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Contract Report 2012-03 | Executive Summary

Northeastern Illinois Water Supply Planning Investigations: Opportunities and Challenges of Meeting Water Demand in Northeastern Illinois

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1 Introduction

The availability and sustainability of an adequate and dependable water supply is essential for public, environmental, and economic health. This understanding led to the initiation, under the direction of Executive Order 2006-01, of a three-year program for comprehensive regional water supply planning and management in Illinois. The Illinois Department of Natural Resources' Office of Water Resources (IDNR-OWR), in coordination with the Illinois State Water Survey (ISWS), selected two regions having a high potential for water conflict—east-central Illinois and northeastern Illinois—for pilot planning under the framework of the Order. This report summarizes technical studies in support of water supply planning in the northeastern Illinois region, which includes Boone, Cook, DeKalb, DuPage, Grundy, Kane, Kankakee, Kendall, Lake, McHenry, and Will Counties. These studies highlight the opportunities and challenges of meeting water demand in the region.

The Chicago Metropolitan Agency for Planning (CMAP) guided formation of a 35-member grassroots water supply planning group for northeastern Illinois, the Northeastern Illinois Regional Water Supply Planning Group (RWSPG). The RWSPG was charged with developing water supply planning and management recommendations for the region. The Illinois State Water Survey (ISWS) and the Illinois State Geological Survey (ISGS), both within the University of Illinois' Prairie Research Institute, along with the Illinois Department of Natural Resources' Office of Water Resources (IDNR-OWR), were responsible for providing technical support to the RWSPG.

A water supply study program, developed by IDNR-OWR and the State Surveys, called for estimation of water withdrawals to 2050 and assessment of the impact on the region's water resources of these withdrawals. This report describes estimated impacts based on scenarios of future water withdrawals developed by Southern Illinois University investigators. The authors discuss impacts to three principal sources of water available to the region: the deep bedrock aquifers (called the deep aquifers) underlying all of the region; sand and gravel and shallow bedrock aquifers (called the shallow aquifers) underlying only the Fox River watershed; and the inland surface waters of the Fox River. The authors also assess the ability of Lake Michigan to meet public water supply demand. A surface water accounting tool, a watershed model, and a groundwater flow model were developed to estimate the impacts of future demands on the Fox River and aquifers within the region. Time and budget limitations did not permit the authors to evaluate shallow aquifers outside of the Fox River watershed nor other inland surface waters such as the Kankakee River. Figure ES-1 illustrates the planning region.

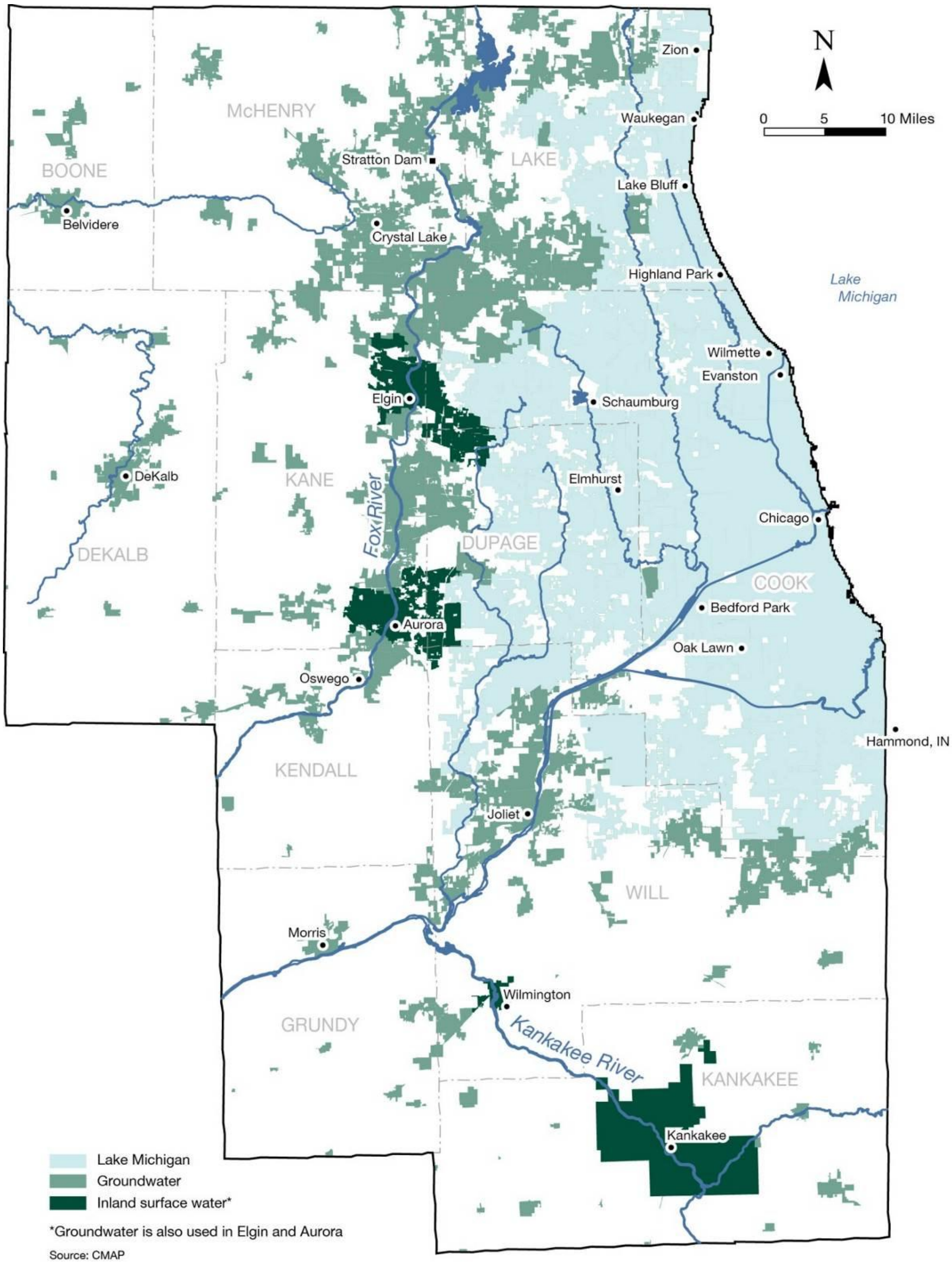

Figure ES-1. Eleven-county northeastern Illinois water supply planning region and currently utilized community water supply sources (adapted from the Chicago Metropolitan Agency for Planning)

2 Sources of Water in Northeastern Illinois

Sources of water currently used in northeastern Illinois include Lake Michigan; inland surface waters of the Chicago Sanitary and Ship Canal, the Cal Sag Channel, and the Chicago, Des Plaines, Fox, Illinois and Kankakee Rivers (only the Fox and Kankakee Rivers are used currently for community water supply); and groundwater (Figure ES-1). Lake Michigan provided about 69 percent of water used for all purposes except power generation, and about 85 percent of public water supply, in 2005 (Table ES-1). Much of the water withdrawn for power generation is returned directly to its source, with a small percentage lost to evaporation after being circulated once for cooling in through-flow power plants. Dziegielewski and Chowdhury (2008) distinguish this category of power generation water use—referred to in this report as *once-through flow* or, more simply, *through flow*—from *makeup water* pumped by *closed-loop power plants*, which recirculate cooling water. Makeup water is water that is pumped to replace losses and "blowdown" in cooling towers or losses and discharges from perched lakes or ponds. Power generation through-flow totaled more than 4,200 million gallons per day (Mgd) in 2005. Note that Table ES-1 contains both reported pumping totals, which reflect drought conditions in 2005, and totals that have been mathematically adjusted to remove the effects of the drought; the latter values reflect average daily temperature and average annual precipitation during the period 1971-2000.

Groundwater sources available to northeastern Illinois (Figure ES-2) include the deep aquifers—layers consisting principally of sandstone that are, for purposes of this study, referred to as the Ancell Unit, Ironton-Galesville Unit, and Mt. Simon Unit—and the shallow aquifers, bedrock units lying above the deep aquifers together with unconsolidated sand and gravel aquifers contained within the Quaternary Unit of Figure ES-2. In northeastern Illinois, the Mt. Simon Unit is used far less than the Ancell and Ironton-Galesville Units because of the expense of drilling to it and because deeper portions of the Mt. Simon contain water that is too salty for most uses.

Table ES-1. Water Withdrawals in Northeastern Illinois, 2005 (Mgd) (Dziegielewski and Chowdhury, 2008)

Water-supply sector or other accounting category		***Reported***	***Adjusted to 1971-2000 climate***
Public supply		1,255.7	1,189.2
Self-supplied commercial and industrial		191.6	162.4
Self-supplied domestic		36.8	31.8
Irrigation and agriculture		62.0	44.6
Power generation	makeup	52.3	52.3
	through flow	4,207.2	4,207.2
TOTAL all sectors		**5,805.6**	**5,687.5**
TOTAL excluding power generation through-flow		**1,598.4**	**1,480.3**
TOTAL excluding power generation		**1,546.1**	**1,428.0**

