

**KANSAS GEOLOGICAL SURVEY
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Time-Series Water-Quality Sampling:
A Tool For Determining Aquifer-Baseline Quality,
Contaminant Sources, and Remedial Policies

by

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TIME-SERIES WATER-QUALITY SAMPLING---A TOOL FOR
DETERMINING AQUIFER-BASELINE QUALITY, CONTAMINANT
SOURCES AND REMEDIAL POLICIES

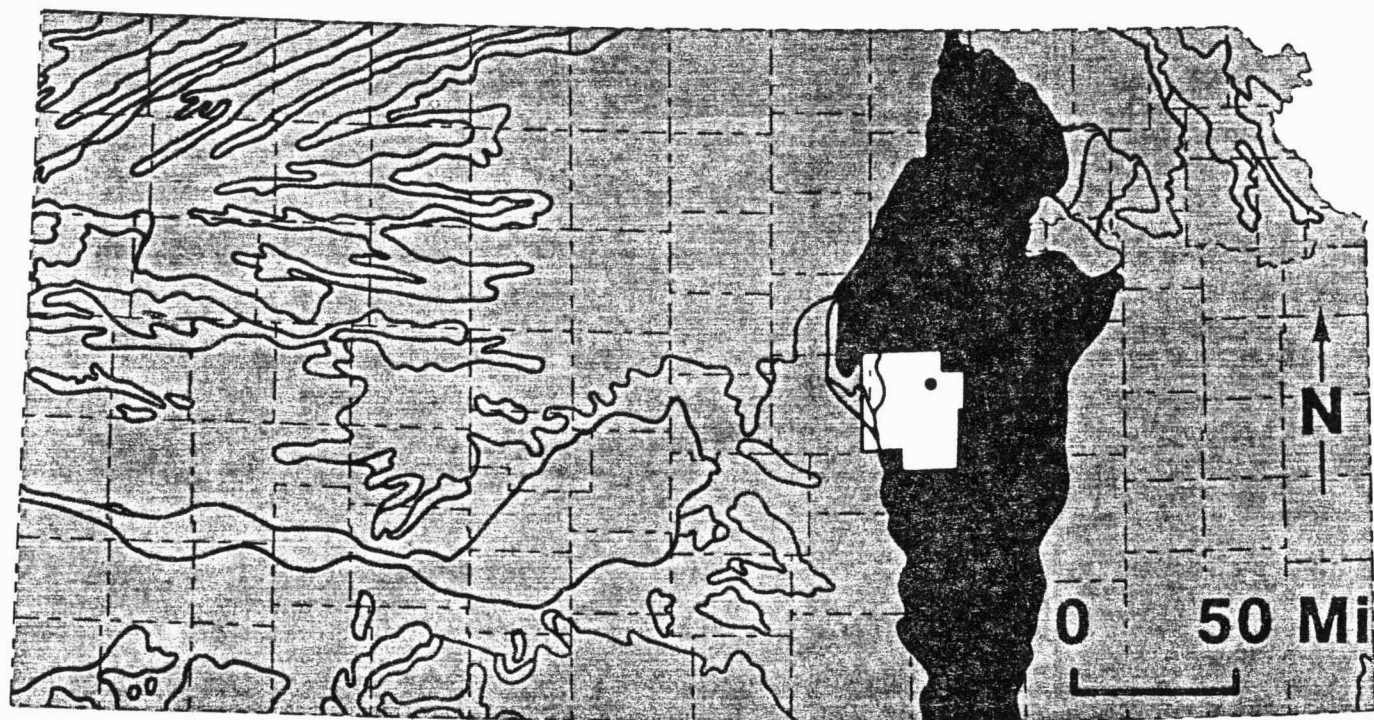
by

Howard G. O'Connor and Pamela K. Chaffee

A small town domestic-water well in Lincolnville, Kansas, and a farm domestic-water well located 6 mi north were used as observation wells in a countywide study from December 1981 to July 1984. While both wells tap the same confined aquifer, water levels and water-quality constituents fluctuated significantly in the town well compared to the farm well.

In order to determine the cause of these large fluctuations, which constituents fluctuate, how the fluctuations occur, and if any public health significance results from the fluctuations, a one-year time-series water-quality sampling program was initiated using more than 20 wells in Lincolnville, Kansas.

Lincolnville is located in Marion County (Fig. 1), which is situated predominantly in the Flint Hills Upland physiographic region of east-central Kansas. The town is underlain by Permian-age rocks.



• Lincolnville



Permian
System

Marion
County

Figure 1. Map of Kansas showing Marion County and the town of Lincolnville.

Lincolnvilleville (Fig. 2) is a small town with a population of about 240. It has approximately 100 homes and is served by US-77 and one railroad. Public sewage-treatment and trash-collection systems are utilized.

Figure 3 shows the wells in and around Lincolnvilleville that were used in the 12-month study and the sampling frequency. First we will look at hydrographs of the two observation wells from the countywide study that gave rise to this investigation. Well #31, the farm well 6 mi north of Lincolnvilleville, and well #10, in town, both have a period of record from December 1981 to July 1984.

In Figure 4 hydrographs show water-level, chloride-concentration, and specific-conductance fluctuations with respect to time for well #31, the farm well. Water levels in this well fluctuate very little in the two and one-half year period with about a 5-ft rise in the spring of 1984. Similarly, the chloride concentration and specific conductance hardly change at all. Specific electrical conductance is a valuable indicator of the amount of mineralization in the water. Conductance values indicate the electrical conductivity, in micromhos, of 1 cm³ of water at 25°C. The tick marks on the time axis represent four-month periods.

In contrast, the town well #10 (Fig. 5) shows significant fluctuations in water levels (as much as 9 ft), from late winter through early summer. This is also the period of greatest precipitation and, therefore, greatest recharge in the area (Figs. 6 and 7). Similarly, the chloride concentration and

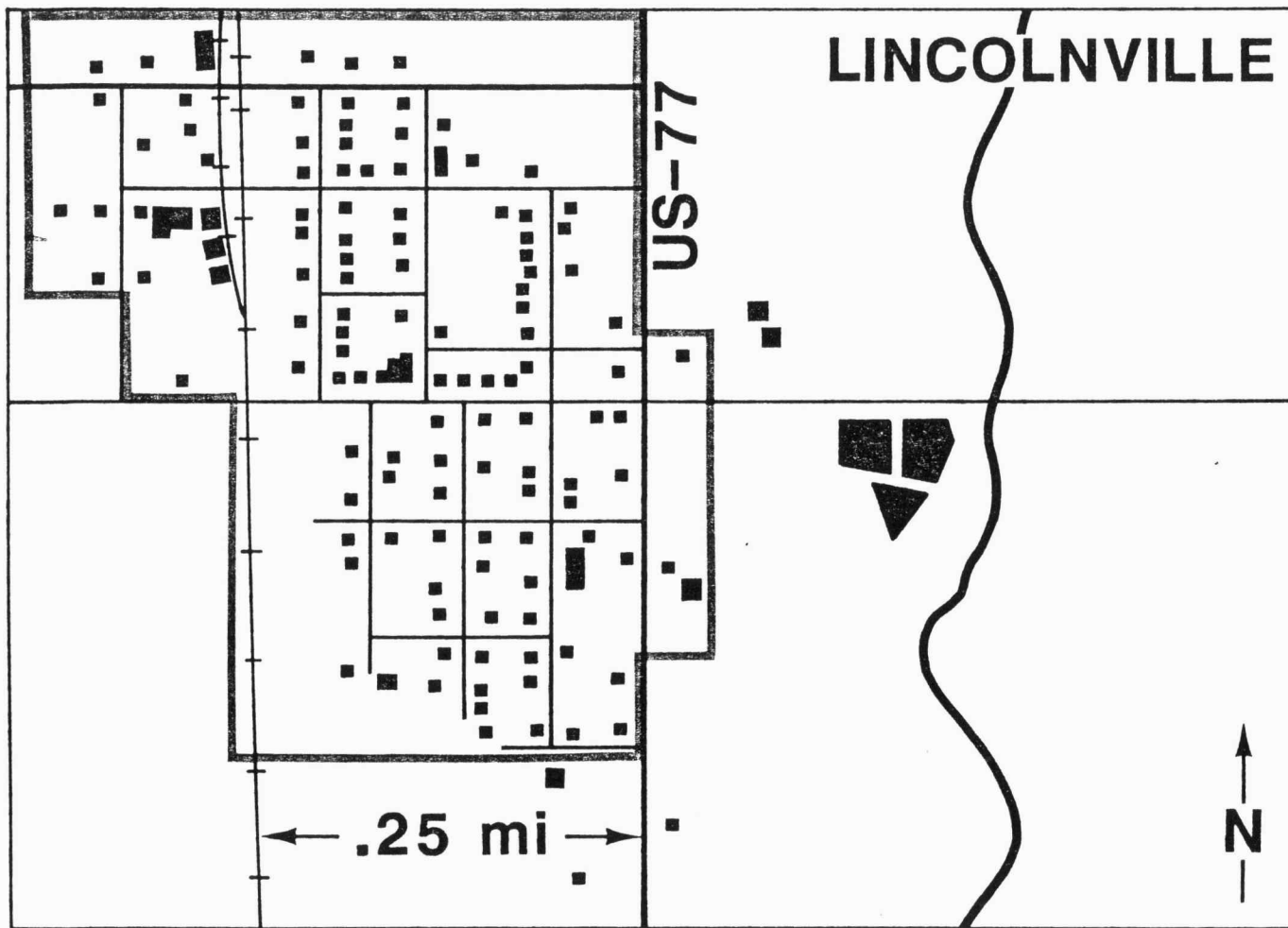
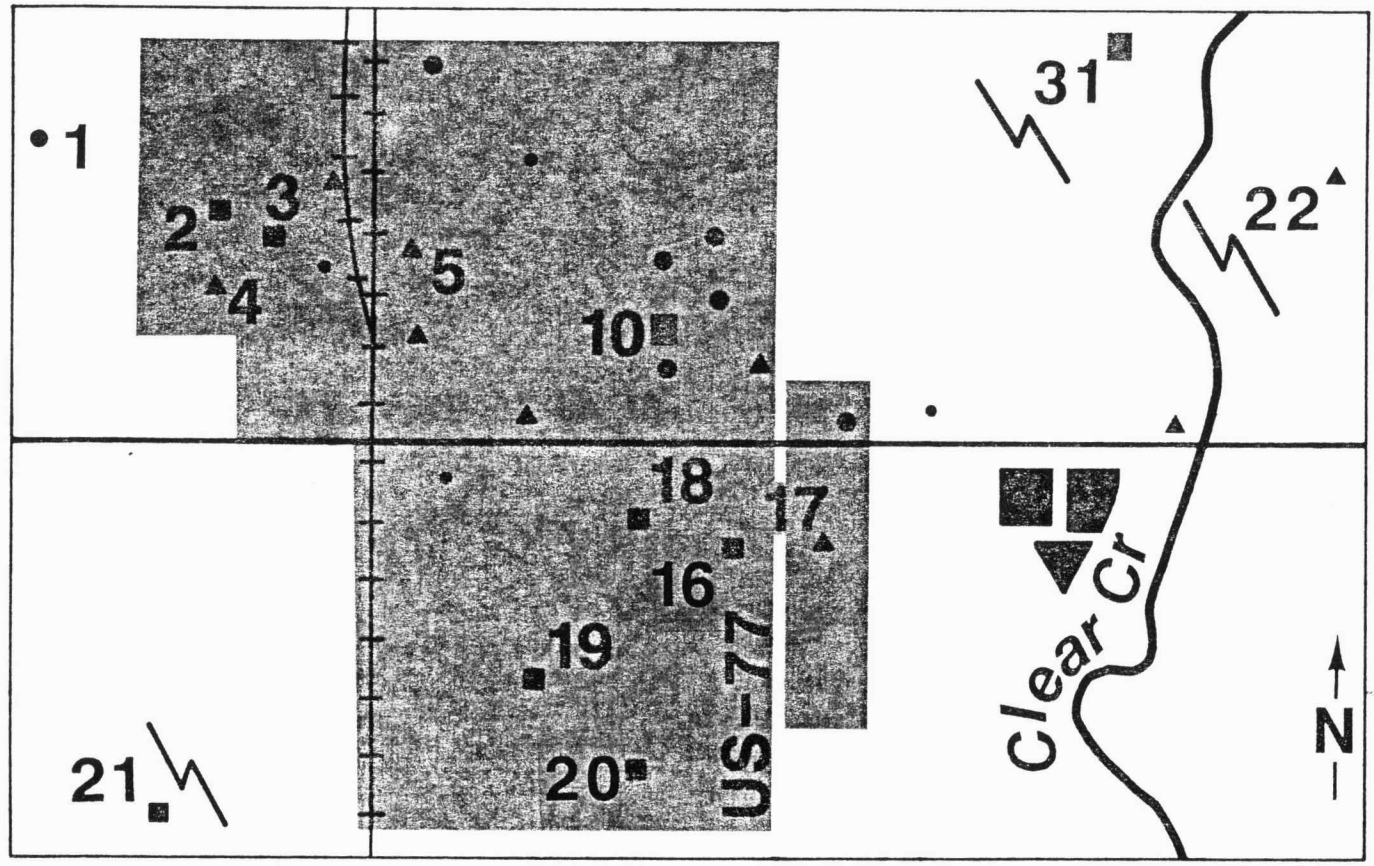


Figure 2. Map of Lincolnville showing cultural features.



samples/year

• 1-2 • 3-5 ▲ 6-11 ■ monthly ■ obs well 1981-84

Figure 3. Map of Lincolnville showing water wells used in study and sampling frequency.

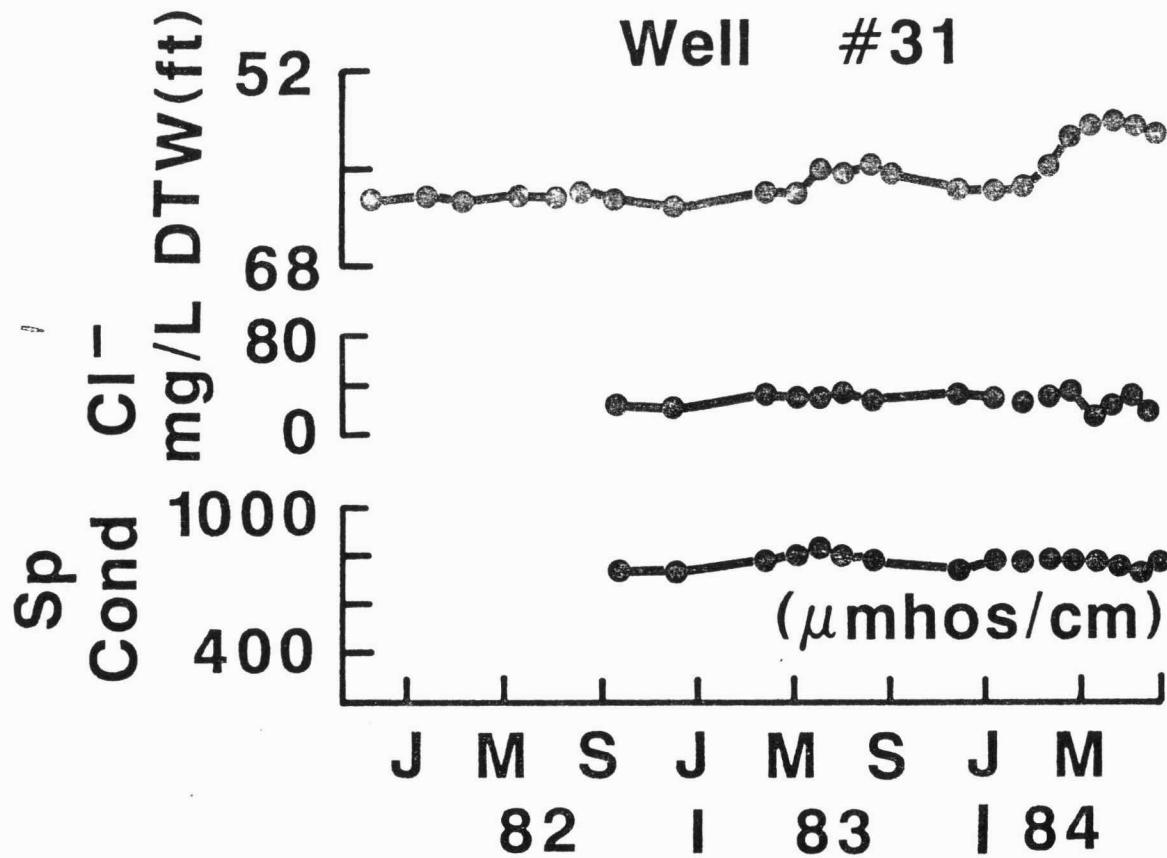


Figure 4. Hydrographs for well #31 showing depth to water (feet below land surface), chloride concentration (mg/L), and specific conductance (umhos/cm @ 25° C).

