DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL RESOURCES

Regional Water Demand Scenarios for Northeastern Illinois: 2005-2050

PROJECT COMPLETION REPORT

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June 15, 2008

SOUTHERN ILLINOIS UNIVERSITY CARBONDALE

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The Chicago Metropolitan Agency for Planning

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EXECUTIVE SUMMARY

Regional Water Demand Scenarios for Northeastern Illinois: 2005-2050

Purpose

This study presents future water-demand scenarios for geographical areas which encompass groundwater withdrawal points and surface water intakes in the 11-county regional planning area of Northeastern Illinois. The region under study includes the Illinois counties of Boone, Cook, DeKalb, DuPage, Kane, Kankakee, Kendall, Grundy, Lake, McHenry, and Will.

The study generated three water demand scenarios by major user sectors and geographical sub-areas within the region. The three scenarios represent water withdrawals under current demand conditions representing a current trends or "baseline" scenario (CT scenario) as well as under a less resource intensive and more resource intensive scenarios (LRI and MRI scenarios), which were extended to the year 2050. The three scenarios focus only on off-stream uses of water in the region and do not include the future water needs for aquatic ecosystems or other in-stream uses.

Methods

The project team at Southern Illinois University Carbondale (SIUC), in collaboration with the Illinois State Water Survey (ISWS), and the Illinois District of the United States Geological Survey (USGS), prepared data sets on historical withdrawals, which were subsequently used in developing water-demand relationships for future scenarios. Data used to specify explanatory variables and their future values came from several sources.

The principal source of data on historical water withdrawals is the Illinois Water Information Program (IWIP) of the ISWS, a voluntary water-withdrawal reporting program established in 1978. Additional data were obtained from the National Water Use Inventory Program (NWUIP) of the USGS. Information on major drivers of water demand including population and employment were obtained from the Chicago Metropolitan Agency for Planning (CMAP). Other data were obtained from state and federal agencies, most often from routinely collected statistics available from libraries, or in electronic format on agency websites.

The techniques for developing future water demand varied by sector and included unit-use methods, multiple regressions, and mass balance estimation of irrigation demands. These techniques provide future water demand numbers as a function of demand drivers (i.e., population, employment, power generation, irrigated acreage, depending on user sector) and variables which influence average rates of water demand (i.e., weather conditions, price of water, income, employment mix, and others). Table ES-1 lists the drivers and estimated elasticities of the explanatory variables for each demand sector.

Future water withdrawals will respond to changes in the future values of the driver variables (i.e., population, employment, electric generation, or irrigated acreage). However, the change in water demand will not be strictly proportional to changes in demand drivers. The increases or decreases in future demand will also depend on the future values of explanatory variables such as price, income, or weather conditions. These variables will influence future unit rates of water usage (i.e., gallons per capita or gallons per employee). The effects of changes in explanatory variables on unit-use rates are determined by the elasticities and coefficients which were derived through statistical analysis of the historical data and are shown in the last column of Table ES-1.

Table ES-1 Drivers of Water Demand and Elasticities of Explanatory Variables

Demand Sector	Demand Driver	Explanatory Variables	Elasticity/ Coefficient
Public Supply	Population served	Air temperature	1.0951
		Precipitation	-0.0949
		Employment fraction	0.0931
		Price of water	-0.1458
		Median household income	0.2845
		Conservation trend	-0.0593
Power Generation	Gross electric generation	Unit-use coefficients	0.67-0.89[a] 10.8 -78.9[b]
Industrial & Commercial	Employment	Cooling degree-days	0.3298
		Precipitation	-0.0896
		Manufacturing employment (%)	0.0279
		Transportation employment (%)	-0.1077
		Fraction of self-supplied (%)	0.0032
		Conservation trend	-0.0074
Agricultural & Irrigation	Irrigated acres	Rainfall deficit	1.000
	Livestock counts	Unit-use coefficients	0.03-35.0[c]
Domestic Self-supplied	Population	Air temperature	1.6238
		Precipitation	-0.2186
		Median household income	0.3499
		Conservation trend (linear)	-0.0325

[a] The values represent unit withdrawal coefficients in gallons per kilowatt-hour of gross generation in plants with closed-loop cooling systems. [b] The values represent unit withdrawal coefficients in plants with open-loop once through cooling systems. [c] The values represent unit use coefficient per animal type.

Future Scenarios

Estimates of future water demand were prepared for three different scenarios. The scenarios were defined by varying assumptions regarding the future values of demand drivers and explanatory variables. The purpose of the scenarios is to capture future water withdrawals under three different sets of future conditions. The scenarios do not represent forecast or predictions, nor set upper and lower bounds of future water use. Different assumptions or conditions could result in withdrawals that are within or outside of this range. A listing of assumptions for each of the three scenarios is given in Table ES-2. The assumptions used in formulating the scenarios are not connected (i.e., causally linked). For example, the assumption of the higher growth rate of income is not related to the assumption of more population growth in the collar counties.

Additional discussion of sector-specific assumptions is included in the chapters which describe water demand scenarios for each sector.

Table ES-2 Assumptions for Factors Affecting Future Water Demands in the 11-County Area of Northeastern Illinois

Factor	Scenario 1- Current Trends (CT) or Baseline	Scenario 2- Less Resource Intensive (LRI)	Scenario 3 – More Resource Intensive (MRI)
Total population	CMAP projections	CMAP projections	CMAP projections
Distribution of population of growth	CMAP projections	More population in Cook and DuPage counties	More population in Kane, Kendall and McHenry counties
Mix of commercial/ industrial activities	Current trends	Decrease in high water-using activities	Increase in high water-using activities
Median household income	Existing projections of 0.7 %/year growth	Existing projections of 0.5 %/year growth	Higher growth of 1.0 %/year
Demand for electricity	9.61 kWh/capita + 0.56% annual growth	9.61 kWh/capita without growth	9.61 kWh/capita + 0.56% annual growth
Power generation	No new plants within study area, 3 units retired	No new power plants within study area, 3 units retired, 2 plants convert to closed-loop cooling	Two new power plants in study area with closed-loop cooling
Water conservation	Continuation of historical trend	50% higher rate than historical trend	No extension of historical trend
Future water prices	Recent increasing trend (0.9%/year) will continue	Higher future price increases (2.5%/year)	Prices held at 2005 level in real terms
Irrigated land	Constant cropland, increasing golf courses (10/decade)	Decreasing cropland + no increase in golf courses	Constant cropland increasing golf courses (20/decade)
Livestock	Baseline USDA growth rates	Baseline USDA growth rates	Baseline USDA growth rates
Weather (air temperature and precipitation)[d]	30-year normal (1971-2000)	30-year normal (1971-2000)	30-year normal (1971-2000)

[d] Changes in normal weather conditions were considered under separate climate change scenarios.

Water Demand Drivers

The main drivers of future water demand are future population and economic growth which is represented in this study as future employment. The data on future increases in resident population of the study area were provided by CMAP. Table ES-3 shows the expected increase in total population in each of the 11 counties by 2050. For the 11-county study area, total resident population is expected to increase between 2005 and 2050 from 8,743,856 to 12,113,169. This represents an increase of 3,369,313 persons (or 38.5 percent).

Table ES-3 Resident Population Projections for the Study Area

County	2005 Population	2050 Population	2005-2050 Change	2005-2050 Change, %
Boone	50,483	68,626	18,143	35.9
Cook	5,303,683	6,336,829	1,033,146	19.5
DeKalb	97,665	159,147	61,482	63.0
DuPage	929,113	1,070,063	140,950	15.2
Grundy	43,838	85,419	41,581	94.9
Kane	482,113	928,027	445,914	92.5
Kankakee	107,972	162,755	54,783	50.7
Kendall	79,514	280,552	201,038	252.8
Lake	702,682	973,458	270,776	38.5
McHenry	303,980	589,272	285,292	93.9
Will	642,813	1,459,021	816,208	127.0
NE Illinois	8,743,856	12,113,169	3,369,313	38.5

Source: Population projections were provided by CMAP. Population projections for 2050 are made solely for this project's purposes.

Table ES-4 shows the projected total employment for each of the 11 counties in the study area. Between 2005 and 2050, total employment is projected to increase by 2,458,281 employees or by 56.4 percent.

Table ES-4 Employment Projections for the Study Area

County	2005 Employment	2050 Employment	2005-2050 Change	2005-2050 Change, %
Boone	17,428	28,127	10,699	61.4
Cook	2,420,303	3,675,291	1,254,988	51.9
DeKalb	51,069	77,632	26,563	52.0
DuPage	677,073	977,696	300,623	44.4
Grundy	21,975	50,087	28,112	127.9
Kane	237,175	499,298	262,123	110.5
Kankakee	49,889	104,169	54,280	108.8
Kendall	42,608	150,123	107,515	252.3
Lake	357,871	562,842	204,971	57.3
McHenry	160,222	175,568	15,346	9.6
Will	319,603	512,664	193,061	60.4
NE Illinois	4,355,216	6,813,497	2,458,281	56.4

Source: Employment projections for 2050 are made solely for this project's purposes.

Future Water Withdrawals

Table ES-5 provides a summary of the future scenarios of average day water withdrawals for six categories of users within the four major sectors. For 2005, both the reported values and weather-adjusted values (where adjustments were possible) are shown. The future scenario withdrawals in 2050 are compared to 2005 values – both withdrawal numbers represent normal weather conditions. The last column of the table shows changes in 2050 withdrawals relative to the baseline CT scenario.

Table ES-5 Summary of Water Withdrawal Scenarios for Northeastern Illinois (in MGD)

Scenario/ Sector	2005 Reported With-drawals	2005[e] Normal With-drawals	2050 Normal With-drawals	2005-2050 Change MGD	2005-2050 Change (%)	Change From CT Scenario MGD
CT- Current Trends (Baseline)						
Public Supply	1,255.7	1,189.2	1,570.2	381.0	32.0	0.0
Self-supplied I&C	191.6	162.4	291.6	129.2	79.6	0.0
Self-supplied Domestic	36.8	31.8	41.2	9.4	29.6	0.0
Irrigation and Agriculture	62.0	44.6	55.4	10.8	24.2	0.0
Power Plants (Makeup)	52.3	52.3	52.3	0.0	0.0	0.0
Power Plants (Through flow)	4,207.2	4,207.2	3,830.2	-377.0	-9.0	0.0
Total - All sectors	5,805.6	5,687.5	5,840.9	153.4	2.7	0.0
Total w/o through-flow power	1,598.4	1,480.3	2,010.7	530.4	35.8	0.0
LRI – Less Resource Intensive						
Public Supply	1,255.7	1,189.2	1,217.9	28.7	2.4	-352.3
Self-supplied I&C	191.6	162.4	222.1	59.7	36.8	-69.5
Self-supplied Domestic	36.8	31.8	37.3	5.5	17.3	-3.9
Irrigation and Agriculture	62.0	44.6	43.8	-0.8	-1.8	-11.6
Power Plants (Makeup)	52.3	52.3	66.4	14.1	27.0	14.1
Power Plants (Through flow)	4,207.2	4,207.2	2,472.3	-1,734.9	-41.2	-1,357.9
Total - All sectors	5,805.6	5,687.5	4,059.8	-1,627.7	-28.6	-1,781.1
Total w/o through-flow power	1,598.4	1,480.3	1,587.5	107.2	7.2	-423.2
MRI – More Resource Intensive						
Public Supply	1,255.7	1,189.2	1,837.2	648.0	54.5	267.0
Self-supplied I&C	191.6	162.4	391.4	229.0	141.0	99.8
Self-supplied Domestic	36.8	31.8	49.3	17.5	55.0	8.1
Irrigation and Agriculture	62.0	44.6	60.7	16.1	36.1	5.3
Power Plants (Makeup)	52.3	52.3	90.8	38.5	73.6	38.5
Power Plants (Through flow)	4,207.2	4,207.2	3,830.2	-377.0	-9.0	0.0
Total - All sectors	5,805.6	5,687.5	6,259.6	572.1	10.1	418.7
Total w/o through-flow power	1,598.4	1,480.3	2,429.4	949.1	64.1	418.7

[e] For comparison with future values, the 2005 withdrawals were adjusted by the model to represent normal weather conditions. Small decimal point discrepancies in different tables are due to independent rounding.

The last two rows of each scenario panel in Table ES-5 show the sum of total withdrawals with and without the once-through flow withdrawals for power generation. This distinction is made because the power industry representatives on the RWSPG expressed a concern that the very high volumes of water withdrawals for once-through cooling are not directly comparable to withdrawals by other sectors. In order to address this concern, thermoelectric water withdrawals were separated into two categories: withdrawals by through flow plants and withdrawals by makeup water intake plants. Once-through flow (run-of-the-river) plants pump water directly to the condensers and almost immediately return it back to the river or lake. Closed-loop makeup water plants withdraw water to replace losses and "blowdown" in cooling towers, or water losses and discharges from perched lakes or ponds. This separation of plants provides for a better consistency in representing non-consumptive and consumptive water withdrawals for power production. Water withdrawn by through flow plants represents mainly non-consumptive use since nearly all water withdrawn is returned to the source. Withdrawals by makeup water plants represent a sum of both consumptive and non-consumptive use and are comparable with withdrawals by the industrial/commercial and agricultural sectors. The discussion which follows concentrates primarily on total withdrawals which exclude once-through flows in power plants.

Comparison of Withdrawals by Scenario

Table ES-6 compares total water withdrawals in terms of gross per capita water use in gallons per capita per day. The gross per capita values were obtained by dividing total water withdrawals for all sectors (excluding once-through flow in power plants) by total resident population in the study area.

Table ES-6 Changes in Population and Gross per Capita Water Usage (GPCD)

Description	2005 Reported	2005 Normal	2050 Normal	2005-2050 Change	2005-2050 Change, %
Total Population	8,743,856	8,743,856	12,113,169	3,369,313	38.5
CT Scenario					
Water Withdrawals, mgd	1,598.4	1,480.3	2,010.7	530.4	35.8
Gross Per Capita, gpcd	182.8	169.3	166.0	-3.3	-2.0
LRI Scenario					
Water Withdrawals, mgd	1,598.4	1,480.3	1,587.5	107.2	7.2
Gross Per Capita, gpcd	182.8	169.3	131.1	-38.2	-22.6
MRI Scenario					
Water Withdrawals	1,598.4	1,480.3	2,429.4	949.1	64.1
Gross Per Capita	182.8	169.3	200.6	31.3	18.5
Reference, constant GPCD					
Water Withdrawals, mgd	1,598.4	1,480.3	2,050.7	570.4	38.5
Gross Per Capita, gpcd	182.8	169.3	169.3	0.0	0.0

The results in Tables ES-6 (and ES-5) show that by 2050 total water withdrawals could range from 1,587.5 mgd under LRI scenario, to 2010.7 mgd under CT scenario, and up to 2,429.4 mgd under the MRI scenario. In each case, the future increase in total withdrawals represents a net effect of total population growth and the future change in gross per capita water use. If future water withdrawals were strictly proportional to population growth, the 2050 withdrawals would be 2,050.7 mgd. This value is shown in the bottom panel of Table ES-6 as a "reference" case which assumes constant future value of gross per capita withdrawals. This case was not a part of the scenario analysis and is used here only to compare the three aggregate scenario values. The three scenarios represent cases where future withdrawals grow slower or faster than total population.

CT Baseline Scenario

Table ES-5 shows that under the baseline (CT) scenario, total withdrawals (excluding once-through flow in power plants) would increase from the reported (actual weather) value of 1,598.4 mgd in 2005 to 2,010.7 mgd in 2050. When compared to normal-weather demands in 2005, the total increase would be 530.4 mgd, or 35.8 percent. Most of this increase (about 96 percent) represents growth in withdrawals of the public supply sector and industrial and commercial sector.

The CT scenario's 2050 value (in Table ES-5) for public-supply sector is 1,570.2 mgd – a 381.0 mgd increase (32.0 percent) over the 2005 (normal weather) withdrawals. This increase is the result of a 39.1 percent increase in population served, and a 5.0 percent decrease in per capita rate of public-supply water use. The public-supply per capita withdrawals are projected to decrease from 142.1 gpcd (gallons per capita per day) in 2005 to 134.9 gpcd in 2050. The 7.2 gpcd decrease is a net result of increasing income (0.7 percent per year), increasing price (0.9 percent per year) and a continuing conservation trend. Without conservation, the 2050 per capita demand would be 146.1 gpcd. This indicates a 2050 conservation effect in the public-supply sector of 11.2 gpcd, or 7.7 percent.

The CT scenario's 2050 value for self-supplied industrial and commercial sector is 291.6 mgd – a 129.2 mgd increase (79.6 percent) over the 2005 (normal) withdrawals. This increase is the result of a 56.4 percent increase in employment and a 9.9 percent increase in per employee rate of water use. Per employee withdrawals are projected to increase from 109.3 gpcd (gallons per capita per day) in 2005 to 120.1 gpcd in 2050. The 10.8 gped (gallons per employee per day) increase is primarily a net effect of the assumed increase in labor productivity (1.0 percent per year), and continuing the historical conservation trend (0.74 percent per year).

LRI Scenario

Under the assumptions of the LRI scenario, total withdrawals (excluding once-through flow in power plants) would increase from the normal weather value of 1,480.3 mgd in 2005 to 1,587.5 mgd in 2050. The total increase would be 107.2 mgd, or 7.2 percent. Relative to the CT scenario for 2005, this represents a decrease of 423.2 mgd. Most of this decrease comes from lower demands in the public supply and industrial and commercial sectors.

The largest impacts on decreasing the demands in the public supply sector come from the assumption of increasing future prices of water (2.5 percent per year), and increasing the conservation effect. The per capita public-supply withdrawals under LRI scenario are projected to decrease from 142.1 gpcd (gallons per capita per day) in 2005 to 104.7 gpcd in 2050. Without the conservation trend, the 2050 per capita demand would be 117.9 gpcd. This indicates a conservation effect in the public supply sector of 13.2 gpcd, or 11.2 percent.

In the industrial and commercial sector the 69.5 mgd decrease in 2050 demands relative to the CT scenario is the result of the projected decrease of per employee rate from 109.3 gped in 2005 to 90.6 in 2050. This decrease results from the assumption of the annual conservation rate which is 50 percent higher than the historical rate (i.e., 1.11 percent versus 0.74 percent per year).

MRI Scenario

Finally, under the MRI scenario, total withdrawals (excluding once-through flow in power plants) would increase from the normal weather value of 1,480.3 mg in 2005 to 2,429.4 mgd in 2050. The total increase would be 949.1 mgd, or 64.1 percent. Relative to the CT scenario for 2005, this represents a 418.7 mgd increase in total withdrawals. The main reasons for the increase are the assumptions of no price increase and no conservation, combined with a higher rate of growth in median household income.

Withdrawals for Once-through Cooling

Under all three scenarios, total withdrawals for once-though cooling are projected to decline. The decline of 377.0 mgd shown for the CT and MRI scenarios in Table ES-5 is the result of retiring three generation units (one in the Waukegan plant and two in the Will County plant). The decline of 1,734.9 mgd under the LRI scenario is the result of the scenario assumption that two power plants with once-through cooling system in Will County would be retrofitted with closed-loop cooling tower systems (one in 2020 and another in 2030).

Water Withdrawals by Source of Supply

Table ES-7 shows the current and future withdrawals of water (excluding the through-flow power generation) by the three major sources of water supply in the study area: groundwater, local rivers, and Lake Michigan. The mix of water supply sources will change throughout the period from 2005 through 2050 because of differential growth rates among water systems and geographical subareas with different mixes of supply sources. In all three scenarios, groundwater withdrawals are projected to increase faster than surface water withdrawals. The highest percentage increases are projected for groundwater withdrawals, followed by withdrawals from local rivers, with the lowest percentage increase in withdrawals from Lake Michigan.

When comparing weather-normalized 2005 and 2050 withdrawals, the groundwater withdrawals would increase by 84.3 percent (210.9 mgd) under the CT scenario. The corresponding increases of groundwater withdrawals under LRI and MRI scenarios would be 43.6 percent (109.0 mgd), and 134.9 percent (337.4 mgd), respectively. Water withdrawals from surface non-lake water (rivers), would increase between 2005 and 2050 by 54.2 percent under the CT scenario. The corresponding increases under LRI and MRI scenarios would be 29.8 percent (63.2 mgd), and 109.8 percent (232.9 mgd), respectively. Finally, water withdrawals from Lake Michigan would increase by 20.1 percent (204.7 mgd) under the CT scenario and would decrease by 6.4 percent (65.1 mgd) under LRI scenario, and increase by and 37.2 percent (378.9 mgd) under the MRI scenario.

Table ES-7 Scenario Water Withdrawals by Source (in MGD)

Year	Ground-Water	River Water	Lake Michigan Water	Total Withdrawals
CT Scenario				
2005 (Reported)	285.9	236.5	1,076.1	1,598.4
2005 (Normal)	250.1	212.2	1,018.0	1,480.3
2010	268.6	247.8	1,035.1	1,551.5
2015	288.3	255.9	1,053.6	1,597.8
2020	310.7	264.5	1,074.7	1,649.9
2025	336.4	273.6	1,098.0	1,708.0
2030	365.5	283.2	1,124.8	1,773.6
2035	386.4	293.4	1,145.8	1,825.6
2040	409.0	304.0	1,169.8	1,882.9
2045	433.9	315.2	1,195.2	1,944.2
2050	461.0	327.1	1,222.7	2,010.7
2005-2050 Change	210.9	114.9	204.7	530.4
2005-2050 %	84.3	54.2	20.1	35.8
LRI Scenario				
2005 (Reported)	285.9	236.5	1,076.1	1,598.4
2005 (Normal)	250.1	212.2	1,018.0	1,480.3
2010	246.7	222.4	933.5	1,402.7
2015	258.8	226.4	930.9	1,416.0
2020	272.9	241.2	931.1	1,445.3
2025	289.3	245.8	933.7	1,468.8
2030	307.6	254.0	939.3	1,500.9
2035	318.9	259.1	940.0	1,518.0
2040	331.3	264.3	943.2	1,538.8
2045	344.5	269.7	947.3	1,561.5
2050	359.1	275.3	952.9	1,587.5
2005-2050 Change	109.0	63.2	-65.1	107.2
2005-2050 %	43.6	29.8	-6.4	7.2
MRI Scenario				
2005 (Reported)	285.9	236.5	1,076.1	1,598.4
2005 (Normal)	250.1	212.2	1,018.0	1,480.3
2010	281.5	243.0	1,055.2	1,579.7
2015	311.6	257.6	1,093.8	1,663.0
2020	345.2	273.6	1,133.8	1,752.6
2025	383.5	310.1	1,175.7	1,869.3
2030	426.5	328.8	1,221.3	1,976.5
2035	461.3	349.2	1,260.9	2,071.3
2040	499.4	390.4	1,304.0	2,193.8
2045	541.4	414.3	1,349.0	2,304.6
2050	587.6	445.0	1,396.9	2,429.4
2005-2050 Change	337.4	232.9	378.9	949.1
2005-2050 %	134.9	109.8	37.2	64.1

Geographical Distribution of Water Demands

Table ES-8 shows the projected total water withdrawals (excluding withdrawals by once-through systems in power plants) for the 11 counties in the study area.

Table ES-8 Scenario Water Withdrawals by County (in MGD)

County	2005 Reported	2005[e] Normal	2050 Normal	2005-50 Change	2005-2050 Change, (%)	Change From CT Scenario
CT Scenario						
Boone	9.0	7.2	9.9	2.6	36.7	0
Cook	1,024.5	972.8	1,171.6	198.8	20.4	0
DeKalb	15.0	13.8	21.3	7.5	54.1	0
DuPage	111.2	101.2	124.2	22.9	22.7	0
Grundy	11.2	9.2	22.1	12.9	141.2	0
Kane	61.5	52.5	101.9	49.5	94.4	0
Kankakee	37.6	33.6	40.6	7.0	21.0	0
Kendall	12.0	9.5	31.3	21.8	230.4	0
Lake	105.3	91.3	131.6	40.3	44.1	0
McHenry	50.6	38.8	64.7	25.9	66.7	0
Will	160.2	150.5	291.5	141.0	93.7	0
Total	1,598.4	1,480.3	2,010.7	530.4	35.8	0
LRI Scenario						
Boone	9.0	7.2	7.9	0.7	9.7	-1.9
Cook	1,024.5	972.8	915.3	-57.5	-5.9	-256.3
DeKalb	15.0	13.8	17.1	3.2	23.4	-4.3
DuPage	111.2	101.2	103.5	2.3	2.3	-20.7
Grundy	11.2	9.2	18.0	8.8	96.5	-4.1
Kane	61.5	52.5	67.8	15.3	29.2	-34.2
Kankakee	37.6	33.6	33.9	0.3	0.9	-6.7
Kendall	12.0	9.5	19.8	10.4	109.8	-11.4
Lake	105.3	91.3	103.1	11.8	13.0	-28.5
McHenry	50.6	38.8	46.7	7.9	20.3	-18.0
Will	160.2	150.5	254.3	103.8	69.0	-37.2
Total	1,598.4	1,480.3	1,587.5	107.2	7.2	-423.2
MRI Scenario						
Boone	9.0	7.2	11.5	4.3	59.9	1.7
Cook	1,024.5	972.8	1,340.3	367.5	37.8	168.7
DeKalb	15.0	13.8	25.4	11.6	83.6	4.1
DuPage	111.2	101.2	142.2	41.0	40.5	18.1
Grundy	11.2	9.2	52.4	43.3	472.7	30.3
Kane	61.5	52.5	135.7	83.2	158.7	33.8
Kankakee	37.6	33.6	54.0	20.4	60.8	13.4
Kendall	12.0	9.5	62.3	52.9	558.7	31.1
Lake	105.3	91.3	160.1	68.9	75.4	28.6
McHenry	50.6	38.8	100.1	61.3	157.7	35.4
Will	160.2	150.5	345.2	194.7	129.4	53.8
Total	1,598.4	1,480.3	2,429.4	949.1	1,835.2	418.7

[e] The 2005 withdrawals were adjusted by the model to represent normal weather conditions.

Under the CT scenario, the highest increments in total withdrawals between 2005 and 2050 are projected for the Cook and Will counties; the lowest for Boone, DeKalb and Kankakee counties. The highest percentage increases in withdrawals are projected for Grundy and Kendall counties.

Under the LRI scenario, the growth in total withdrawals would be slower in all counties with the highest reduction relative to CT scenario in Cook County. Under the MRI scenario Cook and Will counties show the highest growth in withdrawals between 2005 and 2050. Grundy, Kane, Kendall, McHenry and Will show the highest percentage increases (greater than 100 percent). A significant portion of the shifts in county level withdrawals is the result of the assumed shifts in the distribution of population growth between Cook and DuPage versus Kane, Kendall and McHenry counties.

Sensitivity to Future Climate

Climate models indicate that by 2050, there may be a possible average annual temperature departure of up to +6 °F, and a possible departure from normal annual precipitation in a range from -5 inches to +5 inches per year from the 1971-2000 long-term normal in Illinois (ISWS, 2007b). Due to the nature of climate scenarios no probabilities can be placed on the possible ranges of future air temperature and precipitation.

The changes in annual temperature and precipitation would also result in average-weather changes during the growing season. The temperature increase of 6 °F will also apply to the summer growing season. The distribution of precipitation changes is expected to range from +2.5 inches to -3.5 inches during the growing season. The effects of these changes vary by user sector, depending on each sector's sensitivity of water withdrawals to air temperature and precipitation. Table ES-9 shows the impacts of climate change on water withdrawals under the CT scenario. The +6 °F increase in temperature has more than four-fold greater effect on water demand than the -3.5 inches decrease in precipitation.

The five lower panels in Table ES-9 show the impacts of the individual climate change components and their combinations on future water withdrawals. These include: increase in air temperature, increase in precipitation, decrease in precipitation, and the combination of temperature increase with increase in precipitation and temperature increase with decrease in precipitation.

The last column of Table ES-9 shows the changes in withdrawals relative to the withdrawals under the CT scenario. The largest change in total withdrawals by 2050 is 229.5 mgd, resulting from the combined effect of the temperature increase and decrease in summer precipitation.

