APPENDIX 1

East-Central Illinois in Perspective

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Introduction

One reason for developing regional water supply plans is recognition of the diversity of environmental, social and economic conditions across Illinois. Agricultural East-Central Illinois, for example, is very different from the Chicago Metropolitan Area. Therefore, an underlying philosophy of this planning project involves making water supply plans for distinct geographic and hydrographic regions rather than applying a single statewide, "one-solution-fits-all" approach.

Water supplies are drawn from aquifers and from streams, reservoirs and lakes that occur within watersheds or river basins. In all regions, aquifers do not coincide with river basins, and neither aquifers nor river basins coincide with county boundaries. In the 15-county region of East-Central Illinois focus is on the Mahomet Aquifer System and the major river basins; the Mahomet Aquifer System includes the Mahomet Aquifer and the overlying shallow aquifers within the boundary of the Mahomet Bedrock Valley. There is considerable internal homogeneity within the region, but also considerable sub-regional diversity that needs to be considered in developing a regional water supply management plan.

This appendix describes geographical characteristics of East-Central Illinois that are relevant to water supply planning, focusing on groundwater resources. It also includes a summary of regional water use and water supply developments and issues in Champaign, McLean, Mason and Tazewell Counties to illustrate some important reasons for selecting East-Central Illinois as a priority water quantity planning area for the present study and necessary future investigations.

Geography of East-Central Illinois

The total area of the 15-county region is 6,394,936 acres (9,992 square miles) with a population of 1,033,772 in 2000. Average population density was 103.4 persons per square mile. Population ranged from 188,951 in Sangamon County to only 12,486 in Menard County. There were 8 communities with population greater than 30,000: Springfield, Champaign, Urbana, Decatur, Pekin, Bloomington, Normal and Danville [1]. The population of 1,033,772 in 2000 and the projected population of 1,221,729 in 2030[1] are far short of the population of 1,605,000 projected for the 15-county region in 2020 in the 1967 state water plan[2]. This illustrates the difficulties in projecting future population and water demand accurately.

The region is a glaciated plain formed by the last two continental ice sheets to enter the state. It is a terrain of near-level and slightly undulating surfaces rippled at intervals by nearly concentric curving lines of low hills – the glacial moraines that characterize the landscape of northeastern Illinois. Its western edge – the sandy dune lands of the Havana Lowlands in Mason and southern Tazewell Counties – is a wide, long floodplain scoured flat during the last glacial episode by a torrent of glacial meltwater descending the Illinois Valley. Elevations range from over 900 feet in southeast McLean County to less than 500 feet along the lower Sangamon River.

Present day surface drainage follows the south and westward courses cut by the meltwater streams draining off the ice fields into the tributaries and main valleys of the Illinois and Wabash Rivers. For the most part, the better drained lands are found in the older, more eroded glacial plain south and west of the Shelbyville Moraine. Behind (east of) the Shelbyville Moraine on the younger glacial plain, drainage was ponded in many local sags, depressions and glacial-like basins until the state's drainage laws were enacted in 1879. In the ensuing 30 years, most agricultural lands were tiled and ditched. Minor natural streams involved in these systems were straightened and deepened. The total effect has been to lower the water table generally and to hasten runoff, greatly affecting the recharge of shallow aquifers and stream regimens.

Land use in the 15-county region of East-Central Illinois is predominantly agricultural with corn and soybeans the main crops. Total harvested cropland in 2002 was 5,249,516 acres – 82.1 percent of the region – of which 150,880 acres, or 2.4 percent, were irrigated, mainly in Mason and Tazewell Counties[1].

The water resources, economy and society of the region are strongly influenced by climate and geology.

Underlying the region are layers of ancient bedrock millions of years old. In a few parts of the region, dolomite and sandstone yield potable water to wells. The bedrock is largely covered by many layers of mud, sand, and gravel as much as 400 feet thick. These beds were laid down by glaciers, streams, and wind, largely during and after the advances and retreats of three continental ice sheets. Gaining an understanding of the distribution and nature of glacial, proglacial and wind-borne materials provides the basis for understanding the major aquifers, streams, landscapes, and soils of the region[3,4]. The soils are some of the richest agricultural soils in the world and support high yields.

The Mahomet Aquifer extends across the region from the Indiana border to the Illinois River, ranges from 8 to more than 14 miles wide, and is complex in nature[4] (Figure 1 and 1.1). A simplified conceptual model shown in Figure 1.1. is the basis for the groundwater flow model of the Mahomet Aquifer System. This conceptual model is in turn a simplification of the hydrogeologic conceptual model of the region that is, in turn, a simplification of the geologic conceptual model of the region. This series of models represents the process of simplifying the complexities of the deposits in order to make the groundwater flow model more manageable.

The average thickness of the coarse-grained sand-and-gravel deposit that constitutes the Mahomet Aquifer is about 100 feet. It is buried about 100-200 feet below the surface in the eastern and central parts of the region, where smaller sand and gravel bodies – minor aquifers, younger in age – lie above it and occasionally intersect it. More often several layers of fine-grained glacial till – gravelly, silt and clay muds – separate the Mahomet Aquifer from those above it[4]. Water moves/seeps very slowly through these fine-grained, compacted layers, and so they act as confining layers, slowing recharge to the Mahomet Aquifer and protecting it from surface pollution and the effects of climate variability.

The Mahomet Aquifer rests upon the surface and sides/walls of the underlying bedrock valley system.