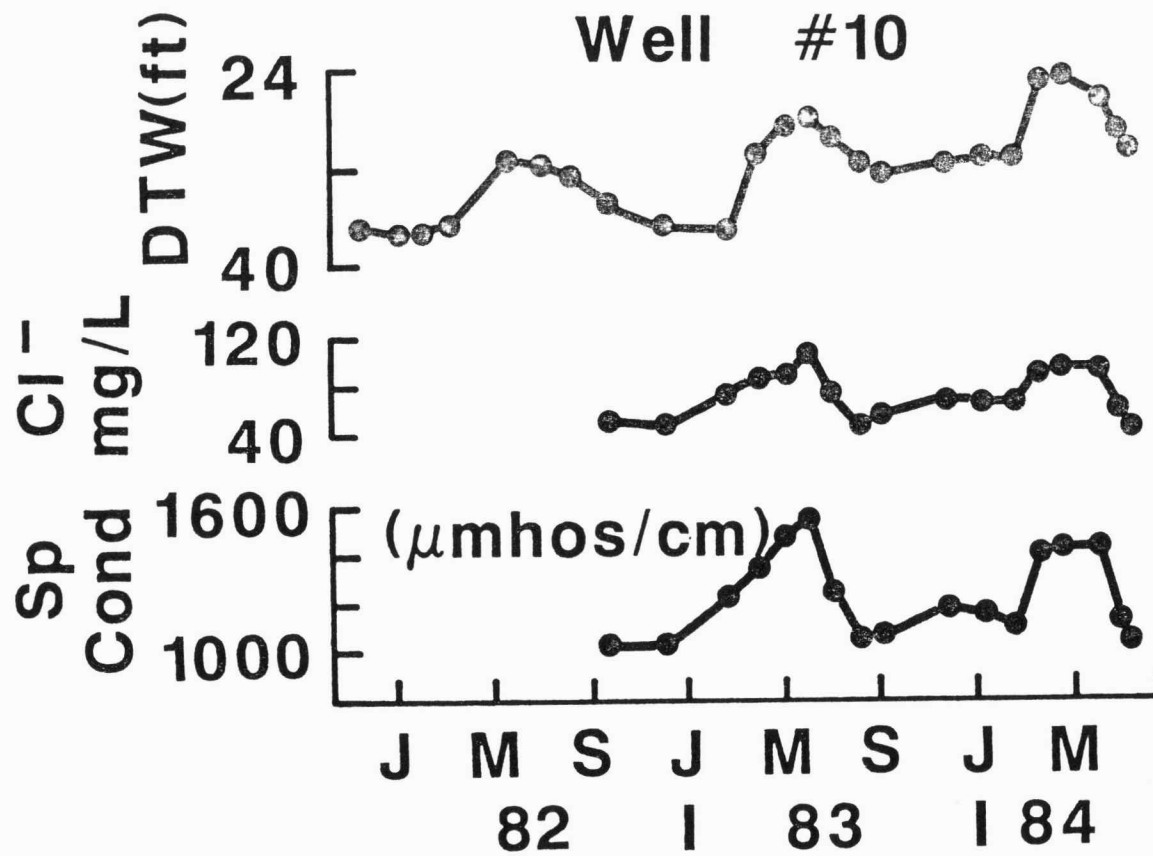


Figure 5. Hydrographs for well #10 showing depth to water (feet below land surface), chloride concentration (mg/L), and specific conductance (umhos/cm @ 25° C).

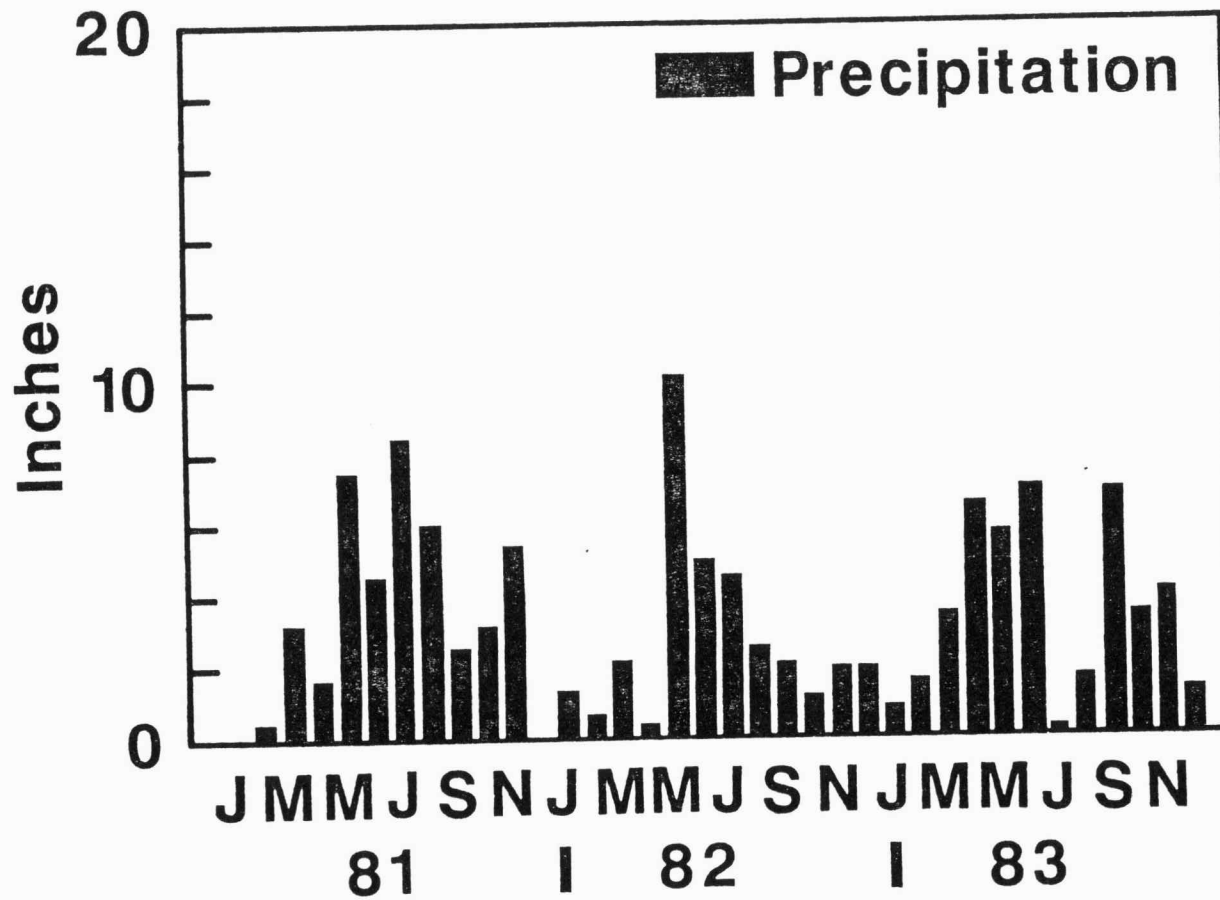


Figure 6. Precipitation in Lincolnville, Kansas 1981 - 1983 (inches).

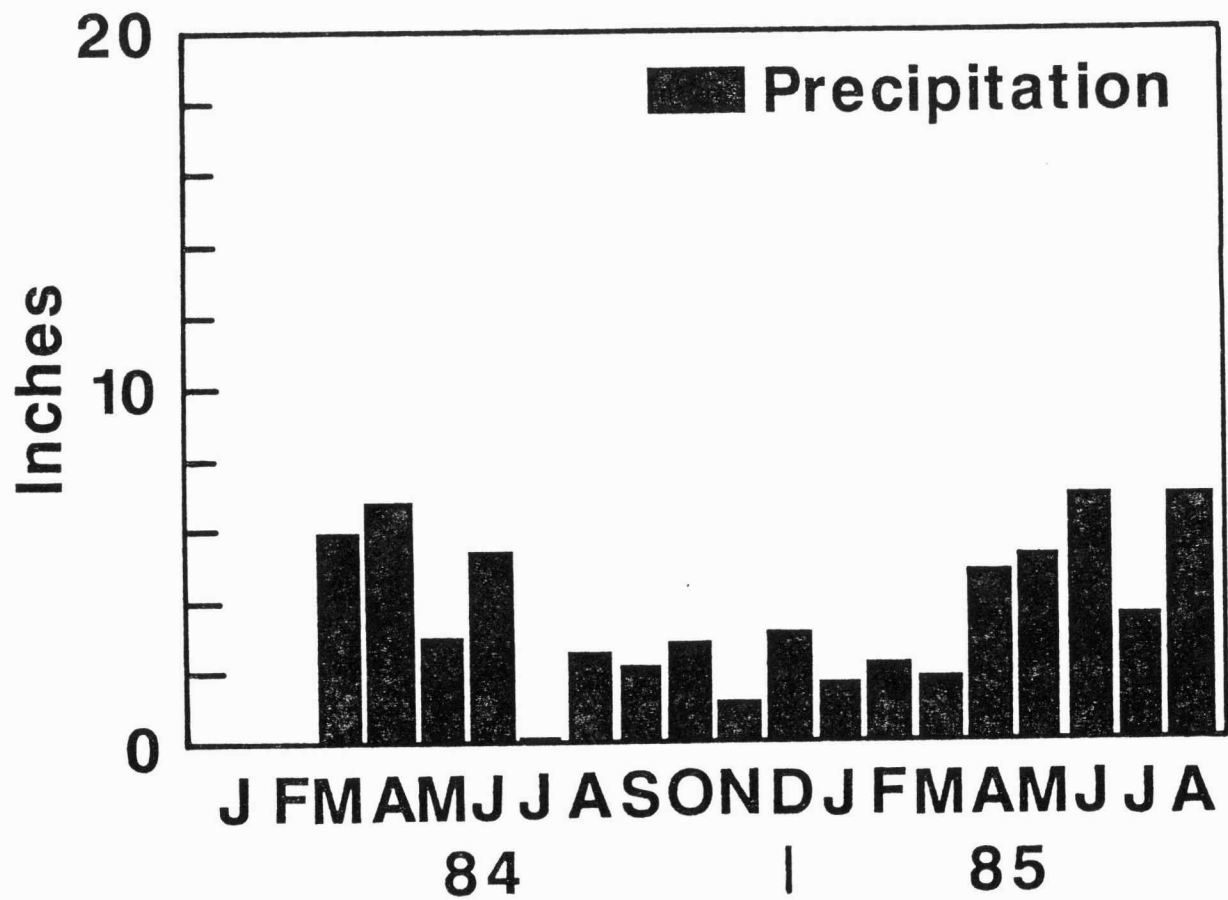


Figure 7. Precipitation in Lincolnville, Kansas 1984 through August 1985 (inches).

specific conductance increase significantly during the same period that the water levels are rising (Fig. 5). During the summer through fall/winter period, water levels, as well as chloride concentration and specific conductance, decline and become relatively stable.

We used the graphs for well #10 (Fig. 5) to select times for sampling for bacteriological, volatile and nonvolatile organic carbon, methane, and standard inorganic chemistry analyses in our one-year study. One sampling was in the rising water-level phase and another was in the declining water-level phase, in addition to the monthly samplings for chloride and nitrate concentrations and specific-conductance analyses.

An east-west geologic cross section through Lincolnville (Fig. 8) is represented by logs for wells #1, #4, and #10 (see figure 3 for location of wells). At the surface is a thin veneer of soil and weathered Wellington shale which overlies the Nolans Limestone which is about 30 ft thick. These are the surface rocks for both the town wells and the farm wells monitored in the study. The Odell Shale, about 20-40 ft thick, acts as a confining bed above the principal aquifer, the Winfield Limestone, which is about 35 ft thick and yields 10-50 gallons per minute to domestic wells. For wells within the town of Lincolnville, none of the drillers' logs indicates any ground-water contribution from the Nolans; however, early in the town's history, dug domestic wells obtained ground water from the Nolans.

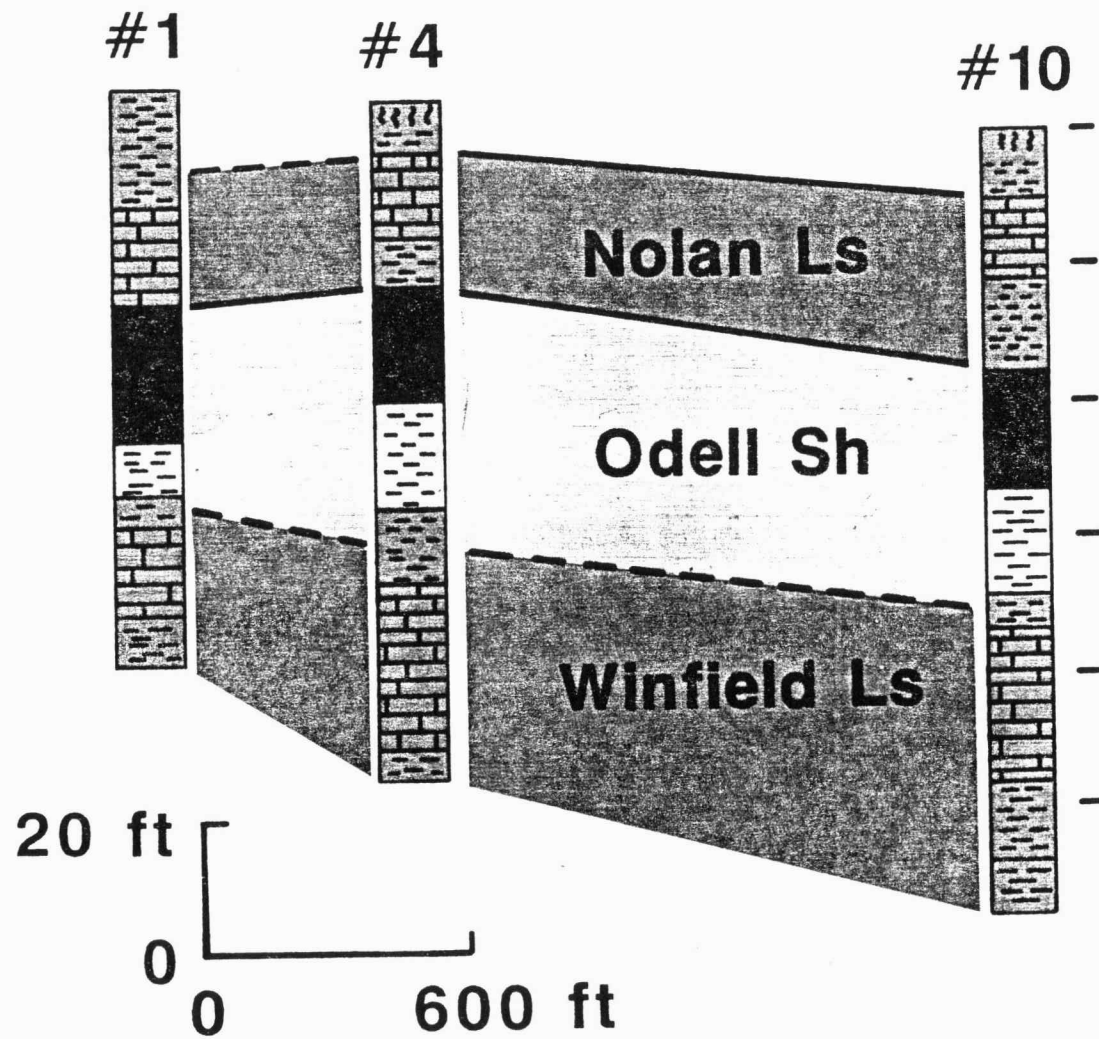


Figure 8. East-west geologic cross-section through Lincolnville, Kansas based on drillers' logs for wells #1, #4, and #10.

Before this project was initiated, we speculated as to why the chloride and specific conductance of our observation well #10 increased during the March-June period. This well (Fig. 9) was drilled in 1979 and met all the minimum-construction standards established in 1974 by the State of Kansas. One of the standards is a minimum of 10 ft of grout at the surface in the space between the inside of the drilled hole and the outside of the casing, or the annulus of the well. Our theories centered around the construction of well #10 and the fact that it was not grouted throughout the entire thickness of the Nolans Limestone. We speculated that this and many of the other town wells constructed in the same manner since 1974, act as drains each spring for movement of shallow Wellington and Nolans water to the underlying confined Winfield aquifer.

