Chapter 8

Baseline water chemistry, nitrate concentrations, and aquifer sensitivity of glacial sequences in LaGrange County, Indiana

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Abstract

A project was initiated to evaluate the chemistry and relative age of groundwater in glacial sequences in LaGrange County in northeastern Indiana in 2002. The intent was to acquire a baseline dataset for selected ions, trace elements, and isotopes in water from 50 wells. In 2003, samples were collected from 18 additional wells that produce groundwater known to have high nitrate–nitrogen (NO_3–N) concentrations. The 68 wells draw water from sand and gravel deposits in the Topeka fan, Lima plain, interlobate, and Oliver Lake glacial sequences.

The prevalent chemical character of the groundwater from the 68 wells is dominated by calcium bicarbonate. The 2002 water samples average 63% calcium and 85% bicarbonate of the major ion distribution; the 2003 water samples average 61% calcium and 64% bicarbonate. The decrease in the percentage of bicarbonate is attributed to the addition of nitrate.

Nitrate–nitrogen concentrations in the water samples collected in 2002 are generally low; 84% of the samples have concentrations below the detection limit. Only one water sample has a NO_3–N concentration above the U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL); that sample is from a well located in the Topeka fan. Nitrogen isotopes for four wells have ratios ranging from 7.60 to 19.3 parts per thousand (‰). The nitrogen isotope ratios are similar to those measured in shallow groundwater from wells in the following land-use settings in the Minnesota sand-plains aquifers: livestock feedlots, residential areas with septic systems, and nonirrigated-cultivated areas. The nitrate data suggest that the Topeka fan aquifers are sensitive to anthropogenic contamination.

Nitrate–nitrogen in the 2003 groundwater samples ranges from 7.0 to 30.4 mg l⁻¹; NO₃–N concentrations in 72% of the samples are above the EPA MCL. The isotope ratios for samples from the Lima plain and Oliver Lake sequences range from 4.9 to 9.6‰ and show a positive correlation with sodium concentration. This suggests that the source of the nitrogen in these sequences may include septic waste. The nitrogen isotope ratios for samples from the Topeka fan sequence range from 5.3 to 22.3‰. The nitrogen isotope ratios are similar to those measured in the following land-use settings in the Minnesota sand plains: livestock feedlots, residential areas with septic systems, and nonirrigated-cultivated areas.

The tritium values in the 2002 water samples range from below the detection limit (<0.8 TU) to 17.0 TU; 35 of the samples have values above the detection limit. Tritium is generally not detected in waters from wells 30.48 m or greater in depth. The $\delta^{18}O$ and δ^2H values in the water samples from LaGrange County are similar to those reported for groundwater samples from unconsolidated glacial deposits in northwestern Indiana.

The tritium data indicate that 62% of the water in wells sampled in the Topeka fan and Oliver Lake basin has been recharged from the surface since 1952. The groundwater in the remaining wells in the Topeka fan and Oliver Lake glacial sequences has been recharged between 10,000 years before present and 1953.

8.1. Background

LaGrange County is located in northeastern Indiana and lies in the St. Joseph River Basin; the estimated 2002 population of the county was 35,410 (U.S. Census Bureau, 2004). Groundwater is the source of 75% of the water withdrawn in the basin (Indiana Department of Natural Resources Division of Water, 1987). Agriculture is the primary land use in the area, and farms make up nearly 78% of the acreage in the county (1997 data from U.S. Department of Agriculture, 2004).

A number of these farms are small and employ older farming methods that rely on crop rotation and the use of manure as fertilizer. The farmsteads, several of the smaller towns, and lakeshore residences concentrated along the many natural lakes in the region rely on septic systems for sewage disposal. The towns of LaGrange (population: 2906 in 2002), Shipshewana (531 in 2002), Topeka (1155 in 2002), and Wolcottville (460 in 2002) (STATS Indiana, 2004) have sewage treatment facilities (W. F. Grant, LaGrange County Health Department). Wolcottville lies in both LaGrange County and Noble County. Only the population in

LaGrange County is reported here. The town of Howe in northern LaGrange County does not have a sewage treatment facility.

To evaluate the chemistry, potential contamination, and relative age of the groundwater in LaGrange County, the Indiana Geological Survey (IGS) at Indiana University began this project in 2001. The study was conducted to determine the baseline water chemistry and the levels of naturally occurring and man-made contaminants in the groundwater.

8.2. Aquifers

Water samples were collected from 50 public and private wells in La-Grange County during the summer of 2002 (Fig. 8.1). These wells, which are from 3.05 to 67.06 m deep, draw water from mixed deposits of gravel, sand, silt, and clay that were deposited during the Pleistocene.

Some sampled wells draw water from a glacial deposit composed of sand and gravel and known as the Topeka fan glacial sequence (Figs. 8.1 and 8.2a). Other sampled wells draw water from sand and gravel in the lacustrine Oliver Lake glacial sequence (Figs. 8.1 and 8.2b). The Oliver Lake sequence contains more clay and silt than the Topeka fan sequence.
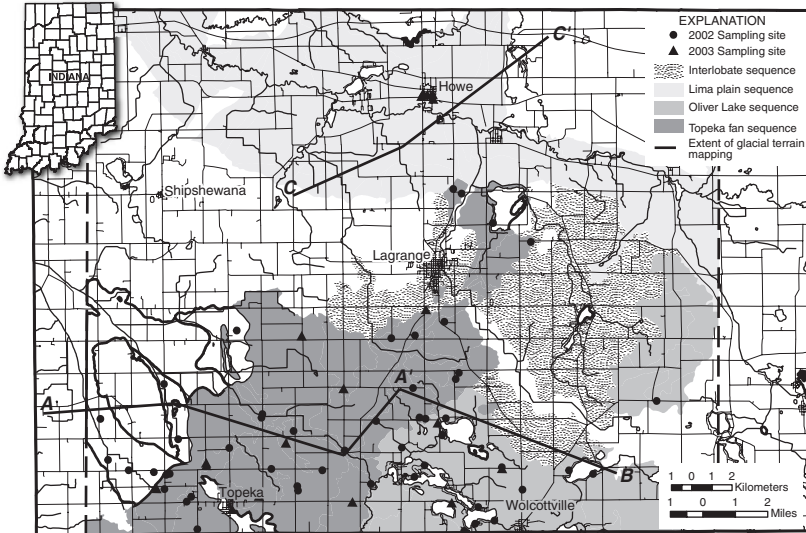

