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Shallow Groundwater Sampling in Kane County, 2015

Walton R. Kelly, Daniel R. Hadley, Devin H. Mannix

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Illinois State Water Survey
Prairie Research Institute
University of Illinois at Urbana-Champaign

Champaign, Illinois

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Abstract

In October 2003, scientists from the Illinois State Water Survey (ISWS) sampled 75 shallow wells for water-quality analysis in Kane County to provide a "snapshot" of groundwater quality in these shallow aquifers, and to compare water quality from different parts and aquifers of Kane County. In the fall of 2015, the study was repeated to assess how groundwater quality had changed since 2003. Sixty-eight wells were sampled in 2015, 55 of which had been sampled in 2003.

The quality of shallow groundwater in Kane County is generally good, especially in the western and central thirds of the county. However, the total dissolved solids (TDS) values of samples from the eastern third of the county were significantly higher than elsewhere in the county; chloride was the ion of greatest concern. Two-thirds of the samples from the eastern wells sampled had TDS and/or chloride concentrations above their drinking water standards. Road-salt runoff is most likely the major source of elevated TDS and chloride.

Of the wells sampled in both 2003 and 2015, about 60 percent had higher TDS values in 2015, with three having increases greater than 100 mg/L. The average increase for the wells with increasing TDS values was 50 mg/L. The increase in TDS is entirely explained by increases in chloride and sodium concentrations, which increased in 78 percent and 59 percent of the wells, respectively. The average increase for wells with increasing values was 25.4 mg/L for chloride and 19.2 mg/L for sodium. The average rate of increase in chloride concentrations in the urban eastern third of Kane County was 3.9 mg/L/yr, which is similar to rates found in other studies in northeastern Illinois.

Introduction

Kane County is located in northeastern Illinois in the Chicago metropolitan area (Figure 1). Kane County has seen significant development and population growth in recent decades; it is now the fifth most populous county in Illinois with over half a million residents. The majority of residents rely on groundwater for their drinking water supply, and the county has taken steps to better understand and protect their groundwater resources. In the early 2000s, the Kane County Illinois Board funded Illinois State Water Survey (ISWS) and Illinois State Geological Survey (ISGS) projects to collect data and develop tools to provide a scientific basis for managing the county's water resources. One of the projects was designed to evaluate shallow groundwater quality in Kane County, and involved collecting samples from 75 shallow (< 250 ft deep) wells for water-quality analyses. The quality of shallow groundwater in Kane County was found to be good, especially in the western and central thirds of the county (Kelly, 2005). However, the total dissolved solids (TDS) values of samples from the eastern third of the county were significantly higher than elsewhere in the county. The ions of greatest concern were chloride and sulfate, and almost two-thirds of samples from the eastern wells sampled had TDS, chloride, and/or sulfate concentrations above their secondary drinking water standards. Road-salt runoff, vehicular exhaust, and industrial discharges were suggested to be the most likely sources of these elevated solutes. Because groundwater moves slowly, the widespread presence of high TDS groundwater in the eastern urban corridor of Kane County suggested a fairly long history of shallow groundwater contamination. In 2015, the Kane County Board funded a follow-up study to assess how shallow groundwater quality had changed since 2003. This report gives the results of that study.

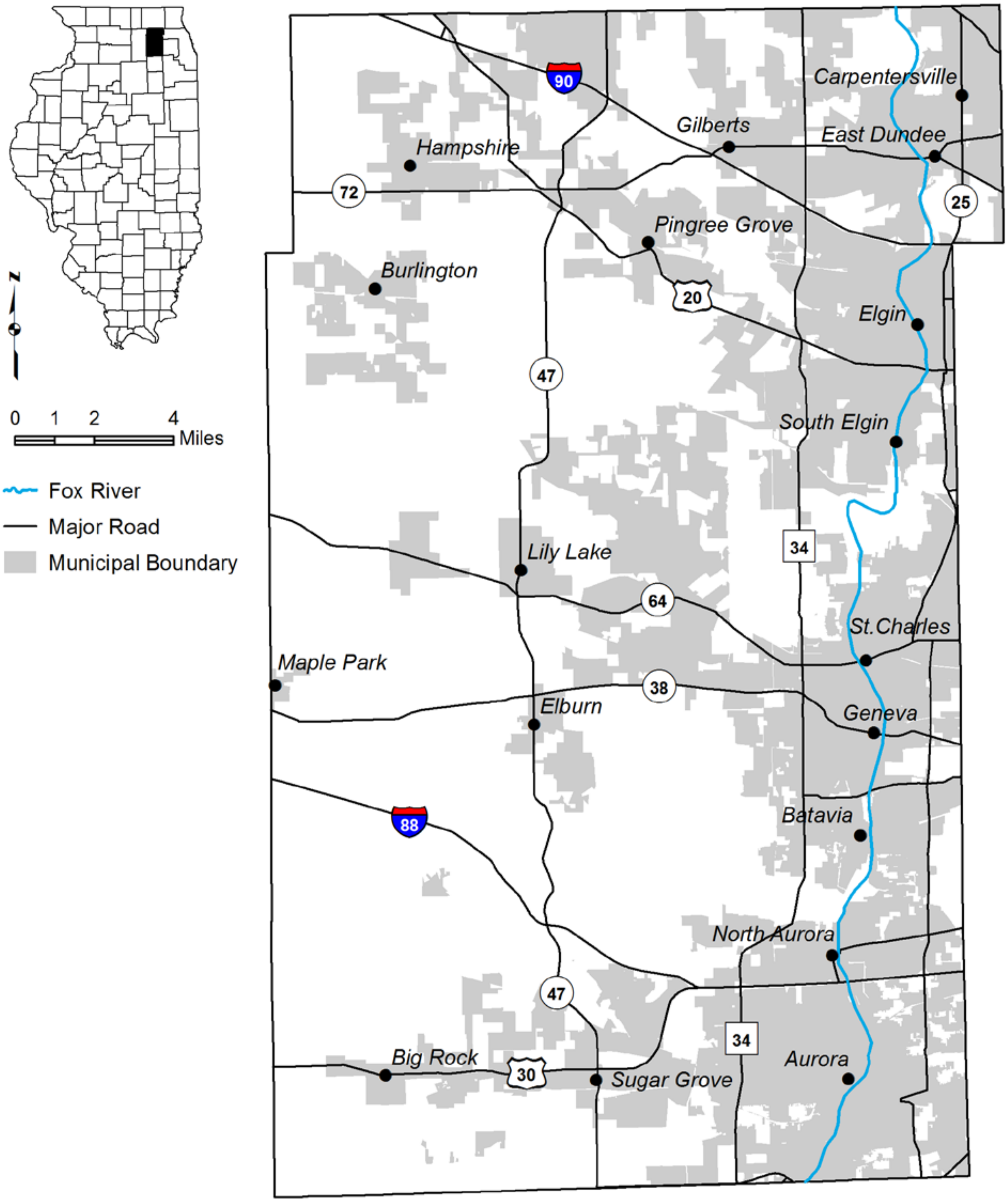

Figure 1. Kane County Illinois.

Acknowledgments

Several ISWS researchers contributed to this project. Dan Webb, Omar Ali, Rita Bargon, Malcolm P. Cole, Tatyana V. Grandt, Brenda Houy, Ruth Ann Nichols, Kaye Surratt, Jennifer Tester, and Monte R. Wilcoxon of the ISWS Public Service Laboratory (PSL) provided most of the chemical analyses. Shari Fanta of the ISGS provided stable isotope analyses. Tom Holm (ISWS, retired) and Sam Panno (ISGS) provided constructive peer reviews of the report. Special thanks is given to all the well owners who allowed sampling of their wells.

The Kane County Board sponsored this project, and Jodie Wollnik, Kane County Water Resources Department, acted as liaison to the board and championed the project. We also thank Paul Schuch for his continued support for the Illinois State Water Survey and Prairie Research Institute (PRI). The views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsor, the ISWS, or PRI.

Objectives

The first three objectives of the investigation were the same as for the 2003 study, i.e., to (1) provide a “snapshot” of water quality in shallow aquifers in Kane County; (2) compare water quality from different parts of Kane County, especially the eastern urban corridor and the western agricultural section; and (3) compare water quality from different shallow aquifers, i.e., bedrock vs. unconsolidated deposits. The fourth objective was to compare Kane County shallow groundwater-quality conditions between 2003 and 2015.

Geologic Setting

Glacial deposits cover the entirety of Kane County but vary in thickness, composition, and hydrogeologic characteristics (Figure 2). Glacial deposits are over 300 feet thick in portions of northwestern Kane County where the Marengo Moraine is present, and in southeastern Kane County where the St. Charles Bedrock Valley is present (Curry et al., 2013, Dey et al., 2007c). The unconsolidated material that was deposited in several glaciation episodes consists of clays, silts, sands, gravels, or mixtures of poorly sorted sediments (tills). Productive aquifers are usually present where the sands and gravels are thick and laterally extensive. Glacial tills typically have a high clay content and generally act as confining units between the sand and gravel deposits or the underlying bedrock aquifers (Figure 2). The bedrock underlying the glacial material consists of Silurian Dolomite and Maquoketa Shale, both of which serve as aquifers where they are fractured and weathered (Locke and Meyer, 2007). The younger Silurian Dolomite is thickest in southeastern Kane County and generally becomes thinner towards the northwest (Dey et al., 2007b). The Silurian Dolomite is eroded in most of the northwest portion of the county and also in the major bedrock valleys (Figure 2). The underlying Maquoketa Shale is exposed at the bedrock surface in these areas and extends throughout the entire county, except for a small area near Big Rock, where the underlying Galena Dolomite is exposed.

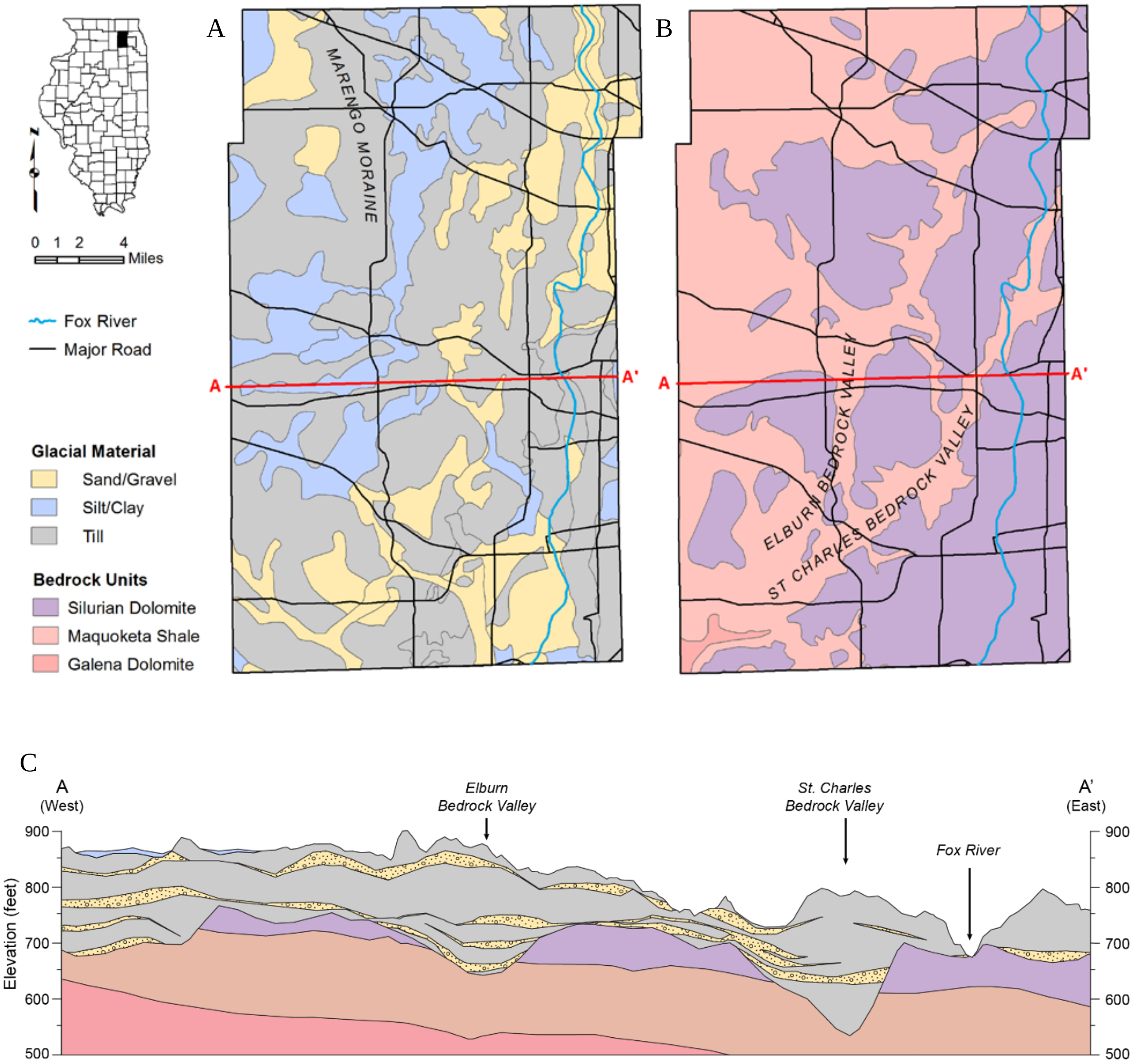

Figure 2. A) Surficial geologic map of Kane County indicating the type of glacial material deposited at land surface. Map modified from Stiff (2000); B) Bedrock geologic map of Kane County indicating bedrock units exposed at the bedrock surface and major bedrock valleys. Map modified from Kolata (2005); C) Geologic cross-section through central Kane County from west to east. Note the presence of glacial sand and gravel deposits separated by low permeability till material, major bedrock valleys, and the modern Fox River valley. Cross-section modified from Dey et al. (2007c).

Procedures

Well Selection

For the 2003 sampling, 75 shallow (< 250 ft deep) wells were sampled. The wells were selected from a database compiled by the ISWS as part of the study of groundwater resources in Kane County (Locke and Meyer, 2007). Most wells were domestic supply wells, with the remaining being commercial or county park district wells. Because one of the goals of the original study was to compare water quality in the eastern urban corridor with that of rural agricultural areas in the west, it was decided to sample 30 wells in both the eastern and western thirds of the county, and 15 wells in the central third. Two additional restrictions were imposed on well selection. Within each U.S. Geological Survey (USGS) 7.5 minute topographic quadrangle, wells were selected so that they were representative with respect to location, depth, and source aquifer (shallow bedrock or unconsolidated deposits). A complete description of the well-selection procedure is found in Kelly (2005).

A major goal of this study was to re-sample as many of the wells sampled in 2003 as possible, and we were able to sample 55 of those wells. For the other 20 wells, we were either denied permission, could not make contact with the well owner, or the well had been sealed. An attempt was made to replace those 20 wells with other wells with a similar location, depth, and source aquifer. We were able to sample 13 replacement wells; for the other seven wells we were unable to get permission to sample a suitable replacement.

The locations, depths, and source aquifers of each well sampled in 2015 are shown in Figure 3.

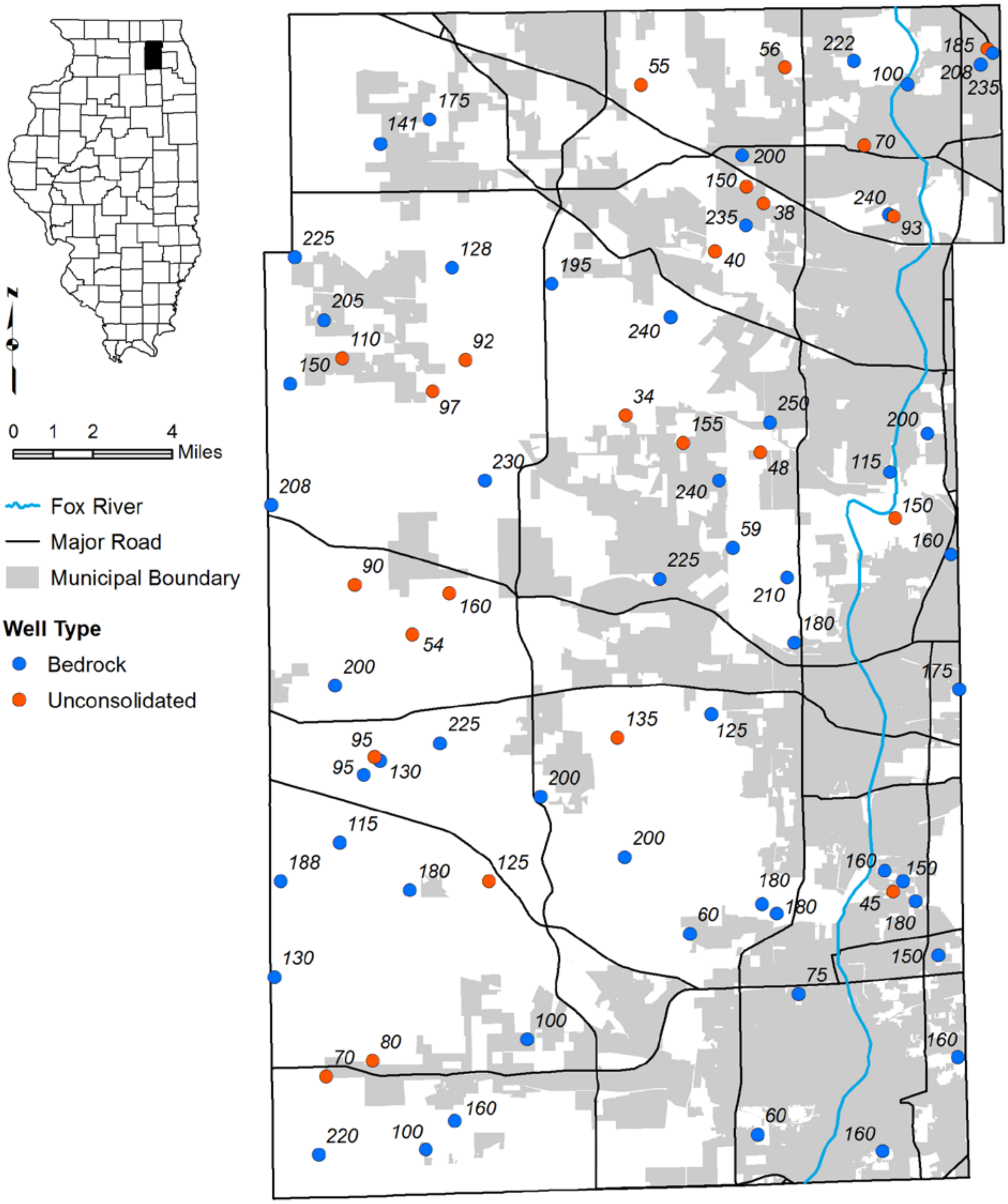

Figure 3. Locations and depths (ft) of sampled wells.

Sample Collection

Several types of sample containers and preservatives were used (Table 1). Bottle sets (one bottle for each analyte in Table 1) were assembled in two-gallon resealable plastic bags.

Table 1. Sample Containers, Preservatives, and Holding Times

Analyte	*Container*	*Preservative (%)*	*Filtered*	*Holding Time (days)*
Metals	HDPE	0.2% HNO_3	Yes	180
Anions/alkalinity	HDPE	None	Yes	2
NH_3-N	HDPE	0.2% H_2SO_4	Yes	24
DOC	Glass	0.5% H_3PO_4	Yes	28
δD, $\delta^{18}O$	HDPE	None	Yes	
Coliform Bacteria	Sterile HDPE	None	No	ASAP
Fecal Coliform, *E. coli*	Sterile HDPE	None	No	ASAP

Notes: Preservative percentage was by volume of concentrated high-purity acid.
Holding time for dissolved organic carbon was not specified for acidified samples.

A multi-probe instrument was used to measure temperature, specific conductance (SpC), pH, platinum-electrode oxidation-reduction potential (ORP), and dissolved oxygen (DO). Manufacturer's directions (Hydrolab MS-5 Mini-Sonde, OTT Hydromet) were used to calibrate the instrument before each sampling day.

Wells were sampled from outside taps indicated by owners to be upstream of any treatment. A flow splitter was attached to the tap. A garden hose was connected to one branch of the connector, and a flow cell was connected to the other branch. The tap was turned to maximum flow, and most of the flow went through the hose. Temperature, pH, and the other variables were monitored until the readings stabilized. Readings were considered stable if there was a temperature change of less than 0.1°C, SpC within 5 percent of the initial value, a pH change of less than 0.02, and an ORP change of less than 5 millivolts (mV) over a 60 second period. Readings typically stabilized within 5-10 minutes except for DO, which sometimes continued to drift downward. The DO probe responds very slowly to DO concentrations below ~ 1 milligram per liter (mg/L); if the DO reading fell to below ~0.8 mg/L and was still falling, undetectable DO was assumed.

After the readings were recorded, the flow cell was disconnected from the sampling line to collect samples. One of the sampling crew, the only one to handle sample bottles, donned powder-free gloves. An unfiltered sample was collected to measure hydrogen sulfide. The sample tube then was connected to a 0.45 micrometer (μm) filter capsule, and filtered samples were collected to measure metals, anions, alkalinity, ammonium-nitrogen (NH_3-N), dissolved organic carbon (DOC), and the stable isotopes of water (δD, $\delta^{18}O$). Appropriate acids were added to the metals, NH_3-N, and DOC sample bottles in the field (Table 1). The flow splitter then was removed from the tap and the tap was flame sterilized. Unfiltered samples for bacterial analysis (total coliform (TC), fecal coliform (FC), and *E. coli*) were then collected directly from the tap in sterile bottles. After all samples were collected, the bottles were returned to their Zip-Lock® bags and stored in a cooler with ice. If the sampling crew was not returning to the ISWS that day, additional ice was added to the coolers as necessary.

