Illinois State Water Survey
Center for Groundwater Science

An Evaluation of Temporal Changes in Shallow Groundwater Quality in Northeastern Illinois

Abstract

The rapid increase in population and developed land in the Chicago, Illinois, metropolitan area has placed a heavy demand on water resources. Water sources most likely to be developed in this region during the next few decades are shallow aquifers. Since shallow aquifers are vulnerable to surface-derived contaminants, the increase in developed land may be escalating the rate at which groundwater quality is being degraded. A statistical study of historical groundwater quality data was undertaken to determine if urbanization activities have affected shallow groundwater quality. Of the major ions, chloride (Cl^-) concentrations have shown the largest increases in the region, due primarily to road salt runoff. In the majority of shallow public supply wells in the western and southern collar counties of DuPage, Kane, McHenry, and Will, Cl^- concentrations have been increasing since the 1960s. About 43 percent of wells in these counties have rate increases greater than 1 milligram per liter per year (mg/L/yr) and 15 percent have increases

Contents

List of Figures

Introduction

Population and infrastructure have grown rapidly in the Chicago, Illinois, metropolitan area in rethht24 met17(a)-11(n)]reitan and Hollocher, 1976; Pilon and Howard, 1987; Amrhein et al., 1992; Howard and Haynes, 1993,

II and accelerated rapidly across the United States starting in the 1960s (Figure 1) (Salt Institute, 2008). Once in groundwater, Cl^- and other contaminants can persist for a long period due to slow travel times. Howard et al. (1993) estimated that, even if road salting was stopped immediately in the Toronto, Canada, area, it would be decades before Cl^- concentrations in shallow groundwater returned to pre-1960 levels.

The Illinois State Water Survey (ISWS) has conducted several shallow groundwater quality studies in the Chicago region. In 1979, Sasman et al. (1981) sampled 282 shallow public,

County. Water quality was good in undeveloped and newly developed areas, but was relatively poor in developed areas. Visocky (1990) examined data from 30 sand and gravel public supply wells in Kane County. Although the water quality was generally good, concentrations of TDS, Cl^-, and SO_4^{2-}

et al. (1993) sampled 186 shallow public, com ,3(l)15(y d)4/ 1*•2!q,h,ŽÂ§4ÁYUqQ•q$Ǩ—XRâCb!n>BŷÑ42!RqQâ
feet) monitoring wells, and wells next to Intey -8(s)5(t)-17(a)8(t)-4(e 9)6(4 h)-1(a)-8(d C)10(l)]TJ6.996 0 0 6.996

Kane County in October 2003. Concentrations of TDS, Cl^-

with virtually no data prior to 1970. Concentrations of many trace constituents are commonly present at or below detection limits, and detection limits have varied considerably over time,

Data Quality Considerations

Data quality issues included samples with incomplete or incorrect information (well number, location, and depth) and concerns about the quality of the water-chemistry data itself. Most data problems were corrected by examining hard-copy sampling reports archived at the ISWS, when available, or by comparing database records with information in the ISWS Public, Industrial, and Commercial Survey (PICS) well database.

The most common water-chemistry problem was an unacceptable ion balance. Ion balances are calculated to ensure that positively charged ions (cations) are present in approximately the same amount as negatively charged ions (anions). Ion balances were calculated using the following equation:

(1)

Ion concentrations are in milliequivalents per liter (meq/L), and %E is the percent error. Major ions typically make up more than 95 percent of the ionic charge in groundwater samples. In samples with substantial concentrations of other ions (e.g., potassium [K^+], nitrate [NO_3^-], ammonium [NH_4^+], iron [Fe^{2+}]), these ions were added to the ion balance. Samples with an ion balance

when available. Transcription errors were found for many problem samples; when corrected, ion balances were usually acceptable. Samples that could not be corrected to produce acceptable ion balances were not used in data analysis.

TDS errors were found for a considerable number of samples. TDS was reported as a

sample volume. It also can be calculated from a formula by adding major ion concentrations. The following equation was used to calculate TDS for samples for which complete major ion analyses

(3)

Values from this revised calculation are slightly less than TDS values. However, the equation allows TDS trend evaluation over a longer time period, assuming that K and SiO_2 concentrations did not change substantially during the period of record.

Trends for individual wells were analyzed by determining the Kendall S statistic, a nonparametric test of the data, calculated by:

Chicago area, and no changes in Cl^- concentrations were observed for these wells prior to 1960 (Kelly, 2001).

The effects of geology on Cl^- concentrations in the shallow aquifers were evaluated

contain information such as screen location, aquifer depth and thickness, source aquifer, thickness of overlying till, etc. Some well log information (e.g., casing length, screen location, and/or overlying till thickness) was available for 200 of 242 wells examined individually. All of these wells had source aquifer information (shallow bedrock, unconsolidated sand and gravel, or both). Chloride trend data were plotted as a function of several of these parameters.

Geospatial data, such as till thickness, depth to aquifer, soil leachability, location of major roads, etc., were downloaded from the Illinois Natural Resources Geospatial Data Clearinghouse (http://www.isgs.uiuc.edu/nsdihome/ISGSindex.html). The geological data are from Keefer (1995a, 1995b) and Berg and Kempton (1988). Chloride concentrations and trend data were plotted on these maps to observe potential relationships. Relationships were tested using ANOVA on ranks and rank sum tests. Chloride concentration data from between 1998 and 2004 were used. For wells that did not have samples collected during this period, Cl^- concentrations were

$_1$ values for the year 2000.

Data and Statistical Limitations

There are a number of limitations in evaluating these data that need to be noted. First, these are generally not random samples, but are instead primarily either public supply wells required to be sampled or private wells sampled at the discretion of the well owner. Second, there is variability in location with time due to changes in population patterns and decisions regarding water sources. For example, prior to 1970, about 30 percent of samples in the Chicago region came from wells in Cook County, but that number has been dropping as users in Cook County increasingly use Lake Michigan water instead of groundwater for water supply. Between 1990 and 2005, only 8 percent of the samples came from Cook County. In contrast, the number of samples from Kane and McHenry Counties has been increasing as residential density has increased; the percentage of samples from these two counties combined increased from about 25 to 45 percent between 1950 and 2005. Thus, when looking at the bulk data without regard to location, earlier samples are more heavily weighted to locations close to Chicago, and later samples are more heavily weighted to locations relatively far from the city.

Results and Discussion

Box-and-whisker plots for the major ions (alkalinity, Ca, Mg, Na, Cl^-, and SO_4^{2-}) and

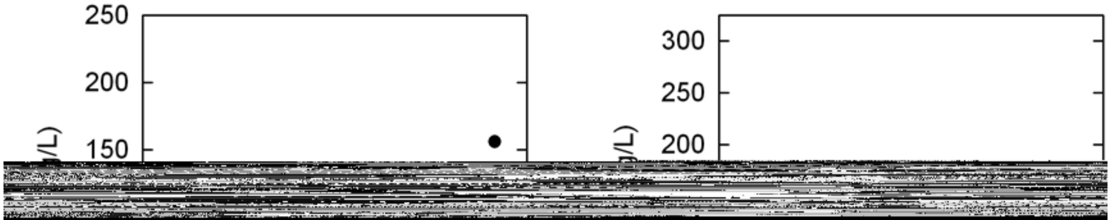
and IQR values are reported in Tables 1–9, and a complete report of the basic descriptive statistics is found in Appendix A. When all data in the six-county area are combined, the most obvious trend in increased concentrations is for Cl^-. The median Cl^-

Concentration trends were generally the same for both the shallower and deeper wells. There were increasing trends for Cl^- concentrations for both shallower and deeper wells, with the median concentration increasing from 8 to 36 mg/L in the shallower wells and from 5 to 17 mg/L in the deeper wells from prior to 1950 to 1990-2005. The IQR values also increased over time. Sodium increased in both the shallower and deeper wells at similar rates since the 1950s, while the other cations (Ca and Mg) have remained fairly steady in both depth ranges since the 1950s. The increase in alkalinity has been greater in the shallower wells, while SO_4^{2-} has decreased at similar rates in both depth ranges.

It needs to be noted again that there are limitations to examining the entire data set due to spatial differences and temporal changes in sample locations. For example, there are relatively few samples from wells < 100 feet in DuPage County (only 7 percent of the total). If there were more samples from DuPage County, where trends are highest, we would anticipate greater trends in the entire data set than is shown. Also, there has been an increasing percentage of samples from Kane, McHenry, and Will Counties with time. Prior to 1970, about 43 percent of samples from wells < 100 feet came from Cook, Lake, and DuPage Counties, while only about 25 percent came from these counties in 1990-2005.