Figure 8.1. Map showing the areal extent of the Topeka fan, Oliver Lake, Lima plain, and interlobate glacial sequences and the 2002 and 2003 sampling sites. Modified from Fleming et al. (1997), Brown et al. (1998), and Brown and Jones (1999a–d).
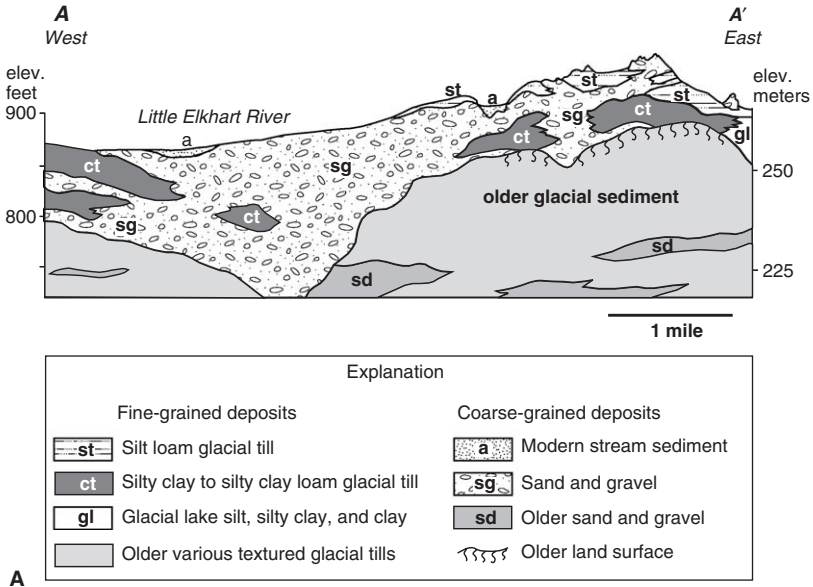
Figure 8.2a. West-to-east schematic cross section showing the Topeka fan glacial deposits. The Topeka fan sequence is characterized by coarser-grained deposits. Cross section was modified by Steven E. Brown from Brown (1999).

Much of the clay and silt was deposited in glacial lakes that once covered parts of the landscape.

The 2003 wells draw water from either sand and gravel deposits in the Topeka fan, Lima plain (Figs. 8.1 and 8.2c), and interlobate glacial sequences or localized sand and gravel deposits in the Oliver Lake sequence. The Topeka fan, Lima plain, and interlobate sequences are areas of groundwater recharge; the Oliver Lake basin is an area of groundwater discharge with areas of local recharge.

8.3. Site selection

The 2002 wells sampled in the Topeka Fan and Oliver Lake glacial sequences were selected from the IGS natural gamma-ray log database and the LaGrange County Health Department (LCHD) nitrate database. The majority (36) of the well sites were selected from the gamma-ray log database because it contains information for newer wells (1994–1998), which were drilled and completed professionally by water well drillers.
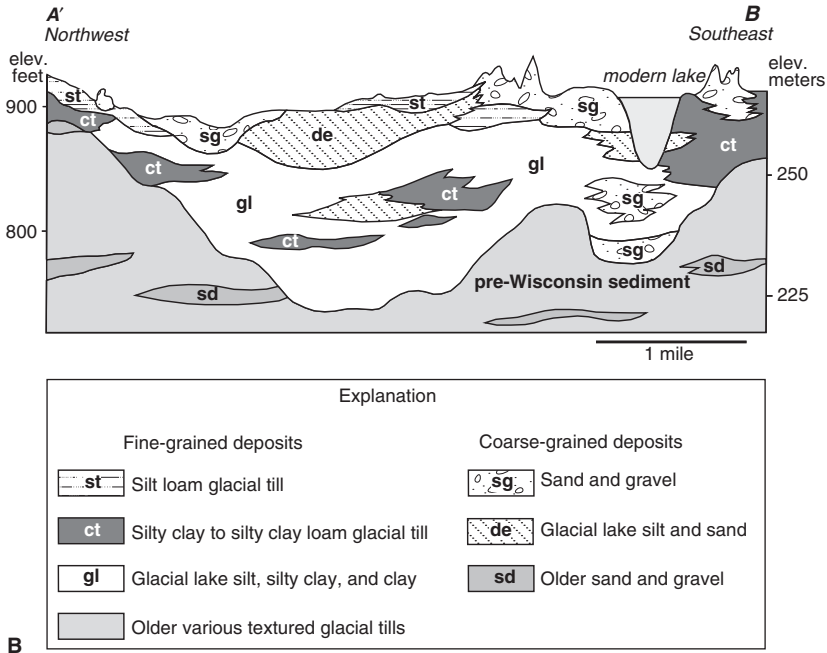
Figure 8.2b. Northwest-to-southeast schematic cross section showing the Oliver Lake glacial deposits. The Oliver Lake sequence is characterized by finer-grained deposits. Cross section was modified by Steven E. Brown from Brown (1999).

Also, gamma-ray geophysical logs and samples are available for many of these wells. The remaining 14 well sites were selected from the LCHD nitrate database, which contains data compiled from 1983 to 1998. The wells selected had reported nitrate values of less than $3\,mg\,l^{-1}$.

The 18 wells sampled in 2003 in the Topeka fan, Lima plain, inter-lobate, and Oliver Lake sequences were selected from the LCHD nitrate database, which contains information from 1983 to 1998, and the LCHD nitrate spreadsheets, which contain information from 1998 to 2003. The wells selected from the database and spreadsheet had reported nitrate values of $10\,mg\,l^{-1}$ or greater.