Field analyses of semi-quantitative hydrogen sulfide were conducted during sample collection using a portable colorimetric testing kit (CHEMetrics, Inc., Calverton, VA). A plastic sample cup was used to collect 25 mL of water. Three drops of an activator solution (ferric chloride in concentrated HCl) was added to the sample, then stirred. An ampule containing N,N-dimethyl-p-phenylene diamine was opened in the bottom of the cup, which was inverted several times until the solution had a uniform color. After waiting five minutes, a visual color comparator was used to determine the solution's approximate hydrogen sulfide concentration.

Samples for bacteria analyses were delivered to Suburban Laboratories in Geneva, Illinois, within 24 hours of collection.

Chemical Analyses

The ISWS Public Service Laboratory (PSL) in Champaign, IL conducted most of the chemical analyses, using standard methods (www.sws.uiuc.edu/chem/ias/). Anions were analyzed by ion chromatography, metals by inductively coupled plasma-atomic emission spectrometry, alkalinity by titration, NH_3-N by colorimetry, DOC by carbon analyzer, and arsenic by graphite furnace atomic absorption spectrometry with Zeeman background correction.

Analyses of the water isotopes were conducted at the ISGS Isotope Laboratory in Champaign. The $\delta^{18}O$ value was determined using a modified CO_2-H_2O equilibration method as originally described in Epstein and Mayeda (1953), with modifications described in Hackley et al. (1999). The δD was determined using the Zn-reduction method described in Coleman et al. (1982) and Vennemann and Oneil (1993), with modifications described in Hackley et al. (1999).

Bacterial analyses were conducted at Suburban Laboratories in Geneva, IL. Standard Method 9223, the chromogenic substrate coliform test, was used to determine the presence of total coliform (Standard Methods, 2016). Standard Method 9222D, the fecal coliform membrane filter procedure, was used to determine fecal coliform and *E. coli* bacteria numbers (Standard Methods, 2016).

Statistical Analyses

Chemical data were compared in a variety of ways. Because most of the data are not normally distributed, nonparametric tests were used, i.e., Mann-Whitney rank sum test when comparing two populations and Kruskal-Wallis analysis of variance (ANOVA) on ranks tests when comparing more than two populations. Dunn's method was used to determine whether differences between population pairs were significant when ANOVA results indicated a significant difference. Significance was determined at the 95 percent level ($p < 0.05$) for all tests. The tests were run using SigmaPlot software (Systat, 2008).

ISWS Groundwater Quality Database

The ISWS maintains a Groundwater Quality Database (GWQDB), which contains historical water-quality data dating back to the late 1890s from both public and domestic wells. Well owners usually collect samples from domestic wells in containers provided by and mailed to the ISWS PSL for analyses of inorganic water quality. Sample data collected during this project were supplemented with GWQDB data from Kane County domestic wells less than 250 feet deep. To minimize possible temporal changes in groundwater quality, only GWQDB sample data collected since 2012 were used. Ten GWQDB samples met these criteria and are included in some of the graphs. Because GWQDB samples were not collected following the same sampling protocols of this study, they were not used in statistical analyses to avoid skewing the results.

Results and Discussion

Complete chemical results for samples collected in this study appear in Appendix A (Tables A-1 – A-8). Names and addresses were removed to protect the anonymity of well owners. All well owners received individual sampling results in January 2016 (see sample letter in Appendix B). Additional chemical results for GWQDB samples appear in Table A-9.

After reviewing the analytical results, it was determined that seven samples collected in 2015 had passed through a water softener. These samples were identified by their anomalously low concentrations of calcium, magnesium, iron, and other metals, and relatively high sodium concentrations. Two samples were determined to have passed through an aerator, identified by high levels of dissolved oxygen, high pH, and low metal concentrations. Results for the treated samples are reported in Tables A-5 – A-8. These samples were not included in statistical analyses except when considering major anions (chloride, sulfate), whose concentrations are not affected by these treatments.

Water-quality data are collected primarily to determine if water is safe for consumption or if contaminants need to be removed. The U.S. Environmental Protection Agency (USEPA) has promulgated maximum contaminant levels (MCLs) for about 100 inorganic and organic chemicals, microorganisms, disinfectants and disinfection byproducts, and radionuclides (USEPA, 2016). Most of these MCLs are primary standards for which potentially undesirable health effects have been identified when the standards are exceeded. These standards apply only to public water supplies and are legally enforceable. Secondary standards exist for 15 contaminants, primarily inorganic chemicals that may cause aesthetic or cosmetic problems; they are not enforceable. Analyses conducted at the ISWS for this study included 21 constituents on either the primary or secondary standard lists (Table 2); copper and fluoride have both primary and secondary MCLs. The detection limits for antimony, cadmium, lead, and selenium were greater than their primary MCLs of 0.006, 0.005, 0.015, and 0.05 mg/L, respectively.

Groundwater quality data also are collected to elucidate geochemical conditions within the source aquifer. Use of these data along with geological, hydrologic, and biological data helps scientists to understand processes that may affect the fate and transport of contaminants, mineral dissolution/ precipitation reactions, and aquifer recharge rates.

Dissolved Solids and Major Ions

The total dissolved solids (TDS) concentration of a water sample is determined by evaporating a measured volume of water and weighing the residue. TDS can be estimated in two ways. For this study, we elected to calculate TDS by summing up concentrations of the measured dissolved constituents. Another method is to use specific conductance, which is the measure of how water conducts an electrical current. Because the presence of charged ionic species makes a solution conductive, specific conductance is an indirect measure of the amount of dissolved minerals in water. There is generally a linear relationship between specific conductance and TDS for most groundwater samples (Hem, 1989). The linear relationship ($r^2 = 0.98$) between specific conductance and calculated TDS for the samples collected in this study is shown in Figure 4; the slope calculated using linear regression was 0.59, which is the representative value reported by Hem (1989).

A map of the calculated TDS values in Kane County indicates a difference in the shallow groundwater quality between the western and eastern thirds of the county (Figure 5); values were considerably higher in the eastern wells than in the western or central wells. The difference between the eastern and western wells was statistically significant (Table 3). Differences are also apparent when plotting median and 10th, 25th, 75th, and 90th percentile values and outliers for all sampled wells (Figure 6). Calculated TDS values of 19 sampled wells exceeded the secondary MCL of 500 mg/L, including 16 of the 26 wells in the eastern third of the county. The highest concentration was 1,242 mg/L.

Table 2. Primary and Secondary Drinking Water MCLs for Contaminants Analyzed in this Study (mg/L except for pH)

Primary Standards	*MCL*	*Potential Health or Other Effects*
Arsenic	0.010	Skin damage; problems with circulatory systems; increased cancer risk
Barium	2	Increase in blood pressure
Beryllium	0.004	Intestinal lesions
Chromium	0.1	Allergic dermatitis
Copper	1.3	Short-term exposure: gastrointestinal distress Long-term exposure: liver or kidney damage
Fluoride	4.0	Bone disease (pain and tenderness) and tooth discoloration in children
Nitrate-nitrogen	10	Infants below 6 months of age could become seriously ill and may die if untreated for shortness of breath and blue-baby syndrome
Total coliforms	0	Not a health threat in itself, but used to indicate presence of other potentially harmful bacteria
Secondary Standards		
Aluminum	0.05 - 0.2	Colored water
Chloride	250	Salty taste
Copper	1.0	Metallic taste; blue-green staining
Fluoride	2.0	Tooth discoloration
Iron	0.3	Rusty color; sediment; metallic taste; reddish or orange stains
Manganese	0.05	Black to brown color; black staining; bitter metallic taste
pH	6.5 - 8.5	*<6.5:* bitter metallic taste; corrosion; *>8.5*: slippery feel; soda taste; deposits
Sulfate	250	Salty taste
Total Dissolved Solids	500	Hardness; deposits; colored water; staining; salty taste
Zinc	5	Metallic taste

Note: Antimony, cadmium, lead, and selenium were analyzed, but detection limits were greater than the MCLs.

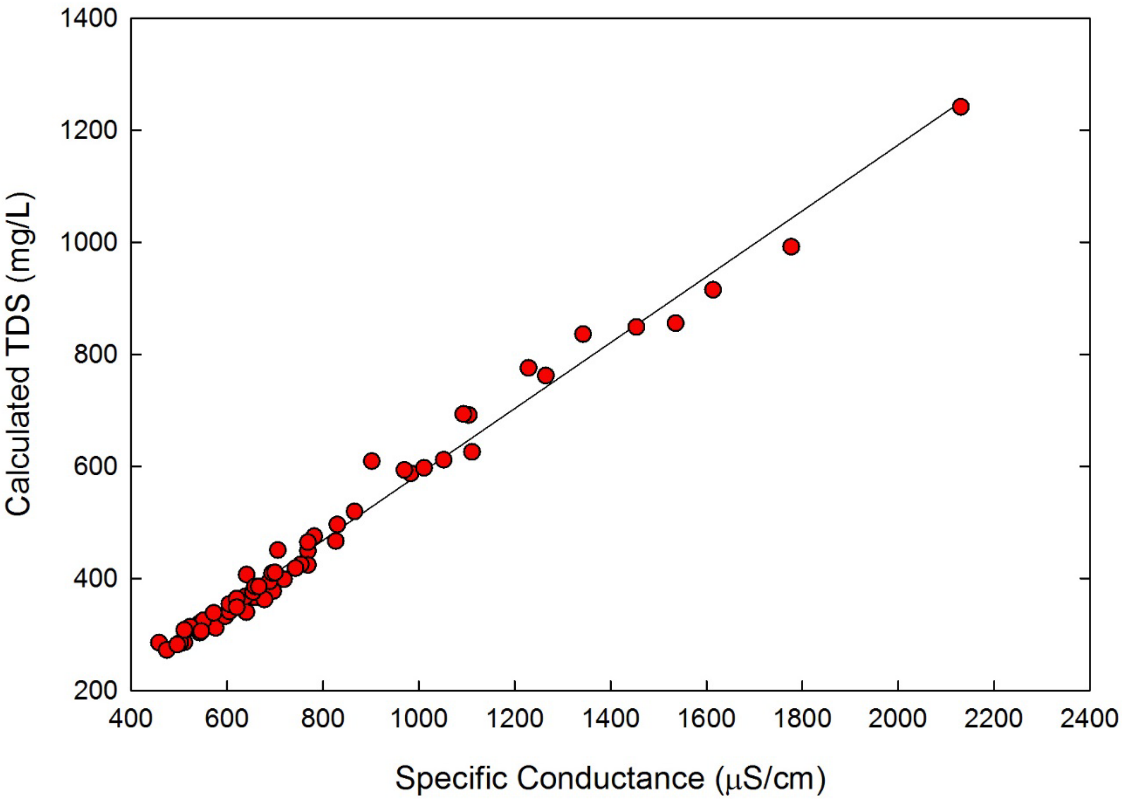

Figure 4. Calculated TDS vs. specific conductance. Linear regression gives a slope of 0.59 with $r^2 = 0.98$.

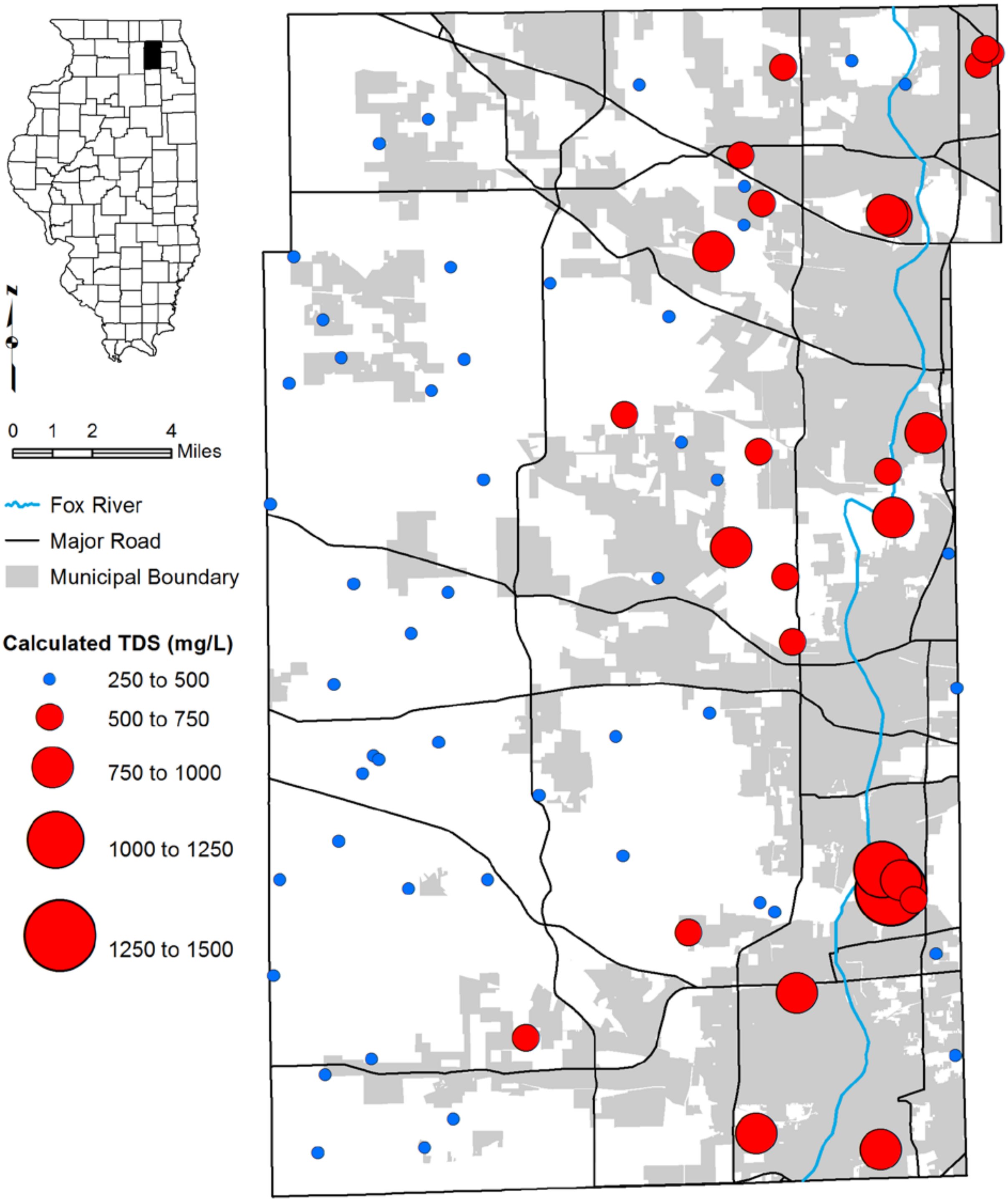

Figure 5. TDS values of sampled wells and well samples from the GWQDB. Red circles indicate concentrations above the secondary MCL.

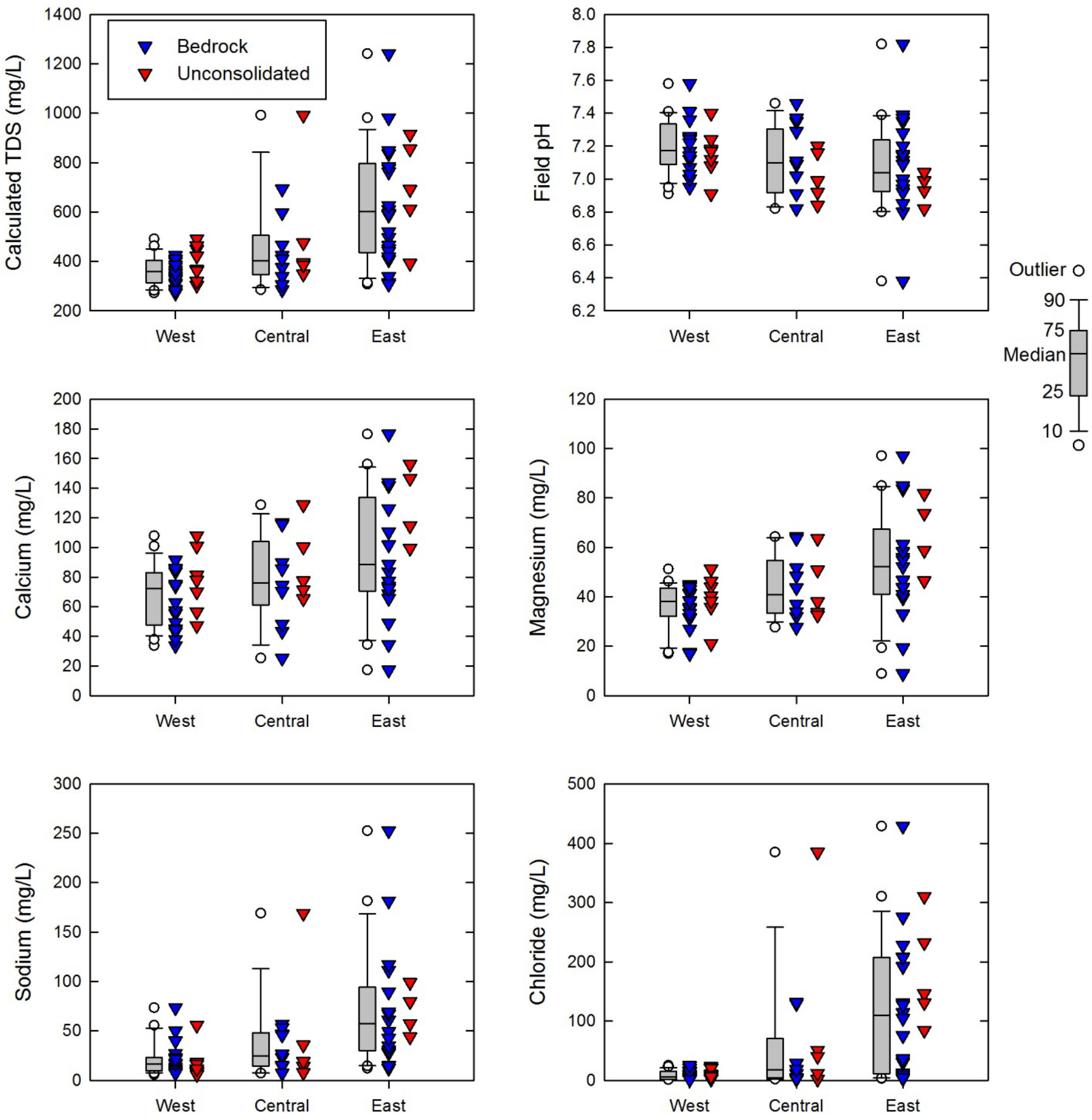

Figure 6. Box and whisker and point plots for TDS, pH, and major ion concentrations of sampled wells. Box and whisker plots are for all data and show median and 10th, 25th, 75th, and 90th percentile concentrations. Point plots show concentrations for wells distinguished by source aquifer.

TDS values are primarily a function of the concentrations of major ions in solution: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), chloride (Cl^{-}), bicarbonate (HCO_3^{-}), and sulfate (SO_4^{2-}). Although HCO_3^{-} was not measured directly, its contribution to TDS can be calculated by multiplying alkalinity by 0.6. When discussing dissolved inorganic carbon, this report generally uses alkalinity, which was measured for this study, rather than HCO_3^{-}. The concentrations of all the major ions were greater in the eastern third of the county than in the central and western thirds (Figures 6 and 7). The concentrations of magnesium, sodium, alkalinity, chloride, and sulfate were significantly greater in the eastern wells than in the western wells, and concentrations of sodium and sulfate were also significantly greater in the eastern wells than in the central wells (Table 3).

The most likely explanation for the high chloride and major cation (Ca^{2+}, Mg^{2+}, and Na^{+}) concentrations in the eastern third of Kane County is road-salt runoff. A map of chloride concentrations is shown in Figure 8. Historically, halite (NaCl) has been the primary deicing material applied to roads. Halite is very soluble and dissolves readily into its constitutive parts (Na^{+} and Cl^{-}) when exposed to water. Chloride typically migrates conservatively (i.e., at approximately the same rate as groundwater flow) in the subsurface, and chloride concentrations have been increasing in many shallow wells in northeastern Illinois since the 1960s when large quantities of road salt first began to be used (Kelly, 2008). Chloride concentrations in three wells in the east and one in the central sections exceeded the 250 mg/L secondary MCL, with the highest concentration being 429 mg/L. Sodium is more reactive than chloride, and when it enters the subsurface it may exchange with calcium and magnesium ions on clay surfaces, releasing $Ca^{2+}$and Mg^{2+} into solution (Hem, 1989). Thus, the concentrations of all three major cations may increase as a result of road-salt runoff.

