A TIME-SERIES WATER QUALITY STUDY, LINCOLNVILLE, PILSEN AND RAMONA, MARION COUNTY, KANSAS

by

HOWARD G. O'CONNOR AND PAMELA K. CHAFFEE

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ABSTRACT

INTRODUCTION

Background:

During an earlier study of the Geohydrology of Marion County, 14 observation wells were selected for monitoring water levels, chloride and specific electrical conductance changes. The wells utilized were existing irrigation, domestic and stock wells pumping water from the principal aquifers in various parts of the county. The wells were monitored about 10 times each year for two years. The water levels generally rose in the spring months and declined or showed little change the remainder of the year. Chloride and specific electrical conductance values showed little change throughout the year for both confined and unconfined aquifers if the well construction and well siting were appropriate. The exceptions were for the two observation wells in small towns, Lincolnville and Ramona

Purpose and Scope:

The purpose of this study is to determine why private water wells in small towns such as Lincolnville and Ramona show significant increases in chloride and specific electrical conductance values during the spring months when water levels are rising. Both of these small town wells which were monitored are sited in sanitary locations, are constructed to meet state standards and obtain ground water from confined aquifers. The nature of the constituents causing the increase in specific conductance or dissolved solids was not known and will be determined. Well construction standards will be reviewed and the mechanisms of recharge which cause the changes in water quality will be determined. Potential health effects of water quality changes will be identified.

Location and Description of the Study Area:

Private water supply wells in three small towns, Lincolnville, Pilsen, and Ramona located in northeastern Marion County, Kansas (Figure 1) comprise the study area. Lincolnville (population 241) and Ramona (population 117) have had public sewage collection and treatment facilities for more than 20 years. Pilsen (population+/-90) utilizes septic tank and pit privy systems for sewage disposal.

Climate and Precipitation:

The climate of the study area is a continental climte typical of the interior of a large land mass in the middle latitude and is characterized by large daily and seasonal variations in temperature and precipitation. The normal annual precipitation, based on a 30 year period of record (1955 to 1985), is 34.4 inches at Herington, a town 12 miles north of Lincolnville or about 8 miles northeast of Ramona (National Weather Service, NOAA, 1985).

The U.S. Weather Service has maintained a precipitation gage at Lincolnville since 1966. The mean annual precipitation in Lincolnville (1980-1984) is 35.2 inches. The monthly precipitation at Lincolnville for the period January 1981 through August, 1985, including the period of ths study is shown in Figure __. Pilsen and Ramona have essentially similar climate and rainfall.

About 70 to 75 percent of the average precipitation falls in April through September which is the normal growing season. The mean annual runoff for the study area is 3.7 to 3.9 inches (Kansas Water Resources Board, 1960) indicating that about 30 inches of precipitation soaks into the soil and is returned to the atmosphere by transpiration or evaporation except for the small part that recharges the area aquifers.

ACKNOWLEDGEMENTS

Appreciation is expressed to all of the residents in the study area who allowed us to inventory, measure and sample their wells and for providing information about wells or activities

that might affect the community water supplies. Mr. Charles Penner, Marion County health officer and the Marion County Commission provided information on the three towns and arranged for a public meeting at which results of this study were described. N. Jack Burris and Marvin Dyck, Kansas Department of Health and Environment, consulted with us on the study and provided the bacteriology analyses. Steve Randtke and Charles Judson, Department of Civil Engineering and Director of the Mass Spectrometer at the University of Kansas, respectively provided analyses of volatile and non-volatile organic carbon and determinations of the dissolved gasses, methane, oxygen and carbon dioxide in water samples. Larry Hathaway, manager of Kansas Geological Survey analytical services supervised the water analyses during the entire project. Albert Riffle, weather observer at Lincolnville, provided precipitation data for Lincolnville.

We especially wish to thank the water well drillers, Paul Backus, Paul Benda, Brant Rader, the Arnold Riffle, William Schimpf and Joe Zinn, who provided much useful information about wells they had drilled. Joe Zinn was especially helpful in providing detailed lithologic logs, notifying us when wells were to be drilled and providing lithologic samples from the wells.

Richard Teaford, county engineer, and the Kansas Department of Transportation provided engineering and hydrogeology information concerning the bridge over Clear Creek at Lincolnville.

PHYSIOGRAPHY AND SOILS

Lincolnville, Pilsen and Ramona are located in the Flint Hills upland of the Osage Plains section of the central lowland physiographic province (Schoewe, 1949) shown in Figure 3. The eastern half of the Flint Hills upland is underlain by alternating limestones and shales which has prominent rocky terraced slopes and topographic relief of 100 to 250 feet. Several of the limestones contain abundant flint or chert nodules which are resistant to weathering and form very stony soils and give rise to the term Flint Hills.

The western half of the Flint Hills upland is developed on shale beds containing a few relatively thin and soft limestones and included several beds of anhydrite and gypsum. The area has a gently rolling to nearly flat topography. Lincolnville is located topographically along the west bank of Clear Creek essentially along the boundary of the two subregions of the Flint Hills upland whereas Pilsen and Ramona are located in the western subregion in the rolling topography developed on the Wellington shales and are both located in relatively higher local topographic settings.

The predominant soil in Lincolnville is Irwin silty clay loam with 1 to 3 percent slopes, slow percolation rates (0.2 to 0.6 inches/hr.) and moderate to high shrink-swell potential. Part of the town has clime silty clay loam soils with 1 to 7 percent slopes, slow percolation rates (0.2-0.6 inches/hr.) and moderate shrink-swell potential. Organic matter in both soils ranges from 2 to 4 percent. The soils have a high risk for corrosion to uncoated steel and a low risk to concrete.

The soils at Pilsen are all clime silty clay loam with 1 to 3 percent slopes, slow percolation rates (0.2-0.6 inches/hr.) and have moderate shrink-swell potential and form in the residium of calcareous clay shale. The soils are corrosive to uncoated steel but not to concrete. Organic matter in the soil ranges from 2 to 4 percent.

Ramona has Irwin silty clay loam soils with 1 to 3 percent slopes, slow percolation rates (0.2 to 0.6 inches/hr.), moderate to high shrink-swell potential and 2 to 4 percent organic matter.

GEOLOGY

The consolidated rocks which outcrop and underlie the study area in northeastern Marion County are all of Permian age (Figures 1, 4, 5, and 6). Throughout much of the area the rocks dip westward about 15 to 20 feet per mile. The rocks consist of beds of shale and mudstone, limestone, dolomite, gypsum and anhydrite. Some of the limestones are cherty and siliceous.

Wellington Formation:

Within the study area, the Wellington Formation is the principal source of potable ground water for both Pilsen and Ramona. The Geuda Springs Shale member (Ver Wiebe, 1937), the uppermost Wellington member of concern in this study, has a thickness of about 200 feet and consists largely of light to dark gray shale but includes some tan, green, and red shale, thin gypsum or anhydrite beds and their limestone beds. Next below is the Hollenberg Limestone member, about 1 1/2 to 4 feet thick, the principal aquifer at Pilsen and Ramona. The Hollenberg is light to dark gray in color and may be brown and ferrugineous in part. The basal part may be conglomeratic. On outcrops it is partly finely crystalline limestone and partly carbonate mud but in the subsurface where it is an aquifer it is a calcarenite (calcareous sand) that has good porosity and permeability, made up largely of casts of tiny coiled mollusks. Below the Hollenberg are about 40 feet of buff to greenish gray shale, claystone and mudstone beds called the Pearl Shale member containing one or more thin, argillaceous limestones. A red or maroon zone occurs in the lower part.