The Indiana Department of Natural Resources Division of Water Well Record Database was reviewed to obtain additional information pertaining to these water wells. During this review and discussions with the well owners, it was noted that some of the wells having high-nitrate values originally reported in the LCHD database had been abandoned and new water wells had been drilled to deeper aquifers.
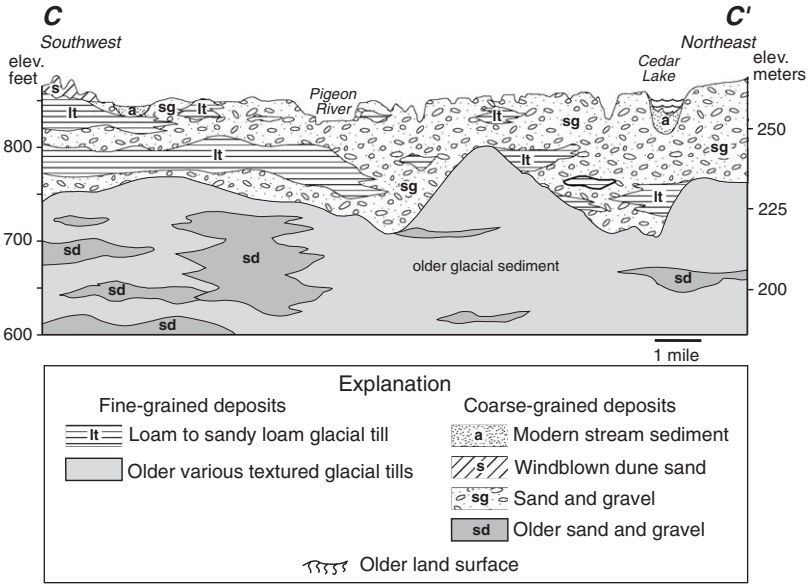
Figure 8.2c. Southwest-to-northeast schematic cross section showing the Lima plain glacial deposits. The Lima plain sequence is characterized by coarser-grained deposits. Cross section modified by Steven E. Brown from Fleming et al. (1997).

8.4. Groundwater chemistry

8.4.1. Introduction

The intent of the 2002 sampling was to acquire baseline data by analyzing for selected major and minor ions, trace elements, and isotopes in groundwater. The chemical analyses of the groundwater samples included pH and alkalinity (from which bicarbonate and carbonate concentrations were calculated); the major ions chloride, sulfate, calcium, magnesium, and sodium; the minor ions fluoride, nitrate–nitrogen, iron, manganese, silicon, strontium, and zinc; and the trace elements arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The total dissolved solids (TDS) were calculated from the major and minor ions. Total hardness for each sample was calculated from calcium and magnesium concentrations. Water samples were also analyzed to determine the concentrations of the radioactive isotope tritium and the stable isotope ratios of oxygen, deuterium (hydrogen), and nitrogen. The intent of the 2003 sampling was to collect water samples known to have high-nitrate values and to determine the NO_3–N concentrations and potential sources of the

nitrogen by analyzing stable isotope ratios of nitrogen in nitrates. In addition to nitrogen isotopes, the field parameters and major ions noted above were determined for the 2003 samples.

8.4.2. Methods

Samples were collected from the water wells after receiving permission to sample from the well owners. The field crew flushed the well pressure tank by opening a spigot to which a flow-through cell with a multi-probe sonde was connected. When temperature and conductivity readings were observed to stabilize, indicating that fresh groundwater was being flushed through the system, field parameters were recorded and sample collection commenced. Samples were collected for chemical analyses by connecting the discharge hose to a positive-pressure stainless steel tripod filter stand containing a 0.45 μm cellulose nitrate filter and dispensing several aliquots for each sample into high-density polyethylene (HDPE) plastic bottles. One aliquot collected for selected anion analysis was kept refrigerated at 4°C. Two additional aliquots collected for determining major cations and trace elements were preserved with concentrated nitric acid so that pH was less than 2; these aliquots were transported on ice and refrigerated until used. Additional unfiltered aliquots were collected for isotope analyses and stored on ice until the field crew returned to the IGS, where the samples were frozen and shipped to the University of Waterloo Environmental Isotope Laboratory where isotopic analyses were performed.

At the IGS geochemistry laboratories, anions were analyzed using EPA method 300.0 (U.S. Environmental Protection Agency, 1993) on a Dionex DX100 suppressed ion chromatograph (IC) equipped with a conductivity detector; cations were determined by EPA method 200.7 (U.S. Environmental Protection Agency, 1994) employing simultaneous inductively coupled plasma-atomic emission spectroscopy (ICP-AES); trace element concentrations were measured using graphite furnace atomic absorption spectrophotometry (GFAA) following EPA method 200.9 (U.S. Environmental Protection Agency, 1994); and potassium levels were quantified by atomic emission spectroscopy (AES) as defined in Standard Methods section 3111B (American Public Health Association, 1995). At the University of Waterloo Environmental Isotope Laboratory, stable isotopes were determined by ratio mass spectrometry on processed samples. Deuterium ratios were measured for hydrogen gas produced from water samples reduced on hot manganese. Oxygen ratios were assessed from CO_2 equilibrated with water samples at constant temperature, and nitrogen ratios for dissolved nitrate were analyzed after sample concentration using an anion resin. Tritium values were determined by

the University of Waterloo Environmental Isotope Laboratory on samples enriched by electrolysis and analyzed with a liquid scintillation counter.

All lab procedures used check standards, sample replicates, and sample spikes to monitor instrument performances. Ten percent of samples collected included duplicate aliquots to monitor precision. Data quality control also included charge balance calculations from major ion concentrations as the percentage of the difference between the anions and cations divided by the sum of the anions and cations. Any charge balance exceeding 10% was considered to have significant error in one or more major ion component and was not included in data evaluation.

8.4.3. Prevalent water chemistry

The composition of groundwater collected from 44 of the 50 wells in 2002 is dominated by calcium bicarbonate (Fig. 8.3a). Three of the remaining six wells contained no dominant cation while three others contained 100% sodium and are suspected of having been treated with an in-line water softener. Calcium averages 63% of the cation content, varying from 27 to 71% in the 47 wells known to be untreated with a water softener (Table 8.1). Bicarbonate is the dominant anion found in all wells, varying from 54 to 100% of the anion content and averaging 85% for the 47 nontreated wells. The high proportion of calcium and bicarbonate suggests that carbonate minerals dominate the water–rock interactions in the aquifer.