Especially in the eastern and central parts of the Mahomet Aquifer, the groundwater it contains generally is 3,000 to 10,000 years. Scientists who determined the water ages reported that "Rain and snow that falls on the surface in Champaign County begins a roughly 3,000-year journey downwards to the Mahomet Aquifer, traveling at an average rate of less than an inch a year. Once it reaches the aquifer, it travels laterally in every compass direction but south. After about 7,000 years, water that journeyed westward seeps into the Illinois River along the river bottom near Havana, Illinois"[4]. Such were the natural predevelopment conditions, but these have been modified by groundwater development. It takes much longer to replace water taken out of storage from the more deeply buried, till-confined parts of the Mahomet Aquifer than it does to replace water withdrawn from surface waters and shallow unconfined aquifers.

In the Havana Lowlands in Mason and Tazewell counties, there are no confining layers of silt and clay covering the aquifer to impede the infiltration of precipitation. The aquifer's sands and gravels outcrop at the surface and this part of the Mahomet Aquifer system is an unconfined aquifer where recharge is direct and fast. These characteristics are the reasons why there is much crop irrigation in Mason and Tazewell Counties: the low water-holding capacity of the sandy soils makes irrigation beneficial and facilitates faster groundwater recharge.

Recharge to the Mahomet Aquifer in the eastern and central parts of the planning region generally is limited by the low permeabilities of overlying clay and silt beds – the confining layer(s). Where there are direct connections – overlapping contacts – between the Mahomet Aquifer and overlying shallow aquifers, recharge can be greater. Not all aquifer interconnections have been found, but they have been discovered to occur in several areas, such as is southwestern McLean County and along the Sangamon River in Piatt County. These have large effects on the flow patterns in the Mahomet Aquifer[5,6].

The second major source of potential recharge to the Mahomet Aquifer is leakage from streams that cut down into the Mahomet sands or into shallow sand bodies at or near their connections to the underlying Mahomet Sand. However, the reaches of streams and rivers where water can be induced into the groundwater system by pumping wells are generally limited. Stretches of three streams – Sugar Creek near McLean, the Sangamon River at Allerton Park, and the Middle Fork of the Vermilion River southeast of Paxton – have potential to leak large amounts of water into the aquifer. Other large streams such as the Illinois River, the Mackinaw River, and the lower Sangamon River flow in channels cut into the aquifer and serve primarily as groundwater discharge points.

The impacts of groundwater withdrawals and waste-water discharges on streamflow must be taken into consideration[5,6]. Groundwater discharges can help maintain low flows in receiving streams: Champaign-Urbana, for example, discharges treated waste water to the Salt Fork and the Kaskaskia River.

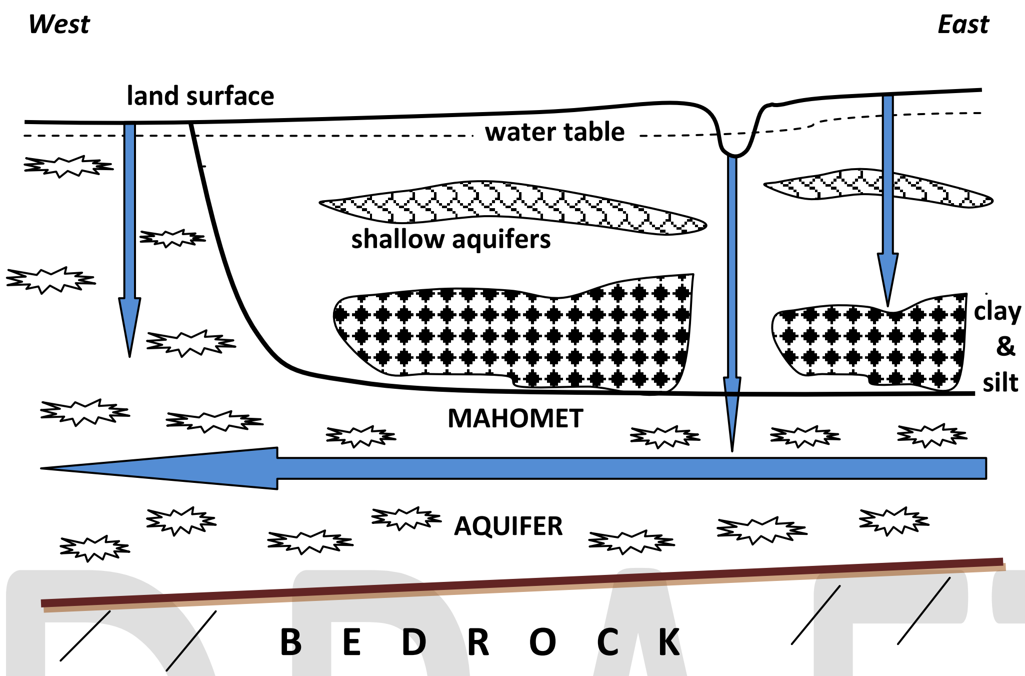

Figure 1.1. Schematic diagram of the Mahomet Aquifer System. TO BE REPLACED

The water tables in shallow unconfined aquifers typically are highest in March and typically fall about 3.5 feet through autumn due to increased evapotranspiration and reduced recharge[7]. Similarly, streamflow in late summer typically is about 60 percent lower than in spring[7]. Changes in water levels caused by pumping water from aquifers and surface waters, discharging water to surface waters, and year-to-year climate variations are superimposed on this natural seasonal variability. In shallow, unconfined aquifers water levels typically have a range of about 5 feet or more from wet years to dry years (e.g., Snicarte in Figure 3).

The Mahomet Aquifer is one of the largest groundwater resources of the state.