There were substantial differences for individual counties based on well depth (Appendix A), although some counties, such as Cook and DuPage, had very few samples from shallow wells (< 100 feet) during some time periods. Trends observed for the complete data sets for a particular county were generally observed for both shallow and deep (100–200 feet) well sets. In DuPage County, increases in all parameters were observed for both shallow and deep wells, and trends

- concentrations
began to increase. Positive vbeD1-7(vu4(20tP)20ta(4g-24(e TT1C(n)6(TJu4(20t)-24(r)-)n)y TT1()43(3)40(.v)n)0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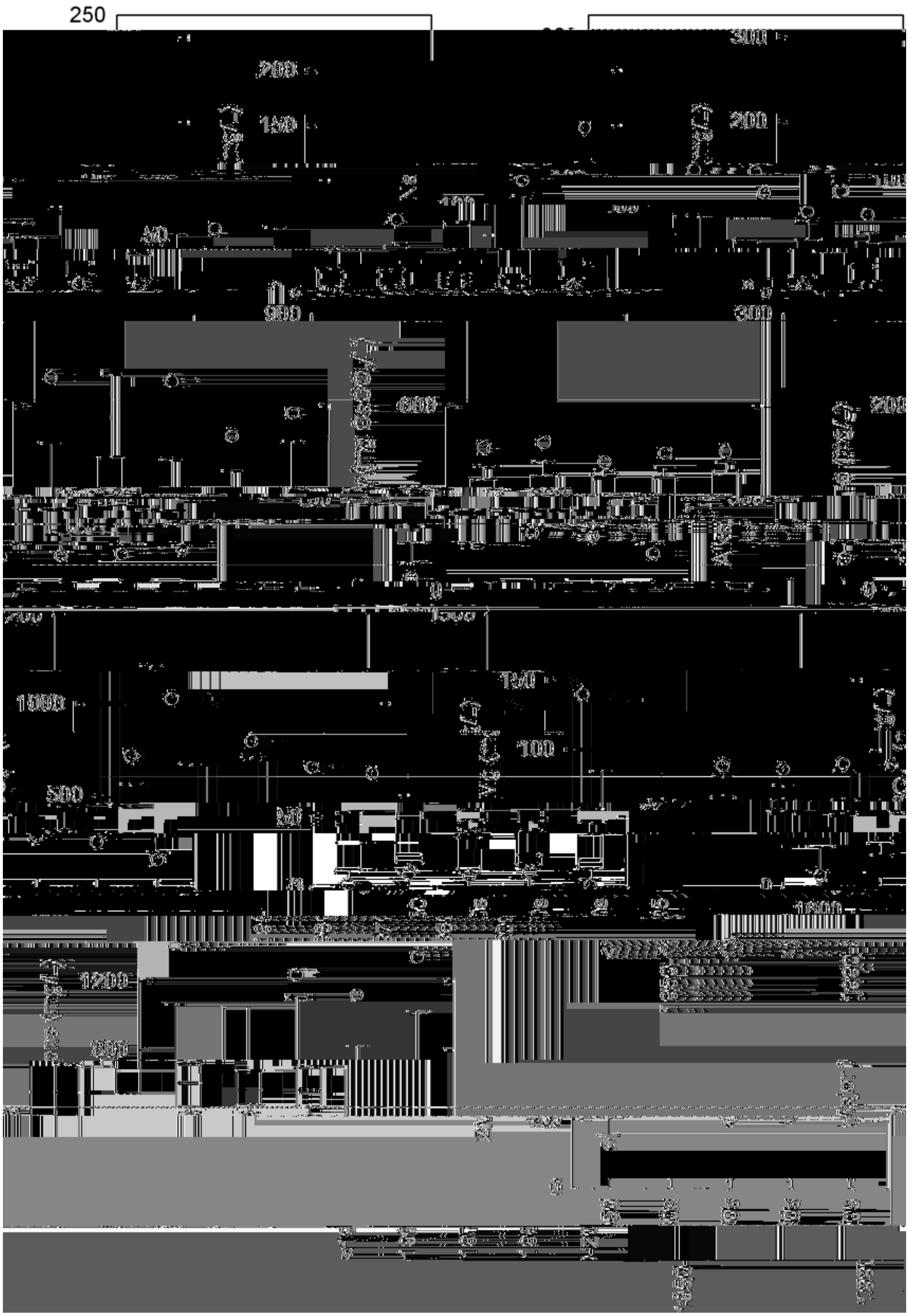

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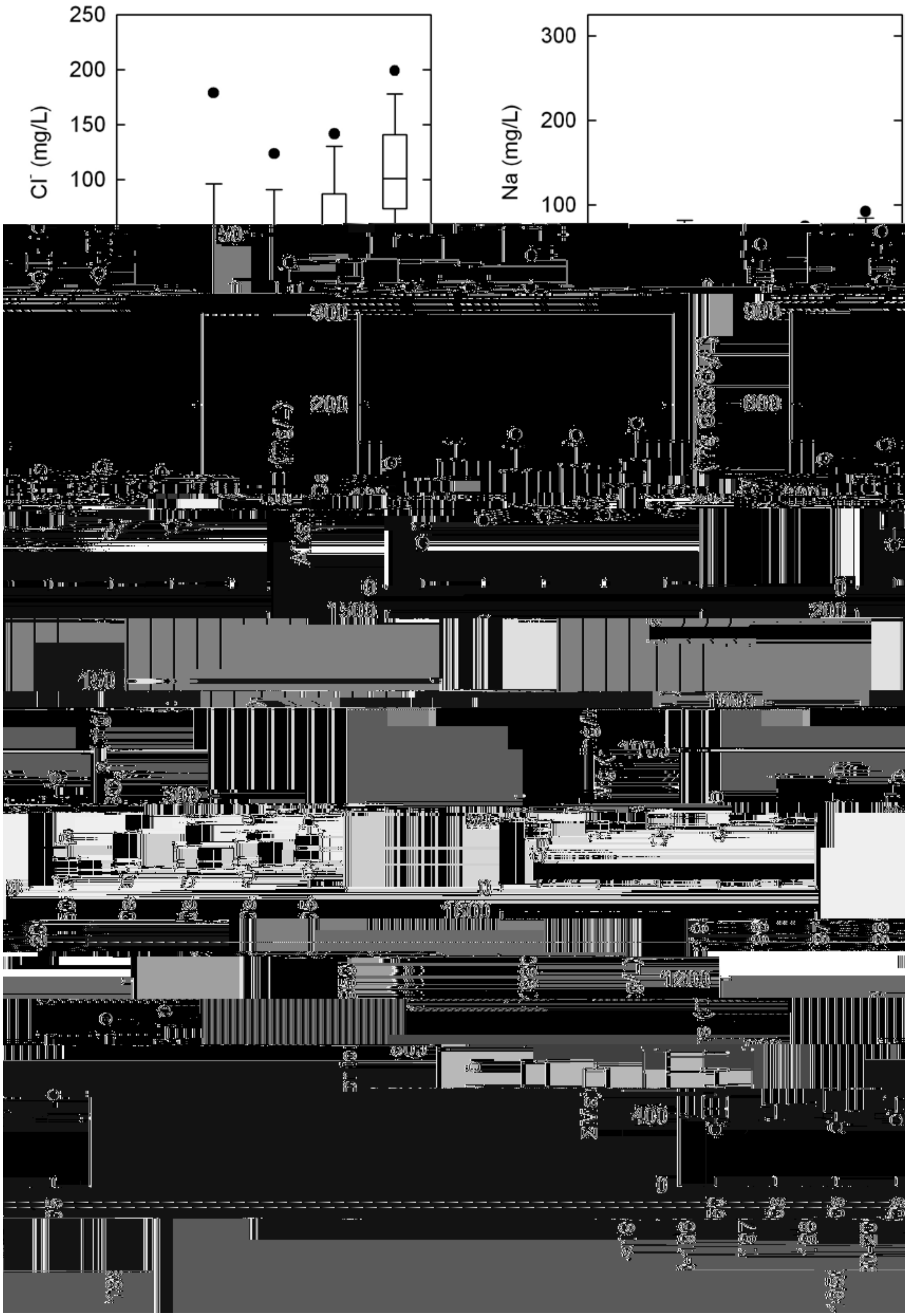