Data from the 18 wells sampled in 2003 contain a greater degree of mixture in the prevalent chemistry (Fig. 8.3b). Calcium remains the dominant cation for most of the samples averaging 61%, while sodium and potassium content increases from an average of 7% in 2002 to 14% in wells sampled in 2003 (Table 8.1). The relative percentage of calcium remains nearly unchanged in the cation distribution; however, bicarbonate does not maintain as dominant a proportion of the anion composition as in the 2002 dataset. The presence of nitrate in this set of wells exerts a significant enough influence on the anion distribution that the average bicarbonate proportion decreases from 85% in the 2002 wells to 64% in the 2003 wells while average nitrate + chloride increases from 5% in the 2002 wells to 27% in the 2003 wells (Table 8.1).

The calculated TDS and measured alkalinity suggest that the change in major ion proportions is primarily due to nitrate + chloride addition to the ion chemistry rather than exchange reactions. The TDS average for water sampled in 2002 is 367 mg l^{-1}; the TDS average for water sampled in 2003 is 501 mg l^{-1} (Table 8.1). In contrast, the average alkalinity for 2002
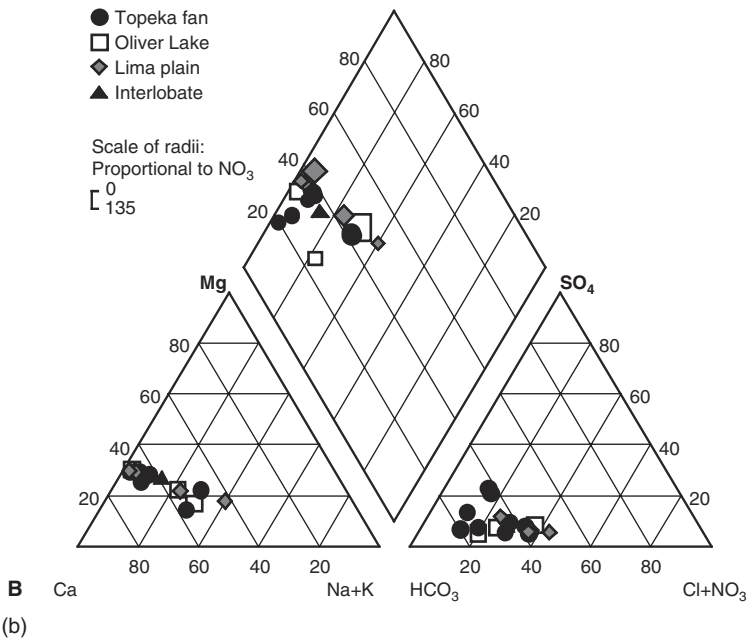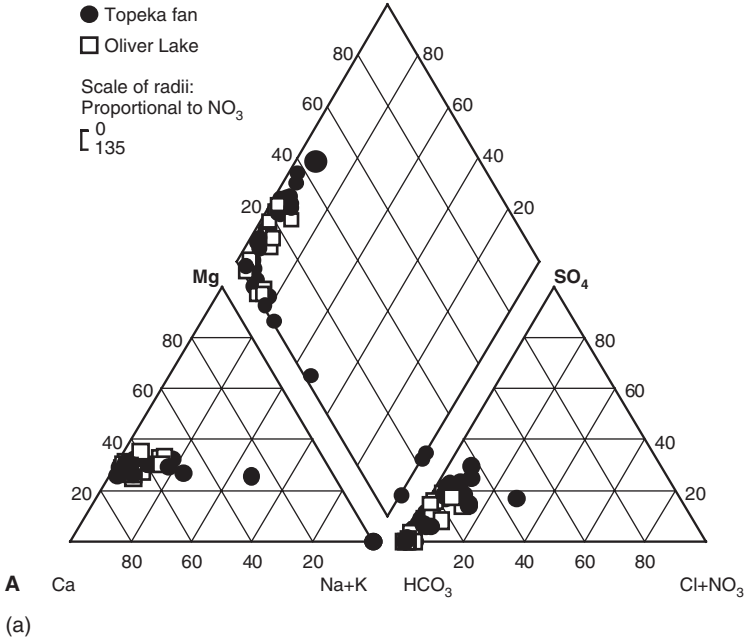
Figure 8.3. (a) Trilinear plot showing the chemistry of the groundwater samples collected in 2002. Modified from Hasenmueller and Branam (2004). (b) Trilinear plot showing the chemistry of the groundwater samples collected in 2003.

Table 8.1. Relative percentages of major ions

	2002				2003			
	Minimum	Maximum	**Average**	**Median**	Minimum	Maximum	**Average**	**Median**
Ca (%)	27	71	**63**	**65**	42	68	**61**	**65**
Mg (%)	25	34	**30**	**30**	15	31	**26**	**28**
Na + K (%)	2	46	**7**	**4**	2	40	**14**	**8**
HCO$_3$ (%)	54	100	**85**	**86**	51	80	**64**	**63**
SO$_4$ (%)	0	30	**10**	**10**	5	23	**9**	**8**
Cl + NO$_3$ (%)	0	29	**5**	**3**	12	44	**27**	**29**
TDS[a]	273	579	**367**	**344**	387	610	**501**	**518**
Alkalinity	207	382	**289**	**285**	223	358	**286**	**279**

[a]Calculated values.

wells is $289 \, \text{mg} \, \text{l}^{-1}$ as calcium carbonate equivalents and the average for 2003 wells is $286 \, \text{mg} \, \text{l}^{-1}$. This indicates that while the percentage distribution of bicarbonate is less in the 2003 dataset, the actual average bicarbonate concentrations are virtually the same in both datasets and the shift in relative percentages is due to the addition of nitrate and chloride as confirmed by the TDS data.