Also, the older (pre-1974) town wells generally are not well protected from shallow, easily contaminated water in that they are not grouted, whether the casing used is light-weight, screw-joint, galvanized steel; heavy oil-field iron; or plastic. The resulting downward drainage contributes to the large rise in water levels and change in water quality observed in many of the town wells. The galvanized steel casing (Fig. 10) is especially susceptible to corrosion and deterioration. We have observed old wells with holes in galvanized casing, tree roots growing through and hanging inside the casing, and shallow water entering the casing through holes or at casing joints.

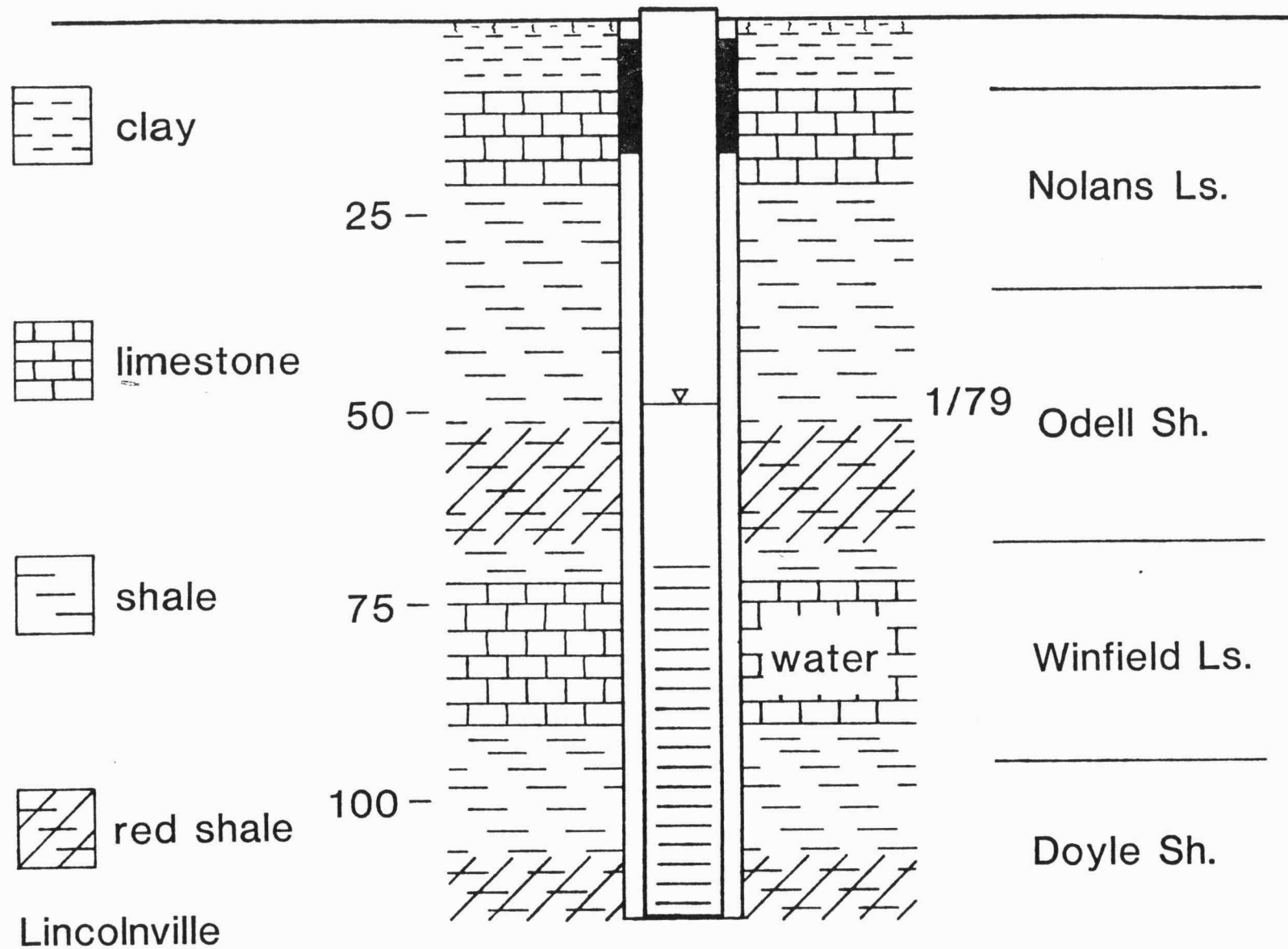


Figure 9. Cross-section showing well construction details for well #10 (vertical scale in feet).



Figure 10. Photo showing deteriorated galvanized steel casing that has been removed from a well.

In addition, completing wells in pits a few feet below ground surface (Fig. 11) was not uncommon. In time, seepage of water from saturated soil conditions that occur during wet periods fills the bottom of the pit to a point that the water can flow directly into the well (Fig. 12). This is supported by field observations of several wells in pits. We estimate that about one-fourth of the wells in Lincolnville are in unsanitary pits that allow the periodic downward drainage of contaminated water into the confined Winfield aquifer.

The more obvious potential sources of contaminants we could identify are shown in Figure 13. These include (as shown by letters), A) service stations and bulk petroleum-products storage, B) bulk and bagged fertilizer-handling facilities, C) farm-chemical (herbicides and pesticides) tank-mix areas, D) grain elevators, E) garage-machine shop, F) car wash, G) sewage treatment lagoons, H) livestock pens, and I) the highway that has deicing salts applied to it in winter. Not shown are abandoned dug or drilled wells, trash-burning sites, fertilized lawn and garden areas, and former privies, septic tanks, and lateral fields, any of which could be potential sources of contamination. Stream gaging on Clear Creek has shown it to be a gaining stream and, therefore, not a contaminant source.

In the area of the service stations near the highway, leakage of fuel in the past has been reported and some wells in the vicinity have been contaminated. In the area of the fertilizer and farm-chemical storage and handling facilities, spillage has been observed.

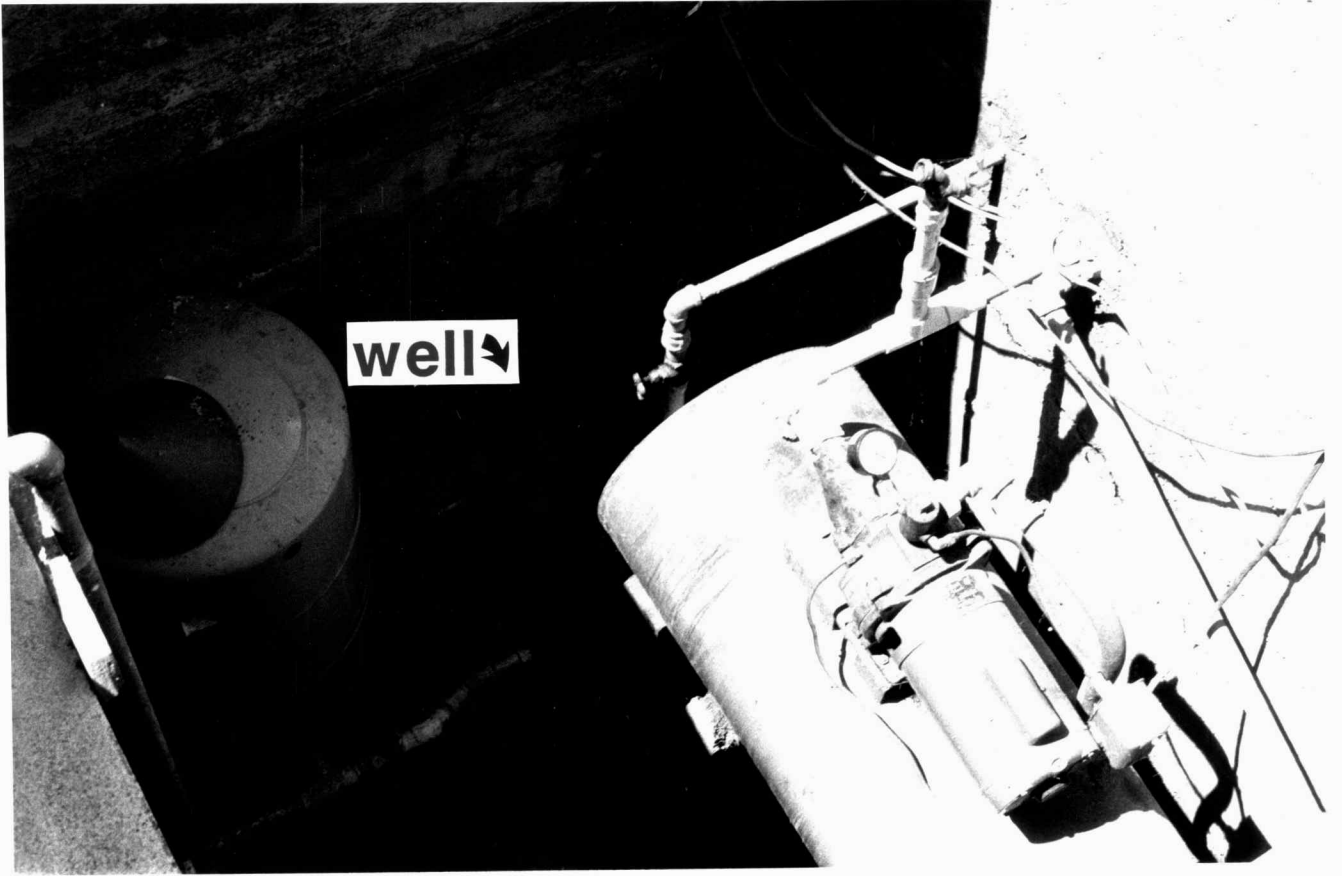


Figure 11. Photo showing well in pit.

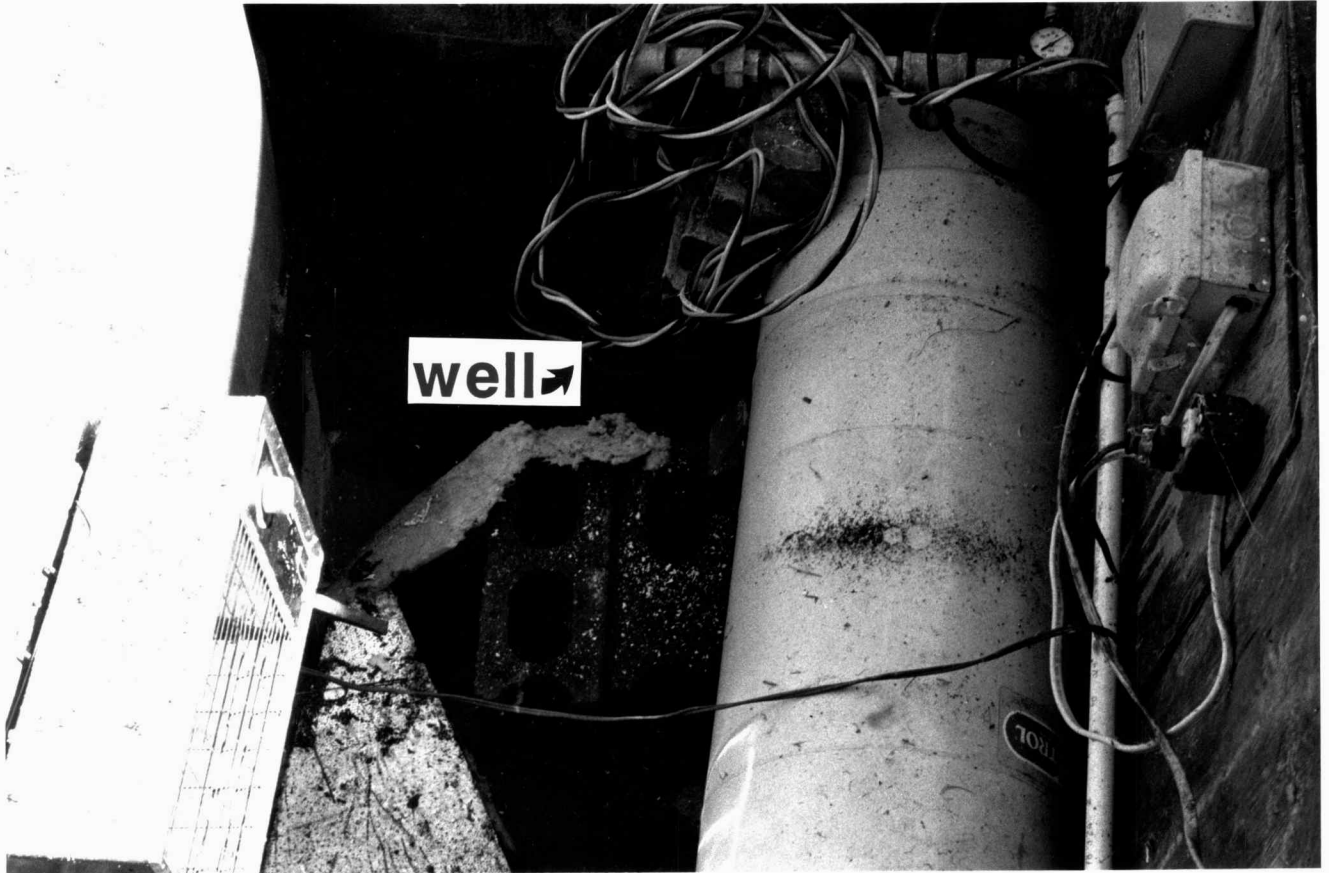


Figure 12. Photo showing well in pit.

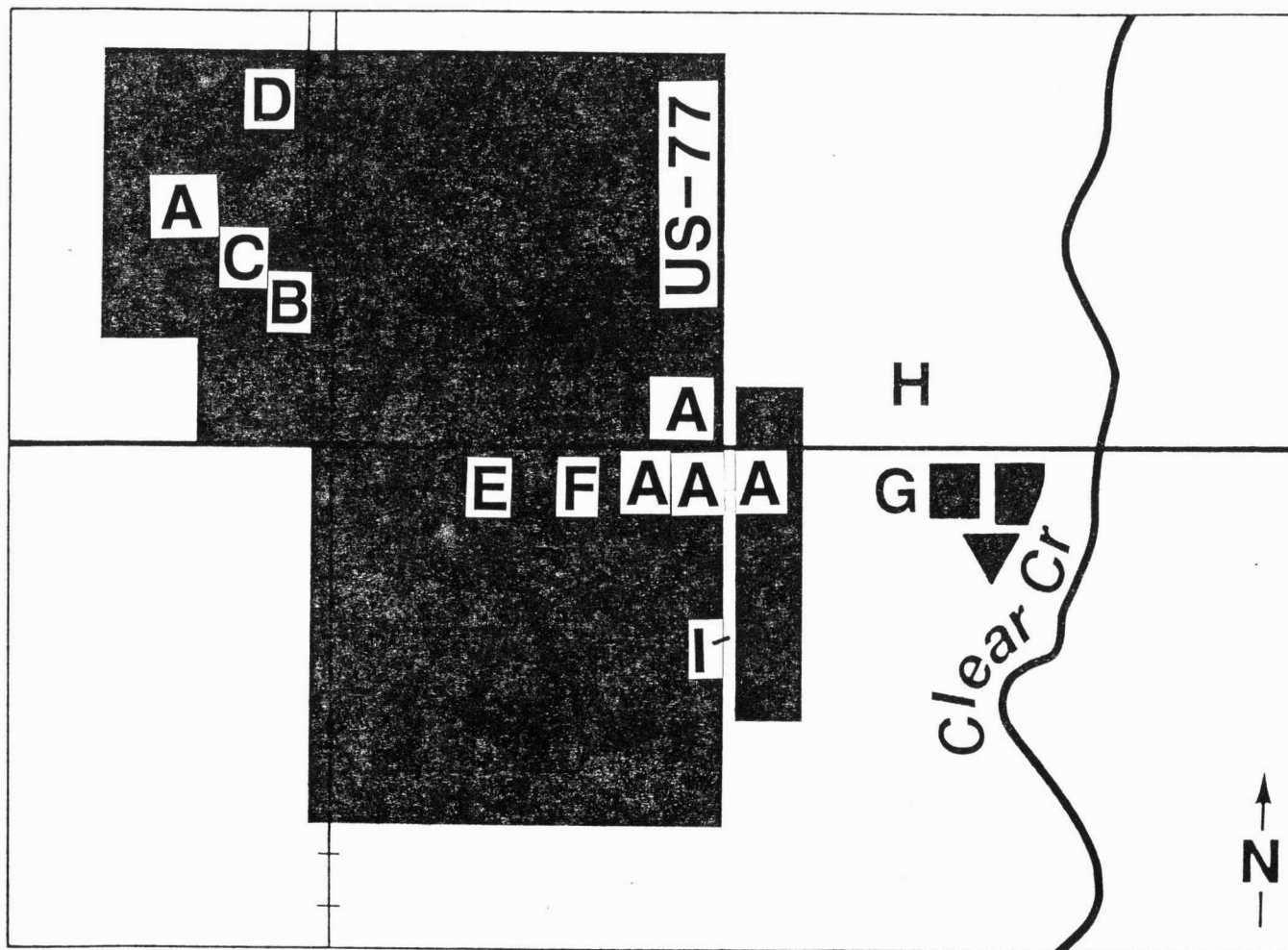


Figure 13. Location of potential sources of contamination identified in Lincolnville, Kansas.