Chase Group:

The Chase Group consists of four limestone and three separating shale formations which have a thickness of about 310 feet in northeastern Marion County. Only the upper five formations including the Nolans Limestone, Odell Shale, Winfield Limestone, Doyle Shale and Barnestone Limestone contain fresh or useable groundwater and are pertinent to this study.

The Nolans Limestone is the uppermost formation of the Chase Group and consists of three members in descending order: Herington Limestone, Paddock Shale and Krider Limestone. The Herington Limestone consists of 10 to 15 feet of tan to light gray medium bedded dolomite or dolomite limestone with thin shale partings. The middle part is more massive and contains abundant grades 1/2 to 3 inches in diameter and less abundant chert nodules. Casts of small mollusks are abundant. The Paddock shale member is 9 to 15 feet thick, light fray to tan dolomitic shale with grades lined with drusy or finely crystalline quartz and calcite in the upper part. The underlying Krider Limestone, 2 to 6 feet thick, consists of soft greenish gray dolomite limestone and gray to tan dolomitic shale. Typically, drillers log both the Paddock and Krider as shale because they are soft.

The Odell Shale ranges from about 15 to 29 feet in thickness and is light gray to tan in the upper and lower part with prominent red, maroon and greenish shale and mudstone in the middle. Much of the unit is calcareous and locally thin discontinuous limestones are present in the upper or middle part. Below the Odell Shale is the Winfield Limestone containing the Casswell Limestone, Grant Shale and Stovall Limestone members. The Cresswell member ranges from about 15 to 29 feet thick. The upper 1 to 4 feet typically is a hard coherent shell hash of finely crystalline light gray limestone with some shale clasts. Below this bed are 10 to 15 feet of massive, poorly coherent light gray to nearly white porous limestone containing local thin gray to green shale partings. The bed contains silicious concretions and chert nodules. The lower part is light gray to tan thick bedded to massive limestone containing light to dark gray silicious concretions. The Grant Shale member about 6 to 8 feet thick is light gray argillaceous or calcareous shale. The Stovall Limestone member, generally about 2 to 3 feet thick, is a hard light gray to buff limestone with sparse to abundant gray or dark gray chert nodules.

The Doyle Shale containing the Gage Shale towards limestone and Holmsville Shale members has a thickness of about 50 to 70 feet. The Gage Shale member, 25 to 40 feet thick, is light gray to tan calcareous shale in the upper part and locally may include 1 to 4 feet of limestone. The middle and lower part consist of maroon, red and greenish shale and mudstone. The Towanda Limestone is reported by drillers to range in thickness from about 10 to 15 feet and comprises medium gray hard dense limestone beds separated by shale partings. The Holmesville Shale member typically is 10 to 15 feet thick is largely greenish and gray shale with impure limestone or gypsum beds near the middle.

The Barneston Limestone consists of the Fort Riley Limestone, Oketo Shale and Florence Limestone members having a thickness of about 80 feet. The upper and middle beds of the Fort Riley are soft light blue gray to ran limestone that is chalky to platy and with thin shale breaks. Only the lower part is massive and hard. It has a thickness of about 35 to 40 feet. Below the Fort Riley is 1 or 2 feet of gray calcareous Oketo Shale. The basal Florence Limestone member about 35-39 feet thick, is a hard light gray to tan limestone containing abundant nodules and beds of blue gray chert. Locally the Florence may be 50 percent chert.

Deeper stratigraphic units contain highly mineralized water and were not considered in this study.

HYDROLOGY

Regional Flow Systems:

The stratified or layered limestone and shale beds in the study area generally have a gentle westward dip or slope (Figures 5 and 6). The limestones are the principal aquifers for the water wells in Lincolnville, Pilsen, and Ramona. Recharge water to the aquifers enters the aquifers directly where the limestones are exposed at or near the surface or through the soil and weathered zone where the limestones are overlain by a few feet of soil and weathered shale. The regional flow of groundwater in the limestone aquifers moves in a generally westward direction down the dip of the rocks. The ground water becomes confined where the limestones are overlain, as well as underlain by unweathered shale beds. The regional flow of groundwater in the confined aquifers moves down the dip and toward areas in which streams are incised into the aquifers at lower elevations. The regional flow systems are shown on Figure 1.

Declining Head Relationships:

Within each of the three towns there are generally two or more fresh water aquifers. The water level in the shallowest aquifer has the highest head. The water level in a well constructed into the shallowest aquifer would stand higher than the water level stands in any well drilled to a deeper fresh water aquifer (wells 1, 2, and 3, Figure 9). In Lincolnville the shallow aquifer includes the weathered Wellington Shale and the Nolans Limestone which are at or very near the land surface throughout the town. This is the aquifer topped by Well No. 1 in Figure 8. In Pilsen and Ramona fresh ground water occurs under water table of unconfined conditions in the weathered zone at the land surface developed in shales of the Wellington Formation. The shallowest water zone may be present only intermittently in each of the three towns where the weathered zone is thin or may be permanent where the weathered zone is 20 to 30 feet thick.

Effects of Boreholes:

Boreholes of all kinds including test holes, seismic shot holes, old oil and gas wells that did not have the casing cemented through the fresh water zones, and water wells both in use and abandoned have the potential for allowing ground water from one aquifer to flow from a shallower water zone to a deeper water zone under a declining head relationship as shown in well No. 4 (Figure 9).

In a similar fashion, wells drilled in search of oil and gas, if the casing is not cemented through the fresh useable water zones, may allow downward drainage of fresh and useable water into deep salt-water bearing formations resulting in a waste of fresh or useable roundwater.

Stream-Aquifer Relationships:

Clear Creek in the vicinity of Lincolnville gains flow in a downstream direction. In the reach of Clear Creek between 3 miles above Main street (south side sec. 11, T18S, R4E) to 1 miles below Main Street the flow of the creek increases about 448 gpm (gallons per minute) based on measurements made September 22, 1983. This gain is primarily from ground water discharge from the Nolans Limestone and secondarily in the lower part of this reach from the Winfield Limestone. Water levels in the Nolans Limestone are at higher elevations than the creek and therefore contribute seepage to the creek. A test boring for the budge over Clear Creek on Main Street in Lincolnville flowed water above the level of Clear Creek indicating the Winfield Limestone aquifer is confined by the overlying Odell Shale and the potentiometric surface or head is above the water level of Clear Creek.

Both Pilsen and Ramona are located in upland areas in which water levels in wells topping the Hollenberg Limestone aquifer stand at higher levels than water levels in nearby streams and the stream reaches gain flow in a downstream direction indicative groundwater is influent to the streams. Aquifer Water Quality: Systematic water sampling from representative water wells in Lincolnville, Pilsen and Ramona indicate that the confined aquifers in each town contain acceptable quality water for drinking water and that wells located in uncontaminated sites away from sources of pollution and properly constructed to prevent the downward drainage of shallow unconfined ground water to the confined aquifer show little change in dissolved chemical constituents throughout the year.