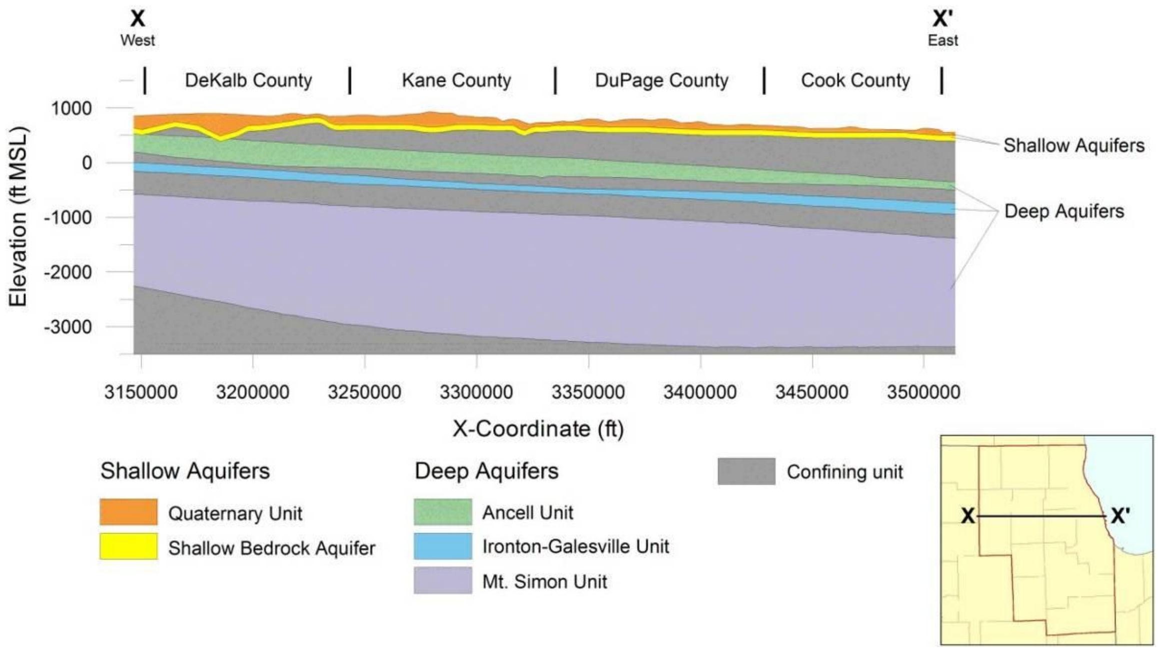

Figure ES-2. East-west cross section showing regional hydrostratigraphic units

In most of northeastern Illinois, shallow and deep aquifers are separated by a laterally extensive, relatively impermeable confining unit that greatly limits vertical leakage of water to the deep aquifers. For this study and in discussing groundwater in the region, the *shallow* and *deep* aquifers, units, and wells are all separated by the top of the Ancell Unit: *shallow* units and aquifers overlie the top of the Ancell Unit, and *deep* units and aquifers underlie the top of the Ancell Unit. Shallow wells do not penetrate below the top of the Ancell Unit, and deep wells penetrate below it. In practice, wells drilled into deep units are sometimes left open to all overlying units, so withdrawals from deep wells can also include water from both shallow and deep units. However, in 2005, withdrawals from such wells (deep wells open to shallow aquifers) constituted only about 3 percent of total groundwater withdrawals in the region.

Limitations in available time and budget constrained the flexibility to represent alternative future water supply networks. For this initial study, the authors assume that future withdrawals are obtained from the same network of surface intakes and wells in use in 2005. Moreover, it is assumed that the future distribution of withdrawal rates within a given facility is proportional to its distribution in 2005. For example, if a particular well provided 3 percent of the facility's withdrawals in 2005, it is assumed that the well provides 3 percent of its withdrawals in 2050. In essence, the authors assume that water sources and pumping operations remain fixed to reflect 2005 practices. In reality, hundreds of water system managers continually install new withdrawal points, abandon others, and alter pumping operations, their decisions dictated by hydrology, land use, urban growth patterns, economics, politics, and other considerations. The authors highly recommend follow-up modeling studies of plausible future water supply networks that reflect such factors.

3 Future Water Needs

Dziegielewski and Chowdhury (2008) employed reported and estimated withdrawals in 2005, along with estimates of population growth, urban/suburban migration, and economic growth, to estimate future water withdrawals. They used three combinations of assumptions about future socioeconomic conditions to develop three scenarios of future withdrawals. The scenarios represent a rational and plausible range of future withdrawals, but future withdrawals may fall outside the range of the scenarios. All three scenarios assume 1971-2000 average daily temperature and average annual precipitation. The scenarios include a low withdrawal realization called the Less Resource Intensive (LRI) scenario and a high withdrawal realization called the More Resource Intensive (MRI) scenario. Between these is a moderate withdrawal realization which the authors call the Baseline (BL) scenario, but which Dziegielewski and Chowdhury call the Current Trends (CT) scenario.

Table ES-2. Water Withdrawals in Northeastern Illinois, by County (Excluding Through Flow for Power Generation) (Dziegielewski and Chowdhury, 2008) (Mgd)

County	*2005 (adjusted to 1971-2000 climate)*	*2050 (LRI)*	*2050 (BL)*	*2050 (MRI)*
Boone	7.2	7.9	9.9	111.5
Cook	972.8	915.3	1,171.6	1,340.3
DeKalb	13.8	17.1	21.3	25.4
DuPage	101.2	103.5	124.2	142.2
Grundy	9.2	18.0	22.1	52.4
Kane	52.5	67.8	101.9	135.7
Kankakee	33.6	33.9	40.6	54.0
Kendall	9.5	19.8	31.3	62.3
Lake	91.3	103.1	131.6	160.1
McHenry	38.8	46.7	64.7	100.1
Will	150.5	254.3	291.5	345.2
TOTAL	**1,480.3**	**1,587.5**	**2,010.7**	**2,429.4**

Withdrawals by county in 2005 (adjusted to average 1971-2000 climate) and 2050 are shown in Table ES-2. Note that Table ES-2 includes makeup water used in power generation, but not once-through cooling water used in power generation, which is largely returned to its source following use. Depending on the demand scenario, the 11-county planning area may need from 107 to 949 Mgd more water in 2050 than was withdrawn in 2005. This report seeks to address the question of whether this amount of additional water is available in the region and describe the impacts of providing this water. The authors will address each source of water individually and summarize.

4 Lake Michigan

Completion of the Chicago Sanitary and Ship Canal (CSSC) in 1900 allowed the direction of the Chicago River to be reversed, keeping waste and flood waters out of Lake Michigan by sending them into the Mississippi River basin. Numerous court challenges over the next 60+ years sought to eliminate or limit Illinois' diversion, and in 1967 a U.S. Supreme Court Decree limited the Illinois diversion to 3200 cubic feet per second (cfs) (2068 Mgd).

The size of Illinois' lake diversion can change dramatically from year to year, and the changes are challenging to predict. A major influence on the lake diversion is climate variability, since climate affects precipitation, runoff, and Lake Michigan water levels, Several measures or tools can be implemented to make more water available for domestic/public supply use. Such measures include, for example, completion of the Tunnel and Reservoir Project (TARP). The effectiveness of such water management measures is challenging to quantify, and involves a unique set of political, technical, and financial considerations that reach far beyond the scope of this initial assessment.

A total of 194 public water systems hold Lake Michigan allocation permits from IDNR-OWR. Public water supply use principally includes household domestic uses, but also includes water purchased for industrial, commercial, and recreational purposes from a public water system holding a lake allocation. Withdrawals for public supply in 2050 (Table ES-3) could plausibly range from 10 percent less to 31 percent more than in 2005 (Table ES-1).

Table ES-3. Estimated Lake Michigan Public Supply Withdrawals (Dziegielewski and Chowdhury, 2008) (Mgd)

Year	*BL Scenario*	*LRI Scenario*	*MRI Scenario*
2015	1,054	931	1,094
2020	1,075	931	1,134
2025	1,098	934	1,176
2030	1,125	939	1,221
2035	1,146	940	1,261
2040	1,170	943	1,304
2045	1,195	947	1,349
2050	1,223	953	1,397

Analysis for this project suggests that Illinois can accommodate public water system demand in the existing Lake Michigan service area to 2050, provide additional water to new permittees (or contribute to a water bank), and still remain in compliance with the 3200 cfs court limit. The analysis employs estimates of each diversion component (public supply, stormwater runoff, navigation make-up, lockage, leakage, and discretionary diversion) based on assumed constraints, historical averages, and future

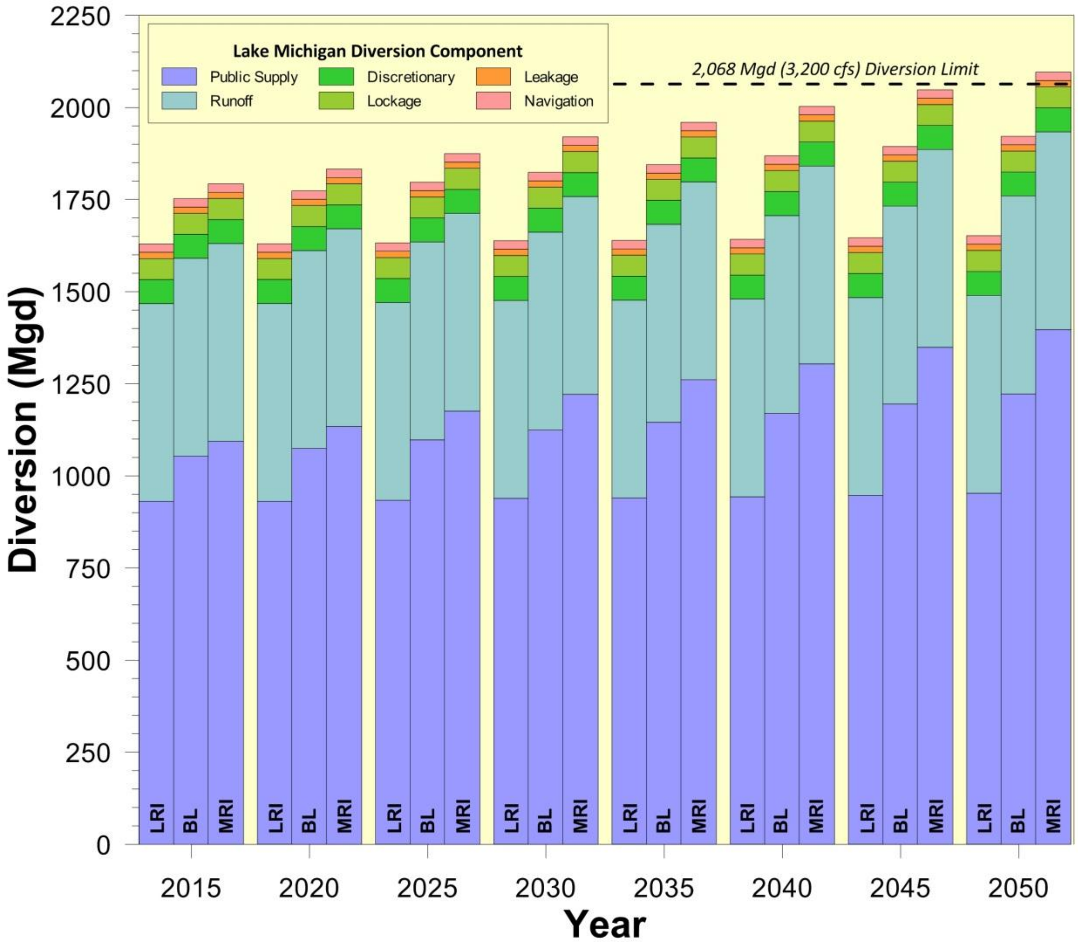

Figure ES-3. Estimated total Lake Michigan diversion, 2015–2050

public supply withdrawals from Dziegielewski and Chowdhury (2008) (Table ES-3) to compute estimates of total lake diversion. The total diversion exceeds the 2068 Mgd limit only in 2050, and only under the MRI scenario, by about 30 Mgd. Under the BL scenario, the total diversion in 2050 is 145 Mgd below the limit, and under the LRI scenario it is 445 Mgd below the limit (Figure ES-3). Although the historical averages used in the analysis may not be representative of future component values, especially in a changing climate, the values are the best currently available. In addition, the analysis permits only the public supply component of the diversion to change; all other components are not permitted to vary. In reality, all diversion components are changeable, and management of Illinois' lake diversion must acknowledge this dynamism to ensure compliance with the court decree.