8.4.4. Nitrate

Nitrogen is a biologically active element involved in chemical reactions that are important to life and that affect water quality. Decaying plant and animal materials release organic nitrogen, which is altered through transformation processes to produce reduced or oxidized species. Komor and Anderson (1993) identify the following transformation reactions: ammonification, nitrification, denitrification, and dissimilatory nitrate reduction. The first two reactions occur above the water table, while the last two, both nitrate-reducing reactions, occur below the water table under oxygen-deficient conditions (Freeze and Cherry, 1979). Other potential sources of nitrate–nitrogen in groundwater are inorganic nitrogen-based fertilizers, septic systems, animal waste, and fixations of atmospheric nitrogen. The EPA has established a MCL of $10 \, \text{mg} \, \text{l}^{-1}$ for NO$_3$–N in drinking water.

Specific sources of nitrate contamination can be identified by studying the proportions of stable nitrogen isotopes. The ability to identify specific sources is dependent on the number and types of sources, the distance from the sources, and the chemical or biological processes that can alter the isotopic signature of the nitrogen source. In the current study,

adequate time and resources were not available to pursue the identification of the number and types of nitrogen sources.

Another factor affecting the concentration and isotopic signature of nitrate in groundwater is the variability of nitrate through time owing to changing source concentrations and isotope-altering processes, namely, denitrification with well depth. The nitrate-reducing reactions described by Komor and Anderson (1993) are catalyzed by microbial activity and have been characterized by $\delta^{15}N$ depletion in products and $\delta^{15}N$ enrichment in the residual nitrate reactant (Kaplan, 1983; Heaton, 1986). In a study on water quality in private rural wells in the Midwest, Richards et al. (1996) noted that nitrate contamination in rural wells varies from region to region owing to geologic and hydrologic factors and land use. Because of these variables, a long-term site-specific sampling program might result in a more definitive dataset to determine the potential nitrate sources.

The 2002 nitrate data represent NO_3–N concentrations and potential sources at the specific time of the field sampling of the water wells. The 2003 nitrate data also represent NO_3–N concentrations and potential sources at the specific time of field sampling; however, nitrate values for these wells are known to have been high in the past from the data in the LCHD nitrate database and spreadsheets.

The NO_3–N concentrations in groundwater sampled and analyzed in 2002 were generally low; 42 of the samples had concentrations below the detection limit ($<0.2\,mg\,l^{-1}$). Only one sample had a NO_3–N concentration above the EPA MCL (Fig. 8.4). Seven of the eight samples

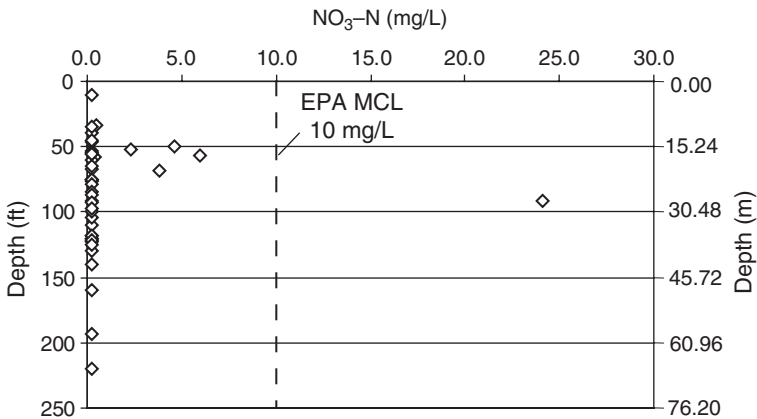*Figure 8.4.* Graph showing well depth versus NO_3–N concentration for the 2002 groundwater samples. Modified from Hasenmueller and Branam (2004).

containing measurable NO_3–N were from wells in the Topeka fan glacial sequence.

In a report on the quality of well water and its vulnerability to agricultural contamination in the midwestern United States, Richards et al. (1996) reported that shallower and older wells are more likely to be contaminated than deeper and newer wells. In the LaGrange County project, total well depths were available for seven of the eight 2002 sampling sites where the water samples contained measurable NO_3–N. The seven water samples containing NO_3–N were from wells less than 30.48 m in depth (Fig. 8.4).

Nitrogen isotope ratios were used to aid in the identification of the sources of nitrates in wells where sufficient concentrations allowed the determination of the isotope ratios. Stable nitrogen isotope ratios for four 2002 Topeka fan samples ranged from 7.60 to 19.3‰. The pattern of the distribution of the isotope ratios for the 2002 and the 2003 Topeka fan samples are similar to the pattern of the distribution of nitrogen isotope ratios reported by Komor and Anderson (1993) for groundwater from shallow wells in the central Minnesota sand-plain aquifers (Fig. 8.5). The
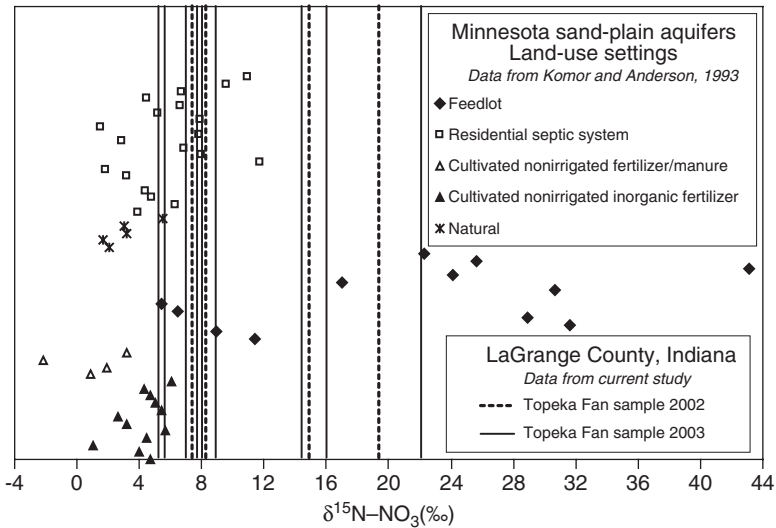

Figure 8.5. Graph showing the range of nitrogen isotope ratios for the 2002 and 2003 groundwater samples from the Topeka fan glacial sequence in LaGrange County, Indiana. The isotope ratios from the Topeka fan samples cluster into two subsets on the graph. The LaGrange County isotope data are overlain on data from the Minnesota sand-plain aquifers (Komor and Anderson, 1993, Table 3).