Table 3. Minimum, Median, and Maximum Values of Various Physical and Chemical Constituents as a Function of Location in Kane County

Constituent	*West*			*Central*			*East*			*Statistical significance*
	Min	*Med*	*Max*	*Min*	*Med*	*Max*	*Min*	*Med*	*Max*	
Well depth (ft)	54	135	230	40	145	240	56	167	250	
Overlying till thickness (ft)	32	95	165	30	100	170	33	87	231	
Temperature (°C)	11.2	12.5	17.5	11.4	12.4	15.3	11.0	12.8	21.1	
pH	6.91	7.18	7.58	6.82	7.10	7.46	6.38	7.04	7.82	
ORP (mv)	47	105	381	53	100	334	77	136	228	E > W
Spec. conductance (µS/cm)	474	605	769	458	695	1777	511	983	2131	E > W
Dissolved oxygen	0	0.1	4.0	0	0	2.1	0	0	7.7	
Hydrogen sulfide	<0.1	<0.1	0.1	<0.1	<0.1	2.5	<0.1	<0.1	0.9	
Arsenic (µg/L)	<0.79	0.929	46.0	<0.79	1.83	19.3	<0.79	0.992	21.7	
Barium	0.0326	0.0808	0.276	0.0212	0.0929	0.769	0.0069	0.0873	0.242	
Boron	<0.023	0.0827	2.39	0.0252	0.108	0.406	0.0290	0.109	1.77	
Calcium	33.6	72.0	108	25.2	75.9	129	17.2	88.5	177	
Copper	<0.0016	<0.0016	0.0171	<0.0016	<0.0016	0.0393	<0.0016	<0.0016	0.0097	
Iron	<0.024	1.13	3.11	0.0358	2.11	4.27	0.0378	1.37	6.69	
Magnesium	16.9	38.1	51.2	27.6	40.8	64.3	8.83	52.1	97.1	E > W
Manganese	0.0023	0.0152	0.104	0.0024	0.0239	0.115	0.0023	0.0299	0.384	
Molybdenum	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	0.0433	
Phosphorous	<0.073	<0.073	0.135	<0.073	<0.073	0.198	<0.073	<0.073	0.162	
Potassium	1.06	1.46	28.2	1.22	2.16	9.65	1.67	3.46	20.2	E > W
Silicon	3.44	8.32	11.6	5.37	8.44	12.6	3.56	7.88	12.4	
Sodium	5.62	16.1	73.3	7.12	24.7	169	12.1	57.3	253	E > W; E > C
Strontium	0.120	0.480	1.14	0.105	0.600	2.89	0.0806	0.657	2.33	
Thallium	<0.017	<0.017	0.0198	<0.017	<0.017	0.0216	<0.017	<0.017	<0.017	
Zinc	<0.0097	<0.0097	0.0784	<0.0097	<0.0097	0.0275	<0.0097	<0.0097	0.0207	
Alkalinity ($CaCO_3$)	262	317	358	247	346	436	274	359	577	E > W
Fluoride	0.167	0.414	1.53	0.126	0.401	0.829	0.110	0.424	1.48	
Chloride	0.885	5.46	24.9	1.59	18.1	385	2.85	109	429	E > W
Bromide	<0.08	<0.08	<0.08	<0.08	<0.08	0.112	<0.08	<0.08	0.403	

Table 3. Minimum, Median, and Maximum Values of Various Physical and Chemical Constituents as a Function of Location in Kane County (continued)

	West			*Central*			*East*			*Statistical significance*
Constituent	*Min*	*Med*	*Max*	*Min*	*Med*	*Max*	*Min*	*Med*	*Max*	
Sulfate	<0.21	3.88	106	<0.21	12.0	94.8	<0.21	60.2	211	E > W; E > C
Nitrate-N	<0.04	<0.04	2.80	<0.04	<0.04	0.0818	<0.04	<0.04	0.147	
Ammonium-N	<0.03	0.425	3.04	<0.03	0.484	7.56	<0.03	0.399	25.6	
DOC	0.330	1.10	5.67	<0.31	1.48	6.64	0.453	1.01	21.4	
TDS (calculated)	272	347	491	285	402	992	308	609	1242	E > W
Hardness	156	337	480	195	357	582	79	451	840	E > W
δD (‰)	-54.3	-50.4	-44.7	-54.4	-49.7	-42.5	-57.8	-51.7	-46.0	
δ^{18}O (‰)	-8.42	-7.90	-7.26	-8.37	-7.88	-6.27	-8.67	-8.07	-6.70	
Fecal Coliform	<1	<1	>200	<1	<1	<1	<1	<1	5	

Notes: All values are mg/L unless otherwise specified.
Statistical significance indicates a population significantly different than another based on the Kruskal-Wallis ANOVA on ranks test.

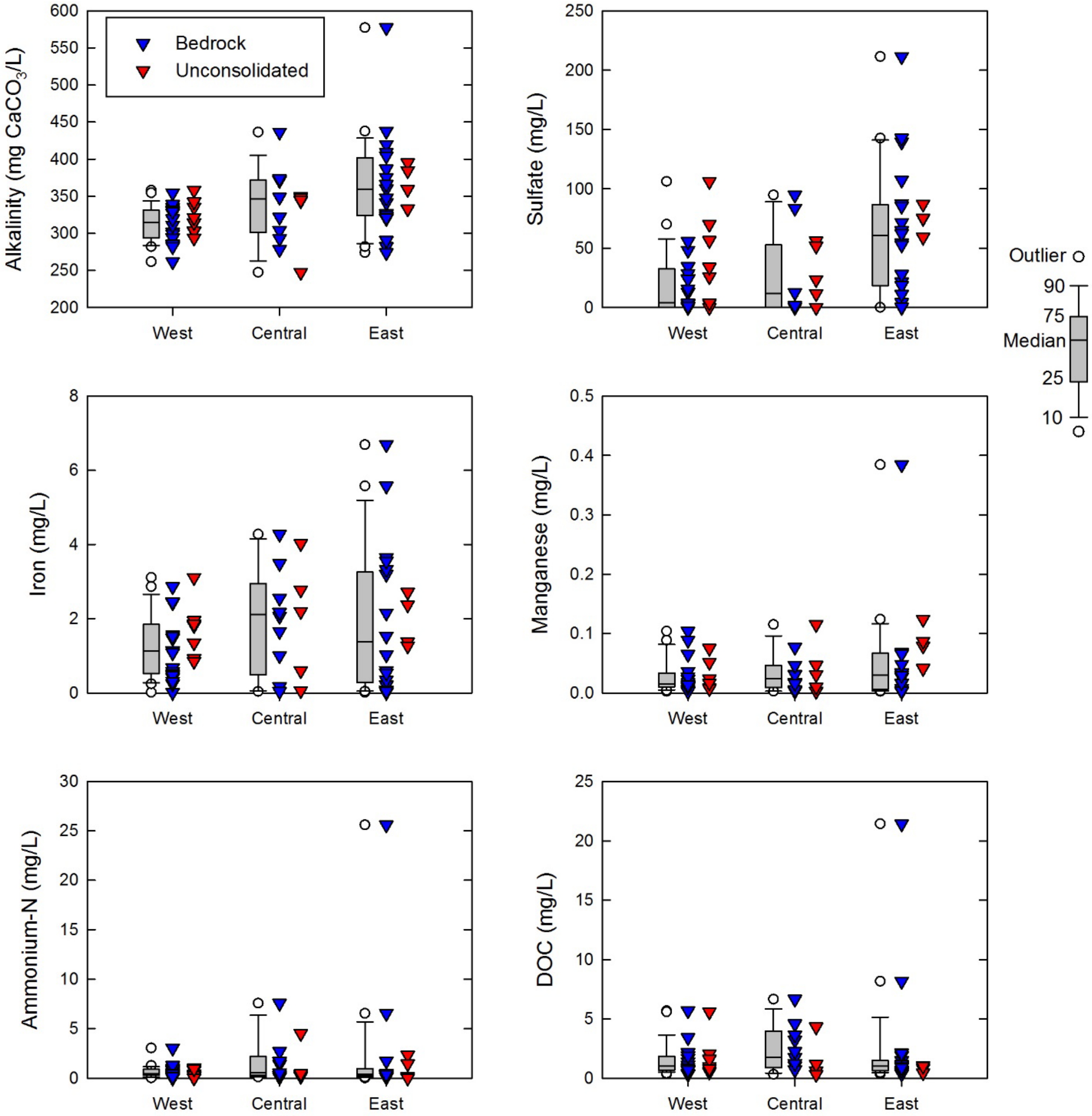

Figure 7. Box and whisker and point plots for various chemical parameters of sampled wells. Box and whisker plots are for all data and show median and 10th, 25th, 75th, and 90th percentile concentrations. Point plots show concentrations for wells distinguished by source aquifer.

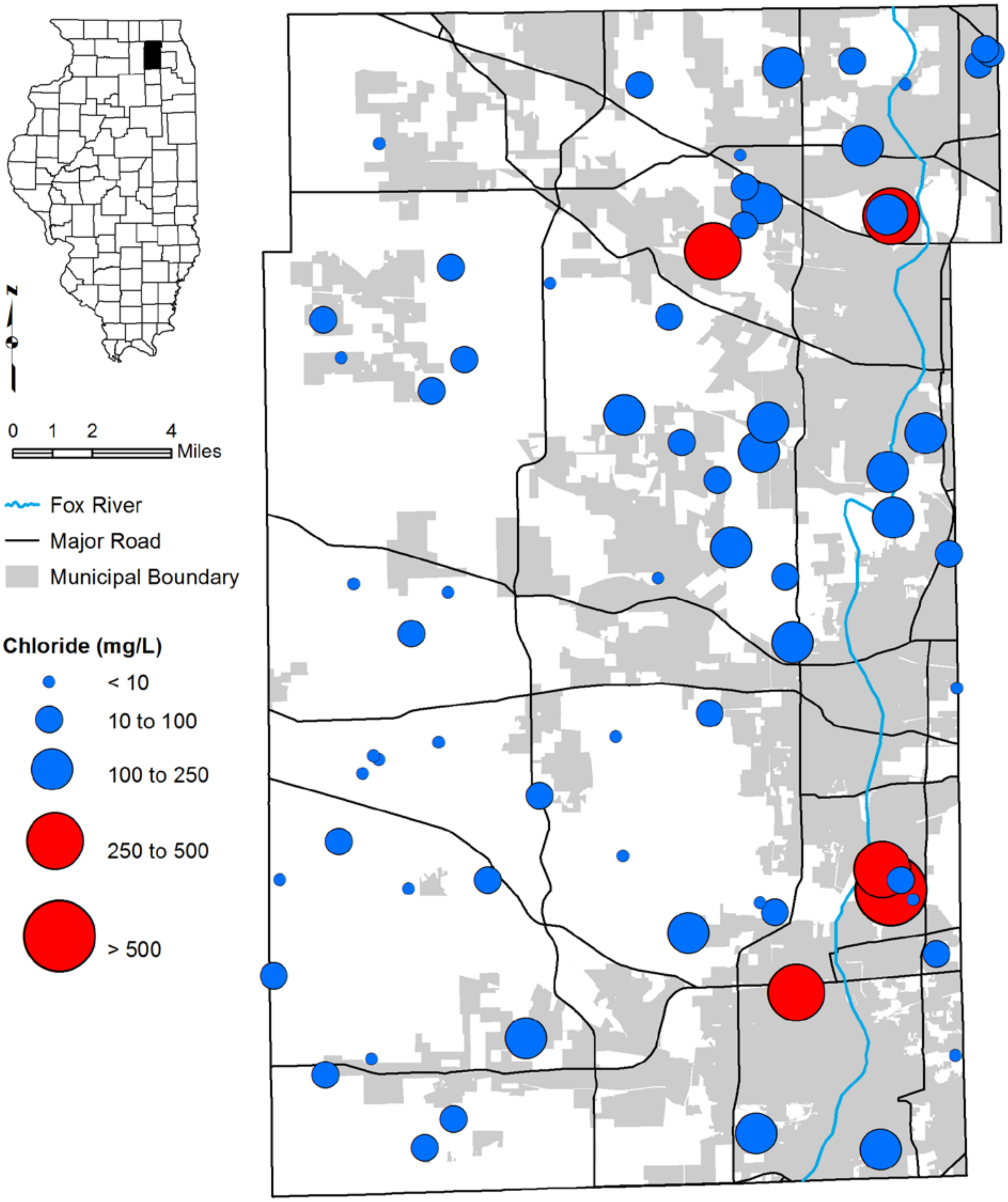

Figure 8. Chloride concentrations of sampled wells and well samples from the GWQDB. Red circles indicate concentrations above the secondary MCL.

Another potential source of chloride and sodium in Kane County is domestic septic systems that discharge brine from water softeners. Because groundwater in Kane County and in many other parts of Illinois is hard (has high levels of calcium and magnesium), domestic well owners commonly have water softeners. The calcium and magnesium ions that make water hard are replaced by sodium ions that are obtained from resin in the softening equipment. Iron and other heavy metals are also usually removed in the exchange process. When the resin reaches capacity and can no longer remove calcium and magnesium ions, it needs to be regenerated, usually with a concentrated NaCl brine solution. The brine is typically discharged into the septic system and eventually into the shallow groundwater. High-density housing with private septic systems thus may be a source of sodium and chloride to shallow groundwater (Katz et al., 2011).

The greater alkalinity in the east is at least, in part, a result of lower pH values than in the west or central portions of Kane County (Figures 6 and 7). As pH decreases, bicarbonate is converted to carbonic acid (H_2CO_3):

$$\mathrm{HCO_3^-} + \mathrm{H^+} \leftrightarrow \mathrm{H_2CO_3}$$

This reaction decreases alkalinity but does not affect the total dissolved carbon dioxide (HCO_3^- + H_2CO_3) in solution. The relationship between alkalinity and pH for the samples is shown in Figure 9. Alkalinity also may have been influenced by oxidation-reduction processes, as discussed in the next section.

Lower pH values in the eastern third of Kane County may reflect more acidic precipitation from industrial atmospheric discharges. Acidic precipitation may also explain the higher sulfate concentrations in the county’s eastern third (Figure 10). Elevated sulfate concentrations have been observed in other urban settings, as vehicles and industries contribute sulfur compounds to the atmosphere that eventually return to the land surface via precipitation and enter groundwater (Long and Saleem, 1974). Another potentially more important source of sulfate is from excavation of soils and sediments for construction purposes. The disturbance of soil and sediments can expose sulfide minerals such as pyrite (FeS_2) to air, causing them to oxidize and release sulfate (Wagner et al., 1982). These reactions also produce acid and may be a cause of lower pH values in the eastern third of the county. The highest sulfate concentration measured was 211 mg/L.

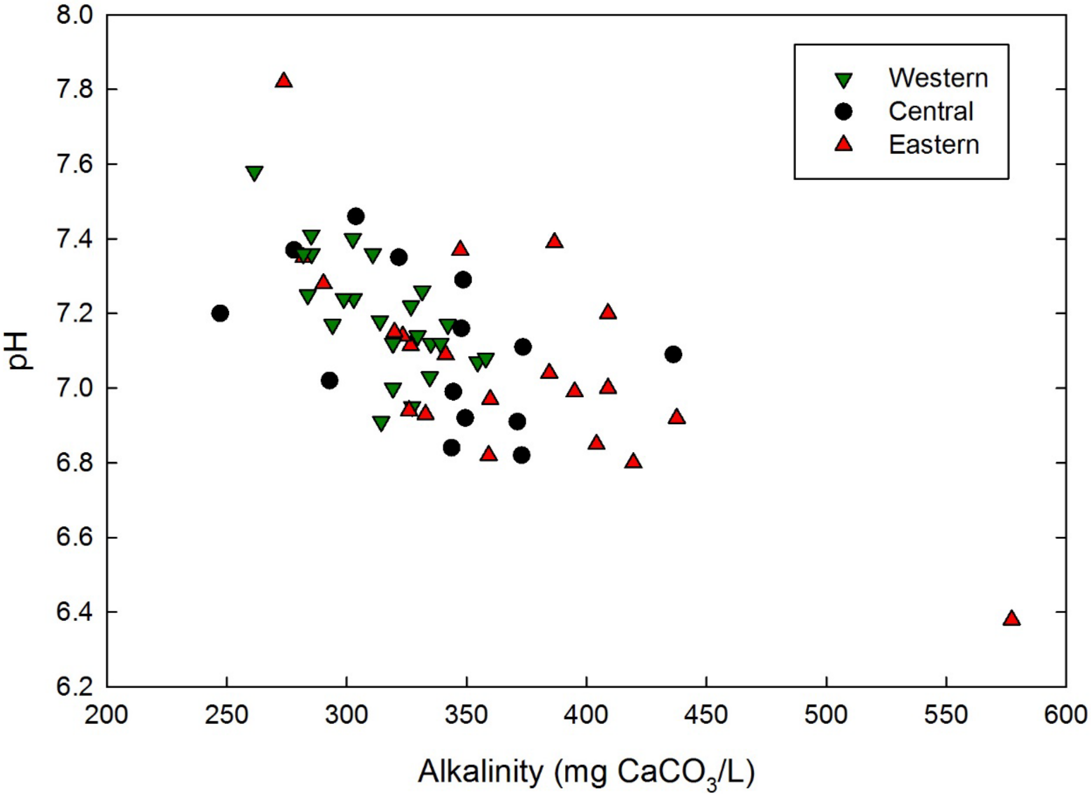

Figure 9. pH vs. alkalinity in sampled wells, identified by location in County.

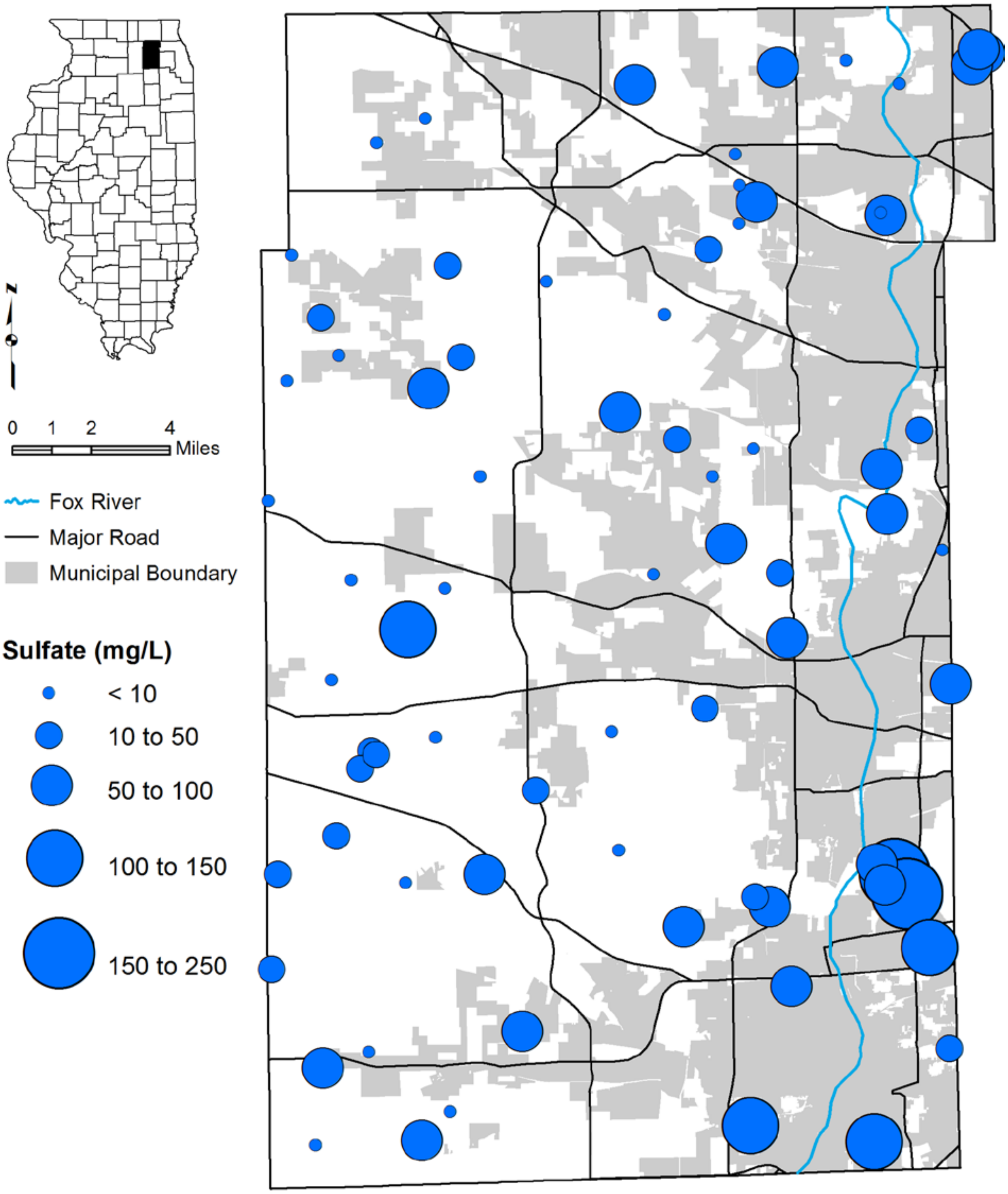

Figure 10. Sulfate concentrations of sampled wells and well samples from the GWQDB.

Water Isotopes

The stable isotopes of water ($\delta^{18}O$ and δD) are plotted in Figure 11, along with the meteoric water line (MWL) for the Chicago region [$\delta D = 7.2956(\delta^{18}O) + 3.9084$]. Almost all the samples plot above the line, indicating an enrichment in deuterium. This deviation has been observed in the Great Lakes region, due to evaporated moisture from the lakes mixing with atmospheric waters (Gat et al., 1994). There is no significant difference in isotope values between wells in bedrock vs. unconsolidated aquifers. The data are indicative of relatively recent recharge with little or no mixing with older Pleistocene waters.

Oxidation-Reduction Conditions

An important control on biogeochemical processes in groundwater is oxidation-reduction (redox) conditions in the aquifer. Redox reactions are chemical reactions that transfer electrons from one ion to another. Because surface waters have abundant oxygen due to contact with the atmosphere, conditions there are usually oxidizing. Oxygen in groundwater, however, is limited and often removed before it is transported very far due to the oxidation of organic matter and iron, and conditions are usually reducing. Oxygen removed from groundwater is not easily replaced, so other compounds are used in oxidation reactions. These other compounds, referred to as electron acceptors, include nitrate, ferric iron, and sulfate.