Table ES-9 Effects of Possible Climate Change on Water Withdrawals (MGD)

Weather Scenario/ Sector	2005[1] Water With-drawals	2030 Water With-drawals	2005-2030 Change	2050 Water With-drawals	2005-2050 Change	Change from CT in 2050
CT Scenario						
Public supply	1,189.2	1,392.4	203.2	1,570.2	381.0	0.0
Self-supplied I&C	162.4	240.9	78.5	291.6	129.2	0.0
Self-supplied domestic	31.8	38.1	6.3	41.2	9.4	0.0
Irrigation and agriculture	44.6	49.9	5.3	55.4	10.8	0.0
All sectors (w/o power)	1,428.0	1,721.3	293.3	1,958.4	530.4	0.0
• T +6°F Temperature only						
Public Supply	1,189.2	1,457.4	268.2	1,702.7	513.5	132.5
Self-supplied I&C	162.4	258.6	96.2	328.3	165.9	36.7
Self-supplied domestic	31.8	41.1	9.3	47.1	15.3	5.9
Irrigation and agriculture	44.6	51.4	6.8	58.3	13.7	2.9
All sectors (w/o power)	1,428.0	1,808.5	380.5	2,136.4	708.4	178.0
+2.5" Precipitation only						
Public Supply	1,189.2	1,376.6	187.4	1,552.3	363.1	-17.9
Self-supplied I&C	162.4	237.8	75.4	287.8	125.4	-3.8
Self-supplied domestic	31.8	37.5	5.7	40.8	9.0	-0.4
Irrigation and agriculture	44.6	43.6	-1.0	48.6	4.0	-6.8
All sectors (w/o power)	1,428.0	1,695.5	267.5	1,929.5	501.5	-28.9
-3.5" Precipitation only						
Public Supply	1,189.2	1,418.7	229.5	1,600.2	411.0	30.0
Self-supplied I&C	162.4	246.3	83.9	298.1	135.7	6.5
Self-supplied domestic	31.8	40.2	8.4	43.8	12.0	2.6
Irrigation and agriculture	44.6	58.6	14.0	64.9	20.3	9.5
All sectors (w/o power)	1,428.0	1,763.8	335.8	2,007.0	579.0	48.6
• T +6°F Temperature & +2.5" Precipitation						
Public Supply	1,189.2	1,440.9	251.7	1,683.2	494.0	113.0
Self-supplied I&C	162.4	255.2	92.8	324.0	161.6	32.4
Self-supplied domestic	31.8	40.1	8.3	46.0	14.2	4.8
Irrigation and agriculture	44.6	45.1	0.5	51.5	6.9	-3.9
All sectors (w/o power)	1,428.0	1,781.3	353.3	2,104.7	676.7	146.3
• T +6°F Temperature & -3.5" Precipitation						
Public Supply	1,189.2	1,485.0	295.8	1,735.1	545.9	164.9
Self-supplied I&C	162.4	264.4	102.0	335.6	173.2	44.0
Self-supplied domestic	31.8	43.0	11.2	49.4	17.6	8.2
Irrigation and agriculture	44.6	60.1	15.5	67.8	23.2	12.4
All sectors (w/o power)	1,428.0	1,852.5	424.5	2,187.9	759.9	229.5

[1] 2005 water withdrawals are adjusted for normal weather conditions. • *T* = temperature increase

Effects of Drought

Another type of climate impact on water demand is the effect of periodic droughts. In the future, even in the absence of possible changes in the long-term mean annual temperature and precipitation, it can be expected that periodic droughts will occur. While the severity and duration of future droughts is not known, their potential future impact on water demand can be determined by examining the historical climate records.

The most severe historical droughts in Illinois took place in the 1930s and 1950s. These were multiyear droughts which were associated with growing season precipitation deficits during the driest year of approximately 40 percent below normal. For the purpose of this study, it was assumed that, during future droughts, the 1971-2000 normal summer precipitation for the growing season would be reduced by 40 percent, representing a worst-case historical drought. Table ES-10 shows the change in water withdrawals under the conditions of a worst-case historical drought.

Table ES-10 Impacts of Drought Related Precipitation Deficit (MGD)

Weather Scenario/ Sector	2005[1] Water With-drawals	2030 Water With-drawals	2005-2030 Change	2050 Water With-drawals	2005-2050 Change	Change from CT in 2050
CT Scenario						
Public supply	1,189.2	1,392.4	203.2	1,570.2	381.0	0.0
Self-supplied I&C	162.4	240.9	78.5	291.6	129.2	0.0
Self-supplied domestic	31.8	38.1	6.3	41.2	9.4	0.0
Irrigation and agriculture	44.6	49.9	5.3	55.4	10.8	0.0
All sectors	1,428.0	1,721.3	293.3	1,958.4	530.4	0.0
Drought Year (40% precipitation deficit)						
Public Supply	1,189.2	1,461.9	272.7	1,649.2	460.0	79.0
Self-supplied I&C	162.4	254.4	92.0	308.0	145.6	16.3
Self-supplied domestic	31.8	42.9	11.1	46.8	15.0	5.6
Irrigation and agriculture	44.6	75.0	30.4	82.6	38.0	27.2
All sectors	1,428.0	1,834.2	406.2	2,086.6	658.6	128.1

[1] 2005 water withdrawals are for weather adjusted normal conditions.

The data in Table ES-10 indicate that a future drought with a 40 percent deficit in summer precipitation would result in a 128.1 mgd increase in total water demands, as compared to the CT scenario.

Peak Season and Peak Day Withdrawals

The future demand scenarios presented above developed estimates of total annual water withdrawals. The actual units used to express the annual volume of withdrawals were million gallons per day (mgd). For each future year and geographical area this measure of water demand was calculated by dividing total annual volume of withdrawals by 365 days. However, the temporal pattern of withdrawals changes throughout the year – it is the highest during the growing season and the lowest during winter months. Historical data were used to determine the magnitude of water withdrawals during the growing season (i.e., the four peak months from May 1 to August 31, and maximum-month) as well as the maximum daily withdrawals (i.e., peak-day during the year). Table ES-11 lists the global (aggregated for the entire study area) peaking factors which were derived based on the available data.

Table ES-11 Historical Global Peaking Factors

Sector	Seasonal Peaking Factor	Monthly Peaking Factor	Max-day Peaking Factor
Public-supply	1.18	1.33	1.91
Industrial and commercial	--	--	1.66
Irrigation and agriculture	3.0	4.7	7.11
Power generation	--	--	--

"–" peaking data were not available.

The global peaking factors represent average peaking ratios which were weighted by water withdrawals of public water supply systems and other entities. These global peaking factors should provide reasonable approximations of future demands during seasons, months, and days of the highest water demand. More accurate estimates of peak demands can be obtained by deriving and applying peaking factors which are site-specific.

The maximum-day peaking factor for the public-supply sector of 1.91 indicates that, for the 2050 average day withdrawals in this sector of 1,570.2 mgd, the withdrawals to match the peak-day demand would be 2,999.1 mgd. Similarly the average day withdrawals of 402.3 mgd in the industrial and commercial sector would result in peak day demands of 667.8 mgd. Finally, peak-day withdrawals for irrigation and agriculture would be approximately seven-fold higher than average day annual values.

Key Findings

An important finding of the analysis of future water demand scenarios is that total water withdrawals in the 11-county area of Northeastern Illinois will continue to increase to meet the demands of growing population and the concomitant growth in the economy of the region. However, the growth in total water demand could be faster or slower depending on which assumptions and expectations about the future conditions will prevail.

The baseline conditions and assumptions, which are captured in the Current Trends scenario, indicate that, by 2050, total water withdrawals (excluding water withdrawn for once-through cooling in electric power plants) would increase above the 2005 level by 35.8 percent, or 530 million gallons per day. During the same period of time, total population is projected to increase by nearly 3,370,000, or 38.5 percent. This implies that water demand would grow slightly slower than the region's population. Gross per capita water withdrawals (i.e., total withdrawals by all sectors divided by total population) during the dry year of 2005 were estimated at 182.8 gallons per capita per day (gpcd). Under normal weather conditions, the 2005 demands would be 169.3

gpcd (see Table ES-6). Under the CT scenario, the gross per capita usage would decrease to 166.0 gpcd. This relatively unchanged per capita rate is a result of assumptions about a gradual increase in water prices and a continuation of the historical trend in water conservation.

Future water demands would grow faster than total population if income grows at somewhat higher rate than under the CT scenario (1.0 percent per year versus 0.7 percent per year), if future prices of water do not grow faster than inflation, if no additional gains in water conservation are achieved, and if more population growth takes place in the collar counties of Kane, Kendall and McHenry in single-family housing. These are the key assumptions of the MRI scenario. Under these conditions, by 2050, total water withdrawals (again, excluding water withdrawn for once-through cooling in electric power plants) under normal weather conditions would increase above the 2005 level by 64.1 percent, or 949.1 million gallons per day. The growth of water demand would exceed the rate of population growth because of the increasing gross per capita usage rate. By 2050 it would increase to about 200.6 gpcd, as compared to the 2005 weather-normalized rate of 169.3 gpcd (see Table ES-6). In a sense, the MRI scenario could be viewed as a warning that there is a possibility of a large increase of water demands in the future.

There is also a possibility that future demands will grow significantly slower than population if income grows at somewhat slower rate than under CT scenario (0.5 percent per year vs. 0.7 percent per year), if future prices of water grow significantly faster than inflation, if additional gains in water conservation are achieved, and if more population growth takes place in the urbanized counties of Cook and DuPage, in multifamily housing. These are the key assumptions of the LRI scenario. Under these conditions, by 2050, total water withdrawals (again, excluding water withdrawn for once-through cooling in electric power plants) would increase above the 2005 level by about 7.2 percent, or 107.2 million gallons per day. The growth of water demand would be much slower than the rate of population growth because of the decreasing gross per capita usage rate. By 2050 it would decrease to about 131.1 gpcd, as compared to the 2005 weather-normalized rate of 169.3 gpcd (See Table ES-6). This scenario could be interpreted as a future outcome which requires an “intervention” in order to maintain a slower growth of demand. This intervention would require monitoring and management of water demand and making investments in long-term efficiency of water use.

Other findings of the study pertain to additional factors which could alter future water demands in the study area. The main factors are future climate and periodic droughts. Another factor relates to seasonal and daily peaking of demands. The findings of the analysis of these influences are:

1. Future demands in all sectors are likely to be higher if future annual average air temperature increases and/or annual precipitation decreases. If, by 2050, temperature increases by 6°F, total withdrawals would increase by 178.0 mgd (9.1 percent) above the CT scenario values. The largest increase in total withdrawals above the CT scenario would be 229.5 mgd (or 11.7 percent) by 2050, resulting from the combined effect of the temperature increase and a decrease in summer precipitation.

2. Future demands will likely increase during future droughts. Given a re-occurrence of a worst historical drought, with a 40 percent deficit in precipitation during the summer

growing season, total water withdrawals in 2050 would increase by 128.1 mgd (or 6.5 percent) as compared to the CT scenario.

3. Water withdrawals which are presented for each of the three scenarios reflect annual values expressed as average daily rate. Actual withdrawals will be higher during peak summer season and maximum-day use and lower during winter season and off-peak days. Given the approximate overall maximum-day peaking factor in the study area of about 2.0, total demands on a peak day would be twice the reported average day demands.

Recommendations

The results of this study lend support to several recommendations which are offered here for consideration by the resources agencies of the State of Illinois and the Northeastern Illinois Regional Water Resources Planning Group.

The experience of preparing this project points to the importance of the availability of accurate data on water withdrawals and use. The State of Illinois is fortunate to have instituted a voluntary water inventory program at the Illinois State Water Survey. The IWIP database on withdrawal points and annual quantities of water withdrawn during the last three decades made this study possible. However, the program is voluntary, subject to intermittent funding, and not all withdrawals are reported during the yearly surveys.

Improved data reporting would provide a basis for future studies of water demands. State resource agencies should consider actions that would improve the quality of water withdrawal data, as well as expand the scope of data collection to include data on return flows, which would permit estimation of consumptive use and preparation of water budgets within different hydrologic regions of Illinois.

With respect to the 11-county study area in Northeastern Illinois, the large growth in total water withdrawals of 530.4 mgd under CT scenario and 949.1 mgd under MRI scenario makes a compelling case for the need to manage regional water demands. Meeting these additional demands would require large capital outlays on water infrastructure and would likely have significant impacts on some of the regional sources of water supply, especially groundwater aquifers and local rivers. Therefore, a reasonable goal for water demand management would be to maintain the level of growth in total withdrawals that would approach the growth captured by the LRI scenario. Development of strategies for management of future water demands could start with the two key assumptions of the LRI scenario: water conservation and water pricing.

Water conservation trend in the historical data captures only past conservation. However, it is a crude measure of the achieved gains in long-term efficiency of water usage. More detailed studies of the current water usage should be undertaken in order to measure the ongoing improvements in the efficiency of water use and, more importantly, determine the potential for future efficiency gains. This study could be viewed as only the initial step in gaining the knowledge which is critical to the future efforts to manage water demands. With this knowledge, new conservation practices could be identified and implemented by water users in the various sectors in order to achieve the saving which are assumed in the LRI scenario.

Appropriate pricing of water is a necessary condition of achieving efficient water use. Low or nearly “flat” growth in water withdrawals under the LRI scenario is in large part the result of the assumed annual rate of future increases in the retail prices of water of 2.5 percent above the general inflation. However, this rate of price increases may not happen across all communities and water systems in the study area and, more importantly, future rate increases may not achieve the improvements in water-use efficiency if the rate structures are not designed to provide the optimal way of charging for water while simultaneously achieving the objective of water conservation. Review of water rates and ratemaking practices in Northeastern Illinois would be an important initial step in developing a long term water conservation program.

Finally, an important component of water resources management is monitoring of water use over time. Therefore, it would be important to establish and maintain an inventory of water withdrawals and use for each of the 11 counties. The inventory should include both the data on withdrawal points and on water use in geographically-referenced water demand areas, such as areas served by public water supply system or irrigated lands. The data collected in this study could serve as a starting point. The inventory should be updated through data collection and/or compilation of the ISWS statewide data on at least the annual basis. The most important function of a water use data inventory would be the ability to monitor future changes in water withdrawals and use. The inventory could be developed and maintained by the Chicago Metropolitan Agency for Planning using the approach of the ongoing CMAP program of compiling population estimates and preparing population projections.

In summary, the overall recommendation based on the results of this study is to encourage the RWSPG to recognize the need to create and maintain an expanded knowledge base about both the regional and local water demands by all sectors and subsectors of water users. This knowledge base is needed to support a regional long-term water management program in Northeastern Illinois.

CHAPTER 1

INTRODUCTION

BACKGROUND

The knowledge of the amount of water that will be required in the future and the availability of existing and potential sources of supply are two important requirements in water supply planning and management. Since major sources of water supply such as groundwater aquifers, lakes, or rivers are shared by users in many localities, studies of water supply must be conducted at the regional scale.

The State of Illinois is endowed with abundant water resources which include Lake Michigan, major rivers, and aquifers. Nevertheless, the availability of water supplies is a concern in some regions of the State where water availability is limited because of court ordered limits on water allocation, minimum flow requirements, or local hydrological conditions especially during periods of drought.

In an effort to avert potential future water resources problems, state agencies and the Illinois State Water Survey prepared the *Illinois State Water Plan* which identified the need for long-term water supply and demand projections for the state (ISWS, 2001; IDOT, 1984). Subsequently, Governor Blagojevich issued the Executive Order 2006-1 which has lead to two regional studies of water supply and demand: Northeastern Illinois (including the sources from Sand and Gravel Aquifers, Deep Bedrock Aquifer, Lake Michigan and Fox River Basin) and East-Central Illinois (including the sources from Mahomet Aquifer and Sangamon River Basin). The studies are supported through the creation of a representative body for policy and plan recommendations – the Regional Water Supply Planning Group (RWSPG) for Northeastern Illinois and the Regional Water Supply Planning Committee (RWSPC) for East-Central Illinois. This report is a part of the study in Northeastern Illinois.

PURPOSE AND SCOPE

The purpose of this study is to prepare future water-demand scenarios for geographical areas which encompass groundwater withdrawal points and surface water sources in the 11-county regional planning area of Northeastern Illinois. The region under study includes the counties of Boone, Cook, DeKalb, DuPage, Kane, Kankakee, Kendall, Grundy, Lake, McHenry, and Will. The study generated three basic water demand scenarios by major user sectors and geographical service areas within the region. The future scenarios (defined later in this chapter) represent water withdrawals under current trends as well as under less and more resource intensive demand assumptions which were extended to the year 2050. The three scenarios focus only on off-stream uses of water in the region and do not include the future water needs for aquatic ecosystems or other in-stream uses.

The project team at Southern Illinois University Carbondale (SIUC), in collaboration with the Illinois State Water Survey (ISWS) and Illinois District of the U.S. Geological Survey (USGS) prepared data sets for the three water demand scenarios. The historical water withdrawals for public water supply were organized into service areas and county "remainder" areas in order to estimate sector-specific water demand relationships for the 11-county region.

Data and Demand Sectors

The historical water withdrawal data for benchmark years 1985, 1990, 1995, 2000 and 2005 were obtained from the ISWS. The data included information on geographically aggregated water withdrawals from which average daily and peak day demands could be determined. The major sectors of water users include:

1. public supply municipal and industrial sector, and self-supplied domestic;
2. self-supplied commercial and industrial sector (including mining);
3. thermoelectric power generation sector; and
4. agricultural irrigation including golf course irrigation, and livestock and environmental uses.

The historical data on water withdrawals in each sector were supplemented with the corresponding data on demand drivers and explanatory variables for each demand area and user sector. These additional data include:

1. resident population and population served;
2. employment by place of work;
3. median household income;
4. marginal price of water;
5. gross and net thermoelectric generation;
6. irrigated acres of cropland and golf courses;
7. livestock counts;
8. air temperature during growing season;
9. growing season precipitation; and
10. cooling degree-days.

The projections of future population and employment as well as data on future values of explanatory variables were used to generate the estimates of future water withdrawals by four sectors and 37 geographical areas. The scenarios of future water withdrawals for each period and geographical area include:

1. average-daily demand;
2. peak-day demand for public supply systems; and
3. drought-year demand.

The future scenarios of water withdrawals were prorated to the current points of water withdrawal (groundwater wells and surface water intakes) which correspond to specific service areas. The point withdrawals and the associated peak-day demands were prepared in the form of electronic spreadsheets and provided to the Illinois State Water Survey for direct input into groundwater and surface water models.

Withdrawals vs. Consumptive Use

The study is focused on future water need as measured by water withdrawals, and did not include determinations of consumptive and non-consumptive uses for each category of withdrawals. The term "water use" is often applied using its broad meaning that denotes "the interaction of humans, and their influence on the hydrologic cycle and may include both off-stream and in-stream uses such as water withdrawal, delivery, consumptive use, wastewater release, reclaimed wastewater, return flow, and in-stream use" (Hutson et al., 2004). The term "water withdrawal" is more precisely defined as a component of water use. It designates the amount of water that is taken out from natural water sources such as lakes, rivers, or groundwater aquifers.

The difference between the amount of water withdrawn and water returned to the source (or discharge) is usually taken to represent "consumptive use". This is the "part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment" (Hutson et al., 2004). The quantity of water "consumed" is utilized in calculating regional annual and monthly water budgets, and represents a measure of the volume of water that is not available for repeated use.

While a major portion of water withdrawals for public water supply, power generation, and industrial purposes represent "non-consumptive" use, these withdrawals can have significant impacts on water resources and other uses of water. For example, water withdrawn from an aquifer and then returned into a surface water body may have a positive impact on streamflow or lake water levels, but a negative impact on the source of groundwater. Similarly, water withdrawn from a river for public water supply must be continuously available at the intake and is not available upstream or immediately downstream from the intake for other uses, such as irrigation or industrial cooling.

This study is limited to the quantification of water demand in terms of the volumes of water withdrawals from surface and groundwater sources in the 11-county study area in Northeastern Illinois. It does not quantify the water volumes being re-circulated or reused within industrial facilities, or discharges of treated wastewater to surface water bodies, or the infiltration of treated effluents into groundwater aquifers.

At the time of this study, the data on return flows which could be matched to withdrawals were not readily available and therefore the partitioning of the volume of water withdrawn into consumptive and non-consumptive use could not be determined and validated. An inventory of actual return flows should be developed in the future and an in-depth analysis of the "matched" data on withdrawals and return flows (as well as inflows unrelated to withdrawals) should produce relationships that would be adequate for estimating consumptive and non-consumptive use of water withdrawn for each major sector.

In-Stream Uses and Aquatic Ecosystem Needs

The broad definition of water use also includes environmental and in-stream uses of water. The USGS defines in-stream use as "water use that occurs within the stream channel for such purposes as hydroelectric-power generation, navigation, fish and wildlife preservation, water-quality improvement, and recreation" (Hudson et al., 2004).

The in-stream uses include ecosystem water needs for both in-channel and riparian uses where the streamflow supports a wide range of ecological functions of rivers and other surface water bodies. Increasing societal recognition of ecosystem services implies that in addition to future water demand increases to provide for new population and economic growth, there will be an increasing need to manage streams to support aquatic habitat, provide for assimilative capacity to maintain water quality and also for recreational values. During the last four decades there has been an increasing public interest and growing effort to protect environmental resources and restore ecosystems.

However, the effect of in-stream flow requirements and other ecosystem needs on the availability of water supply for off-stream uses is difficult to quantify. There are some rules of thumb such as those developed by Tennant (1975), however, they are not directly applicable to Illinois streams. The actual values must take into consideration a number of hydrological and ecological factors. The two dominant concerns in Northeastern Illinois are: (1) safeguarding that shallow groundwater use and residential development do not reduce the natural low flows in streams, and (2) maintenance and improvement of water quality to improve aquatic habitat and recreation opportunities. With the exception of the Kankakee River, the dominant source of low flows for most northeastern Illinois streams is wastewater effluent. With population growth, the amount of effluents and associated magnitude of low flows will likely continue to increase. Management of these effluents is likely to be more important to aquatic health in the rivers, than a curtailment of the small number of existing uses or storage.

This study of water demand scenarios does not include water needs for aquatic ecosystems or other in-stream uses in the Northeastern Illinois study area. Some of the issues related to in-stream flow needs will be considered in Section 3 (Water Cycle) of the report being prepared by ISWS/ISGS entitled "Water Availability, Supply and Impact Analysis for Northeastern Illinois."

ANALYTICAL METHODS

Data Sources and Data Quality

Data on water withdrawals within the study area were collected through the Illinois Water Inventory Program (IWIP) of the Illinois State Water Survey (ISWS), a voluntary water-use reporting program established in 1978. Under this program, annual data on water withdrawal, water use, and some data on water returns are collected each year from water-using facilities which are inventoried in the database (all users are not included in the IWIP data base; e.g., questionnaires are not sent to agricultural irrigators). The data obtained through annual surveys include locations and annual amounts of water withdrawn from surface water and groundwater sources, and amounts of water purchased from local suppliers. The annual estimates are reported for five categories of use: public water supplies, self-supplied industries, agricultural irrigation, fish and wildlife, and conservation uses. Data can also be queried and summarized geographically and by water source categories.

Data used to specify explanatory variables and their future values came from several sources. Information on major drivers of water demand including population and employment were obtained from the Chicago Metropolitan Agency for Planning (CMAP). Data were also obtained from state and federal agencies, most often from routinely collected statistics available from libraries or in electronic format on agency websites.

Standard procedures were used to identify, correct and/or discard data with apparent errors caused by mistakes in collection or data input. The data checking procedures included: (1) arranging data in spreadsheets and visually inspecting for apparent anomalies; (2) calculating and examining standard ratios (i.e., per capita water quantity, per employee or per acre water quantity); (3) graphing time-series data to identify outliers and large shifts in values over time; and (4) comparing data values against other available data sources.

While the overall accuracy of the data used in this project is not ideal, the available data and their quality are considered to be adequate for the purpose of developing future scenarios of water demand.

Data on the current and historical water withdrawals obtained from the Illinois Water Inventory Program (IWIP) of the Illinois State Water Survey capture all significant groundwater and surface water withdrawals within the State of Illinois, although there is a small possibility that some significant withdrawals by self-supplied users are omitted because of the voluntary nature of the reporting program. However, this potential shortcoming was minimized by examining other sources of data on water use and data on known users of water (such as domestic wells), and correlates of water use (such as irrigated acreage). The examination of corroborating data is routinely employed by the United States Geological Survey (USGS) in preparing county level estimates of water withdrawals as a part of the National Water Use Information Program (NWUIP). The USGS county-level estimates for the years 1985, 1990, 1995, 2000, and 2005 were used to verify the estimates derived from the ISWS data. In case of data discrepancies, additional inquiries about the reported values were made in order to obtain the correct values.

Data on demand drivers such as population or employment as well as data on explanatory variables such as income or weather reflect the data quality of the governmental agencies involved in data collection and reporting. The main source of these data is the U.S. Census. Other agencies include CMAP, Bureau of Economic Analysis, and the National Oceanic and Atmospheric Administration (NOAA).

Water Demand Models

The selection of analytical techniques for developing estimates of future water withdrawals (plus purchases) were dictated by the type of data on actual water quantities and the corresponding data on explanatory variables that were available for each sector of water users. The two principal techniques which are used in this report are the unit-use coefficient method and multiple regression. The general approach to estimating future water demand can be described as a product of the number of users (i.e., demand driver) and unit quantity of water as:

$$Q_{cit} = N_{cit} \times q_{cit} \tag{1.1}$$

where:

Q_{cit} = water withdrawals (or demand) in user sector *c* of study area *i* in year *t;*
N_{cit}= number of users (or demand driver) such as population, employment, or acreage; and
q_{cit} = average rate of water requirement (or water usage) in gallons per capita-day, gallons per employee-day, etc.

The unit-use coefficient method assumes that future water demand will be proportional to the number of users N_{cit} while the future average rate of water use, q_{cit} is usually assumed to remain constant or is changed based on some assumptions. Modeling of water demand usually concerns the future changes in average rate of water usage, q_{cit} , in response to changing future conditions.

Water-demand relationships which quantify historical changes in q_{cit} can be expressed in the form of equations, where the average rate of water usage is expressed as a function of one or more independent (also called explanatory) variables. A multivariate context best relates to actual water usage behaviors, and multiple regression analysis can be used to determine the relationship between water quantities and each explanatory variable. The functional form (e.g., linear, multiplicative, exponential) and the selection of the independent variables depend on the category of water demand. For example, public supply withdrawals can be estimated using the following linear model:

$$PS_{it} = a + \sum_{j} b_j X_{jit} + \varepsilon_{it} \tag{1.2}$$

where: PS_{it} represents per capita public supply water withdrawal within geographical area *i* during year *t*, X_j is a set of explanatory variables (e.g., air temperature, precipitation, price of water, median household income and others), which are expected to explain the variability in per capita use, and ε_t is random error term. The coefficients *a* and b_j can be estimated by fitting a multiple regression model to historical water-use data.

The actual models used in this study were specified as double-log (i.e., log-linear models) with additional variables which served to fit the model to the data and also isolate observations which were likely to be outliers:

$$\ln PS_{it} = \alpha_o + \sum_j \beta_j \ln X_{jit} + \sum_k \gamma_k \ln R_{kit} + \sum_l \delta_l D_{lit} + \sum_m \rho_m S_{mit} + \varepsilon_{it} \qquad (1.3)$$

where: PS_{it} represents per capita public supply water withdrawals (plus purchases) within geographical area *i* during year *t* (in gallons per capita per day), $X_j^{'s}$ are a set of explanatory variables, R_k are ratio (percentage) variables such as ratio of employment to population, D_l are indicator (or binary) variables designating specific water supply systems which assume the value of 1 for observations for the system and zero otherwise, S_m are indicator spike variables designating individual observations in the data, ε_{it} is the random error, and $\alpha, \beta^{'s}, \gamma^{'s}, \delta^{'s}$ and $\rho^{'s}$ are the parameters to be estimated.

A large number of econometric studies of water demand have been conducted during the last 50 years. A substantial body of work on model structure and estimation methods was also performed by the USGS (Helsel and Hirsch, 1992). The theoretical underpinnings of water demand modeling and a review of a number of determinants of water demand in major economic sectors are summarized by Hanemann (1998). Useful summaries of econometric studies of water demand can be found in Boland et al. (1984). Also, Dziegielewski et al. (2002) reviewed a number of studies of aggregated sectoral and regional demand.

Model Estimation and Validation Procedures

Several procedures were used to specify and select the water demand models. The main criteria for model selection were: (1) the model included variables that had been identified as important predictors by previous research, and their estimated regression coefficients were statistically significant and within a reasonable range of *a priori* values, and with expected signs; (2) the explanatory power of the model was reasonable, as measured by the coefficient of multiple determination (R^2); and (3) the absolute percent error of model residuals was not excessive.

The modeling approach and estimation procedure were originally developed and tested in a study conducted by Dziegielewski et al. (2002a). Additional information on the analytical methods, estimated model, and assumptions is included in the chapters which describe the analysis of water withdrawals and development of future water-demand scenarios for each major sector of use. A detailed description of the model development procedure is provided in Chapter 2 Annex.

Uncertainty of Future Demands

It is important to recognize the uncertainty in determining future water demands in any study area and user sector. This uncertainty is always present and must be taken into consideration while making important planning decisions on future water conservation and supply requirements. Generally, the uncertainty associated with the analytically derived future values of water demand can come from a combination of the following distinct sources:

(1) Random error: The random nature of the additive error process in a linear (or log-linear) regression model which is estimated based on historical data guarantees that future estimates will deviate from true values even if the model is specified correctly and its parameter values (i.e., regression coefficients) are known with certainty.

(2) Error in model parameters: The process of estimating the regression coefficients introduces error because estimated parameter values are random variables which may deviate from the true values.

(3) Specification error: Errors may be introduced because the model specification may not be an accurate representation of the "true" underlying relationship.

(4) Scenario uncertainty: Future values for one or more model variables cannot be known with certainty. Various assumptions must be introduced when projections are made for the water demand drivers (such as population, employment or irrigated acreage) as well as when projecting the values of the determinants of water usage (such as income, price, precipitation and other explanatory variables).

The approach used in this study is uniquely suited for dealing with the last source of error – the scenario error. By defining three alternative scenarios the range of uncertainty associated with future water demands in the study area can be examined and taken into consideration in planning decisions. A careful analysis of the data and model parameters was undertaken in other to minimize the remaining three sources of error.

WATER DEMAND SCENARIOS

Estimates of future water withdrawals were prepared for three different scenarios. The scenarios include a less resource intensive (LRI) outcome, a current trends (CT) or baseline case scenario, and a more resource intensive (MRI) outcome. The scenarios were defined by different sets of assumed conditions regarding the future values of demand drivers and explanatory variables.

The purpose of the scenarios is to capture future water withdrawals under three different sets of conditions. The three scenarios do not represent forecasts or predictions, nor do they set upper and lower bounds of future water use. Different assumptions or conditions could result in withdrawals that are within or outside of the range represented by the three scenarios.