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200
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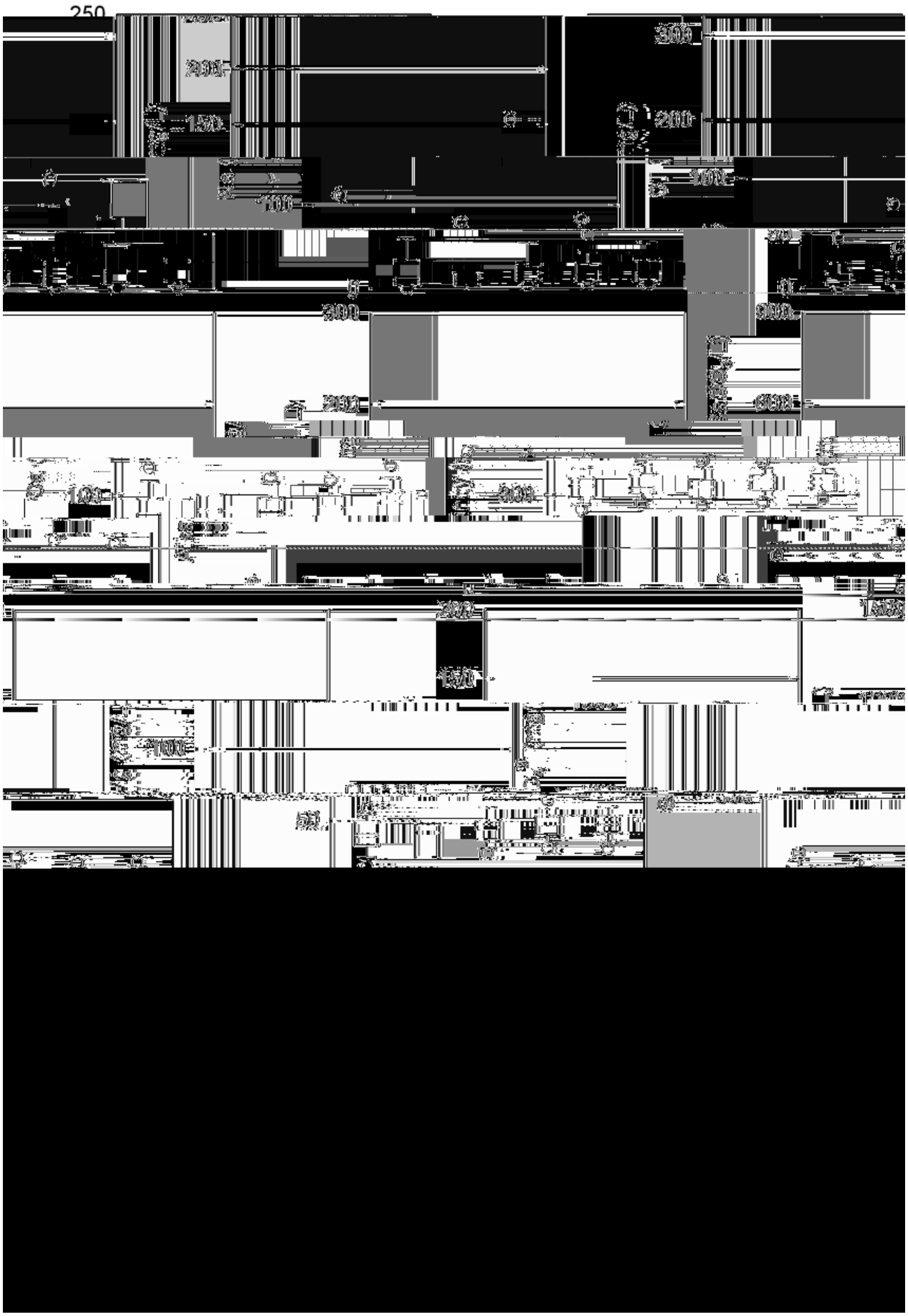
Cl⁻ (mg/L)
300
200
100
Na (mg/L)

Xefpi 82 Qihmer erh MUV gsrgirxvexmsrw jsv xli qensv mswrw erh ÛQensv mswrw ew e jyrgxmsr sj xmqi for Kane County wells. Concentrations in mg/L; n is the number of samples.

Years	*n*	*Median*	*IQR*	*n*	*Median*	*IQR*
		Cl^-			*Na*	
<1950	105	7	10	62	11	30
1950-1960s	67	7	11	5	13	11
1970s	155	11	21	121	20	18
1980s	134	17	35	135	17	21
1990-2005	160	26	58	161	19	24
		Alkalinity ($CaCO_3$)			*Ca*	
<1950	104	330	65	64	79	36
1950-1960s	67	324	64	8	84	24
1970s	155	328	56	125	83	30
1980s	131	342	47	132	88	27
1990-2005	161	343	49	161	92	28
		SO_4^{2-}			*Mg*	
<1950	71	85	103	65	39	18
1950-1960s	12	65	82	6	41	21
1970s	122	68	53	125	45	14
1980s	129	75	49	132	47	14
1990-2005	161	62	78	161	48	12
		Major ions				
<1950	55	424	157			
1950-1960s	5	411	10			



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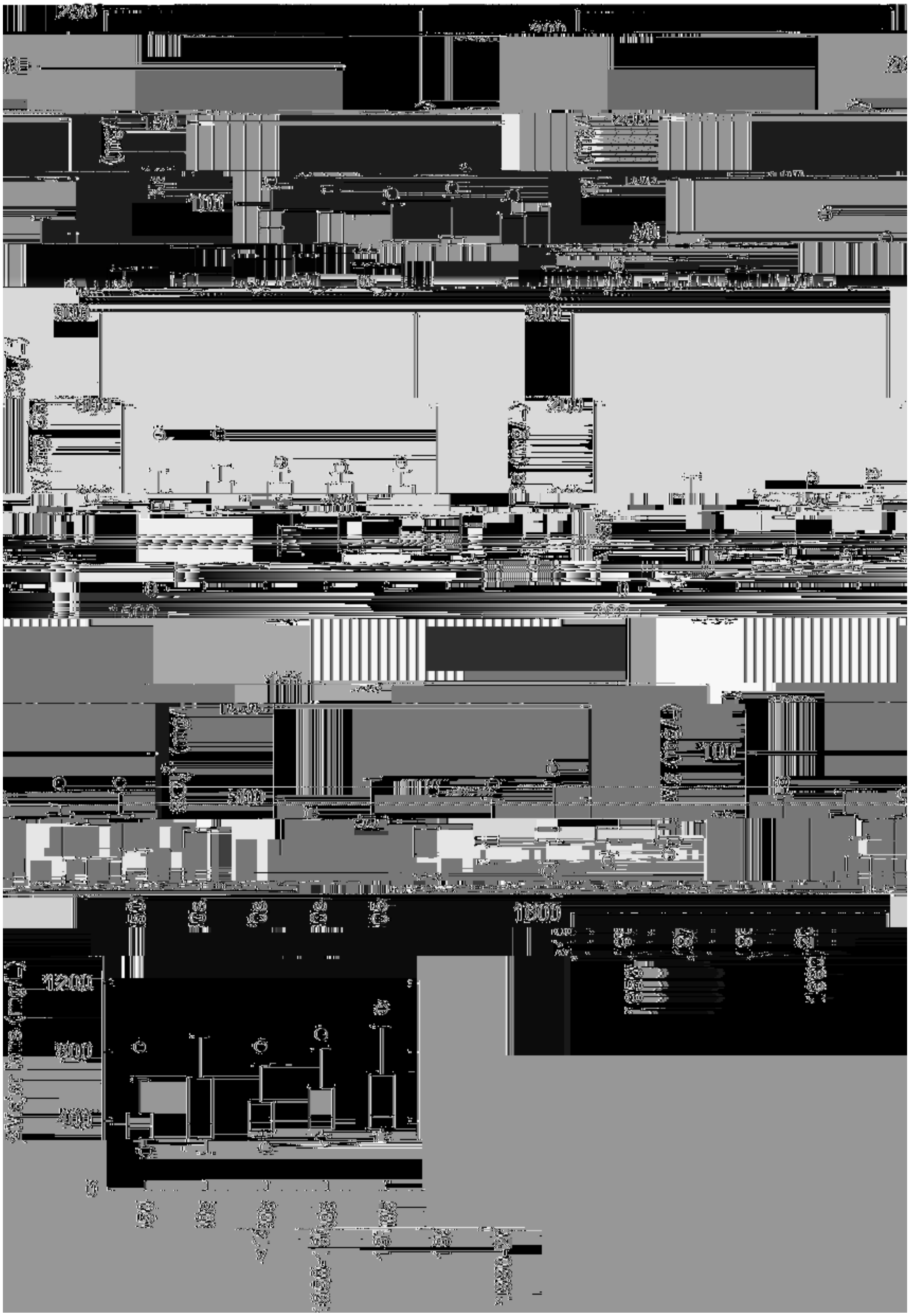