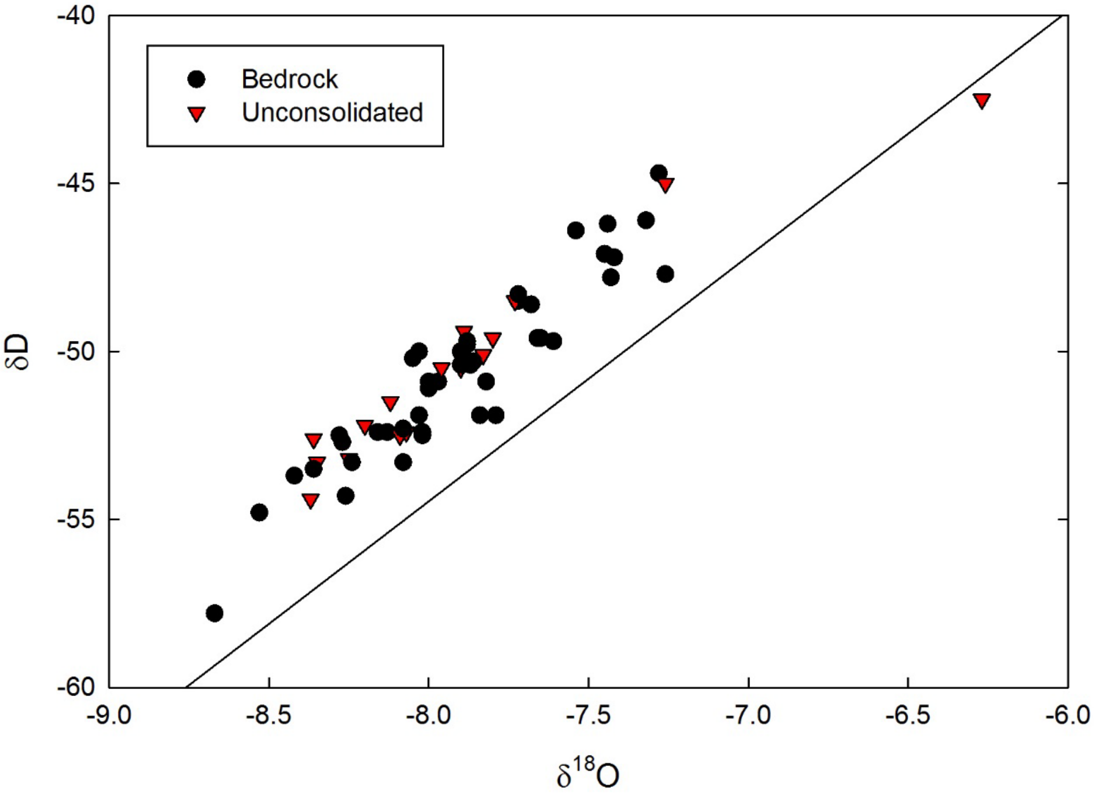

Figure 11. Stable isotopes for water in collected samples. Isotope values in parts per thousand (‰). Line is meteoric water line for the Chicago region [$\delta D = 7.2956(\delta^{18}O) + 3.9084$].

The values of most of the redox-sensitive parameters (DO, ORP, nitrate, iron, manganese, sulfate, hydrogen sulfide, and NH_3-N) indicate mild to strong reducing conditions in the shallow aquifers of Kane County. Reducing conditions in shallow, unconfined aquifers in Illinois are common (Kelly et al., 2005).

Buried organic matter is abundant in surficial glacial deposits (Coleman et al., 1988), and oxidation of these compounds removes oxygen from water during aquifer recharge. Reduction of iron oxyhydroxide minerals, also common in glacial deposits, occurs under moderately reducing conditions and increases dissolved iron concentrations in groundwater. Iron concentrations in 39 of the 49 non-softened and non-aerated samples (80 percent) exceeded the secondary MCL of 0.3 mg/L, and about 60 percent exceeded 1 mg/L (Figure 7).

Iron concentrations were generally lowest in the western third of the county (Figure 7), but the difference was not statistically significant (Table 3). There are several possible explanations for elevated iron levels in the more-developed parts of Kane County. As mentioned previously, sulfide minerals such as pyrite are found in sediments, and urban/suburban development may expose greater amounts of the glacial till to the atmosphere, causing pyrite oxidation and releasing iron into solution. More organic matter also may be exposed by development, increasing oxidation rates and reducing iron oxyhydroxide minerals. Solubilities of iron hydroxide minerals are a function of pH, and lower pH values may account for increased dissolution of iron oxyhydroxide minerals. Figure 12 shows correlations between iron and alkalinity ($r^2 = 0.30$ for all data; 0.48 for eastern data) and iron and pH ($r^2 = 0.26$ for all data; 0.39 for eastern data). This suggests the latter two mechanisms discussed above may control iron concentrations; high alkalinity concentrations could be due to increased organic matter oxidation.

Under more strongly reducing conditions, sulfate is reduced, producing hydrogen sulfide (H_2S). Sulfate was below detection in 15 wells, and its absence suggests its complete removal by sulfate-reducing bacteria. Hydrogen sulfide was detected in five of the wells, also evidence of sulfate reduction. Production of hydrogen sulfide can cause iron and other metals to precipitate out of solution as sulfide minerals within the aquifer. The wells with the three highest levels of H_2S (> 0.1 mg/L) had some of the lowest concentrations of iron and manganese in this study, and no detectable arsenic.

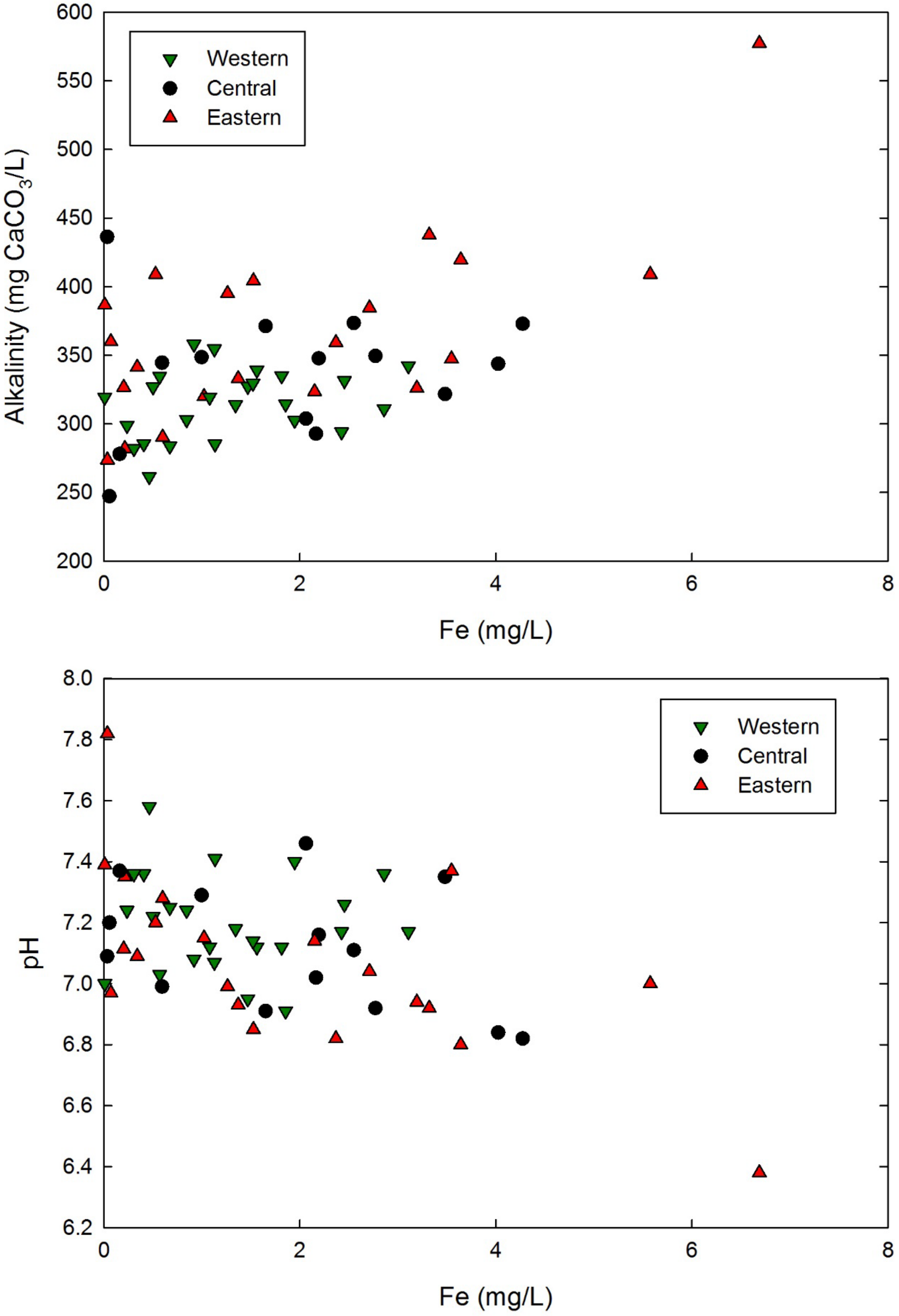

Figure 12. Alkalinity and pH vs. iron concentrations sampled wells as a function of location in Kane County.

Nitrate

Elevated nitrate-nitrogen (NO_3-N) is common in groundwater in agricultural regions, due to leaching of synthetic fertilizer and natural soil nitrogen from the soil zone (Spalding and Exner, 1993). However, only seven samples had detectable NO_3-N (> 0.07 mg/L), and the highest concentration detected was 2.8 mg/L, well below the MCL of 10 mg/L. Two of the samples with detectable nitrate were from systems were there was aeration, which may have resulted from the oxidation of ammonium, which is much more prevalent than nitrate in these aquifers. These nitrate results are quite different from what other researchers have found in similar settings throughout the state. For example, a large number of wells in McHenry County have NO_3-N concentrations above the MCL (Hwang et al., 2015).

There are several potential explanations for the lack of nitrate found in the shallow groundwater in Kane County. It is possible that most of the nitrate reaching the groundwater is denitrified. In the presence of a suitable electron donor, such as organic matter, microorganisms readily reduce nitrate to nitrogen gas under moderately reducing conditions:

$$4\mathrm{NO_3^-} + 5\mathrm{CH_2O} + 4\mathrm{H^+} \rightarrow 2\mathrm{N_2} + 5\mathrm{CO_2} + 7\mathrm{H_2O}$$

where CH_2O is a generic representation of organic matter. As discussed previously, the aquifers were generally under reducing conditions, with abundant organic carbon as the most common source of electrons for denitrification. Four of the five non-aerated wells with detectable nitrate-N also had relatively low iron concentrations, suggesting conditions that were not sufficiently reducing to reduce iron.

Another possible explanation for the lack of nitrate in the groundwater is that much of Kane County farmland is tile drained. Thus, most of the surface-derived nitrate may be transported to streams and drainage ditches rather than remaining in the groundwater (Spalding and Exner, 1993).

Arsenic

Ten wells were above the 10 µg/L MCL for arsenic, with the highest concentration being 46.0 µg/L. These wells were in the central or northern half of the county (Figure 13). Nine of the 10 wells are finished in the shallow bedrock aquifer, although the well with the highest arsenic concentration is finished in an unconsolidated aquifer.

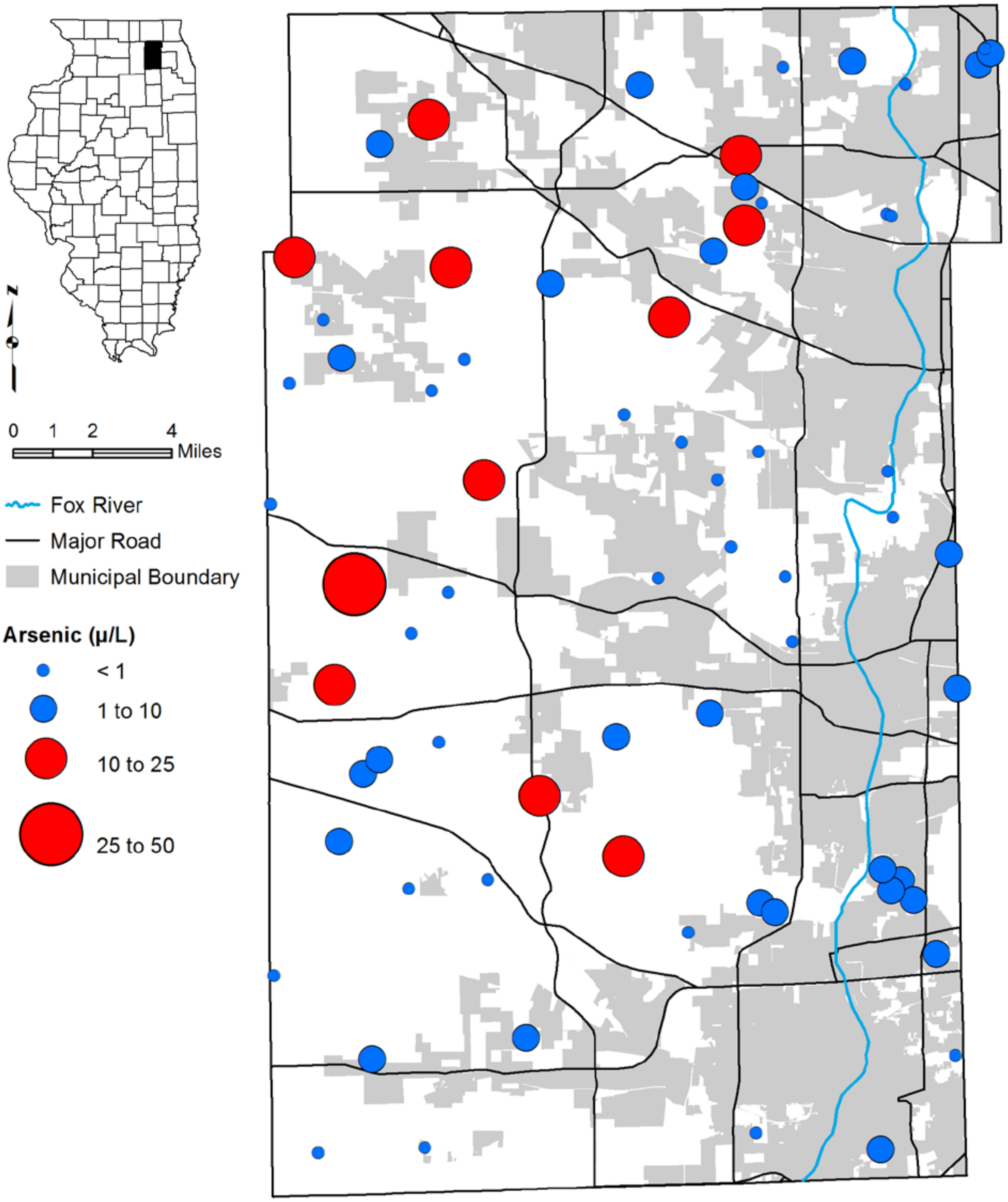

Figure 13. Arsenic concentrations of sampled wells and wells from the GWQDB. Red circles indicate concentrations above the primary MCL.

Well samples with high arsenic concentrations tended to have low levels of sulfate (Figure 14), which has been observed in other aquifers in Illinois (Kelly and Holm, 2011, Kelly et al., 2005, Kirk et al., 2004). Those researchers hypothesized that if sulfate is present and sulfate reduction is active, arsenic concentrations are low because any arsenic entering solution is probably removed by precipitation as an arsenic sulfide mineral or by coprecipitation with other sulfide minerals. After elimination of sulfate, methanogenesis becomes the dominant metabolism and, without a precipitation pathway, arsenic builds up in the groundwater. Based on the relationship between arsenic, hydrogen gas, and other redox-sensitive species, Kirk et al. (2004) suggested that some degree of iron reduction may be occurring in zones dominated by both methanogenic and sulfate-reducing bacteria.

Arsenic concentrations did not correlate well with any other chemical parameters except chloride. Wells with elevated concentrations of arsenic tended to have very low concentrations of chloride, although there is no obvious physical or chemical explanation for this.

Coliform Bacteria

None of the sampled wells had detectable *E. coli* bacteria, although 10 tested positive for total coliform bacteria and four had detectable fecal coliform, including one sample with a concentration greater than the upper detection limit (> 200 colony forming units (cfu)/100 mL). The presence of coliform bacteria is usually a local problem, either due to poor wellhead protection or contamination in the well or water distribution system. All well owners were informed that the analysis method used was not approved for regulatory purposes, and were instructed to contact the county health department if they wanted their well more rigorously tested for coliform bacteria.

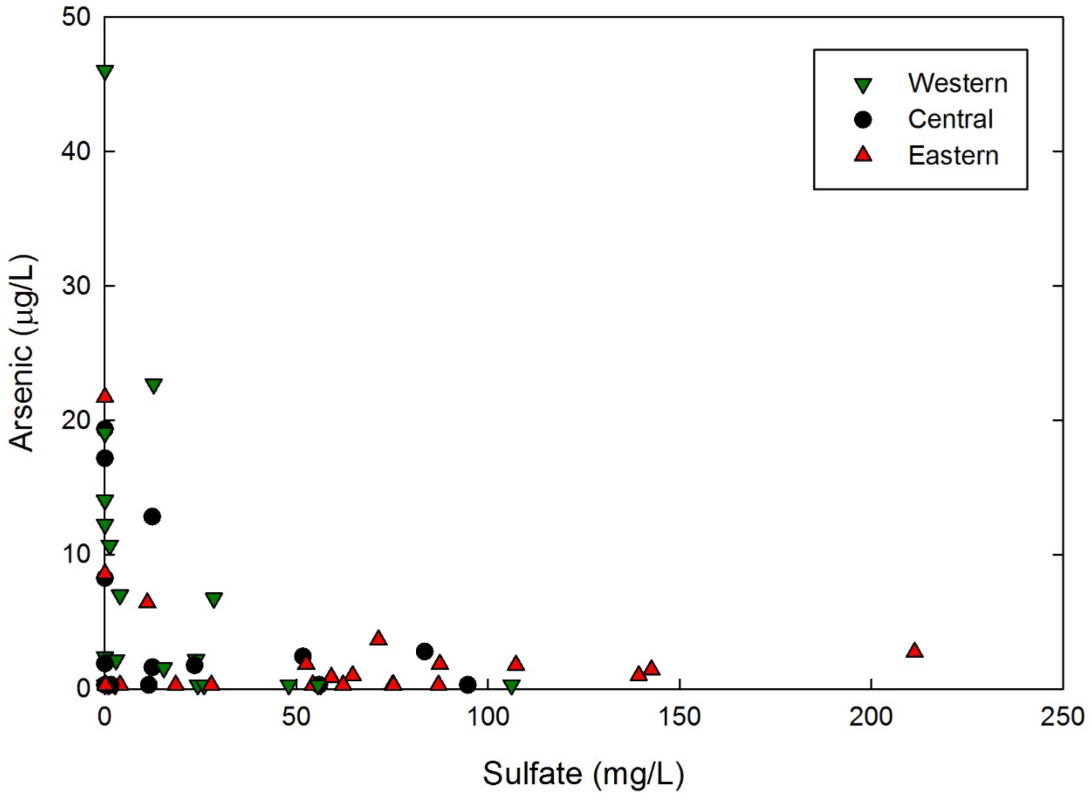

Figure 14. Arsenic vs. sulfate concentrations of sampled wells as a function of location in Kane County.

Other Contaminants

Chemical contaminants above their primary or secondary MCLs included arsenic, chloride, iron, manganese, and TDS in wells in both shallow bedrock and unconsolidated aquifers (Figure 15). Other contaminants found were almost never above their MCLs. Barium was detected in all wells, but always well below the 2-mg/L MCL, with the highest concentration being 0.77 mg/L. The concentrations of the toxic metals beryllium, cadmium, chromium, and selenium were always below the instrument detection limits (Table A-2). Aluminum was also not detected in any samples. Copper was only detected in 10 samples, with a maximum concentration of 0.039 mg/L, which is well below the MCL of 1.3 mg/L. The maximum zinc concentration was 0.078 mg/L, which is well below the secondary 5-mg/L MCL, and is therefore not a concern.

Thirteen wells had manganese levels above the 0.05-mg/L MCL. These wells are located throughout Kane County but primarily in the eastern third (Figure 15). Manganese and iron often exhibit similar trends, and there was a slight positive correlation between these two metals.