Although the regional flow of groundwater in the confined aquifers into each town is of good quality there are many poorly constructed wells, wells in pits that leak, and wells with leaky casings that are point sources of contaminants that, especially during the spring recharge period, allow downward drainage of surface or shallow ground water that may be significantly more mineralized, contaminated with fertilizers and other organic and inorganic products and bacteria, or in other instances may be less mineralized than the confined aquifer water. These point sources create plumes of significantly different quality water in the regional flow of ground water in the confined aquifers underlying each town.

SELECTION OF WELLS FOR SAMPLING

At the beginning of this study, 72 water wells or approximately 25 percent of the existing water wells in Lincolnville, Pilsen and Ramona were inventoried. Based on this inventory, a total of 20 wells from the three towns were selected for sampling and measuring on a monthly basis including 8 wells in or near Lincolnville, 4 wells in or near Pilsen, and 8 wells in or near Ramona. Included in these 20 wells were one well in each town that was outside the town proper and was intended to serve as a background well not affected by the activities and businesses in the towns. Fifteen of the 20 wells selected for monthly sampling in the 3 towns were wells for which water well records or WWC-5 forms (Figure ___) were available and which were constructed to current state standards with respect to the well site, approved casing type, completed above ground and grouted for a minimum of 10 feet in the anular space around the casing. One additional well met all the state requirements and for which we had a WWC-5 record but the well was completed in a well pit with casing cut off below ground level. Three wells were completed in well pits and did not meet state standards for construction and one well was completed in an above ground well house but did not meet state standards (WWC-5 record, not grouted). As data were acquired during the first few months of the study, 22 additional wells were added in the three towns to broaden and improve our data base for the water quality changes we anticipated would occur in the January to August sampling period, including the spring rise in water levels. Each of the 22 additional sampled wells were sampled 3 to 8 times during the 8 month period January through August, 1985. Table 1 is a record of the wells and test holes used in this study together with the results of monthly sampling for chloride and nitrate content, specific conductance, and water level.

At the beginning of the project, a press release describing the objectives and procedures of the project was prepared and published in the local newspapers and during the initial well inventory much interest was expressed by individual well owners in cooperating. As the study progressed, several additional well owners expressed interest in having their well water sampled and included in the study.

KANSAS WATER WELL STANDARDS

In 1973, the Kansas legislature enacted legislation known as the Kansas Groundwater Exploration and Protection Act (82a-1201 through 1215). the law provides for 1) the licensing of all water well drillers, 2) establishes standards for water well construction including grouting of at least 10 feet of the casing with approved grout, reconstruction, treatment and plugging, 3) requires each licensed water well contractor to keep and transmit to the state a copy of the log of the well, pump test data if available and water quality samples, and 4) maintains within the state geological survey of Kansas a record system of well logs and water quality data which will be available to the public. The law and associated rules and regulations are administered by the Kansas Department of Health and Environment.

WATER QUALITY PARAMETERS INVESTIGATED AND FREQUENCY

Standard Inorganic Chemistry:

Water samples were collected twice (Table ___) during the one year study for standard inorganic chemistry analyses. The first samples were collected in September, 1984 during the time period when water levels were declining or stable and the second set of samples were collected during May 1985 when water levels were rising and recharge to the aquifers was occurring.

The standard inorganic chemistry analyses were performed by the analytical Services Section of the Kansas Geological Survey. The ionic balances computed for the results indicate that the analyses are very good with the greatest deviation from electroneutrality (the difference between the sums of milliequivalents/L of anions and cations divided by total milliequivalents/L) equal to 2.87 percent for the September 1984 analyses and 2.37 percent for the May 1985 analyses (Hathaway, 1984 and 1985).

There were significant increases in the values for some of the anions and cations between the September 1984 and May 1985 water samples from some wells and for other wells there were significant decreases in anion and cation values between the September 1984 and May 1985 water samples. This suggests a mixing of water in the confined aquifer underlying each town with waters of different character recharging the confined aquifer at various points within each town whenever recharge occurred.

Fecal Bacteria:

Water samples were collected twice for bacteriological examination for fecal coliform (FC) or fecal streptococcus (FS) bacteria. The bacteriological analyses were made by the Kansas Department of Health and Environment using standard methods (Standard Methods for the Examinations of Water and Wastewater, 1980). Thses bacteria are used as indicator bacteria for the bacteriological safeness of drinking water quality. The bacteria which are non-pathogenic or non-disease producing occur in the gut and the feces of warm blooded animals including humans, birds, hogs, chickens, dogs, horses and cattle. These bacteria, if present in the soil, may enter the confined aquifer underlying each town if bacteriologically contaminated surface water or shallow groundwater that has not been adequately filtered by movement through the soil drains into a well via a well pit, a gravel pack around a well casing, an ungrouted or inadequately grouted well or through non-water tight casing joints or holes or breaks in casing. Fecal coliform and fecal streptococcus bacteria have relatively short lives outside the animal hosts, the fecal coliform having shorter survival times than the fecal streptococci (Bitton and others, 1983). Their presence in well water in each of the three towns indicates a local source because they would not survive the transit time for the ground water to move from the natural recharge areas. The ratio of fecal coliform to fecal streptococcus bacteria in a water sample may be used as an indicator of the source of the bacteria (Pixes, 1982). The ratios of FC/FS from water samples collected in this study indicate the sources of bacterial pollution were from bird and animal waste rather than human waste.

The first water samples collected for bacteriological examination were collected in December 1984 when the soil was frozen, water levels in wells were declining and recharge to the aquifer was not occurring or was insignificant. The second set of water samples were collected in May 1985 when soils were not frozen, ground water levels were rising, recharge to the aquifers was occurring and precipitation was more abundant. Neither the December 1984 nor the May 1985 water samples showed fecal coliform bacteria. Fecal streptococcus bacteria were found in 2 of 20 water samples in December 1984 and in 8 of 20 water samples in May 1985. The two contaminated water samples in the December sampling were from the background farm wells near Lincolnville and Ramona and in discussions with the well owner it was learned that a garden hose connected to a frost proof yard hydrant used to fill a stock watering tank did not have a backflow preventer on the hydrant and a stock tank full of water had accidently backsyphoned into the well earlier and was the probable cause of the contamination (Well L-21). The background well at Ramona (Well R-1) also is on a farm where livestock and other animals are present and maintain a fresh supply of fecal materials in the vicinity of the well. There is an abandoned well between the cattle pens and the sampled well and there was active surface subsidence within 50 feet of the sampled well near the corner of the house which may or may not have conducted local surface runoff to the confined aquifer. The results of the two samplings are shown in Table ___ and Figures ________.

Total Organic Carbon:

The total organic carbon (TOC) content of water indicates the presence of organic carbon compounds that are either naturally occurring of resulting from human activities. TOC includes both nonvolatile organic carbon (NVOC) and volatile organic carbon (VOC). The NVOC includes both dissolved organic carbon (DOC) and particulate organic carbon (POC). DOC is defined as the concentration of organic matter in a water sample passing through a 0.45 micrometer membrane filter. The groundwater samples collected for TOC analysis in this study (Table ___) were not filtered prior to analysis, therefore, potentially containing both dissolved organic carbon (DOC) and particulate organic carbon (POC). The NVOC levels of uncontaminated ground water are generally observed to be quite low, 0.1 to 15 mg/L (Leanheer, et al., 1974; Symons, et al., 1975). Miller (1987) did a statewide survey in Kansas (March and April, 1986) of TOC in ground water from 47 wells including 22 samples from alluvial aquifers, 12 samples from other unconsolidated aquifers, and 13 samples from consolidated rock aquifers. The consolidated rock aquifers had the lowest TOC values with a mean of 0.48 mg/L and the alluvial aquifers had the highest TOC values with a mean of 1.59 mg/L.