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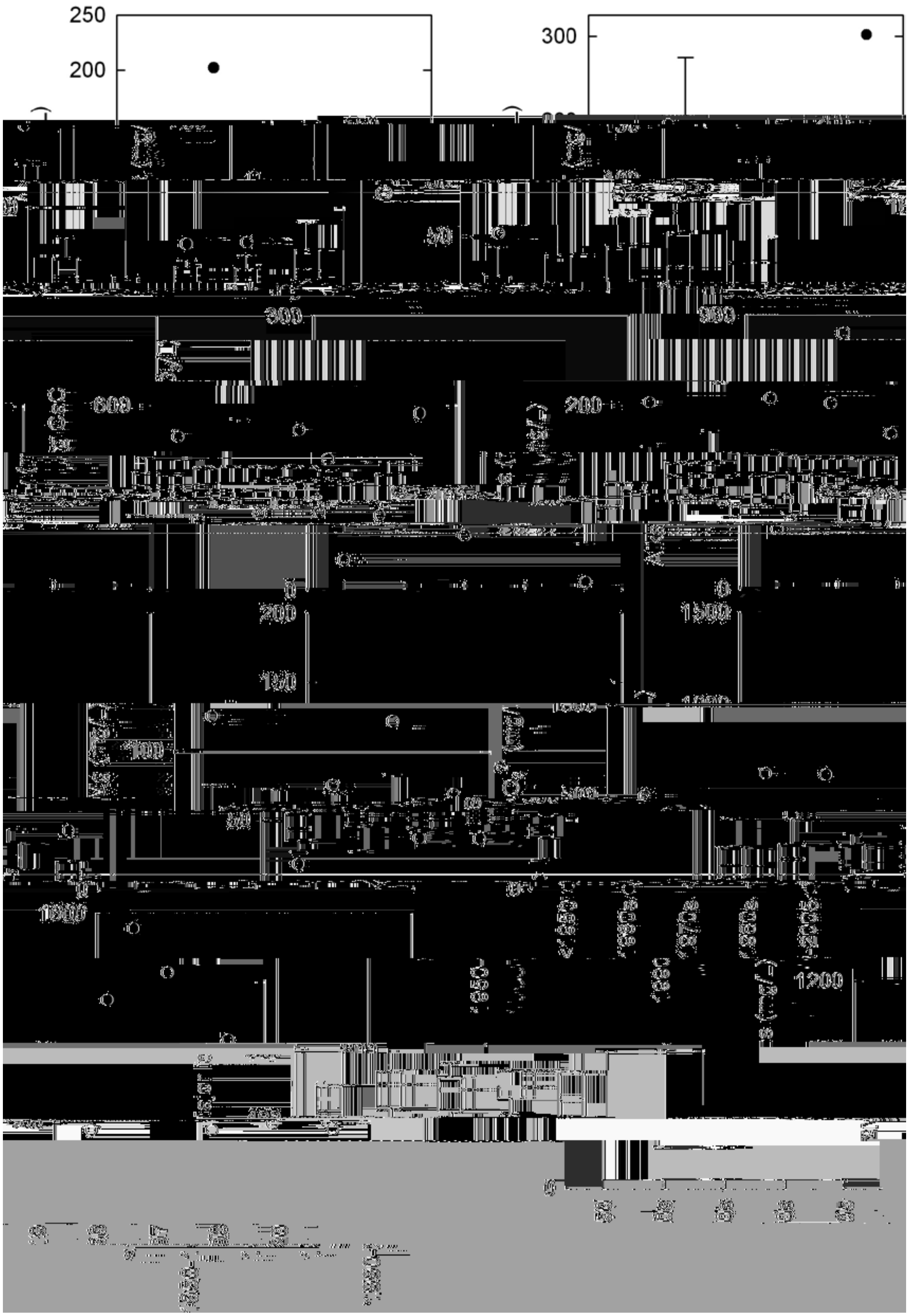
Xefpi ;2 Qihmer erh MUV gsrgirxvexmsrw jsv xli qensv msrw erh ÛQensv msrw ew e jyrgxmsr sj xmqi for Will County wells. Concentrations in mg/L; n is the number of samples.

Years	*n*



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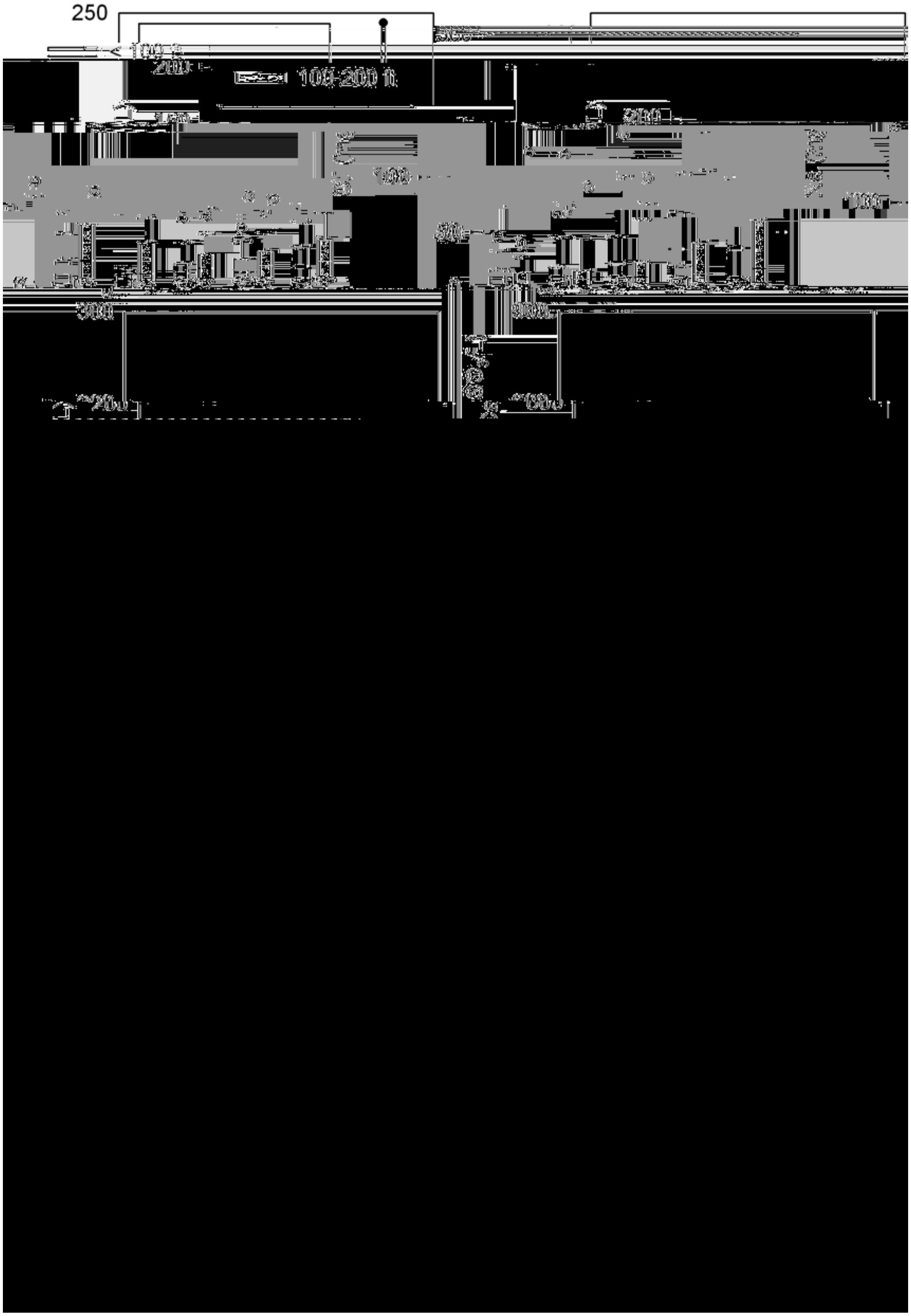
Years	*n*	*Median*	*IQR*	*n*	*Median*	*IQR*
		Cl^-			*Na*	
<1950	236	8	13	128	13	27
1950-1960s	152	9	14	13	7	12
1970s	223	22	37	117	18	18
1980s	127	35	46	127	19	22
1990-2005	110	36	95	111	26	36

*Alkali*36



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Xefpi 542 Qihmer erh MUV gsrgirxvexmsrw jsv xli qemsv mswrw erh ÛQemsv mswrw ew e jyrgxmsr sj xmqi for all public supply wells in the six- county region. Concentrations in mg/L; n is the number of samples.

Years	*n*	*Median*	*IQR*	*n*	*Median*	*IQR*
		Cl^-			*Na*	
<1950	168	5	7	139	15	27
1950-1960s	256	7	9	56	15	27
1970s	677	10	24	570	21	24
1980s	684	17	43	687	26	28
1990-2005	377	29	65	381	31	39
		Alkalinity ($CaCO_3$)			*Ca*	
<1950	157	312	89	144	82	33
1950-1960s	257	316	77	62	88	50
1970s	679	312	76	572	87	37
1980s	682	320	81	683	87	38
1990-2005	373	330	80	381	90	42
		SO_4^{2-}			*Mg*	
<1950	155	109	150	144	42	14
1950-1960s	72	123	170	62	45	15
1970s	576	100	122	573	48	16
1980s	669	102	112	682	49	17
1990-2005	378	79	93	381	48	14
		Major ions				
<1950	126	432	191			
1950-1960s	58	464	240			
1970s	565	477	213			
1980s	664	488	218			
1990-2005	371	483	240			

Graphical representations of Cl^- concentrations as a function of time are presented in

increases in Cl^- concentrations for the majority of the wells (55 percent), based on the Kendall's tau statistic (Table 13). Lake County had the lowest percentage of wells with increasing Cl^- trends (39 percent) and Kane County had the highest (71 percent). Negative trends were found wells, with 37 percent having values greater than 1 mg/L/yr and 12 percent with values greater than 4 mg/L/yr. DuPage, Kane, and McHenry Counties had the highest percentages of wells with positive slope values (62–70 percent), and Lake County had the lowest (39 percent). DuPage County had by far the largest percentage of wells with slope values greater than 1 and 4 mg/L/

County. It should be noted that percentages reported in Table 13 apply only to the data set and cannot be used to draw conclusions for the entire population of wells in each county. Slope values

- trends are reported in Appendix B for each public supply well

o-3(s)5(t(h)-1(a11li)30(f (62(1)89(1)46(3 o)30(f2h)104)31(2t)56(o)30(f t)-11(h)9(ewI)25(e)19(l)-4(l)2(s h)-1(a

comparing wells with relatively thin till deposits (< 100 feet), which had a median slope value of 0.98 mg/L/yr, with thick till deposits (> 100 feet; median 0.20 mg/L/yr).