No wells exceeded the secondary 2-mg/L MCL for fluoride concentrations, although there were three wells with concentrations greater than 1 mg/L, with a maximum of 1.53 mg/L. For most shallow groundwater in Illinois, natural fluoride concentrations are generally in the range of 0.2–0.6 mg/L. Higher concentrations can come from either natural or anthropogenic sources. Naturally high fluoride is often positively correlated with sodium but not with chloride. A plot of sodium vs. fluoride for these samples indicates a complex relationship (Figure 16). Samples with high sodium but low fluoride concentrations likely indicate road-salt runoff contamination. Samples with high concentrations of both may indicate natural sources for these two ions. One of the samples with high fluoride (sample 64) is from a well located along the Fox River. In a previous study, samples collected from wells adjacent to the Fox River

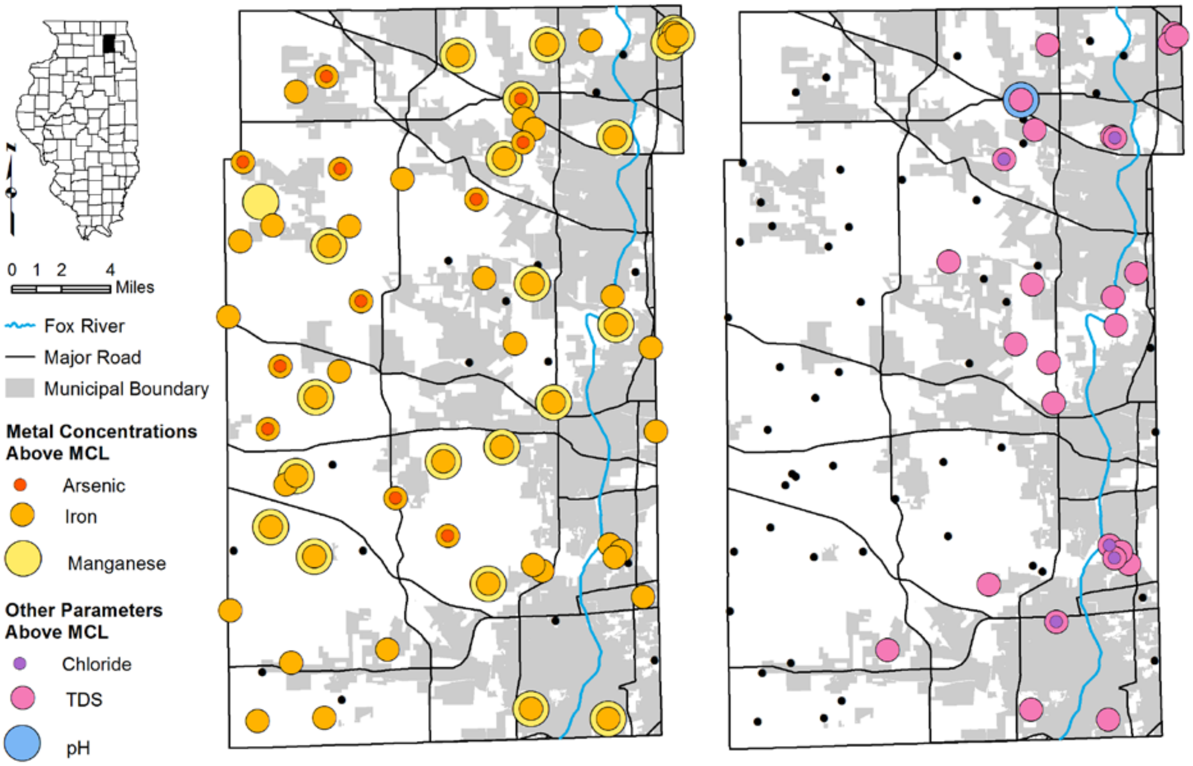

Figure 15. Chemical contaminants above the primary (As) or secondary MCL of sampled wells. Wells with no contaminants exceeding MCLs indicated by small black circles.

in Kendall County also had anomalously high fluoride and sodium levels (Roadcap et al., 2013). Roadcap et al. (2013) attributed these to upward migration of groundwater from deeper bedrock units and/or the influence of shales. The sample in Figure 16 with elevated fluoride and extremely high sodium (sample 38) has most likely been contaminated by a surface source, as it also has a very elevated chloride concentration (208 mg/L). Fluoride is generally not elevated in road-salt runoff, so the source of contamination in this sample might be human sewage, because many water treatment plants add fluoride to drinking water.

The well sample with the highest fluoride concentration also had the highest potassium and boron concentrations. This may be the result of septic system discharge (Katz et al., 2011).

Groundwater in one well had a pH of 6.38, below the recommended pH range. That well is in an industrial area and had other water-quality problems, but it is not used for drinking water (Figure 15). It had by far the highest measured concentrations of NH_3-N (25.6 mg/L), DOC (21.4 mg/L), iron (6.69 mg/L), and alkalinity (577 mg/L). These water quality issues also existed in 2003.

Water Quality as a Function of Well Depth and Aquifer Sensitivity

Water-quality data were divided into two populations based on well depth (Table 4): ≤ 100 feet and 100-250 feet. Twenty sampled wells were ≤ 100 feet deep, and 48 were between 100 and 250 feet deep. Shallower wells are more susceptible to surface-derived contaminants.

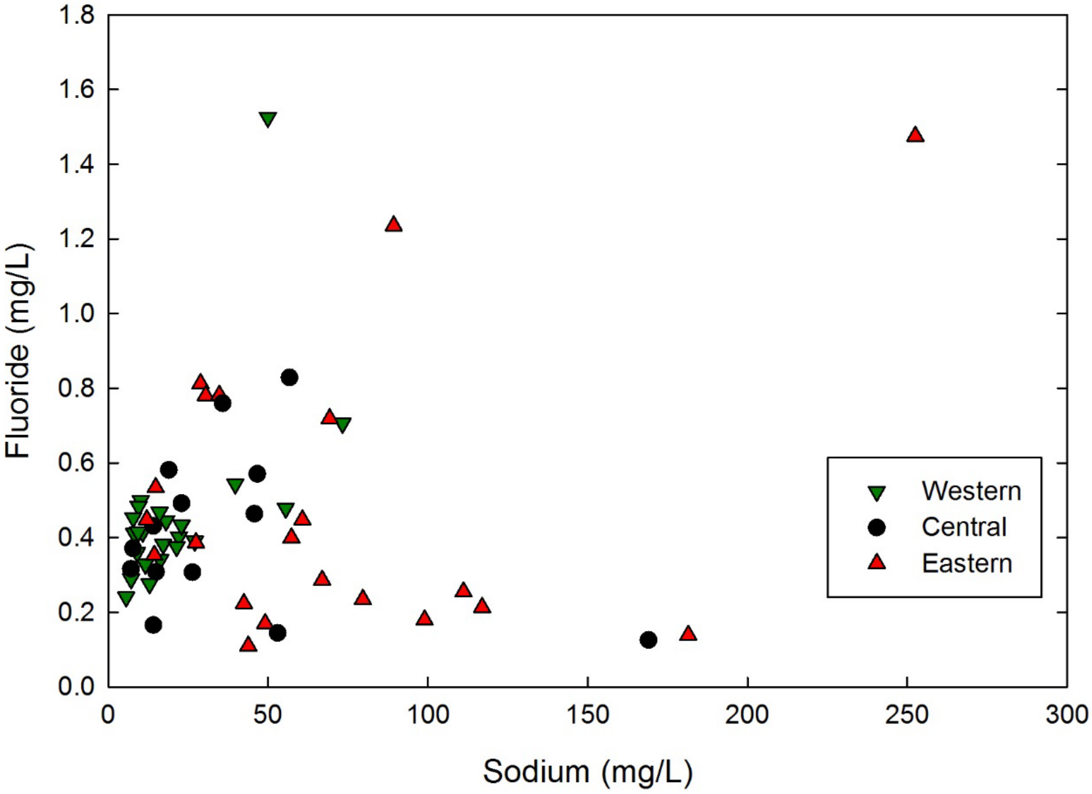

Figure 16. Fluoride vs. sodium concentrations in sampled wells as a function of location in Kane County.

Table 4. Median Values for Measured Parameters Based on Well Depth

Constituent	*≤ 100 ft*	*> 100 ft*	*Significant Difference?*
Temperature (°C)	13.1	12.6	Shallow > Deep
pH	7.12	7.17	
ORP (mv)	123	120	
Specific Conductance (µS/cm)	782	672	Shallow > Deep
Arsenic (µg/L)	< 0.79	1.61	
Boron	0.045	0.160	Deep > Shallow
Barium	0.090	0.080	
Calcium	101	72.2	Shallow > Deep
Copper	< 0.0016	< 0.0016	
Iron	1.90	1.00	Shallow > Deep
Potassium	1.70	2.34	
Magnesium	46.4	40.9	
Manganese	0.047	0.016	Shallow > Deep
Molybdenum	< 0.022	< 0.022	
Sodium	15.5	27.1	
Phosphorous	< 0.041	< 0.041	
Silicon	8.43	7.96	
Strontium	0.241	0.679	Deep > Shallow
Zinc	< 0.0097	< 0.0097	
Alkalinity ($CaCO_3$)	326	330	
Fluoride	0.308	0.445	Deep > Shallow
Chloride	31.6	10.5	Shallow > Deep
Nitrate-N	< 0.04	< 0.04	
Sulfate	59.3	22.7	Shallow > Deep
DOC	0.871	1.19	
Ammonium-N	0.298	0.460	
δD (‰)	-50.3	-50.5	
$\delta^{18}O$ (‰)	-7.92	-7.89	
TDS (calculated)	475	394	Shallow > Deep

Notes: Results are in mg/L unless otherwise indicated.
20 wells were ≤ 100 feet and 48 were > 100 feet.
The Mann-Whitney rank sum test was used to determine significance at the 95 percent level.

Kelly (2008) and Kelly et al. (2012) observed that municipal wells shallower than 100 feet deep in the Chicago region had greater chloride concentrations, presumably due to road-salt runoff, than wells between 100 and 200 feet deep. In this study, we also observed that shallower wells contained TDS, calcium, iron, magnesium, manganese, chloride, and sulfate at greater concentrations than in deeper wells, with all but magnesium being statistically significant (Table 4). On the other hand, deeper wells had greater concentrations of sodium, potassium, strontium, fluoride, boron, DOC, and ammonium. However, only strontium, fluoride, and boron were shown to be statistically significant (Table 4). Relatively elevated TDS and chloride in shallower wells was expected, assuming the source was road-salt runoff. The fact that sodium was lower in the shallower wells indicates a different source of sodium than road salt, probably due to natural processes. For the shallower wells, an exchange of sodium ions from road salt runoff with calcium and magnesium ions would be expected, and these latter two ions were elevated in shallower wells. Relatively elevated sulfate concentrations in shallower wells may reflect surficial sources of sulfur, e.g., disruption of soils/sediments due to excavation and industrial discharge (Wagner et al., 1982). Higher concentrations of iron and manganese in shallower wells, along with no differences due to depth in other redox-sensitive parameters (e.g., DOC, NH_3-N, and ORP), indicate pervasive reducing conditions in the shallow aquifer system regardless of depth.

Dey et al. (2007a) produced an aquifer sensitivity map of Kane County to depict the relative potential for aquifer contamination from sources at or near the land surface. Aquifer sensitivity considers both depth and hydrogeological information. Areas with high potential for contamination have aquifers at least 20 feet thick and within 20 feet of the land surface, and areas with moderately high potential for contamination have aquifers less than 20 feet thick and within 20 feet of the land surface. Areas with low to moderate sensitivity have at least 20 feet of fine-grained till overlying the shallow aquifers.

The TDS values (calculated from specific conductance) were plotted on a version of Dey et al.'s map (2007a) to determine if there was a correlation between water quality and aquifer sensitivity (Figure 17). Most wells with TDS values greater than 500 mg/L were found in areas of high or moderately high potential for contamination. Many wells with TDS values less than 500 mg/L were found in areas of moderate to low sensitivity, especially in the western third of the county. However, the geographic location of a well (i.e., in an urban corridor versus a rural area) appears to have more of an impact on TDS values than aquifer sensitivity.

Some wells with relatively low TDS values in the eastern third of Kane County were in areas that did not have high or moderately high potential for contamination, suggesting that till thickness may influence groundwater quality. Because relatively low-permeability till deposits can act as a protective layer for underlying aquifers, retarding movement of contaminants from the surface, it was hypothesized that groundwater quality may be better in areas with relatively thick overlying till. Till thicknesses were estimated from drillers' logs prepared when the wells were drilled. These records are stored at the ISWS and are of variable quality. Till thicknesses of 67 of the 68 wells were estimated and used in the analysis.

There appeared to be a weak relationship between till thickness and several water-quality parameters, including TDS, chloride, calcium, and sulfate, with greater concentrations correlating to thinner till thicknesses (Figure 18). Some of the highest parameter values were in samples from areas with relatively thin till layers (< 70 feet thick). However, well location within the county seemed to have more impact on the concentration of surface-derived contaminants than till thickness.

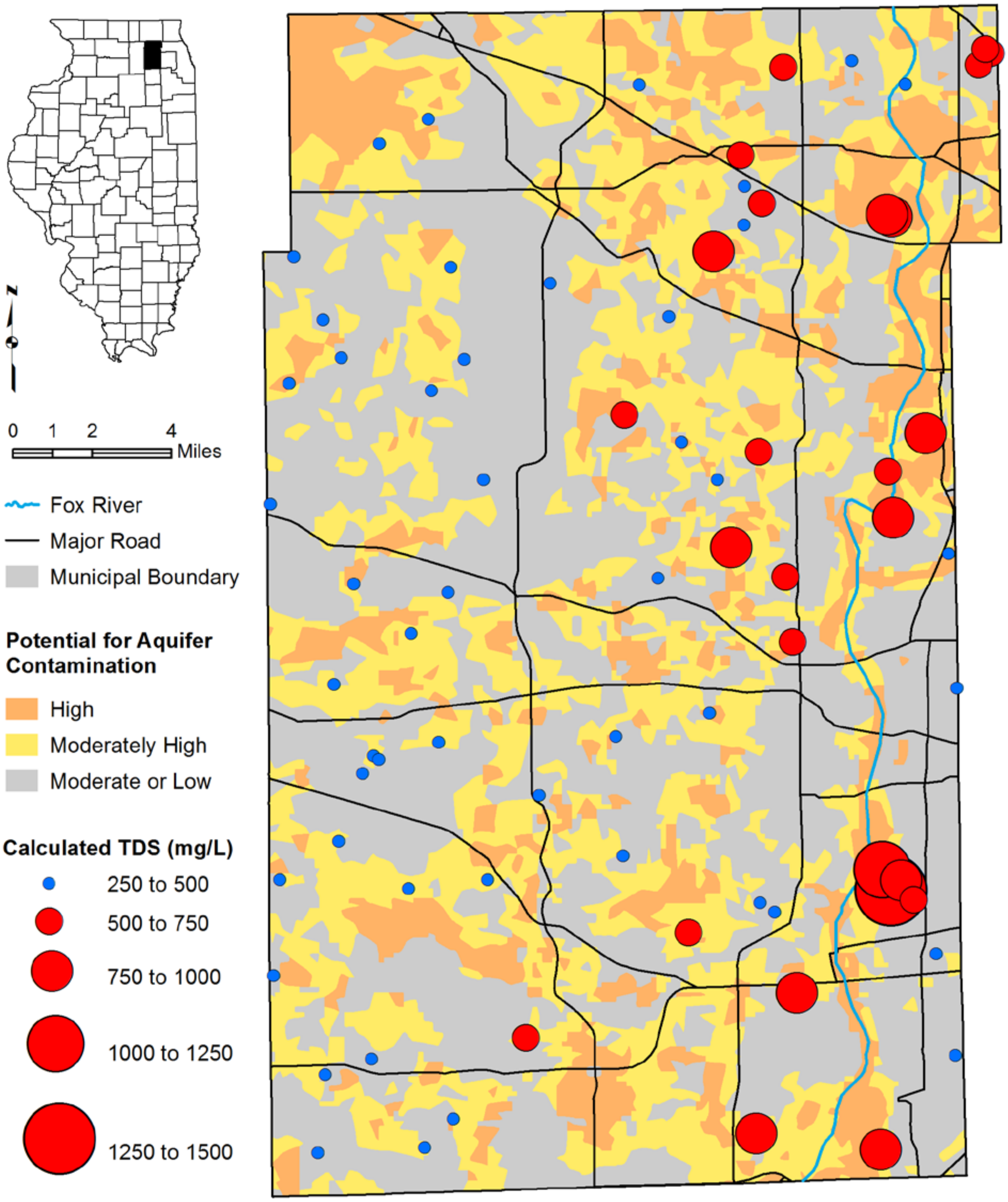

Figure 17. TDS values and aquifer sensitivity. Potential for aquifer contamination data from Dey et al. (2007). Red circles are wells for which TDS exceeded the secondary MCL (500 mg/L).

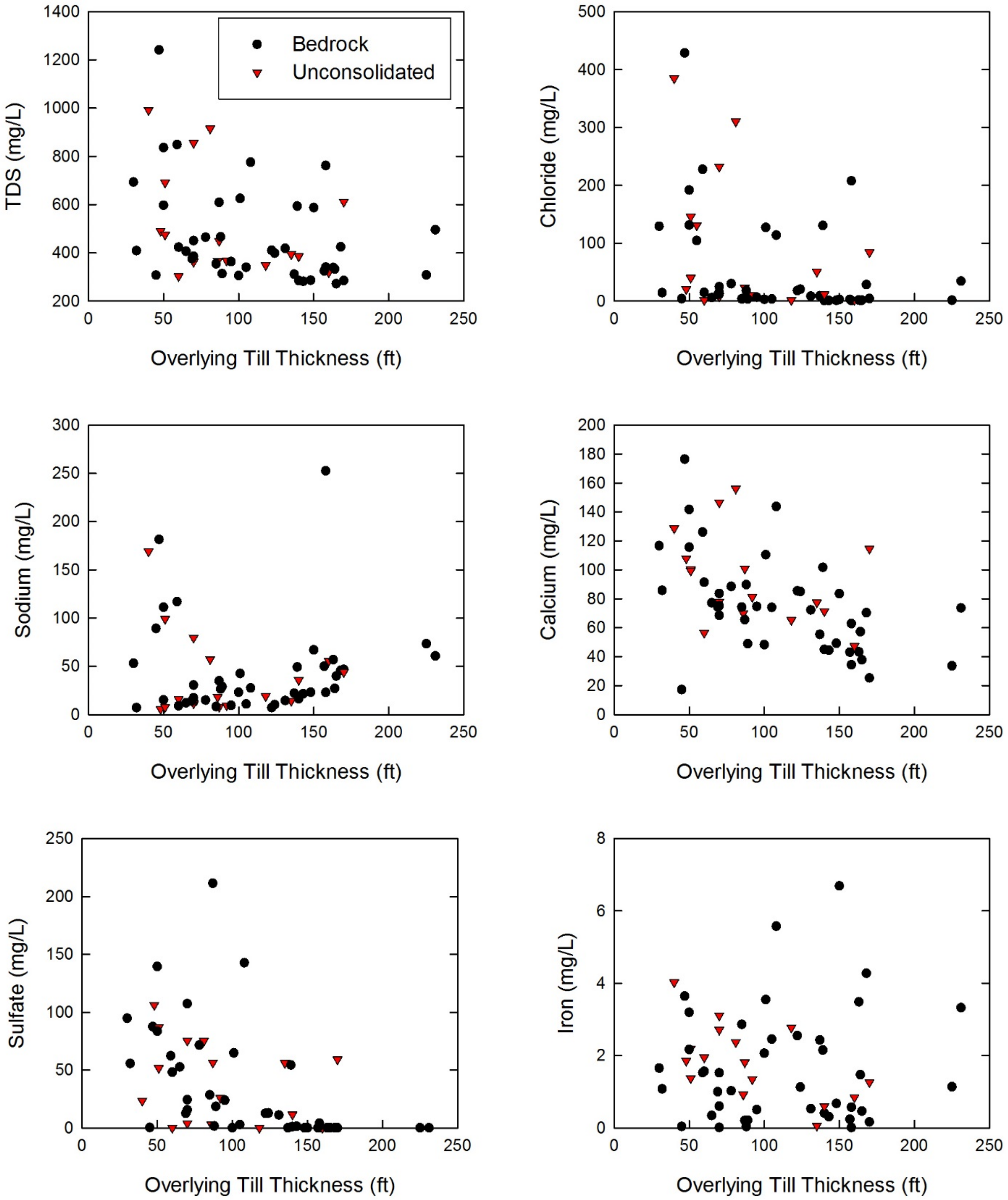

Figure 18. Concentrations of various water-quality parameters of sampled wells as a function of overlying till thickness.

Water Quality as a Function of Source Aquifer Material

Water-quality data also were divided into two groups based on the source aquifer material (Table 5): shallow bedrock (primarily Silurian dolomite) and unconsolidated deposits (sand and gravel). Forty-nine wells were finished in bedrock and 19 were screened in unconsolidated material. Wells in unconsolidated aquifers were expected to be more susceptible to surface-derived contaminants because they tend to be shallower and generally are overlain by thinner till deposits.

Concentrations of TDS, chloride, sulfate, calcium, magnesium, iron, manganese, silicon, and barium were greater in the wells screened in unconsolidated aquifers, and concentrations of sodium, potassium, fluoride, strontium, arsenic, boron, DOC, and NH_3-N were greater in the wells open to the shallow bedrock (Table 5). Only boron was statistically significant, however. Elevated boron levels in groundwater have been associated with marine shales (Panno et al., 1994), and it is possible the Maquoketa Shale may be the source of boron in Kane County.

The higher silicon value in the unconsolidated wells may be due to the greater amount of silicon in sand and gravel, primarily as quartz (SiO_2) and feldspars, versus the shallow bedrock, which is primarily fractured dolomite [$CaMg(CO_3)_2$]. Barium may be associated with feldspars, but it is unclear why there would be differences in boron as a function of aquifer type.

Changes between 2003 and 2015

Of the 49 wells sampled in both 2003 and 2015 (raw water samples only), 29 had higher TDS values in 2015, and three had increases greater than 100 mg/L (Figure 19). The average increase for all 49 wells was 21 mg/L, while for the 29 wells with increasing values the average was 50 mg/L. The increase in TDS is entirely explained by increases in chloride and sodium concentrations, which increased in 38 and 29 wells, respectively (Figure 20 and 21). The average increase in chloride for all wells was 19.2 mg/L (25.4 mg/L for wells with an increase), while the average increase for sodium was 10.8 mg/L (19.2 mg/L for wells with an increase). Three wells had increases in chloride of greater than 100 mg/L, with a high of 259 mg/L. All of the other major ions (calcium, magnesium, alkalinity, and sulfate) had average decreases in concentrations of between -1 and -6 mg/L.

Fifteen of the 17 wells in the eastern section and all 11 central wells had increasing chloride concentrations. The average increase was 46.3 mg/L in the eastern section (3.9 mg/L/yr) and 15.8 mg/L in the central section (1.3 mg/L/yr). These rates of increase are similar to those observed by Kelly (2008) for public supply wells in the region.

It appears that road salt runoff continues to be an issue in Kane County. A piper diagram, shown in Figure 22, displays the relative proportions of the major ions in groundwater. Uncontaminated shallow groundwater in the region is dominated by HCO_3^- among the anions and a mix of calcium and magnesium for the cations (shown in boxes in Figure 22). The input of road-salt runoff is changing the geochemical character of the groundwater in the eastern urban corridor; it is becoming more enriched in chloride and sodium. The increase in chloride may be increasing the corrosivity of the water. The Larson-Skold index is used to predict the aggressiveness of water (Larson and Skold, 1958). The index is a function of the anion composition of the water:

$$Larson - Skold\ Index = \frac{(Cl^- + SO_4^{2-})}{(HCO_3^- + CO_3^{2-})}$$

where the concentrations are in equivalents per liter. Values > 0.8 suggest mildly corrosive water and values > 1.2 indicate highly corrosive waters. About 18% of the collected samples had values > 0.8 and about 10% had values > 1.2.