The major portion of naturally occurring organic compounds is nonvolatile and consists of fulvic acid derived from the decay processes of plant material in the soil (Pettyjohn, 1983). VOC's are largely man made compounds such as gasoline, solvents, metal cleaners, degreasers, grain fumigants and some agricultural chemicals. Except for methane, which may sometimes be found as a naturally occurring VOC in fresh groundwater, these organic carbon compounds are not normally found in uncontaminated ground water.

The organic carbon analyses (TOC, VOC, NVOC) were performed on two sets of samples collected in May and August 1985 using a Dohrman/Envirotech DC-80 TOC analyzer according to methods described by Barcelona (1984) at the C.L. Burt Laboratory at the University of Kansas by

Dr. Steven J. Randtke. Analytical precision was +/- 2 percent and the detection limit was approximately 0.02 mg/L of carbon. The type of pumps (jet, submersible) used in the sampled wells were not conducive to sampling for volatiles and may have resulted in some loss of VOC, if present. In addition concentrations in the May samples may also have been affected by equipment malfunction in the laboratory. The analyses were performed with samples having 1 to 2 ml. of headspace in the sample bottles for 24 hours because equipment malfunction had caused the original analyses to be invalid (Randtke, 1985) and could have affected the detection of VOC.

Volatile Organic Carbon:

Twenty-two water samples were collected in May and twenty-three water samples in August 1985 from wells in the study area. There were no detectable amounts of VOC (<0.02 mg/L) in any of the May and only one of the August samples. One sample was collected from a well in August in addition to the wells sampled in May because the well owner had expressed interest in having his well water analyzed because he indicated it had a slight odor of gasoline. A leaking underground service station fuel tank across the street from well R-27 had earlier contaminated the service stations well and is the apparent source of the confirmed VOC of 1.191 mg/L in well R-27. ùNonvolatile Organic Carbon:ú Except for the L-27 water sample collected in august 1985 none of the sampled wells contained detectable amounts of VOC therefore the nonvolatile organic carbon (NVOC) reported in Table ___ is also the total organic carbon (TOC) value. the range of NVOC in the May sampling was from 0.50 to 6.12 mg/L with a mean value of 1.41 mg/L. The range of NVOC in August was from 1.24 to 5.80 mg/L with a mean of 3.00 mg/L.

Chloride:

Chloride is one of the constituents for which Federal Secondary Drinking Water Regulations have been established primarily on the basis of aesthetic qualities relating to the public acceptance of drinking water (USEPA, 1979). The Secondary Maximum Contaminant Level

(SMCL) is 250 mg/L. Waters containing greater amounts of chloride may have a salty taste and the water is also more corrosive to metal piping and plumbing. small amounts of chloride are found in all natural waters. Chloride is a very mobile constituent of water. Ground waters affected by sewage, animal wastes, highway driving salts, some fertilizers, and oil field brines will have elevated chloride values and when used in conjunction with the specific conductance values, both of which can be rapidly and inexpensively determined using field equipment, can give indications of contamination or changing water quality when compared to background uncontaminated samples of formation waters.

Chloride concentrations were determined by using a hand-held digital titrator, a 2.256N mercuric nitrate titration cartridge, and diphenylcarbazon reagent powder pillows (Hach Co., Ames, Iowa). The analyses were performed on 100 ml. samples of water. In all of the field or laboratory analyses performed during the study, care was taken to have water samples at the correct temperature, filtered if necessary, and compared with blank (distilled) water and four standards before and after each group of samples or when reagents of one lot number were exhausted and those of another were started. These titrated values were used to construct a calibration curve which was then used to correct the titrated sample concentration. the estimated analytical error for the chloride determinations was 4 percent. The chloride results are shown in Table ____.

Nitrate:

The U.S. Environmental Protection Agency has established Interim Primary Drinking Water Standards that relate to the safety, rather than the aesthetic quality of drinking water. Nitrate is an inorganic constituent for which a maximum contaminant level of 10 mg/L of nitrate (N), or 45 mg/L of nitrate (NO3) has been established (USEPA, 1984).

The principal identified health affect of nitrates are related to the risk of methemoglobinemia for infants. Nitrates in water do not cause this problem with adults, but there are possible other health effects that have not been adequately documented (National Research Council, Panel on Nitrates, 1978).

Increasing levels of nitrate in ground water have been attributed at least in part to increased usage of nitrate fertilizers in agriculture (Olson, et al., 1973; National Research Council, Panel on Nitrates, 1978;   ).

Small amounts of nitrogen in the atmosphere are combined into nitric oxides by lightning discharges which dissolve in rainwater to produce nitrous and nitric acids. Most of the precipitation which falls in this area soaks into the soil where it is available for use by plants. Some plants (legunes) are able through bacteria on nodules on their roots to take nitrogen from the air and fix it in the soil as nitrate. Nitrogen in plant debris, animal and bird wastes, septic tank wastes, sweage effluent and man made inorganic fertilizers are also applied or added to the soil and may be leached downward to aquifers by percolating waters.

The largest local sources of nitrates in the three towns, which we could identify were the bulk fertilizer facilities on the rail lines at Lincolnville and Ramona where we observed several hundered pounds of fertilizer spillage during the unloading from rail car to bulk storage building and the subsequent loading into farm vehicles. All three towns had some livestock pens or areas where animal manures accumulated near some of the water wells inventoried. Pilsen had septic tanks and privies for disposal of human wastes into the soil providing concentrated nitrate sources that could be leached downward into aquifers. Lawns that were well kept and provided with regular applications of fertilizer or with fertilizer plus pesticides (weed and feed products) may also provide a leachable source of nitrate to the underlying aquifers.

Miller (1987) sampled 50 wells across Kansas, 47 of which were collected between March 7 and April 11, 1986 and three samples were collected in June and July, 1986. Thirty four samples were from public water-supply wells and 16 samples were from private domestic wells which were located in sites without nearby potential contamination and for which construction details were known and met current state standards. Only 3 of the 50 wells (6 percent) contained more than 45 mg/L of nitrate (NO3). Heiman, et al. (1987), in a Kansas Farmstead Well Water

Quality Study sampled 104 farmstead wells during December 1985 and January 1986 in a random but statistically representative distribution across Kansas and found 29 percent of the wells sampled exceeded the 45 mg/L nitrate standard. Spruill (1983) has published statistical information for 24 chemical constituents or properties from 766 wells in the Kansas Groundwater Quality Network which were analyzed between 1976 and 1981. He divided the state into 14 ground water regions based partly on physiographic regions or aquifer age. Lincolnville is included in the region where the Chase and Council Grove Group are the principal aquifers. Eleven percent of the 60 well samples in this network region contained more than 45 mg/L nitrate. Pilsen and Ramona is included in the region which include the Wellington Formation. Twenty-two percent of 18 water samples from the network in this region contained more than 45 mg/L nitrate.