Minnesota sand plains are composed of glacial outwash of Quaternary age (Wright and Ruhe, 1965). The 2002 nitrogen isotope ratios are similar to those measured in the following land-use settings in Minnesota: livestock feedlots, residential areas with septic systems, and nonirrigated-cultivated areas (Fig. 8.5).

The 18 wells sampled in 2003 were selected because the previously reported nitrate values for the groundwater from these wells were high. The NO_3–N concentrations in the 2003 groundwater samples ranged from 7.0 to 30.4 mg l^{-1}. Seventy-two percent of the 2003 water samples had NO_3–N concentrations above the EPA MCL. The NO_3–N concentration in the water sample from the interlobate glacial sequence was 19.7 mg l^{-1}. Nitrate–nitrogen concentrations in the water samples in the other glacial sequences ranged from 8.3 to 30.2 mg l^{-1} in the Lima plain sequence, 12.5 to 30.4 mg l^{-1} in the Oliver Lake sequence, and 7 to 20.9 mg l^{-1} in the Topeka fan sequence. The water samples from the Lima plain sequence are from home-use wells located in the town of Howe, which has no wastewater treatment facility. In regard to the NO_3–N in wells sampled in a study of private rural wells in the midwestern United States, Richards et al. (1996) indicated that consistent incidences of contamination may indicate contamination of the aquifer locally. This may be the case in the vicinity of the town of Howe. Several of the water samples from the Oliver Lake sequence are from lakeshore residences concentrated along natural lakes; these sites have no wastewater treatment facilities. The water samples from the Topeka fan are predominantly from rural sites.

Nitrogen isotope ratios for the 2003 groundwater samples range from 4.9 to 22.3‰. The isotope ratios for the samples from wells in the Lima plain and Oliver Lake sequences range from 4.9 to 9.6‰ (Fig. 8.6). These $\delta^{15}N$ values indicate multiple sources when compared to the data from Komor and Anderson (1993); the positive correlation of the $\delta^{15}N$ with sodium concentrations (Fig. 8.7) suggests that septic waste is a primary source of the nitrogen in these two sequences (Bleifuss et al., 2004).

The nitrogen isotope ratios for the 2003 water samples from the Topeka fan sequence range from 5.3 to 22.3‰ (Fig. 8.5). In the Topeka fan glacial deposits, one group of isotope data ranges from 5.32 to 9.14‰; the other group has heavier isotopic signatures and ranges from 14.5 to 22.32‰ (Fig. 8.5). The group of lighter nitrogen isotope ratios is similar to ratios reported for livestock feedlots, residential areas with septic systems, and nonirrigated-cultivated areas by Komor and Anderson (1993). The group of heavier nitrogen isotope ratios is similar to the ratios reported for feedlots by Komor and Anderson (1993).
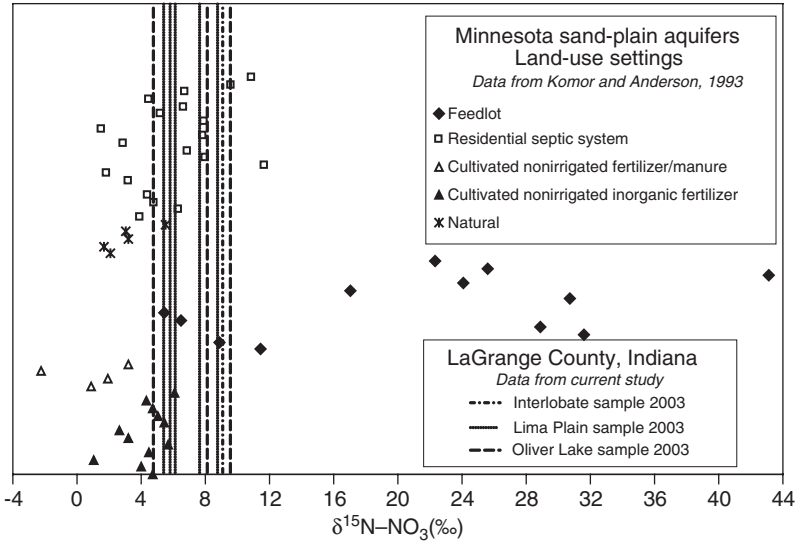
Figure 8.6. Graph showing the range of nitrogen isotope ratios for the 2003 groundwater samples from the interlobate, Lima plain, and Oliver Lake glacial sequences in LaGrange County, Indiana. The LaGrange County isotope data are overlain on data from the Minnesota sand-plain aquifers (Komor and Anderson, 1993, Table 3).
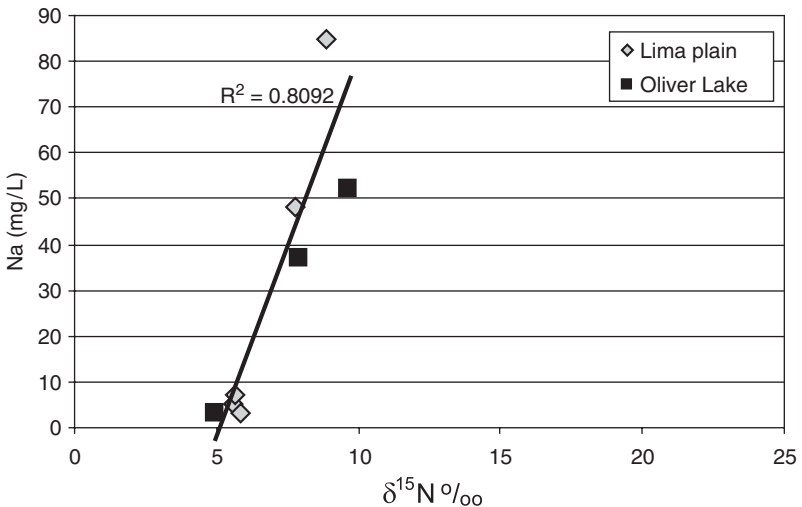

Figure 8.7. Graph showing the relationship of sodium (mg l^{-1}) to nitrogen isotope ratios for the 2003 groundwater samples from the Lima plain and Oliver Lake glacial sequences.