Looking again at Figure 3, we see the seven wells in town (including well #10) and a farm well three-quarters of a mile south, well #21, that were selected to be monitored on a monthly basis for chloride and nitrate concentrations, specific conductance, and water level. These wells were also sampled twice for analysis of fecal bacteria, volatile and nonvolatile organic carbon, and standard inorganic chemistry. We also continued to monitor the farm well 6 mi north (#31) on a monthly basis.

Additional wells in areas of interest were added later but sampled less frequently, including farm well #22, which is about two-thirds of a mile east of town, and wells #4, #5, and #17 in town. Note the location of wells #2 and #4, which are west of the fertilizer and farm-chemical mixing facilities, and well #5 which is east of the these facilities. A well at the facilities (Fig. 14) was sampled several times, and the nitrate concentration of the water ranged from 250 mg/L to more than 600 mg/L as NO₃. Water-quality hydrographs for wells #2, #4, and #5 show the effects of the activities at the facilities.

Also note the location of well #17, which is in the vicinity of service stations and bulk-fuel storage. Within months of being drilled, well #17 became contaminated with a petroleum product. The driller reconstructed the well grouting to a depth of 35 ft. We will look at the water quality of this well and two other wells, #18 and #19.

First we will look at the farm wells outside of town: well #21 (south), well #22 (east), and well #31 (north). Figure 15

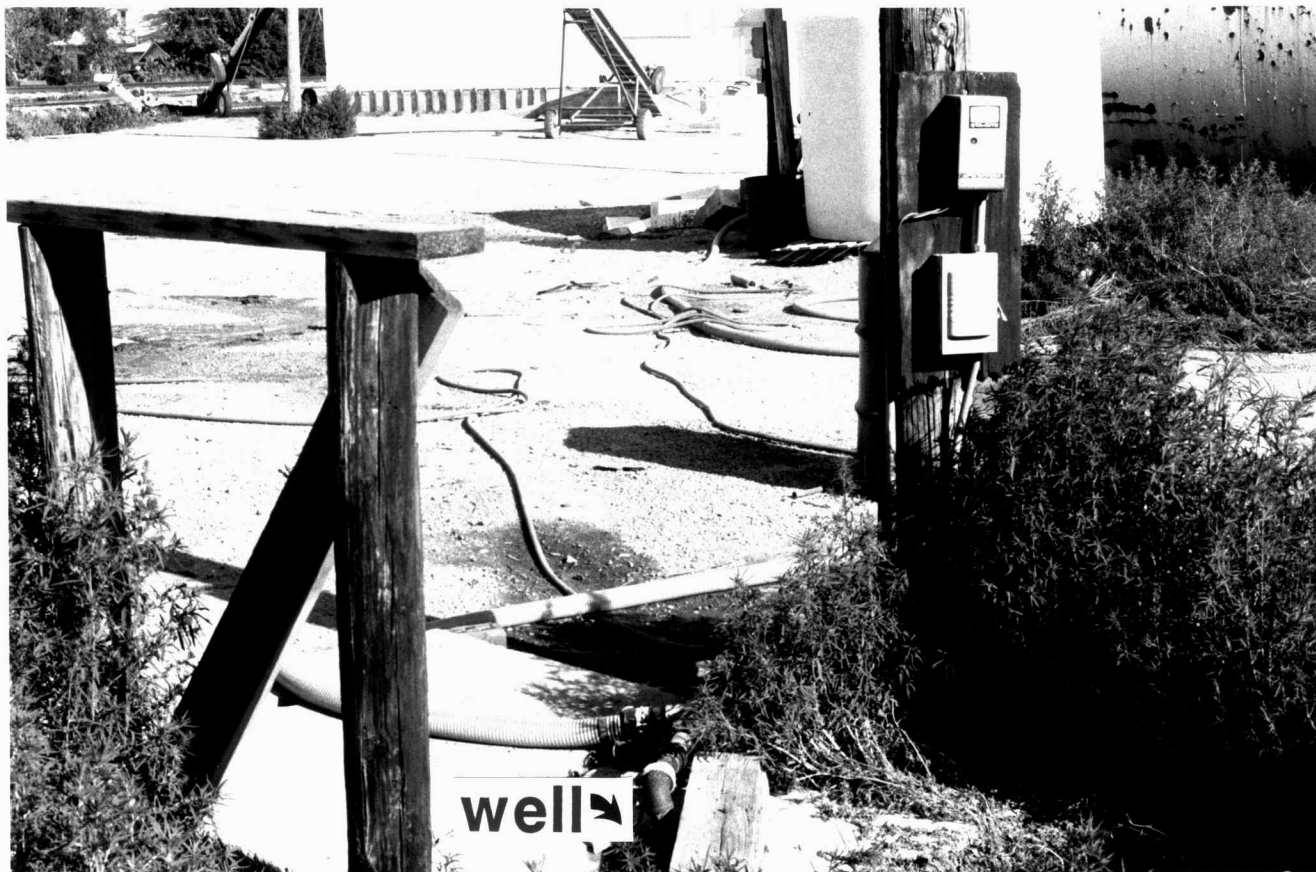


Figure 14. Photo of well at bulk fertilizer storage and farm chemical tank mixing facilities in Lincolville, Kansas.

shows specific conductance of water samples collected from the farm wells for the one-year period. The specific conductance of water from these wells fluctuates very little. Wells #21 and #31 show slight declines in the summer through winter period and then slight increases of not more than 100 $\mu\text{mhos/cm}$ in the late winter through late spring period. Well #22 hardly changes at all from winter to summer.

This same pattern can be seen in the chloride concentration of the water from these wells (Fig. 16) and the nitrate concentrations (Fig. 17). The nitrate concentrations vary generally less than 10 mg/L as NO_3 for all three wells with the exception of the September value for well #21, which cannot be explained at this time. The recommended limit of nitrate in water for public-water supplies in Kansas is 45 mg/L (as NO_3).

Looking at the water levels in the farm wells (Fig. 18), we see water-level fluctuations of 5-8 ft. Note the gradual decline in water levels from summer through late winter/early spring, then a slight rise through early summer in all three wells.

Now if we compare these wells to the town wells we will see a significant contrast. Figure 19 shows the specific conductance of water from wells #2, #4, and #5 in the northwest part of town. Recall the location of these wells with respect to the fertilizer and farm-chemical mixing facilities. Wells #2 and #4 are to the west and well #5 is to the east of the facilities. Note the sudden decline of specific conductance in well #2 from July 84 to early fall, then a leveling off through early spring 1985. This uniformity in specific conductance can be seen in all

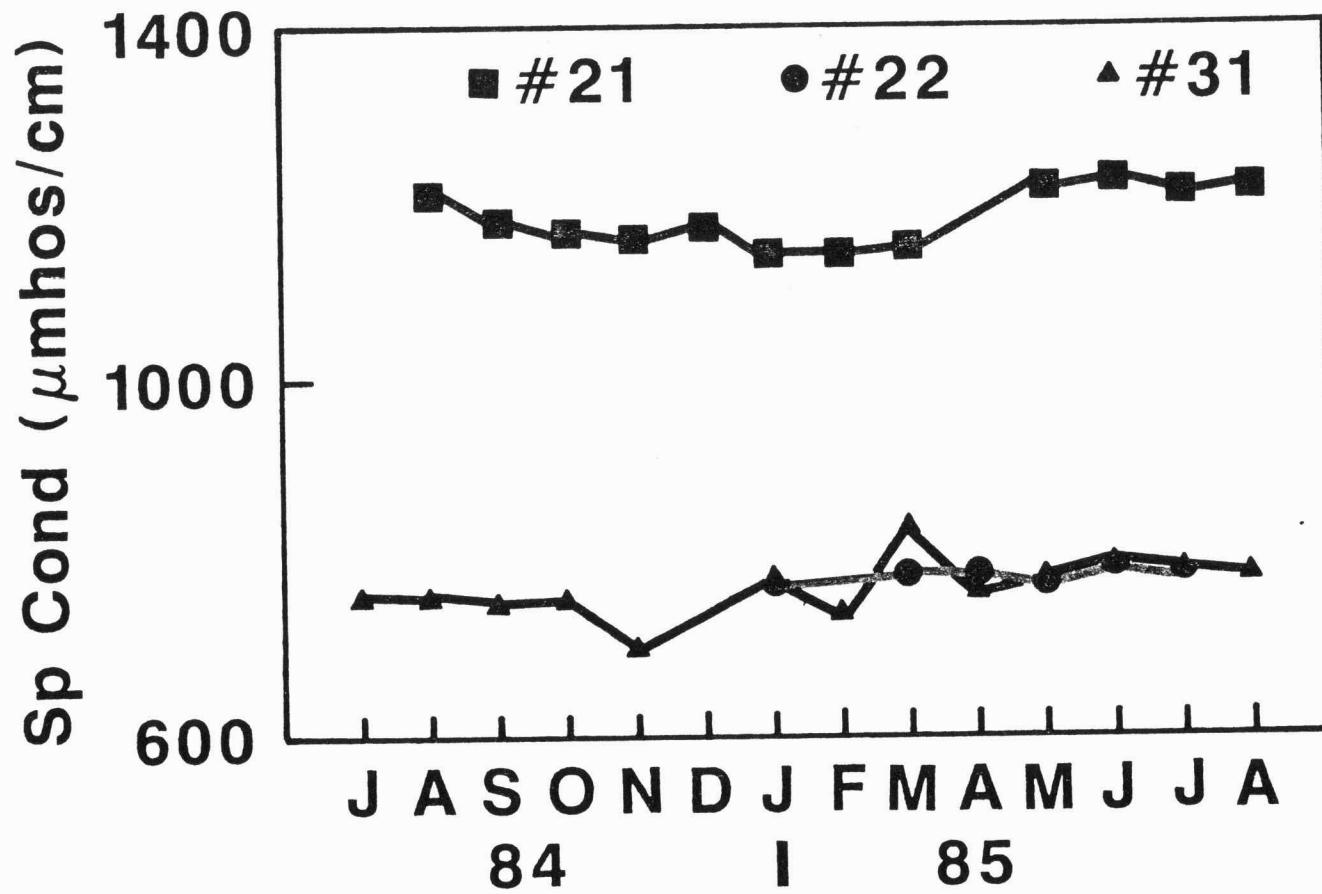


Figure 15. Hydrographs showing specific conductance of water from wells #21, #22, and #31 ($\mu\text{mhos/cm}$ @ 25°C).

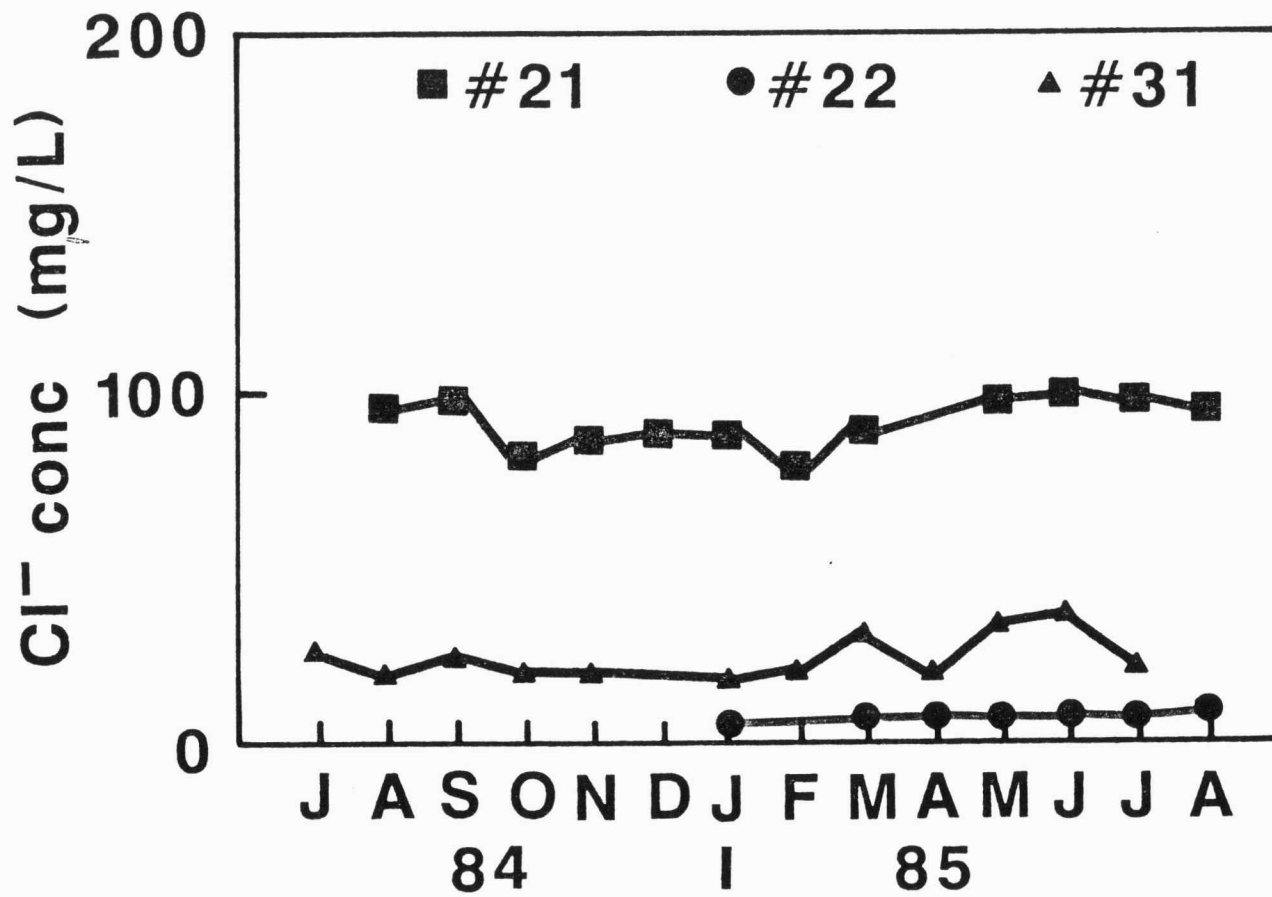


Figure 16. Hydrographs showing chloride concentration of water from wells #21, #22, and #31 (mg/L).

