, but nitrate elaboration falls with falling temperatures. Before elaborated nitrate can be washed from the source of origin and the soil profile and into the ground water, rains in excess of field moisture capacity are required. Thus the high precipitation that occurred during the months of May and June, as shown on Table No. XVIII caused the sharp rise of the nitrate content in the ground water during this period. As noted above, in addition to the wells that were regularly sampled, a number of wells were sampled irregularly.

The data from the irregularly sampled water are presented in Table No. XIX. The same seasonal trends of nitrate nitrogen concentration in the ground water can be seen in spite of the incompleteness of the records. What is borne out however, and this quite conclusive, is the correlation that exists between nitrate nitrogen concentration in the well-water and the location of the respective wells in relation to the farmyard and the usual sources of contamination. Five of these seven wells are located in farmyards; three of them are situated east of, and not far removed from the barns. Previous investigations have established definitely that the barns and yards are the chief sources of contamination and that the direction of ground water lateral movement in this district to the east and north-east. Thus, it is only natural that the three wells situated in the direction of ground water flow have the highest concentrations of nitrate nitrogen.

Well designated as 13 is located nearest to a barn, i.e. about 150 feet away, and here the nitrate content of the water, at times, runs up to 400 parts per million. Well number 14 also is located in the same farmyard and east of the barn, but it is some 300 feet away. The nitrate content of the water here runs between 30 and 70 parts per million during the closed season and rises sharply to 300 parts per million during June and July. However, although the nitrate content of this water is high, nevertheless, a considerable reduction occurred during the cold months. Being farther away from the source of contamination, this well shows the greatest effects of a stoppage of nitrate elaboration and subsequent washings into the ground water upon the arrival of low temperatures. Well designated 12 also lies to the east of a barn. It is located about 275 feet from two sheds or barns, which are used to shelter livestock only during the winter months. The main barn is further north as shown in Figure No. XV. During the summer months the nitrate nitrogen content in the water here reached 55 to 60 parts per million, but it dropped to 20 parts per million in late fall and early winter.

The remaining two farm wells are located west of the barnyards and again the nitrate nitrogen content in the well water is lower, especially in the case of well No. 9. Throughout most of the year the nitrate level of this well was below the minimum toxicity limit of 10 parts per million and when it did go above this limit a maximum peak of only 15 parts per million was attained. Water from well designated as number 8 has a somewhat higher nitrate content. The level was maintained at 20 to 30 parts per million during most of the

TABLE NO. XIX

MONTHLY MEAN OF BI-MONTHLY TESTS OF WELL WATER FOR THE PRESENCE OF NITRATE NITROGEN IN THE GLADSTONE-NEEPAWA-LANGRUTH AREAS, 1952 - 1953

DATA OF IRREGULARLY SAMPLED WATER

CONCENTRATION OF NITRATE NITROGEN EXPRESSED AS PPM

Time of Sampling	8 70 ft. east of garden and west of barn yard	9 70 ft. south of garden and west of barnyard	12 About 250 ft. east of two barns in a vegetation free field	13 In a barnyard 150 ft. east of barn and near haystacks	14 Same site as No. 13 but 300 ft. east of barn	20 Dugout well at Langruth	21 Well on ridge at Langruth
1952							
November	20.00	3.00	50.00	400.00	-	20.00	30.00
December	-	2.40	25.00	400.00	60.00	20.00	35.00
1953							
January	20.00	4.00	20.00	300.00	45.00	20.00	40.00
February	20.00	5.00	20.00	300.00	30.00	-	30.00
March	20.00	4.50	16.33	216.66	33.33	7.50	8.00
April	20.00	4.00	10.00	100.00	30.00	7.50	9.50
May	11.00	11.00	13.50	-	50.00	8.00	30.00
June	30.00	9.33	40.00	300.00	300.00	33.33	23.33
July	30.00	7.00	-	-	300.00	30.00	30.00
August	30.00	7.50	60.00	300.00	-	30.00	35.00
September	15.00	15.00	55.00	300.00	-	20.00	50.00
October	30.00	10.00	30.00	200.00	-	15.00	40.00
November	20.00	-	20.00	200.00	-	10.00	-

- No sample sent in for analyses

period that the tests were conducted. This well also is located as shown Figure No. XIV, west of the barnyard, however, it is located near to, and east of a garden. In all probability the garden in this case is the source of the higher nitrate content in the well water.