There were no obvious changes in concentration between 2003 and 2015 for any of the minor elements (arsenic, iron, manganese, fluoride, boron, barium).

Table 5. Median Values for Measured Parameters Based on Source Aquifer Material

Constituent	*Bedrock*	*Unconsolidated*	*Significant Difference?*
Depth (feet)	180	93	Bedrock > Unconsolidated
Temperature (°C)	12.8	12.6	
pH	7.16	7.10	
ORP (mv)	121	121	
Specific Conductance (µS/cm)	696	709	
Arsenic (µg/L)	1.60	< 0.79	
Boron	0.139	0.0457	Bedrock > Unconsolidated
Barium	0.0844	0.0938	
Calcium	74.1	90.3	
Copper	< 0.0016	< 0.0016	
Iron	1.13	1.83	
Potassium	2.34	1.81	
Magnesium	41.1	45.1	
Manganese	0.0168	0.0358	
Molybdenum	< 0.022	< 0.022	
Sodium	27.1	18.5	
Phosphorous	< 0.041	< 0.041	
Silicon	7.95	8.80	
Strontium	0.618	0.372	
Zinc	< 0.0097	< 0.0097	
Alkalinity ($CaCO_3$)	327	339	
Fluoride	0.423	0.385	
Chloride	11.8	20.8	
Nitrate-N	< 0.04	< 0.04	
Sulfate	27.9	56.0	
DOC	1.10	0.967	
Ammonium-N	0.450	0.341	
δD (‰)	-50.4	-50.5	
$\delta^{18}O$ (‰)	-7.88	-7.96	
TDS (calculated)	408	435	

Notes: Results are in mg/L unless otherwise indicated.
49 wells are finished in shallow bedrock and 19 in unconsolidated deposits.
The Mann-Whitney rank sum test was used to determine significance at the 95 percent level.

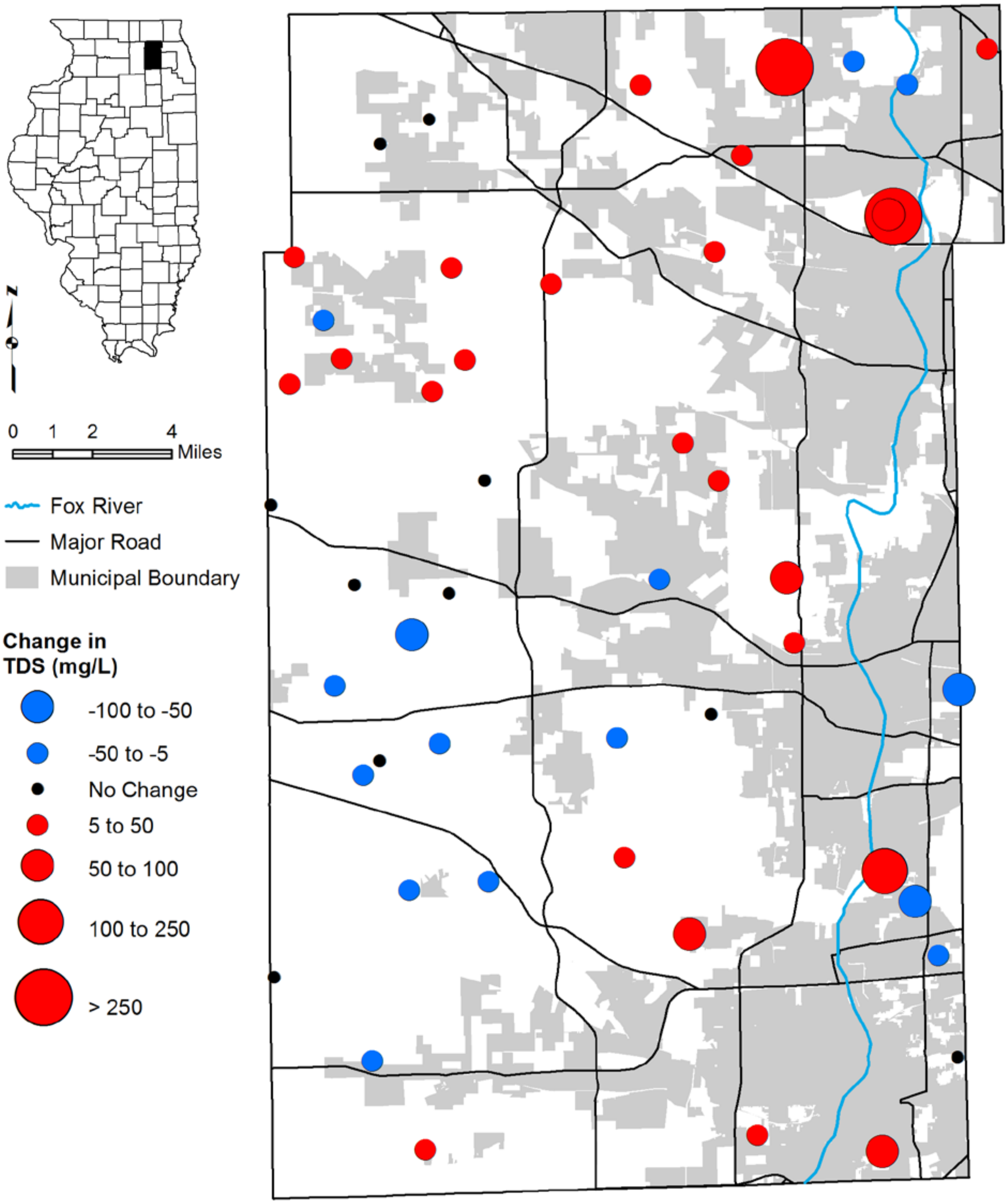

Figure 19. Changes in TDS concentrations between 2003 and 2015 for wells sampled both years. Red circles indicate an increase in concentration.

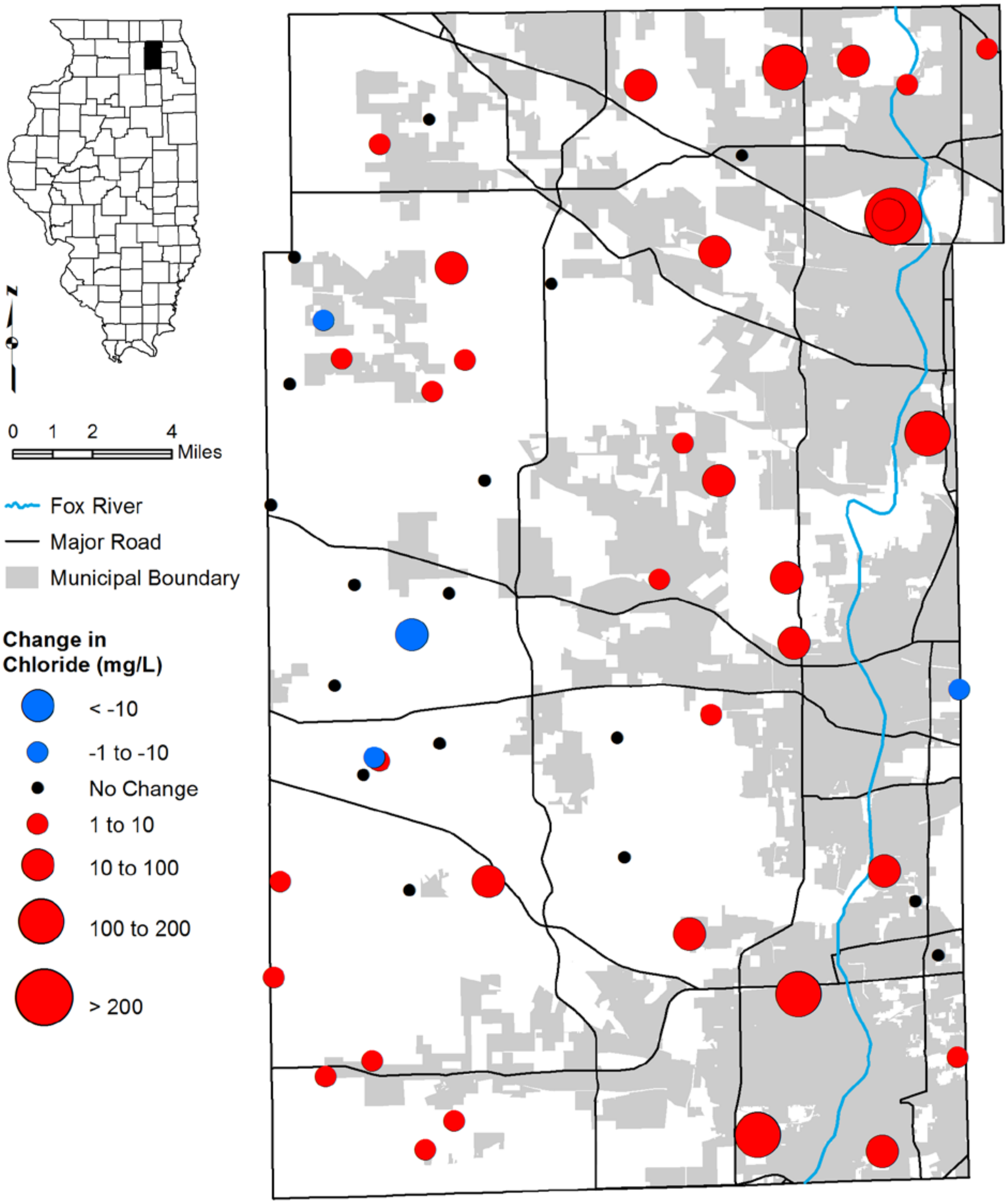

Figure 20. Changes in chloride concentrations between 2003 and 2015 for wells sampled both years. Red circles indicate an increase in concentration.

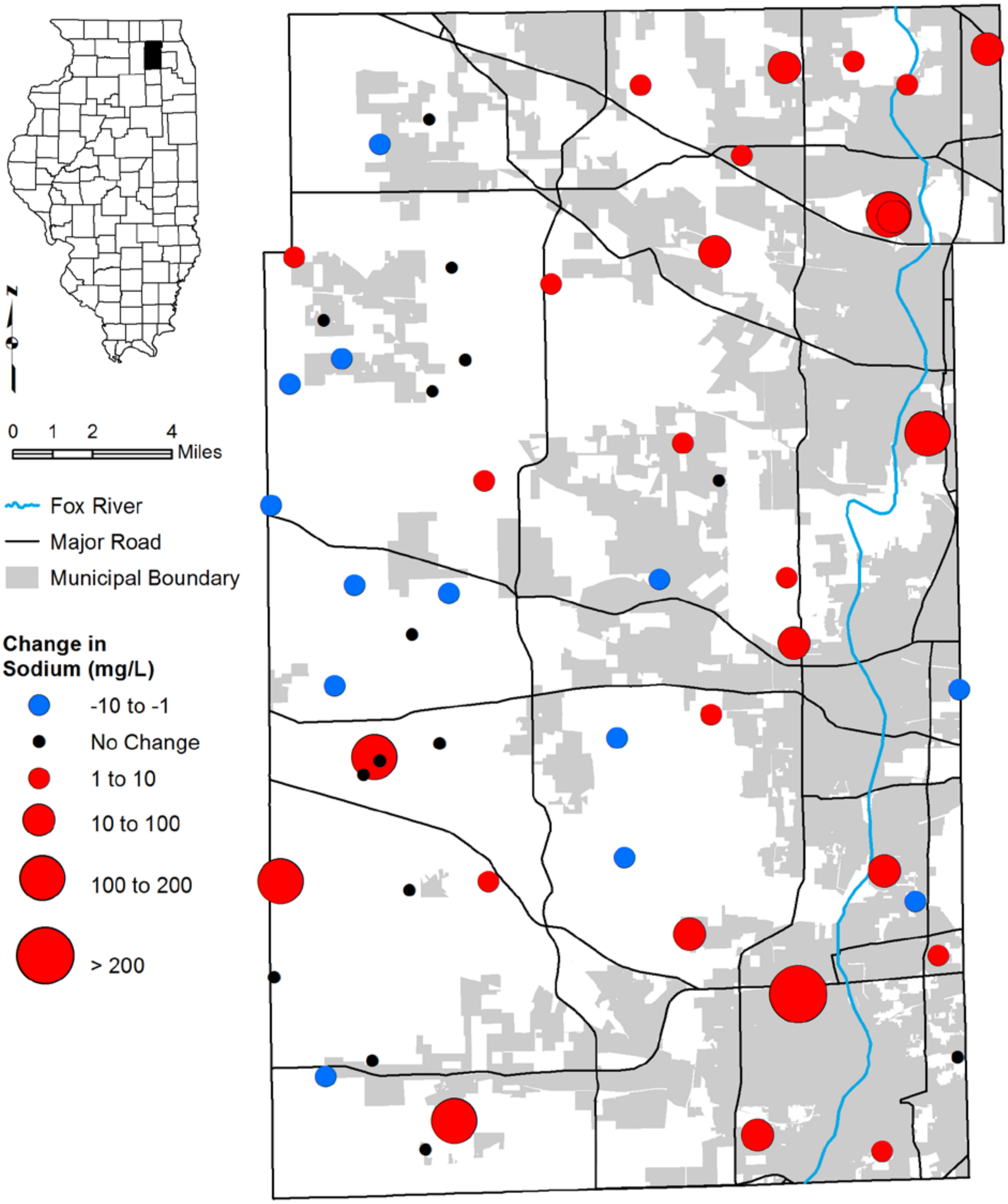

Figure 21. Changes in sodium concentrations between 2003 and 2015 for wells sampled both years. Red circles indicate an increase in concentration.

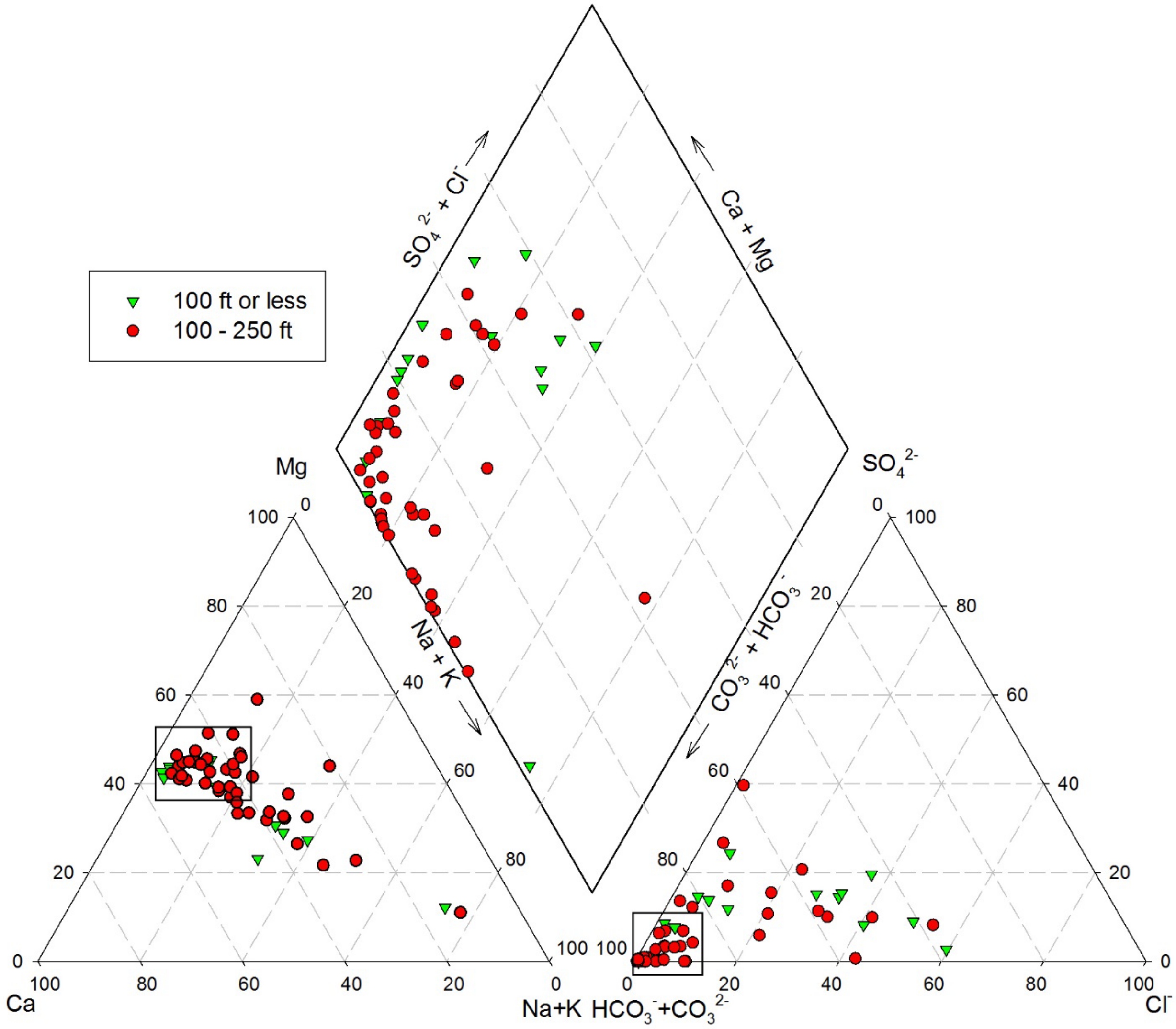

Figure 22. Piper diagram showing relative concentrations of major ions for sampled wells as a function of well depth. Boxes show where uncontaminated samples tend to plot.

Conclusions and Recommendations

The results of this study indicate that the quality of shallow groundwater in Kane County in 2015 was still generally good, especially in the western and central thirds of the county. Nitrate-N concentrations were low, suggesting that agricultural activities are not seriously degrading the groundwater quality. Arsenic was above the MCL in about 16 percent of the wells. Iron and manganese were elevated in many wells, but this is common in shallow aquifers throughout Illinois. Except for arsenic, toxic metals were not present at concentrations exceeding their MCLs in any sample.

The TDS values of samples from the eastern third of the county continue to be significantly greater compared to the rest of the county. The ion of greatest concern is chloride. Two-thirds of the samples from the eastern wells sampled had TDS and/or chloride concentrations above the secondary MCL. Vehicular exhaust, industrial discharges, and especially road-salt runoff are the most likely sources of the elevated TDS and chloride. Lower pH values in the eastern third of the county may reflect greater acidic deposition due to industrial emissions. There was no evidence of increased levels of any toxic metals.

Common treatment processes such as water softeners usually remove some contaminants found in raw water samples. These processes are designed to remove excess calcium and magnesium, but also tend to reduce iron and manganese levels. They also may be effective at removing arsenic and other metals: all treated samples collected in this study had arsenic concentrations well below the MCL and low iron concentrations. Well owners were informed that chemical analyses of treated water samples were available from the ISWS PSL.

The presence of coliform bacteria in some wells may indicate contamination from human sewage or animal manure. It was suggested to those well owners that they contact the County health department to run a more rigorous test to determine the presence of fecal contamination. Because the sampling done in this study did not meet regulatory standards, well owners whose samples did not test positive for coliform bacteria also were advised to contact the County health department for a more definitive test for such contamination.

Because groundwater moves slowly, usually measured in feet per week or even feet per year, the widespread presence of high TDS groundwater in the eastern, highly developed part of Kane County suggests a fairly long history of shallow groundwater contamination. As Kelly (2008) demonstrated, chloride levels in shallow aquifers in this region have been increasing since the 1960s. Howard and Beck (1993) showed that even if road-salt use stopped immediately, chloride concentrations could, in fact, increase before decreasing, and groundwater quality could remain degraded for decades. Results from the 2015 sampling indicate TDS and chloride concentrations are continuing to increase in the eastern part of the county with no signs of leveling off yet.

Contamination from road-salt runoff is widespread but not a serious human health concern, except possibly to people who need to be on low sodium diets. Increased levels of dissolved solids, however, do lead to increased water treatment costs. Also, chloride is a highly corrosive ion, and elevated levels may increase corrosion of pipes in homes and industrial plants if not inhibited. In addition to a water softener, reverse osmosis or distillation typically are used in domestic systems to remove excess dissolved solids.

It may be inevitable that increased growth of urban and suburban areas will lead to degradation of groundwater quality in shallow aquifers, a problem in many cities throughout the world. Cities in northern latitudes commonly have high TDS and chloride concentrations due to road-salt runoff (Corsi et al., 2015, Kelly, 2008, Novotny et al., 2009).

Development in Kane County generally is moving from east to west. Protecting the very good shallow groundwater quality in the central and western thirds of Kane County should be a prime goal of water resource planners. Because roads need to be cleared following snow and ice events, road deicing activities will need to continue. There are some mitigation measures that can be taken to limit the impacts. The National Research Council (NRC, 1991) made several recommendations, including (1) diverting runoff from sensitive areas through drainage improvements; (2) reducing road-salt application near public water supplies; and (3) using other, more environmentally benign deicing agents, such as sand or calcium magnesium acetate. Since 2003, Kane County and other counties in the Chicago region have begun to provide various levels of training in deicing practices, which are designed to ensure proper storage and application procedures to minimize environmental effects.

This project updates the baseline for shallow groundwater quality in Kane County. It would be helpful to repeat this study at 10-year intervals, sampling as many of the same wells as possible, to determine water-quality changes as Kane County undergoes land-use changes. More detailed studies at more frequent intervals for particularly sensitive areas or those with rapid changes in land use also may be helpful to water resource planners. The best method for tracking changes in groundwater quality would be to install a dedicated monitoring well network. Wells could be installed in desired locations using standardized methods, avoiding problems inherent in sampling private wells, such as well access issues and the possibility of change in ownership.