Streams, reservoirs and lakes are other major source of water supply, especially for Springfield, Decatur, Bloomington, Danville and the nuclear power plant at Clinton. The region includes the Sangamon River Basin and parts of the Kaskaskia, Mackinaw, Vermilion (Wabash Basin), Vermilion (Illinois Basin), Embarras, Wabash and Iroquois River Basins. Because the land is quite flat and there are no deep river valleys, suitable sites for large reservoirs are limited, especially in headwater areas in the eastern half of the region.

The Sangamon River basin drains about 5,448 square miles in central Illinois (see Figure 1). The river is about 250 miles long and its watershed represents about 10 percent of the land area of the state. The basin is triangular in shape with a major east-west axis of about 120 miles and a minor north-south axis of about 90 miles. Drainage is generally from east to west. Land-surface elevation in the basin ranges from about 430 feet above mean sea level at the confluence of the Sangamon and Illinois Rivers at Browning to almost 930 feet at the crest of the Bloomington Moraine in McLean County. Major tributaries to the Sangamon River are Salt Creek (1,803 square miles) and the South Fork (1,180 square miles)[8].

Major parts of the Sangamon River Basin overlie the Mahomet Aquifer and there are important natural hydraulic connections between surface waters and groundwater. These connections are important from both a water quantity and water quality standpoint and are important considerations for water supply planning and management.. Also, there are important man-made connections between surface water and groundwater withdrawals: for example, the well field in DeWitt County operated by Decatur is used sporadically to supplement the water supply from Lake Decatur; LyondellBasell occasionally pumps groundwater from the Mahomet Aquifer near Bondville to supplement the surface water flow in the Kaskaskia River. Because of these hydraulic connections, groundwater withdrawn from the aquifers and discharges of treated and untreated groundwater can result in changes in streamflow.

Climate in the region typically is continental with cold winters, warm summers, and frequent fluctuations in temperature, precipitation, humidity, cloudiness, and wind. Average climatic conditions conceal large monthly, annual and decadal variations to which major businesses are highly sensitive[9,10,11].

Average annual temperature is about 51 degrees Fahrenheit (^{o}F) in the north and 53^{o}F in the south. Average winter highs are in the 30s and average summer highs in the 80s. Days with sub-zero temperature occur occasionally in winter and days above 100^{o}F occur occasionally in summer. The average length of the growing season ranges from about 175 days in the north to 185 days in the south[9].

Average annual precipitation is about 40 inches per year in the east and south and 36 inches in the west. The highest annual precipitation recorded is over 50 inches, but it falls to less than 25 inches in a drought year. Multiple-year droughts have occurred, especially in the first 60 years of the 20th Century, and have had major effects on water availability and water demand[10,11]. High temperature and low precipitation typically diminish streamflow and the amount of water in lakes, reservoirs and shallow aquifers. Water availability in the deeper confined portions of the Mahomet Aquifer is thought to be much more resistant to climatic variations[5,6]. During hot and dry periods the demand for water from all sources increases.

Climate in Illinois has changed in the past due to natural factors and no doubt will do so again in the future. Future climatic conditions are highly uncertain due to natural variability and the possibility of human-induced climate change. Most global climate models suggest that average annual temperature in Illinois could increase by 0 to 6 degrees F (^{o}F) by 2050. However, climate models are quite inconsistent in their projections of future precipitation in Illinois: some models show higher precipitation, and some show lower precipitation. Even in the absence of human-induced climate change, severe droughts are likely to recur from time-to-time[10,11].

There are high concentrations of naturally occurring arsenic in some parts of the Mahomet Aquifer and the water tends to be “hard” (i.e., high concentrations of minerals)[4] . Water in streams, reservoirs and shallow aquifers is more susceptible to pollution and high concentrations of nitrate exceeding the drinking water standard occur occasionally in untreated water. All public water supplies must meet federal and state water quality standards, but private domestic supplies are unregulated.

Regional water withdrawals and use

The Illinois Water Inventory Program at the Illinois State Water Survey is a voluntary program to inventory water withdrawals throughout the state and was begun in 1978. For each water-using facility inventoried, the database includes locations and amounts of water withdrawn from surface water and groundwater sources, as well as significant amounts of water purchased from other facilities. Return flows are not subtracted from the withdrawal to determine water use; however, facilities with significant return flow are flagged for data retrieval to determine consumption. Agricultural uses of water for row-crop irrigation are not significantly tracked for a number of reasons, one being the lack of meters on irrigation wells. Livestock water use is similarly limited, while rural domestic uses are not inventoried. Water withdrawn for row-crop irrigation can be estimated from county-irrigated acreages and precipitation deficits. For the 2005 inventory, 89 percent of the questionnaires were returned and estimates were made to fill data gaps; the percentage of questionnaires returned for the 2008 inventory could be as high, but ultimately depends on the number of staff available to follow up on non-reporters. Data can be summarized geographically by county, township, and drainage basin, as well as by various water use and water source categories for inclusion in the National Water Information System[12]. Funding for the Illinois Water Inventory Program is unstable and its future in question.

An accurate and complete inventory of water withdrawals would provide a solid foundation for many applications, but an inventory of current withdrawals is only one factor in determining future water withdrawals. The inherent inability to predict future withdrawals accurately is due mainly to the large uncertainties and assumptions that have to be made about economic, demographic, social and climatic factors that drive water demand.

In total, about 1,783 million gallons per day (mgd) were withdrawn from groundwater and surface water in the region in 2005 and used for domestic, commercial, agricultural, industrial and recreational purposes. Seventy four percent (1,315 mgd) was used for thermoelectric power generation and 26 percent (468 mgd) for public and domestic supplies, irrigation, agriculture, commerce and industry. The irrigation and agriculture figure included 226.5 mgd of water for crop irrigation, 2.4 mgd for irrigating 72 golf courses, and 4.2 mgd for watering a total of 785,410 dairy cows, beef cattle, hogs, horses, sheep and chickens[1].