IV GENERAL DISCUSSION

The investigations carried out in the summer of 1951 established the fact that the type of surface geological deposits which permit the accumulation of ground water at shallow depths, especially when accompanied by the presence of large amounts of organic wastes at the surface, provide the conditions necessary for the accumulation of excessive amounts of nitrate in the local ground water. Such conditions occur in the shallow deposits of the Lower Assiniboine Delta and in the gravel ridges and coarse textured deposits of the Lowlands Basin Area.

In the neighboring areas such as on the Stockton and Newdale Soil Associations the same conditions for nitrate elaboration occur as those prevailing in the Lower Assiniboine Delta Area and on the gravel beaches. These soils are also in the Blackearth zone and consequently the organic matter in the "A" or surface horizons is relatively high. Furthermore, farmsteads with their accumulation of organic wastes and villages with their privies and garbage refuse are common to all these soil associations.

The fundamental difference between the soil areas with nitrate contaminated ground water, and the areas where nitrate is not a problem, lies in the water regime of the respective surface geological deposits. The conditions which favor large amounts of nitrate in the water supply are, that the soil must have a low water retention capacity and it must be porous enough to allow water to percolate through the profile and into a substrata where it is held at shallow depths because of impeded downward movement. Such conditions occur in the light textured Almasippi soils and gravel beaches.

Both the Almasippi and Stockton soils have a low water retention capacity with the result that a large percentage of the open season precipitation percolates through the profile and into the substrate. This downward movement of water goes on until a saturated substrate or an impervious layer is encountered and there, ground water accumulates.

In the Stockton soils of the Upper Assiniboine Delta Area, downward movement of water is arrested by a saturated subsoil. Here very deep depositions of sands are found (up to 200 feet) which act as a vast natural reservoir for water many feet in depth. Here water is obtained from drive point wells and the water table is reached generally at about 20 feet from the surface. The quantities of nitrate nitrogen normally leached into this large volume of water results in a solution so dilute that the occurrence of toxic amounts of nitrate in the ground waters can be discounted.

Different conditions are encountered in the Almasippi soils of the Lower Assiniboine Delta Area. Here lacustrine clay deposits or till usually found at about eight to 16 feet from the surface arrests the downward movements of leachate. The volume of water into which any nitrate may be carried is therefore much less than that of the Upper Assiniboine Delta Area so that the concentration of the solution is proportionately greater.

In periods of heavy rainfall the water table may rise in the Almasippi soils to within 30 inches from the surface. The chief factors responsible for lowering the water table to a more normal level is removal by vegetation (transpiration and evaporation) and by lateral movement. In the absence of plant life, removal of water is by lateral movement and before this can take place there may be, and there are local pockets of heavily contaminated water directly under and in the immediate vicinity of heavy accumulations of organic matter. Such conditions are prevalent at every farmstead and village throughout the area under discussion. The degree of pollution is more or less proportional to the supply of organic wastes at the surface and the rate of its decomposition by micro-organisms. It follows therefore, that the farms with larger numbers of animal units will have correspondingly higher concentrations of nitrate in the ground water about the farmstead than those with smaller numbers of livestock.

The studies conducted show that there is lateral movement of ground water in the Almasippi Soil Area and the direction of lateral movement is to the north-east. The concentration of nitrate is greatest in the ground water in close proximity to the source of contamination, and invariably it is in the above mentioned direction that nitrate bearing waters move into the adjacent areas. On the other hand the absence of nitrate in the ground water removed only several yards to the west of contamination sites, definitely indicates that lateral movement does not take place in that direction. Furthermore, the presence of nitrate-free water immediately to the westward of contamination sites is further evidence that there must be a sufficiently rapid rate of movement to prevent the spreading of nitrate laden waters in all directions.