The nitrate (NO3) values for 397 water samples collected during this study ranged from 0 to 612 mg/L in the three towns. Nitrate values in Lincolnville ranged from 11 to 612 mg/L, in Pilsen 0 to 422 mg/L and in Ramona 0 to 422 mg/L (Table __). For the 20 key wells picked for 12 months of monitoring in the 3 towns, 15 of the wells met current state standards of construction including above ground completion, a water tight sanitary discharge thru the casing, approved casing and a minimum of 10 feet of approved grout around the well. Eleven of these 15 wells or 73.3 percent had nitrate concentrations above 45 mg/L one or more months of the year and 7 of the 15 or 46.7 percent had nitrate values above 45 mg/L in all samples analyzed during the year. Four of the 20 key wells were completed below ground in well pits. Three of the 4 wells in pits had nitrates above the maximum contaminant limite (MCL) at least once during the year. One well was completed in an above ground well house and met the state requirements except the casing was not grouted. Nitrates in this well ranged from 19 to 38 mg/L and never exceeded the MCL during the year.

In both Pilsen and Ramona there were a few wells that consistently had 0.0 or 0.1 mg/L nitrate, an odor of hydrogen sulfide, approximately twice the specific conductance values of other wells in the same town, lower pH values which were near neutral or slightly acidic. One well sampled in Pilsen consistent had significant background levels of nitrate except for one sampling following heavy rainfall which caused standing water in the area of the yard where the well was located, flooding of the well pit and drainage into the well. The chlorides increased more than 3 times the values obtained 2 weeks earlier, nitrates decreased from 33 to 0 mg/L and the electrical conductance increased from 995 micromhos to 2030 micromhos/cm. The significance of these changes will be described in the chapters describing results of the investigations.

Specific Electrical Conductance: The specific electrical conductance or specific conductance was measured monthly for all groundwater and stream samples collected during the study. The specific conductance of ground water and surface water increases with increasing mineral matter in solution and with increasing temperature of the water. The specific conductance values, reported in micromhos, can be converted to approximate total dissolved solids in mg/L for ground waters in Marion County by multiplying by a factor of 0.62 for specific conductance values less than 1,000, by 0.7 for conductances of 1,000 to 2,000 and by 0.8 for conductances greater than 2,000. The approximate error is 15 percent or less for ground waters in the study area. (Whittemore, Chaffee and O'Connor, 1983).

Based on the specific samples collected during this study for Lincolnville, Pilsen and Ramona it was determined that the specific conductance values for Lincolnville could be converted to mg/L by multiplying by 0.62, for Pilsen by multiplying by 0.74 and for Ramona by multiplying by 0.70 to obtain values with an error of +/- 15 percent or less.

Measurements of specific conductance were made at the same time as the chloride analysis. A portable meter (Lectro-MHO, Model MC-1, Mark 4, Lab-Line Instrument Co., Melrose Park, Ill.) was used to determine specific conductance and are expressed in micromhos per centimeter at 25°0 C (Table__). The estimated accuracy of the meter was 2 percent.

Temperature:

Ground water temperatures in confined aquifers at depths of 50 feet or more have very little seasonal variation. However, many factors can slightly increase or decrease the apparent ground-water temperature observed in a pumping well circulating the water through the distribution system. If the water pumped from a well at 58º0 F flows through a pipe buried just below frostline the temperature may be warmed during summer months when soil temperatures are warm (60 to 70º0 F) or may be cooled during wintertime when soil temperatures may be 35 to 45º0 F. A constant temperature may be reached at a house top or a frost proof yard hydrant after 4 to 10 minutes pumping that is the result of actual ground water temperature modified by the soil temperature. A well which taps a confined aquifer that has become partially dewatered so that the upper part is filled with air and the lower part is filled with water will warm in the summer months and cool in the winter months. Changes in barometric pressure will cause air to flow into the well and fill the unsaturated upper part of the aquifer during the passage of a high pressure system and conversely air will flow from the unsaturated part of the aquifer into the well and out the top of the casing whenever a low pressure system passes over the well. Such a well may be described as a "sucking" or "blowing" well in response to the barometric changes. This situation was only observed in one well in this study (Well L-31).

Ground water temperatures in confined aquifers may also show temperature changes if the confined aquifer is recharged locally through a bore hole or a well by the downward flow of surface water or shallow soil or weathered zone water during local recharge events. The resulting mixing of surface or shallow ground water of a different quality and temperature with ground water in the confined aquifer will produce either a blend or a discreet slug of water of differing quality and temperature within the confined aquifer.

The ground water temperatures were measured monthly in a representative number of wells in each town but temperature measurements were not recorded for every well every month.

Dissolved Gases:

Fresh and usable ground waters in the study area normally contain small mounts of dissolved gases to make the water milky upon discharge from a tap and release of pressure that is maintained in the pressurized water distribution system. However, some wells were observed to discharge water having enough dissolved gases to spurt from the faucet or top to have a milky appearance. Because of the oil and gas activity in the county it was considered that the dissolved gases might include naturally occuring methane which would be important to know in the samples analyzed for VOC's and TOC's Duplicate samples were collected May 8, 1985 for analyses of methane (CH4), oxygen (O2) and carbon dioxide (CO2) concurrent with samples collected for VOC, NVOC, and TOC analysis. The samples collected for gas analysis were collected at the same time and manner as samples collected for VOC,NVOC, and TOC analyses described earlier. Samples were immediately stored on ice and transported to the mass spectrometry laboratory at the University of Kansas within 48 hours where the analyses were performed by Dr. Charles Judson. Because the amount of methane was less than 0.02 mg/L in all the samples, methane was not a factor in determining the VOC's and was not collected for the August, 1985 sampling for VOC, NVOC, TOC analyses.

Four of the samples became frozen while in storage at the laboratory and the bottles were broken. As the samples were partly melted they were analyzed but the sample numbers were not recorded. These 4 samples are recorded as x1, x2, x3, and x4 in Table __ and represent samples from wells L21, P1, P3, and R13 but we do not know which analysis matches which well sample.

Carbon dioxide in ground water accelerates the rate of corrosion and incrustation. It may be dissolved in water from precipitation falling through the air, from the soil as it percolates through the soil, or as a result of the bacteria or yeasts producing carbon dioxide in the subsurface confined aquifers if nutrients are present. Under normal atmospheric conditions carbon dioxide is odorless, colorless and soluble in water at 0.7 mg/L (Gass, et al., 1982). The solubility increases rapidly under pressure. Its solubility is sensitive to minor changes in temperature and pressure. Carbon dioxide values ranged from 3.0 mg/L to 40.0 mg./L (Table ___).

Oxygen is soluble at 7 mg/L but it usually occurs in ground water at much lower concentrations because of use by micro-organisms, and the formation of metalic oxides in the soil during the percolation of water thru the soil to an aquifer. Fresh and useable ground water general contains enough oxygen to support some microbial activity in an aquifer (Gass et al., 1982). Oxygen may be added to a confined aquifer if a pathway is provided for colder surface water or shallow ground water to drain downward thru an unplugged abandoned well, flow into a well pit and into the well, cascading water moving into a well entraining air with the water or flowing downward through an unsaturated gravel pack around the well casing.