The reported and estimated 468 mgd withdrawn for public and domestic supplies, commerce and industry, and irrigation and agriculture in 2005, a drought year, slightly exceeded the 1967 state water plan's projection of 453 mgd water demand for the 15 counties in 2020[2].

In 2005, some 947,000 people were served by public water supplies in the region and public water supply withdrawals were about 140 mgd. The Bloomington, Decatur, Springfield, Ashland and Danville service areas rely on surface waters and the remaining communities rely on groundwater. On average, each person served by public water supplies used 145 gallons of water per day, ranging from a high of 288 gallons in Decatur and 220 gallons in Beardstown to as little as 50 gallons per day in residual Menard County and 58 gallons per day in residual Vermilion County[1]. This range reflects variations in personal water use and the amount of water used for commercial and industrial purposes in each community [note: Decatur and Beardstown have large industrial facilities].

Many larger utilities supply water to communities within a service area. Some communities outside the Mahomet Aquifer are served by water pumped from the Mahomet Aquifer. Arcola, Tuscola and other communities to the east and south of Champaign, for example, are served with water pumped from Illinois American Water's wells near Champaign. LyondellBassell and Cabot Corporation in Tuscola occasionally use water pumped from the Mahomet Aquifer near Bondville that is transported south via the Kaskaskia River. The new ethanol plant at Gibson City will receive water pumped from the Mahomet aquifer near Paxton. Decatur has emergency wells in the Mahomet Aquifer in DeWitt County.

Within the region, an estimated 108,076 people obtained water from self-supplied domestic sources, mainly shallow wells, and used an estimated average of about 82 gallons per person per day for a total of 8.9 mgd[1].

Wittman Hydro Planning Associates, Inc. identified a number of factors to account for the historical changes in water withdrawals in the region[1]. The most important factor was population: more people use more water. But, as has been shown, the amount of water used per person varies considerably when commercial and industrial uses are included. Weather and climatic conditions, especially air temperature and precipitation, also have strong influences on overall per capita water use. Other major factors influencing water use are employment, income, the price of water, industrial processes, and conservation. Wittman Hydro Planning Associates, Inc. uses all these factors to construct scenarios of future water demand.

From 1985 to 2005 the population served by public water supplies in the region increased by about 106,000, or about 13 percent, and the amount of water used by the average person increased by about 11 percent[1]. Thus, the 25 percent increase in public water supplies of about 27 mgd could be accounted for by an increase in the number of people and an increase in the amount of water used by the average person.

The price of water is reported[1] to influence how much water is used in the region: the average person tends to use more water if it costs less, and *vice versa*. In 2005, the marginal price of water [defined as the difference in the total water bill between 5,000 and 6,000 gallons of monthly usage] ranged from a low as $0.85 in Watseka in Iroquois County to a high of $6.40 in Hudson in McLean County. The average marginal price across the region was $2.81, which declined slightly from $3.02 in 1985[1]. Thus, the slight decline in the price of water probably was one of the factors accounting for an increase in the amount of water used per person.

Family income also is reported[1] to influence water demand. Generally, the demand for water increases as income increases, and *vice versa*. In 2005, median family income in the region was $44,578, which in real dollars had increased from $42,781 in 1985[1]. Therefore, another factor accounting for the increase in the amount of water used by the average person since 1985 probably was an increase in family income.

Climatic conditions also have influenced water demand historically[1]. Especially in 2005, hot conditions throughout the region and drought, especially in the western counties, resulted in increased water withdrawals. Regional water withdrawals in 2005 (excluding water for electric power production) were about 130 mgd greater than they would have been in a non-drought year, and most of the increase was for irrigation. Peak day withdrawals for public water supplies typically are 50-100 percent greater than annual average day withdrawals. For irrigation, peak day withdrawals can be 700 percent greater than annual average day withdrawals.

The demand for water for residential, commercial and industrial purposes continues to increase. Some of the increasing water demand is to meet the needs of an increasing number of residents in the

15-county region and some is to meet the needs of people in other parts of the state, nation and world for water-consuming goods produced in East-Central Illinois; for example, large quantities of electricity, agricultural goods, processed food, and ethanol produced in the region are “exported”. Assuming that these exports will continue, this means that the future demand for water in the region must take into account East-Central Illinois’ role in meeting external demands for the region’s products, as well as the needs of the residents of the region.

Some water supply operators already have recognized the need to expand capacities for various reasons that include increasing water storage to be prepared for future droughts, increasing pumping capacity to meet growing peak day demands, and expanding water treatment facilities. Illinois American Water recently developed a new regional well field and expanded its water treatment capacity. Springfield and Decatur are seeking to expand their public water supplies and options include expanding reservoir capacities and withdrawing water from the Mahomet Aquifer, shallow aquifers and gravel pits. Bloomington also is evaluating a possible new regional well field in the Mahomet Aquifer. In the past few years, water withdrawals for irrigation have increased dramatically, in part due to the drought of 2005. New industrial plants, if built, would use additional amounts of water.

Population in the 15-county region of East-Central Illinois is expected to increase from 1.03 million in 2000 to 1.34 million in 2050 – a 30 percent increase[1]. By varying the values of some factors that change the average amount of water withdrawn by each person and including the impacts of drought and possible climate change, it is calculated, using data in the Wittman Hydro Planning Associates, Inc. report[1], that water withdrawals in the region (excluding electric power generation) could increase by 220 to 420 million gallons per day more than 2005 withdrawals of about 340 million gallons per day (adjusted to normal weather). This range of increase would be about 100 to 300 mgd above 2005 reported withdrawals of about 460 mgd, which was a drought year in parts of the region. Additional large withdrawals will be needed to meet peak season and peak day demands.