The pollution core usually centres about barns and pig pens etc. Where these have been in position for some time, organic matter accumulates and usually there is an abundant supply in various stages of decay to ensure a constant liberation of nitrate providing moisture and temperature conditions are favorable. Under these circumstances higher rainfall simply means that more nitrate is washed into the ground water. In the late spring of 1953, precipitation was much above the average, and the contaminated waters north-east of the farmsteads carried further in the field than was noted at previous times of observation. In the fall of 1953, the distance to which nitrates were carried had been reduced considerably.

Lesser amounts of organic matter, such as are found in gardens, manured pastures etc., liberate sufficient amounts of nitrate to pollute the ground water directly below, but it appears that little lateral movement is required before the solution is diluted sufficiently, in most case, to reduce the concentration below the toxicity limit. This particular point is well illustrated on the 1953 June and October maps of the farmstead situated on the N.W. 34-13-12, (Figures VII and IX). Water from bore holes in the garden east of the house showed a nitrate content of between 75 and 100 parts per million while only some 50 feet away, and east of the garden, the ground water was free of nitrate. Water from the well north of the house as shown on Figures VII and IX, also was free from nitrate contamination.

In the case of the manure pasture on N.W. 34-13-12, a different situation was encountered. There appears to have been sufficient nitrate elaboration at the surface to contaminate the subsoil water to an extent that its presence could be detected in lateral movement. However, the dense growth of grass in this field assimilated a large percentage of the nitrate before the rains could wash it below the depth of root penetration. Hence only a portion of the nitrate found its way to the ground water below, so that concentrations of over 75 parts per million were seldom encountered. The hatchered area south of the farmstead N.W. 1/4 34-13-12 shown in Figures VII and IX indicates fairly well that there had been little lateral movement of nitrate because polluted ground water was found only where there was manure at the surface directly above it. This is in sharp contrast to the area north-east of the farmstead where the hatchered tongue carries into the fields for a considerable distance beyond any surface organic accumulations.

Further evidence of nitrate pollution of ground water being caused by accumulations of organic matter at the surface of the soil, was provided by farm operations on the N.E. 1/4 26-11-11. A heavy application of manure (at least 20 tons per acre) was made on a stubble field during the winter of

1952-53. Following the spring thaw, this manure was worked in with the surface soil. The subsequent heavy rains during late spring and early summer washed the nitrate elaborated at the surface down to the ground water. Because this particular field was reserved for seeding to corn it was kept free of vegetation till early summer. This was achieved by frequent cultivation which hastened decomposition of the organic matter. The conditions prevailing in this field are:-

(a) a large supply of rapidly decomposing organic matter, (and consequently high nitrate elaboration because there was favorable moisture, temperature and aeration).

(b) very little or no vegetation until the corn crop emerged in early July, (hence before that time, no assimilation of nitrate by plants).

(c) heavy rains which washed the nitrate through the soil profile and into the ground water.

Nitrate concentrations running up to 100 parts per million were encountered in the latter when the tests were conducted in June. Thus exceptionally favorable conditions prevailed both for elaboration of nitrate and its subsequent downward percolation through the profile.

Although the manure appeared to have been spread quite uniformily over the surface, there was a great variation of nitrate content in the ground water at the different bore-hole sites throughout this field. The extremes ran from trace quantities to 100 parts per million. This variable pattern indicates an accumulation of the nitrate laden solution at certain points, but not sufficient nitrate elaborated to form a continuous area of pollution such as was found under barns and, or their immediate vicinity. Because the ground water under the fields on each side of the manured area on N.E. 26-11-11 was either nitrate free or contained less than 10 parts per million, it is reasonable to assume that in the process of lateral movement, the concentration was reduced below the toxic level due to the dilution that inevitably accompany the penetration of meteoric waters.