8.4.5. Tritium, ^{18}O, and Deuterium

Tritium (^{3}H), ^{18}O, and deuterium (^{2}H) can be used to determine the locations of groundwater recharge areas, the circulation patterns in aquifers, the sources of dissolved solids in groundwater, and the age of groundwater (Fetter, 1988). Knowledge of relative ages of groundwater contributes to the understanding of groundwater flow and sensitivity to contamination. Only the water samples collected in 2002 were analyzed for tritium, ^{18}O, and deuterium.

Tritium is an unstable radioactive isotope of hydrogen with a half-life of 12.43 years. It is produced naturally in low concentrations by the interaction of cosmic rays with nitrogen and oxygen in the atmosphere. The most significant source of tritium, however, is anthropogenic from the atmospheric testing of nuclear weapons from 1952 to 1969. Tritium in the atmosphere is directly incorporated into the water molecule and is introduced to groundwater through rainfall. Tritium is used to identify modern recharge to groundwater systems.

In the 2002 water samples, tritium concentrations ranged from below the detection limit (<0.8 tritium units [TU]) to 17.0 TU. Of the 50 samples, 35 had values above the detection limit. A tritium concentration greater than 2 TU is interpreted as indicative of the presence of post-1952 recharge water (Fontes, 1980). A similar range of values was observed in aquifers of unconsolidated glacial deposits in northwestern Indiana, where tritium values from the detection limit (0.8 TU) to 28.2 TU were reported by Hasenmueller et al. (2001).

In the LaGrange County study, the presence or absence of tritium correlated with the depth of the well. A total well depth was available for 44 of the 2002 sampling sites. Tritium concentrations greater than 2.0 TU were detected in 83% of the wells that were less than 30.48 m in depth (Fig. 8.8). Concentrations greater than 2.0 TU were detected in only 20% of the wells that were 30.48 m or greater in depth (Fig. 8.8).

In the water samples collected and analyzed in 2002, the δ^{18}O values ranged from -9.07 to -5.47‰ and the δ^2H values ranged from -60.11 to -40.76‰. The δ^{18}O and δ^2H values for the 19 water samples with tritium concentrations of 2 TU or less exhibited a smaller range -8.99 to -8.35‰ (Fig. 8.9a) and -58.62 to -54.97‰ than the δ^{18}O and δ^2H values for the 31 water samples with tritium concentrations greater than 2 TU (Fig. 8.9b).

The δ^{18}O and δ^2H values in the water samples from LaGrange County are slightly more negative than the current mean average annual values calculated by Drever (1988) for this area. The average δ^{18}O and δ^2H values for the 2002 LaGrange County water samples were -8.59‰ and -55.83‰. Similar values were reported for δ^{18}O and δ^2H for
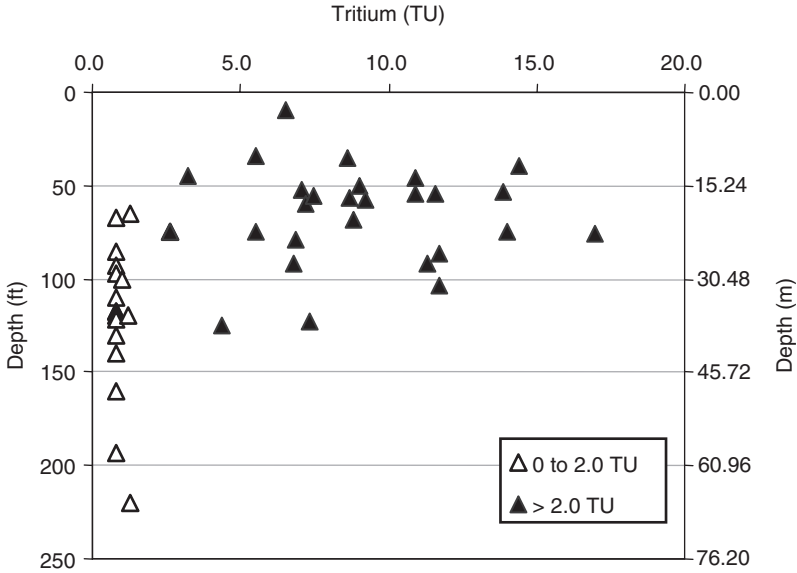
Figure 8.8. Graph showing well depth versus tritium concentration for the 2002 ground-water samples. Modified from Hasenmueller and Branam (2004).
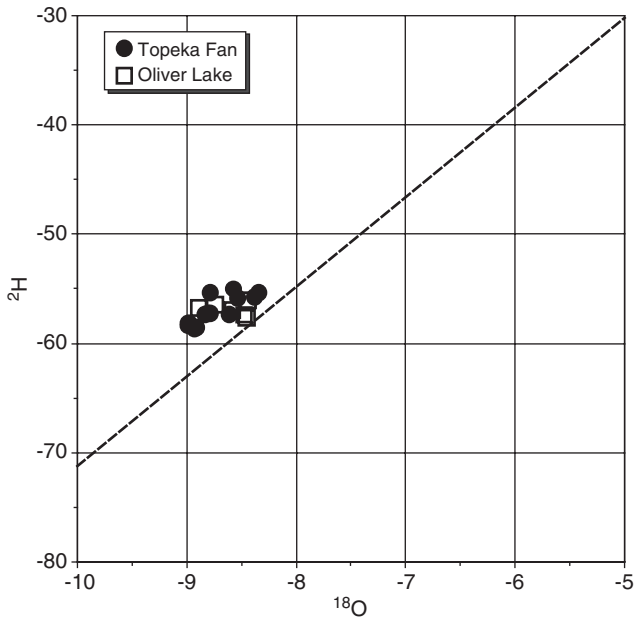