The study followed the assumptions developed by CMAP for the "population density and distribution of growth" variable. The assumptions made for this variable across the less resource intensive (LRI) and more resource intensive (MRI) scenarios and for the county scale growth pattern are:

- Higher density settlement (LRI) tends to result in lower overall per capita water demands as compared to lower density settlements (MRI);
- The Lake Michigan service region is generally a higher density "landscape" with a higher proportion of multifamily housing, and it can accommodate a large percentage of regional growth projections;
- Cook and DuPage Counties are predominantly both higher residential density than the other nine remaining counties and within the Lake Michigan service region;
- Growth projections for the outer four counties – Boone, DeKalb, Grundy, and Kankakee Counties – are not modified for the LRI and MRI scenarios because people who will move into those four counties are largely doing so due to jobs in those counties and are thus are not likely to consider DuPage and Cook Counties as alternative living choices (i.e. the outer four are typically not within the Chicago region);
- Growth projections for Will and Lake Counties are not modified for the purpose of the two scenarios because both counties are a mixture of low/high density settlement and both counties are served by both Lake Michigan water and groundwater;
- For the LRI scenario, additional population growth is added to Cook and DuPage Counties. The increase in population is equivalent to 30 percent of the projected combined growth in McHenry, Kane, and Kendall Counties; and
- For the MRI scenario, additional population growth is added to McHenry, Kane, and Kendall Counties. The population increase is equivalent to 30 percent of the combined growth in Cook and DuPage Counties.

In all three scenarios, total population growth in the 11-county study area is assumed to remain the same. Additional general assumptions used in defining each of the three scenarios are described below.

Scenario 1 – Current Trends (CT) or Baseline Scenario

The basic assumption of this scenario is that the recent trends (last 10 to 20 years) in population growth and urban development patterns will continue. With respect to population growth the "current trends" are represented by the official forecasts of population and employment in the 11-county planning area. The official forecast prepared by CMAP includes the total number of residents and jobs for the region, and the distribution of growth that is the *most likely* to occur given market forces and expected implementation of public policies. The CMAP population projections are based on technical analyses of demographic trends and examination of development activity in the region.

The CT scenario does not rely on a simple extrapolation of recent historical trends in total or per capita (or per employee) water use into the future. Instead, the future unit rates of water use are determined by the water demand model as a function of the key explanatory variables. The "recent trends" assumption applies only to future changes in the explanatory variables. Accordingly, the CT scenario assumes that the explanatory variables such as income and price will follow the recent historical trends or their official or available forecasts. This scenario also assumes that recent trends in the efficiency of water usage (mostly brought about by the effects of plumbing codes and fixture standards, as well as actions of water users) will continue. The conservation trend in the historical data on water use is estimated as a part of the regression model.

Scenario 2 – Less Resources Intensive (LRI) Scenario

In this scenario, the pattern of population and urban development within the 11-county study area is modified by shifting some population and employment growth to more urbanized counties of the study area (Cook and DuPage) and away from the fast-growing western collar counties (Kane, Kendall and McHenry) while keeping total population and employment growth in the study area at the same level as in Scenario 1. Industrial withdrawals of water would decrease as some less water-intensive industrial activities continue to expand or locate in the study area. The efficiency assumptions include more water conservation (e.g., implementation of additional cost-effective water conservation measures by urban and industrial users), as well as lower income and higher water prices in the future. An associated outcome of this scenario is a greater reliance of new population on the existing water infrastructure and water withdrawals from Lake Michigan than under the CT scenario.

Scenario 3 – More Resource Intensive (MRI) Scenario

In this scenario, the pattern of population and urban development within the 11-county study area is modified by shifting some population and employment growth toward the western collar counties (Kane, Kendall and McHenry) and away from the more urbanized counties of the study area (Cook and DuPage) while keeping total growth at the same level as in Scenario 1. The efficiency assumptions include less water conservation than indicated by the recent trends in Scenario 1. Industrial withdrawals of water would increase as some water-intensive manufacturing categories continue to expand or locate in the study area. The price of water is assumed to remain unchanged in real terms, which implies that future price increases will only offset the general inflation. A higher rate of growth of median household income is also assumed. An associated outcome of this scenario is a greater reliance of new population on new water infrastructure and a higher level of water withdrawals from groundwater sources and Fox River Basin. A detailed listing of assumptions for each of the three scenarios is given in Table 1.1. Additional discussion of sector-specific assumptions for each scenario is included in the chapters which describe estimates of water demand in each sector.

Table 1.1 Factors Affecting Future Water Demands in the 11-County Area of NE Illinois

Factor	Scenario 1- Current Trends (CT) or Baseline	Scenario 2- Less Resource Intensive (LRI)	Scenario 3 – More Resource Intensive (MRI)
Total population	CMAP projections	CMAP projections	CMAP projections
Redistribution of population of growth	CMAP projections	More population in Cook and DuPage counties	More population in Kane, Kendall and McHenry counties
Mix of commercial/ industrial activities	Current trends	Decrease in high water-using activities	Increase in high water-using activities
Median household income	Existing projections of 0.7 %/year growth	Existing projections of 0.5 %/year growth	Higher growth of 1.0 %/years
Demand for electricity	9.61 kWh/capita + 0.56% annual growth	9.61 kWh/capita without growth	9.61 kWh/capita + 0.56% annual growth
Power generation	No new plants within study area, 3 units retired,	No new power plants within study area, 3 units retired, conversion to closed-loop cooling	Two new power plants in study area with closed-loop cooling
Water conservation	Continuation of historical trend	50% higher rate than historical trend	No extension of historical trend
Future water prices	Recent increasing trend (0.9%/year) will continue	Higher future price increases (2.5%/year)	Prices held and 2005 level in real terms
Irrigated land	Constant cropland increasing golf courses (10/decade)	Decreasing cropland + no increase in golf courses	Constant cropland increasing golf courses (20/decade)
Livestock	Baseline USDA growth rates	Baseline USDA growth rates	Baseline USDA growth rates
Weather (air temperature and precipitation)	30-year normal (1971-2000)	30-year normal (1971-2000)	30-year normal (1971-2000)

ORGANIZATION OF THE REPORT

The report is organized into an executive summary and seven chapters. The executive summary combines the results for all sectors and briefly discusses some of the implications of this study for the further analysis of water withdrawals in Northeastern Illinois.

Chapter 1 introduces the data and analytical models for estimating future water demands. The four major water use sectors are described in the four subsequent chapters (Chapters 2, 3, 4, and 5). Each of these chapters begins with a brief review of the definition of the water demand sector, a summary of the historical changes in reported water withdrawals in the sector, and the procedure for deriving water-demand relationships for the sector. This is followed by a description of the assumptions used to develop water-demand scenarios for the sector, and a summary of the scenario results. Each chapter also includes a Chapter Annex which contains detailed tables with primary data and/or auxiliary worksheets and other information used in the process of deriving future water withdrawals.

Chapter 6 describes the sensitivity analysis, which shows the impacts on water withdrawals under five climate change scenarios.

Chapter 7 addresses peak-day and water demand for public-supply sector and peak month demand for other sectors, as well as the potential increase in water demands during a period of drought.

References for all the chapters appear at the end of the report.

The final part of this project included an allocation of future withdrawals within each geographical area to the existing withdrawal points. The results of this work are not included in this report. Instead, the electronic tables of withdrawals allocated into approximately 1,700 individual points of water withdrawal were provided directly to the Illinois State Water Survey for their use as inputs into hydrologic groundwater (and surface water) models.

CHAPTER 2

PUBLIC AND DOMESTIC WATER SUPPLY

BACKGROUND

Public water supply refers to water that is withdrawn, treated, and delivered to individual residential, commercial, industrial, institutional, and governmental users by public water supply systems. Water can also be purchased from a nearby system and delivered to users. The U.S. EPA defines a "public" water system as a publicly-owned or privately-owned system that serves at least 25 people or 15 service connections for at least 60 days per year (USEPA, 2004a). Not all users of water within a given geographical area rely on water delivered by public systems; some users have their own sources of supply and are considered to be self-supplied. The self-supplied users include industrial and commercial establishments using their own wells or surface water intakes, as well as residential users who rely on private wells. The latter group of users is called the self-supplied domestic sector, and is included in the last section of this chapter.

Definition of Study Areas

According to the EPA data, there are 530 public water supply systems in the 11-county area of Northeastern Illinois (Table 2.1). These systems serve the estimated population of 8,351,206 persons, as well as local businesses and institutions. In addition, it is estimated that an additional 392,650 people are served by domestic wells and other sources in the self-supplied domestic sector in 2005.

Table 2.1 Public Water Supply Systems in Northeastern Illinois

County	2005 Resident County Population [a]	All Public Systems [b]		Systems in This Study	
		Number of Systems	Est. 2005 Population Served*	Number of Systems (Subsystems)	Est. 2005 Population Served**
Boone	50,483	10	33,618	1 (1)	23,500
Cook	5,303,683	163	5,425,187	10 (130)	5,356,788
DeKalb	97,665	19	85,344	1 (2)	40,000
DuPage	929,113	53	786,652	1 (33)	728,427
Grundy	43,838	19	31,865	1 (1)	13,282
Kane	482,113	40	489,688	2 (4)	312,572
Kankakee	107,972	21	77,987	1 (3)	67,000
Kendall	79,514	9	41,278	1 (1)	23,000
Lake	702,682	105	600,247	6 (30)	429,085
McHenry	303,980	34	210,891	1 (2)	40,440
Will	642,813	57	455,803	1 (3)	130,830
NE Illinois – 11 counties	8,743,856	530	8,238,560	26 (210)	7,164,924

[a] Source: Population Division, U.S. Census Bureau, Release Date: March 16, 2006

[b] Number of systems and population served obtained from EPA: http://oaspub.epa.gov/;

* Population served in 2005 as reported by the EPA is lower than the estimates used in this study because not all of the EPA's estimates of population served for individual systems are updated for 2005

** The total for 26 systems does not include the population served by systems in the 11 county remainder areas.

In order to develop future public water-use scenarios for the 11-county area, a sample of 26 large "dominant" public water supply systems (with some systems including multiple subsystems) was selected for detailed study of historical water use. For the purpose of this study, each of the 26 systems was defined as a water supply system in a geographical area consisting of one or more geographical parts with contiguous piped water services, provided by one dominant system. The dominant system consists of a water source (surface water, groundwater or purchased water), and related infrastructure, through which the dominant system provides water to a part, or, in some cases, to the entire area. If only a part of an area is served by the dominant system, the "system" definition, and its related statistical information, also includes all of the population, water demand, and related data for the entire partially-served entity, including water from sources other than the dominant system.

The 26 large systems, in total, account for 210 public water subsystems. The complete listing of systems and subsystems included in the study is given in Table A2.1 in the Annex to this chapter. As shown in Table 2.1 above, the 26 large systems served the population of 7,164,924 or approximately 86 percent of the total population served by the 530 systems which are listed in the EPA data.

In order to account for all population served in the study areas, the systems and subsystems which were not included among the 26 principal service areas, were grouped for each county as "county remainder" (also referred to as "county residual") study sub-areas (thus representing combined other systems). In this way, the 26 selected principal service areas and 11 county remainder areas include all population served by public systems in the 11-county area.

Historical Water Withdrawal Data

The data on public-supply water withdrawals were obtained from Mr. Timothy Bryant, Coordinator of the Illinois Water Inventory Program administered by the Illinois State Water Survey (ISWS). Under this program, a questionnaire is sent to all of the nearly 1,800 community water systems in the state, including questions about water sources, withdrawals, and water deliveries to domestic, commercial, and industrial users (ISWS, 2007). If systems do not complete a survey for the USGS target years, water withdrawal is estimated based on extrapolation from data submitted in previous years. The withdrawal and population served data from each reporting systems were aggregated to create the data for the 26 dominant systems and 11 county remainder areas.

Table 2.2 shows the 2005 water withdrawal data for public supply and self-supplied domestic users for the study area prepared in this study. The data indicate total withdrawals of 1,255.71 mgd. An additional 35.34 mgd are withdrawn by the self-supplied domestic sector. The combined public-supply and self-supplied domestic withdrawals in 2005 were 1,291.05 mgd or approximately 148 gallons per capita per day (gpcd).

Table 2.2 Public-Supply and Self-Supplied Domestic Water Use for 2005

County	Public Supply Withdrawals				Self-supplied Domestic	
	Population Served	26 Systems MGD	County Remainder MGD	Total Public MGD	Self-supplied Population	Total MGD
Boone	39,320	3.66	0.66	4.31	11,160	1.00
Cook	5,445,377	916.14	9.53	925.67	5,300	0.48
DeKalb	82,120	4.36	4.26	8.62	15,550	1.40
DuPage	810,417	90.62	7.92	98.55	22,160	2.00
Grundy	35,140	1.64	1.34	2.97	8,700	0.78
Kane	581,277	33.64	26.38	60.01	1,930	0.17
Kankakee	87,200	12.89	2.13	15.01	20,770	1.87
Kendall	52,190	2.36	2.11	4.47	27,320	2.46
Lake	615,870	55.09	18.77	73.87	86,810	7.81
McHenry	284,947	5.43	20.36	25.79	54,860	4.94
Will	317,349	16.47	19.96	36.43	138,090	12.43
Total 11 Co.	8,351,206	1,142.29	113.42	1,255.71	392,650	35.34

Data on Explanatory Variables

A substantial data collection and processing effort was required in order to prepare appropriate explanatory variables for development of water-demand relationships. The dependent variable for the public-supply sector was defined as gross water demand per capita (including residential deliveries as well as deliveries to commercial, industrial, and institutional establishments located within areas served by public systems). Five independent variables were used to explain the variability of per capita water usage across study sites and at different time periods. They included: summer season air temperature, summer season precipitation, ratio of local employment-to-population, marginal price of water, and median household income. The data on the weather variables were obtained from Dr. Kenneth E. Kunkel, Director of the Center for Atmospheric Science of the Illinois State Water Survey. The data included observations on monthly temperature and precipitation for 12 stations in Northeastern Illinois, listed in Table 2.3.

Table 2.3 Locations of Weather Stations in Northeastern Illinois

Station No.	Location	County
110338	Aurora	Kane
111497	Chicago Botanical Garden	Cook
111577	Chicago Midway Airport 3SW	Cook
112223	De Kalb	DeKalb
112736	Elgin	Kane
114530	Joliet Brandon Rd. Dam	Will
114603	Kankakee Metro Wastewater Plant	Kankakee
114837	Lake Villa 2NE	Lake
115326	Marengo	McHenry
116616	Park Forest	Cook
119221	Wheaton 3SE	DuPage
117382	Rockford Airport (for Boone Co.)	Winnebago

The weather data for each system and county remainder area were obtained from the closest station. For the Chicago system, average values from the three Cook County stations were used.

Data on employment and median household income were obtained from the U.S. Census (http://quickfacts.census.gov/qfd/states) and from the 2005 American Community Survey. Data on historical prices of water were developed using data from a survey of state water prices conducted in 2003 (Dziegielewski, Kiefer and Bik, 2004). The 2005 prices were obtained from other available sources and directly from water utilities.

One additional variable was included to account for unspecified changes that are likely to be influencing water withdrawals over time, and that represents general trends in water conservation behavior. Such influences include the increase in water-use awareness programs, implementation of Federal laws mandating adoption of conservation technologies, and a new emphasis on adoption of full-cost pricing of water. The “conservation trend” variable was specified as zero for 1985, 5 for 1990, 10 for 1995, 15 for 2000, and 20 for the year 2005.

WATER-DEMAND RELATIONSHIPS

Per Capita Water Withdrawals

A log-linear model (specified as Equation 3 in Chapter 1) was applied to capture the relationship between per capita water withdrawals (and purchases) and the explanatory variables.

The statistical model explained per capita water withdrawal as a function of the maximum daily air temperatures during growing season (May to September), total precipitation during growing season, the ratio of employment to resident population, the marginal price of water, median household income, and the conservation trend variable.

The estimated structural part of the regression model is shown in Table 2.4. The complete model with estimates of the coefficients of binary variables is included as Table A2.19 in the Annex to this chapter. The Annex also includes a detailed description of the analytical steps of model development.

Table 2.4 Estimated Log-Linear Model of Per Capita Water Demand (GPCD) in Public-Supply Sector

Variables*	Estimated Coefficient	t Ratio	Probability >|t|
Structural model			
Intercept	-0.6152	-0.20	0.8400
Max. summer temperature (ln)	1.0951	1.63	0.1065
Summer precipitation (ln)	-0.0949	-1.56	0.1203
Employment-population ratio	0.0931	1.62	0.1071
Marginal price of water (ln)	-0.1458	-4.25	<.0001
Median household income (ln)	0.2845	5.90	<.0001
Conservation trend (ln)	-0.0593	-4.29	<.0001

*Other model parameters and diagnostics are included in Chapter 2 Annex.

The estimated elasticities of the explanatory variables in the structural model have the expected signs and magnitudes. The constant elasticity of summer season temperature indicates that, on average, a 1 percent increase in temperature increases per capita water usage by 1.0951 percent. The negative constant elasticity of summer rainfall variable indicates that on average a 1 percent increase in summer precipitation decreases per capita water usage by 0.0949 percent. Similarly, a 1 percent increase in marginal price of water is associated with a 0.1458 percent decrease in per capita water deliveries, and a 1 percent increase in median household income results in a 0.2845 percent increase in per capita water usage.

The coefficient of employment-to-population ratio of 0.0931 indicates that in study areas with higher commercial/industrial employment relative to resident population, per capita water usage tends to be higher. Specifically, an increase of the ratio from the average of 0.6 to 0.7 would result in an increase of 1.3 gallons per capita per day (gpcd), or approximately a 0.9 percent increase.

Another variable is the conservation trend, with the estimated coefficient of -0.0593. It indicates that in the historical data there was a significant declining trend in per capita water withdrawals of approximately 0.3 percent per year.

The estimated regression equation also includes binary variables with statistically significant regression coefficients. These variables provide for a tighter fit of the model predictions to historical data, and their coefficients represent adjustments to the model intercept for individual study sites. In addition to site-specific intercept adjustments, the estimated model also includes several binary spike variables. These estimates represent the effect of individual observations which had high prediction residuals. Their inclusion in the equations removes their influence on model parameters and results in increased significance of some of the coefficients of the structural model.

The complete regression model explained 89 percent of time-series and cross-sectional variance in log-transformed per capita water use. An additional measure of the performance of the regression model is the mean absolute percent error (MAPE) of the model’s estimation of the data used to estimate the regression equation. The MAPE of the model is 9.1 percent.

Model Estimated and Reported Water Withdrawals in 2005

The estimated water-demand equations were used to generate estimates of both the historical and future water withdrawals in each of the 37 study areas. Table 2.5 compares the model-estimated and reported values of combined water withdrawals and purchases for each system, and within county residual areas. The differences between the predicted and reported values are relatively small, since in several cases where the differences for the 2005 data year were larger, additional calibrations of model intercepts were performed. The calibrated 2005 intercepts were retained in preparing estimates of future water use. A comparison of the actual and predicted values of per capita water use for all historical observations is included in Table A2.21 in the Annex to this chapter.

Table 2.5 Comparison of Model-Estimated and Reported Water Withdrawals and Purchases in 2005

System Name/Area	Estimated Population Served	Model-estimated Withdrawals In MGD	Reported Withdrawals In MGD
Aurora	170,000	18.13	18.10
Bedford Park*	130,415	25.65	25.36
Belvidere	23,500	3.71	3.66
Central Lake Co. JAWA	197,446	21.11	21.21
Chicago*	3,960,041	731.05	729.56
Crystal Lake	40,440	6.13	5.43
DeKalb	40,000	4.77	4.36
DuPage Water Com.*	728,427	90.32	90.62
Elgin	142,572	15.78	15.54
Evanston	354,258	45.61	45.73
Glencoe	8,600	1.79	1.87
Hammond WSS	133,035	18.23	18.36
Highland Park	59,580	12.30	11.77
Joliet	130,830	15.73	16.47
Kankakee Aqua Illinois	67,000	12.61	12.89
Lake County PWD	29,536	3.39	3.01
Lake Forest	21,477	4.89	4.75
Morris	13,282	1.59	1.64
North Chicago	19,127	4.86	4.69
Northbrook	36,975	5.53	6.08
Northwest Sub. M. JAWA*	309,084	35.83	35.93
Oak Lawn*	316,389	36.77	36.58
Oswego	23,000	2.57	2.36
Waukegan	101,919	9.32	9.66
Wilmette	90,391	11.66	12.86
Winnetka	17,600	2.87	3.83
Residual Boone	9,597	0.74	0.66
Residual Cook*	295,666	20.29	9.53
Residual DeKalb	39,757	4.44	4.26
Residual DuPage	112,062	7.62	7.92
Residual Grundy	19,625	1.46	1.34
Residual Kane	219,403	25.99	26.38
Residual Kankakee	21,540	2.52	2.13
Residual Kendall	18,835	1.92	2.11
Residual Lake	132,228	14.74	18.77
Residual McHenry	192,795	15.68	20.36
Residual Will	141,587	21.63	19.96
Total Study Area	8,368,021	1,259.21	1,255.71

*The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

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Water Withdrawals by Source

The main sources of water supply in the 11-county study area include Lake Michigan, groundwater, and surface water from local rivers. Table 2.6 shows the percentage shares of 2005 water withdrawals by the public systems and county remainder areas.

Table 2.6 Percentage Shares by Source of 2005 Water Withdrawals in the Northeastern Illinois Study Areas

Public Water System/ Supply Area	Percent Groundwater	Percent Surface Water – Rivers	Percent Surface Water – Lake Michigan
Aurora	56.0	44.0	0.0
Bedford Park	0.0	0.0	100.0
Belvidere	100.0	0.0	0.0
Central Lake County JAWA	0.1	0.0	99.9
Chicago	0.0	0.0	100.0
Crystal Lake	100.0	0.0	0.0
DeKalb	100.0	0.0	0.0
DuPage Water Commission	0.3	0.0	99.7
Elgin	5.7	94.3	0.0
Evanston	0.1	0.0	99.9
Glencoe	0.0	0.0	100.0
Hammond WSS	0.0	0.0	100.0
Highland Park	0.0	0.0	100.0
Joliet	100.0	0.0	0.0
Kankakee-Aqua Illinois	0.0	100.0	0.0
Lake County PWD	0.0	0.0	100.0
Lake Forest	0.0	0.0	100.0
Morris	100.0	0.0	0.0
North Chicago	0.0	0.0	100.0
Northbrook	0.0	0.0	100.0
Northwest Suburban JAWA	0.3	0.0	99.7
Oak Lawn	0.0	0.0	100.0
Oswego	100.0	0.0	0.0
Waukegan	0.0	0.0	100.0
Wilmette	0.0	0.0	100.0
Winnetka	0.0	0.0	100.0
Residual Boone	100.0	0.0	0.0
Residual Cook	96.0	0.0	4.0
Residual DeKalb	100.0	0.0	0.0
Residual DuPage	100.0	0.0	0.0
Residual Grundy	100.0	0.0	0.0
Residual Kane	100.0	0.0	0.0
Residual Kankakee	100.0	0.0	0.0
Residual Kendall	100.0	0.0	0.0
Residual Lake	94.5	0.0	5.5
Residual McHenry	100.0	0.0	0.0
Residual Will	96.6	3.4	0.0

FUTURE WATER DEMAND

Future Population Growth

The main driver of future water demand in the public-supply sector is population served. The data on future increases in resident population of the study area were provided by CMAP. Table 2.7 shows the expected increase in total population in each of the 11 counties by 2030 and 2050. The 2000-2030 projections for the original six counties included in the Northeastern Illinois Planning Commission (NIPC) studies (i.e., Cook, DuPage, Lake, Will, Kane, and McHenry) represent projections which have been reviewed by local officials through a process used by CMAP. For the remaining five counties, the projections are based on data provided to CMAP by the State of Illinois in 2006.

The 2030 to 2050 extension of population forecasts for the 11-county area was the product of a linear growth extension rather than an exponential growth (i.e., compounded via an annual growth rate). The population estimates for the period 2000-2030 were regressed on the year variable, and then the estimated intercept and slope were applied to obtain the estimates for 2040 and 2050. The linear extension was considered as the most reasonable assumption for extending the 2000–2030 population projections.

Table 2.7 Resident Population Projections 2000-2050 for 11-County Study Area

County	2000	2005	2030	2050	2000-2050 Change	Percent change
Boone	41,786	50,483	57,890	68,626	+26,840	64
Cook	5,376,741	5,303,683	5,952,794	6,336,829	+960,088	18
DeKalb	88,969	97,665	131,076	159,147	+70,178	79
DuPage	904,161	929,113	1,003,702	1,070,063	+165,902	18
Grundy	37,536	43,838	66,266	85,419	+47,883	128
Kane	404,119	482,113	718,464	928,027	+523,908	130
Kankakee	103,833	107,972	139,186	162,755	+58,922	57
Kendall	54,545	79,514	190,149	280,552	+226,007	414
Lake	644,463	702,682	841,860	973,458	+328,995	51
McHenry	260,077	303,980	457,594	589,272	+329,195	127
Will	502,584	642,813	1,076,446	1,459,021	+956,437	190
NE Illinois	8,418,814	8,743,856	10,635,427	12,113,169	+3,694,355	44

Source: Chicago Metropolitan Agency for Planning (CMAP, 2007). 2005 estimates shown for comparison.

The values in Table 2.7 show that for the 11-county study area, total resident population is expected to increase between 2000 and 2050 from 8,418,814 to 12,113,169. This represents an increase of 3,694,355 persons (or 44 percent). In two counties, Cook and Will, the population is expected to increase by nearly one million.

Table 2.8 shows the projected changes in future population in each of the 26 principal water supply systems included in the study.

Table 2.8 Projections of Population Served by 26 Principal Water Supply Systems

Water Supply System	2000	2005	2030	2050	2000-2050 Change	Percent Change,%
Aurora	140,000	170,000	185,571	217,668	77,668	55
Belvidere [a]	20,820	23,500	26,869	32,019	11,199	54
Central Lake Co. JAWA	172,724	197,446	240,706	280,533	107,809	62
Chicago*	5,109,707	5,444,356	6,195,291	6,767,740	1,658,033	32
Chicago (system)	*3,730,376*	*3,960,041*	*4,399,312*	*4,681,903*	*951,527*	*26*
Bedford Park	*89,129*	*130,415*	*226,446*	*308,865*	*219,736*	*247*
DuPage Water Com.	*715,034*	*728,427*	*822,131*	*902,364*	*187,330*	*26*
Northwest Sub. JAWA	*299,534*	*309,084*	*331,334*	*349,017*	*49,483*	*17*
Oak Lawn	*275,634*	*316,389*	*416,068*	*525,591*	*249,957*	*91*
Crystal Lake	36,300	40,440	43,808	48,095	11,795	32
DeKalb [a]	39,000	40,000	49,885	63,937	24,937	64
Elgin	134,040	142,572	211,974	274,777	140,737	105
Evanston	315,261	354,258	381,167	402,660	87,399	28
Glencoe	8,600	8,600	8,957	9,087	487	6
Hammond WSS	130,448	133,035	140,405	155,672	25,224	19
Highland Park	58,656	59,580	62,536	69,447	10,791	18
Joliet	106,745	130,830	155,718	189,109	82,364	77
Kankakee Aqua Illinois	65,000	67,000	74,013	84,354	19,354	30
Lake County PWD	27,992	29,536	43,252	54,052	26,060	93
Lake Forest	18,817	21,477	22,197	23,910	5,093	27
Morris [a]	11,928	13,282	21,499	32,080	20,152	169
North Chicago	20,400	19,127	32,810	38,683	18,283	90
Northbrook	36,200	36,975	43,900	48,849	12,649	35
Oswego [a]	12,000	23,000	52,160	78,335	66,335	553
Waukegan	86,689	101,919	108,562	118,492	31,803	37
Wilmette	89,244	90,391	98,730	106,831	17,587	20
Winnetka [a]	17,619	17,600	19,970	21,997	4,378	25
Total for 26 systems	6,658,190	7,164,924	8,219,979	9,118,327	2,460,137	37

Source: Chicago Metropolitan Agency for Planning (CMAP, 2007); based on municipal data. Population-served estimates usually differ from the estimates of municipal resident population. [a] Projections for these 5 systems were not developed by CMAP, the estimates are obtained by prorating county-level population projections.

* The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Future Changes in Explanatory Variables

The future values of the five explanatory variables (i.e., temperature, precipitation, employment/population ratio, price, and income) will determine the future rates of per capita water withdrawals in the public-supply sector in each study area. In preparing scenarios the future values have to be estimated by making calculations based on specified assumptions. The selection of the future values is described below.

Summer Temperature and Precipitation

Per capita water withdrawals are affected by summer weather conditions. A higher or lower average of maximum summer temperatures will result in higher or lower per capita water usage as determined by elasticity of +1.0951. Similarly, a higher or lower total of summer season precipitation will result in lower or higher per capita water usage as determined by elasticity of -0.0949. The future values of summer season temperature and precipitation were assumed to represent "normal" weather. This means that the values used for each future year will be average values from each of the 12 weather stations for the 30-year period from 1971 to 2000. The maximum-daily temperature values are shown in Table 2.9.