Individual pumping wells may entrain air into the pumped water if the pump and drop pipe are not submerged enough, if there is too little water in the well for the pump capacity or if there is a hole in the pipe allowing air to entrain into the pressurized water system. Oxygen concentrations in the sampled waters ranged from 0.3 mg/L to 27.0 mg/L (Table __).

Hydrogen sulfide is another important gas that may occur in ground water. It gives the water the distinct odor of rotten eggs even at low concentrations of 0.01 mg/L. Hydrogen sulfide may originate in ground water from the bacterial reduction of organic or inorganic sulfates or when pollution from sewage contaminates the water supply. Water containing hydrogen sulfide is corrosive to many metals.

Nitrogen is the most abundant gas in air and therefore may also occur in water. The denitrification of nitrates in ground water can also provide nitrogen gas in solution in ground water. At least locally in adjacent Morris County to the north of the study area hydrogen and nitrogen gases both occur in deep wells in approximately 40 percent and 60 percent respectively (Goebel et al., 1984) outgassing from the earths mantle has been considered as the abiogenic source for the hydrogen and nitrogen. A few miles southwest of the study area natural discharges of gas to a streambed have a composition of 92.3 percent N2, 2.81 percent CO2 and 1.28 percent 4O2. Therefore although nitrogen was not analyzed in the gas analyses, it may be a significant component of the dissolved gases in the ground water. Samples for gas analyses were collected only one time in May 1985.

Sediment, Color and Odor:

Whenever monthly water samples were collected the pumped water was examined for sediment, color and odor. The principal kinds of sediment included pipe scale, calcite crystals of sand or silt size and shale fragments. A few wells produced water with large amounts of turbidity caused by slaking clay zones in the shales that provide a continuous source of the clays because of improper well construction. Fragments of baird roots or other fibrous material were noted from some wells in each of the three towns. Turbidity from slaking tan colored clay zones was most significant in some Ramona wells. Yellowish or yellow brown water was pumped from one or more wells in each town that had the appearance of water discolored by burmic materials but was present only for part of the year. Leaking fuel tanks or gasoline spills have contaminated wells in each town but no wells were inventoried or sampled in Pilsen at the owners request. Hydrogen sulfide odors were present in some wells in Pilsen and Ramona.

SAMPLE COLLECTION AND LABORATORY ANALYSIS

Following the initial inventory of wells in the three small towns and the selection of 20 wells for monthly sampling for chloride, nitrate and specific electrical conductance, water samples were collected using a standard routine. Where practical, water samples were collected from a tap of faucet closest to the well, either at the well house, a frost proof yard hydrant or on the outside of the house. Some samples were collected from faucets inside the house and all of the samples for bacteriological examination were collected inside the house from cold water, unsoftened water taps without aerators according to instructions from the Kansas Department of Health and Environment. Water pumped from the well was allowed to flow until a constant water temperature was obtained, generally about 4 to 6 minutes in order to obtain representative formation water from the well. Generally the wells were used on a daily basis, therefore a long pumping period was not required. Whenever outside hydrants or faucets were used, water was usually allowed to run to waste into a white 5 gallon plastic bushel to calculate the approximate discharge rate, observe the water for sediment, odor, turbidity and dissolved gasses.

Samples were collected in 500 ml. polyethelene bottles for chloride and nitrate concentrations and specific conductance. The filled bottles were numbered, stored on ice, and transported in ice chests to a nearby motel room or to laboratory facilities at the Kansas Geological Survey. There, measurements of nitrate concentrations were usually conducted within 24 hours using a portable colorimeter (Hach Company, Model DR/1A, Ames, Iowa). However, on a few occasions some samples were held longer, as much as 55 hours before analysis. Several acidified duplicate samples were collected for nitrate determination by the KGS Analytical Service Section. Results showed relatively good agreement in concentration values with the Hach method, especially for samples analyzed within 24 hours. The estimated analytical error for samples analyzed by the Analytical Services Section was 4 percent or less. The difference in nitrate concentrations determined by the two methods ranged from 4 to 27 percent with the average difference being 16 percent. The greater percent differences were associated with longer holding times of some samples before nitrate analyses could be made using in-field testing equipment. Because samples analyzed using the in-field testing equipment were not preserved at times of collection, nitrate values reported were either in relatively good agreement or were lower than concentrations determined in the Analytical Services laboratory from preserved samples.

Most samples collected did not require filtration, with the exception of several samples from Clear Creek, wells L-26 and R-16. Samples from these sources were filtered prior to analysis using filtration equipment at the KGS Analytical Services laboratory.

After the nitrate determinations were complete, the samples were stored at room temperatures until the chloride and specific conductance measurements could be performed generally within 1 to 10 days. The estimated analytical error of the chloride determinations using in-field testing equipment was 4 percent and was based on repeated determinations of standards during each set of samples. The estimated error for specific conductance was approximately 2 percent.

Samples collected for analysis of total organic carbon (TOC) and for volatile and nonvolatile organic carbon (VOC and NVOC), and the dissolved gases methane, oxygen, and carbon dioxide (May 8 and August 15, 1985) were collected from the same taps as were used for the monthly samplings, after temperatures of the discharging water had stabilized. After the temperature had stabilized the discharge rate was substantially reduced to slow, steady, smooth, flow with the least turbulence in order to obtain samples without loss of potential VOC's, if present, and any dissolved gases in the water. However, because all of the wells used in this study were equipped with variable displacement (jet or submersible) pumps some degassing may have affected the concentrations of VOC's and dissolved gasses that were obtained (Barcelona, et al., 1984). Two 100 ml glass serum bottles were filled slowly until overflowing. A teflon-lined septum inserted in an aluminum seal and carefully placed over each bottle was then crimped tightly into place. If at this point any air bubbles were present in the bottle, the seal was removed, the sample recollected, and the sealing process repeated until a sample was collected that contained no bubbles. The two samples per well were marked, stored on ice and transported to the University of Kansas within 48 hours. One set of samples was delivered to the C.L. Burt Laboratory for the analyses of VOC, NVOC and TOC'S by Dr. Stephen J. Randtke. The second set of samples (May sampling only) was delivered to the Mass Spectrometry Laboratory in Malott Hall for analysis of methane, oxygen, and carbon dioxide by Dr. Charles Judson. Because there were no detectable amounts (<0.02 mg/L) of VOC in the August 1985 samples, analyses for dissolved gases were not conducted.

Sampling for the standard inorganic chemistry analyses (September 24, 1984 and May 8, 1985) involved pumping the well until one well-bore volume of water had been discharged. Then field measurements of temperature, pH (portable meter–Model 607, Fisher Scientific Co., St. Louis, Mo.), and specific conductance (portable meter–Lectro-MHO Meter Model MC-1, Mark 4, Lab-Line Instrument Co., Melrose Park, Ill.) were made on several grab samples until these parameters had stabilized. One 500 ml. polyethelene bottle was then filled for determination of pH, specific conductance and major anions and cations. Also a 250 ml. redistilled 6N hydrochloric acid was filled to 200 ml. for measurement of trace metals, nitrate and ammonium. These bottles were marked, stored on ice, and transported to the Analytical Services Section laboratory of the KGS where the analyses were performed under the supervision of Dr. Lawrence Hathaway.