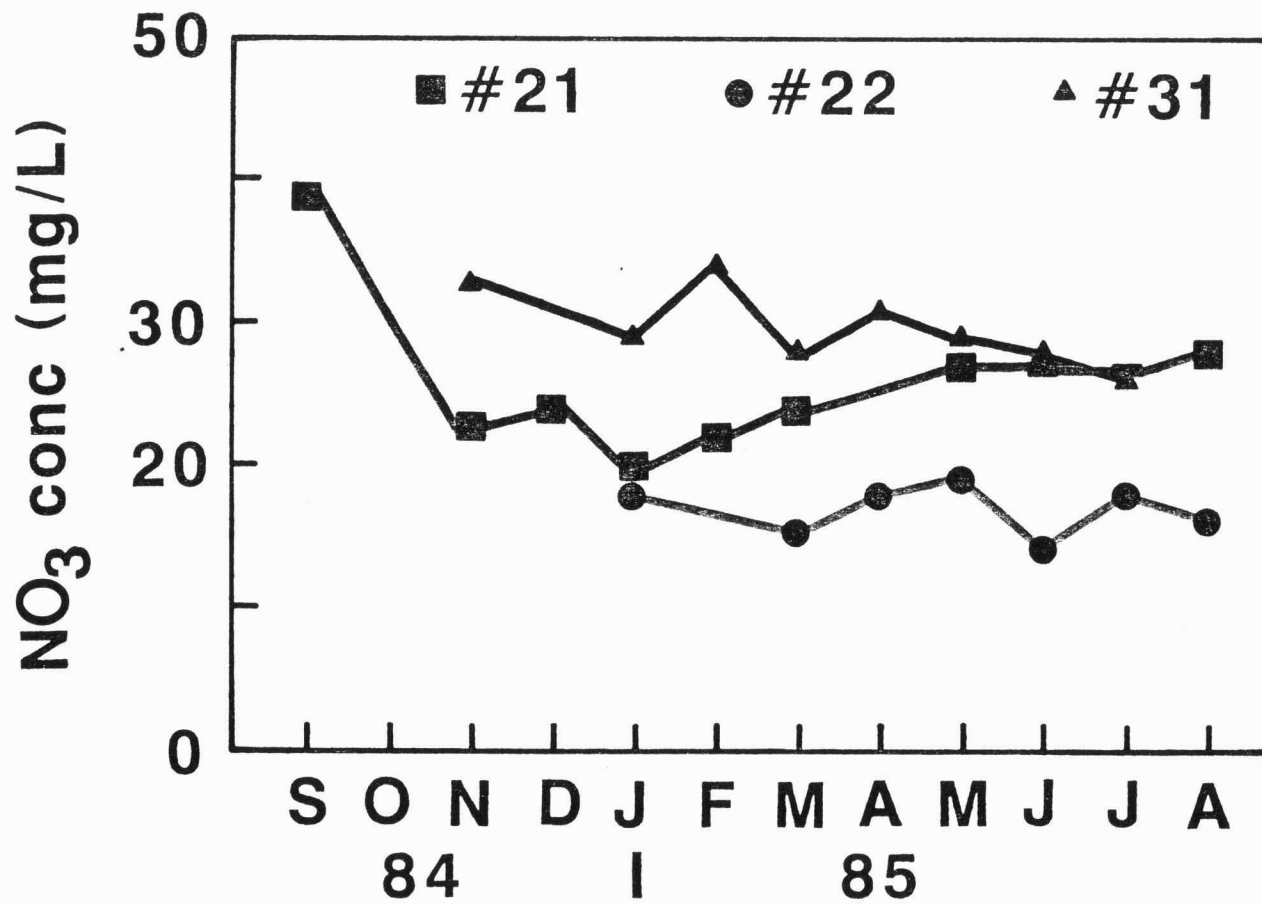


Figure 17. Hydrographs showing nitrate concentration of water from wells #21, #22, and #31 (mg/L as NO_3).

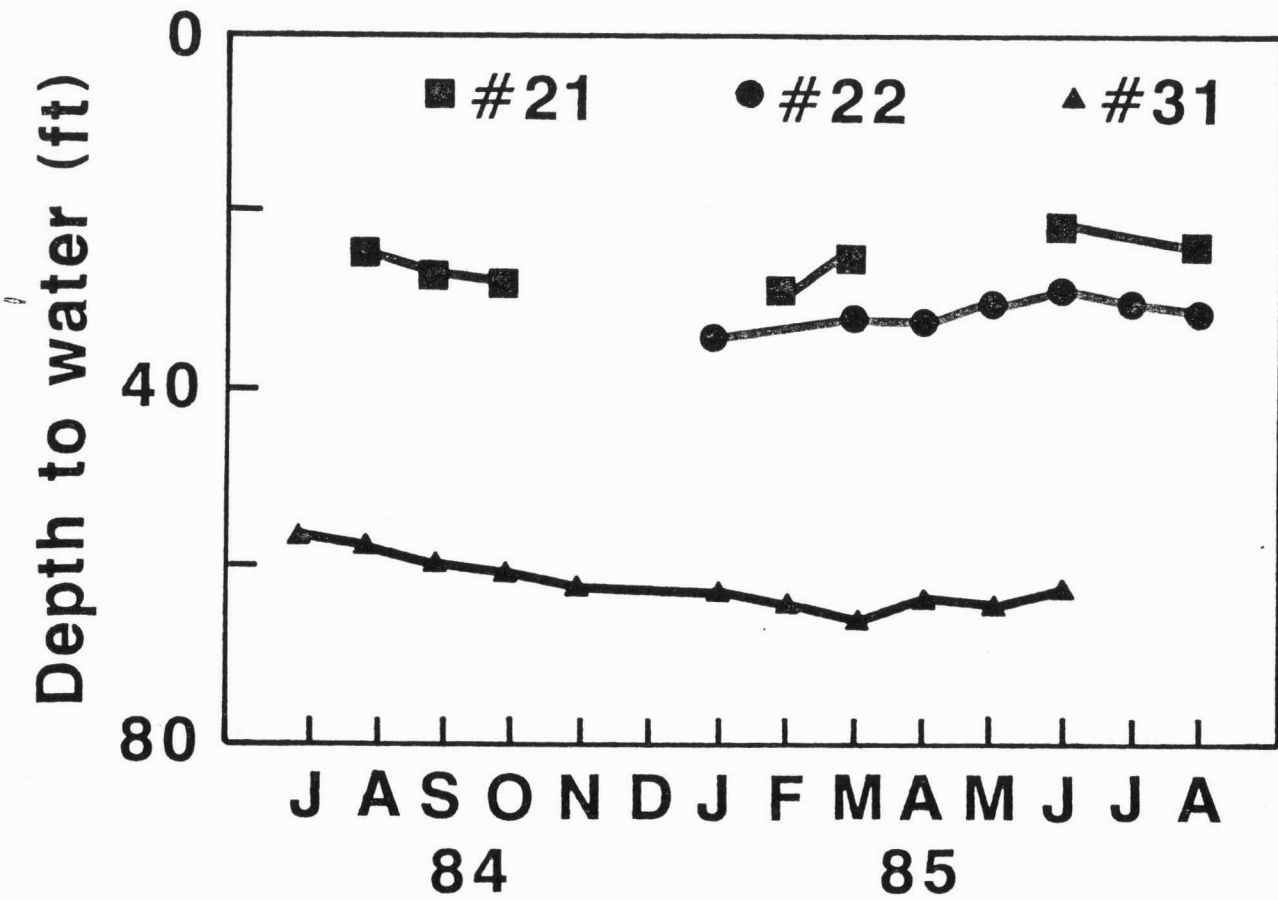


Figure 18. Hydrographs showing depth to water in wells #21, #22, and #31 (feet below land surface).

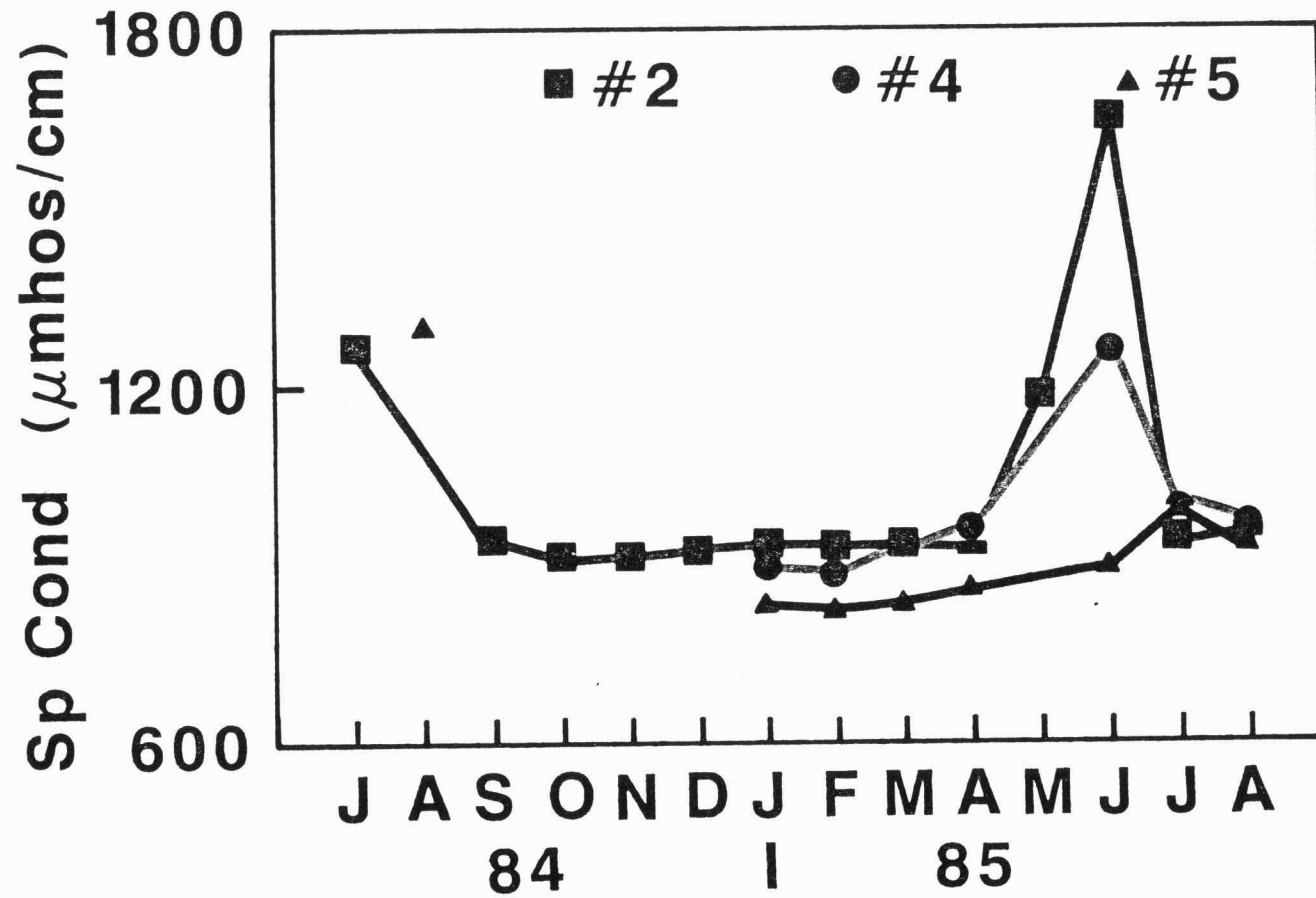


Figure 19. Hydrographs showing specific conductance of water from wells #2, #4, and #5 ($\mu\text{mhos/cm}$ @ 25°C).

three wells from winter to early spring. Wells #2 and #4 then show dramatic increases in only two-months time. Well #5 shows only a small increase with its highest conductance occurring one month later than those for wells #2 and #4.

This same pattern is very evident in the chloride (Fig. 20) and nitrate concentrations (Fig. 21). We believe these data show that a contaminated plume of ground water, known to exist at the fertilizer and farm-chemical mixing facilities, is moving to the west, showing up in wells #2 and #4 during the spring-recharge months.

Water levels in wells #2, #4, and #5 (Fig. 22) show fluctuations of 4-8 ft, which closely agree with those in the farm wells for the same time period. Again, the decline in water levels for summer to late winter is evident as is the rise through the spring months.

We will now look at three other town wells #17, #18, and #19 in the east and south part of Lincolnville (Fig. 3). Recall that well #17 is the well that had been reconstructed to prevent shallow, intermittent Nolans water, that had been contaminated by a petroleum product in that area, from draining downward through the annulus to the Winfield aquifer which it taps.

Looking at the specific conductance for these town wells (Fig. 23), we see that wells #17 and #18 fluctuate only very slightly throughout the year, but well #19 fluctuates significantly with a large increase in the spring months.

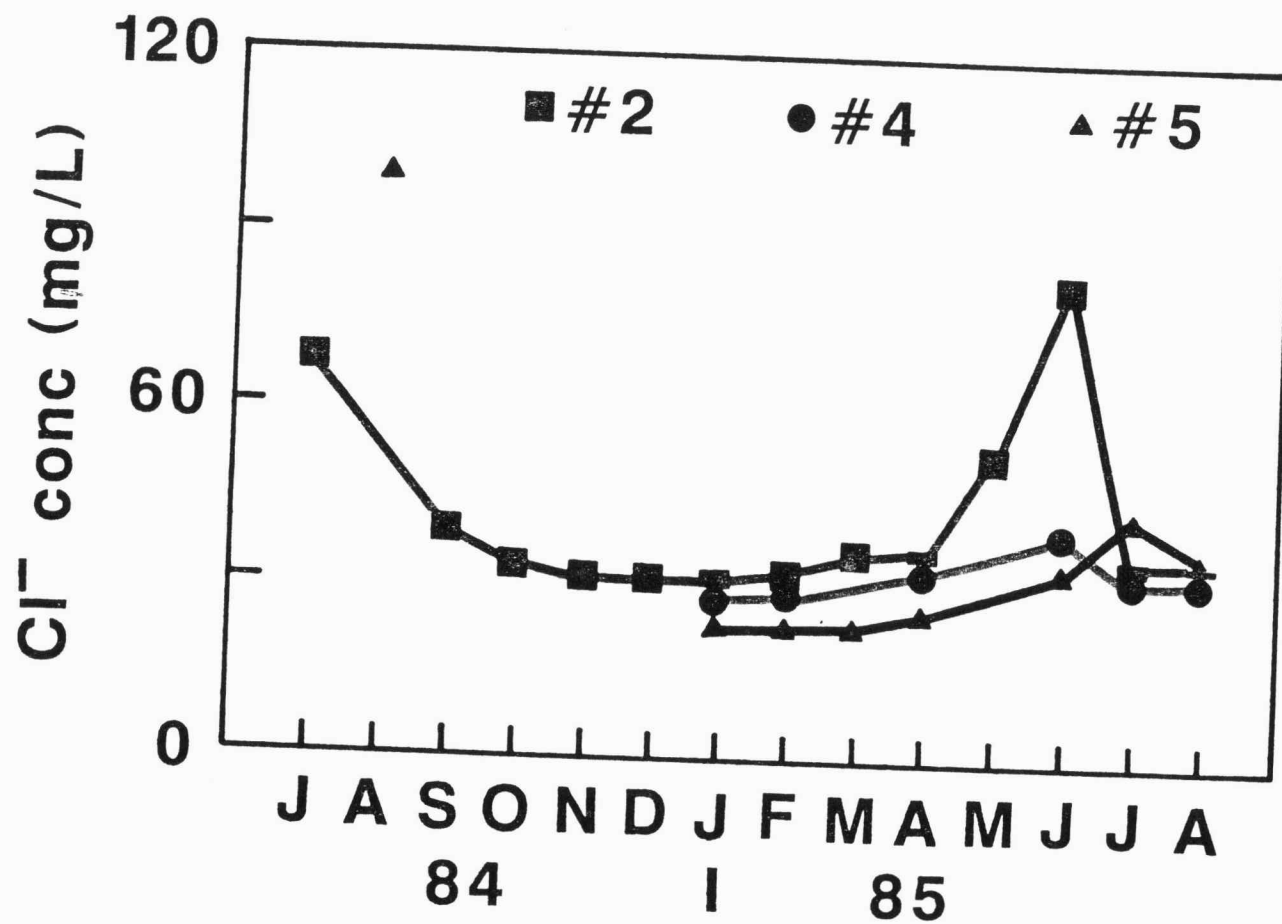


Figure 20. Hydrographs showing chloride concentration of water from wells #2, #4, and #5 (mg/L).