The manured field under discussion produced a heavy stand of corn during the summer. This crop was intertilled quite frequently during that time with the result that decomposition of the manure was hastened. Much nitrate must have been assimilated by the corn crop during the growing season because in September, 1953, the ground water under this manured patch, like that of the neighboring fields, was free of nitrate. At that time also there was no evidence of manure at the soil surface.

V. SUMMARY AND CONCLUSIONS

(1) The cause of methemoglobinemia in infants and of nitrate poisoning of cattle, in the Neepawa and adjacent districts, has been attributed to the presence of excessive amounts of nitrate in domestic and farm water supply.

(2) The present investigation has shown that the occurrence and distribution of nitrate contaminated waters are closely correlated with the water regime in the surface geological deposits.

(3) The terrain of the Neepawa and adjacent district is divided naturally into four main physiographic or landscape areas, i.e. (a) The Western Uplands Area (b) The Upper Assiniboine Delta Area (c) The Lower Assiniboine Delta Area (d) The Lowlands or Lake Basin Area.

(4) Geographically it was ascertained that nitrate affected well waters were found to be of common occurrence in the shallow sandy deposits of the Lower Assiniboine Delta Area; in the gravelly and coarse textured deposits immediately west and north of Neepawa; and in the coarse textured beach, lacustrine and water worked deposits of the Lake Basin Areas. However, in

the boulder till area of the Western Uplands Area and in the deep sandy deposits of the Upper Assiniboine Delta Area, nitrate affected well waters appeared to be relatively infrequent and of casual rather than of common occurrence.

(5) Generally, nitrate charged waters were found to occur above the contact of a shallow sandy or coarse textured mantle and a fine textured substrate. They were not found to be of common occurrence where the soil substrate had free internal drainage.

(6) To measure the amounts of nitrate leached from soils under field conditions, metal catchment pans were placed in triplicate below the "A" horizon of the soil under fallow, grain, alfalfa-grass mixture, brome grass and an old refuse site. Analyses of the leachates indicated that although there was some loss of nitrate under fallow, percolating water from fields under crop are not likely to contribute to a high nitrate content in the well waters of the area studied. Consequently, the chief source of the high nitrate levels commonly found in the shallow wells of the Neepawa and adjacent districts is not soil but must be derived from some other source.

(7) Extensive tests of ground water obtained from many points of sampling show that privies, barns, barnyards, pig pens, poultry yards, corrals and village sites should be regarded as the chief source of excessive amounts of nitrate in the shallow ground waters commonly found in the Lower Assiniboine Delta Area and Lowland areas. In comparison with the high level of nitrate contamination derived from habitation, small amounts of nitrate derived from soil may be considered as of relatively little consequence. Where farm and village habitations have been established for a considerable time, on sites where mixed textured strata retard internal drainage so that ground waters occur at relatively shallow depths, and especially where no provision is made

to avoid accumulation of organic and habitation refuse it is quite natural that nitrate charged waters should appear to be regional. This regionality however, is only apparent because ground water in the fields between the habitation sites and out of seepage range did not show excessively high levels of nitrate.

(8) Although well waters in the Lower Assiniboine Delta Area were frequently found to be nitrate bearing, surface waters stored in dugouts and ponds, or carried by streams, invariably were found at the time of inspection, to be either negative or free from toxic quantities of nitrate. Two factors appear to be responsible. Firstly, run-off and surface flowing waters derived from melting snow and rainfall are less likely to be contaminated with nitrate, than waters which flow through contaminated earth on farmyards or village sites. Secondly, the sloughs and dugout waters invariably supported phyto and zooplanktonic life in profusion during the summer months. Aquatic plants also were observed to be present in most cases, and plant and micro-organisms assimilate and build up soluble nitrate into organic body compounds.

(9) In the fall and early winter of 1953, an attempt was made to grow micro-organisms in water obtained from dugouts, with and without added nitrate, and thus ascertain the rate and quantity of nitrate assimilated. Unfortunately, the artificial conditions, and period in the life cycle of the organisms were unfavorable and this experiment proved to be unfruitful.