Table 2.9 Normal Values of May-September Average of Maximum Daily Temperature for 12 Weather Stations Used in the Study

Station No.	Location	County	Max. Temp. 2000	Max. Temp. 2005	1971-2000 Normal
110338	Aurora	Kane	79.0	81.6	78.7
111497	Chicago Bot. Garden	Cook	76.7	80.0	76.8
111577	Chicago Midway	Cook	78.7	81.1	78.8
112223	DeKalb	DeKalb	77.0	80.4	78.0
112736	Elgin	Kane	77.3	81.8	77.4
114530	Joliet Brandon	Will	78.4	81.1	79.2
114603	Kankakee	Kankakee	80.4	82.1	80.4
114837	Lake Villa	Lake	75.3	79.1	76.2
115326	Marengo	McHenry	77.3	80.7	78.8
116616	Park Forest	Cook	77.9	80.2	78.0
117382	Rockford	For Boone	77.4	80.9	78.8
119221	Wheaton	DuPage	82.0	82.9	81.8

Table 2.10 Normal Values of 2000 and 2005 May-September Total Precipitation (Inches) for 12 Weather Stations Used in the Study

Station No.	Location	County	Summer Precip. 2000	Summer Precip. 2005	1971-2000 Normal
110338	Aurora	Kane	20.3	9.2	20.5
111497	Chicago Bot. Garden	Cook	22.1	10.7	19.0
111577	Chicago Midway	Cook	24.8	9.0	19.2
112223	DeKalb	DeKalb	22.9	12.4	20.9
112736	Elgin	Kane	24.0	10.1	20.1
114530	Joliet Brandon	Will	24.3	14.7	19.4
114603	Kankakee	Kankakee	20.8	14.4	19.9
114837	Lake Villa	Lake	26.3	10.5	17.5
115326	Marengo	McHenry	24.0	12.1	20.3
116616	Park Forest	Cook	20.6	16.9	19.9
117382	Rockford	For Boone	30.8	12.6	23.2
119221	Wheaton	DuPage	23.3	10.9	19.8

Total summer precipitation values are shown in Table 2.10. The data indicate that the year 2000 had total summer season precipitation which was generally above normal. Whereas during the summer of 2005, total precipitation was much lower than normal values, thus indicating the presence of drought.

Employment-to-Population Ratios

The future ratios of employment to population were obtained by dividing the CMAP projections of employment by projected population.

Marginal Price of Water

Future changes in retail water prices will result in changes of per capita water usage as determined by the estimated price elasticity of -0.1458. The marginal price of water in the historical data was calculated as the incremental price per 1,000 gallons at the level of consumption between 5,000 gallons and 6,000 gallons per month.

Future values of marginal price will depend on the adoption of pricing strategies by retail water suppliers as well as the frequency of rate adjustments. Water rate structures often remain unchanged for several years thus resulting in a decline of real price with respect to inflation. There is an expectation in the water supply industry, however, that in the future the retail prices for water will increase faster than inflation because of several factors – water quality issues will require more investment in treatment processes, the increasing cost of energy, and the other increasing water system costs, especially infrastructure replacement costs.

Recent trends in water prices were determined from a survey of water rates in Illinois (Dziegielewski, Kiefer and Bik, 2004). The data for 219 water systems in Illinois showed only a 3 percent increase in median value of total water bill at the consumption level of 5,000 gallons per month between 1990 and 2003 (increasing from $18.18 in 1990 to $18.70 in constant 2003 dollars). During the same period, the median value of the marginal price of water increased from $2.59 to $2.90, which represents an increase of 12 percent (in constant 2003 dollars) or 0.9 percent per year. The modest increase in price is a result of a number of systems which kept the nominal prices of water unchanged. Real water price declined (due to inflation) in 112 systems and was increased in 107 systems. The average increase in the 107 systems in terms of total bill was 25 percent, and 39.6 percent in average marginal price (or 2.6 percent per year).

Other sources (in the published literature) also reported increases in the price of municipal water. The NUS Consulting (2007) reported that the average price of water in 51 systems located throughout the United States increased by 6 percent for the period of July 1, 2006 to July 1, 2007. Earth Policy Institute (2007) reported an increase of 27 percent in the United States during the last 5 years. Based on the changes in inflation during the five year period (CPI 2000 = 172.2, CPI 2005 = 195.3), the increase in real price would be approximately 12 percent (or 2.3 percent per year).

For the purpose of this study, it is assumed that changes in future rates will span the range from (1) remaining constant in real terms, to (2) gradually increasing water rates following the recent trend in Illinois of 0.9 percent per year, to (3) increasing the marginal price by 2.5 percent per year. The 2.5 percent increase in marginal price represents an inflation-adjusted increase of 5 to 6 percent per year which was suggested by the RWSPG. The 2.5 percent increase would represent a pricing strategy which provides an increased incentive to conserve water.

Median Household Income

Future changes in median household income will result in changes of per capita water usage as determined by the estimated income elasticity of +0.2845. In the historical data for 1990, 1995, 2000, and 2005, the average trend in median household income (expressed in constant 2005 dollars) was an increase of 0.15 percent per year. Future income is likely to grow, following economic growth in the study area. However, official projections of future income growth at the county or system levels were not available.

One projection of income growth for the State of Illinois was obtained from the Illinois Region Econometric Input/Output Model (IREIM) developed by Hewings (1999). These projections indicate that for the State of Illinois the average annual growth in personal income between 1997 and 2022 is projected to increase at the rate of 1.5 percent per year. Because the growth in median household income is generally less than the expected growth in total personal income, the assumed rates of growth are lower.

The assumed annual growth rate of median household income for the current trends scenario is 0.7 percent. This assumption is based on analysis of the data from the U.S. Census Bureau, Bureau of Labor Statistics performed by Dr. Parry Frank from CMAP (Frank, 2008). The assumed values for less resource intensive and most resource intensive scenarios are 0.5 and 1.0 percent per year, respectively.

Water Demand Under Three Scenarios

The three future scenarios are designed to capture future conditions of water demand for public supply water withdrawals under three different sets of conditions. The scenarios include a less resource intensive outcome, a current trends (or baseline case) scenario, and a more resource intensive outcome. While the scenario outcomes provide a range of future withdrawals, they do not represent forecasts or predictions, and do not set upper and lower bounds for future water use. Different assumptions or different future conditions could result in future withdrawals that are within or outside of this range. The scenario outcomes are estimates of future withdrawals that could occur under the conditions estimated to exist under the assumptions described below.

Scenario 1 – Current Trends/Baseline Case (CT)

The intent of this scenario is to define future conditions as an extension of the recent trends in the factors which influence water demand and using the official projections of population prepared by CMAP. The specific assumptions of this scenario are:

1. Population growth in the service areas of the 26 principal water-supply systems will follow the CMAP projections. However, projections for five systems (Belvidere, DeKalb, Morris, Oswego, and Winnetka) were not developed by CMAP, and these estimates are obtained by prorating county-level population projections.

2. Population changes in county remainder areas are derived by subtracting system-level projections from the CMAP projections for each of the 11 counties.

3. Changes in employment relative to population will follow the CMAP employment projections.

4. Marginal prices of water after 2005 will be increasing at the annual rate of 0.9 percent.

5. Annual growth of median household income during the 2005-2050 period will be 0.7 percent.

6. Future rates of per capita water usage will be affected by the annual “conservation” trend which was estimated from historical data.

7. Summer temperature and precipitation will represent normal values derived from the historical data for the 30-year period from 1971 to 2000.

Scenario 2 – Less Resource Intensive Case (LRI)

The intent of this scenario is to define a set of conditions which would lead to less water use by the public-supply sector. Other conditions not included in this analysis could also lead to less water use. Such an outcome would result if more population growth concentrates in the more densely urbanized areas of Cook and DuPage Counties, and less population growth occurs in the collar counties of Kane, Kendall, and McHenry. Since per capita rate of water usage (gpcd) is lower in high-density residential areas, this should lead to decreased water use in the LRI scenario. The magnitude of the shift was assumed by CMAP at 30 percent of the projected future increase in population of the three collar counties.

The county-level shifts in population were allocated for systems and county residual areas of each of the five counties by adding population growth to systems with historically lower rate of per capita water usage and subtracting growth from systems (and county residual areas) with higher per capita water use. However, because per capita usage was generally higher in Cook and DuPage counties than in the three collar counties the shifts in population growth had only a minor effect on overall per capita withdrawals. The assumed population shifts at the county level for 1010, 2030 and 2050 are shown in Table 2.11.

Table 2.11 Assumed Shifts in Population Served
for Less Resource Intensive Scenario

County	Population Shifts		
	2010	2030	2050
Cook	4,192	75,090	139,837
DuPage	4,192	75,090	139,837
Kane	-3,225	-70,905	-133,774
Kendall	-1,544	-33,191	-60,311
McHenry	-3,614	-46,084	-85,588

The specific assumptions for the Less Resource Intensive (LRI) scenario are:

1. Population growth will be greater in Cook and DuPage counties and smaller in Kane, Kendall, and McHenry Counties, as assumed by CMAP. Population changes in county remainder areas are adjusted to reflect the assumed population shifts.

2. Changes in employment relative to population will follow the CMAP assumed shifts in population (i.e., employment/population ratios will remain unchanged).

3. Marginal prices of water will increase at the rate of 2.5 percent per year (in constant 2005 dollars) in order to provide water conservation incentives.

4. Annual growth of median household income during the 2005-2050 period will be 0.5 percent.

5. Future rates of per capita water usage will be affected by the annual "conservation" trend which is 50 percent higher than the trend in historical data.

6. Summer temperature and precipitation will represent normal values derived from the historical data for the 30-year period from 1971 to 2000.

Scenario 3 – More Resource Intensive Case (MRI)

The intent of this scenario is to define future conditions which would lead to more water usage by the public water-supply sector. Such an outcome would result if the population growth is shifted toward less densely urbanized areas in the collar counties. Since per capita rate of water usage (gpcd) is higher in low density suburban housing, such a shift should lead to high water use in the MRI scenario. To formulate this scenario, CMAP assumed a shift of 30 percent of 2000-2050 growth away from the Cook and DuPage Counties, and toward more growth in the collar counties of Kane, Kendall, and McHenry. Table 2.12 shows the actual shifts of population numbers among the systems in these five counties for the MRI scenario years 2010, 2030 and 2050.

Table 2.12 Assumed Shifts in Population Served
for More Resource Intensive (MRI) Scenario

System/County	Population Shifts		
	2010	2030	2050
Bedford Park	-1,688	-8,752	-15,749
Chicago	-25,595	-132,673	-238,734
DuPage Water Com.	-5,052	-26,386	-47,670
Oak Lawn	-2,873	-14,894	-26,800
Residual Cook	-438	-2,269	-4,082
Residual DuPage	-133	-692	-1,251
Residual Kane	17,013	88,287	158,959
Residual Kendall	5,236	27,169	48,917
Residual McHenry	13,530	70,209	126,410

As in the LRI scenario, the county-level shifts in population were allocated for systems and county residual areas of each of the five counties by adding population growth to systems with historically lower rate of per capita water usage and subtracting growth from systems (and county residual areas) with higher per capita water use. However, because per capita usage was generally higher in Cook and DuPage counties (partly because of high commercial use) than in the three collar counties the shifts in population growth had only a minor effect on overall per capita withdrawals.

The specific assumptions for the More Resource Intensive (MRI) scenario are:

1. Population growth will be greater in Kane, Kendall, and McHenry Counties and smaller in Cook and DuPage Counties, as assumed by CMAP. Population changes in selected systems and county remainder areas are adjusted to reflect the assumed population shifts.

2. Changes in employment relative to population will follow the CMAP assumed shifts in population (i.e., employment/population ratios will remain unchanged).

3. Marginal prices of water will remain constant at the 2005 values (in constant 2005 dollars) thus implying that future increases in water prices will only offset inflation.

4. Annual growth of median household income during the 2005-2050 period will be 1.0 percent.

5. Future per capita rates of water usage will not be affected by the historical conservation trend.

6. Summer temperature and precipitation will represent normal values derived from the historical data for the 30-year period from 1971 to 2000.

SCENARIO RESULTS

Total Public-Supply Withdrawals

The results of the assumptions for each of the three scenarios on water withdrawals in the 11-county study area are summarized in Table 2.13 below. The values of future total and per capita water withdrawals and purchases at the system level for the three scenarios are presented in Tables A2.7 to A2.12 in the Annex to this chapter.

Under the current trend (CT) scenario, the future total water withdrawals for public water supply would increase from 1,255.7 mgd in 2005 (under actual 2005 weather conditions) to 1,570.2 mgd in 2050 (under normal weather conditions). After adjusting the actual 2005 withdrawals to normal weather conditions, the future withdrawals are expected to increase by 32.0 percent from the weather-normalized 2005 withdrawals of 1,189.2 mgd to 1,570.2 mgd in 2050. This 381.0 mgd increase is the result of a 39.1 percent increase in population served and 5.0 percent decrease in weather-normalized per capita values of water withdrawals. The per capita water withdrawal data for three scenarios were generated by the regression model. Total withdrawals are obtained by multiplying future population served by model-generated values of per capita water withdrawals.

Under the Less Resource Intensive (LRI) scenario, the future weather-normalized total water withdrawals for public water supply would increase by 2.4 percent, from the normal weather demand of 1,189.2 mgd in 2005, to 1,217.9 mgd in 2050. This 28.7 mgd increase is the result of a 39.1 percent increase in population served between 2005 and 2050, and a 26.3 percent decrease in per capita water withdrawals during the same period.

Finally, under the More Resource Intensive (MRI) scenario, the future water withdrawals for public water supply would increase by 54.5 percent, from the normal weather demand of 1,189.2 mgd in 2005, to 1,837.2 mgd in 2050. This 648.0 mgd increase is the result of 39.1 percent increase in total population served between 2005 and 2050, and an 11.1 percent increase in per capita water withdrawals during the same period.

Surface and Groundwater Withdrawals

The mix of water supply sources will change throughout the period from 2005 through 2050 because of differential growth rates among water systems with different mixes of supply sources. In all three scenarios, groundwater withdrawals are projected to increase faster than surface water withdrawals. The highest percentage increases are projected for groundwater withdrawals, followed by withdrawals from local rivers, with the lowest percentage increase in withdrawals from Lake Michigan.

When comparing weather-normalized 2005 and 2050 withdrawals, the groundwater withdrawals would increase by 111.9 percent (167.0 mgd) under the CT scenario. The corresponding increases under LRI and MRI scenarios would be 60.8 percent (90.7 mgd), and 168.7 percent (251.7 mgd), respectively.

Water withdrawals from surface non-lake water (river) sources are very small compared to lake and groundwater withdrawals. By comparing weather-normalized 2005 and 2050 values, the surface non-lake water withdrawals would increase by 53.0 percent under the CT scenario. The corresponding increases under LRI and MRI scenarios would be 18.8 percent, and 96.7 percent, respectively.

In comparison, Lake Michigan withdrawals would increase by 19.5 percent (196.7 mgd) under the CT scenario, they would decrease by 6.8 percent (68.3 mgd) under LRI scenario, and increase by and 36.2 percent (364.5 mgd) under the MRI scenario.

It is important to note that the use of Lake Michigan water within Illinois, including the total quantity diverted, is limited by conditions established to comply with a U.S. Supreme Court decree. A public water utility's water source can be changed to a Lake Michigan surface water supply only if the utility applies to the Illinois Department of Natural Resources for a Lake Michigan allocation, and can meet the conditions established to comply with the U. S. Supreme Court decree.

Table 2.13 Public Supply Water Demand Scenarios of 11-County Study Area

Scenario/ Year	Population Served	Per Capita GPCD	Total Withdrawals MGD	Ground-Water MGD	Surface Non-Lake Water MGD	Surface Lake Water MGD
CT	*Current Trends – Baseline Scenario*					
2005 (Reported)	8,368,021	150.4	1,255.7	156.7	36.2	1,062.8
2005 (Normal)	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	140.7	1,219.8	162.2	34.0	1,023.6
2015	9,000,551	139.4	1,254.4	177.5	35.5	1,041.3
2020	9,360,062	138.3	1,294.5	195.8	37.1	1,061.6
2025	9,751,671	137.4	1,340.1	217.0	39.0	1,084.1
2030	10,178,737	136.8	1,392.4	241.5	40.9	1,109.9
2035	10,514,026	136.1	1,430.8	257.7	43.1	1,130.1
2040	10,868,264	135.6	1,473.8	275.4	45.3	1,153.1
2045	11,241,979	135.2	1,519.8	294.8	47.7	1,177.4
2050	11,636,341	134.9	1,570.2	316.2	50.3	1,203.8
2005-2050 Change	3,268,320	-7.2	381.0	167.0	17.4	196.7
2005-2050 %	39.1	-5.0	32.0	111.9	53.0	19.5
LRI	*Less Resource Intensive Scenario*					
2005 (Reported)	8,368,021	150.4	1,255.7	156.7	36.2	1,062.8
2005 (Normal)	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	126.8	1,099.3	145.1	30.7	923.5
2015	9,000,551	123.0	1,106.8	155.0	31.3	920.4
2020	9,360,062	119.6	1,119.4	167.1	32.1	920.2
2025	9,751,671	116.6	1,136.6	181.2	33.1	922.3
2030	10,178,737	113.9	1,158.9	197.4	34.1	927.3
2035	10,514,026	111.2	1,169.6	206.7	35.3	927.6
2040	10,868,264	108.9	1,183.4	216.7	36.5	930.3
2045	11,241,979	106.7	1,199.3	227.7	37.7	933.8
2050	11,636,341	104.7	1,217.9	239.9	39.1	938.8
2005-2050 Change	3,268,320	-37.4	28.7	90.7	6.2	-68.3
2005-2050 %	39.1	-26.3	2.4	60.8	18.8	-6.8
MRI	*More Resource Intensive Scenario*					
2005 (Reported)	8,368,021	150.4	1,255.7	156.7	36.2	1,062.8
2005 (Normal)	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	143.9	1,247.3	168.6	35.0	1,043.8
2015	9,000,551	145.6	1,310.1	191.7	37.3	1,081.2
2020	9,360,062	147.2	1,377.9	218.1	39.9	1,119.9
2025	9,751,671	148.8	1,451.5	248.5	42.7	1,160.3
2030	10,178,737	150.6	1,532.8	283.0	45.7	1,204.1
2035	10,514,026	152.2	1,599.8	308.8	48.9	1,242.1
2040	10,868,264	153.9	1,672.4	336.8	52.3	1,283.3
2045	11,241,979	155.6	1,749.4	367.4	55.9	1,326.1
2050	11,636,341	157.9	1,837.2	400.9	64.7	1,371.6
2005-2050 Change	3,268,320	15.8	648.0	251.7	31.8	364.5
2005-2050 %	39.1	11.1	54.5	168.7	96.7	36.2

2005 (Reported) = actual reported values of water withdrawals for 2005.

2005 (Normal) = weather normalized withdrawals for 2005 obtained by substituting normal weather conditions in the regression model.

Differences Between Scenarios

Table 2.14 shows the differences in estimated water withdrawals between the less resource intensive (LRI) and more resource intensive (MRI) scenarios during the 2005-2050 period as compared to the current trends (CT) scenario. It shows that the differences between the CT scenario and the LRI and MRI scenarios are somewhat asymmetric. Total withdrawals would be 22.4 percent lower under LRI scenario, and 17.0 percent higher under MRI scenario, as compared to the CT scenario. These correspond to differences in water withdrawals between the CT scenario and the LRI and MRI scenarios of -352.4 mgd, and +267.0 mgd, respectively.

Table 2.14 Comparison of Changes in Withdrawals between Scenarios by Source

Source of Supply	2005 Normal (MGD)	2050 CT (MGD)	2050 Scenarios (MGD)	Scenarios -CT (MGD)	%
CT vs. LRI Scenario					
Groundwater	149.2	316.2	239.9	-76.3	-24.1
Surface Water - Rivers	32.9	50.3	39.1	-11.1	-22.2
Surface Water - Lake Michigan	1,007.1	1,203.8	938.8	-264.9	-22.0
Total withdrawals	1,189.2	1,570.2	1,217.9	-352.4	-22.4
CT vs. MRI Scenario					
Groundwater	149.2	316.2	400.9	84.7	26.8
Surface Water - Rivers	32.9	50.3	64.7	14.4	28.6
Surface Water - Lake Michigan	1,007.1	1,203.8	1,371.6	167.8	13.9
Total withdrawals	1,189.2	1,570.2	1,837.2	267.0	17.0

LRI – CT = LRI volume in 2050 minus CT volume in 2050; MRI – CT = MRI volume in 2050 minus CT volume in 2050, % = percent change relative to CT scenario volume

Major factors contributing to the differences in water withdrawals between the scenarios are the result of different assumptions about three influencing factors: the rate of growth in future income, future prices of water and future trends in water conservation. The main effect of the different geographic growth patterns is the shift in water withdrawals between Lake Michigan, groundwater and other surface water sources (Fox River). The effect geographical growth pattern on total overall per capita water usage rates and thus total withdrawals was minor and different than expected.

This lack of impact on per capita use is related to the methodology which was used in preparing water demand scenarios. The approach used was capable of capturing the shifts between water supply sources but lacked the proper data resolution to accurately estimate the effect on per capita water usage caused by the shifts of population between high-density and low density residential areas. The differences in water usage would result primarily from the differences between residential per capita water usage rates in multifamily dwellings in densely urbanized areas relative to per capita usage in single-family homes in low density suburban settings. Because the methodology used in evaluating the scenarios used aggregate municipal water demand (including both the residential and nonresidential uses of water) the effect on residential water use could not be discerned.

DOMESTC SELF-SUPPLIED SECTOR

Historical Withdrawals

The self-supplied domestic sector accounts for a relatively small share of water withdrawals from domestic wells and other sources. For the 11 counties in Northeastern Illinois, USGS estimated the self-supplied population and withdrawals every five years from 1990 to 2005. Table 2.15 shows a significant decrease in total self-supplied population in 1995. Since 1995, the total self-served population oscillated around 400,000 persons.

Table 2.15 USGS Estimated Self-Supplied County Population

County	1990	1995	2000	2005
Boone	13,180	13,010	14,820	11,160
Cook	5,080	4,590	5,380	5,300
DeKalb	23,580	15,550	18,780	15,550
DuPage	101,540	4,270	21,660	22,160
Grundy	9,740	15,210	17,000	8,700
Kane	38,100	1,500	1,620	1,930
Kankakee	30,050	31,030	24,280	20,770
Kendall	28,980	30,490	33,060	27,320
Lake	118,440	37,030	80,980	86,810
McHenry	72,560	92,280	99,270	54,860
Will	116,570	132,170	131,070	138,090
Total NE Illinois	557,820	377,130	447,920	392,650

Source: USGS NWUIP, various years

In 2005, withdrawals of water from domestic sources totaled 35.34 mgd. Table 2.16 shows historical changes in the estimated water withdrawals by self-supplied domestic sector from 1990 to 2005. Significant decreases in total self-supplied domestic withdrawals in DuPage, Kane and Lake Counties were reported for 1995.

Table 2.16 County Level Self-Supplied Domestic Withdrawals (in MGD)

County	1990	1995	2000	2005
Boone	1.21	1.17	1.33	1.00
Cook	0.47	0.41	0.48	0.48
DeKalb	2.16	1.40	1.69	1.40
DuPage	9.30	0.38	1.95	2.00
Grundy	0.89	1.37	1.53	0.78
Kane	3.49	0.14	0.15	0.17
Kankakee	2.17	2.79	2.19	1.87
Kendall	2.65	2.74	2.98	2.46
Lake	10.85	3.33	7.29	7.81
McHenry	6.65	8.31	8.93	4.94
Will	10.68	11.90	11.80	12.43
Totals	50.52	33.94	40.32	35.34

Source: USGS NWUIP, various years

Water Demand Relationship

A log-linear model was estimated to capture the relationship between per capita water usage rates in the residential (domestic) sector of public-supply water and selected explanatory variables. The data on residential deliveries of water by public systems were obtained from the ISWS IWIP database. The regression model presented in Table 2.17 estimated the elasticities of explanatory variables, and includes several binary variables with statistically significant coefficients.

This model explained the per capita residential water withdrawals as a function of median household income and two weather variables: temperature and precipitation. The constant elasticity of median household income indicates that, on average, a 1 percent increase in income increases per capita residential water usage by 0.3499 percent. The elasticity of air temperature indicates that a 1.0 percent increase in temperature would increase water usage by 1.6238 percent. With respect to precipitation, a 1.0 percent increase in summer rainfall would decrease per capita water usage by 0.2186 percent. The conservation trend variable with an estimated coefficient of -0.0325 indicates that, in the historical data on residential water deliveries, there was a significant declining trend in the per capita water use.

Table 2.17 Estimated Log-Linear Model of Per Capita Water Demand (GPCD) for Self-supplied Domestic Sector

Variable	Estimated Coefficient	t Ratio	Probability >|t|
Intercept	-3.4407	-0.59	0.5547
Summer air temperature (ln)	1.6238	1.28	0.2048
Summer precipitation (ln)	-0.2186	-2.05	0.0435
Median household income (ln)	0.3499	4.06	0.0001
Conservation trend (ln)	-0.0325	-1.26	0.2119
N = 122; R^2 = 0.765, Mean Y = 4.411; Root MSE = 0.050			

The relationship from Table 2.17 was applied to estimate per capita water withdrawals in the self-supplied domestic sector.

Projected Self-supplied Population

Since the majority of self-supplied population is served by domestic wells, the future self-supplied domestic population in each county was estimated using the self-supplied population in 2005, the projected increase in total county population since 2005, and the rate of installation of new domestic wells per 1,000 persons of the projected additional future population in each county. The historical data on domestic wells were analyzed in order to establish the trend in the number of new wells which are developed for each 1,000 persons of new population. The historical estimates are included in the Annex to this chapter as Table A2.14.

For the 11-county study area, total self-supplied population is expected to increase between 2005 and 2050 from 392,650 to 476,621. This represents an increase of 83,971 persons (see Table

2.18). In two counties, (Boone, and Kendall) only small increases of self-served population are projected.

Table 2.18 Self-supplied Population Projections
for 11 Northeastern Illinois Counties

County	2000	2005	2030	2050	2005-2050 Change
Boone	14,820	11,160	12,039	12,117	957
Cook	5,380	5,300	11,685	15,385	10,085
DeKalb	18,780	15,550	16,771	17,409	1,859
DuPage	21,660	22,160	24,251	25,084	2,924
Grundy	17,000	8,700	10,340	10,864	2,164
Kane	1,620	1,930	4,619	4,791	2,861
Kankakee	24,280	20,770	27,829	30,567	9,797
Kendall	33,060	27,320	28,277	28,295	975
Lake	80,980	86,810	96,863	99,936	13,126
McHenry	99,270	54,860	83,458	91,732	36,872
Will	131,070	138,090	140,390	140,440	2,350
Total 11-Co.	447,920	392,650	456,522	476,621	83,971

Water Demand Under Three Scenarios

The three scenarios of self-supplied domestic water withdrawals captured future conditions of water demand in this sector. The three scenarios include a current trend (baseline case) scenario, a less resource intensive outcome, and a more resource intensive outcome. In all three scenarios, the self-supplied population growth is estimated based on the number of new well installations per 1,000 people of future county population. Therefore, self-served population is assumed to follow the county total population growth. The specific assumptions for each scenario are listed below. The results of three scenarios are presented in Table 2.19.

Scenario 1 – Current Trends Case (CT)

The assumptions of the CT scenario are: (1) the annual growth of median household income during the 2005-2050 period will be 0.7 percent; and (2) future conservation rate will follow the estimated historical trend.

Scenario 2 – Less Resource Intensive Case (LRI)

The Less Resource Intensive scenario captures future conditions which would lead to less water withdrawals by self-supplied domestic sector. The assumptions of the LRI scenario are: (1) the annual growth of median household income during the 2005–2050 period will be 0.5 percent; and (2) the annual conservation effect will be increased by 50 percent.

Scenario 3 – More Resource Intensive Case (MRI)

The more resource intensive scenario demonstrates future conditions which would lead to more water withdrawals by self-supplied domestic sector. The main assumptions of this scenario are: (1) the annual growth of median household income during the 2005 – 2050 period will be 1.0 percent; and (2) the annual conservation effect will not continue during the 2005-2050 period.

Scenario Results

The results of the three scenarios for the 11-county study area are shown in Table 2.19. Under the current trends scenario, self-supplied domestic withdrawals are projected to increase from a weather normalized value of 31.8 mgd in 2005, to 41.2 mgd in 2050. This represents an increase of 9.3 mgd, or 29.3 percent.

Under the LRI scenario, the withdrawals would decrease to 37.3 mgd by 2050. This represents an increase of 5.5 mgd, or 17.2 percent.

Under the MRI scenario, the withdrawals would increase to 49.3 mgd by 2050. This represents an increase of 17.5 mgd, or 54.9 percent.

Future self-supplied water withdrawals by county are shown in Table A2.13 in the Annex to this chapter.