Xefpi 582 Tivgirxeki sj { ippw lezmrk wmkrmĂgerx tswmxmzi erh rikexmzi xvirhw erh wpsti zepyiw jsv major ions (other than Cl- - erh ÛQensv msrw jsv mrhmzmhyep { ippw {mxl qypxmtpi weq tpiw2 WmkrmĂgerx xvirhw hixivqmrih f} Oirhepp xey wxexmwxmg0 wmkrmĂgerx wpstiw hixivqmrih f} x wxexmwxmg2

Parameter	*County*	*N*	*Positive trend*	*Negative trend*	*Positive slope*	*Negative slope*
Alkalinity	Cook	29	0.14	0.10	0.24	0.14
	DuPage	43	0.40	0.07	0.42	0.07
	Kane	41	0.37	0.05	0.34	0.02
	Lake	49	0.14	0.04	0.18	0.06
	McHenry	51	0.27	0.06	0.31	0.04
	Will	26	0.15	0.15	0.12	0.12
	Total	239	0.26	0.07	0.28	0.07
Ca	Cook	29	0.38	0.07	0.31	0.07
	DuPage	42	0.45	0.00	0.52	0.00
	Kane	39	0.26	0.03	0.31	0.05
	Lake	48	0.17	0.10	0.25	0.13
	McHenry	48	0.21	0.06	0.25	0.06
	Will	24	0.25	0.00	0.25	0.13
	Total	230	0.28	0.05	0.32	0.07
Mg	Cook	29	0.38	0.14	0.38	0.17
	DuPage	42	0.33	0.10	0.40	0.10

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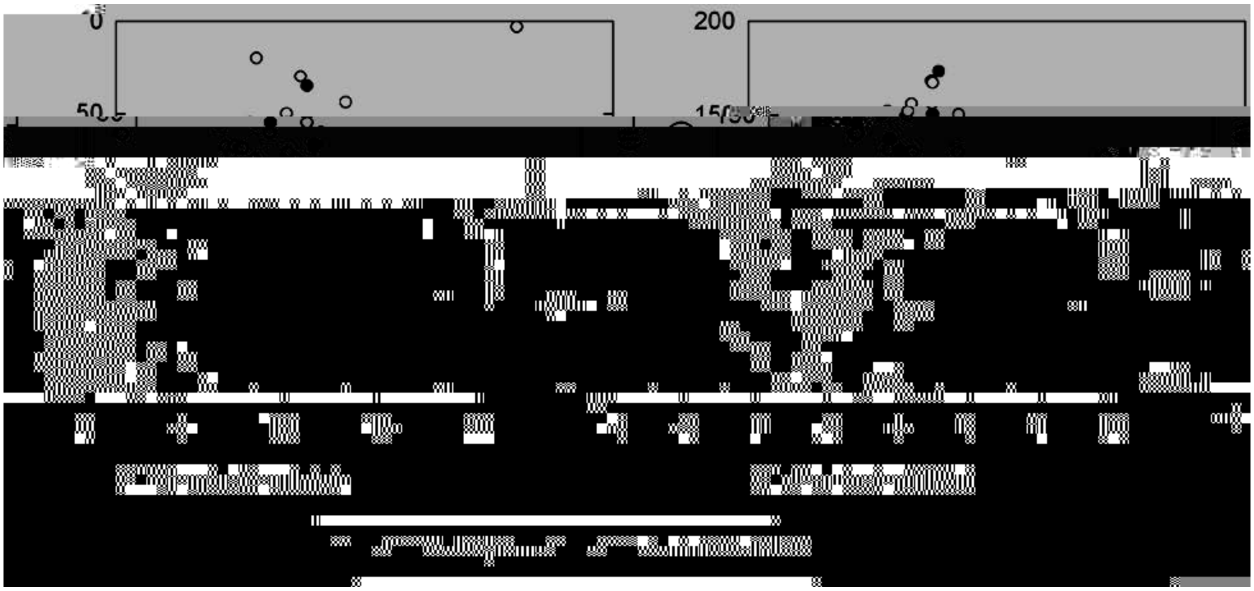


Clearly, Cl^- concentrations have been increasing in shallow groundwater in the Chicago area starting around 1960. In terms of volume, road salt is the largest potential source of Cl^- in the Chicago region, and its large volume application began in 1960. Because of the large numbers of

annually. In an average winter, the Illinois Department of Transportation uses about 143,000 tons of road salt in the six-county region, with counties and municipalities applying approximately the same amount (Keseley, 2006). There are more than 55,000 lane miles in the Chicago region, and most wells are located in the vicinity of major roads. Of the 242 individual wells examined, 209 were located within one mile of an interstate highway or major arterial road. There were no

$^-$ or for Cl^- concentrations in 1998-2004 between those wells close to (< 1 mile) versus far away (> 1 mile) from major roads. Median rate and concentration values, however, were considerably lower for wells far away from roads in Lake, McHenry, and Will Counties. For example, the median Cl^-

in Will County located far away from major roads was 25.0 mg/L, compared to 46.9 mg/L in 21 wells close to major roads. Median Cl^- concentrations were higher in wells far away from roads in Cook County, and approximately the same in Kane County. All wells in DuPage County were within one mile of major roads.

Septic systems are another potentially important source of Cl^- to shallow groundwater. Approximately 95 percent of households in the Chicago region were connected to public sewers in 1990, ranging from 57 percent in McHenry County to 99 percent in Cook County; Lake County had the largest number of septic systems (28,855), and Kane County had the fewest (17,505) (U.S. Census Bureau, 1993). Assuming each household with a septic system has a water softener and uses the typical manufacturer's recommended amount of rock salt (NaCl, 5 pounds/

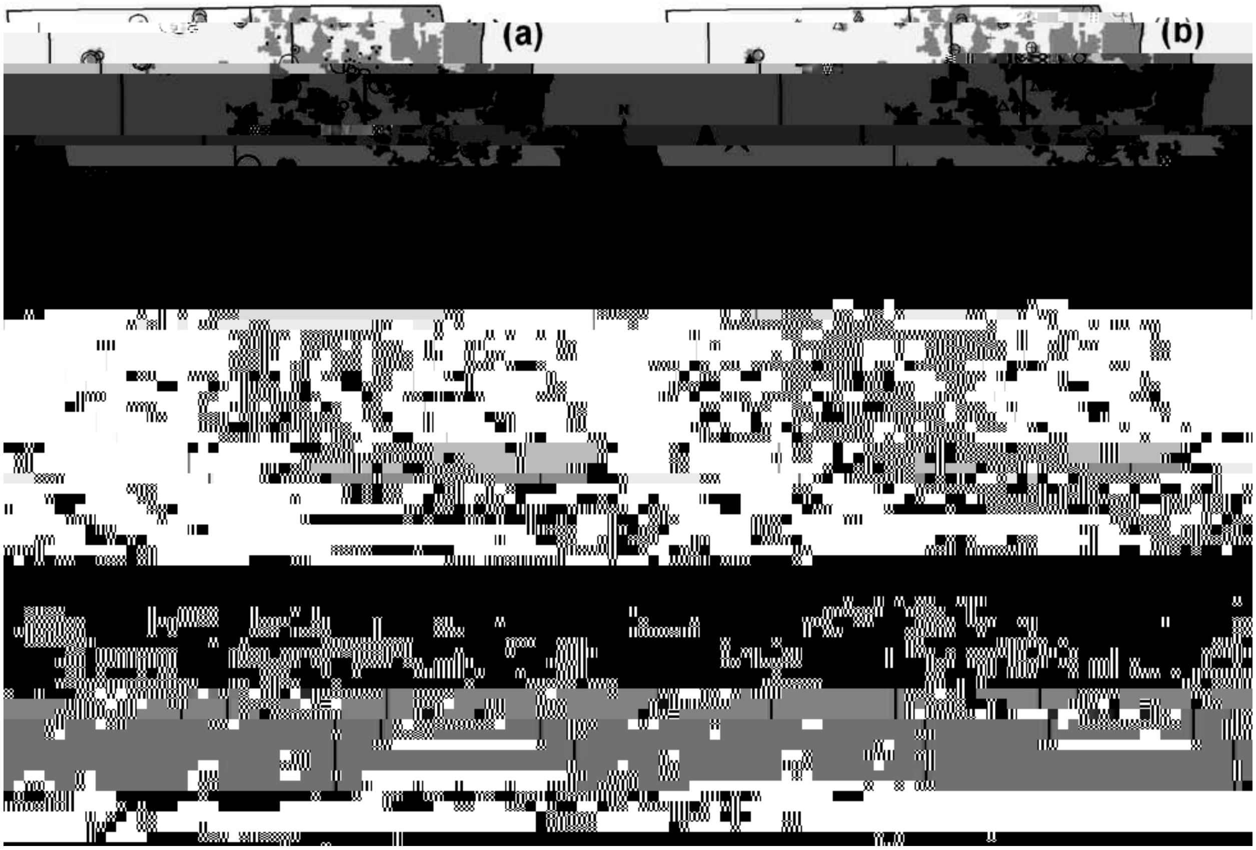
day), a maximum of about 140,000 tons of rock salt are potentially available to enter the subsurface environment, less than half of the amount of road salt applied. In practice, water in shallow