Using data in the Wittman Hydro Planning Associates, Inc. report[1], total water withdrawals for the 15-county region in 2005 and for three scenarios to 2050 are shown in Figure 1.2. – under normal (1971-2000) weather conditions and excluding water withdrawals for the electric power generation sector. Increased water withdrawals with drought conditions in 2050 for the Baseline (BL) scenario also are shown.

The BL scenario is a business-as-usual scenario. The Less Resource Intensive (LRI) scenario assumes less water demand and the More Resource Intensive (MRI) scenario assumes an increase in water demand. Population growth and the percentage of population employed are the same in all three scenarios.

The three public water supply factors whose values are varied in the scenarios are family income, water price and conservation. Family income is assumed to grow at 0.5 percent per year (in real dollars) in the LRI scenario and 1.0 percent per year in the MRI scenario. The price of water is assumed to increase at 1.5 percent per year (in real dollars) in the LRI scenario and is assumed to be constant in the MRI scenario. A combination of lower family income, higher water price, and more conservation in the LRI scenario lead to lower water demand. In the MR scenario, a combination of higher family income, constant water price, and less conservation lead to higher water demand

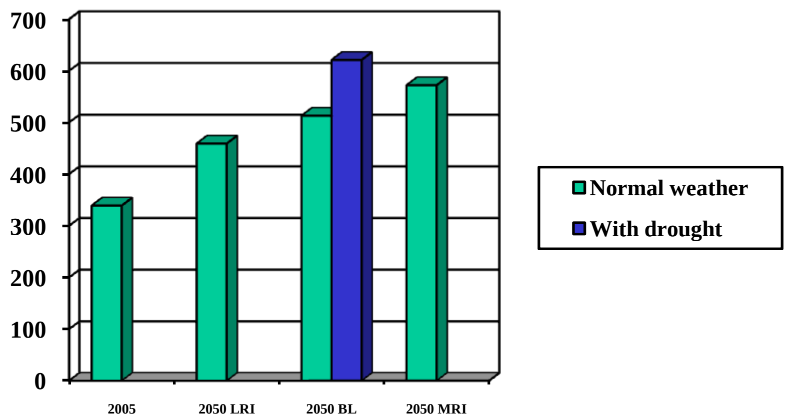

Figure 1.2. Water withdrawals (mgd) in East-Central Illinois in 2005, in 2050 for three scenarios (under normal weather conditions), and with drought conditions for the BL scenario.

In the self-supplied industrial and commercial sector, increasing water demand from the LRI to the MRI scenario is driven primarily by assumptions that the number of new water-intensive industries will increase, water use will be less efficient, and there will be less conservation. In all three scenarios, it is assumed that growth in health services will outpace retail trade growth and manufacturing will decline.

The major assumption accounting for increasing water demand from the LRI to the MRI scenario in the self-supplied irrigation and agriculture sector is a faster growth in irrigated cropland and golf course acres.

Total water withdrawals for each of the 15 counties in East-Central Illinois in 2005 (adjusted to normal weather conditions) and in 2050 are shown in Table 1 (excluding electric power generation). In 2005, 84 percent of total withdrawals occurred in Champaign, Macon, Mason, McLean, Sangamon and Tazewell counties. This percentage remains virtually unchanged in the three scenarios to 2050.

Using data in the Wittman Hydro Planning Associates Inc. report[1], total water withdrawals by water use sector are shown in Figure 1.3. for 2005 and for three scenarios to 2050 with normal weather conditions.

For electric power generation, it is assumed that future water withdrawals will continue to be from surface waters that serve six major thermoelectric power plants in DeWitt, Mason, Sangamon, Tazewell, and Vermilion Counties and a new clean-coal power plant with a closed-loop cooling system will be added in Woodford County[1]. These plants withdraw 80 percent of all water in the region, but some 98 percent of that water is recycled and returned to the source.

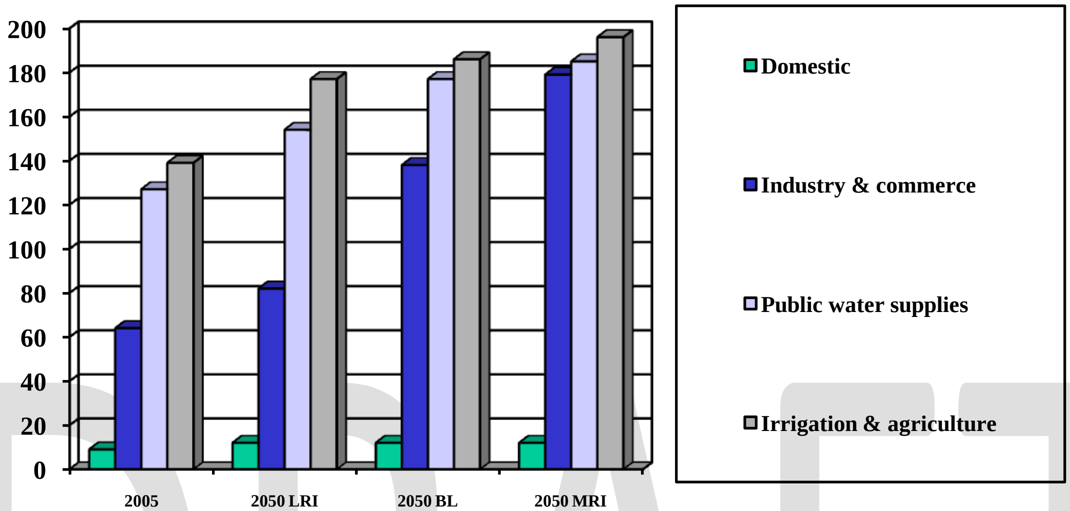

Figure 1.3. Water withdrawals in millions of gallons per day in East-Central Illinois by water use sector in 2005 and for three scenarios in 2050 (under normal weather conditions).