Table 2.19 Self-Supplied Domestic Water Withdrawal Scenarios

Year	Self-supplied Population	Self-supplied GPCD	Self-supplied Withdrawals MGD
CT	*Current Trends – Baseline Scenario*		
2005	392,650	93.6	36.8
2005 N	392,650	81.1	31.8
2010	410,485	81.3	33.4
2015	424,925	81.7	34.7
2020	437,100	82.2	35.9
2025	447,516	82.8	37.0
2030	456,522	83.4	38.1
2035	463,030	84.1	38.9
2040	468,202	84.8	39.7
2045	472,698	85.6	40.5
2050	476,621	86.4	41.2
2005-50 Change	83,971	5.3	9.3
2005-50 %	21.4%	6.5%	29.3%
LRI	*Less Resource Intensive Scenario*		
2005	392,650	93.6	36.8
2005 N	392,650	81.1	31.8
2010	410,485	77.1	31.7
2015	424,925	76.9	32.7
2020	437,100	76.9	33.6
2025	447,516	77.0	34.5
2030	456,522	77.2	35.2
2035	463,030	77.4	35.8
2040	468,202	77.7	36.4
2045	472,698	78.0	36.9
2050	476,621	78.3	37.3
2005-50 Change	83,971	-2.8	5.5
2005-50 %	21.4%	-3.4%	17.2%
MRI	*More Resource Intensive Scenario*		
2005	392,650	93.6	36.8
2005 N	392,650	81.1	31.8
2010	410,485	90.2	37.0
2015	424,925	91.8	39.0
2020	437,100	93.4	40.8
2025	447,516	95.0	42.5
2030	456,522	96.6	44.1
2035	463,030	98.3	45.5
2040	468,202	100.0	46.8
2045	472,698	101.7	48.1
2050	476,621	103.5	49.3
2005-50 Change	83,971	22.4	17.5
2005-50 %	21.4%	27.6%	54.9%

CHAPTER 2 ANNEX

Chapter 2 Annex – Part 2: Tables

Table A2.1. Public-Supply Water Systems and Subsystems Included in the Study

CHICAGO SYSTEM*
Chicago
Alsip
Crestwood
Palos Heights
South Palos Sanitary Dist
Berwyn
Blue Island
Bridgeview
Brookfield
Lagrange Park
Lyons
North Riverside
Calumet Park
Central Stickney San. Dist.
Cicero
Des Plaines
IL Am. - Waycinden Div.
Dolton
Elmwood Park
Evergreen Park
Forest Park
Forest View
Franklin Park
Garden Home San. Dist.
Harvey
Dixmoor
Hazelcrest
East Hazelcrest
Homewood
Flossmoor
Posen
Harwood Heights
Berkeley
Hillside
Hometown
IL Am. - Moreland
Hickory Hills
Justice
Willow Springs
Lincolnwood
Maywood
McCook
Countryside
Indian Head Park
La Grange Highlands San Dist
Hodgkins
Lagrange
Riverside

CHICAGO SYS. cont
Melrose Park
Bellwood
Leyden Twsp Water Dist.
Northlake
Stone Park
Merrionette Park
Markham
Midlothian
Morton Grove
Golf
Niles
Glenview (Partial)
Norridge
Oak Park
Park Ridge
River Forest
River Grove
Riverdale
Robbins
Rosemont
Schiller Park
South Holland
Phoenix
South Stickney Sanitary Dist.
Stickney
Summit
Broadview
Madden Health Ctr.
Loyola Univ. Med. Ctr.
Westchester
Worth

BEDFORD PARK SYS.
Bedford Park
IL Am. – W. Sub. Div/Santa Fe
Plainfield--Will Co pt.
Shorewood
IL Am. - Derby M. (SW Sub.)
Burr Ridge

EVANSTON SYSTEM
Evanston
Northwest Water Comm.
Arlington Heights
Buffalo Grove
Palatine
Wheeling
Skokie

NORTH W. SUB. SYS.
NW Sub. Mun. JAWA
Elk Grove Village
Hanover Park
Hoffman Estates
Mount Prospect
Rolling Meadows
Schaumburg
Streamwood

WINNETKA SYS.
Winnetka
Northfield

OAK LAWN SYS.
Oak Lawn
Chicago Ridge
Country Club Hills
Matteson
Oak Forest
Olympia Fields
Orland Park
Il Am Water Alpine Hgts Div
Palos Hills
Palos Park
Tinley Park
IL Am. - Fernway Division
Mokena
New Lenox

WILMETTE SYS.
Wilmette
Glenview (Partial)
IL Am. Water-Chicago Sub.U.
Prospect Heights

GLENCOE SYS.

NORTHBROOK SYS.
Northbrook
Mission Brook San. Dist.

HAMMOND SYS.
Burnham
Calumet City
Chicago Heights
Ford Heights
Glenwood
South Chicago Heights

Table A2.1 Public-Supply Water Systems and Subsystems Included in the Study (cont.)

HAMMOND SYS. Cont.
Thornton
Lansing
Lynwood

AQUA IL. KANKAKEE SYS.
Aqua Illinois - Kankakee
Bourbonnais
Bradley
Kankakee

OSWEGO SYSTEM

AURORA (w/o Kendall Pt.)

ELGIN SYSTEM
Elgin
Bartlett
Sleepy Hollow

CNTR. LAKE CO. JAWA
Central Lake County JAWA
Grayslake
Gurnee
Lake Bluff
Lake Co. P. Wks: Knollw./Ron.
Lake Co. P. Wks: Vernon Hills
Lake Co. P. Wks: Wildwood
Libertyville
Mundelein
Round Lake
Round Lake Beach
Round Lake Heights
Round Lake Park

LAKE CO. PWD SYS.
Illinois Beach State Park (IDNR)
Winthrop Harbor
Zion

HIGHLAND PARK SYS.
Highland Park
Bannockburn
Deerfield
Riverwoods
Glenbrook Sanitary District
Linconshire
Us Navy (Ft. Sheridan)

NORTH CHICAGO

LAKE FOREST SYSTEM
Lake Forest
Del Mar Woods

WAUKEGAN SYSTEM
Waukegan
Beach Park
Green Oaks
Park City
Park City MH Park

CRYSTAL LAKE SYSTEM
Crystal Lake
Oak Brook Estates MH Park

JOLIET SYSTEM
Joliet Will Co Portion Only
Aqua Illinois - Oakview
Channahon E. (Will Co Part)

DEKALB SYSTEM
DeKalb
Northern Ill. Univ. - DeKalb

BELVIDERE

MORRIS

DUPAGE WATER COMMISSION
Addison
Argonne National Lab
Bensenville
Bloomingdale
Carol Stream
Clarendon Hills
Darien
Downers Grove
Elmhurst
IL AM. – Country Club Hills
Glen Ellyn
IL AM. – Liberty Ridge East
Glendale Heights
Hinsdale
IL AM. – Valley View
Itasca
Lisle
IL AM. – DuPage Utility
Lombard
IL AM. – Lombard Heights
Naperville
Oak Brook
Oakbrook Terrace
Roselle
Villa Park
Westmont
Wheaton
IL AM. – Arrow Head
Willowbrook
Winfield
IL AM. – Liberty Ridge West
Wood Dale
Woodridge

*The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Table A2.2 2005 Fractions of Population Served by Dominant Systems within Counties (cont.)

System Name	2005 Population Served	Boone	Cook	De-Kalb	Du-Page	Grundy	Kane	Kanka-kee	Ken-dall	Lake	Mc-Henry	Will
Belvidere	23,500	100.0										
Chicago	3,960,041		100.0									
Evanston	354,258		92.0							8.0		
Glencoe	8,600		100.0									
Hammond	133,035		100.0									
Northbrook	36,975		100.0									
Northwest	309,084		94.4		5.6							
Oak Lawn	316,389		87.8									12.2
Wilmette	90,391		100.0									
Winnetka	17,600		100.0									
Bedford park	130,415		8.6		6.1							85.3
DeKalb	40,000			100.0								
DuPage W.C.	728,427		0.3		94.5							5.2
Morris	13,282					100.0						
Aurora	170,000				27.4		72.6					
Elgin	142,572		9.1		18.2		72.8					
Kankakee Aqua Ill.	67,000							100.0				
Oswego	23,000								100.0			
Highland Park	59,580		2.1							97.9		
Lake County PWD	29,536									100.0		
Lake Forest	21,477									100.0		
North Chicago	19,127									100.0		
Waukegan	101,919									100.0		
Central Lake Co. JAWA	197,446									100.0		
Crystal Lake	40,440										100.0	
Joliet	130,830											100.0

Table A2.3 Historical Values of Dependent and Independent Variables for 26 Systems

System Name	Year	MGD	GPCD	Temp.	Precip.	E/P Ratio	Price	Income
Belvidere, Boone	1990	3.53	182.9	77.0	26.9	0.513	0.60	29,509
	1995	3.13	173.0	79.1	18.1	0.521	0.83	35,385
	2000	3.24	157.0	77.4	30.8	0.524	1.04	42,529
	2005	3.66	164.3	80.9	12.6	0.415	1.26	44,600
Bedford Park, Cook Co.	1990	9.75	256.4	76.4	21.5	0.890	0.58	52,439
	1995	18.83	269.4	79.3	15.5	1.710	1.56	63,663
	2000	19.80	237.8	77.8	20.6	1.400	1.97	77,726
	2005	25.36	197.3	80.4	16.9	0.770	3.23	80,433
Chicago, Cook Co.	1990	886.92	261.9	76.4	24.1	0.471	0.84	36,728
	1995	916.58	242.5	79.3	14.2	0.420	1.04	39,520
	2000	826.58	220.3	77.8	22.5	0.510	1.16	42,369
	2005	729.56	184.1	80.4	12.2	0.506	1.40	44,987
Evanston, Cook Co.	1990	46.25	137.8	76.4	24.1	0.361	1.30	47,609
	1995	47.76	155.2	79.3	14.2	0.600	1.55	73,194
	2000	46.40	154.6	77.8	22.5	0.540	1.78	104,232
	2005	45.73	127.6	80.4	12.2	0.560	2.06	113,454
Glencoe, Cook Co.	1990	1.55	197.0	76.4	24.1	0.227	1.72	112,321
	1995	1.74	193.5	79.3	14.2	0.230	2.10	136,858
	2000	1.74	178.8	77.8	22.5	0.233	2.47	164,432
	2005	1.87	226.8	80.4	12.2	0.212	2.91	175,300
Hammond WSS, Cook Co.	1990	9.25	161.8	76.4	24.1	0.364	1.40	30,362
	1995	19.43	153.2	79.3	14.2	0.350	1.95	34,922
	2000	19.63	138.8	77.8	22.5	0.386	2.50	40,101
	2005	18.36	140.6	80.4	12.2	0.227	3.04	42,806
Northbrook, Cook Co.	1990	6.12	210.0	76.4	24.1	1.403	1.72	73,362
	1995	6.27	198.8	79.3	14.2	1.339	2.10	83,825
	2000	5.86	171.6	77.8	22.5	1.624	2.46	95,665
	2005	6.08	165.8	80.4	12.2	1.386	3.38	102,000
Northwest Sub. M.. JAWA	1990	28.20	128.5	76.4	24.1	0.636	2.50	47,309
	1995	36.14	122.3	79.3	14.2	0.590	2.97	53,994
	2000	36.70	115.8	77.8	22.5	0.619	3.18	61,601
	2005	35.93	116.0	80.4	12.2	0.514	3.55	65,521
Oak Lawn, Cook Co.	1990	15.86	136.9	76.4	24.1	0.470	1.53	43,238
	1995	30.79	128.2	79.3	14.2	0.358	2.07	50,469
	2000	33.30	116.4	77.8	22.5	0.432	2.61	58,588
	2005	36.58	116.6	80.4	12.2	0.307	3.15	63,153
Wilmette, Cook Co.	1990	13.81	139.7	76.4	24.1	0.465	3.87	47,218
	1995	11.61	143.2	79.3	14.2	0.585	3.50	56,296
	2000	12.60	134.7	77.8	22.5	0.354	3.50	67,051
	2005	12.86	149.3	80.4	12.2	0.423	2.94	71,100
Winnetka, Cook Co.	1990	3.19	229.3	76.4	24.1	0.832	1.70	106,587
	1995	3.65	218.5	79.3	14.2	0.780	2.13	124,095
	2000	3.31	194.8	77.8	22.5	0.688	3.02	144,415
	2005	3.83	215.1	80.4	12.2	0.657	3.07	153,488
De Kalb, DeKalb Co.	1990	3.97	110.1	76.1	22.8	0.442	3.05	25,387
	1995	3.06	109.9	79.5	18.2	0.528	2.64	29,708
	2000	4.27	107.5	77.0	22.9	0.461	1.92	35,153
	2005	4.36	110.8	80.4	12.4	0.434	1.67	36,100
Du Page Water Com., DuPage	1990	80.90	136.0	79.6	23.7	0.759	2.00	50,130
	1995	77.02	125.9	82.9	16.3	0.661	3.00	59,153
	2000	88.00	123.1	82.0	23.3	0.771	3.23	70,357
	2005	90.62	124.2	82.9	10.9	0.740	3.24	72,836

Table A2.3 Historical Values of Dependent and Independent Variables for 26 Systems, cont.

System Name	Year	MGD	GPCD	Temp.	Precip.	E/P Ratio	Price	Income
Morris, Grundy	1990	1.37	137.2	77.5	24.8	0.775	1.63	31,699
	1995	1.34	130.2	79.7	15.1	0.742	2.12	37,596
	2000	1.84	153.9	78.5	24.6	0.652	2.52	44,739
	2005	1.64	118.8	82.1	17.5	0.647	2.74	46,900
Aurora, Kane	1990	11.32	130.3	77.7	25.2	0.498	2.47	35,039
	1995	15.02	126.0	80.2	18.3	0.530	3.34	43,845
	2000	16.66	120.8	79.0	20.3	0.444	4.14	55,950
	2005	18.10	106.7	81.6	9.2	0.480	4.68	54,861
Elgin, Kane	1990	10.47	114.5	75.8	20.0	0.527	1.20	37,503
	1995	12.49	106.5	78.3	18.8	0.481	1.66	46,706
	2000	13.57	101.2	77.3	24.0	0.559	2.16	59,080
	2005	15.54	109.4	81.8	10.1	0.476	3.12	58,768
Kankakee - Aqua Ill., Kankakee	1990	9.78	197.8	78.7	22.5	0.745	1.63	26,786
	1995	11.63	191.8	80.9	18.1	0.910	2.12	32,373
	2000	12.02	191.3	80.4	20.8	0.927	2.52	38,249
	2005	12.89	194.4	82.1	14.4	1.044	2.74	42,964
Oswego, Kendall	1990	0.38	103.8	77.7	25.2	0.530	1.63	43,889
	1995	0.72	101.7	80.2	18.3	0.530	2.12	57,265
	2000	1.26	101.7	79.0	20.3	0.520	2.52	76,900
	2005	2.36	101.6	81.6	9.2	0.520	2.75	71,502
Central Lake Co. JAWA, Lake Co.	1990	13.25	112.0	74.1	21.7	0.514	3.31	46,932
	1995	16.46	114.0	77.4	15.0	0.663	3.58	57,345
	2000	18.50	103.6	75.3	26.3	0.547	4.51	71,711
	2005	21.21	108.2	79.1	10.5	0.490	4.45	70,262
Highland Park, Lake Co.	1990	7.97	205.8	74.1	21.7	0.825	1.40	76,272
	1995	10.17	200.3	77.4	15.0	0.905	1.95	91,220
	2000	11.33	189.0	75.3	26.3	1.130	2.50	111,151
	2005	11.77	193.8	79.1	10.5	1.151	3.04	111,151
Lake County PWD, Lake Co.	1990	2.21	119.0	74.1	21.7	0.210	2.41	35,237
	1995	2.62	116.4	77.4	15.0	0.292	3.01	41,568
	2000	2.75	105.4	75.3	26.3	0.220	3.25	49,578
	2005	3.01	97.4	79.1	10.5	0.220	3.58	50,875
Lake Forest, Lake Co.	1990	3.34	193.9	74.1	21.7	0.513	1.40	94,824
	1995	3.64	197.3	77.4	15.0	0.779	1.76	113,189
	2000	3.37	179.2	75.3	26.3	0.977	2.20	136,462
	2005	4.75	212.6	79.1	10.5	1.110	3.72	140,100
North Chicago, Lake Co.	1990	7.53	327.5	78.1	21.7	0.515	1.63	25,500
	1995	5.59	310.4	81.0	15.0	0.433	2.12	31,080
	2000	6.59	323.2	78.7	26.3	0.368	2.23	38,180
	2005	4.69	252.8	81.1	10.5	0.494	2.44	39,200
Waukegan, Lake Co.	1990	9.36	121.5	74.1	21.7	0.444	3.54	33,320
	1995	9.24	116.0	77.4	15.0	0.460	4.75	38,825
	2000	9.02	104.1	75.3	26.3	0.417	6.00	46,127
	2005	9.66	95.1	79.1	10.5	0.390	2.03	46,243
Crystal Lake, McHenry	1990	3.27	143.1	77.0	25.9	0.660	0.96	46,197
	1995	4.23	144.0	80.3	15.0	0.700	1.08	56,837
	2000	5.10	132.5	77.3	24.0	0.730	1.08	73,100
	2005	5.43	131.0	80.7	12.1	0.620	1.16	66,872
Joliet, Will Co.	1990	11.79	129.0	77.5	23.3	0.421	1.63	31,841
	1995	11.40	132.0	79.7	15.9	0.625	2.12	41,783
	2000	11.87	124.3	78.4	25.1	0.604	2.40	57,637

Table: A2.4 Allocation of Future Population Served to Water Supply Systems (CT Scenario)

System Name	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	140,000	170,000	173,006	176,065	179,179	182,347	185,571	193,122	200,980	209,157	217,668
Bedford park	89,129	130,415	149,621	168,827	188,034	207,240	226,446	247,051	267,656	288,260	308,865
Belvidere	20,820	23,500	24,138	24,794	25,467	26,159	26,869	28,073	29,331	30,646	32,019
Central Lake Co. JAWA	172,724	197,446	205,426	213,729	222,367	231,355	240,706	250,098	259,857	269,997	280,533
Chicago*	3,730,376	3,960,041	4,044,238	4,130,225	4,218,040	4,307,722	4,399,312	4,468,319	4,538,408	4,609,597	4,681,903
Crystal Lake	36,300	40,440	41,092	41,755	42,429	43,113	43,808	44,843	45,902	46,985	48,095
DeKalb	39,000	40,000	41,806	43,694	45,667	47,730	49,885	53,078	56,476	60,091	63,937
DuPage Water Com.	715,034	728,427	748,292	768,699	789,662	811,197	833,319	855,005	877,255	900,084	923,507
Elgin	134,040	142,572	154,342	167,083	180,877	195,809	211,974	226,181	241,341	257,517	274,777
Evanston	315,261	354,258	359,483	364,786	370,166	375,626	381,167	386,430	391,766	397,175	402,660
Glencoe	8,600	8,600	8,670	8,741	8,812	8,884	8,957	8,989	9,022	9,054	9,087
Hammond WSS	130,448	133,035	134,477	135,936	137,409	138,899	140,405	144,076	147,842	151,706	155,672
Highland Park	58,656	59,580	60,160	60,745	61,336	61,933	62,536	64,197	65,901	67,651	69,447
Joliet	106,745	130,830	135,467	140,268	145,240	150,387	155,718	163,467	171,603	180,143	189,109
Kankakee Aqua Illinois	65,000	67,000	68,347	69,722	71,124	72,554	74,013	76,473	79,015	81,641	84,354
Lake County PWD	27,992	29,536	31,877	34,404	37,132	40,075	43,252	45,731	48,351	51,122	54,052
Lake Forest	18,817	21,477	21,619	21,762	21,906	22,051	22,197	22,613	23,037	23,469	23,910
Morris	11,928	13,282	14,625	16,104	17,732	19,525	21,499	23,761	26,262	29,026	32,080
North Chicago	20,400	19,127	21,307	23,735	26,440	29,454	32,810	34,189	35,626	37,123	38,683
Northbrook	36,200	36,975	38,267	39,603	40,987	42,419	43,900	45,088	46,309	47,562	48,849
Northwest Sub. M. JAWA	299,534	309,084	313,411	317,799	322,248	326,759	331,334	335,669	340,061	344,510	349,017
Oak Lawn	275,634	316,389	334,203	353,019	372,896	393,891	416,068	441,098	467,634	495,766	525,591
Oswego	12,000	23,000	27,093	31,913	37,592	44,281	52,160	57,742	63,921	70,762	78,335
Waukegan	86,689	101,919	103,214	104,526	105,854	107,199	108,562	110,963	113,418	115,927	118,492
Wilmette	89,244	90,391	92,000	93,639	95,306	97,003	98,730	100,696	102,701	104,745	106,831
Winnetka	17,619	17,600	18,050	18,512	18,986	19,472	19,970	20,459	20,959	21,472	21,997
Residual Boone Co.	10,469	9,597	11,053	12,742	14,633	16,704	18,982	20,260	21,605	23,015	24,490
Residual Cook Co.	156,684	295,666	271,066	245,138	217,805	188,988	158,603	140,950	122,034	101,767	80,058
Residual DeKalb Co.	36,544	39,757	43,966	48,512	53,420	58,714	64,421	67,573	70,852	74,261	77,801
Residual DuPage Co.	79,551	112,062	104,465	96,509	88,164	79,396	70,171	59,465	48,259	36,523	24,229
Residual Grundy Co.	14,723	19,625	21,940	24,556	27,492	30,774	34,427	36,348	38,336	40,382	42,475
Residual Kane Co.	163,910	219,403	251,882	288,387	329,149	374,490	424,804	456,377	490,199	526,413	565,172
Residual Kankakee Co.	17,056	21,540	23,869	26,619	29,783	33,358	37,344	39,625	42,136	44,873	47,834
Residual Kendall Co.	21,663	18,835	29,789	43,700	61,123	82,807	109,712	123,539	138,756	155,500	173,921
Residual Lake Co.	150,488	132,228	145,025	158,825	173,568	189,206	205,692	217,728	230,394	243,680	257,582
Residual McHenry Co.	151,417	192,795	212,356	235,947	263,350	294,737	330,327	356,170	384,855	415,919	449,445
Residual Will Co.	178,683	141,587	190,788	249,530	318,688	399,414	493,087	548,581	610,207	678,456	753,865
Total Study Area	7,639,375	8,368,021	8,670,432	9,000,551	9,360,062	9,751,671	10,178,737	10,514,026	10,868,264	11,241,979	11,636,341

* The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Table: A 2.5 Allocation of Future Population Served to Water Supply Systems (LRI Scenario)

System Name	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	140,000	170,000	170,000	173,006	176,065	179,179	182,347	185,571	193,122	200,980	209,157
Bedford park	89,129	130,415	130,415	149,621	168,827	188,034	207,240	226,446	247,051	267,656	288,260
Belvidere	20,820	23,500	23,500	24,138	24,794	25,467	26,159	26,869	28,073	29,331	30,646
Central Lake Co. JAWA	172,724	197,446	197,446	205,426	213,729	222,367	231,355	240,706	250,098	259,857	269,997
Chicago*	3,730,376	3,960,041	3,960,041	4,044,238	4,130,225	4,218,040	4,307,722	4,399,312	4,468,319	4,538,408	4,609,597
Crystal Lake	36,300	40,440	40,440	41,092	41,755	42,429	43,113	43,808	44,843	45,902	46,985
DeKalb	39,000	40,000	40,000	41,806	43,694	45,667	47,730	49,885	53,078	56,476	60,091
DuPage Water Com.	715,034	728,427	728,427	748,292	768,699	789,662	811,197	833,319	855,005	877,255	900,084
Elgin	134,040	142,572	142,572	154,342	167,083	180,877	195,809	211,974	226,181	241,341	257,517
Evanston	315,261	354,258	354,258	359,483	364,786	370,166	375,626	381,167	386,430	391,766	397,175
Glencoe	8,600	8,600	8,600	8,670	8,741	8,812	8,884	8,957	8,989	9,022	9,054
Hammond WSS	130,448	133,035	133,035	134,477	135,936	137,409	138,899	140,405	144,076	147,842	151,706
Highland Park	58,656	59,580	59,580	60,160	60,745	61,336	61,933	62,536	64,197	65,901	67,651
Joliet	106,745	130,830	130,830	135,467	140,268	145,240	150,387	155,718	163,467	171,603	180,143
Kankakee Aqua Illinois	65,000	67,000	67,000	68,347	69,722	71,124	72,554	74,013	76,473	79,015	81,641
Lake County PWD	27,992	29,536	29,536	31,877	34,404	37,132	40,075	43,252	45,731	48,351	51,122
Lake Forest	18,817	21,477	21,477	21,619	21,762	21,906	22,051	22,197	22,613	23,037	23,469
Morris	11,928	13,282	13,282	14,625	16,104	17,732	19,525	21,499	23,761	26,262	29,026
North Chicago	20,400	19,127	19,127	21,307	23,735	26,440	29,454	32,810	34,189	35,626	37,123
Northbrook	36,200	36,975	36,975	38,267	39,603	40,987	42,419	43,900	45,088	46,309	47,562
Northwest Sub. M. JAWA	299,534	309,084	309,084	313,411	317,799	322,248	326,759	331,334	335,669	340,061	344,510
Oak Lawn	275,634	316,389	316,389	334,203	353,019	372,896	393,891	416,068	441,098	467,634	495,766
Oswego	12,000	23,000	23,000	27,093	31,913	37,592	44,281	52,160	57,742	63,921	70,762
Waukegan	86,689	101,919	101,919	103,214	104,526	105,854	107,199	108,562	110,963	113,418	115,927
Wilmette	89,244	90,391	90,391	92,000	93,639	95,306	97,003	98,730	100,696	102,701	104,745
Winnetka	17,619	17,600	17,600	18,050	18,512	18,986	19,472	19,970	20,459	20,959	21,472
Residual Boone Co.	10,469	9,597	9,597	11,053	12,742	14,633	16,704	18,982	20,260	21,605	23,015
Residual Cook Co.	156,684	295,666	295,666	275,258	264,077	253,298	243,097	233,693	230,553	227,212	223,661
Residual DeKalb Co.	36,544	39,757	39,757	43,966	48,512	53,420	58,714	64,421	67,573	70,852	74,261
Residual DuPage Co.	79,551	112,062	112,062	108,656	115,449	123,657	133,505	145,261	149,069	153,437	158,417
Residual Grundy Co.	14,723	19,625	19,625	21,940	24,556	27,492	30,774	34,427	36,348	38,336	40,382
Residual Kane Co.	163,910	219,403	219,403	248,657	270,553	295,263	322,966	353,898	371,229	389,868	409,895
Residual Kankakee Co.	17,056	21,540	21,540	23,869	26,619	29,783	33,358	37,344	39,625	42,136	44,873
Residual Kendall Co.	21,663	18,835	18,835	28,245	36,462	46,914	60,064	76,522	84,523	93,319	102,987
Residual Lake Co.	150,488	132,228	132,228	145,025	158,825	173,568	189,206	205,692	217,728	230,394	243,680
Residual McHenry Co.	151,417	192,795	192,795	208,741	223,141	240,460	260,786	284,243	301,126	320,266	341,163
Residual Will Co.	178,683	141,587	141,587	190,788	249,530	318,688	399,414	493,087	548,581	610,207	678,456
Total Study Area	7,639,375	8,368,021	8,670,432	9,000,551	9,360,062	9,751,671	10,178,737	10,514,026	10,868,264	11,241,979	11,636,341

* The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Table: A2.6 Allocation of Future Population Served to Water Supply Systems (MRI Scenario)

System Name	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	140,000	170,000	173,006	176,065	179,179	182,347	185,571	193,122	200,980	209,157	217,668
Bedford park	89,129	130,415	147,933	165,420	182,876	200,301	217,694	236,592	255,462	274,303	293,116
Belvidere	20,820	23,500	24,138	24,794	25,467	26,159	26,869	28,073	29,331	30,646	32,019
Central Lake Co. JAWA	172,724	197,446	205,426	213,729	222,367	231,355	240,706	250,098	259,857	269,997	280,533
Chicago*	3,730,376	3,960,041	4,018,643	4,078,572	4,139,859	4,202,537	4,266,639	4,309,776	4,353,570	4,398,030	4,443,168
Crystal Lake	36,300	40,440	41,092	41,755	42,429	43,113	43,808	44,843	45,902	46,985	48,095
DeKalb	39,000	40,000	41,806	43,694	45,667	47,730	49,885	53,078	56,476	60,091	63,937
DuPage Water Com.	715,034	728,427	743,240	758,481	774,166	790,312	806,934	823,441	840,418	857,878	875,837
Elgin	134,040	142,572	154,342	167,083	180,877	195,809	211,974	226,181	241,341	257,517	274,777
Evanston	315,261	354,258	359,483	364,786	370,166	375,626	381,167	386,430	391,766	397,175	402,660
Glencoe	8,600	8,600	8,670	8,741	8,812	8,884	8,957	8,989	9,022	9,054	9,087
Hammond WSS	130,448	133,035	134,477	135,936	137,409	138,899	140,405	144,076	147,842	151,706	155,672
Highland Park	58,656	59,580	60,160	60,745	61,336	61,933	62,536	64,197	65,901	67,651	69,447
Joliet	106,745	130,830	135,467	140,268	145,240	150,387	155,718	163,467	171,603	180,143	189,109
Kankakee Aqua Illinois	65,000	67,000	68,347	69,722	71,124	72,554	74,013	76,473	79,015	81,641	84,354
Lake County PWD	27,992	29,536	31,877	34,404	37,132	40,075	43,252	45,731	48,351	51,122	54,052
Lake Forest	18,817	21,477	21,619	21,762	21,906	22,051	22,197	22,613	23,037	23,469	23,910
Morris	11,928	13,282	14,625	16,104	17,732	19,525	21,499	23,761	26,262	29,026	32,080
North Chicago	20,400	19,127	21,307	23,735	26,440	29,454	32,810	34,189	35,626	37,123	38,683
Northbrook	36,200	36,975	38,267	39,603	40,987	42,419	43,900	45,088	46,309	47,562	48,849
Northwest Sub. M. JAWA	299,534	309,084	313,411	317,799	322,248	326,759	331,334	335,669	340,061	344,510	349,017
Oak Lawn	275,634	316,389	331,329	347,221	364,119	382,083	401,174	423,300	446,884	472,016	498,790
Oswego	12,000	23,000	27,093	31,913	37,592	44,281	52,160	57,742	63,921	70,762	78,335
Waukegan	86,689	101,919	103,214	104,526	105,854	107,199	108,562	110,963	113,418	115,927	118,492
Wilmette	89,244	90,391	92,000	93,639	95,306	97,003	98,730	100,696	102,701	104,745	106,831
Winnetka	17,619	17,600	18,050	18,512	18,986	19,472	19,970	20,459	20,959	21,472	21,997
Residual Boone Co.	10,469	9,597	11,053	12,742	14,633	16,704	18,982	20,260	21,605	23,015	24,490
Residual Cook Co.	156,684	295,666	270,628	244,255	216,468	187,189	156,334	138,239	118,873	98,150	75,975
Residual DeKalb Co.	36,544	39,757	43,966	48,512	53,420	58,714	64,421	67,573	70,852	74,261	77,801
Residual DuPage Co.	79,551	112,062	104,332	96,241	87,757	78,848	69,479	58,637	47,292	35,416	22,978
Residual Grundy Co.	14,723	19,625	21,940	24,556	27,492	30,774	34,427	36,348	38,336	40,382	42,475
Residual Kane Co.	163,910	219,403	268,895	322,733	381,149	444,469	513,091	561,895	613,238	667,264	724,131
Residual Kankakee Co.	17,056	21,540	23,869	26,619	29,783	33,358	37,344	39,625	42,136	44,873	47,834
Residual Kendall Co.	21,663	18,835	35,024	54,269	77,125	104,342	136,881	156,010	176,619	198,844	222,838
Residual Lake Co.	150,488	132,228	145,025	158,825	173,568	189,206	205,692	217,728	230,394	243,680	257,582
Residual McHenry Co.	151,417	192,795	225,885	263,260	304,702	350,387	400,536	440,082	482,700	527,929	575,856
Residual Will Co.	178,683	141,587	190,788	249,530	318,688	399,414	493,087	548,581	610,207	678,456	753,865
Total Study Area	7,639,375	8,368,021	8,670,432	9,000,551	9,360,062	9,751,671	10,178,737	10,514,026	10,868,264	11,241,979	11,636,341