Sampling for the examination for fecal coliform and fecal Streptococcus bacteria (December 17, 1984 and May 20, 1985) was according to instructions of the Kansas Department of Health and Environment. The procedure involved running the water for at least five minutes through a nonaerated cold water tap inside the house. Samples were collected in specially prepared and marked plastic bottles provided by KDHE. The samples were stored on ice and transported to the Environmental Laboratory (Forbes Building 740, Topeka) within 24 hours to be examined for the presence of fecal coliform and fecal Streptococcus bacteria. The results were then interpreted and reported by KDHE.

HEALTH ASPECTS OF DRINKING WATER

Drinking water regulations:

The federal Interim Primary Drinking Water Regulations were promulgated December 24, 1975, in accordance with the provisions of the Safe Drinking Water Act (Public Law 93-523). additional Interim Primary Regulations for radioactivity in drinking water were promulgated on July 9, 1976. Additional standards are currently being considered for a host of synthetic organic chemicals, such as benzene, toluene, and carbon tetrachloride. These primary regulations are intended to protect the human health aspects of public water supplies and are listed in Table __.

Table __. National Interim Primary Drinking Water Standard

Constituent	Maximum Contaminant Level (in mg/L or ppm unless specified)
Inorganic chemicals	0.05
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05

Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05
Fluoride	1.4-2.4
Organic chemicals turbidity	1 tu up to 5 tu*
Coliform bacteria	1/100 ml (mean)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaprene	0.005
2, 4-D	0.1
2, 4, 5-TP (Silvex)	0.01
Radionuclides	
Radium 226 & 228 (combined)	5 p Ci/L**
Gross alpha particle activity	15 p Ci/L
Gross beta particle activity	4 mrem/yr***
Total Trihalomethanes	0.1

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* tu = turbidity unit

** p Ci/L = picocuries/ Liter

*** mrem = millirem/year

Source: USEPA, Office of Drinking Water 1977

Kansas has adopted the federal standards for public water supplies and is responsible for administration and enforcement of the regulations. National Secondary Drinking Water Regulation (HO CFR Part 143) have been established according to the Safe Drinking water act and also apply to public water supply systems. These regulations cover contaminants which may adversely affect the aesthetic quality of drinking water such as taste, odor, color and appearance which may deter public acceptance of drinking water provided by public water systems Table __.

Table __. National Secondary Drinking Water Regulations, maximum contaminant levels for public water systems

Contaminant	Level
Chloride	250 mg/L
Color	15 color units
Copper	1 mg/L
Corrosivity	Noncorrosive
Foaming agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Sulfate	250 mg/L
Total dissolved solids	500 mg/L
Zinc	5 mg/L

Source: USEPA, 1979

These levels represent reasonable goals for drinking water quality, but are not enforceable at the federal or state level. In Kansas many public and private water supplies have one or more of the Secondary contaminants such as chloride, sulfate, or total dissolved solids that exceed the standards.

Acute and Chronic Effects:

The drinking of contaminated ground water may cause acute or chronic effects depending on the nature and amount of the contaminants in the water. Acute effects have a sudden onset of illness such as a few hours or days and may be caused by microbial or chemical contamination.

Chronic or long term effects of drinking contaminated ground water are those that persist either because the injury is persistent or progressive, or because the exposure to the contaminant is prolonged and the rate of new injury exceeds the rate of repair (National Academy of Science, 1977). The effects appear after weeks, months or years of drinking the contaminant (Kamrin, in D'Itri and Wolfson, 1987). Chronic effects may be associated with the mineral characteristics of the water or with organic chemical contamination.

Bacteriological Contaminants:

The quality of drinking water is judged partly on its bacteriological quality as indicated by the presence of indicator bacteria. Indicator bacteria used in this study were fecal coliform and fecal streptococcus bacteria. The presence of these organisms in ground water pumped from confined aquifers that should be free of fecal bacteria indicates a local source or sources of contamination to the aquifer. It also indicates that pathogenic or disease causing bacteria may also access and contaminate the aquifer through the same pathways or sources. Gastrointestinal illnesses constitute the major category of illnesses resulting from groundwater contamination (Hubert and Canter, 1980a).

Organic Compounds:

Some of the organic compounds used in industry, agriculture and even domestic or household use have been identified in public and private ground-water supplies. Some of these organic compounds are known to be toxicants, carcinogens, mutogens, and teratogens as indicated by animal bioassay tests conducted at high dosages (USEPA, 1984). The effect on humans of long term ingestion of low levels of many organic chemicals in drinking water is not known but maximum contaminant limits (MCL) for each hazardous compound is now being developed by the Environmental Protection Agency under the Safe Drinking Water Act. A recent random survey of contamination of farmstead wells in Kansas by pesticides, volatile organics and inorganic chemicals (Steichen, et al., 1988) showed that 8 percent of the tested wells contained detectable amounts of pesticides and 2 percent had detectable amounts of volatile organic chemicals.

The Kansas Department of Health and Environment (Kovach, 1986) has established Groundwater Contaminant Cleanup Target Concentrations for many organic chemical compounds where ground water contamination has been identified.

Heavy Metals:

Limits on the amount of several of the heavy metals, i.e., arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver have been established (Table __) because of the known toxic effect of the metals in drinking water. These metals may cause either chronic or acute poisoning.

Although trace amounts of some of the heavy metals are widespread in the environment, they generally do not occur in toxic amounts. Arsenic was formerly widely used in pesticides, lead is or was used in paints, batteries and as a component of gasoline, mercury compounds have been widely used as a seed treatment and therefore may be present in each of the towns and enter the aquifers if a pathway is provided.

Lincolnville Study

Results of Investigation

On the following pages the results of the one year study of water quality changes in Lincolnville, Pilsen, and Ramona are described together with the factors of geology, hydrology, well construction, had proximity to contaminant sources that may affect water quality. A total of 72 wells were inventoried and sampled between July 31, 1984 and August 19, 1985 at least once and Clear Creek at Lincolnville was sampled eleven times during the study. A total of 455 water samples were collected from 66 wells used in the study on which chloride and specific conductance values were determined. From November 1984 through August 1985 nitrate values were also determined on 389 of the water samples. Eleven water samples were also collected from Clear Creek at the east edge of Lincolnville for chloride, nitrate and specific conductance determinations. Water level measurements were made in 48 of the wells used in the study. Some wells could not be measured because of the way they were constructed. Information on the wells inventoried and used in this study together with the water level measurements and values for monthly chloride, nitrate and specific conductance are given in Table ___.

Lincolnville Hydrologic Setting

The presence of the Herington Limestone Member of the Nolans Limestone at or a few feet below the land surface or the soil throughout Lincolnville make it easier to move soluble contaminants into fractures and solution openings of the Herington Limestone. Road salt (NaCl) and some fertilizers (KCl) move through the soil from roadside ditches and fertilized lawns with infiltrating water and into the Herington Limestone which contains many fractures and solution openings. Once in the Herington Limestone, water can move laterally through the fractures and solution openings but not downward because the underlying Paddock Shale and Odell Shale which have very low permeability and prevent a significant transfer of ground water from the Herington Limestone to the underlying Winfield Limestone aquifer. However, any of the wells which have 1) loose jointed galvanized casing, 2) a permeable pack around the casing, or 3) any cased well which does not have the casing driven into the Odell Shale or is not effectively grouted from near land surface to the Odell Shale may act as a drain for any water that percolates downward into the Herington Limestone.