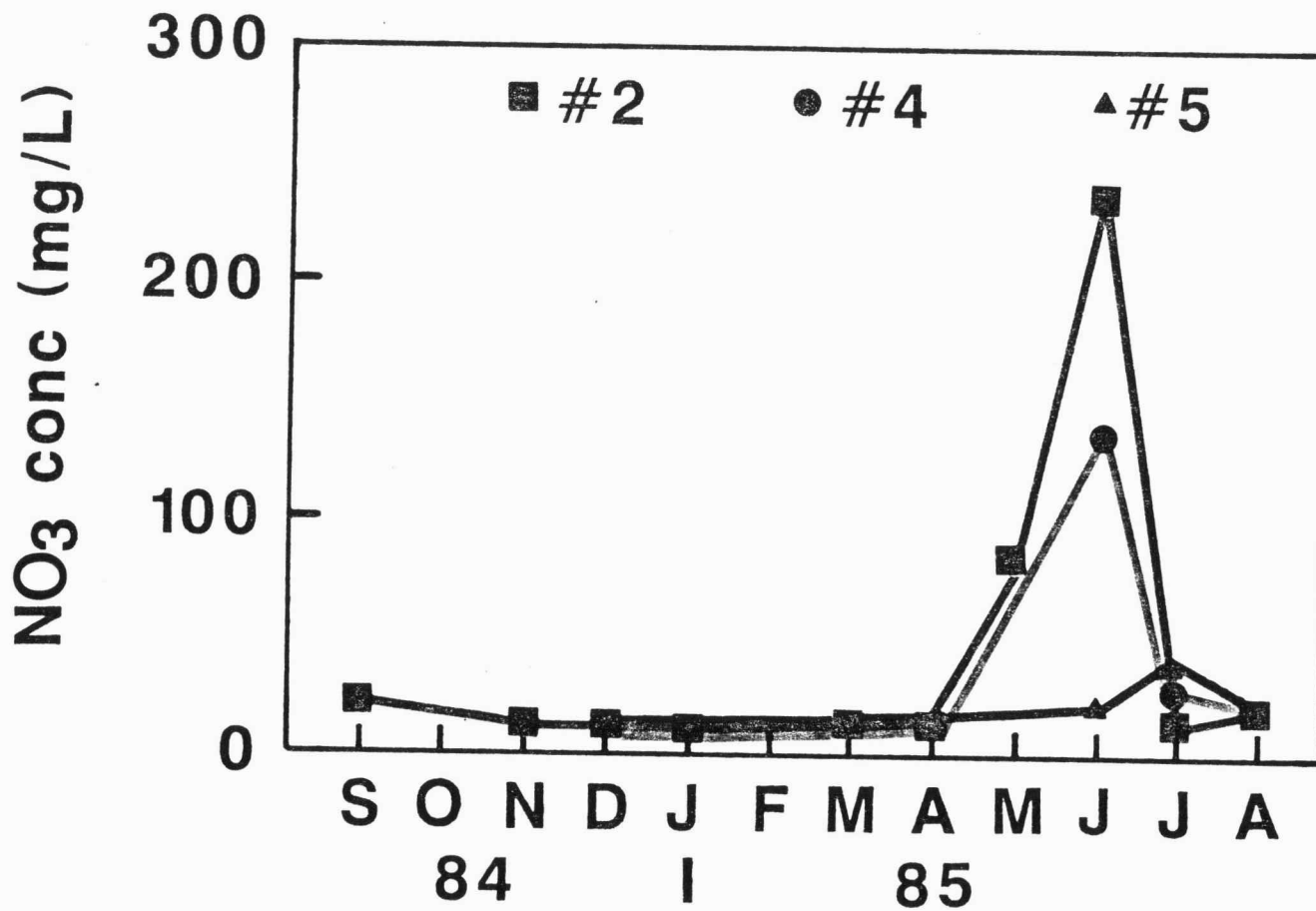


Figure 21. Hydrographs showing nitrate concentration of water from wells #2, #4, and #5 (mg/L as NO_3).

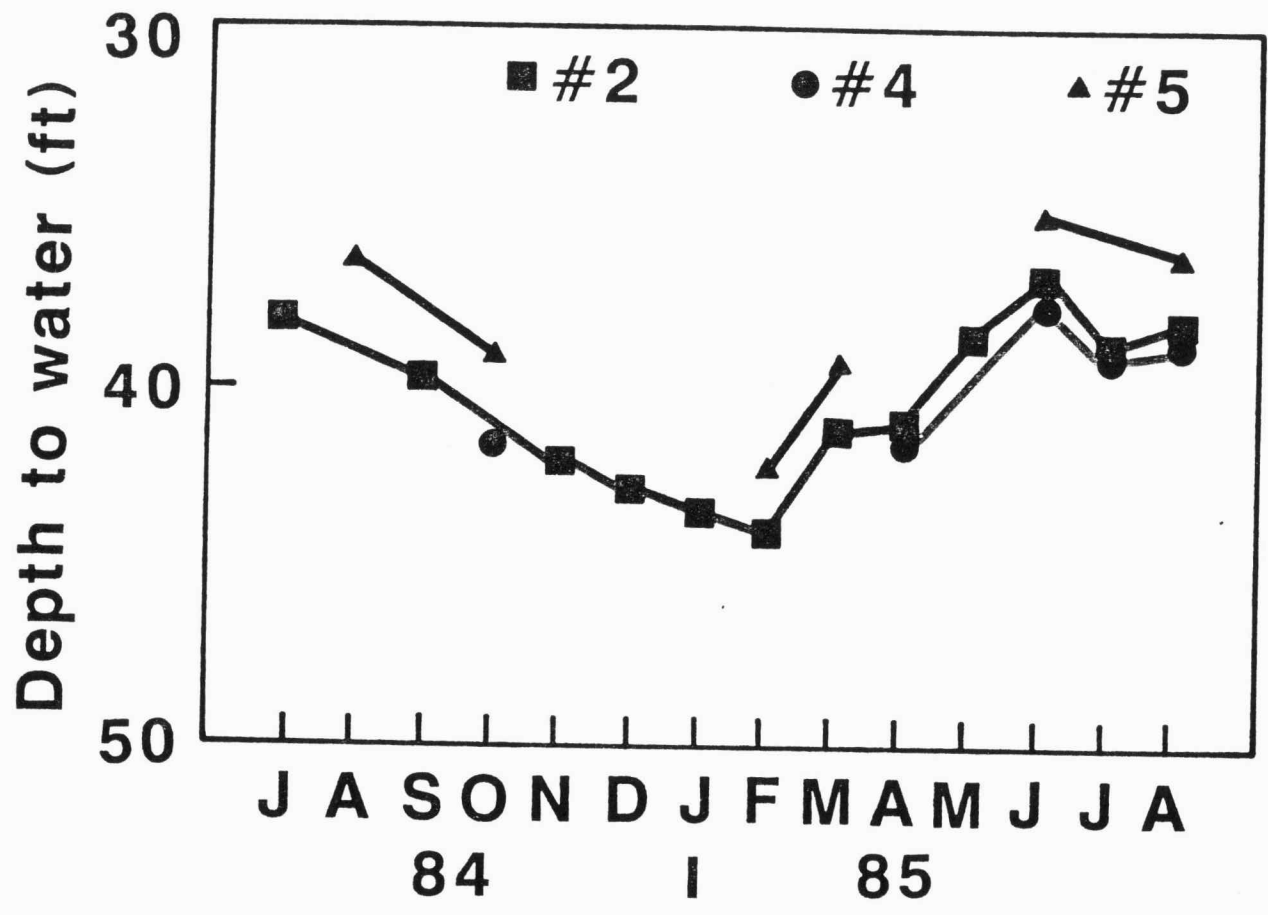


Figure 22. Hydrographs showing depth to water in wells #2, #4, and #5 (feet below land surface).

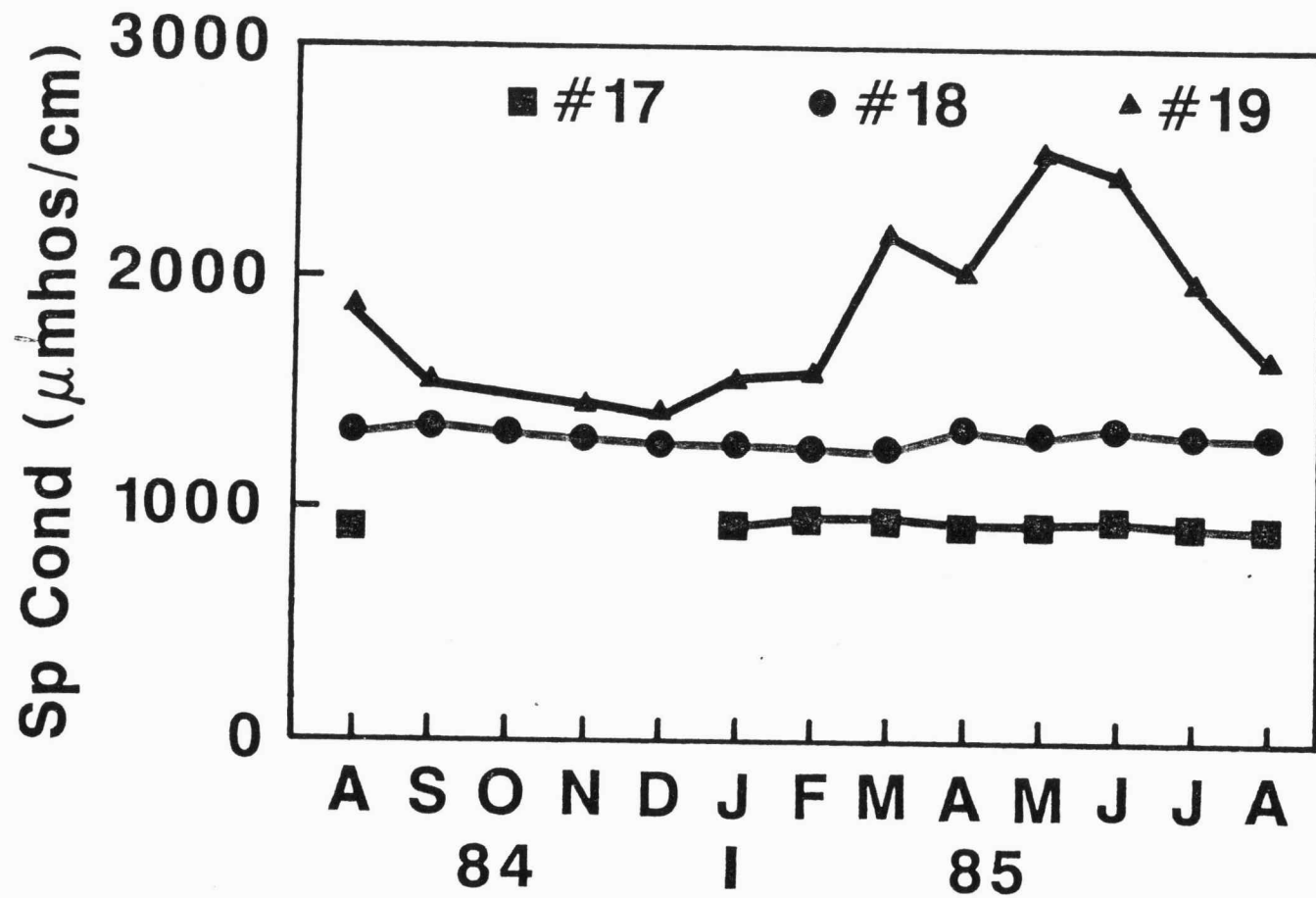


Figure 23. Hydrographs showing specific conductance of water from wells #17, #18, and #19 ($\mu\text{mhos/cm}$ @ 25°C).

The chloride concentrations for the wells show this same pattern (Fig. 24) with well #18 showing a little more fluctuation, well #17 hardly showing any, and well #19 showing a significant increase from the late winter to early summer period.

Again, the same pattern is evident in the nitrate concentrations in the wells (Fig. 25). We do not know the source of the increased water-quality constituents in well #19. They could be the result of a contaminated plume moving toward the well from an area that we did not identify or from the activities of the landowners at the well site, which include application of fertilizer and weed-control chemicals on lawn and garden areas.

Wells #18 and #19 (Fig. 26) show water levels rising in the spring and early summer months. Water-level measurements were not obtainable in well #17.

Samples were collected in December 1984 and May 1985 for examination of fecal coliform and fecal Streptococcus bacteria (Fig. 27). The examinations were performed by the Kansas Department of Health and Environment, and the results showed that essentially none of the town wells contained fecal bacteria in December (less than 5 counts per 100 ml). However, the farm well (#21) south of town contained some fecal Streptococcus bacteria. We learned after collecting that sample that a frost-proof hydrant without a check valve had earlier been connected by a garden hose to a stock tank and had back-syphoned half a tank of water into the well, potentially contaminating the well.

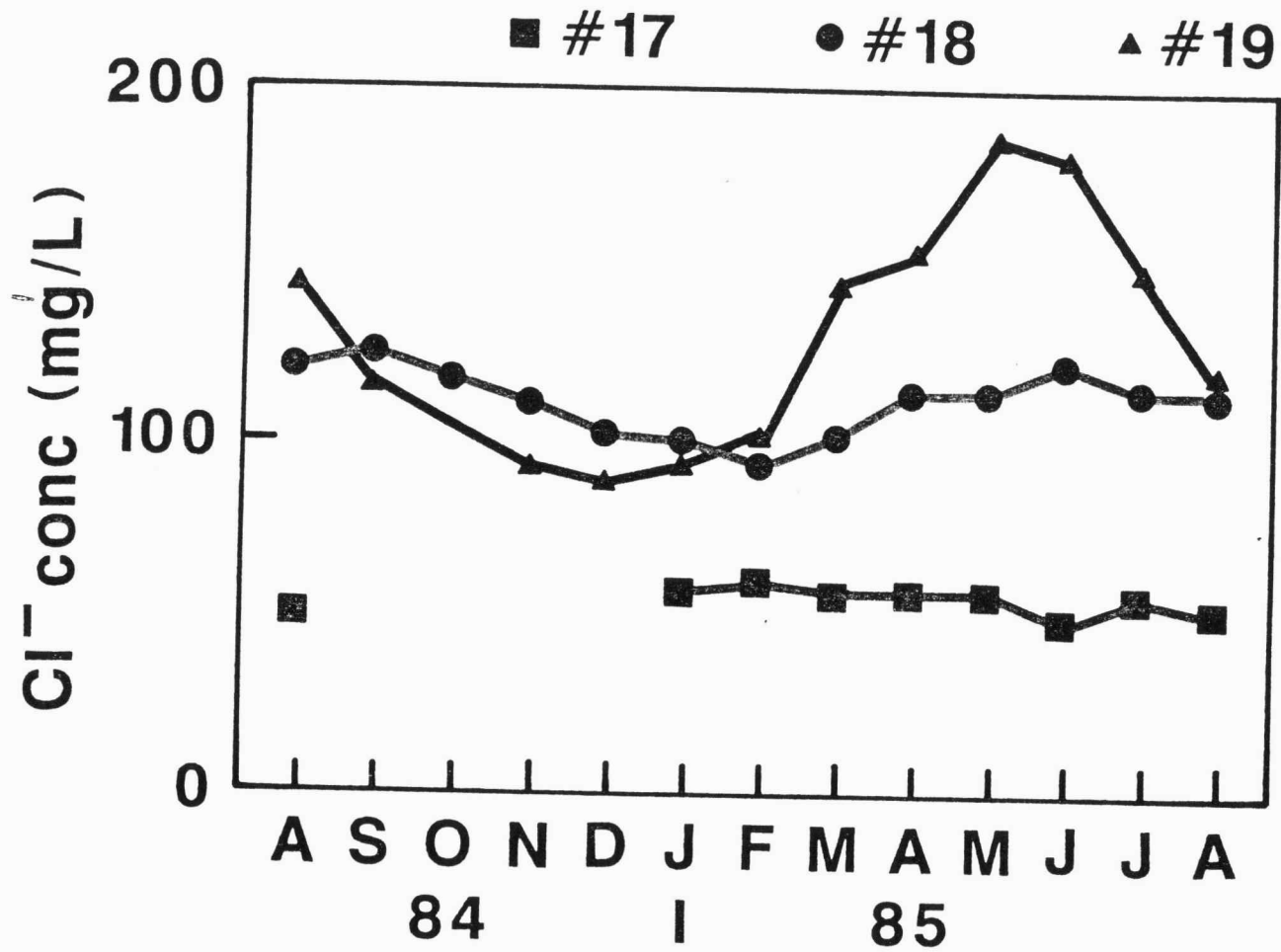


Figure 24. Hydrographs showing chloride concentration of water from wells #17, #18, and #19 (mg/L).