There is reason to be cautiously optimistic about Lake Michigan water availability for public supply. The state's diversion over the past 14 years has remained consistently below the court limit. Per capita use appears to be on a slight downward trend, and Lake Michigan water levels remain below the long-term average, resulting in less diversion for lockage and leakage. In 2015, the authors expect completion of the TARP, which will reduce discretionary diversion into the CSSC by about 110 Mgd. Although the Lake

Michigan water allocation program must remain flexible to remain in compliance with the Decree, IDNR believes that it can accommodate an increase of about 50–75 Mgd in public water demand without major changes in diversion management policy (while also continuing to satisfy growing water demand within the current Lake Michigan service area).

5 Fox River

To accommodate the limited time and budget available for this project, the Fox River was selected from among the inland surface waters of the region for this study because it is the subject of prior and ongoing modeling and analysis, because watershed population and water use are rapidly increasing, and because it is already used for water supply by two public water systems, Elgin and Aurora.

This discussion focuses on impacts to low flow on the Fox River because low flow is a reasonable estimate of both the maximum flow under drought conditions and the minimum flow available to satisfy instream flow needs on the river. Instream flow needs are uses of water within the stream channel and include flow required for aquatic habitat, assimilation of wastewaters, water-based recreation, and stream aesthetics. Absent detailed analyses for a given stream regarding instream flow needs, IDNR commonly uses the 7-day 10-year low flow value ($Q_{7, 10}$) as the protected minimum flow for Illinois' public waters, including the Fox River. This means that no new withdrawal from these rivers is permitted if it causes flow to be reduced below the $Q_{7,10}$.

Four primary factors have had a direct influence on the change in low flow quantity: (1) climate variability, (2) discharge of treated wastewaters into the Fox River, (3) water use withdrawals from the river, and (4) modifications in the gate operations of Stratton Dam, which partially controls the outflow of water from the Fox Chain of Lakes in McHenry County. Of these factors, effluent (treated wastewater) discharges have had the greatest overall impact on low flow amounts along most reaches of the Fox River.

Effluent discharges to the Fox River and its tributaries in Illinois and Wisconsin, mostly from municipal wastewater treatment plants, average about 138 Mgd and account for roughly 10 percent of the average river flow. The two largest water reclamation districts, serving Aurora, Elgin, and neighboring communities, account for nearly 40 percent of total effluent discharge, and the Waukesha, Wisconsin region accounts for nearly 15 percent. The authors estimate effluent discharge to the Fox and its tributaries during extreme low streamflow conditions, such as the lowest 7-day period during a 10-year drought (when flow is equivalent to the $Q_{7,10}$), to total about 84 Mgd. Most of this effluent originates as groundwater that is withdrawn from local aquifers, used by residents and industries, treated, and discharged to the Fox River. To a great extent, historical increases in river low flow reflect increasing discharge of treated groundwater into the river. This effluent substantially elevates low flow in the Fox River. The authors estimate natural base flow in the Fox River at its confluence with the Illinois River, a component of flow originating as natural groundwater discharge, at about 120 Mgd.

For the past 100 years, almost all of the water used in the Fox watershed was obtained from groundwater sources. But in 1983, Elgin's public water system began withdrawing water from the Fox River, and, except for one year, over 90 percent of Elgin's water was obtained from the river during the period 1991–2005. Aurora began withdrawing water from the Fox in 1992. Total Fox River withdrawals by the two water systems have remained fairly steady since 1992, averaging 19.8 Mgd from 1992 to 2005.

Figure ES-4 shows the overall impact of human influences on low flow in the Fox River along a reach from near Crystal Lake downstream to Yorkville, comparing the present-day (2005) 10-year low flow to estimated natural or unaltered flow during a

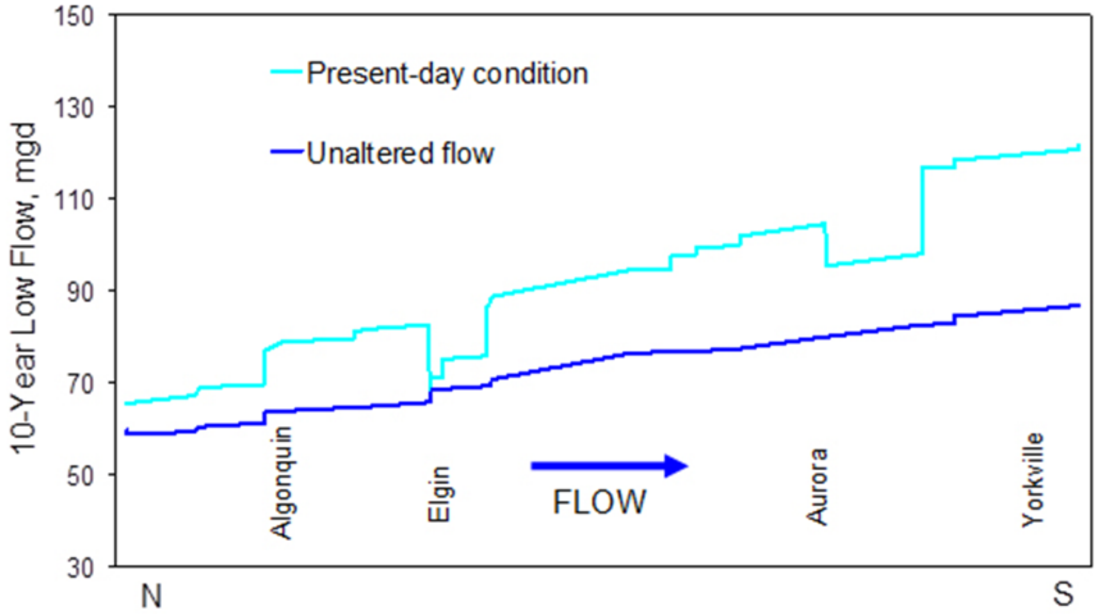

Figure ES-4. Ten-year low flow under unaltered conditions and approximate 2005 (present-day) conditions, Fox River from near Crystal Lake to Yorkville

10-year drought. In the upstream (northern) portion of this reach, the present-day 10-year low flow slightly exceeds the estimated unaltered flow, which is controlled by low flow releases from Stratton Dam. Downstream, the unaltered low flow gradually increases through natural accretion of base flow to the Fox River and its tributaries. In contrast, the present-day flow progressively gains considerable additional flow from effluent discharged by groundwater-using public water systems. “Dips” or decreases in the present-day flow mark withdrawals, with subsequent effluent discharge, by Elgin and Aurora. At the downstream (southern) end of this reach at Yorkville, the present-day low flow is 35 Mgd greater than the unaltered flow. This 35-Mgd net increase in low flows is roughly equivalent to the difference between the effluent discharges (+58 Mgd) and water supply withdrawals (–24 Mgd) on the river between Stratton Dam and Yorkville.

Impacts in 2050 were estimated for the BL, LRI, and MRI scenarios described in Section 3. Changes in effluent discharges for all Fox watershed communities were assumed to be proportional to growth in water use. All community water supply systems in the watershed currently obtain water from groundwater sources except Elgin and Aurora, which obtain part of their water from the Fox River. Except where noted in the following paragraphs, Elgin and Aurora are assumed to continue to operate the only surface water withdrawals in the watershed, with projected increases in surface water withdrawals under the 2050 BL scenario of 82 and 25 percent, respectively.

Figure ES-5 shows the modeled impact in 2050 of the BL scenario on low flow in the Fox River, again along a reach extending from near Crystal Lake downstream to Yorkville. Similar results were evaluated for the LRI and MRI scenarios. The modeling results show that low flow in the Illinois portion of the Fox River, and the proportion of low flow originating as effluent, will continue to increase. The increase in effluent more than offsets the expected increase in withdrawals at Elgin and Aurora.

Additional model simulations examine the potential that new withdrawals from the Fox River could provide water to additional communities. Instream flow guidelines used by IDNR specify that new withdrawals should not cause flow in the Fox River to fall below the $Q_{7,10}$, which is shown in Figure ES-4 and Figure ES-5 as the present-day (2005) low flow. Additional water could be obtained from the Fox River if IDNR revised its guidelines to fix the protected flow level at the present-day $Q_{7,\ 10}$ so that the protected flow would not change even as additional effluent increases actual low flow.

Figure ES-5 shows locations on the Fox River downstream of Elgin where the projected 2050 low flow is greater than the present-day flow by more than 10 Mgd, allowing development of a new 10-Mgd withdrawal under a management policy that fixes the protected low flow at its present-day condition. For example, Figure ES-6 shows projected low flow on the Fox River, assuming the BL scenario, if two additional river withdrawals are developed near St. Charles and Yorkville by 2050. In this example, the hypothetical withdrawals at St. Charles and Yorkville total 15 and 10 Mgd, respectively. The authors have selected 8- to 10- Mgd as a rough threshold for a new surface water supply in acknowledgment of the economies of scale associated with surface water treatment costs. The feasibility of water supply withdrawals from the river would, of course, also involve evaluating potential impacts related to water quality and aquatic ecosystem diversity.