Figure 8.9a. Graph showing the $\delta^{18}O$ and δ^2H values for the 19 water samples with tritium concentrations of 2 TU or less.
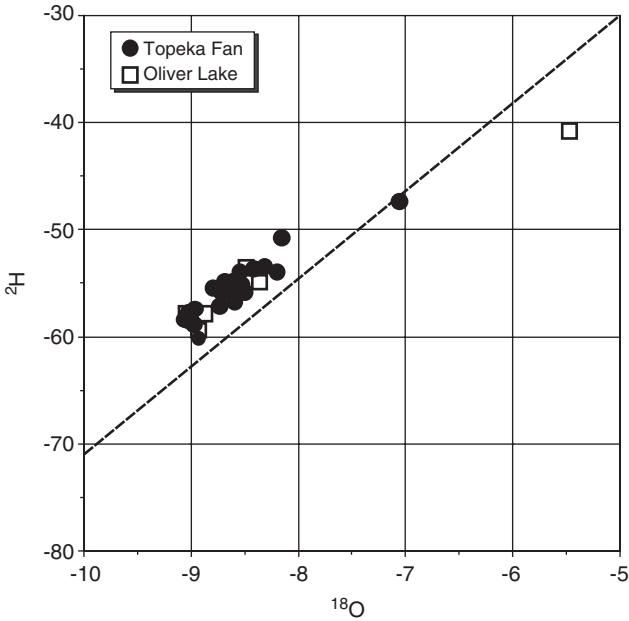
Figure 8.9b. Graph showing the $\delta^{18}O$ and $\delta^{2}H$ values for the 31 water samples with tritium concentrations greater than 2 TU.

groundwater samples from unconsolidated glacial deposits in north-western Indiana (Hasenmueller et al., 2001). In that study, the $\delta^{18}O$ values ranged from -9.3 to $-6.66‰$ and averaged $-8.35‰$; $\delta^{2}H$ values ranged from -61.84 to -51.83 ‰ and averaged $55.52‰$. The water isotope data from the unconsolidated deposits in LaGrange County and northwestern Indiana plot close to the meteoric line (Fig. 8.10).

8.5. Conclusions and recommendations

The prevalent chemical character of the groundwater in LaGrange County is calcium-bicarbonate. The primary difference between the 2002 and 2003 datasets is (1) the addition of nitrate that caused an increase in the TDS content and (2) a moderate shift in the relative percentages of major anion species, which was not sufficient enough to modify the prevalent chemical character.

The 2002 and 2003 nitrate data indicate that groundwater in the Top-eka fan, Lima plain, and interlobate glacial sequences and in localized sand and gravel deposits in the Oliver Lake sequence, is sensitive to
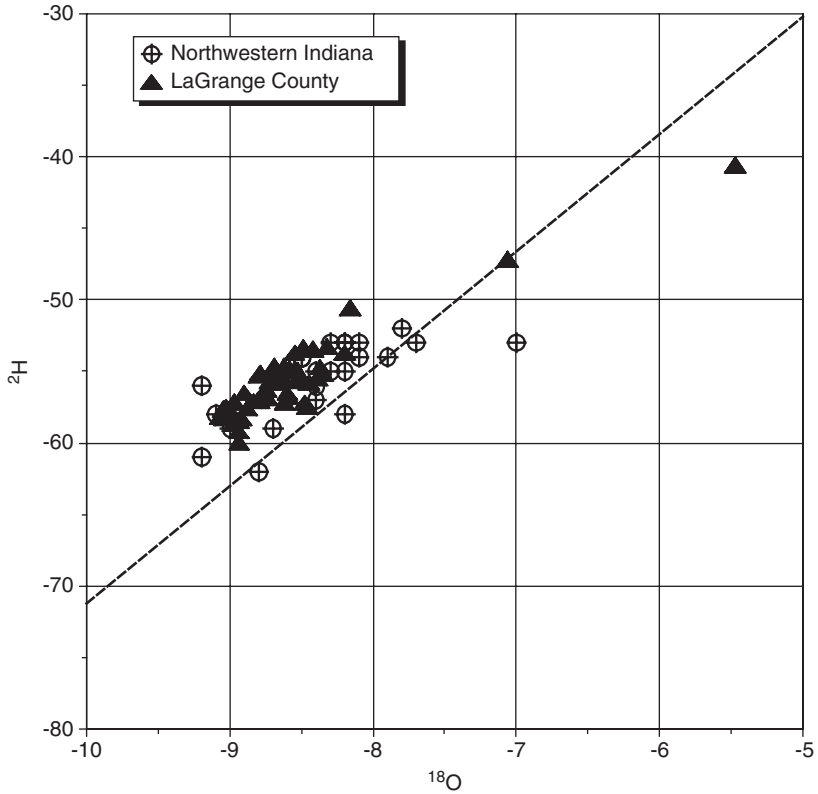
Figure 8.10. Graph showing stable isotopes correlations to meteoric water line for water samples from unconsolidated glacial materials in northern Indiana.

anthropogenic contamination from the surface. The nitrogen isotope ratios from groundwater in wells in LaGrange are similar to those measured in the following land-use settings in Minnesota sand plains: livestock feedlots, residential areas with septic systems, and nonirrigated-cultivated areas. Poorly performing septic systems may be a source of some of the nitrate and may be more readily identified as nitrogen sources when positive correlations occur between nitrogen isotope values and other component concentrations, such as sodium. Septic failure often occurs as the result of the absorption field being plugged; however, this type of failure is not as common in LaGrange County. In this county, most failures occur when septic systems are completed in coarse-grained deposits, which are permeable and allow sewage to flow into the groundwater aquifer system. Such failures can cause groundwater contamination.

The 2002 tritium data indicate that the groundwater in 62% of the wells sampled in the Topeka fan and Oliver Lake areas has been recharged since 1952. The groundwater in the remaining wells in the Topeka fan and Oliver Lake glacial sequences has been recharged between 10,000 years before present and 1953.

The coarse sand and gravel aquifers in the area facilitate the rapid flow of groundwater. To prevent contamination of the groundwater in the county, property owners should consider nearby sources of potential contamination, such as septic systems or farm-animal storage areas, before drilling new water wells. Farmers should be encouraged to participate in the voluntary manure management program currently available. And when feasible, additional wastewater treatment facilities should be built to treat waste from the smaller communities and lakeshore properties.

To more definitively determine the nitrate sources contributing to contamination, long-term site-specific water monitoring and site evaluation are necessary. This should include water sampling at various distances from identified sources and at various depths.

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