* The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Table A2.7 Current Trends (CT) Public-Supply Water Demand Scenario For Water Supply Systems MGD

Study Areas (Systems)	2005 Reported	2005 Normal	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	18.10	16.16	16.31	16.47	16.67	16.90	17.09	17.82	18.53	19.28	20.17
Bedford Park	25.36	24.46	27.78	30.71	33.62	36.52	38.95	42.54	45.66	48.78	52.32
Belvidere	3.66	3.45	3.50	3.55	3.61	3.68	3.76	3.91	4.06	4.23	4.40
Central Lake Co. JAWA	21.21	19.32	20.01	20.68	21.41	22.21	22.93	23.96	24.90	25.90	27.14
Chicago*	729.56	697.02	703.52	712.45	723.12	735.10	750.52	757.99	768.49	779.61	791.36
Crystal Lake	5.43	5.68	5.77	5.82	5.89	5.96	6.11	6.17	6.31	6.46	6.59
DeKalb	4.36	4.39	4.53	4.69	4.87	5.06	5.26	5.58	5.92	6.29	6.68
DuPage Water Com.	90.62	84.06	85.63	87.36	89.33	91.50	93.71	96.21	98.72	101.37	104.36
Elgin	15.54	13.90	14.78	15.84	17.01	18.30	19.65	20.94	22.27	23.69	25.26
Evanston	45.73	43.09	43.67	43.92	44.28	44.70	45.12	45.66	46.19	46.74	47.38
Glencoe	1.87	1.64	1.65	1.65	1.65	1.66	1.66	1.66	1.67	1.67	1.67
Hammond WSS	18.36	17.22	17.32	17.43	17.46	17.57	17.70	18.11	18.55	19.01	19.50
Highland Park	11.77	11.26	11.29	11.34	11.41	11.50	11.57	11.93	12.27	12.63	13.01
Joliet	16.47	14.92	15.37	15.80	16.29	16.81	17.32	18.23	19.14	20.11	21.26
Kankakee Aqua Illinois	12.89	11.95	12.01	12.10	12.22	12.37	12.53	12.87	13.23	13.60	14.00
Lake County PWD	3.01	3.11	3.31	3.54	3.80	4.08	4.38	4.62	4.88	5.15	5.44
Lake Forest	4.75	4.47	4.47	4.47	4.47	4.49	4.55	4.60	4.68	4.78	4.82
Morris	1.64	1.51	1.64	1.79	1.96	2.15	2.36	2.60	2.86	3.16	3.48
North Chicago	4.69	4.45	4.87	5.39	5.98	6.64	7.48	7.69	8.02	8.37	8.67
Northbrook	6.08	5.06	5.30	5.49	5.71	5.96	6.18	6.50	6.80	7.13	7.50
Northwest Sub. M. JAWA	35.93	33.85	34.34	34.63	35.02	35.47	35.93	36.51	37.08	37.69	38.38
Oak Lawn	36.58	34.74	36.76	38.47	40.34	42.36	44.62	47.05	49.74	52.60	55.72
Oswego	2.36	2.29	2.66	3.10	3.63	4.25	4.98	5.49	6.06	6.69	7.39
Waukegan	9.66	8.53	8.55	8.58	8.63	8.69	8.78	8.92	9.10	9.28	9.46
Wilmette	12.86	11.02	11.23	11.33	11.46	11.60	11.82	11.96	12.17	12.39	12.62
Winnetka	3.83	2.71	2.73	2.79	2.82	2.92	2.98	3.07	3.16	3.24	3.34
Res Boone	0.66	0.71	0.81	0.92	1.05	1.19	1.35	1.43	1.53	1.62	1.72
Res Cook	9.53	20.15	18.42	16.52	14.59	12.60	10.43	9.34	8.07	6.72	5.29
Res DeKalb	4.26	4.08	4.46	4.88	5.34	5.84	6.32	6.68	6.99	7.31	7.65
Res DuPage	7.92	7.09	6.54	5.99	5.45	4.89	4.31	3.65	2.96	2.24	1.49
Res Grundy	1.34	1.39	1.53	1.70	1.89	2.10	2.34	2.47	2.59	2.73	2.86
Res Kane	26.38	22.88	25.93	29.41	33.32	37.69	42.56	45.55	48.78	52.26	56.00
Res Kankakee	2.13	2.39	2.62	2.90	3.23	3.61	4.04	4.29	4.56	4.86	5.19
Res Kendall	2.11	1.71	2.68	3.91	5.44	7.35	9.73	10.95	12.30	13.79	15.45
Res Lake	18.77	13.48	14.60	15.84	17.19	18.64	20.18	21.29	22.47	23.71	25.03
Res McHenry	20.36	14.57	15.84	17.43	19.31	21.48	23.95	25.73	27.71	29.87	32.21
Res Will	19.96	20.52	27.34	35.47	45.05	56.23	69.22	76.86	85.39	94.88	105.42

* The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Table A2.8 Less Resource Intensive (LRI) Public-Supply Water Demand Scenario For Water Supply Systems MGD

Study Areas (Systems)	2005 Reported	2005 Normal	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	18.10	16.16	14.69	14.53	14.42	14.35	14.25	14.60	14.92	15.26	15.70
Bedford Park	25.36	24.46	25.02	27.10	29.09	31.01	32.48	34.85	36.77	38.62	40.73
Belvidere	3.66	3.45	3.15	3.13	3.13	3.13	3.13	3.20	3.27	3.35	3.43
Central Lake Co. JAWA	21.21	19.32	18.02	18.24	18.53	18.87	19.12	19.63	20.05	20.50	21.12
Chicago*	729.56	697.02	633.67	628.61	625.69	624.26	625.89	621.02	618.79	617.12	615.96
Crystal Lake	5.43	5.68	5.20	5.14	5.09	5.06	5.10	5.06	5.08	5.11	5.13
DeKalb	4.36	4.39	4.08	4.14	4.21	4.30	4.39	4.57	4.77	4.98	5.20
DuPage Water Com.	90.62	84.06	77.12	77.08	77.30	77.70	78.14	78.83	79.49	80.24	81.23
Elgin	15.54	13.90	13.31	13.97	14.72	15.54	16.38	17.16	17.93	18.75	19.66
Evanston	45.73	43.09	39.34	38.75	38.31	37.96	37.63	37.41	37.19	37.00	36.88
Glencoe	1.87	1.64	1.49	1.45	1.43	1.41	1.39	1.36	1.34	1.32	1.30
Hammond WSS	18.36	17.53	17.24	17.00	16.70	16.49	16.31	16.40	16.51	16.63	16.77
Highland Park	11.77	11.26	10.17	10.00	9.87	9.77	9.65	9.78	9.88	10.00	10.13
Joliet	16.47	14.92	13.84	13.94	14.09	14.28	14.44	14.94	15.41	15.92	16.55
Kankakee Aqua Illinois	12.89	11.95	10.82	10.68	10.58	10.50	10.45	10.54	10.65	10.77	10.90
Lake County PWD	3.01	3.11	2.98	3.13	3.29	3.46	3.65	3.79	3.93	4.07	4.23
Lake Forest	4.75	4.47	4.02	3.94	3.87	3.81	3.80	3.77	3.77	3.78	3.76
Morris	1.64	1.51	1.48	1.58	1.70	1.82	1.96	2.13	2.30	2.50	2.71
North Chicago	4.69	4.45	4.39	4.76	5.17	5.64	6.24	6.30	6.46	6.62	6.75
Northbrook	6.08	5.06	4.77	4.84	4.94	5.06	5.15	5.33	5.47	5.64	5.84
Northwest Sub. M. JAWA	35.93	33.85	30.93	30.56	30.30	30.12	29.96	29.91	29.85	29.83	29.88
Oak Lawn	36.58	34.74	33.11	33.94	34.90	35.98	37.21	38.55	40.05	41.64	43.37
Oswego	2.36	2.29	2.39	2.74	3.14	3.61	4.15	4.50	4.88	5.30	5.75
Waukegan	9.66	8.53	7.71	7.57	7.47	7.38	7.32	7.31	7.32	7.34	7.37
Wilmette	12.86	11.02	10.12	10.00	9.91	9.85	9.86	9.80	9.80	9.81	9.82
Winnetka	3.83	2.71	2.46	2.46	2.44	2.48	2.49	2.52	2.54	2.57	2.60
Res Boone	0.66	0.71	0.73	0.81	0.91	1.01	1.12	1.18	1.23	1.28	1.34
Res Cook	9.53	19.17	16.03	14.94	13.96	13.09	12.19	11.91	11.51	11.13	10.75
Res DeKalb	4.26	4.08	4.02	4.30	4.62	4.96	5.27	5.47	5.63	5.79	5.96
Res DuPage	7.92	7.09	6.12	6.33	6.61	6.98	7.44	7.49	7.57	7.68	7.83
Res Grundy	1.34	1.39	1.38	1.50	1.63	1.79	1.95	2.02	2.09	2.16	2.23
Res Kane	26.38	22.88	23.06	24.34	25.86	27.60	29.57	30.36	31.24	32.21	33.27
Res Kankakee	2.13	2.39	2.36	2.56	2.80	3.07	3.37	3.51	3.67	3.85	4.04
Res Kendall	2.11	1.71	2.29	2.88	3.62	4.53	5.66	6.14	6.66	7.23	7.85
Res Lake	18.77	13.48	13.15	13.98	14.88	15.83	16.83	17.44	18.09	18.77	19.48
Res McHenry	20.36	14.57	14.02	14.54	15.25	16.14	17.19	17.82	18.57	19.39	20.29
Res Will	19.96	20.52	24.62	31.30	38.98	47.75	57.72	62.97	68.75	75.11	82.05

* The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Table A2.9 More Resource Intensive (MRI) Public-Supply Water Demand Scenario For Water Supply Systems - MGD

Study Areas (Systems)	2005 Reported	2005 Normal	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	18.10	16.16	16.75	17.32	17.90	18.51	19.07	20.24	21.41	22.64	24.05
Bedford Park	25.36	24.46	28.22	31.64	35.12	38.67	41.79	46.26	50.34	54.50	59.22
Belvidere	3.66	3.45	3.59	3.73	3.88	4.03	4.19	4.44	4.69	4.97	5.25
Central Lake Co. JAWA	21.21	19.32	20.55	21.74	23.00	24.33	25.59	27.21	28.76	30.40	32.36
Chicago*	729.56	697.02	718.12	739.85	762.32	785.59	812.21	830.26	851.45	873.23	895.74
Crystal Lake	5.43	5.68	5.93	6.12	6.32	6.53	6.82	7.01	7.29	7.58	7.86
DeKalb	4.36	4.39	4.65	4.93	5.23	5.54	5.87	6.34	6.84	7.38	7.96
DuPage Water Com.	90.62	84.06	87.36	90.64	94.07	97.65	101.25	105.23	109.24	113.42	118.04
Elgin	15.54	13.90	15.18	16.65	18.27	20.05	21.92	23.78	25.72	27.81	30.13
Evanston	45.73	43.09	44.86	46.19	47.56	48.97	50.34	51.86	53.35	54.87	56.51
Glencoe	1.87	1.64	1.69	1.73	1.77	1.81	1.85	1.89	1.92	1.96	2.00
Hammond WSS	18.36	17.22	17.79	18.33	18.76	19.24	19.75	20.57	21.42	22.32	23.25
Highland Park	11.77	11.26	11.60	11.92	12.26	12.60	12.91	13.55	14.17	14.83	15.52
Joliet	16.47	14.92	15.79	16.62	17.49	18.42	19.33	20.70	22.11	23.61	25.35
Kankakee Aqua Illinois	12.89	11.95	12.34	12.73	13.13	13.55	13.98	14.61	15.28	15.97	21.44
Lake County PWD	3.01	3.11	3.40	3.73	4.08	4.47	4.89	5.25	5.63	6.04	6.49
Lake Forest	4.75	4.47	4.59	4.70	4.81	4.92	5.08	5.22	5.41	5.61	5.75
Morris	1.64	1.51	1.69	1.89	2.11	2.35	2.63	2.95	3.31	3.71	4.16
North Chicago	4.69	4.45	5.00	5.67	6.42	7.27	8.35	8.74	9.26	9.82	10.34
Northbrook	6.08	5.06	5.44	5.77	6.14	6.53	6.90	7.39	7.85	8.37	8.95
Northwest Sub. M. JAWA	35.93	33.85	35.27	36.42	37.61	38.86	40.09	41.46	42.82	44.25	45.78
Oak Lawn	36.58	33.04	35.61	37.85	40.24	42.82	45.66	48.78	52.22	55.93	59.99
Oswego	2.36	2.29	2.73	3.26	3.89	4.65	5.55	6.23	7.00	7.85	8.82
Waukegan	9.66	8.53	8.79	9.03	9.27	9.52	9.79	10.14	10.51	10.89	11.29
Wilmette	12.86	11.02	11.54	11.91	12.30	12.71	13.19	13.58	14.06	14.55	15.05
Winnetka	3.83	2.71	2.81	2.93	3.03	3.20	3.33	3.49	3.65	3.81	3.98
Res Boone	0.66	0.71	0.83	0.97	1.13	1.31	1.50	1.63	1.76	1.90	2.05
Res Cook	9.53	19.17	17.97	16.47	14.81	13.00	10.91	9.90	8.64	7.24	5.69
Res DeKalb	4.26	4.08	4.58	5.13	5.73	6.40	7.06	7.58	8.07	8.58	9.13
Res DuPage	7.92	7.09	6.71	6.29	5.82	5.32	4.76	4.08	3.35	2.55	1.68
Res Grundy	1.34	1.39	1.57	1.79	2.03	2.30	2.61	2.80	3.00	3.20	3.42
Res Kane	26.38	22.88	28.04	33.64	39.72	46.30	53.44	58.51	63.84	69.44	75.34
Res Kankakee	2.13	2.39	2.69	3.05	3.47	3.96	4.51	4.87	5.27	5.71	6.20
Res Kendall	2.11	1.71	3.24	5.11	7.38	10.15	13.54	15.70	18.08	20.70	23.61
Res Lake	18.77	13.48	15.00	16.66	18.47	20.42	22.52	24.18	25.95	27.84	29.85
Res McHenry	20.36	14.57	17.31	20.45	23.99	27.97	32.41	36.10	40.14	44.51	49.22
Res Will	19.96	20.52	28.08	37.30	48.39	61.60	77.24	87.28	98.62	111.39	125.73

* The City of Chicago Water Department supplies water to the Chicago system as defined in this study as well as the systems of Bedford Park, DuPage County Water Commission, Oak Lawn, and Northwest Suburban JAWA.

Table A2.10 Current Trends (CT) Public-Supply Water Demand Scenario for Water Supply Systems-Per Capita Usage - GPCD

Study Areas (Systems)	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	95.0	94.3	93.5	93.0	92.7	92.1	92.3	92.2	92.2	92.7
Bedford Park	187.6	185.7	181.9	178.8	176.2	172.0	172.2	170.6	169.2	169.4
Belvidere	146.6	144.9	143.2	141.8	140.8	139.9	139.2	138.5	138.0	137.6
Central Lake Co. JAWA	97.8	97.4	96.7	96.3	96.0	95.3	95.8	95.8	95.9	96.7
Chicago	176.0	174.0	172.5	171.4	170.6	170.6	169.6	169.3	169.1	169.0
Crystal Lake	140.5	140.5	139.5	138.7	138.2	139.5	137.6	137.5	137.5	137.1
DeKalb	109.7	108.4	107.3	106.6	106.0	105.5	105.1	104.8	104.6	104.4
DuPage Water Com.	115.4	114.4	113.6	113.1	112.8	112.4	112.5	112.5	112.6	113.0
Elgin	97.5	95.7	94.8	94.0	93.5	92.7	92.6	92.3	92.0	91.9
Evanston	121.6	121.5	120.4	119.6	119.0	118.4	118.2	117.9	117.7	117.7
Glencoe	190.7	190.2	188.5	187.3	186.3	185.6	185.0	184.6	184.3	184.1
Hammond WSS	129.4	128.8	128.2	127.1	126.5	126.0	125.7	125.5	125.3	125.2
Highland Park	189.0	187.7	186.6	186.0	185.8	185.0	185.9	186.2	186.7	187.4
Joliet	114.1	113.5	112.7	112.1	111.8	111.2	111.5	111.5	111.6	112.4
Kankakee Aqua Illinois	178.4	175.7	173.6	171.9	170.5	169.3	168.3	167.4	166.6	166.0
Lake County PWD	105.2	103.9	103.0	102.3	101.8	101.3	101.1	100.9	100.7	100.6
Lake Forest	208.3	206.6	205.2	204.3	203.7	205.2	203.3	203.3	203.5	201.8
Morris	113.8	112.4	111.4	110.6	110.0	109.6	109.3	109.0	108.8	108.6
North Chicago	232.4	228.6	227.1	226.0	225.4	228.0	225.0	225.1	225.4	224.1
Northbrook	137.0	138.4	138.6	139.4	140.6	140.8	144.3	146.8	149.8	153.6
Northwest Sub. M. JAWA	109.5	109.6	109.0	108.7	108.6	108.4	108.8	109.0	109.4	110.0
Oak Lawn	109.8	110.0	109.0	108.2	107.6	107.2	106.7	106.4	106.1	106.0
Oswego	99.4	98.1	97.2	96.5	95.9	95.4	95.1	94.8	94.6	94.4
Waukegan	83.7	82.9	82.1	81.5	81.1	80.8	80.4	80.2	80.0	79.9
Wilmette	121.9	122.1	121.0	120.2	119.6	119.7	118.8	118.5	118.3	118.2
Winnetka	154.1	151.4	150.6	148.7	149.9	149.3	150.2	150.6	151.1	151.8
Res Boone	73.9	72.9	72.3	71.8	71.4	71.0	70.8	70.6	70.4	70.3
Res Cook	68.1	68.0	67.4	67.0	66.7	65.7	66.3	66.1	66.1	66.0
Res DeKalb	102.7	101.4	100.6	99.9	99.4	98.2	98.8	98.6	98.4	98.4
Res DuPage	63.3	62.6	62.1	61.8	61.6	61.4	61.3	61.3	61.3	61.3
Res Grundy	70.6	69.8	69.1	68.7	68.3	68.0	67.8	67.7	67.5	67.4
Res Kane	104.3	102.9	102.0	101.2	100.6	100.2	99.8	99.5	99.3	99.1
Res Kankakee	110.9	109.8	109.0	108.6	108.3	108.2	108.2	108.2	108.4	108.6
Res Kendall	91.0	90.1	89.5	89.1	88.8	88.7	88.6	88.6	88.7	88.8
Res Lake	101.9	100.7	99.7	99.1	98.5	98.1	97.8	97.5	97.3	97.2
Res McHenry	75.6	74.6	73.9	73.3	72.9	72.5	72.2	72.0	71.8	71.7
Res Will	144.9	143.3	142.2	141.4	140.8	140.4	140.1	139.9	139.8	139.8

Table A2.11 LRI Public-Supply Water Demand Scenario for Water Supply Systems
Per Capita Usage - GPCD

Study Areas (Systems)	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	95.0	84.9	82.5	80.5	78.7	76.8	75.6	74.2	73.0	72.1
Bedford Park	187.6	167.2	160.5	154.7	149.7	143.5	141.1	137.4	134.0	131.9
Belvidere	146.6	130.5	126.3	122.7	119.6	116.7	114.0	111.6	109.2	107.1
Central Lake Co. JAWA	97.8	87.7	85.4	83.3	81.5	79.4	78.5	77.2	75.9	75.3
Chicago	176.0	156.7	152.2	148.3	144.9	142.3	139.0	136.3	133.9	131.6
Crystal Lake	140.5	126.6	123.0	120.0	117.4	116.4	112.8	110.7	108.8	106.7
DeKalb	109.7	97.6	94.7	92.2	90.0	88.0	86.1	84.4	82.8	81.3
DuPage Water Com.	115.4	103.1	100.3	97.9	95.8	93.8	92.2	90.6	89.1	88.0
Elgin	97.5	86.2	83.6	81.4	79.4	77.3	75.9	74.3	72.8	71.6
Evanston	121.6	109.4	106.2	103.5	101.1	98.7	96.8	94.9	93.2	91.6
Glencoe	190.7	171.3	166.3	162.0	158.2	154.8	151.6	148.7	145.9	143.3
Hammond WSS	131.8	128.2	125.0	121.5	118.7	116.2	113.8	111.6	109.6	107.7
Highland Park	189.0	169.0	164.7	161.0	157.8	154.3	152.3	149.9	147.8	145.9
Joliet	114.1	102.2	99.4	97.0	94.9	92.8	91.4	89.8	88.4	87.5
Kankakee Aqua Illinois	178.4	158.3	153.2	148.7	144.8	141.2	137.9	134.8	131.9	129.2
Lake County PWD	105.2	93.6	90.9	88.5	86.5	84.5	82.8	81.2	79.7	78.3
Lake Forest	208.3	186.1	181.0	176.8	173.0	171.1	166.6	163.7	161.1	157.1
Morris	113.8	101.2	98.3	95.7	93.4	91.4	89.5	87.8	86.1	84.6
North Chicago	232.4	205.9	200.3	195.6	191.4	190.1	184.3	181.2	178.4	174.4
Northbrook	137.0	124.6	122.3	120.6	119.4	117.4	118.2	118.2	118.6	119.6
Northwest Sub. M. JAWA	109.5	98.7	96.2	94.0	92.2	90.4	89.1	87.8	86.6	85.6
Oak Lawn	109.8	99.1	96.1	93.6	91.3	89.4	87.4	85.6	84.0	82.5
Oswego	99.4	88.4	85.7	83.5	81.4	79.6	77.9	76.3	74.8	73.4
Waukegan	83.7	74.7	72.4	70.5	68.8	67.4	65.9	64.6	63.3	62.2
Wilmette	121.9	110.0	106.8	104.0	101.6	99.8	97.3	95.4	93.6	92.0
Winnetka	154.1	136.4	132.8	128.7	127.3	124.5	123.0	121.2	119.6	118.2
Res Boone	73.9	65.7	63.8	62.1	60.6	59.2	58.0	56.8	55.8	54.7
Res Cook	64.8	58.2	56.6	55.1	53.9	52.2	51.6	50.7	49.7	48.9
Res DeKalb	102.7	91.4	88.7	86.5	84.4	81.9	80.9	79.4	77.9	76.6
Res DuPage	63.3	56.4	54.8	53.5	52.3	51.2	50.2	49.3	48.5	47.7
Res Grundy	70.6	62.8	61.0	59.4	58.0	56.7	55.6	54.5	53.5	52.5
Res Kane	104.3	92.7	90.0	87.6	85.5	83.5	81.8	80.1	78.6	77.1
Res Kankakee	110.9	98.9	96.2	94.0	92.0	90.2	88.6	87.2	85.8	84.5
Res Kendall	91.0	81.1	78.9	77.1	75.4	73.9	72.6	71.4	70.2	69.1
Res Lake	101.9	90.7	88.0	85.7	83.7	81.8	80.1	78.5	77.0	75.6
Res McHenry	75.6	67.2	65.2	63.4	61.9	60.5	59.2	58.0	56.8	55.8
Res Will	144.9	129.1	125.4	122.3	119.6	117.1	114.8	112.7	110.7	108.8

Table A2.12 MRI Public-Supply Water Demand Scenario for Water Supply Systems Per Capita Usage – GPCD

Study Areas (Systems)	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Aurora	96.8	98.4	99.9	101.5	102.8	104.8	106.5	108.2	110.5	96.8
Bedford Park	190.7	191.3	192.1	193.0	191.9	195.5	197.0	198.7	202.1	190.7
Belvidere	148.8	150.6	152.4	154.2	156.1	158.0	160.0	162.0	164.1	148.8
Central Lake Co. JAWA	100.1	101.7	103.4	105.2	106.3	108.8	110.7	112.6	115.4	100.1
Chicago	178.7	181.4	184.1	186.9	190.4	192.6	195.6	198.6	201.6	178.7
Crystal Lake	144.4	146.7	149.0	151.4	155.7	156.3	158.8	161.4	163.5	144.4
DeKalb	111.3	112.9	114.5	116.1	117.7	119.4	121.1	122.8	124.6	111.3
DuPage Water Com.	117.5	119.5	121.5	123.6	125.5	127.8	130.0	132.2	134.8	117.5
Elgin	98.4	99.7	101.0	102.4	103.4	105.1	106.6	108.0	109.7	98.4
Evanston	124.8	126.6	128.5	130.4	132.1	134.2	136.2	138.2	140.3	124.8
Glencoe	195.4	198.2	201.1	204.1	207.1	210.1	213.2	216.4	219.6	195.4
Hammond WSS	132.3	134.8	136.5	138.6	140.6	142.8	144.9	147.1	149.4	132.3
Highland Park	192.8	196.3	199.8	203.5	206.4	211.1	215.1	219.1	223.5	192.8
Joliet	116.6	118.5	120.5	122.5	124.1	126.7	128.8	131.1	134.1	116.6
Kankakee Aqua Illinois	180.5	182.5	184.6	186.7	188.9	191.1	193.3	195.6	254.2	180.5
Lake County PWD	106.8	108.3	109.9	111.5	113.1	114.8	116.5	118.2	120.0	106.8
Lake Forest	212.2	215.8	219.4	223.1	229.0	230.9	234.9	238.9	240.7	212.2
Morris	115.4	117.1	118.8	120.5	122.3	124.1	125.9	127.7	129.6	115.4
North Chicago	234.9	238.8	242.8	246.9	254.4	255.5	260.0	264.6	267.2	234.9
Northbrook	142.2	145.8	149.7	154.0	157.1	163.8	169.5	175.9	183.2	142.2
Northwest Sub. M. JAWA	112.5	114.6	116.7	118.9	121.0	123.5	125.9	128.4	131.2	112.5
Oak Lawn	107.5	109.0	110.5	112.1	113.8	115.2	116.9	118.5	120.3	107.5
Oswego	100.8	102.2	103.6	105.0	106.5	108.0	109.5	111.0	112.5	100.8
Waukegan	85.1	86.3	87.6	88.8	90.2	91.3	92.6	93.9	95.3	85.1
Wilmette	125.4	127.2	129.1	131.0	133.6	134.9	136.9	138.9	140.9	125.4
Winnetka	155.5	158.3	159.8	164.2	166.6	170.6	173.9	177.4	181.1	155.5
Res Boone	74.9	76.0	77.1	78.2	79.3	80.4	81.5	82.7	83.9	74.9
Res Cook	66.4	67.4	68.4	69.5	69.8	71.6	72.7	73.8	74.9	66.4
Res DeKalb	104.2	105.8	107.3	108.9	109.6	112.2	113.9	115.6	117.3	104.2
Res DuPage	64.3	65.3	66.4	67.4	68.5	69.6	70.8	71.9	73.1	64.3
Res Grundy	71.7	72.7	73.8	74.8	75.9	77.0	78.1	79.3	80.4	71.7
Res Kane	104.3	104.2	104.2	104.2	104.2	104.1	104.1	104.1	104.0	104.3
Res Kankakee	112.7	114.7	116.6	118.7	120.7	122.9	125.0	127.2	129.5	112.7
Res Kendall	92.5	94.1	95.7	97.3	98.9	100.6	102.4	104.1	105.9	92.5
Res Lake	103.4	104.9	106.4	107.9	109.5	111.0	112.6	114.2	115.9	103.4
Res McHenry	76.6	77.7	78.7	79.8	80.9	82.0	83.2	84.3	85.5	76.6
Res Will	147.2	149.5	151.8	154.2	156.6	159.1	161.6	164.2	166.8	147.2

Table A2.13 Self-Supplied Domestic Water Demand Scenarios by County (MGD)

County/Scenario	2000	2005R	2005N	2010	2015	2020	2025	2030	2035	2040	2045	2050
CT Scenario												
Boone	0.99	0.99	0.85	0.88	0.91	0.92	0.94	0.95	0.96	0.97	0.98	0.99
Cook	0.37	0.45	0.38	0.49	0.59	0.68	0.78	0.87	0.95	1.03	1.11	1.19
DeKalb	1.27	1.29	1.09	1.11	1.14	1.16	1.19	1.21	1.24	1.26	1.28	1.31
DuPage	1.85	2.28	1.96	2.01	2.07	2.12	2.16	2.21	2.25	2.29	2.33	2.37
Grundy	1.22	0.73	0.68	0.71	0.74	0.77	0.80	0.83	0.85	0.87	0.89	0.90
Kane	0.12	0.19	0.15	0.23	0.29	0.33	0.35	0.37	0.38	0.39	0.39	0.40
Kankakee	1.74	1.70	1.54	1.67	1.80	1.91	2.02	2.12	2.20	2.28	2.35	2.42
Kendall	2.70	2.83	2.24	2.29	2.32	2.35	2.37	2.39	2.41	2.44	2.46	2.48
Lake	5.85	8.29	6.98	7.22	7.44	7.65	7.84	8.02	8.17	8.32	8.45	8.58
McHenry	7.55	5.29	4.55	5.21	5.77	6.27	6.73	7.13	7.45	7.70	7.92	8.13
Will	9.96	12.72	11.41	11.55	11.66	11.76	11.86	11.96	12.06	12.17	12.29	12.40
LRI Scenario												
Boone	0.99	0.99	0.85	0.84	0.85	0.86	0.87	0.88	0.88	0.89	0.89	0.90
Cook	0.37	0.45	0.38	0.46	0.55	0.64	0.72	0.80	0.88	0.95	1.01	1.08
DeKalb	1.27	1.29	1.09	1.06	1.07	1.09	1.10	1.12	1.14	1.15	1.17	1.18
DuPage	1.85	2.28	1.96	1.91	1.95	1.98	2.01	2.04	2.07	2.10	2.12	2.15
Grundy	1.22	0.73	0.68	0.67	0.70	0.72	0.75	0.77	0.78	0.80	0.81	0.82
Kane	0.12	0.19	0.15	0.22	0.27	0.31	0.33	0.34	0.35	0.35	0.36	0.36
Kankakee	1.74	1.70	1.54	1.59	1.69	1.79	1.88	1.97	2.03	2.09	2.14	2.19
Kendall	2.70	2.83	2.24	2.17	2.19	2.20	2.21	2.21	2.22	2.23	2.24	2.25
Lake	5.85	8.29	6.98	6.85	7.01	7.16	7.30	7.42	7.52	7.61	7.70	7.78
McHenry	7.55	5.29	4.55	4.94	5.43	5.87	6.26	6.60	6.86	7.05	7.22	7.37
Will	9.96	12.72	11.41	10.95	10.98	11.00	11.03	11.07	11.10	11.14	11.19	11.24
MRI Scenario												
Boone	0.99	0.99	0.85	0.98	1.02	1.05	1.08	1.10	1.12	1.15	1.17	1.19
Cook	0.37	0.45	0.38	0.54	0.66	0.78	0.89	1.01	1.11	1.22	1.32	1.42
DeKalb	1.27	1.29	1.09	1.24	1.28	1.32	1.36	1.41	1.44	1.48	1.52	1.56
DuPage	1.85	2.28	1.96	2.23	2.32	2.40	2.48	2.56	2.63	2.70	2.77	2.84
Grundy	1.22	0.73	0.68	0.79	0.83	0.88	0.92	0.96	0.99	1.02	1.05	1.08
Kane	0.12	0.19	0.15	0.26	0.33	0.37	0.40	0.43	0.44	0.45	0.47	0.48
Kankakee	1.74	1.70	1.54	1.86	2.02	2.17	2.32	2.46	2.58	2.69	2.79	2.90
Kendall	2.70	2.83	2.24	2.54	2.61	2.67	2.72	2.77	2.82	2.87	2.92	2.97
Lake	5.85	8.29	6.98	8.01	8.36	8.69	9.00	9.29	9.55	9.80	10.04	10.28
McHenry	7.55	5.29	4.55	5.78	6.48	7.12	7.72	8.26	8.71	9.07	9.42	9.74
Will	9.96	12.72	11.41	12.81	13.09	13.35	13.60	13.85	14.10	14.35	14.60	14.86

2005R = reported water withdrawals for 2005. 2005N = model derived 2005 withdrawals under normal weather conditions.