To summarize, projected increases in low flow under most mode simulations support the conclusion that additional surface water withdrawals from the Fox River can meet approximately half of the expected public sector demand increases in major portions of the Fox River basin, such as the Kane-Kendall County region. However, the additional withdrawals require that IDNR fix the protected flow on the river to present-day $Q_{7,10}$ (Table ES-2). This analysis did not examine water quality, an important low flow issue on the Fox River. Recall also that increases in effluent discharges for all communities are assumed to be proportional to growth in water use, and these effluent increases originate largely from increases in community groundwater withdrawals. Instream flow considerations dictate that the river would likely not be able to provide water via direct withdrawals upstream of Kane County. Surface water users there will likely require off-channel storage. In all analyses, it is assumed that all water used by public water systems is returned as effluent to the Fox River after use.

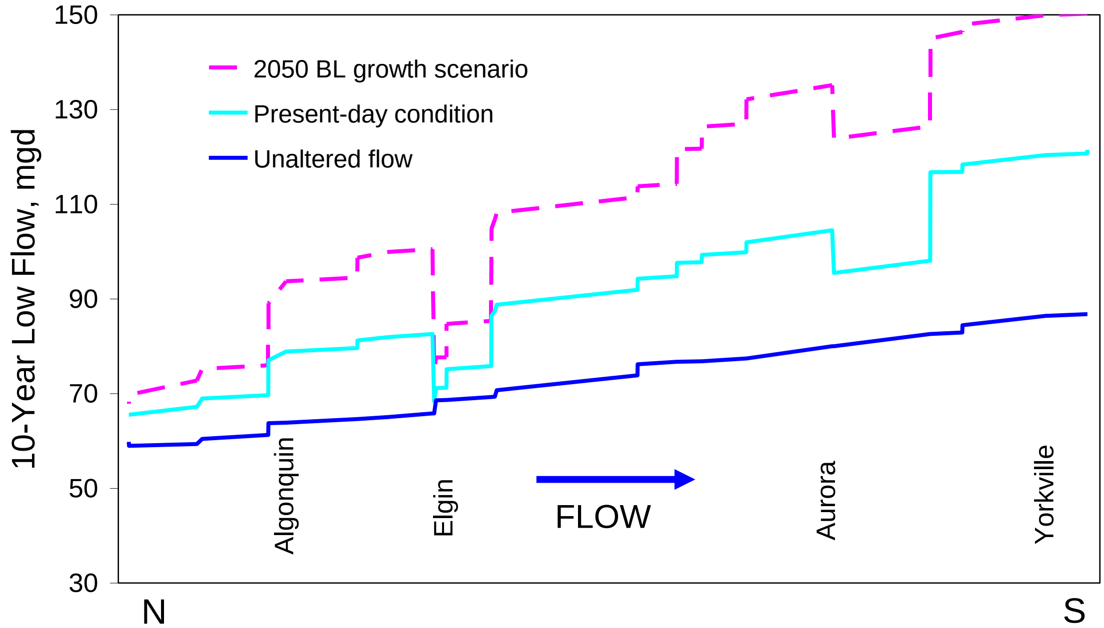

Figure ES-5. Ten-year low flow under unaltered conditions, approximate 2005 (present-day) conditions, and conditions in 2050 (BL scenario), Fox River from near Crystal Lake to Yorkville

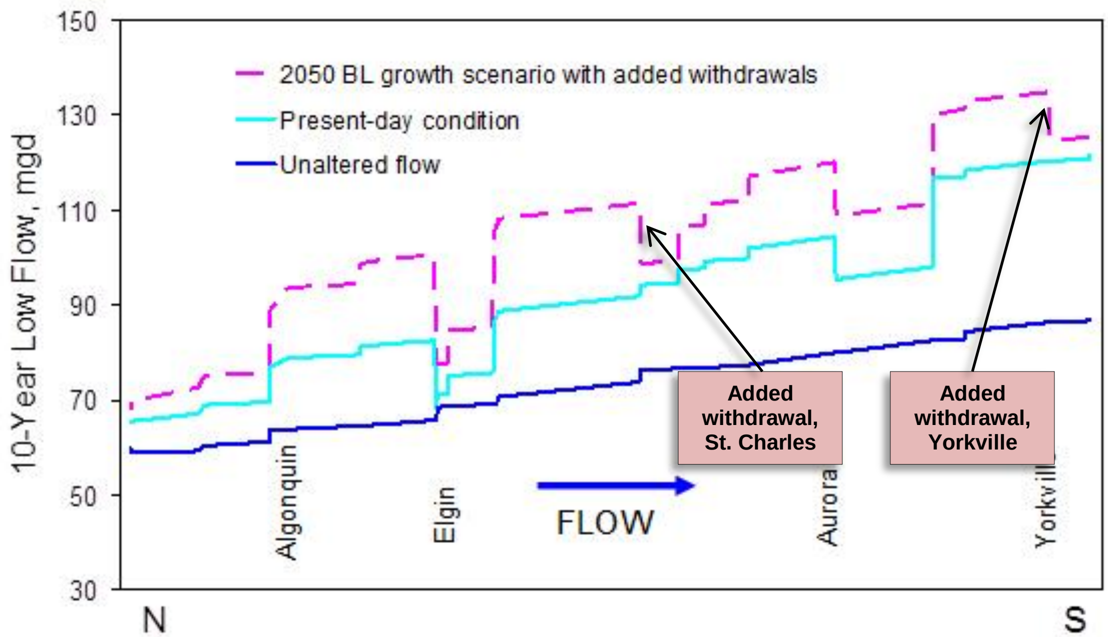

Figure ES-6. Ten-year low flow under unaltered conditions, approximate 2005 (present-day) conditions, and conditions in 2050 (BL scenario) with added withdrawals near St. Charles and Yorkville, Fox River from near Crystal Lake to Yorkville. The total added low flow withdrawal in this example is 25 Mgd

6 Groundwater

Understanding the relationships between groundwater resources, the relationship between groundwater and surface waters, and their response to withdrawals requires a quantitative approach that assimilates the available observations and knowledge, computes flow rates and water levels, and projects these into the future for alternative water-withdrawal scenarios. For the present study, these requirements were met using a computer model of groundwater flow, a set of interrelated mathematical equations that represents aquifers, wells, and streams that is solved using a computer program. The groundwater flow model simulates all major current and historic groundwater withdrawals in northeastern Illinois and the surrounding areas that could plausibly influence groundwater flow in the area (Figure ES-7).

Model layers represent major hydrostratigraphic units underlying northeastern Illinois (Table ES-4). Within the Fox River watershed geologic mapping domain (Figure ES-7), five individual Quaternary hydrostratigraphic units were simulated (Table ES-4) based on actual map unit thicknesses. Outside the Fox River watershed geologic mapping domain, the total Quaternary thickness was divided simply into five Quaternary hydrostratigraphic units of equal thickness.

The groundwater flow model used for this study, which employs a conceptual model developed from expert judgment and calibrated model parameters, represents the authors' best understanding of the groundwater system. Assumptions made in the process of simplifying a complex hydrogeologic environment *and* uncertainty in the data being used to calibrate the model gives rise to inherent model uncertainty. As an acknowledgment of the limitations in accuracy and comprehensiveness of the observations used for model development, the model results are best used as a screening tool to provide a sense of the locations and magnitudes of groundwater pumping impacts. The outcomes and trends in the results provide insight to the ability of the region's groundwater resources to meet potential future water demands.

6.1 Simulated Groundwater Withdrawals

Groundwater withdrawals in northeastern Illinois have declined since the 1980s, largely as a consequence of public water systems in Cook, DuPage, and Lake Counties shifting from groundwater to Lake Michigan as a water source, but also because of improvements in efficiency, reduction of leakage, and deindustrialization (Figure ES-8). The largest annual declines in total groundwater withdrawals occurred in the early 1990s, when many public water systems in DuPage County shifted to Lake Michigan. Declines in withdrawals from deep wells have been greater than those from shallow wells, principally because many of the public water systems that switched to the Lake Michigan source relied heavily on deep wells. The overall spatial effect of this shift has been to move the band of groundwater withdrawals farther west and south as pipelines deliver Lake Michigan water to inland areas at progressively greater distances from the lake. Moreover, groundwater withdrawals by western and southern suburban systems that remain dependent on groundwater continue to increase in response to population growth.

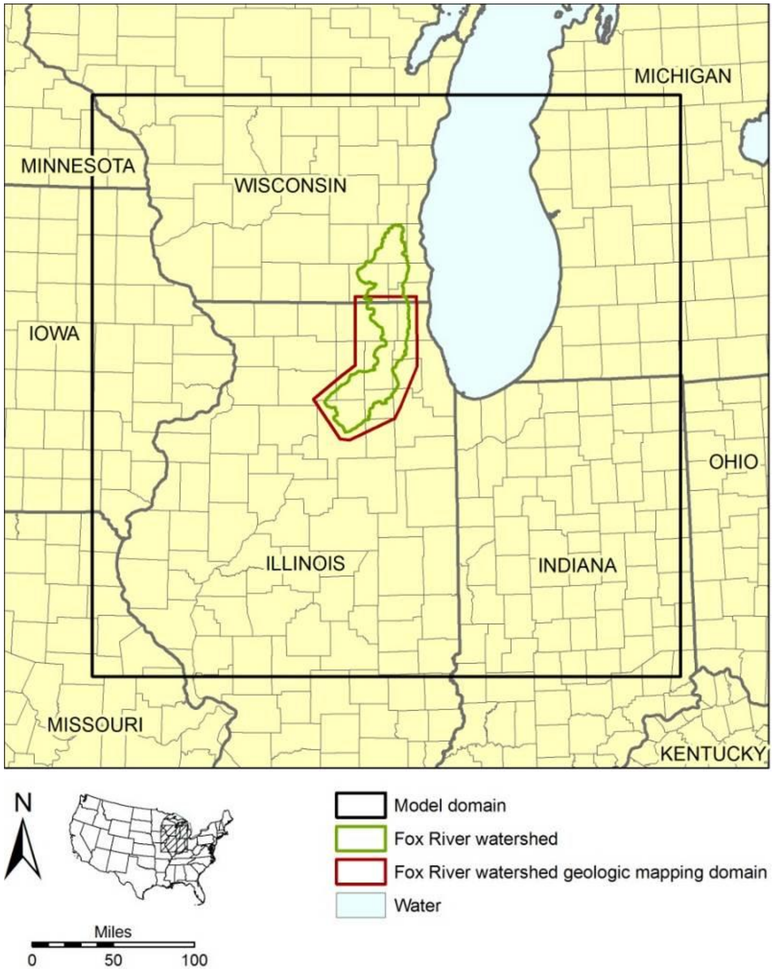

Figure ES-7. Northeastern Illinois regional groundwater flow model domain, Fox River watershed outline, and Fox River watershed geologic model domain