It is evident that many geographical, economic and social factors influence the demand for water in the region. The major variables identified that could result in a change in the average amount of water withdrawn per person each day and, hence, total water withdrawals are household income, the price of water, drought, an increase in temperature, employment and productivity, new industrial facilities, the number of irrigated acres, and water conservation. In the historical records and the scenarios water conservation is a relatively minor factor. Some of the factors – population, household income, climate, employment and productivity – are difficult to control. Water conservation and water prices are more amenable to control.

Growing water demand in Champaign and Mason and Tazewell Counties was one of the major reasons for selecting East-Central Illinois as a priority water quantity planning area. The following sections document the growing demand for water in these counties and exemplify the need for regional water supply planning.

County	2005 normal withdrawals	LRI 2050 withdrawals	BL 2050 withdrawals	MRI 2050 withdrawals
Cass	13	20	22	24
Champaign	35	46	52	57
DeWitt	2	3	3	3
Ford	5	9	10	12
Iroquois	6	8	9	10
Logan	6	8	10	10
Macon	38	51	59	68
Mason	94	111	117	125
McLean	18	26	30	32
Menard	3	4	4	4
Piatt	3	4	4	5
Sangamon	30	38	43	47
Tazewell	71	112	127	149
Vermilion	13	18	18	20
Woodford	4	6	6	6
TOTAL	**341**	**464**	**514**	**572**

Table 1.1. Total water withdrawals in millions of gallons per day (excluding electric power generation) for counties in East-Central Illinois in 2005 (adjusted to normal weather conditions) and three scenarios to 2050[1].

Water withdrawals in Champaign County

Large groundwater withdrawals at Champaign-Urbana began in 1885 when wells for a municipal supply were constructed in the shallow Glasford Aquifer. By the 1940s, water-levels in wells finished in the shallow aquifer near Champaign-Urbana had declined by 100 feet and were about 40 feet below the top of the aquifer (i.e., the aquifer was partially dewatered). Twelve municipal wells were drilled in the deeper Mahomet Aquifer between 1947 and 1964. Withdrawals from the shallow aquifer decreased and water levels in wells finished in that aquifer had increased by 55 feet in 1952, still some 45 feet below the pre-development level. In 1963 withdrawals from the Mahomet Aquifer in the Champaign-Urbana area were 17.83 mgd (9.29 mgd municipal and 8.54 mgd industrial) and water levels in wells finished in the Mahomet Aquifer had declined by 35 feet at Champaign-Urbana. Water levels in wells finished in the shallow aquifer declined by about 10 feet from 1954 to 1963. These data suggested to Visocky and Schicht that the Glasford and Mahomet Aquifers act as a single hydraulic unit under steady state conditions during periods of large groundwater withdrawals: pumping from the Mahomet Aquifer lowered water levels in both aquifers in the vicinity of the pumping[13].

In the 1960s, engineers and scientists at the Illinois State Water Survey developed an analog computer model to simulate groundwater flow in the Mahomet Aquifer System[13,14]. Withdrawals from the Mahomet Aquifer System in a 1,300 square mile area near Champaign-Urbana were stated to be 30.3 mgd (18.6 mgd municipal and 11.7 industrial). It was estimated that an additional 15.0 mgd would be needed by the year 2000, bringing total withdrawals to about 45 mgd. Predicted long-term pumping levels were calculated to further reduce water levels in the Mahomet Aquifer to the northwest of Champaign by about 30 feet and in the overlying shallower aquifer by up to 25 feet. Pumping levels for the additional wells would still be above the top of the Mahomet Aquifer.

Today, on an average day, Illinois American Water pumps some 23 mgd from the Mahomet Aquifer near Champaign to serve communities and commerce and industry in its service area, and some additional 16 mgd are withdrawn in Champaign County[1]. In 2007, water-level elevation (head) in the Petro North observation well on Rising Road, a few miles west of Champaign, was about 83 feet lower than the predevelopment (1930) water level (Figure 7, Chapter 2). The current water level is about 80 feet above the top of the aquifer at that location. The historical records indicate an average drop in water level of 1.08 feet per year since 1930.

Illinois American Water has reported that it expects the average day pumping rate will increase to 26.8 mgd in 2016, with a peak day pumping rate of 44.6 mgd[15]. The capacity of Illinois American's 21 wells in 2006 nominally was about 45 mgd[16], although operational capacity was less, perhaps around 38 mgd. Accordingly, it can be estimated that Illinois American Water needs additional average day pumping capacity of about 7 mgd by 2016.

In forward simulations, Wittman Hydro Planning Associates, Inc.[16] used an average day pumping rate for Illinois American Water of about 35 mgd in 2004, 38 mgd in 2016 and 51 mgd in 2040. Analysis was conducted on the effects of Illinois American Water pumping an additional 16 mgd by 2040 (20 mgd from a new well field near Bondville and 4 mgd reduced pumping from existing wells).