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Appendix A. Complete Data on Water Quality for Samples Collected in This Study and Pertinent Well Samples from the ISWS Groundwater Quality Database

Table A-1. Well Information and Field Analyses for Untreated Samples

Sample No.	*Depth (ft)*	*Aquifer*	*Town*	*Rng*	*Sect*	*Overlying till (ft)*	*Date sampled*	*Temp (°C)*	*pH*	*ORP (mv)*	*SpC (µS/cm)*	*DO (mg/L)*	*H_2S (ppm)*
1	141	C	42N	6E	21	137	9/29/2015	17.5	7.17	60	576	0.0	< 0.1
2	128	C	41N	6E	2	124	9/29/2015	12.0	7.07	99	719	0.2	0.1
3	225	C	41N	6E	5	164	9/29/2015	11.8	6.95	137	597	0.0	< 0.1
4	205	C	41N	6E	8	70	9/29/2015	15.3	7.00	381	696	0.2	< 0.1
5	110	U	41N	6E	16	86	9/29/2015	12.1	7.08	121	658	0.3	< 0.1
6	92	U	41N	6E	13	92	9/30/2015	12.5	7.18	104	638	0.1	< 0.1
7	97	U	41N	6E	23	87	9/30/2015	12.4	7.12	121	769	0.1	0.1
8	150	C	41N	6E	19	148	9/30/2015	11.2	7.25	121	511	0.0	< 0.1
9	208	C	40N	6E	6	158	9/30/2015	11.8	7.03	143	605	0.0	< 0.1
10	90	U	40N	6E	16	60	9/30/2015	13.3	7.40	47	543	0.3	< 0.1
11	160	U	40N	6E	14	160	9/30/2015	11.5	7.24	104	543	0.1	< 0.1
12	54	U	40N	6E	22	48	9/30/2015	NA	6.91	NA	NA	0.2	< 0.1
14	80	U	38N	6E	16	70	10/5/2015	13.5	7.17	94	678	0.7	< 0.1
15	130	C	38N	6E	6	60	10/5/2015	12.9	7.12	103	769	0.0	< 0.1
17	180	C	39N	6E	27	105	10/5/2015	12.6	7.26	58	640	0.7	< 0.1
18	230	C	40N	6E	1	225	10/6/2015	12.1	7.41	89	515	0.0	< 0.1
19	225	C	39N	6E	2	157	10/6/2015	12.9	7.24	151	551	0.3	< 0.1
20	125	U	39N	6E	25	135	10/6/2015	14.1	7.20	334	689	2.1	< 0.1
21	95	C	39N	6E	9	85	10/6/2015	11.9	7.36	61	605	0.0	< 0.1
22	130	C	39N	6E	9	95	10/6/2015	12.7	7.22	126	620	0.0	< 0.1
24	135	U	39N	7E	3	118	10/6/2015	12.3	6.92	104	620	0.9	< 0.1
25	125	C	39N	7E	1	69	10/6/2015	12.5	7.29	87	654	0.0	< 0.1
26	195	C	41N	7E	8	163	10/7/2015	15.3	7.35	66	572	0.0	< 0.1
28	60	C	38N	8E	30	50	10/20/2015	14.9	6.94	125	1343	1.2	< 0.1
29	160	C	38N	8E	34	108	10/20/2015	13.0	7.00	95	1229	0.0	< 0.1
30	160	C	38N	8E	13	89	10/20/2015	12.3	7.35	137	523	0.0	< 0.1
31	150	C	38N	8E	1	70	10/20/2015	13.1	7.28	115	706	0.5	< 0.1
32	180	C	39N	8E	35	87	10/20/2015	11.7	7.11	161	902	0.0	< 0.1
33	160	C	39N	8E	27	47	10/20/2015	13.0	6.80	136	2131	0.0	< 0.1
34	55	U	42N	7E	9	51	10/21/2015	13.5	7.16	90	782	0.5	< 0.1
35	56	U	42N	8E	7	51	10/21/2015	14.1	6.93	165	1104	0.9	< 0.1
36	222	C	42N	8E	9	231	10/21/2015	12.5	6.92	113	830	0.0	< 0.1
37	200	C	42N	7E	24	150	10/21/2015	12.1	6.38	167	983	0.0	< 0.1
38	240	C	42N	8E	34	158	10/21/2015	11.8	7.39	119	1265	0.0	0.9
39	93	U	42N	8E	34	81	10/21/2015	12.1	6.82	132	1614	0.0	< 0.1
40	40	U	41N	7E	1	40	10/21/2015	12.8	6.84	120	1777	0.0	< 0.1
42	210	C	40N	8E	17		10/21/2015	11.1	6.97	228	866	0.0	< 0.1
43	225	C	40N	7E	14	170	10/22/2015	12.1	7.37	138	458	0.0	< 0.1
44	180	C	40N	8E	29	139	10/22/2015	13.7	7.14	104	970	0.0	< 0.1
45	175	C	40N	8E	36	65	10/22/2015	13.6	7.09	168	641	0.0	< 0.1
46	60	C	39N	7E	35	30	10/22/2015	12.8	6.91	145	1093	0.0	< 0.1
47	220	C	38N	6E	29	140	11/4/2015	11.6	7.36	105	502	0.7	< 0.1
49	180	C	39N	8E	32	78	11/4/2015	13.3	7.15	113	769	0.6	< 0.1
50	200	C	39N	7E	22	100	11/4/2015	11.6	7.46	53	546	0.0	< 0.1
52	155	U	41N	7E	35	140	11/4/2015	11.4	6.99	84	658	0.0	0.8
53	240	C	41N	07E	14	168	11/4/2015	11.7	6.82	118	754	0.0	< 0.1
54	175	C	42N	6E	15	165	11/5/2015	13.2	7.58	93	474	0.0	< 0.1
55	185	U	42N	8E	12	170	11/5/2015	11.0	6.99	149	1052	0.0	< 0.1

Table A-1. Well Information and Field Analyses for Untreated Samples (continued)

Sample No.	*Depth (ft)*	*Aquifer*	*Town*	*Rng*	*Sect*	*Overlying till (ft)*	*Date sampled*	*Temp (°C)*	*pH*	*ORP (mv)*	*SpC (µS/cm)*	*DO (mg/L)*	*H_2S (ppm)*
58	150	U	40N	08E	11	70	11/5/2015	12.7	7.04	171	1536	7.7	< 0.1
59	240	C	40N	7E	1	88	11/5/2015	13.0	7.09	230	827	0.6	2.5
60	100	C	38N	6E	26	32	11/11/2015	14.8	7.12	119	694	4.0	< 0.1
61	115	C	39N	06E	20	70	11/11/2015	11.4	7.14	108	666	0.0	< 0.1
62	200	C	40N	6E	32	143	11/11/2015	12.9	7.36	120	496	0.0	< 0.1
63	180	C	39N	08E	30	131	11/11/2015	13.6	7.20	132	743	0.0	< 0.1
64	100	C	42N	8E	15	45	11/12/2015	12.8	7.82	188	511	0.0	< 0.1
65	115	C	40N	08E	2	101	11/12/2015	12.8	7.37	77	1111	0.0	< 0.1
66	100	C	38N	7E	17	50	11/24/2015	12.3	7.02	96	1011	0.0	< 0.1
67	200	C	39N	07E	17	122	11/24/2015	11.6	7.11	96	700	0.0	< 0.1
68	59	C	40N	08E	7	59	11/24/2015	21.1	6.85	138	1454	0.0	< 0.1

Notes: NA = not analyzed.
C = consolidated (bedrock) aquifer, U = unconsolidated aquifer.

Table A-2. Concentrations of Metals in Untreated Samples

Sample No.	*As (µg/L)*	*B (mg/L)*	*Ba (mg/L)*	*Ca (mg/L)*	*Cu (mg/L)*	*Fe (mg/L)*	*K (mg/L)*	*Mg (mg/L)*	*Mn (mg/L)*	*Mo (mg/L)*	*Na (mg/L)*	*P (mg/L)*	*Si (mg/L)*
1	2.38	0.160	0.114	55.3	<0.0016	2.43	2.26	35.0	0.0141	<0.022	22.1	<0.073	7.96
2	22.7	0.057	0.0797	84.9	<0.0016	1.13	1.06	44.9	0.0110	<0.022	10.1	0.074	9.70
3	14.0	0.326	0.110	57.2	<0.0016	1.47	6.87	31.3	0.0119	<0.022	27.1	0.117	8.04
4	<0.79	0.084	0.0568	83.5	0.0171	<0.024	1.18	41.5	0.104	<0.022	13.0	<0.073	6.28
5	2.15	0.139	0.0390	69.9	<0.0016	0.920	1.13	44.0	0.0163	<0.022	18.1	<0.073	8.81
6	<0.79	0.045	0.0818	81.2	<0.0016	1.34	1.16	40.4	0.0234	<0.022	9.50	0.081	9.26
7	<0.79	0.027	0.0998	101	<0.0016	1.81	1.07	46.3	0.0514	<0.022	7.82	0.089	10.0
8	<0.79	0.193	0.0734	49.2	<0.0016	0.675	2.28	31.6	0.0105	<0.022	23.0	<0.073	7.68
9	<0.79	0.408	0.0885	62.8	<0.0016	0.571	12.7	35.0	0.0060	<0.022	22.9	<0.073	4.26
10	46.0	0.081	0.0843	56.4	<0.0016	1.95	1.10	35.7	0.0089	<0.022	16.0	<0.073	7.92
11	<0.79	0.180	0.0469	47.2	<0.0016	0.845	1.37	21.0	0.0072	<0.022	55.5	<0.073	9.45
12	<0.79	<0.023	0.0759	108	<0.0016	1.86	1.72	51.2	0.0751	<0.022	5.62	<0.073	7.01
14	6.97	0.059	0.0762	77.9	<0.0016	3.11	1.69	38.2	0.0167	<0.022	11.6	0.135	11.6
15	<0.79	0.028	0.0598	91.3	<0.0016	1.56	1.42	44.5	0.0227	<0.022	9.02	<0.073	9.05
17	<0.79	0.054	0.0326	74.1	0.0049	2.46	1.51	35.6	0.0357	<0.022	10.8	<0.073	9.73
18	12.2	0.275	0.0373	33.6	<0.0016	1.13	1.19	17.5	0.0169	<0.022	73.3	<0.073	7.91
19	<0.79	2.39	0.276	43.0	<0.0016	0.237	28.2	16.9	0.0041	<0.022	49.9	<0.073	3.44
20	<0.79	0.025	0.0399	77.5	0.0393	0.059	1.89	37.9	0.0024	<0.022	14.1	<0.073	8.03
21	6.74	0.040	0.101	74.2	<0.0016	2.86	1.29	38.0	0.0110	<0.022	8.13	0.108	10.3
22	2.17	0.048	0.0684	74.6	<0.0016	0.503	1.50	41.1	0.0886	<0.022	9.36	<0.073	9.87
24	1.90	0.133	0.0940	65.3	<0.0016	2.77	1.98	33.7	0.0464	<0.022	19.0	0.189	10.1
25	1.61	0.083	0.0697	74.3	<0.0016	1.00	1.49	43.6	0.0307	<0.022	14.1	0.198	7.13
26	8.25	0.354	0.187	43.3	0.0293	3.48	2.49	27.6	0.0164	<0.022	56.8	<0.073	8.67
28	0.99	0.052	0.0873	142	0.0062	3.19	2.48	43.7	0.384	<0.022	111	<0.073	6.86
29	1.42	0.099	0.134	144	<0.0016	5.57	2.78	83.7	0.0681	<0.022	27.4	<0.073	10.2
30	<0.79	0.532	0.0159	48.9	<0.0016	0.214	5.02	33.0	0.0040	<0.022	28.9	<0.073	6.22
31	1.78	0.496	0.0639	68.5	<0.0016	0.601	2.18	46.7	0.0070	0.036	30.5	<0.073	8.44
32	2.73	0.482	0.0357	65.5	0.0020	0.204	2.92	84.9	0.0030	0.043	34.8	<0.073	7.32
33	1.83	0.047	0.242	177	<0.0016	3.64	2.62	97.1	0.0299	<0.022	181	<0.073	12.4
34	2.42	0.025	0.148	100	<0.0016	2.19	1.25	50.8	0.0304	<0.022	7.78	0.086	12.1
35	<0.79	0.031	0.191	99.3	0.0097	1.37	4.69	46.5	0.0789	<0.022	99.0	<0.073	7.79
36	8.57	0.284	0.198	73.6	<0.0016	3.32	4.64	39.6	0.0157	<0.022	60.7	0.128	10.6
37	21.7	0.235	0.182	83.5	<0.0016	6.69	5.97	41.0	0.0326	<0.022	66.9	0.162	8.46
38	<0.79	1.77	0.0112	34.3	<0.0016	<0.024	5.96	19.3	0.0023	<0.022	253	0.075	5.64
39	<0.79	0.058	0.232	156	<0.0016	2.37	3.92	81.8	0.124	<0.022	57.3	0.078	10.4
40	1.75	0.045	0.332	129	<0.0016	4.02	4.79	63.5	0.115	<0.022	169	<0.073	7.25
42	<0.79	1.15	0.0178	73.6	<0.0016	0.073	10.0	40.9	0.0039	<0.022	69.3	<0.073	5.85
43	<0.79	0.273	0.0212	25.2	<0.0016	0.163	2.83	32.0	0.0028	<0.022	46.6	<0.073	6.84
44	<0.79	0.050	0.0857	102	<0.0016	2.15	3.46	52.1	0.0654	<0.022	49.1	<0.073	6.30
45	1.83	0.109	0.0663	77.1	<0.0016	0.341	1.81	43.9	0.0264	<0.022	12.1	<0.073	7.88
46	<0.79	0.041	0.0844	117	0.0021	1.65	2.83	64.3	0.0768	<0.022	53.0	<0.073	8.22
47	<0.79	0.139	0.137	45.0	<0.0016	0.409	2.85	38.5	0.0023	<0.022	16.3	<0.073	8.26
49	3.65	0.160	0.0801	88.5	<0.0016	1.02	1.67	55.9	0.0338	<0.022	14.9	<0.073	8.98
50	17.2	0.184	0.0733	48.3	<0.0016	2.06	1.92	36.8	0.0176	<0.022	23.0	<0.073	5.71
52	<0.79	0.406	0.769	71.3	<0.0016	0.596	9.65	32.5	0.0097	<0.022	35.8	<0.073	5.37
53	19.3	0.225	0.0930	70.3	<0.0016	4.27	2.34	33.9	0.0302	<0.022	45.8	0.087	8.67
54	19.0	0.238	0.164	37.8	<0.0016	0.465	1.39	26.9	0.0096	<0.022	39.8	<0.073	7.02
55	0.87	0.029	0.0935	115	<0.0016	1.26	4.93	58.7	0.0411	<0.022	43.8	<0.073	7.87
58	<0.79	0.081	0.195	147	<0.0016	2.71	3.84	73.8	0.0868	<0.022	79.6	<0.073	9.44
59	<0.79	0.138	0.127	89.7	0.0053	0.036	2.96	51.6	0.0052	<0.022	26.4	<0.073	12.6
60	<0.79	0.042	0.0879	85.8	<0.0016	1.08	1.24	42.9	0.0269	<0.022	7.14	<0.073	9.40
61	1.56	0.076	0.0610	75.0	<0.0016	1.52	1.76	43.9	0.0647	<0.022	17.2	<0.073	7.72
62	10.7	0.123	0.138	44.4	<0.0016	0.308	2.63	33.3	0.0134	<0.022	21.4	<0.073	8.37
63	6.41	0.106	0.0672	72.2	<0.0016	0.529	1.70	54.9	0.0034	<0.022	14.4	<0.073	7.95

Table A-2. Concentrations of Metals in Untreated Samples

(continued)

Sample No.	*As (µg/L)*	*B (mg/L)*	*Ba (mg/L)*	*Ca (mg/L)*	*Cu (mg/L)*	*Fe (mg/L)*	*K (mg/L)*	*Mg (mg/L)*	*Mn (mg/L)*	*Mo (mg/L)*	*Na (mg/L)*	*P (mg/L)*	*Si (mg/L)*
64	<0.79	1.25	0.0069	17.2	<0.0016	0.038	20.2	8.83	0.0168	<0.022	89.3	<0.073	3.56
65	0.99	0.112	0.171	110	<0.0016	3.55	2.96	58.2	0.0295	<0.022	42.5	<0.073	7.47
66	2.77	0.028	0.0928	116	<0.0016	2.17	1.27	63.5	0.0460	<0.022	15.0	<0.073	8.98
67	12.8	0.044	0.0561	85.4	0.0088	2.55	1.22	48.4	0.0155	<0.022	7.12	<0.073	10.7
68	<0.79	0.069	0.117	126	0.0034	1.53	1.94	61.2	0.0480	<0.022	117	<0.073	8.43

Notes: Concentrations of 13 metals were below instrument detection limit (mg/L) in all samples: Al (<0.037), Be (<0.00055), Cd (<0.012), Co (<0.013), Cr (<0.0058), Li (<0.11), Ni (<0.043), Pb (<0.041), Sb (<0.059), Se (<0.13), Sn (<0.086), Ti (<0.00056), V (<0.047).

Table A-3. Concentrations of Metals, Stable Isotopes of Water, and Bacteria Indicators in Untreated Samples

Sample No.	*Sr (mg/L)*	*Tl (mg/L)*	*Zn (mg/L)*	δD *(‰)*	$\delta^{18}O$ *(‰)*	*Total Coliform detected*	*Fecal Coliform (cfu/100 mL)*	*E Coli (cfu/100 mL)*
1	0.810	<0.017	<0.0097	-54.3	-8.26	No	< 1	0
2	0.857	<0.017	<0.0097	-53.7	-8.42	No	< 1	0
3	0.679	<0.017	<0.0097	-48.5	-7.72	Yes	< 1	0
4	0.637	<0.017	<0.0097	-50.9	-7.97	Yes	< 1	0
5	0.904	<0.017	0.0409	-52.4	-8.07	No	< 1	0
6	0.593	<0.017	<0.0097	-50.5	-7.90	No	< 1	0
7	0.422	<0.017	<0.0097	-52.2	-8.20	No	< 1	0
8	0.433	<0.017	<0.0097	-51.1	-8.00	No	< 1	0
9	0.867	<0.017	0.0784	-49.6	-7.65	No	< 1	0
10	0.827	<0.017	<0.0097	-49.6	-7.80	No	< 1	0
11	0.289	<0.017	0.0135	-48.5	-7.73	No	< 1	0
12	0.120	<0.017	<0.0097	-49.4	-7.89	Yes	< 1	0
14	0.324	<0.017	<0.0097	-50.1	-7.83	No	< 1	0
15	0.203	<0.017	<0.0097	-51.9	-8.03	Yes	> 200	0
17	0.373	<0.017	<0.0097	-50.4	-7.87	No	< 1	0
18	0.200	<0.017	<0.0097	-44.7	-7.28	No	< 2	0
19	1.14	<0.017	<0.0097	-51.9	-7.79	No	< 1	0
20	0.105	0.022	0.0253	-42.5	-6.27	No	< 1	0
21	0.354	0.020	<0.0097	-50.9	-8.00	Yes	< 1	0
22	0.493	<0.017	<0.0097	-50.4	-7.90	No	< 1	0
24	2.41	<0.017	<0.0097	-45.0	-7.26	No	< 1	0
25	1.77	<0.017	0.0275	-46.2	-7.44	No	< 1	0
26	2.89	<0.017	<0.0097	-46.1	-7.32	No	< 1	0
28	0.165	<0.017	<0.0097	-49.6	-7.66	No	< 1	0
29	0.746	<0.017	0.0139	-50.3	-7.86	No	< 1	0
30	0.657	<0.017	<0.0097	-47.1	-7.45	Yes	1	0
31	1.20	<0.017	<0.0097	-50.0	-8.03	No	< 1	0
32	2.33	<0.017	<0.0097	-50.2	-8.05	No	< 1	0
33	0.179	<0.017	<0.0097	-48.6	-7.68	No	< 1	0
34	0.193	<0.017	<0.0097	-52.6	-8.36	No	< 1	0
35	0.094	<0.017	0.0119	-53.2	-8.25	No	< 1	0
36	1.92	<0.017	<0.0097	-52.4	-8.13	No	< 1	0
37	1.00	<0.017	<0.0097	-53.3	-8.08	No	< 1	0
38	0.406	<0.017	<0.0097	-57.8	-8.67	No	< 1	0
39	0.658	<0.017	<0.0097	-52.5	-8.09	No	< 1	0
40	0.168	<0.017	<0.0097	-53.3	-8.35	No	< 1	0
42	0.872	<0.017	<0.0097	-52.4	-8.16	No	< 1	0
43	0.648	<0.017	<0.0097	-48.3	-7.72	No	< 1	0
44	0.278	<0.017	0.0150	-52.7	-8.27	No	< 1	0
45	0.397	<0.017	<0.0097	-53.3	-8.24	No	< 1	0
46	0.122	<0.017	<0.0097	-49.8	-7.88	No	< 1	0
47	0.618	<0.017	0.0101	-47.8	-7.43	No	< 1	0
49	0.612	<0.017	<0.0097	-47.2	-7.42	No	< 1	0
50	2.14	<0.017	<0.0097	-46.4	-7.54	No	< 1	0
52	2.39	<0.017	<0.0097	-54.4	-8.37	No	< 1	0
53	1.38	<0.017	0.0134	-53.5	-8.36	No	< 1	0
54	0.919	<0.017	<0.0097	-52.5	-8.28	Yes	< 1	0
55	0.081	<0.017	0.0207	-51.5	-8.12	No	< 1	0
58	0.775	<0.017	0.0099	-50.5	-7.96	No	< 1	0
59	0.551	<0.017	<0.0097	-49.7	-7.88	No	< 1	0
60	0.167	<0.017	<0.0097	-49.7	-7.61	Yes	< 1	0