Table ES-4. Layer Scheme of the Regional Flow Model

HYDROSTRATIGRAPHIC UNIT		***MODEL LAYER***
Other Areas	***Fox River Watershed Geologic Mapping Domain***	
Quaternary Unit	Quaternary Fine-Grained Unit 1	1
	Quaternary Coarse-Grained Unit 1	2
	Quaternary Fine-Grained Unit 2	3
	Quaternary Fine-Grained Unit 3	4
	Quaternary Coarse-Grained Unit 2	5
Upper Bedrock Unit		6
Silurian-Devonian Carbonate Unit		7
		8
		9
Maquoketa Unit		10
		11
Galena-Platteville Unit		12
		13
Ancell Unit		14
Prairie du Chien-Eminence Unit		15
Potosi-Franconia Unit		16
Ironton-Galesville Unit		17
Eau Claire Unit		18
Mt. Simon Unit		19
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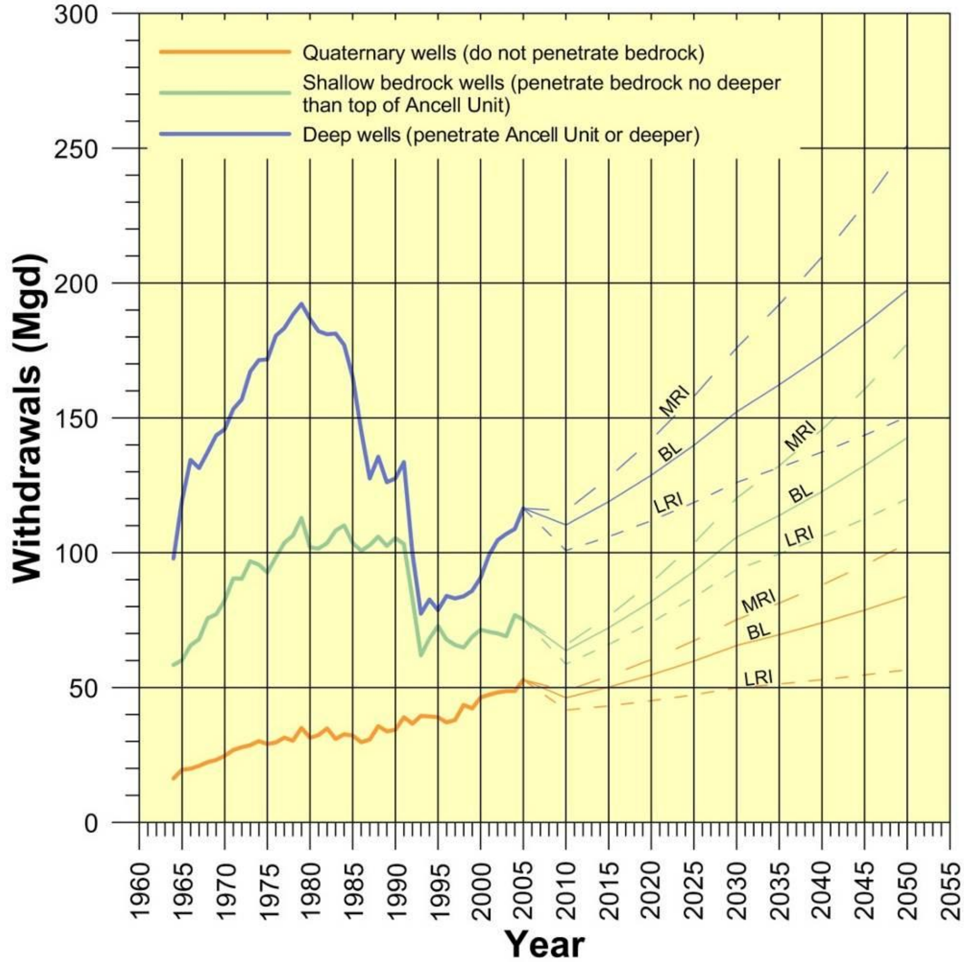

Figure ES-8. Simulated groundwater withdrawals in 11-county area by aquifer group and scenario, 1964–2050

Withdrawals from the shallow units in 2005 are concentrated within a corridor extending from the Indiana boundary in Will County northwestward through the Fox River Valley of Kane County and extreme northwestern Cook County and northward into McHenry County. The source of these shallow withdrawals is predominantly the shallow bedrock aquifer in the southern part of the corridor, while the source is mainly the Quaternary sand and gravel aquifers in the northern part of the corridor (Figure ES-9a and b). Principal areas of withdrawals from the deep units in 2005 are (1) the industrial corridor along the CSSC and Des Plaines River, (2) the Fox River Valley area of southeastern Kane County, and (3) southeastern McHenry County (Figure ES-9c).

The three demand scenarios (BL, LRI, MRI) were simulated for the period 2005 to 2050, although the model may be adapted to simulate a wide range of other demand scenarios. These county-level demands were disaggregated to individual points of withdrawal (wells) for use as model input.

Important assumptions were necessary to disaggregate county-level demands to specific wells for use as model input:

- **No new points of withdrawal were added beyond those wells already operating in 2005.** Future demands were assigned to existing 2005 well locations. Actual siting of new wells will distribute withdrawals differently from the modeled withdrawals and can be executed strategically to reduce impacts below model-simulated levels in severely affected areas. Continued tracking of new well locations and pumping rates, currently conducted by the ISWS Illinois Water Inventory Program, is necessary to keep the model updated.
- **Assignment of future (post-2005) withdrawals reflects facility pumping operations in 2005.** For example, Crystal Lake withdrew about 4.30 Mgd of groundwater in 2005; about 10.4 percent of this total (0.45 Mgd) was pumped from well 11 at that facility. Under the BL scenario, Dziegiewski and Chowdhury (2008) estimated that Crystal Lake would pump a total of about 5.22 Mgd in 2050. For purposes of model simulation, the authors assigned 10.4 percent of that total (0.54 Mgd) to well 11, reflecting the proportion pumped from the well in 2005. They employed the same convention for the post-2005 period for each of the three scenarios. Although the convention does not reflect actual evolution of the regional well network–which is a product of numerous decisions by hundreds of managers, in response to a range of factors, and perhaps without knowledge of management decisions made by other facilities in the region–it was necessary owing to time and budget constraints of this initial assessment. The modeling results based on it permit identification of problematic areas for priority follow-up investigation.
- **Domestic self-supplied withdrawals (i.e., rural domestic wells) are not simulated.** Modeling the tens of thousands of small-capacity (typically <20 gallons per minute) wells distributed across the 11-county area was not attempted but is believed by the authors to have minimal influence on regional water levels simulated with this model.

Simulated groundwater withdrawals in the 11-county region increase between 2005 and 2050 with 2050 totals ranging from 327 to 532 Mgd, depending on the demand scenario (Figure ES-8). The sources of projected withdrawals reflect the 2005 proportionality, with roughly a 50/50 split between the deep and shallow aquifers (shallow aquifers including the shallow bedrock and Quaternary aquifers combined). Model-simulated withdrawals from the deep aquifers in 2050 in the 11-county area total 197 and 251 Mgd under the BL and MRI scenarios, respectively. Notably, these rates are higher than the peak historical withdrawal rate from the deep aquifers of about 190 Mgd, a rate known to produce undesirable impacts (e.g., rapidly falling heads) in some deep wells. For comparison, the geographic distributions of simulated withdrawals in 2050 under the BL scenario are shown in Figure ES-10a (Quaternary Unit wells); Figure ES-10b (shallow bedrock wells); and Figure ES-10c (deep wells).

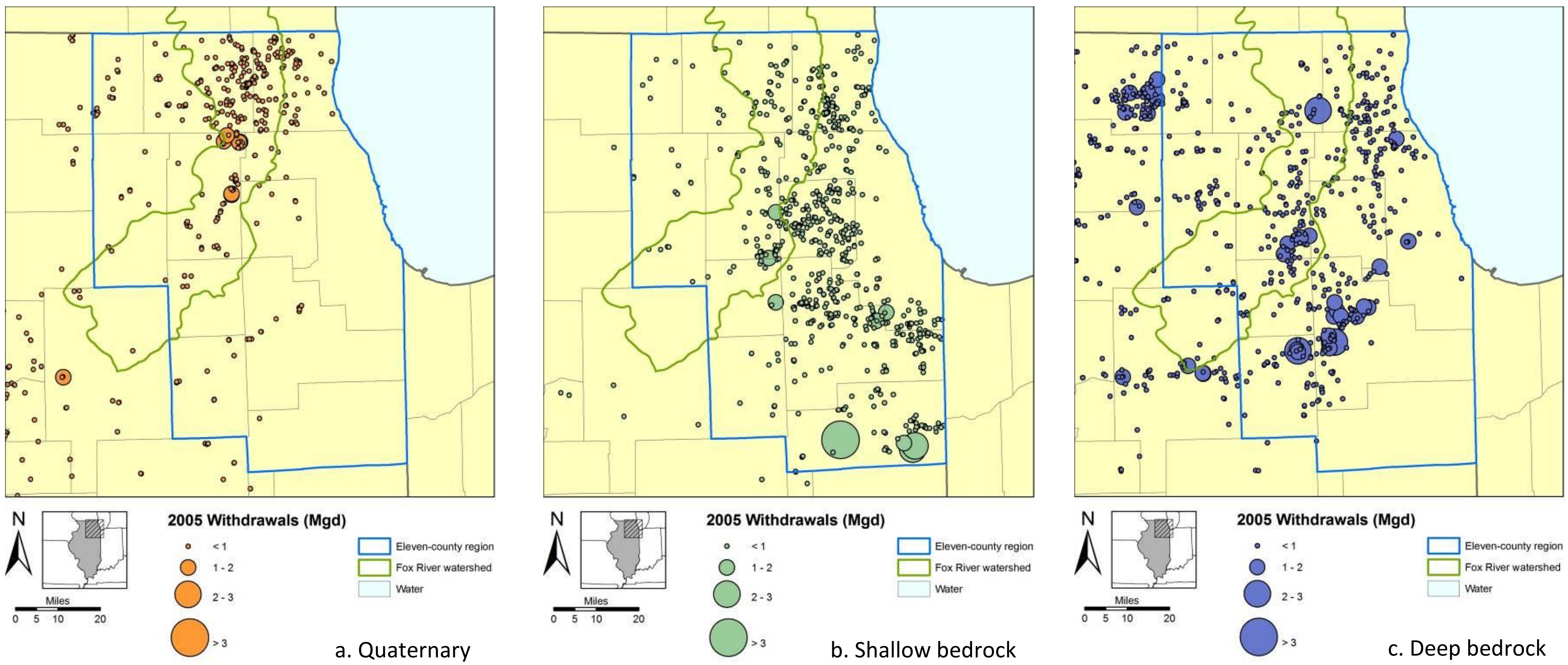

Figure ES-9. Simulated 2005 withdrawals in northeastern Illinois from (a) Quaternary aquifers, (b) shallow bedrock aquifer, and (c) deep aquifers