(10) Studies of dugout and well waters carried out over a twelve month period showed striking differences in nitrate content.

(a) The nitrate content of dugout water in all cases was higher in the winter and lowest in the summer months, but in no case did the concentrations exceed the border level of 10 parts per million.

(b) The nitrate content of well waters was invariably higher in the summer and lower in the late winter and early spring months; moreover, in most cases, the nitrate concentrations were much above the minimum toxic (10 parts per gallon), and the degree of toxicity varied greatly from site to site.

(11) Because, in the Almasippi Soil Area, waters highly charged with nitrate invariably occurred below contaminated sites or in the path of seepage north-eastward from such sites; and because ground water in the fields between the habitation sites and the range of contamination did not show excessively high levels of nitrate; it is obvious that, in order to avoid methemoglobinemia in infants and nitrate poisoning in cattle, satisfactory farm and village wells can be obtained if the sites are selected accordingly. The alternative is to use surface stored water from dugouts and ponds or streams.

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VII. APPENDIX

Figure No. 18
Almasippi soil profile in field under fallow N.W. 27-14-13 showing ground water at about 30 inches from the surface. October 12, 1951.

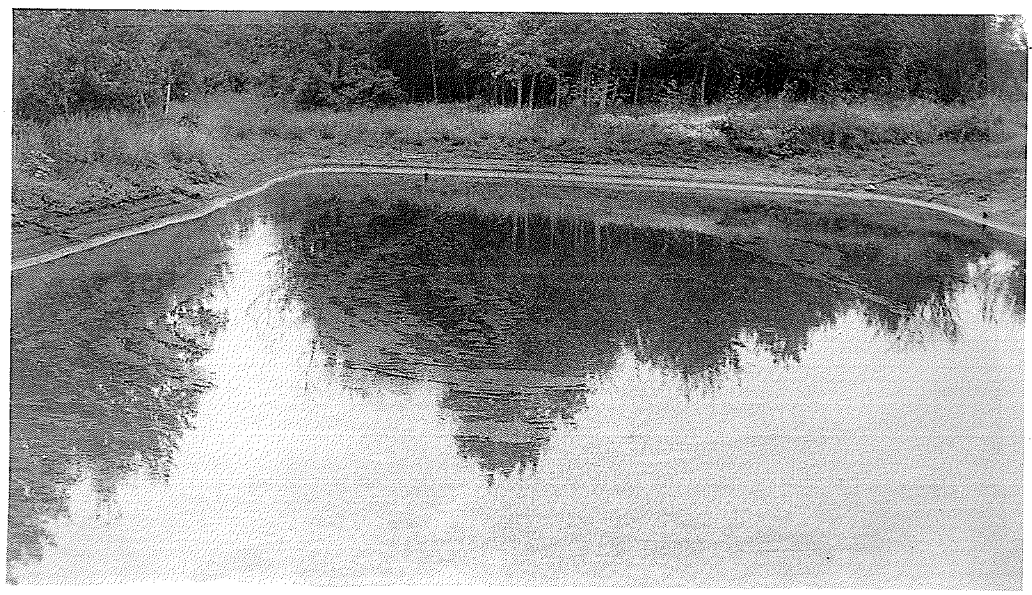

Figure No. 19 - View of dugout located south of Langruth and situated on a gravel ridge. Algae can be seen in the water of the dugout, and examination of the water under a microscope revealed phyto and zooplankton in profusion. Ground water in the gravel contained nitrate, however, the water in the dugout was nitrate-free.