Table A-3. Concentrations of Metals, Stable Isotopes of Water, and Bacteria Indicators in Untreated Samples

(continued)

Sample No.	*Sr (mg/L)*	*Tl (mg/L)*	*Zn (mg/L)*	*δD (‰)*	*$\delta^{18}O$ (‰)*	*Total Coliform detected*	*Fecal Coliform (cfu/100 mL)*	*E Coli (cfu/100 mL)*
61	0.466	<0.017	0.0137	-52.4	-8.02	No	< 1	0
62	0.380	<0.017	<0.0097	-47.7	-7.26	No	< 1	0
63	1.67	<0.017	<0.0097	-50.9	-7.82	No	< 1	0
64	0.317	<0.017	0.0122	-54.8	-8.53	No	< 1	0
65	0.731	<0.017	<0.0097	-51.9	-7.84	No	< 1	0
66	0.236	<0.017	<0.0097	-50.0	-7.90	No	< 1	0
67	0.316	<0.017	<0.0097	-52.5	-8.02	No	< 1	0
68	0.246	<0.017	<0.0097	-52.3	-8.08	No	< 1	0

Table A-4. Concentrations of Anions, DOC, NH_3-N, and TDS in Untreated Samples

Sample No.	*Alkalinity (mg $CaCO_3$/L)*	*F^- (mg/L)*	*Cl^- (mg/L)*	*Br^- (mg/L)*	*NO_3 -N (mg/L)*	*SO_4^{2-} (mg/L)*	*DOC (mg/L)*	*NH_3-N (mg/L)*	*TDS (mg/L)*
1	294	0.40	9.00	<0.08	<0.04	<0.21	1.65	0.99	311
2	355	0.50	20.4	<0.08	<0.04	12.8	1.36	0.73	398
3	327	0.39	1.15	<0.08	<0.04	<0.21	2.11	3.04	332
4	319	0.28	15.7	<0.08	2.80	24.3	0.70	<0.03	377
5	358	0.44	5.05	<0.08	<0.04	3.02	1.62	0.39	366
6	314	0.48	10.1	<0.08	<0.04	26.0	0.51	0.22	367
7	335	0.45	23.0	<0.08	<0.04	56.4	0.97	1.03	449
8	284	0.43	1.19	<0.08	<0.04	<0.21	1.10	0.28	286
9	335	0.43	0.97	<0.08	<0.04	<0.21	3.41	0.78	341
10	303	0.47	1.57	<0.08	<0.04	<0.21	2.04	0.79	303
11	303	0.48	2.17	<0.08	<0.04	<0.21	5.57	0.25	320
12	314	0.24	20.8	<0.08	<0.04	106	0.53	<0.03	491
14	342	0.33	8.26	<0.08	<0.04	4.01	1.58	0.93	363
15	339	0.36	15.0	<0.08	<0.04	48.1	1.10	0.28	424
17	331	0.41	3.45	<0.08	<0.04	2.79	2.16	0.54	340
18	285	0.71	1.32	<0.08	<0.04	<0.21	5.67	0.92	308
19	299	1.53	2.92	<0.08	<0.04	<0.21	0.33	1.26	325
20	247	0.17	50.6	0.11	0.08	56.0	<0.31	<0.03	394
21	311	0.41	3.86	<0.08	<0.04	28.5	1.06	0.41	354
22	327	0.41	6.52	<0.08	<0.04	23.9	0.87	0.37	364
24	349	0.58	1.78	<0.08	<0.04	<0.21	4.30	4.51	349
25	349	0.43	10.9	<0.08	<0.04	12.5	1.74	1.40	376
26	322	0.83	1.59	<0.08	<0.04	<0.21	4.57	1.65	338
28	326	0.26	192	<0.08	<0.04	139	2.13	0.17	836
29	409	0.39	114	0.08	<0.04	143	1.16	0.32	776
30	282	0.81	3.44	<0.08	<0.04	18.6	0.96	0.30	314
31	290	0.78	11.8	<0.08	<0.04	107	1.46	0.46	451
32	327	0.78	5.73	<0.08	<0.04	211	1.10	0.48	609
33	420	0.14	429	0.09	<0.04	87.5	1.49	0.09	1242
34	348	0.37	40.2	<0.08	<0.04	51.8	0.60	0.29	475
35	333	0.18	146	<0.08	<0.04	87.1	0.83	0.16	692
36	438	0.45	34.5	<0.08	<0.04	<0.21	8.15	6.53	496
37	577	0.29	2.85	<0.08	<0.04	<0.21	21.4	25.6	587
38	387	1.48	208	<0.08	<0.04	4.09	0.47	0.45	762
39	359	0.40	310	0.40	<0.04	75.1	1.05	2.32	915
40	344	0.13	385	<0.08	<0.04	23.5	1.16	0.18	992
42	360	0.72	75.3	<0.08	<0.04	27.9	0.51	0.48	519
43	278	0.57	4.35	<0.08	<0.04	<0.21	2.24	0.27	285
44	323	0.17	130	<0.08	<0.04	54.3	0.59	0.09	594
45	341	0.45	5.93	<0.08	<0.04	52.6	1.16	0.28	407
46	371	0.14	129	<0.08	<0.04	94.8	1.03	0.11	693
47	285	0.34	0.90	<0.08	<0.04	1.07	0.63	0.44	285
49	320	0.53	29.9	<0.08	<0.04	71.5	1.01	0.47	465
50	304	0.49	2.96	<0.08	<0.04	<0.21	3.20	2.68	306
52	345	0.76	11.5	<0.08	<0.04	11.6	0.31	0.44	385
53	373	0.46	28.4	<0.08	<0.04	<0.21	6.64	7.56	425
54	262	0.54	1.52	<0.08	<0.04	<0.21	1.88	0.45	272
55	395	0.11	84.4	<0.08	<0.04	59.2	0.45	<0.03	612
58	385	0.23	232	<0.08	0.15	75.4	1.01	1.44	856
59	436	0.31	18.2	<0.08	<0.04	1.62	3.63	1.71	466
60	319	0.29	14.4	<0.08	<0.04	55.7	0.73	0.20	409
61	330	0.38	24.9	<0.08	<0.04	15.5	0.78	0.39	385
62	282	0.38	0.88	<0.08	<0.04	1.39	0.68	0.15	282

Table A-4. Concentrations of Anions, DOC, NH_3-N, and TDS in Untreated Samples (continued)

Sample No.	*Alkalinity (mg $CaCO_3$/L)*	*F^- (mg/L)*	*Cl^- (mg/L)*	*Br^- (mg/L)*	*NO_3 - N (mg/L)*	*SO_4^{2-} (mg/L)*	*DOC (mg/L)*	*NH_3- N (mg/L)*	*TDS (mg/L)*
63	409	0.35	8.41	<0.08	<0.04	11.2	2.08	1.73	418
64	274	1.23	3.91	<0.08	<0.04	0.27	0.64	0.40	308
65	347	0.22	127	<0.08	<0.04	64.7	0.65	0.27	626
66	293	0.31	131	<0.08	<0.04	83.5	0.70	0.31	597
67	374	0.32	18.0	<0.08	<0.04	12.5	1.22	0.53	410
68	404	0.21	228	<0.08	<0.04	62.2	0.87	0.36	849

Notes: TDS calculated by summing dissolved species.

Table A-5. Well Information and Field Analyses for Treated (Softened or Aerated) Samples

Sample No.	*Depth (ft)*	*Aquifer*	*Town*	*Rng*	*Sect*	*Overlying till (ft)*	*Date sampled*	*Temp (°C)*	*pH*	*ORP (mv)*	*SpC (µS/cm)*	*DO (mg/L)*	*H_2S (ppm)*
13	70	U	38N	6E	17	60	10/5/2015	12.5	7.19	148	794	0.0	< 0.1
16	188	C	39N	6E	30	96	10/5/2015	15.3	7.26	345	677	7.3	< 0.1
23	95	U	39N	6E	4	92	10/6/2015	13.2	7.23	336	655	3.5	< 0.1
27	160	C	38N	6E	26	108	10/7/2015	12.4	7.45	300	558	0.0	< 0.1
41	200	C	41N	8E	36	175	10/21/2015	12.8	7.37	134	1290	0.0	< 0.1
48	75	C	38N	8E	8	33	11/4/2015	13.1	7.00	170	1684	0.0	< 0.1
51	250	C	40N	8E	20	117	11/4/2015	18.4	7.28	379	742	0.0	< 0.1
56	70	U	42N	8E	21	55	11/5/2015	15.1	8.62	436	729	8.5	< 0.1
57	250	C	41N	8E	29	55	11/5/2015	16.8	8.57	441	634	8.7	< 0.1

Notes: C = consolidated (bedrock) aquifer, U = unconsolidated aquifer

Table A-6. Concentrations of Metals in Treated (Softened or Aerated) Samples

Sample No.	*As (µg/L)*	*B (mg/L)*	*Ba (mg/L)*	*Ca (mg/L)*	*Cu (mg/L)*	*Fe (mg/L)*	*K (mg/L)*	*Mg (mg/L)*	*Mn (mg/L)*	*Mo (mg/L)*	*Na (mg/L)*	*P (mg/L)*	*Si (mg/L)*
13	3.34	<0.023	<0.00085	0.077	<0.0016	<0.024	0.064	0.031	<0.0015	<0.022	189	<0.073	7.38
16	<0.79	0.036	<0.00085	0.131	0.0267	<0.024	0.114	0.042	<0.0015	<0.022	176	<0.073	9.32
23	<0.79	0.046	<0.00085	0.122	0.0328	<0.024	0.366	0.053	<0.0015	<0.022	180	<0.073	8.79
27	<0.79	0.315	<0.00085	0.509	0.0022	<0.024	1.18	0.219	0.0042	<0.022	155	<0.073	4.47
41	<0.79	0.279	0.00645	2.20	<0.0016	0.102	3.61	1.37	0.0034	<0.022	316	0.073	6.56
48	<0.79	0.071	0.00489	3.87	<0.0016	0.071	0.433	1.43	0.0037	<0.022	388	<0.073	7.01
51	<0.79	1.55	0.00184	0.513	0.0771	<0.024	2.53	0.257	<0.0015	<0.022	187	<0.073	3.71
56	<0.79	0.059	0.0632	32.3	0.0089	<0.024	6.41	15.7	<0.0015	<0.022	93.8	<0.073	2.53
57	<0.79	0.094	0.131	25.4	0.0072	<0.024	7.55	16.2	<0.0015	<0.022	76.4	<0.073	2.66

Notes: Concentrations of 13 metals were below instrument detection limit (mg/L) in all samples: Al (<0.037), Be (<0.00055), Cd (<0.012), Co (<0.013), Cr (<0.0058), Li (<0.11), Ni (<0.043), Pb (<0.041), Sb (<0.059), Se (<0.13), Sn (<0.086), Ti (<0.00056), V (<0.047).

Table A-7. Concentrations of Metals, Stable Isotopes of Water, and Bacteria Indicators in Treated (Softened or Aerated) Samples

Sample No.	*Sr (mg/L)*	*Tl (mg/L)*	*Zn (mg/L)*	*δD (‰)*	*$\delta^{18}O$ (‰)*	*Total Coliform detected*	*Fecal Coliform (cfu/100 mL)*	*E Coli (cfu/100 mL)*
13	0.00039	<0.017	<0.0097	-49.8	-7.99	No	< 1.00	0
16	0.00091	<0.017	<0.0097	-47.1	-7.54	No	< 1.00	0
23	0.00092	<0.017	<0.0097	-50.6	-7.93	No	< 1.00	0
27	0.00681	<0.017	<0.0097	-48.5	-7.64	Yes	< 1.00	0
41	0.0608	<0.017	<0.0097	-52.7	-8.16	Yes	5	0
48	0.00519	<0.017	<0.0097	-47.4	-7.58	No	< 1.00	0
51	0.0105	<0.017	0.0883	-52.9	-8.26	No	NA	0
56	0.338	<0.017	<0.0097	-46.0	-6.70	No	< 1.00	0
57	0.364	<0.017	<0.0097	-48.1	-7.06	No	< 1.00	0

Notes: NA = not analyzed.

Table A-8. Concentrations of Anions, DOC, NH_3-N, and TDS in Treated (Softened or Aerated) Samples

Sample No.	Alkalinity (mg/L $CaCO_3$)	F^- (mg/L)	Cl^- (mg/L)	Br^- (mg/L)	NO_3-N (mg/L)	SO_4^{2-} (mg/L)	DOC (mg/L)	NH_3-N (mg/L)	TDS (mg/L)
13	294	0.17	19.8	<0.08	<0.04	70.0	0.55	<0.03	463
16	302	0.46	5.16	<0.08	0.25	34.4	0.79	<0.03	406
23	321	0.40	5.77	<0.08	0.08	34.0	0.79	<0.03	422
27	294	0.61	10.1	<0.08	<0.04	3.75	0.39	0.06	351
41	375	0.51	207	<0.08	<0.04	21.5	1.89	0.31	784
48	366	0.11	275	<0.08	<0.04	85.4	0.88	<0.03	981
51	321	1.26	35.9	<0.08	<0.04	18.5	0.34	<0.03	441
56	82	1.01	131	<0.08	1.06	61.1	2.45	0.56	392
57	86	0.99	105	<0.08	0.78	53.6	2.01	0.60	338

Notes: TDS calculated by summing dissolved species.

Table A-9. Results for GWQDB Samples Included in Figures 5, 8, 10, 13, and 17

Sample No.	*Depth (ft)*	*Aquifer*	*Town*	*Rng*	*Sect*	*Overlying till (ft)*	*Date sampled*	*As (μg/L)*	*B (mg/L)*	*Ba (mg/L)*	*Ca (mg/L)*	*Cu (mg/L)*
237195	150		39N	08E	26		4/30/2012	4.79	0.254	0.0357	122	0.0757
237467	45		39N	08E	26		3/11/2013	2.05	0.068	0.266	170	0.0328
237726	160		40N	08E	13		4/16/2014	3.40	0.277	0.078	67.9	< 0.0016
237733	34		41N	07E	27		5/14/2014	< 0.95	0.099	0.0775	109	0.0084
237870	48		41N	08E	32		12/16/2014	< 0.95	0.060	0.130	127	0.153
238060	150		42N	07E	25		11/2/2015	7.62	0.578	0.0484	53.9	0.0175
237850	38		42N	07E	25		11/25/2014	< 0.95	0.029	0.199	128	0.0062
237896	235		42N	07E	36		2/9/2015	15.6	0.184	0.105	76.7	0.0516
237235	208		42N	08E	12		5/29/2012	3.59	0.027	0.193	129	0.0051
237171	235		42N	08E	12		4/17/2012	1.68	0.025	0.251	119	0.0051

Notes: C = consolidated (bedrock) aquifer, U = unconsolidated aquifer

Table A-9 (continued). Results for GWQDB Samples Included in Figures 5, 8, 10, 13, and 17

Sample No.	*Fe (mg/L)*	*K (mg/L)*	*Mg (mg/L)*	*Mn (mg/L)*	*Na (mg/L)*	*P (mg/L)*	*Si (mg/L)*	*Sr (mg/L)*	*Zn (mg/L)*
237195	0.634	2.95	99.8	0.0326	24.7	0.155	8.65	1.09	0.060
237467	3.86	2.99	97.5	0.0363	255	< 0.073	11.3	0.268	0.0363
237726	1.14	2.68	38.9	0.0141	37.8	0.090	8.37	0.865	0.004
237733	0.380	1.88	52.5	0.0365	64.6	0.073	6.59	0.029	0.004
237870	4.64	1.53	54.2	0.0669	51.1	0.177	10.2	0.703	0.220
238060	0.725	6.97	33.1	0.0054	94.7	< 0.073	5.89	0.434	0.004
237850	2.19	2.75	63.0	0.0338	50.9	< 0.073	10.2	0.348	0.0145
237896	3.14	3.42	36.5	0.0135	35.7	0.096	10.2	1.51	0.0199
237235	3.39	3.91	69.7	0.0608	24.0	0.168	10.6	0.132	0.0496
237171	2.89	4.01	62.0	0.0572	27.6	0.149	9.44	0.131	0.0107

Notes: Concentrations of 15 metals were below instrument detection limit (mg/L) in all samples: Al (<0.037), Be (<0.00055), Cd (<0.012), Co (<0.013), Cr (<0.0058), Li (<0.11), Mo (<0.022), Ni (<0.043), Pb (<0.041), Sb (<0.059), Se (<0.13), Sn (<0.086), Ti (<0.00056), Tl (<0.017), V (<0.047).

Table A-9 (concluded). Results for GWQDB Samples Included in Figures 5, 8, 10, 13, and 17

Sample No.	*Alkalinity (mg/L $CaCO_3$)*	*F^- (mg/L)*	*Cl^- (mg/L)*	*NO_3 -N (mg/L)*	*SO_4^{2-} (mg/L)*	*DOC (mg/L)*	*NH_3-N (mg/L)*	*TDS (mg/L)*
237195	392	0.59	49.5	0.07	233	NA	NA	796
237467	434	0.12	601	0.11	74.8	NA	NA	1406
237726	357	0.79	36.9	< 0.04	< 0.21	NA	NA	394
237733	357	0.14	137	0.35	55.7	NA	NA	679
237870	445	0.33	130	< 0.04	1.77	2.92	5.53	610
238060	429	0.41	29.9	< 0.04	< 0.21	6.86	NA	485
237850	366	0.33	135	< 0.04	78.5	1.13	NA	689
237896	390	0.47	43.3	< 0.04	< 0.21	5.04	NA	430
237235	387	0.20	88.0	< 0.04	88	NA	NA	661
237171	395	0.19	87.9	< 0.04	89.4	NA	NA	674

Notes: NA = not analyzed.

Appendix B: Sample Letter and Report on Water Quality Sent to Participating Well Owners

[Date]

[Name and address]

Dear Well Owner:

Enclosed is a copy of the chemical analyses made on the raw water sample we collected from your well on 11/24/2015. The analysis shows this sample to be very hard.

The total dissolved solids (TDS) content, which is calculated by summing the major dissolved components in the sample, is above the secondary water quality standard of 500 mg/L. While this is not a health concern, it may result in the water tasting salty or bitter. Reverse osmosis can remove minerals from drinking water.

The hardness in this sample is sufficient to cause the formation of an exceptionally large amount of scale in boilers and hot water heaters, and to consume an exceptionally large amount of soap if used for washing or laundry purposes. There is sufficient iron to cause staining of porcelain ware, etc.

Coliform bacteria were not detected in this water sample. However, the test we used is not approved by the health department, and false positive or negative results are not uncommon with this test. If you wish to have your water more reliably tested for coliform bacteria, please contact the Kane County Health Department.

None of the other parameters tested appear unusual or excessive for Illinois groundwater. However, our laboratory is only capable of identifying a limited number of the contaminants found in the Safe Drinking Water Act. Testing for radionuclides and synthetic organic contaminants, if desired, must be arranged through other laboratories. A listing of such laboratories can be found at www.epa.state.il.us/labs/pdf/comblist.pdf or you can Google "water analytical laboratory". We took a raw water sample from your well; if you wish to have your treated water analyzed for a small fee ($35), you may request a sampling kit from our Public Service Laboratory. Please contact Jennifer Tester at 217/333-9321.

Thank you again for allowing us to sample your well as part of this groundwater quality study. We sampled 68 shallow wells throughout Kane County in the fall of 2015. We are preparing a report on our results for the Kane County Board, which should be completed this spring. The report will be available on the Illinois State Water Survey website when it is published, under the publications page [http://www.isws.illinois.edu/pubs/isearch.asp].

If you have any questions about this report or the project, please contact me.

Sincerely,

Walton R. Kelly
Head, Groundwater Science Section
217/333-3729
wkelly@illinois.edu

Appendix B (concluded)

Well Owner	XXXXX
Address	XXXXX
City	XXXXX
Well Depth (ft)	XXXXX
Date sampled	XXXXX

Field Parameters

Temperature	12.5	°C
Specific Conductance	576	µS/cm
pH	7.17	
Eh	60	mV
Dissolved Oxygen	0.09	mg/L
Hydrogen Sulfide	< 0.1	mg/L

Major Ions

Calcium	55.3	mg/L
Magnesium	35.0	mg/L
Potassium	2.26	mg/L
Sodium	22.1	mg/L
Alkalinity	294	mg/L $CaCO_3$
Chloride	9.00	mg/L
Sulfate	<0.21	mg/L

Nutrients, Bacteria, etc.

Nitrate-Nitrogen	<0.04	mg/L
Ammonium-Nitrogen	0.99	mg/L
Dissolved Organic Carbon	1.65	mg/L
Total Coliform	NEG	
Fecal Coliform (*e coli*)	< 1.00	
E. coli	0	

Hardness	282	mg/L $CaCO_3$
Total Dissolved Solids (calculated)	311	mg/L

Minor Elements

Fluoride	0.40	mg/L
Bromide	<0.08	mg/L
Aluminum	<0.037	mg/L
Antimony	<0.059	mg/L
Arsenic	2.38	µg/L
Barium	0.11	mg/L
Beryllium	<0.00055	mg/L
Boron	0.16	mg/L
Cadmium	<0.012	mg/L
Chromium	<0.0058	mg/L
Cobalt	<0.013	mg/L
Copper	<0.0016	mg/L
Iron	2.43	mg/L
Lead	<0.041	mg/L
Lithium	<0.11	mg/L
Manganese	0.01	mg/L
Molybdenum	<0.022	mg/L
Nickel	<0.043	mg/L
Phosphorous	<0.073	mg/L
Sulfur	<0.22	mg/L
Selenium	<0.13	mg/L
Silicon	7.96	mg/L
Strontium	0.81	mg/L
Thallium	<0.017	mg/L
Tin	<0.086	mg/L
Titanium	<0.00056	mg/L
Vanadium	<0.047	mg/L
Zinc	<0.0097	mg/L