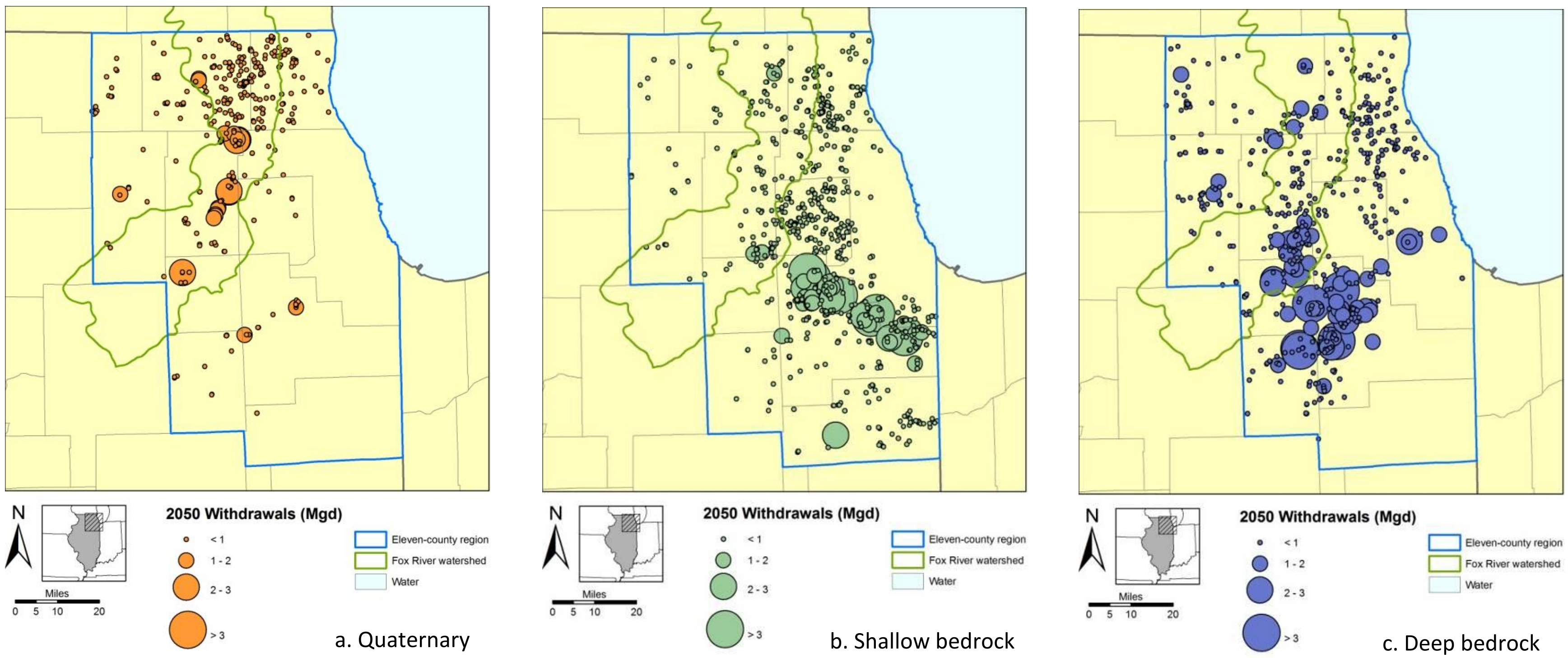

Figure ES-10. Simulated 2050 BL scenario withdrawals in northeastern Illinois from (a) Quaternary aquifers, (b) shallow bedrock aquifer, and (c) deep aquifers

6.2 Summary of Groundwater Flow Model Results

Groundwater modeling for this project simulates pumping between 1864 (when large-scale pumping began in northeastern Illinois) through 2050. The modeling consists of simulations in which pumping for each represented well is varied annually. Only the pumping rates of the wells are changed from year to year in the simulations; all other hydrologic and geologic parameters remain constant.

As previously mentioned, the model results are best used as a screening tool to provide a sense of the locations and magnitudes of groundwater pumping impacts. The results are useful for identifying areas for further data collection and for possible long-term monitoring, and the model itself is useful for assessing impacts from historical pumping as well as alternative pumping strategies possibly directed toward reducing future impacts. As values for model calibration, the authors estimate that the deep aquifer head targets are only accurate to within about ±200 feet and that the shallow head targets are only accurate to within about ±68 feet. They can confirm that modeled heads are only within the head target accuracy; any model can only be as accurate as the data employed to calibrate it. Model accuracy can be improved through acquisition of additional observations in the field and use of these data for conceptual model refinement, calibration, parameterization, and characterization of boundary conditions.

The authors also caution readers that reductions in groundwater discharge to streams suggested by the modeling, as discussed below, may not be observable or easily recognized. Few data are available to verify streamflow reductions, and analysis of existing data is lacking. Moreover, the reductions in natural groundwater discharge resulting from increases in groundwater withdrawals suggested by this study would likely occur in a diffuse fashion, and they may be masked by hydrologic factors that are not simulated by the groundwater flow modeling of this study. Some of these unsimulated processes, such as effluent discharge, could offset the simulated reductions.

The results of the groundwater simulations and their implications are briefly summarized in the following bullet points. Greater detail and recommendations for additional work are provided in the complete report.

- The deep aquifers that underlie all of northeastern Illinois provide relatively consistent yields to wells and have served as a reliable source of water for over 150 years. However, relatively impermeable confining units overlie the deep aquifers and greatly limit leakage into the aquifers from above. In addition, the low transmissivity of the deep aquifers limits eastward movement of replacement water from north-central Illinois, where the relatively impermeable cover is absent. As a result, water levels (heads) have fallen 500 to 800 feet in many deep wells. This slow replacement of water has great implications for future use of the deep aquifers.
- In contrast, replacement water enters the shallow aquifers much more readily, and these comparatively higher rates of leakage function to reduce drawdown. Shallow aquifers, however, are not consistently present throughout northeastern Illinois and well yields are much more variable than deep aquifer wells. Moreover, the shallow aquifers, by their very nature, are more closely connected to streams and wetlands.
- Computer simulation of plausible scenarios of future groundwater demand, using existing well locations, suggests that additional drawdown, reduction in stream base

flow, and changes in the quality of groundwater withdrawn from deep wells are all possible in parts of the 11-county study area before 2050.

- Interformational transfer of water into the Ironton-Galesville is occurring within hundreds of deep aquifer wells in northeastern Illinois that are open across multiple deep aquifer units. Because the model does not simulate this transfer of water, actual Ironton-Galesville heads are probably higher than model-simulated heads due to the addition of water from overlying units while actual Ancell heads are probably lower than model-simulated heads due to the leakage of water from this unit down into the Ironton-Galesville. Borehole transfer of water down to the Ironton-Galesville will slow and eventually stop in areas where the overlying Ancell Unit is dewatered, bringing heads in those areas closer to simulated conditions.
- Model simulations suggest that, in 2005, over 500 feet and over 1100 feet of drawdown have occurred in the Ancell and Ironton-Galesville Units, respectively, in southeastern Kane County and northern Will County since pumping began in the 1860s. These units are the principal deep aquifers in the region. Drawdown causes water levels in wells open to the aquifers to decline, decreasing well yields, increasing pumping expenses and, in extreme cases, causing water supply interruptions that can only be addressed by replacement of the wells or lowering of pumps. Simulations of BL scenario pumping suggest that Ancell and Ironton-Galesville heads in southeastern Kane County and northern Will County will have declined by over 800 and over 1,500 feet, respectively, by 2050 (Figure ES-11 and Figure ES-12).
- Since the model does not simulate borehole transfers of water into the Ironton-Galesville, readers should view the modeled outcome of declining Ironton-Galesville heads and loss of available head above the Ironton-Galesville Unit (e.g., Figure ES-12) as a conservatively large estimate of the expected future impacts. Declining heads in the Ancell and Ironton-Galesville Units could lead to a decline in well yield and increasing pumping expenses. Deep wells in the areas of partial to full desaturation of the Ancell Unit also may be vulnerable to increases in arsenic, barium, and radium concentrations that, left untreated, may be harmful to human health.
- Modeling shows that significant shallow aquifer drawdown affected many locations in the Fox River watershed in 2005, but drawdown in the shallow aquifers is not as widespread as in the deep aquifers, and drawdown magnitude is much less. The lesser drawdown in the shallow aquifers reflects increased availability of replacement water for water withdrawn from shallow wells relative to deep wells. Simulations of future pumping suggest that areas of drawdown exceeding 5 feet in the shallow aquifers present in 2005 will expand by 2050 (Figure ES-13).
- Model simulations suggest that, in 2005, pumping had reduced natural groundwater discharge within the Illinois portion of the Fox River watershed by about 10 percent, the simulated reduction reaching 36 percent in one sub-basin (Figure ES-13). However, available streamflow data do not verify the reductions. Simulated reductions in natural groundwater discharge resulting from increases in groundwater withdrawals may be masked by hydrologic factors that are not simulated by the groundwater flow modeling of this study. Additional research and monitoring are required to more accurately identify locations and quantify reductions in natural groundwater discharge. Nevertheless, the groundwater flow model simulations of

future pumping indicate that future impacts are likely to increase with increases in shallow aquifer pumping.