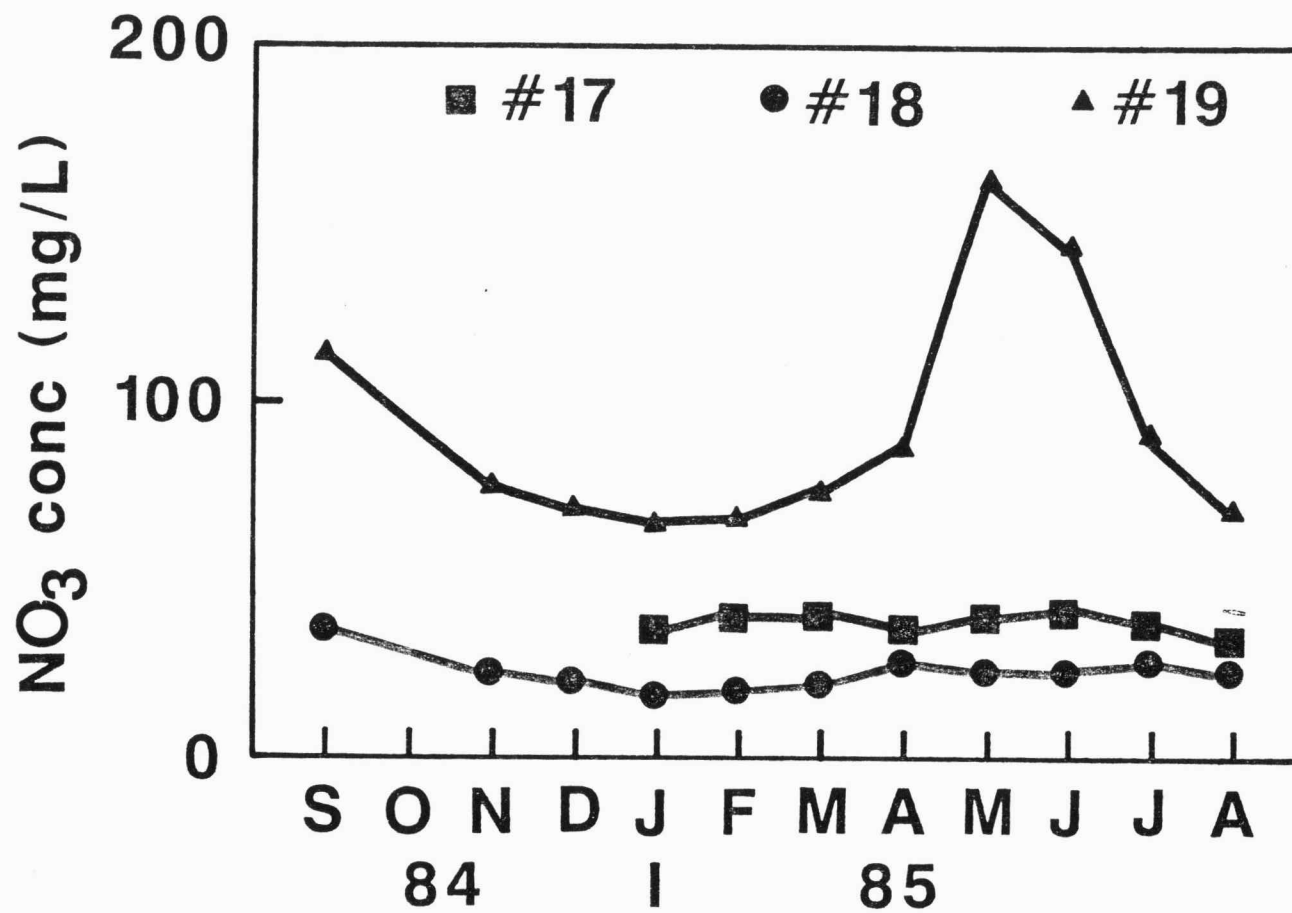


Figure 25. Hydrographs showing nitrate concentration of water from wells #17, #18, and #19 (mg/L as NO_3).

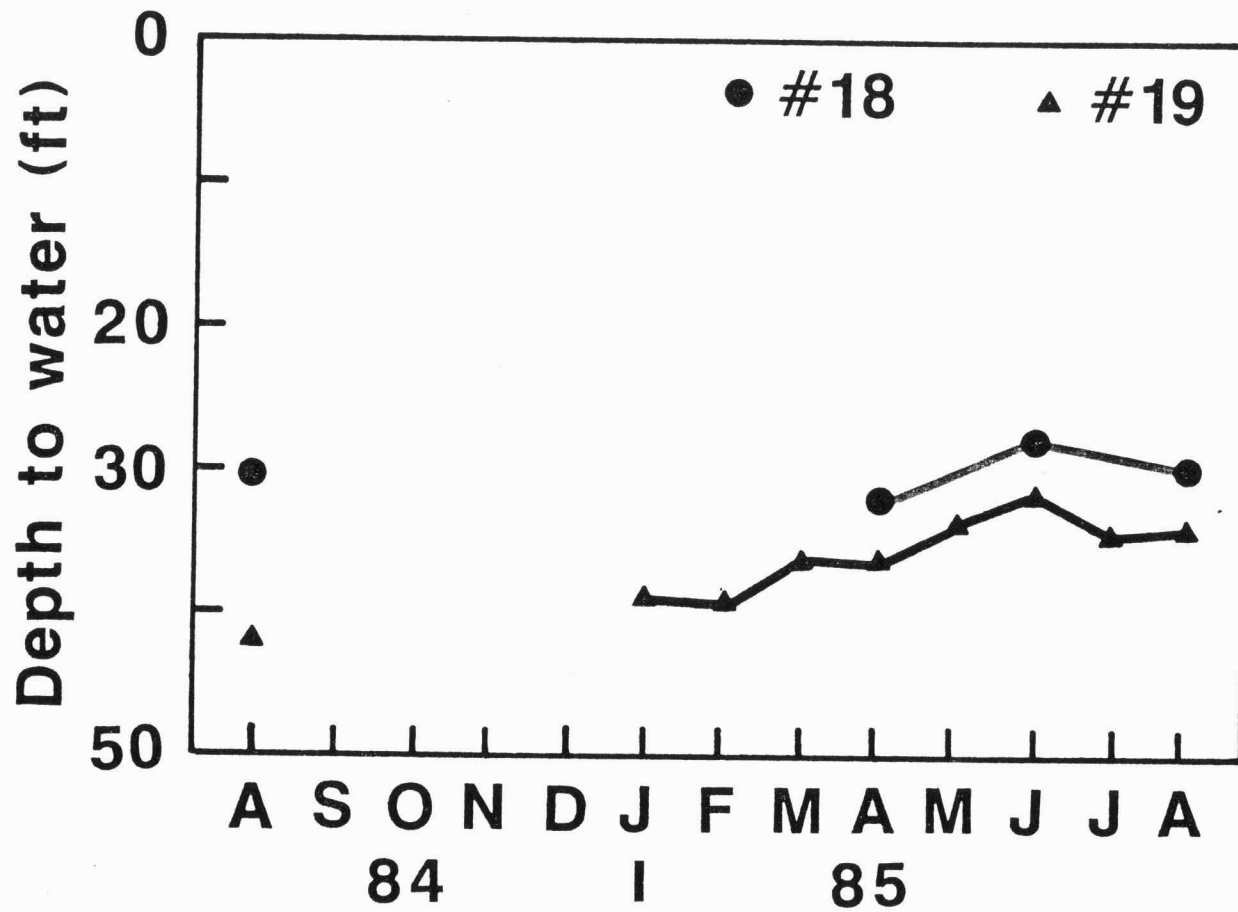


Figure 26. Hydrographs showing depth to water in wells #18 and #19 (feet below land surface).

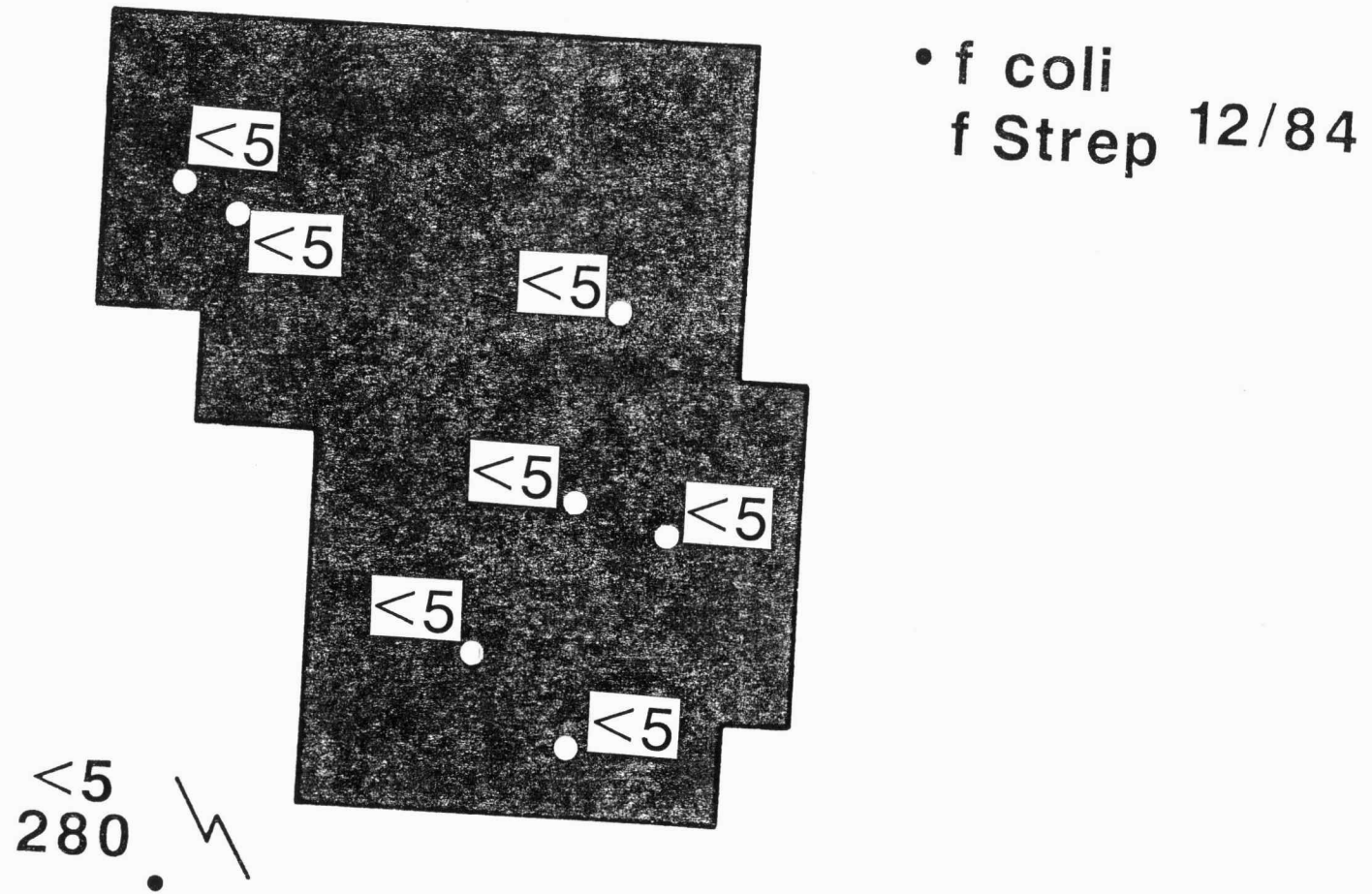


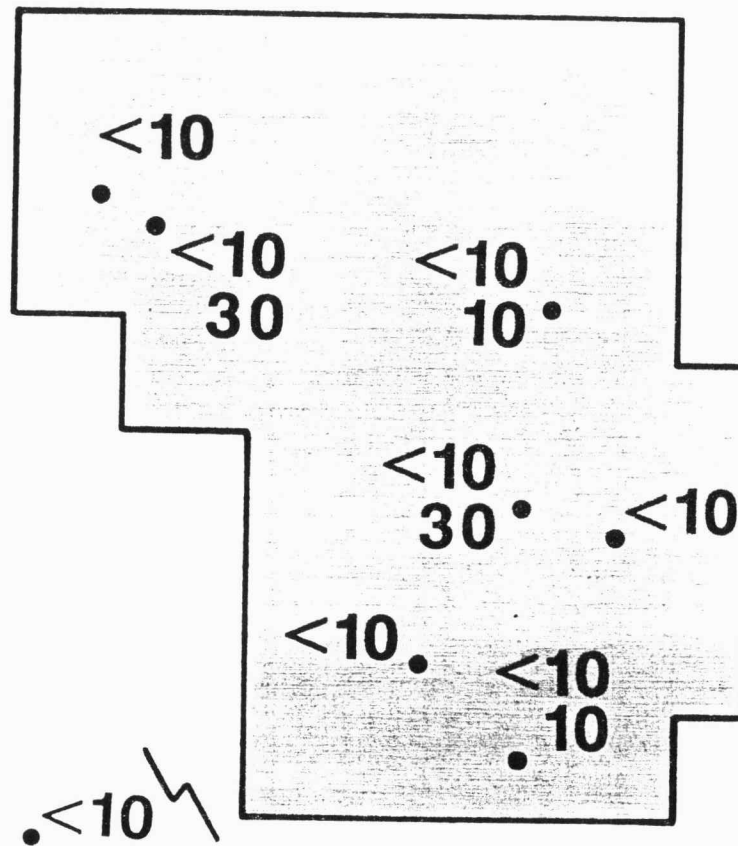
Figure 27. Results of examination for fecal coliform and fecal Streptococcus bacteria in December 1984 (membrane filter count per 100 mL).

Results of the May 1985 sampling (Fig. 28) showed that four of the seven town wells had small amounts of fecal Streptococcus and no fecal coliform bacteria. Well #21 contained neither bacteria.

Samples were collected in May and August 1985 for analysis of volatile and nonvolatile organic carbon (Fig. 29). The volatile organic-carbon fraction in all samples was below the detection limit of 20 parts per billion (ppb). So the total organic carbon (TOC) values shown in figures 29 and 30 indicate the nonvolatile organic-carbon fraction. From the literature, studies in 1974 and 1980 have indicated that TOC levels in uncontaminated ground water generally range from 0.1 to 4 mg/L. Our higher values (>4 mg/L) for three samples in May and four samples in August (Fig. 30) suggest contaminated ground water. For example, well #3 in the northwest part of town had TOC concentrations in May and August of 6.12 mg/L and 5.80 mg/L, respectively. This old well is in an unsanitary pit and at the time of the May sampling, we observed water in the pit flowing into the well.

Analysis for methane was performed on samples collected in May, but since only very small amounts (0.6 to 3.2 ppb) were found, the analysis was not repeated on the August samples. Had the volatile organic-carbon fraction been in the detectable range for any of the samples, knowing what portion was naturally occurring methane would have been important, and then the remaining volatile fraction would have indicated contamination.

Results of the two standard inorganic-chemistry analyses are shown in Table 1 (only the major cation and anion concentrations



f coli
f Strep 5/85

Figure 28. Results of examination for fecal coliform and fecal Streptococcus bacteria in May 1985 (membrane filter count per 100 mL).

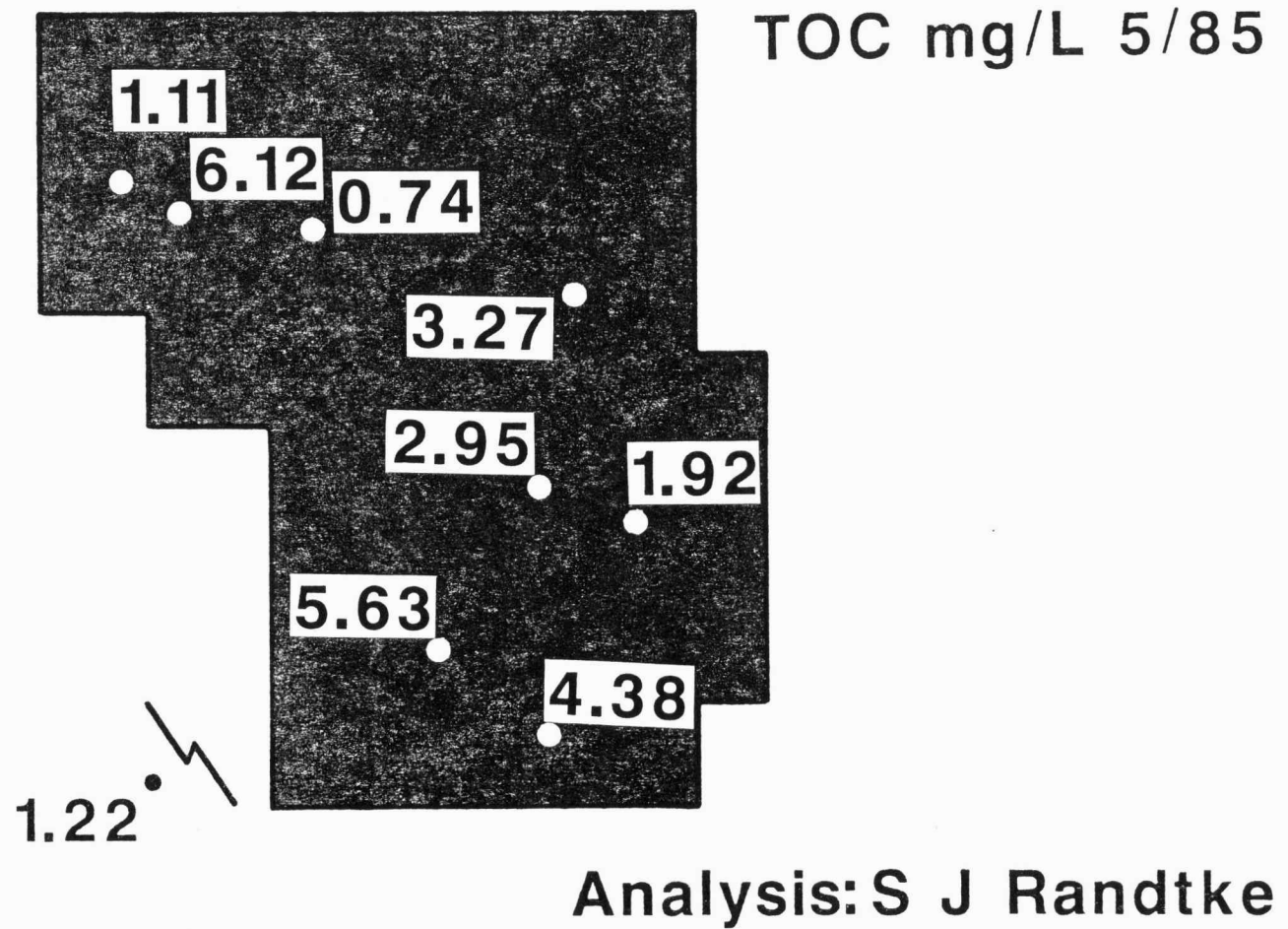


Figure 29. Results of total organic carbon analysis in May 1985 (mg/L).