Table. A2.14 Estimates of Domestic Wells and Population on Wells

Data Year	Number of Active Wells Since 1950	Total County Population	New Wells Per 1000 New People	Persons Per Household	Estimated Population on wells	15-Year Trend wells/1000 new popu.
BOONE COUNTY						
1950	3	17,070	--			
1960	182	20,326	55			
1970	415	25,440	46			
1980	1,441	28,630	322			
1990	2,147	30,806	324	2.81	6,033	
2000	3,267	41,786	102	2.85	9,311	
2005	3,957	50,483	64	2.85	11,277	92
COOK COUNTY						
1950	25	4,508,792	--			
1960	116	5,129,725	0.15			
1970	664	5,492,369	2			
1980	3,286	5,253,655	--			
1990	4,908	5,105,067	--	2.72	13,350	
2000	6,650	5,376,741	6	2.72	18,088	
2005	7,292	5,303,683	--	2.72	19,834	12
DEKALB COUNTY						
1950	1					
1960	52					
1970	264	41981	5			
1980	1,085	53,658	70			
1990	1,578	77,932	20	2.95	4,655	
2000	2,252	88,969	61	2.81	6,328	
2005	2,426	97,665	16	2.81	6,817	43
DUPAGE COUNTY						
1950	4	154,599	--			
1960	593	313,459	4			
1970	1,201	491,882	3			
1980	4,942	658,835	22			
1990	7,650	781,666	22	2.8	21,420	
2000	8,963	904,161	11	2.78	24,917	
2005	9,363	929,113	14	2.78	26,029	12
GRUNDY COUNTY						
1950	14	19,217	--			
1960	212	22,350	63			
1970	347	26,535	32			
1980	853	30,582	125			
1990	999	32,337	83	2.7	2,697	
2000	1,710	37,535	137	2.62	4,480	
2005	2,091	43,838	46	2.62	5,478	95

Table. A2.14 Estimates of Domestic Wells and Population on Wells (Contd.)

Data Year	Number of Active Wells Since 1950	Total County Population	New Wells Per 1000 New People	Persons Per Household	Estimated Population on wells	15-Year Trend wells/1000 new popu.
KANE COUNTY						
1950	12	150,388	--			
1960	140	208,246	2			
1970	607	251,005	11			
1980	4,788	278,405	153			
1990	7,526	317,471	70	2.96	22,277	
2000	10,375	404,119	33	3.02	31,333	
2005	11,612	482,113	14	3.02	35,068	25
KANKAKEE COUNTY						
1950	7	73,524	--			
1960	420	92,063	22			
1970	1,417	97,250	192			
1980	2,634	102,926	214			
1990	3,057	96,255	--	2.78	8,498	
2000	4,285	103,833	162	2.72	11,655	
2005	5,012	107,972	138	2.72	13,633	167
KENDALL COUNTY						
1950	9	12,115	--			
1960	52	17,540	8			
1970	282	26,374	26			
1980	1,395	37,202	103			
1990	1,988	39,413	268	2.96	5,884	
2000	2,959	54,544	64	2.9	8,581	
2005	3,742	79,514	23	2.9	10,852	44
LAKE COUNTY						
1950	129	279,097	--			
1960	445	293,656	22			
1970	1,310	382,638	10			
1980	6,023	440,372	82			
1990	11,222	516,418	68	2.97	33,329	
2000	17,189	644,356	47	2.98	51,223	
2005	19,712	702,682	37	2.98	58,742	46

Table. A2.14 Estimates of Domestic Wells and Population on Wells (Contd.)

Data Year	Number of Active Wells Since 1950	Total County Population	New Wells Per 1000 New People	Persons Per Household	Estimated Population on wells	15-Year Trend wells/1000 new popu.
MCHENRY COUNTY						
1950	12	50,656	--			
1960	141	84,210	4			
1970	542	111,555	15			
1980	5,220	147,897	129			
1990	9,483	183,241	121	2.91	27,596	
2000	15,394	260,077	77	2.91	44,797	
2005	18,507	303,990	60	2.91	53,855	75
WILL COUNTY						
1950	32	134,336	--			
1960	186	191,617	3			
1970	680	249,498	9			
1980	7,668	324,460	93			
1990	11,266	357,313	110	3.06	34,474	
2000	15,109	502,266	27	3.06	45,327	
2005	16,866	642,813	11	3.06	50,598	20

Chapter 2 Annex – Part 2

MODEL DEVELOPMENT

The development of the water use equation for preparing future water withdrawals represented a significant challenge because of the aggregate nature of the data and the limited number of observations on historical water withdrawals. The total number of available cross-sectional and time series observations was 148 (i.e., 37 study areas times 4 time periods). The procedure for estimating the predictive water-use equations consisted of three steps: (1) derivation of a "structural model", (2) compensating for fixed effects of study sites, and (3) examination of outliers on the estimated model coefficients. Each of these steps is described and illustrated with tables and figures below.

Structural Model

A preliminary analysis of the data revealed that population served by public water supply systems in the study area explains 97 percent of the variability in total public-supply withdrawals. Therefore, population served was used to express the dependent variable as average public-supply water withdrawals (and purchases) per capita per day for each study area and data year. If the per capita rate of water withdrawals in each study area can be predicted with sufficient accuracy, then total public supply withdrawals can be estimated by multiplying the per capita use by population served, where the latter represents a driver of public-supply demands. One advantage of modeling the per capita use is that by expressing total withdrawals in per capita terms, the dependent variable is "normalized" across study sites and the heterogeneity associated with total withdrawals among the supply systems is reduced.

The first step was to identify the relevant explanatory variables, which would explain the variability of per capita withdrawals across study sites and time periods. These variables were selected based on information from previous studies of water use. Several combinations of explanatory variables were examined prior to selecting the best "structural" model which explained the variability of historical water quantities in the data in terms of known determinants of water demand. The criteria for developing a good forecasting model are somewhat different from criteria in typical econometric applications where the researcher wishes to know which variables are significant. A useful forecasting model requires not only an appropriate model specification but also accurate estimates of the regression coefficient (or elasticity) for each of the explanatory variables.

Table A2.15 shows the estimated log-liner regression equation of the structural model. The equation includes six relevant explanatory variables. The expected signs (positive or negative) and magnitudes of the regression coefficients in the structural model are based on economic theory and on the underlying physical relationships as well as on the results of the previous studies of aggregate water demand in public water systems. The expected signs are positive for temperature and income, and negative for precipitation and price of water. Expectations about the sign of the other two other variables are: positive for employment-to-population ratio, and negative for time/conservation trend. However, the prior knowledge about the magnitude of the coefficients of these two variables is limited.

Table A2.15 Structural Log-Linear Model of Per Capita Water Demand in Public-Supply Sector (ln GPCD)

Variables	Estimated Coefficient	t Ratio	Probability >|t|
Structural Model			
Intercept	7.0403	1.01	0.3166
Max. summer temperature (ln)	-0.5532	-0.36	0.7209
Summer precipitation (ln)	-0.0812	-0.63	0.5267
Employment-population ratio	0.1557	1.39	0.1667
Marginal price of water (ln)	-0.0321	-0.47	0.6419
Median household income (ln)	0.1399	1.73	0.0863
Conservation trend (ln)	-0.0652	-1.97	0.0509
N=148, R2=0.082, Mean Y=4.929; Root MSE=0.336			

The results in Table A2.15 show that four of the six regression coefficients of the model variables are not statistically significant. Only median household income and conservation trend variables have statistically significant coefficients at 10 percent level of significance. Also, the coefficient of the air temperature variable is negative, which is contrary to the expected sign.

The low significance of the four variables and the inconsistent sign of temperature coefficient are likely a result of the small data sets (n = 148) and possible data errors in some of the observations on the dependent and independent variables. Under such conditions it is a challenge to derive a water-use equation which meets the requirements of a good model for deriving future water use. This is the main reason why alternative model specifications must be considered and each data point needs to be examined in some detail.

Model with Fixed Effects of Study Sites

The next step in model development was to extend the structural model from Table A2.15 by including the binary variables designating individual study sites. A regression of the key structural variables along with the study site binary variables to compete for a significant share of the remaining model variance was estimated. This was accomplished by using a stepwise regression procedure through which binary variable are added to the structural model to account for each study site. The binary study site variables with statistically significant regression coefficients were kept in the model. This extended, fully-specified model is presented in Table A2.16 below. In addition to the six structural model variables it includes 15 binary variables which designate study sites. All 15 binary variables have regression coefficients which are statistically significant. These coefficients can be considered as representing site specific “intercept adjustors” because they increase or decrease the main intercept of the regression equation.

Table A2.16 Re-estimated Log-Linear Model of Per Capita Water Demand With Study Site Binaries (ln GPCD)

Variables	Estimated Coefficient	t Ratio	Probability >|t|
Structural Model			
Intercept	2.8175	0.87	0.3866
Max. summer temperature (ln)	0.2167	0.30	0.7619
Summer precipitation (ln)	-0.0207	-0.36	0.7167
Employment-population ratio	0.1290	2.08	0.0397
Marginal price of water (ln)	-0.1380	-3.73	0.0003
Median household income (ln)	0.3178	6.27	<.0001
Conservation trend (ln)	-0.0641	-4.46	<.0001
System intercepts			
Bedford Park	0.2672	4.79	<.0001
Belvidere	0.2598	4.50	<.0001
Chicago	0.5741	7.16	<.0001
Hammond WSS	0.3232	4.26	<.0001
Highland Park	0.2201	2.76	0.0066
Kankakee - Aqua Illinois	0.6802	8.19	<.0001
North Chicago	1.0170	13.14	<.0001
Oswego	-0.2300	-3.09	0.0025
Boone County rem.	-0.6189	-7.80	<.0001
Cook County, rem.	-0.8206	-10.24	<.0001
Kendall County, rem.	-0.3359	-4.49	<.0001
McHenry County, rem.	-0.2118	-2.71	0.0077
Morris	0.1943	2.55	0.0119
Glencoe	0.1839	1.92	0.0570
DeKalb County, rem.	-0.1967	-2.56	0.0118
N=148, R^2=0.851, Mean Y=4.929; Root MSE=0.143;			

Rem. = remainder of the county area served by systems other than those included in the study.

The structural part of the model in Table A2.16 includes statistically significant regression coefficients for four of the six variables. Also, all six coefficients have the expected sign. However, the coefficients of air temperature and precipitation variables are not statistically significant and their magnitudes are below the expected levels.

Model with Study Sites and Year 2005 Binary

One concern regarding the data was that the year 2005 was a drought year (with a moderate drought in terms of precipitation deficits) and that its inclusion in the data could bias the estimated regression coefficients of the structural variables. In order to determine if this was the case, a time period binary variable which designates the year 2005 was added to the extended model (from Table A2.16) and the model was re-estimated. The resultant regression equation is shown in Table A2.17 below.

Table A2.17 Re-estimated Log-Linear Model of Per Capita Water Demand With Study Site and Year 2005 Binaries (ln GPCD)

Variables	Estimated Coefficient	t Ratio	Probability >|t|
Structural Model			
Intercept	2.3502	0.73	0.4686
Max. summer temperature (ln)	0.3620	0.51	0.6130
Summer precipitation (ln)	-0.0714	-1.11	0.2678
Employment-population ratio	0.1158	1.86	0.0648
Marginal price of water (ln)	-0.1426	-3.87	0.0002
Median household income (ln)	0.3173	6.30	<.0001
Conservation trend (ln)	-0.0574	-3.87	0.0002
System intercepts			
Bedford Park	0.2731	4.92	<.0001
Belvidere	0.2630	4.58	<.0001
Chicago	0.5703	7.16	<.0001
Hammond WSS	0.3224	4.28	<.0001
Highland Park	0.2236	2.83	0.0055
Kankakee - Aqua Illinois	0.6827	8.27	<.0001
North Chicago	1.0125	13.16	<.0001
Oswego	-0.2357	-3.19	0.0018
Boone County rem.	-0.6124	-7.76	<.0001
Cook County, rem.	-0.8164	-10.25	<.0001
Kendall County, rem.	-0.3406	-4.58	<.0001
McHenry County, rem.	-0.2167	-2.79	0.0061
Morris	0.1981	2.62	0.0099
Glencoe	0.1780	1.87	0.0637
DeKalb County, rem.	-0.1972	-2.58	0.0110
Year 2005 Binary	-0.0681	-1.67	0.0981
N=148, R^2=0.851, Mean Y=4.929; Root MSE=0.143;			

The results in Table A2.17 show that the coefficient of the binary time period variable (Year 2005 binary) is significant at the 10 percent level of significance. The addition of the 2005 binary increased the coefficients of temperature and precipitation and slightly decreased (in absolute terms) the coefficient of the conservation trend variable. Also the level of significance of the temperature and precipitation variables has increased, although the coefficients of these variables are not significant at the 10 percent level. Because of the lack of statistical significance of the two regression coefficients the next step in model building was undertaken.

Effects of Outliers on Model Coefficients

The model shown in Table A2.17 was examined further for the effects of possible outliers on the magnitudes and statistical significance of the estimated coefficients. A special procedure was used to examine the effects of outliers on the estimated model without removing any suspected observation from the data or changing the observations in the original data by using a statistical "smoothing" procedure, or other methods. Accordingly, each of the 148 observations in the data set was assigned a binary indicator variable (i.e. a spike dummy) which assumes the value of 1 for a given data point and a value of zero elsewhere. For example, a binary variable designated as Lake

Forest-2005 assumes the value of 1 for the 2005 data point for Lake Forest system and zero for all other observations. Similarly, Wilmette-1995 is binary variable which assumes the value of 1 for 1995 in Wilmette and zero elsewhere.

These binary variables are referred to as “outlier variables” and their estimated coefficients would reveal “outlier effects.” The advantage of this procedure is that all observations can be assessed with respect to the prediction surface of any model being estimated. It is important to note that the term “outlier” as used in this analysis or any other analysis is not necessarily a data error. It is only an observation that is far away from the regression surface or the prediction surface in a multivariate model. This distance depends on the model, and different outliers are identified for different models. In this sense, these data points could be called “model outliers” as opposed to “data outliers.”

Using the above procedure, the effects of outliers on the coefficients of explanatory variables of the model in Table A2.17 are analyzed and are presented in Table A2.18. The fluctuations in the estimated regression coefficients are graphed in Figures A2.1 to A2.6 (a vertical line on each figure shows the selected model – Step 8 in Table A2.18). For some variables these effects appear to be minor. Significant shifts on the regression coefficients were obtained only for the two weather variables: air temperature and precipitation.

Table A2.18 Effects of Adding Binary Study Area and Spike Dummies
on Estimated Regression Coefficients of the Structural Model.

Step	Model specification/ Outliers	Inter-cept	Temp-erature	Precipi-tation	Empl. Ratio	Marginal Price	MH Income	Conservation Trend
0	Structural model only	7.040	-0.553	-0.081	0.156	-0.032	0.140	-0.065
1	W/ 15 study site effects	2.818	0.217	-0.021	0.129	-0.138	0.318	-0.064
2	Study sites + Year 2005	2.350	0.362	-0.071	0.116	-0.143	0.317	-0.057
	Binary Spike Variables:							
3	Lake Forest-2005	1.522	0.568	-0.050	0.116	-0.146	0.286	-0.057
4	Res. Cook Co.-1995	1.553	0.577	-0.074	0.112	-0.147	0.287	-0.057
5	Wilmette-1995	1.293	0.647	-0.093	0.094	-0.139	0.291	-0.058
6	Waukegan-1990	0.157	0.893	-0.084	0.087	-0.151	0.302	-0.056
7	DeKalb-2009	0.026	0.941	-0.086	0.092	-0.147	0.285	-0.055
8	North Chicago-2000	*-0.615*	*1.095*	*-0.095*	*0.093*	*-0.146*	*0.285*	*-0.059*
9	Oakland-1990	-0.569	1.083	-0.090	0.088	-0.149	0.286	-0.063
10	Glencoe-2005	-0.661	1.106	-0.088	0.087	-0.150	0.285	-0.063
11	Res. Kendall-1990	-0.377	1.050	-0.104	0.091	-0.150	0.284	-0.058
12	Northwest JAWA-1990	-0.310	1.031	-0.098	0.096	-0.143	0.284	-0.062

Note: Coefficients of the selected model are shown in Italic

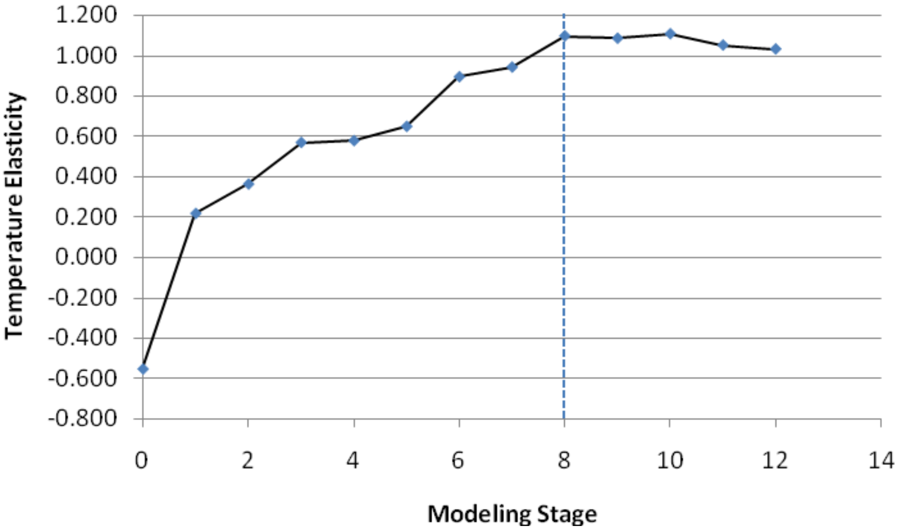

Figure A2.1 Effects of Binary Site Variables and Spike Dummies on Estimated Elasticity of Temperature

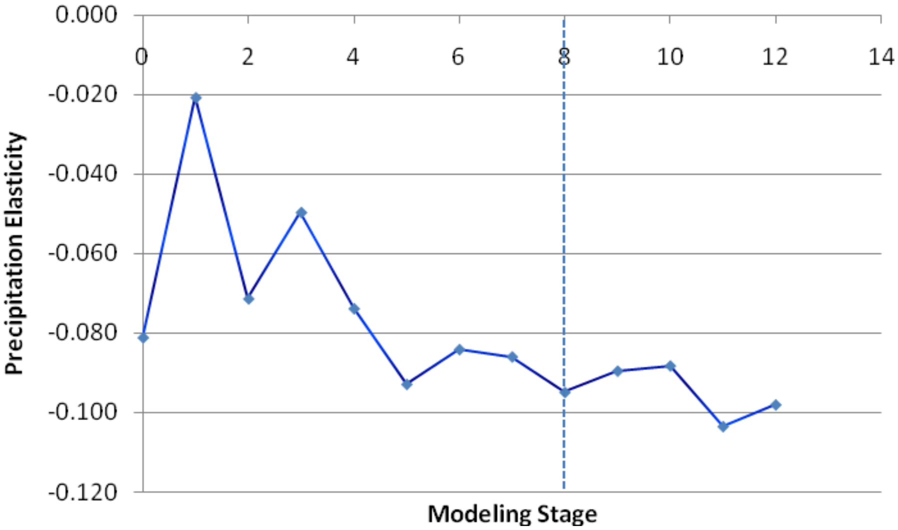

Figure A2.2. Effects of Binary Site Variables and Spike Dummies on Estimated Elasticity of Precipitation

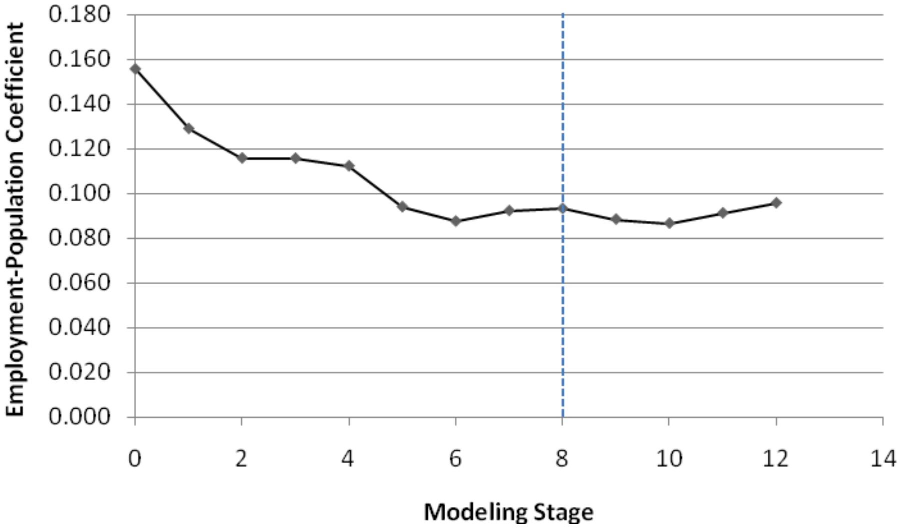

Figure A2.3 Effects of Binary Site Variables and Spike Dummies on Estimated Coefficient of Population-to-Employment Ratio

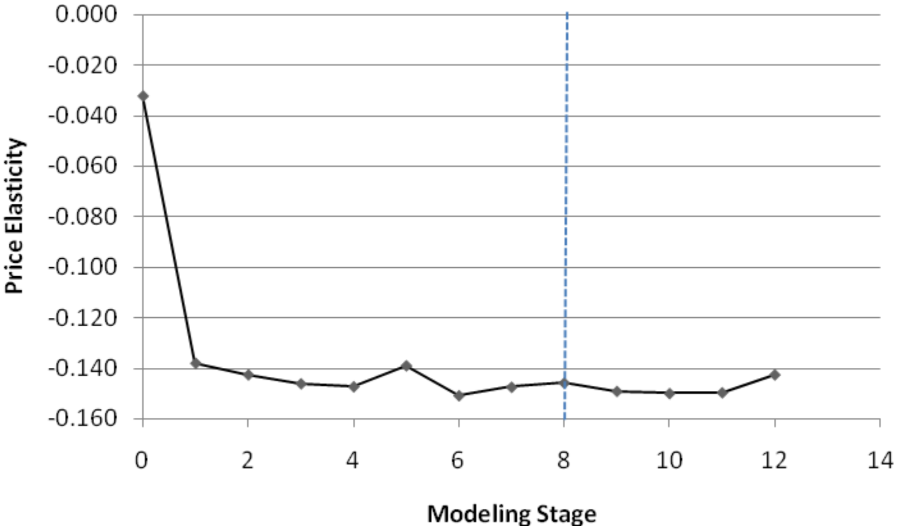

Figure A2.4 Effects of Binary Site Variables and Spike Dummies on Estimated Elasticity of Marginal Price

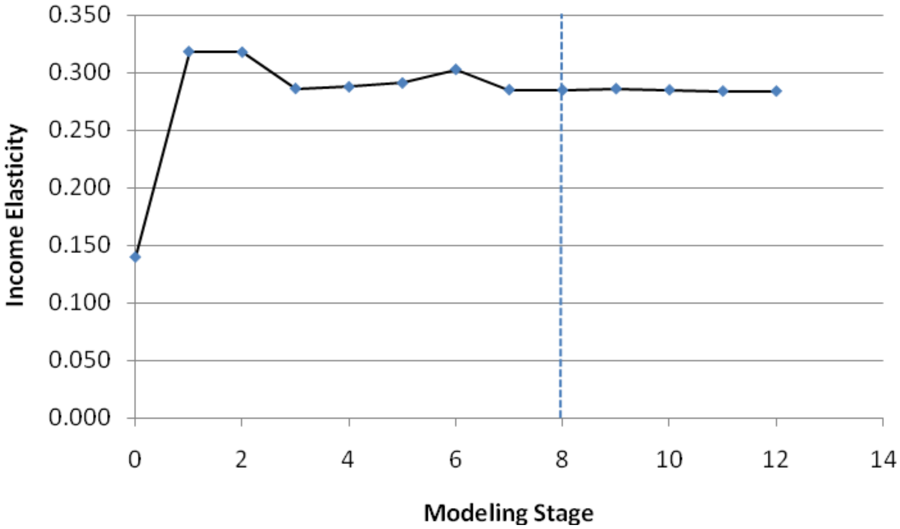

Figure A2.5 Effects of Binary Site Variables and Spike Dummies on Estimated Elasticity of Median Household Income

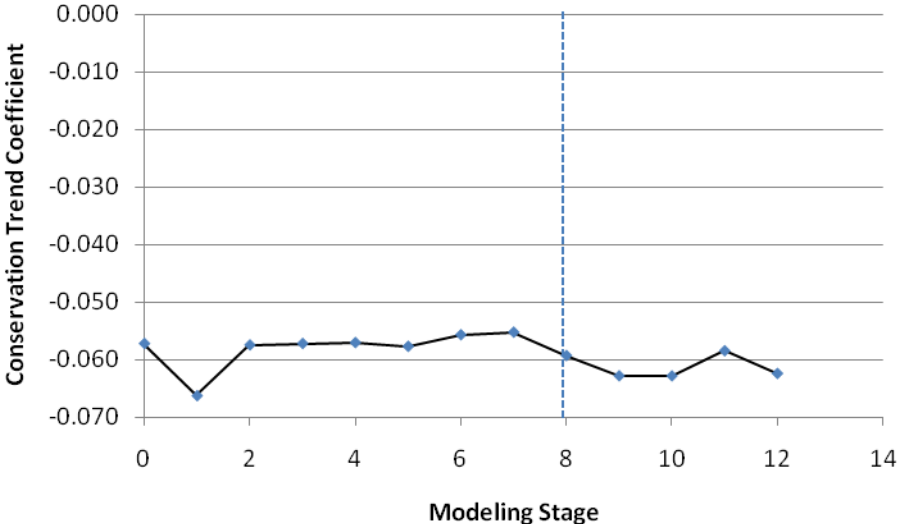

Figure A2.6 Effects of Binary Site Variables and Spike Dummies on Estimated Coefficient of Conservation Trend Variable

Final Regression Model

After examining the effects of model outliers on the estimated regression coefficients of the structural model, six binary outlier variables were added to the model from Table A2.17, thus neutralizing their effects on the estimated structural part of the model. The re-estimated final regression equation with the six outlier variables is shown in Table A2.19 below.