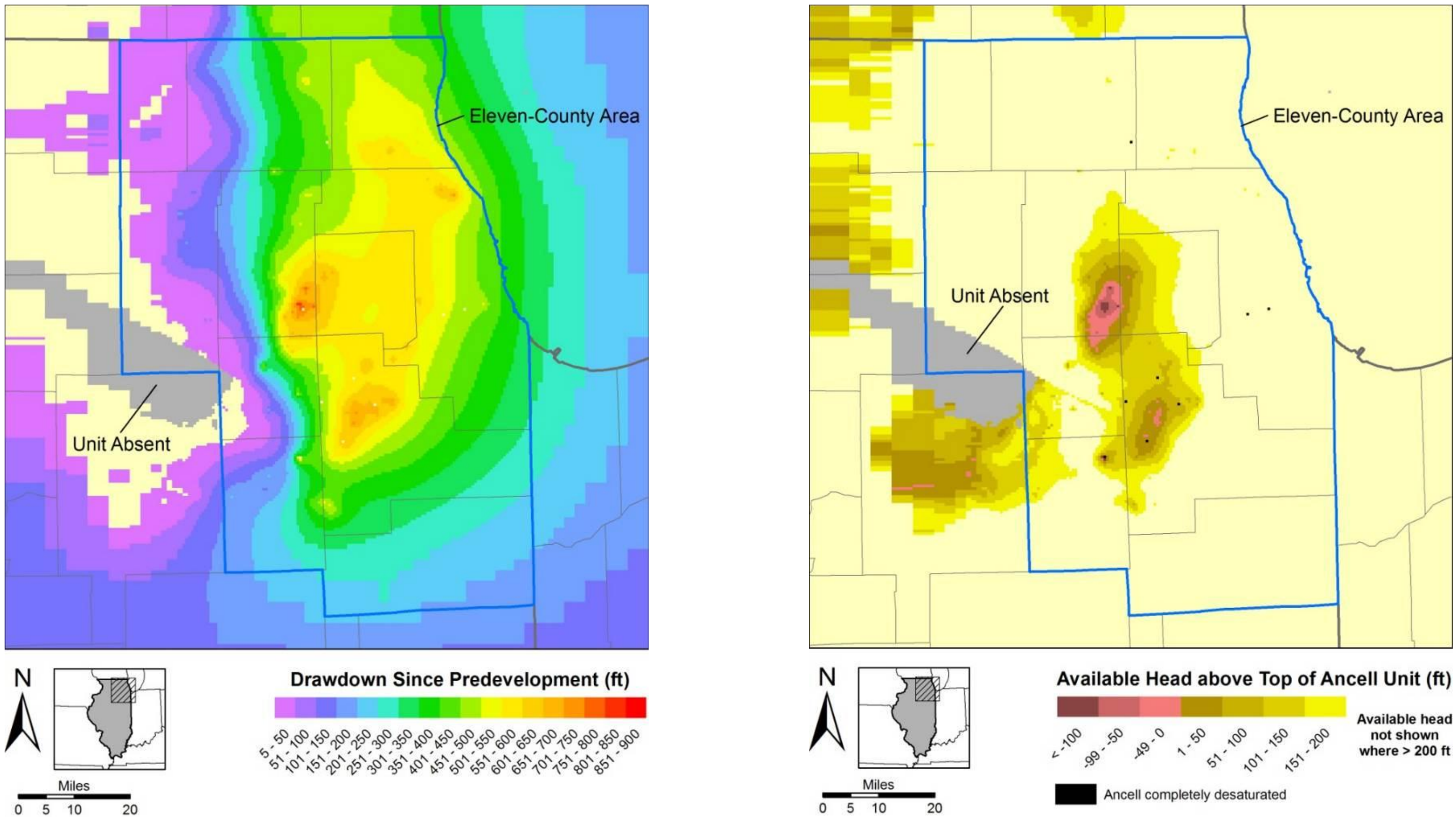

Figure ES-11. Simulated drawdown in the Ancell Unit (left), and available simulated Ancell Unit head above the top of Ancell Unit (right), end of the 2050 summer irrigation season, BL scenario. Available head is not shaded where greater than 200 feet.

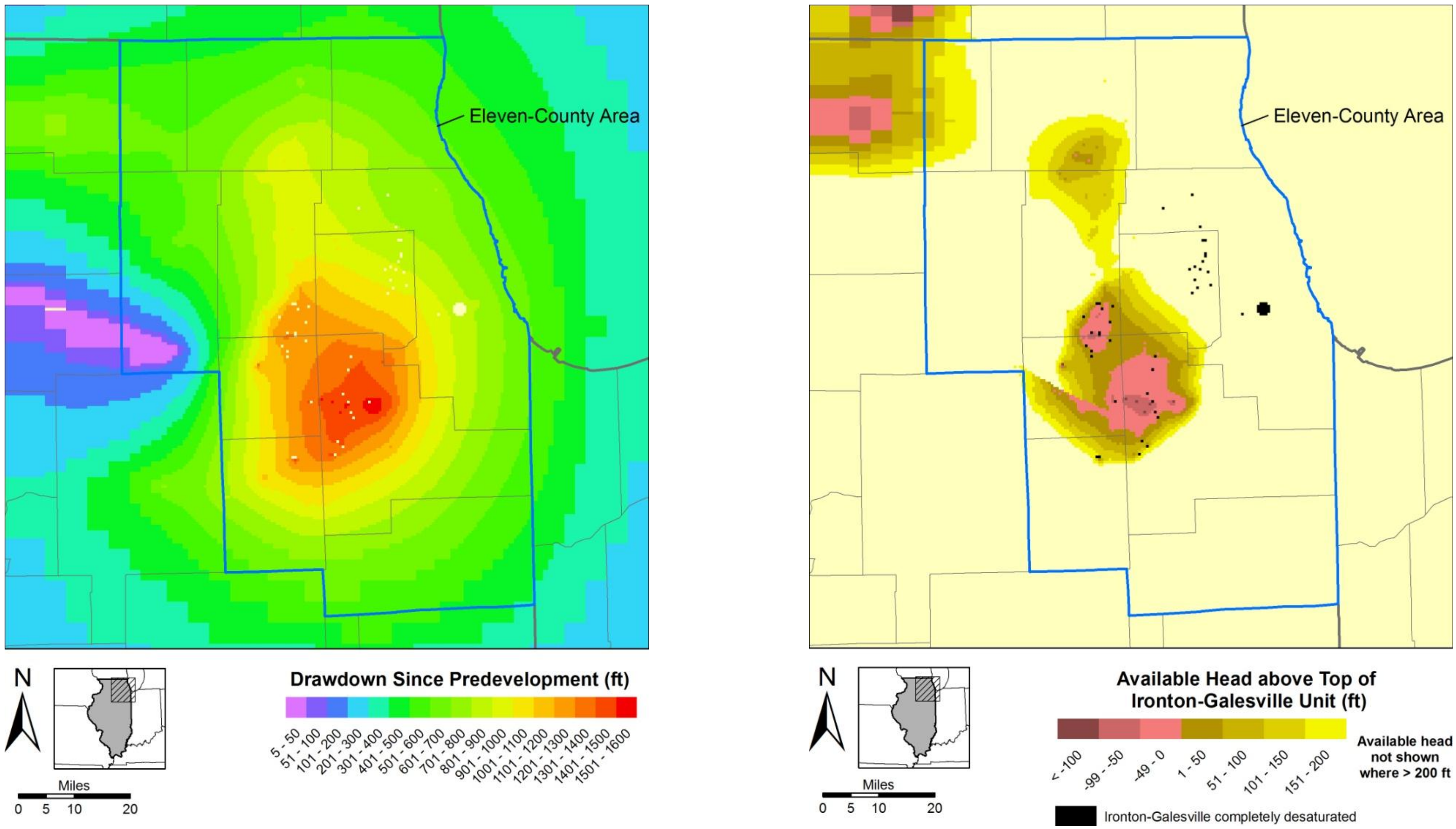

Figure ES-12. Simulated drawdown in the Ironton-Galesville Unit (left) and available simulated Ironton-Galesville Unit head above the Ironton-Galesville Unit (right), end of the 2050 summer irrigation season, BL scenario. Available head is not shaded where greater than 200 feet.

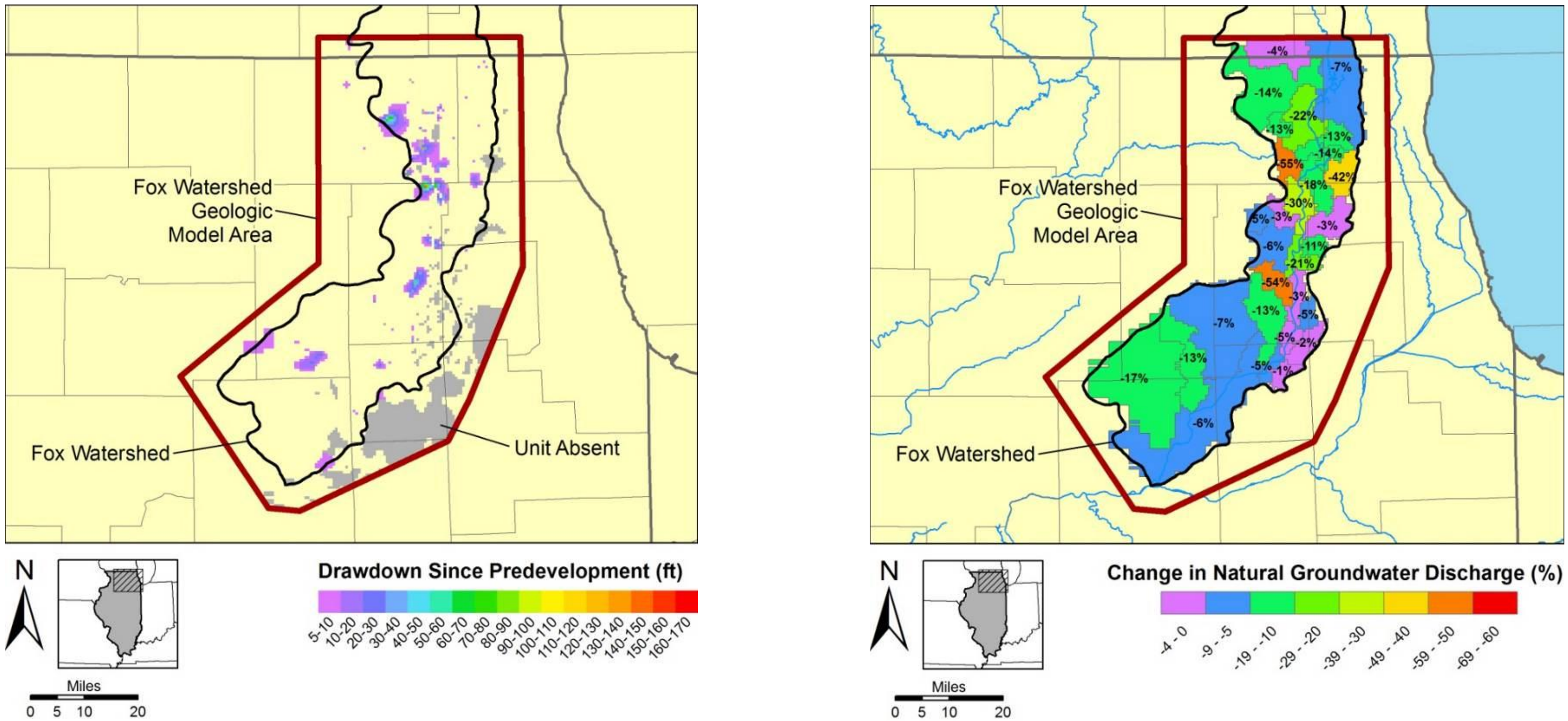

Figure ES-13. Simulated drawdown in Quaternary Coarse-Grained Unit 2 in the Fox Watershed Geologic Model Area (end of the 2050 summer irrigation season, BL scenario) (left) and change in simulated natural groundwater discharge in the Fox watershed caused by pumping (predevelopment to 2050, BL scenario) (right)