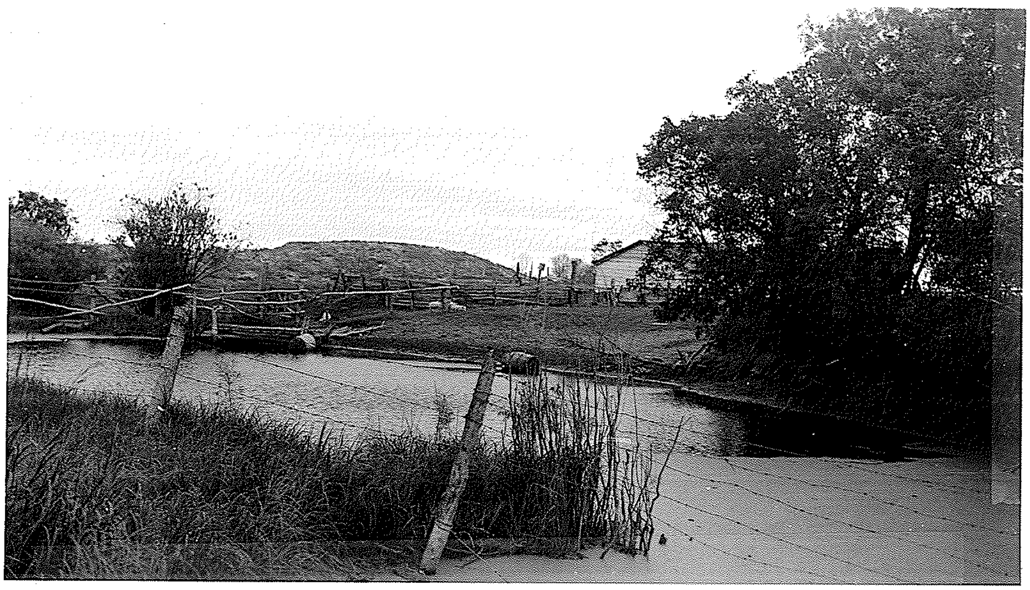

Figure No. 20 - Pond on Almasippi soil showing unsanitary surroundings, i.e. privy, corral, pig pen, manure besprinkled yard, all of which drain into the pond. The remains of a dead horse lie in the willows to the left of the wooden pump seen on the photograph. Tests on the water showed that it was free from nitrate.

Figure No. 21 - View of Langruth dugout and reservoir, showing pump house enclosing pressure system. Water obtained from top to the left of pump house door contains nitrates. Water dipped from dugout showed absence of nitrate.

Figure No. 22 - View of Village dugout at Langruth located at the western edge of Langruth gravel ridge. The fall from the crest of the ridge to the dugout is approximately five feet.

Figure No. 23 - View of a back lane in the village of Arden showing one of the numerous barns commonly found in small towns and villages. Until recently these sheltered a few head of cattle and one or two horses. On the right hand side of the lane can be seen a privy, garden and a pile of organic matter refuse at the corner of the garden.