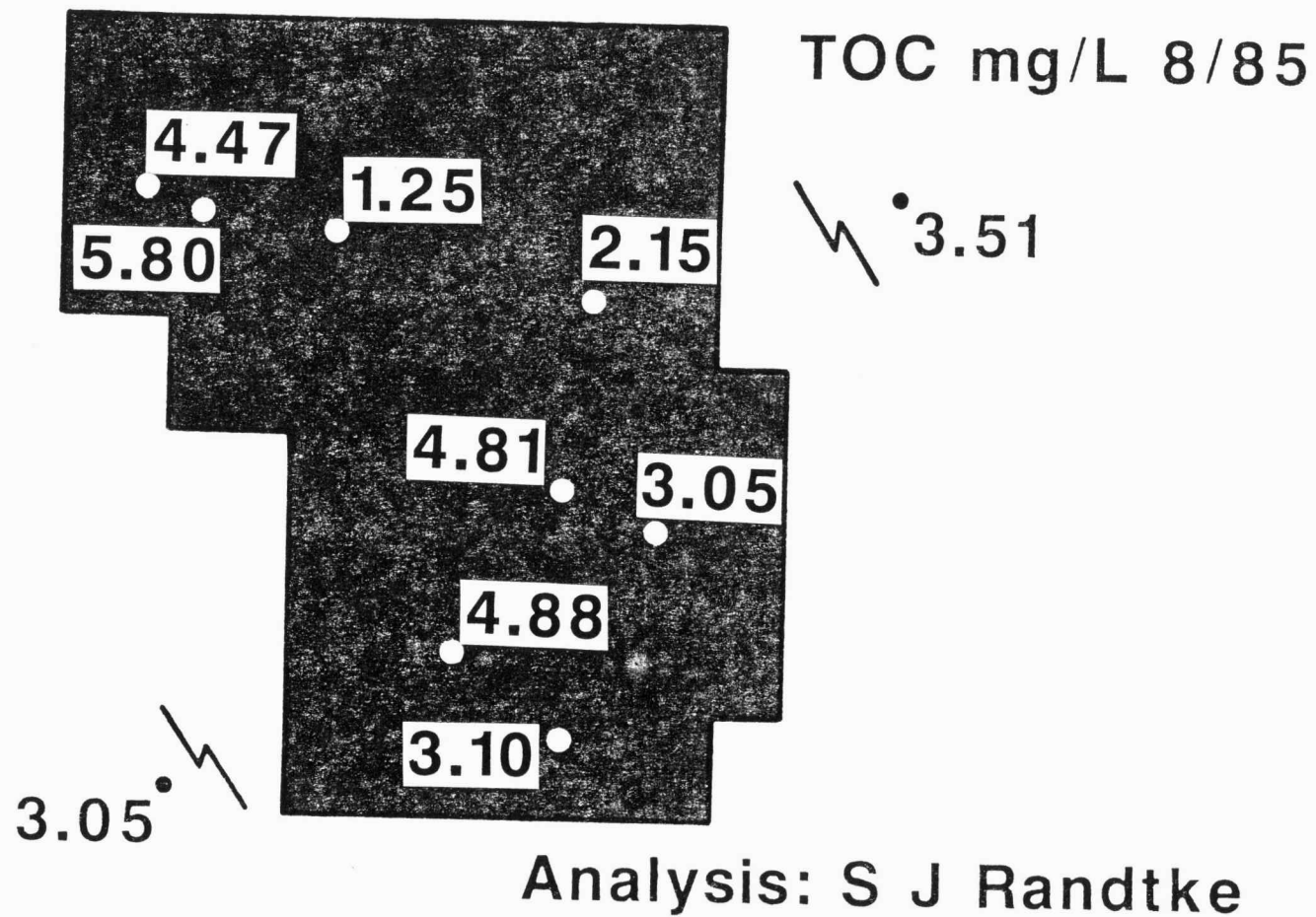


Figure 30. Results of total organic carbon analysis in August 1985 (mg/L).

STANDARD INORGANIC ANALYSIS KGS - ANALYTICAL SERVICES SECTION
WATER WELL SAMPLES - LINCOLNVILLE, KANSAS

Sept. 1984
May 1985

| Well # | Sp. Cond. ($\frac{\mu\text{mhos}}{\text{cm}}$ @ 25°C) [Field] | Ca (mg/L) | Mg (mg/L) | Na (mg/L) | HCO ₃ (mg/L) | SO ₄ (mg/L) | Cl (mg/L) | NO ₃ (mg/L) | TDS calc (mg/L) | |
|--------|--|----------------------------|--------------------------|---------------------------|-----------------------------|---------------------------|---------------------------|---------------------------|-----------------------------|-----------|
| 2 | $\frac{955.}{1122.}$ | $\frac{117.}{132.}$ | $\frac{45.}{49.}$ | $\frac{27.}{42.}$ | $\frac{374.}{400.}$ | $\frac{137.}{163.}$ | $\frac{39.}{47.}$ | $\frac{22.}{47.}$ | $\frac{598.}{699.}$ | |
| 3 | $\frac{1430.}{757.}$ | $\frac{241.}{90.}$ | $\frac{56.}{16.}$ | $\frac{59.}{52.}$ | $\frac{375.}{267.}$ | $\frac{426.}{102.}$ | $\frac{84.}{38.}$ | $\frac{63.}{15.}$ | $\frac{1156.}{464.}$ | |
| 10 | $\frac{960.}{1181.}$ 1540. | $\frac{99.}{104.}$ 126. | $\frac{45.}{47.}$ 61. | $\frac{52.}{89.}$ 126. | $\frac{428.}{523.}$ 553. | $\frac{81.}{93.}$ 148. | $\frac{49.}{63.}$ 106. | $\frac{30.}{17.}$ 35. | $\frac{591.}{690.}$ 898. | June 1983 |
| 16 | $\frac{1270.}{1286}$ | $\frac{134.}{132.}$ | $\frac{58.}{57}$ | $\frac{57.}{56.}$ | $\frac{447.}{441.}$ | $\frac{108.}{117.}$ | $\frac{108.}{104.}$ | $\frac{43.}{35.}$ | $\frac{759.}{744.}$ | |
| 18 | $\frac{1380}{1337}$ | $\frac{143.}{130.}$ | $\frac{56.}{51.}$ | $\frac{78.}{78.}$ | $\frac{473.}{483.}$ | $\frac{120.}{91.}$ | $\frac{125.}{124.}$ | $\frac{38.}{30.}$ | $\frac{825.}{767.}$ | |
| 19 | $\frac{1600}{2430}$ | $\frac{137.}{161.}$ | $\frac{68.}{84.}$ | $\frac{126.}{267.}$ | $\frac{459.}{642.}$ | $\frac{215.}{366.}$ | $\frac{116.}{196.}$ | $\frac{115.}{162.}$ | $\frac{1032.}{1575.}$ | |
| 20 | $\frac{1318}{1159}$ | $\frac{134.}{117.}$ | $\frac{58.}{49.}$ | $\frac{72.}{59.}$ | $\frac{400.}{388.}$ | $\frac{176.}{150.}$ | $\frac{84.}{61.}$ | $\frac{90.}{60.}$ | $\frac{842.}{714.}$ | |
| 21 | $\frac{1219}{1220}$ | $\frac{129.}{125.}$ | $\frac{55.}{50.}$ | $\frac{57.}{60.}$ | $\frac{398.}{410.}$ | $\frac{141.}{123.}$ | $\frac{97.}{104.}$ | $\frac{39.}{28.}$ | $\frac{744.}{713.}$ | |

Table 1. Results of standard inorganic chemistry analyses: September 1984
May 1985

are shown). Wells that showed more than a 10% increase in constituent concentrations from the September 1984 sampling to the May 1985 sampling were wells #2, #10, and #19 (Fig. 3). We have already seen the large fluctuations that occur in these wells during the spring. Wells that showed more than a 10% decrease were wells #3 and #20. In well #3 this dilution effect can be explained by the fact that "fresher" soil water that had seeped into the pit of this well overtopped the casing and flowed directly into the well in May. In well #20, the explanation might be the presence of an uncovered, abandoned well only 20 ft away. The remaining three wells (#16, #18, and #21) showed less than 10% change for most constituents from September to May.

Samples of sediment produced by most of the wells also were collected for analysis. The quantity of sediment produced ranged from trace to excessive amounts. Water from wells producing an excessive amount of clay/silt-size sediment appears very turbid (Fig. 31). X-ray diffraction analysis of the inorganic portion of the sediment showed a predominance of calcite and quartz with lesser amounts of dolomite, feldspar, and clay minerals. A visual inspection of the sediments also showed pipe scale and organic debris including insects, fibers, and fine hair roots from plants. In a few cases water produced from wells was discolored.

These various lines of evidence support the conclusion that wells tapping the confined Winfield aquifer, which are constructed to exclude shallow Nolans water from entering the borehole or casing and which are not in the plume of another well

draining shallow water to the confined aquifer, have very little change in water quality during the year and provide a satisfactory domestic-water supply. Water quality from these wells represents the regional confined ground-water flow in the Winfield aquifer.

Water quality in many of the town wells, however, undergoes large fluctuations in chemical quality caused by a downward flow of contaminated water during the spring-recharge period. The downward flow may occur at the well sampled or at a nearby well or open hole.

We also believe that a public health significance results from these water-quality fluctuations in Lincolnville because of the fact that a) the large increases in nitrate concentration exceed the recommended limit for public-water supplies, sometimes by as much as 14 times; b) small amounts of fecal Streptococcus bacteria are present in the spring while in the winter there was an absence of fecal bacteria; c) the quantity of total organic carbon found in some town wells exceeds what has been found in uncontaminated ground waters; and d) field observations found unsanitary conditions of some wells, especially those in pits where seepage water in the pit flows directly into the well.

In summary we believe that the confined ground water in the Winfield aquifer is a satisfactory domestic-water source in the Lincolnville area and that it shows little variation in chemical and bacteriological quality throughout the year, except where shallow ground water in the weathered near-surface Wellington Formation and Nolans Limestone drains downward through boreholes

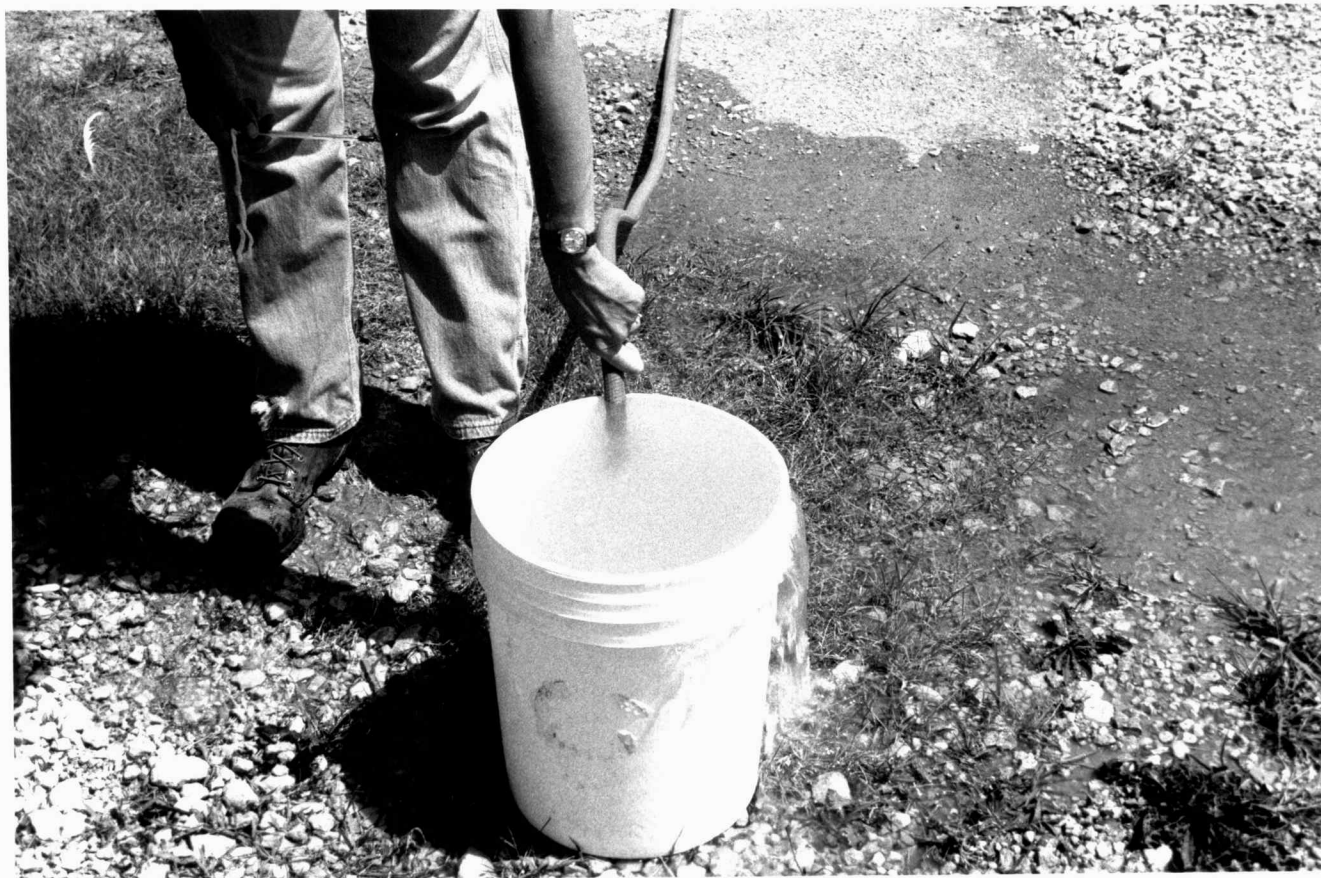


Figure 31. Photo showing turbid appearance of water from well producing an excessive amount of sediment.

to the confined aquifer. During the spring months after frost leaves the soil, a part of the precipitation that falls on the local town area becomes recharge and moves downward through the soil and into the Nolans Limestone where it then moves toward any borehole or well that will allow a downward flow to the Winfield aquifer. The vertical flow in boreholes or wells occurs in the ungrouted or unsealed annular space of the well or it may enter at joints or holes in the casing or it may enter well pits and flow downward inside of the casing to the confined aquifer.

Policy recommendations to individuals in the community and to county and state departments of health, well drillers, and pump installers include the following:

1. All wells which are in pits (Figs. 11, 12, and 32) should be modified to make the wells comply with current regulations for new wells. All other wells that allow downward drainage should also be modified to effectively seal the wells from the shallow, easily contaminated water. All wells with galvanized casing were constructed before 1974 and are likely to have deteriorated; therefore, they should be abandoned, properly plugged, and a new well drilled.
2. All new wells should be cased and grouted to correspond to the geology. Wells should be grouted through the Wellington and Nolans into the Odell or to the top of the Winfield Limestone aquifer. Grouting the top 10-13



Figure 32. Photo showing well in pit covered by wood and composition roof.

ft below land surface does not adequately protect the well from downward drainage of water carrying soluble contaminants.

3. Improved housekeeping and monitoring of business establishments' handling and controlling potentially contaminating materials such as petroleum products (Fig. 33), fertilizers (Fig. 34), pesticides and herbicides (Fig. 35), deicing salts (Fig. 36), and solvents should be required.
4. If the community takes effective action to improve and protect the community-water supply, this action should be done in cooperation with the Kansas Department of Health and Environment, the Kansas Geological Survey, and the local well drillers to develop policies and procedures for implementing well modifications and improvements.



Figure 33. Photo showing fuel storage and dispensing facilities in Lincolnvile, Kansas.



Figure 34. Photo showing spilled fertilizer on railroad tracks in Lincolnvilleville, Kansas.



Figure 35. Photo showing farm chemical tank mix area in
Lincolnvilleville, Kansas.



Figure 36. Photo showing pile of sand/salt mixture for highway use in Marion County, Kansas.