7 Project Summary

The authors conducted an analysis of the impacts of increased water withdrawals to meet prescribed scenarios of water demand to the year 2050 for an 11-county area of northeastern Illinois that includes Boone, Cook, DeKalb, DuPage, Grundy, Kane, Kankakee, Kendall, Lake, McHenry, and Will Counties. Excluding once-through flows for electric power generation, the region may require an additional 106 to 946 Mgd above the estimated 2005 withdrawal, adjusted to average 1971-2000 climate, of 1482 Mgd, an increase of 7 to 64 percent. Sources of water investigated for this study include Lake Michigan, the Fox River, shallow aquifers within the Fox River basin, and deep aquifers underlying the entire region. Excluded from the current analyses were other inland surface waters, most notably the Kankakee River, and shallow aquifers lying outside the Fox River basin, such as those shallow bedrock and sand/gravel aquifers supplying eastern Lake County.

The results of our analyses highlight the hydrologic cycle and the connections between atmospheric water, surface water, and groundwater maintained by natural and artificial flow processes that include precipitation, runoff, recharge, seepage, pumping, and effluent discharge. Under natural conditions, the flows of water within the hydrologic cycle exist in equilibrium over the long term, but human alterations inevitably and unavoidably result in a shift toward a new equilibrium that includes artificial flows such as pumping, conveyance of water through pipe networks, and effluent discharge. A major challenge of water resource management lies in characterizing and maintaining an optimal equilibrium that acknowledges the entire hydrologic cycle and the inevitable alterations to it that are imposed by the human population. Such alterations abound in northeastern Illinois, as do the opportunities and challenges presented by them. In the Fox River watershed, for example, groundwater that is withdrawn for public water system use is typically discharged as treated effluent to the Fox River, providing additional water for downstream public water system use and offsetting reductions, caused by groundwater withdrawals, in natural discharge of groundwater to surface waters. The effluent is discharged at points, however, rather than in the diffuse fashion typical of natural groundwater discharge, and, though treated, its chemistry differs from that of natural groundwater. Management of the effluent with the goal of maintaining native riparian habitats that are dependent on natural groundwater discharge thus becomes a challenge.

Although these studies do not include economic analysis of costs and benefits of the decisions underpinning a carefully considered water resource management plan, they offer insight to the hydrologic effects of likely scenarios of water-resources development in northeastern Illinois, offer a framework for future hydrologic and economic studies, and provide a rational basis for formulation of initial management policy. The authors offer the following summary observations.

Lake Michigan, which provided about 85 percent of all water used for public water systems in 2005 (1,063 Mgd), will probably continue to supply most of the region's water to 2050. Analysis using assumed and historical values for lake diversion components suggests Lake Michigan can continue to meet additional public supply demand or contribute to a water bank, the total diversion exceeding the 3,200 cfs (2,068 Mgd) limit, decreed by the U.S. Supreme Court, only in the final years under the MRI scenario. However, assumed values employed in the analysis, which are based on historical averages, may not be representative of future decades. Under the MRI scenario, Illinois' total diversion exceeds the Court limit by about 30 Mgd in 2050, but it is 145 Mgd below the Court limit under the BL scenario. IDNR believes that Illinois' Lake Michigan water allocation program can remain in compliance with the Court decree and still accommodate an increase of 50 to 75 Mgd in domestic water supply allocation without major policy changes in diversion management (while also continuing to accommodate the growing water demand within the current Lake Michigan service area). This additional supply could accommodate higher than expected demand within the existing Lake Michigan service area or expansion of the service area.

Although the Fox River supplies water to only two public water systems, those of Elgin and Aurora, effluent discharges to the Fox will continue to grow in proportion to community growth (and concomitant increases in water use) throughout the Fox River watershed. Our analysis suggests that, depending on the demand scenario, the Fox River could accommodate projected 2050 demand by Elgin and Aurora as well as 14 to 58 Mgd in additional withdrawals, assuming that IDNR fixes the protected low-flow level at approximately its current value so that it does not continue to increase with increasing effluent discharge. Further analysis of simulated low-flow reductions caused by shallow groundwater pumping is needed to assess whether such reductions would conflict with new points of river withdrawals. If captured streamflow is returned to the Fox River as effluent, however, the overall impact to Fox River water availability is probably minimal.

In general, regional groundwater flow model simulations show that drawdown in the deep bedrock aquifers is much greater than in the shallow aquifers, this difference reflecting the availability of replacement water to the aquifers—i.e., water entering the aquifers to replace groundwater withdrawn through wells. In northeastern Illinois, relatively impermeable confining units overlie the deep aquifers and greatly limit leakage into the aquifers from above, so replacement water to these aquifers is derived principally by slow lateral movement from north-central Illinois, where the relatively impermeable cover is absent. In contrast, low-permeability materials permit greater flow of replacement water into the shallow aquifers (both from adjacent aquifers and through streamflow capture), and drawdown in these aquifers is thus offset.

Computer simulation of plausible scenarios of future pumping suggests that significant additional drawdown, reduction in stream base flow, and changes in the quality of groundwater withdrawn from deep wells are all possible in parts of the 11-county study area before 2050. Regional model simulations suggest heads will continue to recover to a limited degree in eastern parts of northeastern Illinois, where many water systems abandoned deep wells in the 1980s and 1990s. The combination of continued head declines in the Joliet - Aurora area and continued head recovery in Cook and DuPage Counties shifts the deepest parts of the Chicago area cone of depression west-southwest to the Joliet - Aurora area. Modeling suggests limited areas of partial to complete desaturation (draining of pore spaces) of the Ancell Unit by 2050. Deep wells in the areas where the Ancell Unit head is near to the top of the Ancell, and where the Ancell Unit is partially desaturated, may be vulnerable to increases in arsenic, barium, and radium concentrations that, left untreated, may be harmful to human health. Partial desaturation of the Ancell Unit will also lead to decline in well yield and increasing pumping expenses. Modeling also suggests desaturation of portions of the Ironton-

Galesville may occur before 2050, which would contribute to further declines in well yields and increases in pumping costs.

Even with model uncertainties, these results, together with historical experience, suggest that demand assigned to the deep aquifers under the assumptions of this study will, over time, have severe impacts. Projected withdrawals from the deep aquifers in 2050 in the 11-county area total 197 and 251 Mgd under the BL and MRI scenarios, respectively. These rates are higher than the area's peak historical withdrawal rate from the deep aquifers of about 190 Mgd, a rate known to produce undesirable impacts (rapidly falling heads and deteriorating water quality in some deep wells). The model simulations, which terminate in 2050, suggest that the assigned withdrawals under all scenarios result in some degree of mining of the deep aquifers. *Groundwater mining* refers to withdrawal of groundwater at rates exceeding rates of movement of replacement water to the locations of the withdrawals, either by leakage or by lateral flow, and it results in continued drawdown in the mined aquifer. Mining can continue, but doing so limits the future viability of the deep aquifers, because eventually the cost of constructing and operating a deep well will exceed benefits derived in the form of a usable water supply. Future research in support of water supply planning in northeastern Illinois might be directed toward identifying areas of mining, determining when the mined aquifers cannot yield groundwater economically to accommodate forecasted pumping, developing revised pumping forecasts that extend aquifer and well viability, and providing guidance to water systems seeking to shift from dependence on a mined aquifer to a source having greater long-term viability.

In general, model simulations show that drawdown in the shallow aquifers is much more scattered and of lesser magnitude than in the deep aquifers. However, pumping from shallow aquifers has the effect of reducing discharge to wetlands and surface waters. Model analysis suggests that natural groundwater discharge to streams in the Illinois portion of the Fox River basin declined by 10 percent from predevelopment rates to 2005, and may decline as much as 14 percent basin-wide under the 2050 MRI scenario, reflecting increased pumping of shallow groundwater in the basin.

The results of this study should be viewed with some optimism. This analysis suggests that the Fox River and Lake Michigan can accommodate demand from existing public water system recipients in Elgin, Aurora, and the Lake Michigan service area to 2050 and that additional water is available from both sources to satisfy demand elsewhere. Water may also be available from other inland water sources not examined for this study (e.g., the Kankakee River and shallow aquifers outside the Fox River basin), and these resources should be scientifically assessed in further studies. The present study identifies locations of potential water shortages that, with planning, can be offset by shifting demand to other sources and/or by reducing demand through such approaches as water conservation and reuse. Moreover, the present study has developed modeling tools and approaches that can be employed to simulate a range of alternative demand scenarios in support of an ongoing water supply planning effort in the region. There is time (from 10 to 30 years depending on the community) to pursue source and management alternatives, but since major construction projects and regional management plans take time to implement, planners should act now.

8 Reference

Dziegielewski, B. and F.J. Chowdhury. 2008. *Regional Water Demand Scenarios for Northeastern Illinois: 2005-2050*. Project completion report prepared for the Chicago Metropolitan Agency for planning. Department of Geography and Environmental Resources, Southern Illinois University, http://www.cmap.illinois.gov/WorkArea/showcontent.aspx?id=10294 (accessed August 20, 2009).