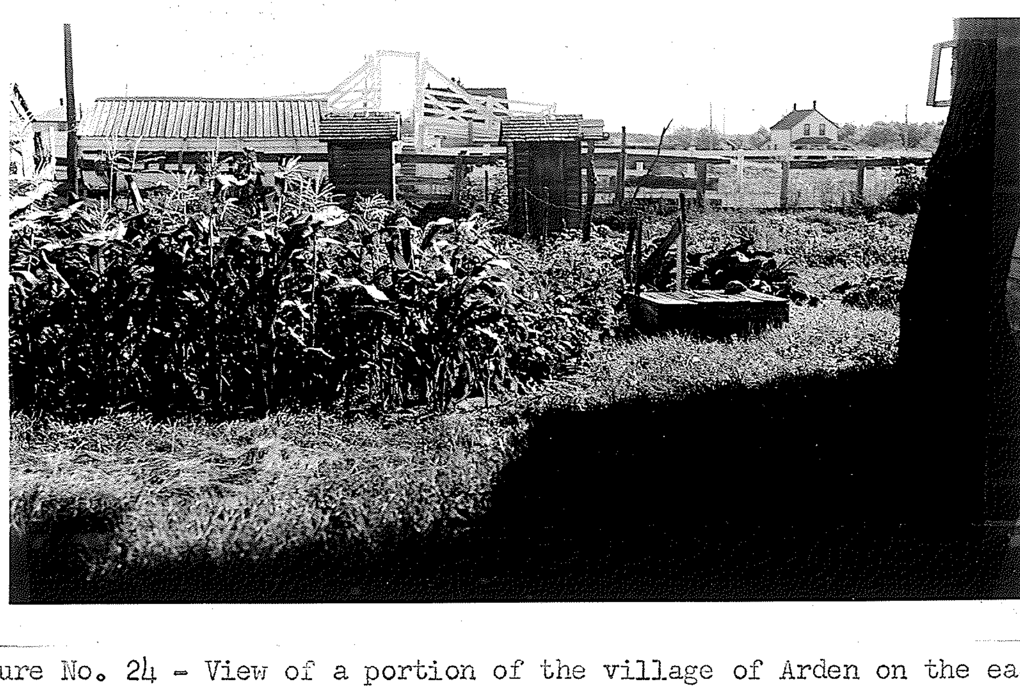

Figure No. 24 - View of a portion of the village of Arden on the east side of the gravel ridge.
Note: - the well in the right foreground, the garden close to, and east of the well, two privies close behind, and an animal loading platform in the background.

Figure No. 25 - View of Leachate "Catchment" installation in a fallow field. Note: the tin enclosures at the soil surface, the metal pans directly below, and the winchester flasks to catch the leachate running from the pans.

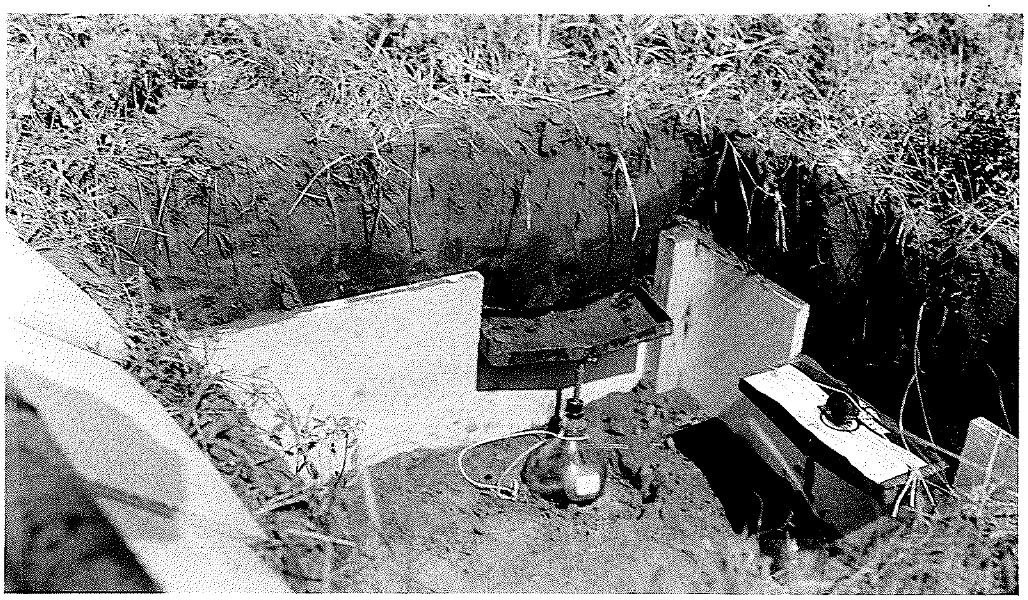

Figure No. 26 - View of Leachate "Catchment" installation in an alfalfa-grass mixture field.
Note: - the "A" horizon or zone of nitrate elaboration above the metal pans (approximate depth is 14 inches).

Figure No. 27 - View of leachate catchment site in an alfalfa-grass mixture field. N.W. 27-14-13.
Note: - rain guage on top of post - Author measuring the amount of rain that fell the previous night.

Figure No. 28 - View of leachate catchment site in a summerfallow field S.W. 34-14-12 showing tin enclosures at soil surface to prevent runoff.