Other potential Cl^-

leachates often have elevated levels of Cl^-, but are point, or localized, sources covering rela-

$^-$ to ground-

water; concentrations in shallow groundwater in predominantly agricultural areas of Illinois rarely exceed 20 mg/L. Leakage from storm water and sewage pipes is a diminishing issue, as construction of new pipes and tunnels has been increasing. If leaky sewage pipes were a major source of Cl^- to groundwater, then one would expect to have seen elevated concentrations in Cook and Lake Counties in the past.



are curbed (M. Cotten, DuPage County Div. of Transportation, personal communication, 2007). Since they developed earlier and are more urban, Cook and Lake Counties probably have higher curbing percentages than DuPage County. The lesser amount of curbing in the western and southern collar counties thus could allow more contaminated runoff to recharge the shallow aquifers. To further test this hypothesis, more detailed data on road curbing would be necessary; such data are not currently available in GIS-ready formats.

An alternative explanation for the greater increase in Cl^- concentrations in the western and southern collar counties is that unconsolidated sand-and-gravel deposits are generally thicker and closer to the surface in these areas, especially in McHenry and Kane Counties (Hansel and Johnson, 1996). Areas where aquifer material (usually sand and gravel) is within 50 feet of the surface in northeastern Illinois are plotted in Figure 14a. Wells with the greatest Cl^- concentrations and rates of change are often found in areas where aquifers are within 50 feet of the surface,

with shallow aquifers versus those without. In fact, when data from all four collar counties are

greater Cl^- concentrations and rates of change in and many wells with elevated Cl^- concentrations, and (2) Kane County, which has shallow aquifers throughout most of the county, but many sampled wells with low Cl^- concentrations. It thus appears that the presence or absence of shallow aquifer material is not the sole control on Cl^-

the first two periods are from the databases, the last is from Kelly (2005).

from 1945-1964 and 65 percent of samples from 1980-1984 collected in the eastern, developed third of Kane County were < 15 mg/L (maximum 34 and 69 mg/L, respectively).

Conclusions

Urbanization can seriously degrade groundwater quality of shallow aquifers, particularly in snowy climes where deicers are heavily used. Patterns and trends in Cl^- concentrations are useful indicators of shallow groundwater quality in such settings. Results of this study showed that shallow groundwater quality in the Chicago metropolitan area has degraded, as indicated by increasing levels of dissolved solids, primarily Cl^-. Shallow groundwater quality has degraded at least since the 1960s, especially in the collar counties (DuPage, Kane, McHenry, and Will), where Cl^- concentrations increased in the majority of public supply wells during that time. About 43 percent of sampled wells in these four counties have rate increases greater than 1 mg/L/yr and 15 percent have increases greater than 4 mg/L/yr. Chloride concentrations in approximately 24 percent of samples collected from public supply wells in the Chicago area in the 1990s were greater than 100 mg/L (35 percent in the collar counties). In comparison, median Cl^- concentrations were less than 10 mg/L prior to 1960. Although there is the potential for septic discharge to cause increases in Cl^- concentrations in some parts of the study area, road salt appears to be the dominant source of Cl^- to the shallow aquifers.

the result of road salt runoff. Increases in Ca and Mg may be attributable indirectly to road salt runoff, as Na entering the subsurface would exchange with Ca and Mg in soils and sediments, releasing these cations into solution. Anion exchange is generally not an important process, however. Trends in alkalinity and SO_4^{2-} are more likely due to other urbanization activities, such as exposure of soils and sediments due to excavation. The exposure of chemically reduced compounds such as organic matter and pyrite (FeS_2) to air can cause these compounds to be oxidized, resulting in increased concentrations of HCO_3^- and SO_4^{2-}. Decreasing SO_4^{2-} concentrations in some areas (primarily Cook and Will Counties) may be because plumes of high-SO_4^{2-} water introduced from earlier excavation activities have migrated through the shallow aquifers. Decreasing SO_4^{2-} concentrations also might have resulted from depletion of unoxidized pyrite in the exposed source materials. More detailed analysis would be necessary to determine why SO_4^{2-} appears to be decreasing in some areas.

Most areas in this region have probably not yet seen maximum concentrations of most major ions. With average groundwater travel times of about 0.6 to 3 ft/yr, the maximum distance traveled since 1960 for the bulk of recharge from the surface is less than 150 feet. Clearly there

concentrations in wells deeper than 150 feet. The pumping of large volumes of water from wells in the Chicago region accounts for some of the more rapid travel times. However, it seems likely that, even if all sources of pollution were stopped immediately, peak concentrations of surface-derived dissolved contaminants will be considerably higher in the future than they are now (e.g., Howard et al., 1993). A more detailed evaluation of the Cl^- data may help in estimating recharge rates to shallow aquifers.

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geology and human activities. The greatest increases in Cl^- concentrations generally occur in

groundwater quality in shallow aquifers in rural parts of these counties is generally good (Kelly, 2005). It thus appears that land use, primarily in the form of road salting, is the major factor affecting Cl^- concentrations in the collar counties. In Cook and Lake Counties, however, lower Cl^- concentrations and rates of change cannot be attributed to lower rates of road salt application.

Acknowledgments

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Appendix A

Table A-3. Summary statistics for DuPage County < 100 ft.

Parameter	Years	N	Mean	StdDev	Range	Max	Min	Med	25%	75%	IQR
Alkalinity	<1950	14	311	39	134	352	218	324	294	340	46
	1950-1960s	20	330	44	180	404	224	334	314	358	44
	1970s	16	349	36	130	398	268	356	332	372	40
	1980-2005	14	391	23	86	430	344	392	374	403	29
Ca	<1950	10	97	27	81	140	59	92	78	119	41
	1950-1960s	1	164	--	--	164	164	164	--	--	--
	1970s	12	135	19	69	165	96	135	123	150	27
	1980-2005	14	144	29	91	195	104	149	110	167	57
Cl^-	<1950	14	11	11	37	38	1.0	5.5	3.0	18	15
	1950-1960s	19	18	19	59	62	3.0	13	5.3	20	14
	1970s	16	45	47	204	210	6.0	30	22	46	24
	1980-2005	14	60	33	113	134	21	59	26	77	51
Mg	<1950	12	40	15	49	59	10	42	30	50	21
	1950-1960s	1	58	--	--	58	58	58	--	--	--
	1970s	12	67	8.5	23	81	58	63	60	76	16
	1980-2005	14	71	12	36	94	58	69	61	79	18
Na	<1950	7	13	12	32	32	0	8.9	3.0	22	19
	1950-1960s	1	26	--	--	26	26	26	--	--	--
	1970s	13	24	25	98	104	5.8	18	17	20	3.8
	1980-2005	14	28	10	36	47	11	27	25	32	7.0
SO_4^{2-}	<1950	11	101	76	260	271	11	86	46	148	102
	1950-1960s	4	174	93	180	270	90	167	94	253	159
	1970s	13	211	73	231	310	79	207	177	278	102
	1980-2005	14	247	90	231	362	131	292	141	308	167
ΣMajor ions	<1950	7	467	123	354	685	331	418	382	536	153
	1950-1960s	1	776	--	--	775	775	775	--	--	--
	1970s	11	722	114	348	915	566	668	628	805	176
	1980-2005	14	783	163	453	1003	551	804	598	910	312

Table A-4. Summary statistics for DuPage County wells 100-200 ft.