Location and Number of Wells

A total of 24 wells were sampled and/or measured within the town proper as part of this study, plus an additional 4 wells near but outside the town boundaries (Table ___; Fig. ___). Eight wells were selected for monthly monitoring and the remaining wells were monitored less frequently as shown on Fig. ____. The measured or reported depths of 25 wells ranged from 66 to 115 feet in depth (median 90 ft) and the depth to water levels below land surface ranged from 21 to 49 ft.

Potential Sources of Pollution Identified

The generally recognized potential pollution sources located in or adjacent to Lincolnville identified by us are shown in Fig. ___. For the most part these are related to past or present small businesses that handle petroleum products, farm chemicals, grain elevators where grain fumigates have been used, garage-machine shops where greases and solvents are used, car washes, waste stabilization lagoons, livestock pens, and roads where driving salts are applied. In addition, five yard privies were identified. Every residential site has the potential for contributing contamination to percolating waters from such sources as buried sewer lines, trash burning sites, fertilizers and pesticides applied to lawn and garden areas and pesticides to house foundations, former privies, septic tanks and lateral drain fields, waste paints and paint solvents that may be disposed of on yards or driveways.

Monthly Sample Analysis

Eight key wells were selected for monthly monitoring for chloride, nitrate and specific conductance (Table ___) beginning in July and early August of 1984. Nitrate analyses using field equipment did not begin until November 1984 owing to a delay in shipping of the equipment. In January 1985, additional wells were added to the monitoring network to broaden the data base for changes we expected to occur from the winter to summer monitoring period and to monitor sites of known or suspected groundwater pollution.

Most of the wells used in the study were domestic wells in daily use and we considered that in most cases one borehole volume of water was pumped from each well on a daily basis. In most cases, wells were pumped until the ground water temperature stabilized near the typical range for ground water in Marion County, 54 to 59 degrees Fahrenheit (12.2 to 15.0 degrees Celsius) before samples were collected (usually after at least 5 minutes of pumping). Temperatures above or below this range when the temperature stabilized usually indicated the water had been affected by warmer or colder soil or air temperatures in contact with the piping system.

Chloride

a total of 200 water samples were collected from the Lincolnville area network of wells for chloride analyses during the study period (Table ___). The number of samples per well ranged from 13 or 14 samples per the well for the eight key wells to one or two samples for wells sampled during the initial inventory and well selection period. The number of samples per well is shown in Table ___ and Fig. ___. Chloride values ranged from 5 to 243 mg/l, all below the Federal Secondary Water Quality Standards for chloride in drinking water.

Seven chloride analyses from well L-22 (Table ___; Fig. ___) about 1/2 mile outside of and east of town made between January and August 1985 showed a range in chloride values from a low of 5 mg/l to a high of 10 mg/l. Nine chloride analyses from well L-17 on the east edge of Lincolnville also show a very small month to month or seasonal change in water quality. Well L-21, also outside of town, had relatively small month to month chloride changes. Hydrographs of these three wells are shown in Fig. 11. Wells L-2, L-3, and L-4 (Fig. 12) and L-16, L-18, and L-19 show more month to month change but are characterized by relatively stable chloride values during the fall and winter months and an increase in chlorides somewhere in the April, May or June period, concurrent with rising ground water levels associated with aquifer recharge (Figs. 11, 12, and 13).

Nitrate

Nitrate (NO3) values for 173 samples of groundwater collected during the study ranged from 7 to 629 mg/l. The number of samples per well ranged from 11 or 12 samples per well for the eight key wells to 1 to 8 samples for most of the remaining wells (Table ___). The USEPA (1984) has established a maximum contaminant level of 10 mg/l of nitrate (N) or 45 mg/l of nitrate (NO3) for public water supplies. Hydrographs of wells L-17 and L-21 outside of town had nitrate concentrations ranging from 14 to 39 mg/l of NO3 during the study period and relatively small month to month fluctuation (Fig. 11). Twelve of the eighteen wells in town sampled three or more times during the study had concentrations of NO3 above 45 mg/l one or more times. In three wells, L-17, L-20, and L-27, NO3 concentrations in all samples (8 to 12 samples) were above 45 mg/l. Hydrographs of NO3 concentrations in wells that showed significant nitrate changes indicate increases generally occurred during the April, May, June period when significant recharge to the aquifer occurred as indicated by rising ground water levels (Fig. 12 and 13; Table 1).

High nitrate concentrations occur in all water samples collected from well L-27 near the site where bulk fertilizers are unloaded from rail cars into a storage building and from the bulk storage building into farm trucks. Several hundred pounds of nitrate fertilizer was spilled in the vicinity of the well and leached into the soil in the spring of 1985. In the south part of Lincolnville, two wells, L-19 and L-20, sampled 12 times each have all NO3 concentrations above 45 mg/l (Table ___). Both of these wells were constructed to state approved standards but neither was grouted through the Nolans Limestone, therefore potentially allowing shallow groundwater infiltrating the soil and into the Nolans Limestone to drain downward to the confined Winfield Limestone aquifer. Sources of nitrate in the ground water pumped from these wells may be from fertilizers applied to lawns and gardens, or from animal waste in animal feeding and holding areas in the vicinity of the wells, but the source or sources are not known. Nine other wells had one or more water samples with nitrate values ranging from 45 to 237 mg/l of NO3.

Specific conductance

Measurements of specific conductance were made on 200 water samples from 27 wells in Lincolnville. The specific conductance values ranged from 757 micromhos/cm to 2,900 micromhos/cm at 25°C. Using a factor of 0.62 to convert specific conductance to approximate total dissolved solids, the total dissolved solids of the water samples ranged from approximately 469 mg/l to 1,798 mg/l (Table ___). Water samples from well L-22 had a specific conductance range from 778 to 796 micromhos/cm (1 percent change) whereas well L-3 had a range from 757 to 2380 micromhos/cm (314 percent change). Many of the wells had changes in specific conductance of 10 percent or greater suggesting that the pumped water had more than one source or that the Winfield aquifer was intermittently recharged with waters of a different quality from many point sources within the town.

Standard inorganic chemistry analyses

Seven of the eight wells sampled produced a calcium bicarbonate (CaH CO3) water and one well produced a calcium bicarbonate type water in the May 1985 sample but a calcium sulfate type water in the September 1984 sampling. Results of the standard inorganic-chemistry determinations are given in Table ___. Along with the concentrations for each constituent is a calculated percentage change which, according to Summers (1972), is necessary in evaluating differences in the source of the sample when only two complete chemical analyses are available. If on a 1:1 comparison most concentrations have changed by at least 10 percent, significant differences have occurred in the source. If the concentration of only one constituent has changed by more than 10 percent, analyses of that constituent is suspect. If the differences are less than 10 percent, differences may exist in the source, but two analyses are not sufficient to identify them. five of the seven wells within the town showed more than 10 percent change (L-2, L-10, L-19, increases; L-3 and L-20, decreases) between the two samplings. Samples from the other two in-town wells, L-16 and L-18, and the outside of town well L-21 showed less than 10 percent change in constituent concentrations between the September and May samplings. However, wells L-16 and L-18 showed a greater than 10 percent change in nitrate concentrations in several consecutive samplings (Table ___).