It was concluded that pumping an additional 16 mgd would lower water levels in this part of the Mahomet Aquifer an additional 40-50 feet. Conditions were considered to be sustainable as long as water levels (presumably in wells some distance away from the production wells) were predicted to remain above the top of the Mahomet Aquifer, i.e., the Mahomet Aquifer remains saturated. However, in this simulation, heads about three miles to the east of Petro North drop to the top of the aquifer and drop below the top of the aquifer in a worst-case scenario, i.e., the aquifer starts to become unsaturated, or partially dewatered. The analysis did not include additional withdrawals from the Mahomet Aquifer by other communities or industries out to 2040, or withdrawals from the Glasford Aquifer. It was recognized that increased pumping by other users would add to the drawdown caused by increased pumping of 16 mgd by Illinois American Water and "reduce the capacity of the aquifer system to yield water in the Champaign area and will exacerbate the effects of expansion of the ILAW source of supply". Also, it was concluded that "dewatering of shallow water-bearing zones will affect some local wells and will ultimately reduce the capacity of the Mahomet Aquifer due to decreased vertical leakage"[16].

Illinois American Water concluded that this level of pumping will be sustainable in Champaign County[15]. Wittman Hydro Planning Associates, Inc.[16] concluded that "the sustainability of Champaign-Urbana public water supply will likely be determined by what other people do". It should be noted that the Glasford Aquifer already is reported to be dewatered in at least one well in Champaign[17].

This brief overview illustrates evolving scientific understanding of groundwater resources and their development in Champaign County. Similar syntheses of the scientific understanding of surface water and other groundwater resources in the region would no doubt also reveal that management decisions are made utilizing the best available data at the time. The fact that data availability and analytical methods and tools change over time provides sound justification for supporting adaptive management.

The possibility of a new regional wellfield in McLean and Tazewell Counties

In 1993, with funding from the Long Range Water Plan Steering Committee, the Illinois State Water Survey and the Illinois State Geological Survey began a study of the aquifers in southwest McLean and southeast Tazewell Counties to estimate the availability of groundwater and determine the hydrogeologic feasibility of developing a regional water supply[18]. The study had two goals: (1) to determine the quantity of water a well field in the Sankoty-Mahomet Sand aquifer could yield; and (2) to determine the possible impacts to groundwater levels and existing wells that might occur in the Sankoty-Mahomet Sand aquifer and overlying aquifers from the development of a well field pumping 10-15 mgd. Hypothetical well field pumping of 15 mgd was simulated at four locations. The results varied from a maximum drawdown of 8 feet in the Hopedale scenario to 55 feet of drawdown in the Armington scenario. If a well field similar to the well fields modeled was installed in the study area, as many as 400 private wells may be impacted. In certain areas near the Mackinaw River, a well field would greatly reduce the groundwater portion of baseflow entering the Mackinaw River. Pumping three of the well fields together, at a total rate of 37.5 mgd, indicated that the aquifer should be able to sustain withdrawals in excess of 37.5 mgd, if the pumpage is distributed in the study area.

Irrigation in Mason and Tazewell Counties

In the Havana Lowlands – the sand plain underlain immediately by the unconfined aquifer in Mason and Tazewell Counties – a number of studies have been conducted to try to understand water budgets, yields and the impacts of increasing groundwater withdrawals.

Walker *et al*.[19] estimated that irrigation withdrawals for 1959 and 1960 in Mason and Tazewell Counties averaged about 0.25 mgd per year. The report indicated that long-term yield of the system was limited to recharge from precipitation. Recharge was estimated to be 10.3 inches per year for sandy soils and 2.6 to 5.7 inches per year where till overlies the aquifer. Regional recharge was estimated to be about 300 mgd on an annual average basis.

Bowman and Kimpel[20] estimated that groundwater withdrawals increased to about 106 mgd in 1989, a drought year.

The Imperial Valley Water Authority was established in 1989 to manage water in Mason County and four townships in Tazewell County. Since that time, irrigated cropland and the amount of water withdrawn for irrigation have increased greatly. In 1997, withdrawals were about 37 billion gallons during the June through September growing season (i.e., an average of 311 mgd through the growing season, or 104 mgd through the year). In 2005, a drought year, withdrawals were about 72 billion gallons (i.e., an average of 586 mgd through the growing season, or 196 mgd through the year, i.e., 65 percent of Walker *et al*.'s 300 mgd recharge estimate[19]). By 2007, withdrawals in a non-drought year had decreased to about 57 billion gallons (i.e., an average of 468 mgd through the growing season, or 156 mgd through the year). The highest monthly withdrawals of 942 mgd were in July 2005[20]. Irrigated cropland in Mason and Tazewell counties more than doubled from 76,352 acres in 1985 to 166,168 acres in 2007[1].

Historical records demonstrate declines in water levels in drought years. For the two-year period September 1995-August 1997, a total of only 53.01 inches of precipitation was recorded in the Imperial Valley area, which was less than the 55.08 inches recorded in 2004-2006, another drought period. Water level in the 42-feet deep Snicarte well did not drop below 40 feet in 1997, but the well dried out in 2006[22] and water level has since recovered[23]. The difference in water levels is perhaps due to a combination of heavier precipitation in 1992-1995 than in 2001-2004 and to 52 billion gallons of irrigation withdrawals in 1996 compared to 72 billion gallons in 2005[22].