Parameter	Years	N	Mean	StdDev	Range	Max	Min	Med	25%	75%	IQR
Alkalinity	<1950	62	293	75	404	452	48	300	270	334	64
	1950-60s	111	325	89	656	692	36	316	292	350	58
	1970s	191	305	46	302	464	162	308	276	330	54
	1980s	114	312	47	387	387	0	320	294	337	43
	1990-2005	57	325	41	243	480	237	331	286	350	65
Ca	<1950	57	85	35	222	247	25	82	64	101	37
	1950-60s	14	102	29	90	156	66	98	86	116	31
	1970s	156	103	37	175	223	48	96	73	123	50
	1980s	110	110	30	159	212	53	111	88	128	40
	1990-2005	57	129	26	117	197	80	126	111	141	30
Cl^-	<1950	61	6.0	10	69	70	1.0	3.0	2.0	6.0	4.0
	1950-60s	110	34	59	314	315	1.0	10	5.0	29	24
	1970s	190	39	49	450	450	0	25	7.0	53	46
	1980s	114	64	53	331	331	0	58	21	89	68
	1990-2005	57	111	48	210	240	30	101	74	142	68
Mg	<1950	58	45	19	144	165	21	43	38	49	12
	1950-60s	15	51	14	46	81	35	48	40	58	18
	1970s	157	54	16	85	113	28	52	43	61	19
	1980s	110	56	12	71	99	28	57	45	64	19
	1990-2005	57	61	10	48	83	35	60	57	67	10
Na	<1950	43	21	22	132	132	0	17	9.0	24	15
	1950-60s	14	33	31	87	87	0	23	4.0	66	62
	1970s	163	31	21	198	202	4.1	27	19	37	18
	1980s	115	39	19	104	110	6.2	33	25	44	19
	1990-2005	57	59	19	93	111	18	57	49	68	20
SO_4^{2-}	<1950	53	146	196	1451	1457	6.0	109	72	160	89
	1950-60s	27	379	448	1450	1482	32	155	119	366	247
	1970s	163	179	126	715	716	1.4	142	104	223	119
	1980s	111	186	89	512	512	0	158	122	245	124
	1990-2005	57	224	90	378	446	68	227	149	298	150
ΣMajor ions	<1950	43	489	255	1720	2041	321	449	400	495	95
	1950-60s	12	581	150	520	868	348	557	473	659	187
	1970s	154	589	216	1127	1429	301	549	430	680	250
	1980s	107	643	176	1039	1151	112	651	499	758	260
	1990-2005	57	779	137	645	1141	496	782	686	860	174

Table A-7. Summary statistics for Lake County wells < 100 ft.

Parameter	Years	N	Mean	StdDev	Range	Max	Min	Med	25%	75%	IQR		
Alkalinity	<1950	26	290	161	694	796	102	233	186	366	180		
	1950-1960s	30	348	163	843	999	156	348	232	384	152		
	1970s	33	331	88	362	452	90	364	301	384	83		
	1980s	26	314	97	363	467	104	325	248	384	136		
	1990-2005	19	349	78	367	466	99	368	326	383	57		
Ca	<1950	24	56	28	90	98	7.7	61	35	80	45		
	1950-1960s	1	49	--	--	49	49	49	--	--	--		
	1970s	17	90	14	42	110	68	91	76	102	26		
	1980s	26	86	42	218	255	37	80	71	98	27		
	1990-2005	19	86	32	111	147	36	80	66	117	51		
Cl^-	<1950	26	15	11	48	49	1.0	15	6.0	18	12		
	1950-1960s	30	27	25	77	79	2.0	16	6.0	49	43		
	1970s	33	38	44	139	140	1.0	13	6.0	61	55		
	1980s	26	298	1201	6147	6150	3.0	28	12	48	36		
	1990-2005	19	61	94	329	330	1.4	4.1	2.2	106	104		
Mg	<1950	25	44	31	100	106	5.6	41	18	75	57		
	1950-1960s	1	18	--	--	18	18	18	--	--	--		
	1970s	17	60	14	53	91	38	54	53	64	11		
	1980s	26	52	19	65	85	20	53	37	60	23		
	1990-2005	19	56	18	75	112	37	48	46	63	17		
Na	<1950	23	64	45	150	153	3.0	61	20	94	73		
	1950-1960s	1	7.0	--	--	7.0	7.0	7.0	--	--	--		
	1970s	21	34	29	115	117	2.1	27	8.0	52	44		
	1980s	26	201	735	3784	3788	4.1	50	14	70	57		
	1990-2005	19	39	42	158	162	4.1	34	8.2	48	40		
SO_4^{2-}	<1950	23	14	0.48	128	0.48	ref	135.54	388.7		0.48	128	0.4

Table A-9. Summary statistics for McHenry County wells < 100 ft.

Parameter	Years	N	Mean	StdDev	Range	Max	Min	Med	25%	75%	IQR
Alkalinity	<1950	41	300	37	172	410	238	302	269	325	56
	1950-1960s	32	323	40	150	402	252	332	292	354	62
	1970s	113	311	63	312	454	142	316	268	361	93
	1980s	48	339	47	228	450	222	339	313	378	65
	1990-2005	22	356	23	85	396	311	363	346	373	27
Ca	<1950	36	98	130	810	848	38	78	64	91	27
	1950-1960s	3	74	14	26	90	63	70	65	85	20
	1970s	37	98	15	68	140	72	97	88	111	24
	1980s	44	100	21	99	135	36	100	86	116	30
	1990-2005	22	103	13	52	130	78	101	95	110	15

[redacted]

Table A-12. Summary statistics for Will County wells 100-200 ft.

Parameter	Years	N	Mean	StdDev	Range	Max	Min	Med	25%	75%	IQR
Alkalinity	<1950	84	351	98	770	862	92	348	296	386	90
	1950-60s	65	409	164	791	999	208	362	315	424	109
	1970s	103	346	110	776	916	140	323	295	360	66
	1980s	56	337	45	197	468	271	332	300	370	70
	1990-2005	47	347	99	528	694	166	329	298	369	72
Ca	<1950	53	104	62	414	420	6.3	93	76	116	40
	1950-60s	8	122	28	86	168	82	123	100	138	38
	1970s	79	111	38	199	244	45	103	91	123	32
	1980s	56	120	34	183	232	49	114	103	130	27
	1990-2005	47	99	52	281	283	2.3	100	68	122	54
Cl^-	<1950	87	17	37	204	204	0	4.0	2.0	9.0	7.0
	1950-60s	64	46	111	740	740	0	7.0	3.0	33	30
	1970s	103	28	36	190	190	0	10	5.0	43	38
	1980s	56	51	110	819	820	1.0	24	7.3	64	57
	1990-2005	47	41	45	176	177	0.6	21	3.1	82	78
Mg	<1950	52	49	29	148	150	1.9	45	37	51	14
	1950-60s	7	55	11	30	75	45	53	47	60	13
	1970s	79	55	22	131	156	25	50	44	58	14
	1980s	56	60	25	122	155	33	53	48	59	11
	1990-2005	47	44	19	102	107	4.6	45	34	55	21
Na	<1950	33	42	69	373	373	0	21	11	42	30
	1950-60s	6	83	177	441	444	3.0	12	6.0	20	14
	1970s	80	26	28	240	245	5.0	22	12	31	19
	1980s	56	32	54	408	411	3.2	22	13	35	22
	1990-2005	47	56	83	333	339	6.2	28	15	48	33

Appendix B

Table B-1. Public supply wells with significant slope values in Cook County. Slope (β_1) and r^2 values determined by linear regression for post-1960 samples only. Well # is local well number, and EPAID is Illinois EPA well code. N is number of samples and latest Cl^- is concentration at final available sample date.

Public Supply	Well #	EPAID	Depth (ft)	β_1 (mg/L/yr)	r^2	N	initial date	final date	Latest Cl^- (mg/L)
Barrington Woods	2	00125	140	-0.243	0.972	4	1958	1982	3.9
Bartlett	1								

Table B-2. Public supply wells with significant slope values in DuPage County. Slope (β_1) and r^2 values determined by linear regression for post-1960 samples only. Well # is local well number, and EPAID is Illinois EPA well code. N is number of samples and latest Cl^- is concentration at final available sample date.

Public Supply	Well #	EPAID	Depth (ft)	β_1 (mg/L/yr)	r^2	N	initial date	final date	Latest Cl^- (mg/L)

Table B-3. Public supply wells with significant slope values in Kane County. Slope (β_1) and r^2 values determined by linear regression for post-1960 samples only. Well # is local well number, and EPAID is Illinois EPA well code. N is number of samples and latest Cl^- is concentration at final available sample date.

Public Supply	Well #	EPAID	Depth (ft)	β_1 (mg/L/yr)	r^2	N	initial date	final date	Latest Cl^- (mg/L)
Aurora	101	00344	116	1.407	0.758	4	1970	1999	50.1
Batavia	6	00732	157	0.893	0.989	3	1988	1999	20.4
Batavia	7	00733	118	0.709	0.967	3	1991	1999	13.4
Carpentersville	3	20028	72	2.334	0.756	8	1971	1986	44
Carpentersville	5	20029	183	1.42	0.860	14	1966	2001	58.7
Carpentersville	6	20030	179	2.785	0.819	15	1973	2000	58.1
East Dundee	0		0	2.086	0.973	5	1923	1984	67
East Dundee	2	20033	69	2.925	0.999	4	1958	1991	78
East Dundee	3	20034	128	1.717	0.83	10	1968	1991	64
Elburn	2	20036	153	-0.074	0.916	6	1937	1989	0.5
Fox River WRD - Skyline	1	20106	131	0.701	0.486	8	1960	1991	31
Fox River WRD - Skyline	2	20107	135	0.96	0.57	7	1969	1991	31
IL Amer-R. Grange Dvn	1	20092	180	0.698	0.779	6	1972	1986	13
IL Amer-Valley Arena	1	20123	187	2.064	0.913	3	1983	1992	51
Montgomery	6		160	2.001	0.695	7	1959	1981	54
Ogden Gardens Sbdv	1	20081	185	0.188	0.866	6	1973	1986	3.5
Patterson MHP	1	20085	80	3.365	0.873	6	1986	2000	103
Powers Water Co	1	20087	80	1.496	0.997	3	1977	1986	17
Subdivision Water Trust	1	20064	147	0.122	0.562	7	1964	1988	5.8
Subdivision Water Trust	2	20065	180	0.200	0.676	8	1964	1988	9.2
Subdivision Water Trust	1-3	20066	196	0.356	0.915	11	1964	1998	13.7
Sleepy Hollow	2		44	6.562	0.973	3	1968	1980	100
South Elgin	4	20097	109	3.705	0.927	6	1973	1997	98.4
South Elgin	5	20098	68	2.079	0.662	5	1959	1997	92
St. Charles	7	20103	173	1.006	0.928	9	1963	1989	29
Sugar Grove	5	20088	200	0.813	0.594	8	1967	1985	19
Utl Inc Ferson Creek	2	20039	186	1.019	0.981	6	1975	1990	18
Utl Inc Ferson Creek	3	20040	175	0.611	0.979	6	1974	1990	11
Utl Inc Lk Marian Water	3	20054	75	5.653	0.967	6	1963	1997	124
West Dundee	2	20114	87	5.006	0.901	6	1969	1985	106