A number of studies illustrate the complexity of understanding water budgets and the impacts of withdrawals for crop irrigation in the Havana Lowlands. Based on the development and application of a detailed numerical groundwater flow model for the sand-and-gravel aquifer, Clark [24] concluded that the Mahomet Aquifer contributed less than one percent of the total inflow to the larger aquifer system in the Havana Lowlands. Crane and Quiver Creeks and the Mackinaw River act as primary internal drainage streams, conveying more than 37 percent of the modeled outflow rising from the aquifer system. Total groundwater outflow from the aquifer system to the Illinois River was calculated to be 398 mgd: this is 33 percent greater than Walker *et al.'s*[19] calculated average annual recharge of 300 mgd and 6 percent greater than Clark's calculated recharge rate of 377 mgd. Clark estimated groundwater outflow to the Illinois River to be 20 percent of the 7-day, 10-year low flow of 1,971 mgd in the Illinois River at Beardstown. Maximum regional drawdown for the drought years of 1988 and 1989 was 8 feet and maximum regional drawdown for the simulation of two consecutive 1988 drought years (worst case simulation) was 15 feet; 14 interior half-mile stream reaches went dry. Drawdown was due to a combination of low precipitation and groundwater pumping. No data have been presented on streams going dry in drought years in the absence of irrigation pumping, or on the potential impacts on aquatic and riparian ecosystems of streams going dry.

Clark[24] also reported on earlier analysis by the Illinois State Water Survey using the Precipitation Augmentation for Crops Experiment (PACE) watershed model. For the 44 years of simulation (1950-1993), the calculated mean annual recharge rate was 9.4 to 12.6 inches for cropland in the Havana Lowlands. In 1956, a drought year, recharge was calculated to be only 1.6 inches, compared to 3.7 inches in 1988, another drought year. This demonstrates the sensitivity of recharge in the unconfined aquifer to variations in precipitation from year-to-year.

A study conducted by Sanderson and Buck in 1995[25] showed recharge rates in the range of 1.3 to 32.0 inches per year. The study concluded with the suggestion that extensive development of the groundwater resource for agricultural irrigation during the past three decades has not diminished the resource. The early 1990s was a time of high precipitation and withdrawals were much less than in recent years. The authors recommended that groundwater levels be considered during or following a significant drought period to monitor and document effects of the drought and the above average withdrawals for irrigation.

Wilson et al. recently reported on data collected from the Imperial Valley rain gauge network and groundwater observation well network for September 2005 through August 2006[22]. A purpose of the networks is to collect long-term data to determine the impacts of groundwater withdrawals in dry periods and during the growing season, and the rate at which the aquifer recharges. It was concluded that 2005-2006 groundwater levels continued to decline because of below-average precipitation. However, no methodology was presented to separate out the influences on water levels of below-average precipitation and water withdrawals.

A thorough understanding of relationships among precipitation, evapotranspiration, groundwater levels, stream flows and water withdrawals remains to be developed. Such an understanding is necessary to be able to understand the natural variability of the system and the impacts of groundwater withdrawals on streamflow and aquatic and riparian ecosystems.

The calculated recharge rates by Walker *et al*.[19] of 300 mgd and Clark[24] of 377 mgd are annual averages. However, there are strong seasonal influences upon recharge, withdrawals and lowering of water levels that available annualized averaged withdrawals do not describe. Water levels are naturally lowest in summer, when evapotranspiration is highest and recharge lowest. Water for irrigation is withdrawn only during summer. What is needed to evaluate the impacts of withdrawals and sustainable yields is for a groundwater flow model to simulate reasonably accurately the natural seasonal hydrological cycle and inter-annual drawdown of groundwater levels and streamflow due to severe drought. This will provide a control run. Seasonal irrigation withdrawals then can be added in a second model run to simulate combined drawdown due to climate variations and water withdrawals. The difference between the two model runs will allow determination of drawdown due to water withdrawals. It is likely that the greatest drawdown will be associated with peak day withdrawals in summer.

In 2005, withdrawals averaged 196 mgd – considerably less than the estimated annual average recharge rate of between 300 and 377 mgd. It is reasonable to conclude from this that such withdrawals do not exceed the annual average recharge rate and are sustainable. However, during the 2005 summer growing season withdrawals averaged 586 mgd – well above the calculated annual recharge rates – and peak day withdrawals were almost one billion gallons. So it must be asked, what is the summer recharge rate and drawdown in a more severe drought year such as 1956, and how much additional drawdown can be tolerated with heavy pumping, given the fact that the aquifer is likely to replenish itself with a return to normal precipitation?

Conclusions

The geographical information and the groundwater case studies, one in the eastern part of the region and two in the west, illustrate a diverse set of water resource conditions across a region sharing similar climate conditions. They also demonstrate why it is important to consider interactions between climate, surface water, groundwater and social, economic and environmental factors in the development of water supply management plans. Although fresh, potable water is ordinarily a renewable resource in our region, thought always must be given to the potential impacts of withdrawals and determination of sustainable yields.

Some 40 years ago, Illinois State Water Survey engineers reported that the potential yield that could be developed from the confined portion of the Mahomet Aquifer was about 445 mgd[13]. They noted that an estimated 40.2 mgd – a mere 9 percent of the potential yield – were withdrawn in 1965[13]. If Walker *et al.'s* annual average recharge estimate of about 300 mgd for the unconfined portion of the Mahomet Aquifer[19] is added to the potential yield from the confined portion of the Mahomet Aquifer, this raises the potential yield for the whole aquifer to about 745 mgd.

In 2005, a drought year in parts of the region, some 350 mgd were withdrawn from aquifers in the 15-county region[26]. The MRI scenario of water demand in 2050 under drought conditions and with an increase in temperature of 3°F suggests that groundwater withdrawals in the 15-county region could increase to more than 400 mgd.

Although the potential yield of the Mahomet Aquifer is large, withdrawals and the impacts of withdrawals are not distributed uniformly across the region. The largest withdrawals are in the unconfined portion of the Mahomet Aquifer in the Havana Lowlands, but drawdown currently is greatest in the confined aquifer in Champaign County. It is timely, therefore, to continue to evaluate the challenges and opportunities for water resources development and protection in the region.

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