Table B-4. Public supply wells with significant slope values in Lake County. Slope (β_1) and r^2 values determined by linear regression for post-1960 samples only. Well # is local well number, and EPAID is Illinois EPA well code. N is number of samples and latest Cl^- is concentration at final available sample date.

Public Supply	Well #	EPAID	Depth (ft)	β_1 (mg/L/yr)	r^2	N	initial date	final date	Latest Cl^- (mg/L)
Antioch	3	20311	141	0.200	0.583	12	1953	1997	11.9
Antioch	5	20313	129	0.492	0.972	5	1978	1997	14.1

Table B-5. Public supply wells with significant slope values in McHenry County. Slope (β_1) and r^2 values determined by linear regression for post-1960 samples only. Well # is local well number, and EPAID is Illinois EPA well code. N is number of samples and latest Cl^- is concentration at final available sample date.

Public Supply	Well #	EPAID	Depth (ft)	β_1 (mg/L/yr)	r^2	N	initial date	final date	Latest Cl^- (mg/L)
Algonquin	0	20212	0	1.519	0.899	7	1922	1987	46
Algonquin	1	20213	165	0.618	0.992	8	1978	1992	12
Algonquin	5	20217	131	0.835	0.696	5	1976	1986	13
Algonquin	6	00186	152	0.824	0.453	7	1984	2000	19.6
Cary	3	20138	155	0.860	0.776	9	1956	1991	39
Cary	8	20142	105	4.827	0.870	5	1982	1997	101
Cary	10	20144	194	1.200	0.870	3	1981	1991	56
Deering Oaks Sbdv	2	20164	178	0.576	0.493	8	1966	1989	31
Eastwood Manor	1	20171	180	1.161	0.950	5	1958	1985	21
Fox River Grove	1	20154	140	1.782	0.322	10	1929	1997	113
Fox River Grove	2	20155	120	1.427	0.394	11	1956	1997	105
Harvard	3	20199	71	5.208	0.669	8	1938	1985	101
Harvard	4	20200	69	2.790	0.673	7	1963	1985	57
Harvard	5	20201	68	2.543	0.826	9	1958	1985	54
Harvard	6	20202	197	0.564	0.919	15	1965	2000	19.4
Harvard	7	00335	144	0.632	0.985	3	1986	1999	14.5
Hebron	4	20187	125	3.094	0.658	9	1983	2000	120
Huntley	5	20204	95	0.496	0.378	9	1969	1989	32
Huntley	6	20205	154	0.327	0.977	4	1979	1989	1.4
Island Lake	4-6	00625	146	6.913	0.996	3	1989	1999	72.2
Lake in the Hills	4	20198	114	0.762	0.623	6	1957	1991	32
Private well: Marengo			30	4.296	0.719	6	1971	1980	67
McHenry	2	20207	60	4.294	0.830	11	1960	2001	153
McHenry	3	20208	185	0.648	0.917	6	1971	1985	10
McHenry	5	20210	95	0.489	0.859	7	1978	2001	20
McHenry	6	20211	131	1.890	0.973	8	1978	1998	43.6
McHenry (Lakeland Park)	2		85	2.300	0.694	7	1958	1982	34
Northern Illinois Utl Inc	1		87	4.328	1.000	3	1958	1981	70
Oakbrook Estates MHP	1	20165	182	6.714	0.722	6	1986	2001	208
Richmond	1	20188	170	1.491	0.405	8	1938	1985	30
Richmond	2	20189	144	2.283	0.901	6	1956	1982	30
Utl Inc Holiday Hills	2	20176	108	0.608	0.855	7	1958	1986	24
Utl Inc Whispering Hills	4	20182	93	4.106	0.869	5	1964	1989	90
Wonder Lake Water Co	1	20149	180	-0.058	0.394	7	1973	1991	1.6
Woodstock	1	22149	196	0.287	0.897	6	1922	1985	9.4
Woodstock	6	22153	193	0.829	0.557	7	1960	1985	27
Woodstock	8	00607	166	1.357	0.997	3	1989	2001	23.8
Woodstock	101	00630	114	3.086	0.999	3	1989	2001	57.8

Table B-6. Public supply wells with significant slope values in Will County. Slope (β_1) and r^2 values determined by linear regression for post-1960 samples only. Well # is local well number, and EPAID is Illinois EPA well code. N is number of samples and latest Cl^- is concentration at final available sample date.

Public Supply	Well #	EPAID	Depth (ft)	β_1 (mg/L/yr)	r^2	N	initial date	final date	Latest Cl^- (mg/L)
Channahon	2,5	00384	55	3.575	0.991	3	1991	2005	138
Greenfield Comm Well	1	20365	120	1.756	0.753	7	1972	1987	74
Hillview Sbdv	1		127	5.190	0.955	5	1972	1982	95
IL American West Suburb	12	21154	157	3.904	0.783	8	1976	2000	116
IL American West Suburb	19	20362	170	3.578	0.784	9	1977	2000	96.3
Joliet	202	22108	90	0.769	0.674	7	1962	1987	28
Joliet	203	22109	83	0.314	0.951	8	1962	1987	9.2
Joliet	204	22110	113	0.540	0.792	9	1950	1987	18
Joliet	205	22111	94	0.480	0.577	8	1962	1985	15
Manhattan	2	20382	156	0.078	0.508	9	1942	1992	6.9

Lake	**Pekara Sbdv**	**2**	20294	155	1960	2000	12	11.9
Lake	Pekara Sbdv	3	20295	141	1978	1987	3	7.1
Lake	Pekara Sbdv	4	20296	150	1978	2001	8	8.9
Lake	Towners Sbdv	2	20243	180	1959	1987	8	5.2
Lake	Utl Inc Harbor Ridge	1	20247	123	1978	1992	5	2.1
Lake	Wildwood Sbdv	3	21046	173	1958	1991	6	3.3
Lake	Winthrop Harbor	5	20292	130	1959	1982	6	6.3
McHenry	Algonquin	3		189	1968	1980	6	2
McHenry	Huntley	4	20203	63	1953	1989	5	40
McHenry	**Island Lake**	**4-10**	00614	146	1989	1999	4	45.7
McHenry	Private well: Marengo			22	1971	1980	8	130
McHenry	Marengo	4	20191	100	1962	1985	5	21
McHenry	Marengo	5	20192	85	1962	1986	7	35
McHenry	Marengo	6	20193	87	1976	1986	6	28
McHenry	McHenry Shores Water Co	1	20150	180	1958	1986	6	5.1
McHenry	McHenry Shores Water Co	2	20151	135	1970	1985	7	0.5
McHenry	Nunda Utl Co	1	20161	189	1971	1987	6	3.5
McHenry	Union	2	20173	192	1938	1985	9	1.5
McHenry	Woodstock	3	22150	198	1939	1983	4	5
McHenry	Woodstock	5	22152	189	1960	1985	7	7.3
McHenry	Woodstock	7	22154	114	1961	1985	8	40
McHenry	Woodstock	10	00609	107	1991	2001	3	76.3
Will	**Beckwith Community Assn**	**1**	20380	187	1977	1987	3	9.7
Will	***Beckwith Community Assn***	***2***	20381	187	1978	1987	4	3.5
Will	Beecher	1	20370	164	1917	1983	5	1.2
Will	East Lawn Sbdv	1		110	1972	1983	5	81
Will	Huntley Community Sbdv	1		155	1972	1983	3	4.3
Will	Joliet	201	22107	103	1950	1983	9	9
Will	Manhattan	4		115	1977	1984	5	1
Will	Peotone	1		135	1906	1985	5	6
Will	Private well: New Lenox			90	1991	2003	4	1.2
Will	***Shorewood***	***3***	20352	151	1973	1985	3	2.1
Will	Utl Inc Cherry Hill Water Co	1	20331	145	1951	1990	5	47