Table A2.19 Final Log-Linear Model of Per Capita Water Demand in Public Supply Sector (ln GPCD)

Variables	Estimated Coefficient	t Ratio	Probability >|t|
Structural Model			
Intercept	-0.6152	-0.20	0.8400
Max. summer temperature (ln)	1.0951	1.63	0.1065
Summer precipitation (ln)	-0.0949	-1.56	0.1203
Employment-population ratio	0.0931	1.62	0.1071
Marginal price of water (ln)	-0.1458	-4.25	<.0001
Median household income (ln)	0.2845	5.90	<.0001
Conservation trend (ln)	-0.0593	-4.29	<.0001
System intercepts			
Bedford Park	0.3330	6.08	<.0001
Belvidere	0.2778	5.29	<.0001
Chicago	0.5621	7.73	<.0001
Hammond WSS	0.3114	4.52	<.0001
Highland Park	0.2692	3.70	0.0003
Kankakee - Aqua Illinois	0.6637	8.75	<.0001
North Chicago	0.9364	11.66	<.0001
Oswego	-0.2398	-3.55	0.0005
Boone County rem.	-0.6063	-8.41	<.0001
Cook County, rem.	-0.7021	-8.50	<.0001
Kendall County, rem.	-0.3449	-5.09	<.0001
McHenry County, rem.	-0.2197	-3.10	0.0024
Morris	0.1881	2.72	0.0075
Glencoe	0.2071	2.35	0.0203
DeKalb County, rem.	-0.1936	-2.78	0.0064
Year 2005 Binary	-0.1206	-3.12	0.0023
Spike Binaries			
DeKalb-1995	-0.2587	-1.94	0.0551
North Chicago-2000	0.2480	1.60	0.1113
Waukegan-1990	0.2652	1.94	0.0549
Wilmette-1995	-0.3299	-2.30	0.0231
Lake Forest-2005	0.4511	3.29	0.0013
Cook Co. rem.-1995	-0.3979	-2.61	0.0103

N=148, R^2=0.885, Mean Y=4.929; Root MSE=0.129; MAPE= 9.1%,

Model specification tests (statistic and significance): Ramsey power 2 = 0.0507 (0.8223), Ramsey power 3 = 0.0520 (0.9493), Ramsey power 4 = 0.4835 (0.6944)

Heteroscedasticity tests (statistic and significance):

White’s test = 98.4 (0.6088), Breusch-Pagan test =43.24 (0.0330)

The results in Table A2.19 show that the significance of the regression coefficients has increased to approximately 10 percent level for the weather variables. Model diagnostics tests shown at the bottom of the table indicate that the model is free from model specification errors (all three Ramsey tests have statistics which are not statistically significant).

The two heteroscedasticity tests of the model in Table A2.19 relate to the classical assumptions of the regression model that the model error variance is constant, or homogeneous, across all observations. If this assumption is violated, the errors are said to be heteroscedastic. Heteroscedasticity (i.e., non-constant error problem) often arises in the analysis of cross-sectional data. The White test (98.4) is highly insignificant thus accepting the null hypothesis of no heteroscedasticity. However, the Breusch-Pagan test (43.24) shows a significant value at generally accepted levels of statistical significance (i.e., 0.05) which, contrary to the White's test, would reject the null hypothesis of no heteroscedasticity. If heteroscedasticity is present in the regression model, then the parameter estimates are still consistent but they are no longer efficient (i.e., with the smallest variance). This implies that while the regression parameters (i.e. coefficients or elasticities) are unbiased, the standard errors of these parameter estimates could be biased and thus inferences about their statistical significance should be made with caution.

Verification of Elasticities

The magnitudes of all six regression coefficients of the structural model variables are within the expected levels. The estimated elasticities of the main variables in the structural model confirm the estimates obtained in other studies of municipal water demand. Table A2.20 shows the elasticities of income, price, precipitation and temperature which were reported in three previous studies. It shows six estimates of per capita income elasticity. All reported elasticities are positive and range from 0.144 to 0.48. The data used in the two studies (Griffin et al., 1990 and Schneider, 1991) were pooled time-series and cross-sectional data – the same data configuration was used in the present study.

Table A2.20 also shows eight estimates of price elasticity. All estimates are negative and range from -0.05 to -0.38. These elasticities indicate that municipal water demand is generally inelastic with respect to price. The highest (absolute) value of -0.38 is for summer season water use, which is expected to be more elastic than non-seasonal (or indoor use). There appears to be a relatively narrow range of estimated elasticities of municipal winter season and annual water demand (also captured by monthly models) with respect to price of –0.05 to –0.16.

Finally, Table 2.20 includes several estimates of the elasticity of municipal demand with respect to the weather variables. All four reported elasticities of precipitation are negative, and range from -0.012 to -0.068. These values indicate relatively low responsiveness of municipal demand to changes in precipitation. The estimated elasticity of municipal demand with respect to air temperature in the study by Berk el al. (1980) is positive 1.37, demonstrating the expected relationship between water use and temperature.

Table A2.20 Examples of Estimated Elasticities of Four Explanatory Variables in Municipal (Public Supply) Water-Demand Models

Study/Variable Definition	Elasticity	Notes
INCOME		
Griffin and Chang, 1990	0.480	Winter water use
Annual per capita income	0.300	Summer water use
Schneider et al., 1991	0.218	Generalized least-squares model (GLS)
Per capita income	0.458	GLS model with inclusion of cross-sectional dummy variables
	0.144	GLS with inclusion of time series dummy variables
	0.309	GLS with inclusion both cross-sectional and time series dummy variables
PRICE		
Berk et al., 1980	-0.090	Monthly water use
Marginal price		
Griffin and Chang, 1990	-0.160	Winter water use
Average water price	-0.380	Summer water use
Schneider and Whitlach, 1991	-0.066	Generalized least-squares model (GLS)
Marginal water cost	-0.057	GLS model with inclusion of cross-sectional dummy variables
	-0.114	GLS with inclusion of time series dummy variables
	-0.049	GLS with inclusion both cross-sectional and time series dummy variables
	-0.137	From partial adjustments, generalized least-squares model with time series dummy variables
PRECIPITATION		
Berk et al., 1980	-0.012	Pooled analysis of monthly data
Total monthly rainfall		
Schneider and Whitlach, 1991	-0.056	Generalized least-squares model (GLS)
Precipitation during summer (May-August)	-0.068	GLS model with inclusion of cross-sectional dummy variables
	-0.046	Partial adjustments, generalized least-squares model with time series dummy variables
TEMPERATURE		
Berk et al., 1980		
Mean monthly temperature	1.370	Pooled cross-sectional time-series data

Sources: Griffin, Ronald. C. and C. Chang (1990); Schneider, M. L. and E. Earl Whitlach (1991); Berk, Richard A., Thomas F. Cooley, C. J. LaCivita, Stanley Parker, Kathy Sredl, and Marilynn Brewer (1980).

In-Sample Prediction Errors

The accuracy of the predictive model shown in Table A2.19 was evaluated by the mean absolute percentage error (MAPE) by using the regression equation to estimate the historical values of water use in the data. This procedure is known as “in-sample” predictions. The calculation of the MAPE is described below.

In a linear model, designating $\hat{Y}_{it}$ to be the predicted value of the dependent variable Y_{it}, the absolute percentage error (APE) is given by

$$APE_{it} = \left| \frac{\hat{Y}_{it} - Y_{it}}{Y_{it}} \right| \times 100 \qquad (4)$$

In a log linear model of the form shown in Table A2.19, the APE in the log scale is given by

$$APE_{it} = \left| \frac{\widehat{\ln Y_{it}} - \ln Y_{it}}{\ln Y_{it}} \right| \times 100\,. \qquad (5)$$

Assuming that the errors are normally distributed in a log-linear model it can be shown that the expected value of the dependent variable converted back into the raw (linear) scale is

$$E(Y \mid \text{explanatory variables}) = e^{\sigma_{\varepsilon}^{2}/2}\left(e^{\widehat{\ln Y}}\right) \qquad (6)$$

where $\hat{\sigma}_{\varepsilon}^{2}$ is the mean square error of the log-linear model. Thus, in log linear models, the predicted raw scale value denoted as $\tilde{Y}$ is given by

$$\tilde{Y} = e^{\hat{\sigma}_{\varepsilon}^{2}/2}\left(e^{\widehat{\ln Y}}\right) \qquad (7)$$

where $\widehat{\ln Y}$ is the predicted value obtained from the log-linear model. APE in the raw scale is obtained as

$$APE_{it} = \left| \frac{\tilde{Y}_{it} - Y_{it}}{Y_{it}} \right| \times 100 \qquad (8)$$

Finally, the mean absolute percentage error (MAPE) is defined as the average over all observations (i.e., over *i* and *t*) of $APE_{it.}$ i.e.,

$$MAPE = \frac{\sum_{i}\sum_{t} APE_{it}}{n} \qquad (9)$$

where n = mT, i.e., number of cross-sectional observations times the number of time periods in the data. The criterion of the MAPE error of less than 10 percent was used in selecting the final regression model. The value of 10 percent ensures that the absolute percentage error for individual predictions is not excessive (i.e., generally not exceeding 20 to 30 percent for individual observations). The regression model from Table A2.19 has the MAPE value for in-sample predictions of 9.1 percent. The actual and predicted values of per capita water use in the data and percentage prediction errors are shown in Table A2.21 below.

Table A2.21 Actual and Predicted Values of Per Capita Water Use in Historical Data

System Name	County	Year	Actual GPCD	Predicted GPCD	Diff.	Error (%)
Aurora	Kane	1990	125.7	126.0	0.3	0.2
Aurora	Kane	1995	126.0	121.0	-5.0	3.9
Aurora	Kane	2000	119.0	115.2	-3.8	3.2
Aurora	Kane	2005	106.5	107.5	1.0	0.9
Bedford Park	Cook	1990	272.6	252.0	-20.6	7.6
Bedford Park	Cook	1995	266.2	235.0	-31.2	11.7
Bedford Park	Cook	2000	222.1	214.2	-7.9	3.6
Bedford Park	Cook	2005	194.4	174.4	-20.0	10.3
Belvidere	Boone	1990	227.6	192.0	-35.6	15.6
Belvidere	Boone	1995	177.1	181.6	4.5	2.5
Belvidere	Boone	2000	155.6	163.0	7.4	4.8
Belvidere	Boone	2005	155.6	154.6	-0.9	0.6
Central Lake County JAWA	Lake	1990	149.9	126.4	-23.5	15.7
Central Lake County JAWA	Lake	1995	121.2	128.3	7.1	5.8
Central Lake County JAWA	Lake	2000	107.1	114.1	7.0	6.5
Central Lake County JAWA	Lake	2005	107.4	111.3	3.9	3.7
Chicago	Cook	1990	268.2	257.9	-10.3	3.9
Chicago	Cook	1995	243.8	244.9	1.1	0.5
Chicago	Cook	2000	221.6	221.9	0.3	0.1
Chicago	Cook	2005	184.2	197.0	12.7	6.9
Crystal Lake	McHenry	1990	133.5	156.9	23.5	17.6
Crystal Lake	McHenry	1995	149.4	159.2	9.8	6.6
Crystal Lake	McHenry	2000	140.6	146.6	5.9	4.2
Crystal Lake	McHenry	2005	134.2	134.3	0.0	0.0
De Kalb	De Kalb	1990	113.6	109.4	-4.2	3.7
De Kalb	De Kalb	1995	85.1	85.8	0.7	0.8
De Kalb	De Kalb	2000	109.5	108.6	-0.9	0.8
De Kalb	De Kalb	2005	109.0	105.7	-3.3	3.0
Du Page Water Commission	Du Page	1990	189.1	152.2	-37.0	19.6
Du Page Water Commission	Du Page	1995	132.1	142.0	9.9	7.5
Du Page Water Commission	Du Page	2000	123.4	135.0	11.6	9.4
Du Page Water Commission	Du Page	2005	124.4	126.1	1.7	1.4
Elgin	Kane	1990	124.0	142.4	18.4	14.8
Elgin	Kane	1995	126.2	132.1	5.8	4.6
Elgin	Kane	2000	106.8	125.0	18.1	16.9
Elgin	Kane	2005	109.0	117.5	8.6	7.9
Evanston	Cook	1990	149.8	147.0	-2.8	1.9
Evanston	Cook	1995	146.6	159.5	12.8	8.7
Evanston	Cook	2000	147.2	152.7	5.5	3.8
Evanston	Cook	2005	129.1	139.4	10.3	8.0
Glencoe	Cook	1990	168.1	218.8	50.6	30.1
Glencoe	Cook	1995	204.3	216.7	12.4	6.1
Glencoe	Cook	2000	202.6	198.1	-4.5	2.2
Glencoe	Cook	2005	240.9	184.6	-56.3	23.4
Hammond WSS	Cook	1990	144.9	174.7	29.8	20.5
Hammond WSS	Cook	1995	187.2	166.7	-20.5	11.0
Hammond WSS	Cook	2000	150.5	149.1	-1.4	0.9
Hammond WSS	Cook	2005	138.0	134.2	-3.8	2.7
Highland Park	Lake	1990	218.3	221.8	3.5	1.6
Highland Park	Lake	1995	180.9	214.2	33.3	18.4
Highland Park	Lake	2000	193.2	194.8	1.6	0.9

System Name	County	Year	Actual GPCD	Predicted GPCD	Diff.	Error (%)
Highland Park	Lake	2005	197.5	168.4	-29.2	14.8
Joliet	Will	1990	145.4	129.9	-15.5	10.7
Joliet	Will	1995	134.1	129.6	-4.5	3.4
Joliet	Will	2000	111.2	121.8	10.6	9.5
Joliet	Will	2005	125.9	106.6	-19.3	15.3
Kankakee - Aqua Illinois	Kankakee	1990	305.7	252.6	-53.1	17.4
Kankakee - Aqua Illinois	Kankakee	1995	270.4	241.1	-29.3	10.8
Kankakee - Aqua Illinois	Kankakee	2000	185.0	233.3	48.3	26.1
Kankakee - Aqua Illinois	Kankakee	2005	192.4	214.0	21.7	11.3
Lake County Public Water District	Lake	1990	113.4	118.6	5.3	4.6
Lake County Public Water District	Lake	1995	117.7	116.0	-1.7	1.4
Lake County Public Water District	Lake	2000	98.4	104.5	6.1	6.2
Lake County Public Water District	Lake	2005	101.9	102.0	0.1	0.1
Lake Forest	Lake	1990	175.7	175.1	-0.6	0.4
Lake Forest	Lake	1995	184.4	174.6	-9.9	5.4
Lake Forest	Lake	2000	196.4	158.4	-38.0	19.4
Lake Forest	Lake	2005	221.3	223.2	1.9	0.8
Morris	Grundy	1990	130.9	160.8	29.9	22.8
Morris	Grundy	1995	166.9	154.2	-12.6	7.6
Morris	Grundy	2000	156.8	137.9	-18.9	12.0
Morris	Grundy	2005	123.4	127.8	4.4	3.6
North Chicago	Lake	1990	305.1	318.7	13.6	4.5
North Chicago	Lake	1995	331.7	305.3	-26.4	8.0
North Chicago	Lake	2000	336.9	339.8	2.8	0.8
North Chicago	Lake	2005	245.3	261.6	16.3	6.7
Northbrook	Cook	1990	172.7	175.8	3.0	1.8
Northbrook	Cook	1995	172.9	169.9	-3.1	1.8
Northbrook	Cook	2000	161.8	150.7	-11.1	6.9
Northbrook	Cook	2005	164.5	132.6	-31.9	19.4
Northwest Suburban Mun. JAWA	Cook	1990	104.4	136.8	32.4	31.0
Northwest Suburban Mun. JAWA	Cook	1995	125.4	132.9	7.5	6.0
Northwest Suburban Mun. JAWA	Cook	2000	122.5	122.8	0.3	0.2
Northwest Suburban Mun. JAWA	Cook	2005	116.2	111.6	-4.6	4.0
Oak Lawn	Cook	1990	101.5	141.1	39.6	39.0
Oak Lawn	Cook	1995	117.4	134.5	17.1	14.6
Oak Lawn	Cook	2000	120.8	120.4	-0.4	0.3
Oak Lawn	Cook	2005	115.6	108.3	-7.3	6.3
Oswego	Kendall	1990	98.3	112.6	14.4	14.6
Oswego	Kendall	1995	119.7	109.8	-9.9	8.3
Oswego	Kendall	2000	105.2	107.4	2.2	2.1
Oswego	Kendall	2005	102.7	98.9	-3.8	3.7
Residual Boone County	Boone	1990	77.2	83.6	6.4	8.3
Residual Boone County	Boone	1995	86.3	79.6	-6.7	7.8
Residual Boone County	Boone	2000	67.0	71.6	4.7	6.9
Residual Boone County	Boone	2005	70.4	68.1	-2.3	3.2
Residual Cook County	Cook	1990	85.5	82.2	-3.3	3.9
Residual Cook County	Cook	1995	52.7	53.2	0.4	0.8
Residual Cook County	Cook	2000	56.9	70.5	13.6	23.9
Residual Cook County	Cook	2005	74.3	64.0	-10.3	13.9
Residual De Kalb County	De Kalb	1990	121.8	121.1	-0.7	0.6
Residual De Kalb County	De Kalb	1995	118.0	119.8	1.8	1.5
Residual De Kalb County	De Kalb	2000	101.4	106.1	4.6	4.5
Residual De Kalb County	De Kalb	2005	101.2	99.2	-2.0	2.0
Residual Du Page County	DuPage	1990	167.0	168.1	1.1	0.7
Residual Du Page County	DuPage	1995	156.2	132.7	-23.6	15.1

System Name	County	Year	Actual GPCD	Predicted GPCD	Diff.	Error (%)
Residual Du Page County	DuPage	2000	94.4	126.5	32.1	34.0
Residual Du Page County	DuPage	2005	96.7	119.0	22.3	23.1
Residual Grundy County	Grundy	1990	110.0	130.1	20.0	18.2
Residual Grundy County	Grundy	1995	129.2	125.7	-3.5	2.7
Residual Grundy County	Grundy	2000	112.7	115.8	3.1	2.8
Residual Grundy County	Grundy	2005	124.8	108.7	-16.1	12.9
Residual Kane County	Kane	1990	172.2	143.1	-29.0	16.9
Residual Kane County	Kane	1995	148.4	134.3	-14.1	9.5
Residual Kane County	Kane	2000	137.4	121.5	-15.9	11.6
Residual Kane County	Kane	2005	115.4	125.7	10.3	8.9
Residual Kankakee County	Kankakee	1990	154.5	146.8	-7.7	5.0
Residual Kankakee County	Kankakee	1995	155.2	135.0	-20.2	13.0
Residual Kankakee County	Kankakee	2000	142.0	123.3	-18.6	13.1
Residual Kankakee County	Kankakee	2005	105.2	114.5	9.3	8.8
Residual Kendall County	Kendall	1990	137.3	105.3	-32.1	23.3
Residual Kendall County	Kendall	1995	121.9	103.8	-18.1	14.8
Residual Kendall County	Kendall	2000	75.2	95.0	19.8	26.3
Residual Kendall County	Kendall	2005	72.2	90.5	18.4	25.4
Residual Lake County	Lake	1990	150.4	133.2	-17.1	11.4
Residual Lake County	Lake	1995	137.6	129.3	-8.3	6.0
Residual Lake County	Lake	2000	121.0	116.5	-4.5	3.7
Residual Lake County	Lake	2005	100.5	120.7	20.2	20.1
Residual McHenry County	McHenry	1990	132.6	119.5	-13.1	9.8
Residual McHenry County	McHenry	1995	120.4	116.6	-3.9	3.2
Residual McHenry County	McHenry	2000	109.6	105.7	-3.9	3.6
Residual McHenry County	McHenry	2005	83.3	102.3	19.1	22.9
Residual Will County	Will	1990	131.8	142.1	10.3	7.8
Residual Will County	Will	1995	139.2	140.8	1.6	1.2
Residual Will County	Will	2000	130.2	122.7	-7.5	5.8
Residual Will County	Will	2005	107.0	125.0	18.0	16.8
Waukegan	Lake	1990	145.9	147.1	1.2	0.8
Waukegan	Lake	1995	108.3	108.1	-0.2	0.1
Waukegan	Lake	2000	106.3	95.4	-10.9	10.3
Waukegan	Lake	2005	94.8	109.6	14.8	15.6
Wilmette	Cook	1990	155.9	176.1	20.2	12.9
Wilmette	Cook	1995	130.6	131.7	1.1	0.8
Wilmette	Cook	2000	141.2	167.4	26.1	18.5
Wilmette	Cook	2005	142.2	159.6	17.4	12.2
Winnetka	Cook	1990	227.7	245.1	17.4	7.6
Winnetka	Cook	1995	209.2	237.5	28.3	13.5
Winnetka	Cook	2000	187.8	207.7	19.9	10.6
Winnetka	Cook	2005	217.3	190.9	-26.4	12.1
Average	--	--	146.8	147.1	0.2	**9.1%**

Table A2.22 Public-Supply Scenario Withdrawals by County

Scenario/County	2005R	2005N	2010	2015	2020	2025	2030	2035	2040	2045	2050
CT Scenario											
Boone	4.3	4.2	4.3	4.5	4.7	4.9	5.1	5.3	5.6	5.9	6.1
Cook	894.3	860.8	869.3	879.1	891.0	904.5	921.5	932.5	946.6	961.4	977.4
DeKalb	8.6	8.5	9.0	9.6	10.2	10.9	11.6	12.3	12.9	13.6	14.3
DuPage	104.9	96.9	98.2	99.8	101.5	103.5	105.5	107.9	110.2	112.7	115.6
Grundy	3.0	2.9	3.2	3.5	3.8	4.3	4.7	5.1	5.5	5.9	6.3
Kane	50.8	44.7	48.5	52.9	57.8	63.3	69.3	73.7	78.4	83.5	89.0
Kankakee	15.0	14.3	14.6	15.0	15.5	16.0	16.6	17.2	17.8	18.5	19.2
Kendall	4.5	4.0	5.3	7.0	9.1	11.6	14.7	16.4	18.4	20.5	22.8
Lake	77.3	67.8	70.4	73.1	76.2	79.6	83.2	86.4	89.8	93.3	97.1
McHenry	25.8	20.3	21.6	23.3	25.2	27.4	30.1	31.9	34.0	36.3	38.8
Will	67.2	64.9	75.3	86.7	99.6	114.1	130.1	142.1	154.7	168.3	183.5
Total 11 counties	1,255.7	1,189.2	1,219.8	1,254.4	1,294.5	1,340.1	1,392.4	1,430.9	1,473.8	1,519.9	1,570.3
LRI Scenario											
Boone	4.3	4.2	3.9	3.9	4.0	4.1	4.3	4.4	4.5	4.6	4.8
Cook	894.3	860.8	784.0	777.6	773.8	772.1	773.6	769.8	768.8	768.4	769.0
DeKalb	8.6	8.5	8.1	8.4	8.8	9.3	9.7	10.0	10.4	10.8	11.2
DuPage	104.9	96.9	88.7	89.1	89.8	90.7	91.8	92.9	94.0	95.1	96.6
Grundy	3.0	2.9	2.9	3.1	3.3	3.6	3.9	4.1	4.4	4.7	4.9
Kane	50.8	44.7	43.4	45.1	47.0	49.3	51.8	53.4	55.1	56.9	59.0
Kankakee	15.0	14.3	13.2	13.2	13.4	13.6	13.8	14.1	14.3	14.6	14.9
Kendall	4.5	4.0	4.7	5.6	6.8	8.1	9.8	10.6	11.5	12.5	13.6
Lake	77.3	67.8	63.4	64.5	65.9	67.6	69.4	70.8	72.3	73.8	75.6
McHenry	25.8	20.3	19.2	19.7	20.3	21.2	22.3	22.9	23.7	24.5	25.4
Will	67.2	64.9	67.9	76.5	86.2	96.9	108.5	116.4	124.5	133.2	142.9
Total 11 counties	1,255.7	1,189.2	1,099.3	1,106.8	1,119.4	1,136.6	1,158.9	1,169.6	1,183.5	1,199.3	1,217.9
MRI Scenario											
Boone	4.3	4.2	4.4	4.7	5.0	5.3	5.7	6.1	6.5	6.9	7.3
Cook	894.3	860.8	885.5	911.8	938.9	967.1	998.5	1,023.5	1,051.6	1,080.7	1,111.0
DeKalb	8.6	8.5	9.2	10.1	11.0	11.9	12.9	13.9	14.9	16.0	17.1
DuPage	104.9	96.9	100.3	103.7	107.2	110.9	114.5	118.5	122.6	126.8	131.5
Grundy	3.0	2.9	3.3	3.7	4.1	4.7	5.2	5.7	6.3	6.9	7.6
Kane	50.8	44.7	51.2	58.3	66.0	74.3	83.2	90.5	98.1	106.1	114.7
Kankakee	15.0	14.3	15.0	15.8	16.6	17.5	18.5	19.5	20.5	21.7	27.6
Kendall	4.5	4.0	6.0	8.4	11.3	14.8	19.1	21.9	25.1	28.6	32.4
Lake	77.3	67.8	72.3	76.9	81.9	87.2	92.9	98.2	103.7	109.5	115.8
McHenry	25.8	20.3	23.2	26.6	30.3	34.5	39.2	43.1	47.4	52.1	57.1
Will	67.2	64.9	76.8	90.2	105.6	123.3	143.0	158.9	175.7	194.2	215.1
Total 11 counties	1,255.7	1,189.2	1,247.3	1,310.2	1,378.0	1,451.5	1,532.9	1,599.8	1,672.4	1,749.4	1,837.2

2000R = reported 2005 withdrawals, 2005 = withdrawals which are model-adjusted to normal weather conditions

CHAPTER 3

SELF-SUPPLIED WATER FOR POWER GENERATION

BACKGROUND

Power Generation Process

Water withdrawn by power plants is classified by the USGS as thermoelectric generation water use. It represents the water applied in the production of heat-generated electric power. The heat sources may include fossil fuels such as coal, petroleum, natural gas, or nuclear fission. The main use of water at power plants is for cooling. Nearly 90 percent of electricity in the United States is produced with thermally-driven, water-cooled generation systems which require large amounts of water.

The three major types of thermoelectric plants include: conventional steam, nuclear steam, and internal combustion plants. In internal combustion plants, the prime mover is an internal combustion diesel or gas-fired engine. Since no steam or condensation cooling is involved, almost no water is used by internal combustion power generation.

In conventional steam and nuclear steam power plants, the prime mover is a steam turbine. Water is heated in a boiler until it turns into steam. The steam is then used to turn the turbine-generator, which produces electricity. The shaft power is produced when a nozzle directs jets of high-pressure steam against the blades of the turbine's rotor. The rotor is attached to a shaft that is coupled to an electrical generator. After leaving the turbine, the steam is condensed and then, in the form of condensate, is returned back to the boiler to be converted to steam again.

Water is used primarily for cooling and condensing steam after it leaves the turbine. In a conventional power-only steam turbine installation, designers increase efficiency by maximizing the pressure drop across the turbines. In this type of generation, the use of cooling water is essential because the collapse of steam volume in the condenser creates a vacuum (or backpressure) which affects the rotation of the turbine. The conventional low-pressure steam turbine generators can operate over a modest backpressure range from 1.0 to 4.0 inches of mercury absolute (Hga) and the optimal efficiency range from 2.0 to 3.5 inches Hga (Micheletti and Burns, 2002). Because the backpressure depends on the removal of "waste" heat by cooling water, the cooling system is an integral part of the power generation process.

Types of Cooling

The "waste" heat removed in the condenser is transferred to the surrounding environment by "wet" or "dry" cooling process. In "wet" systems, which dominate in thermoelectric generation, this is done through a combination of evaporation and sensible heating of water or air. In "dry" systems, the heat is transferred to the atmosphere through sensible heating. The wet systems fall into two broad categories: once-through cooling systems and closed-loop (or recirculating) systems.

In once-through cooling systems, water is withdrawn from a natural water body (such as river, or lake) and is pumped through a heat exchanger (a condenser) to cool down and condense the steam. After leaving the condenser, the cooling water, with an elevated temperature, is discharged into the receiving water body. Thus, in once-through cooling systems the heat is transferred into a surface water body to which the heated cooling water is discharged. The once-through method has several advantages. It is the least costly to construct; it requires less water treatment; and it evaporates less water than evaporative cooling towers. A drawback of the once-through systems is that large amount of surface water needs to be pumped through the condensers. A variation of a once-through system is a recirculating system with an evaporation pond or canal. In such a system the heated water is discharged into a pond or lake where its temperature is lowered by mixing with the lake water and further cooled by forced evaporation due to the overall increase of water temperature in the lake.

Wet closed-loop cooling systems require nearly 95 percent less water to be withdrawn than that required for once-through cooling (Harte, 1978). However, most of water withdrawn by closed-loop systems represents consumptive use, whereas nearly all once-through cooling withdrawals represent non-consumptive use. The conventional type of wet cooling system uses towers that are designed to remove heat by pumping hot water to the top of the tower and then allowing it to fall down while contacting the air which comes in from the bottom and/or sides of the tower. As the air passes through the water, it exchanges some of the heat and some of the water is evaporated. Generally, in cooling towers, as much as 50 to 70 percent of water is evaporated. The cooled water is collected at the bottom of the tower and is then pumped back to the condenser for reuse. Cooling towers have been increasingly used because they require much lower water withdrawals than once-through cooling systems.

Theoretical Cooling Water Requirements

In once-through cooling systems, theoretical water requirements are a function of the amount of "waste" heat that has to be removed in the process of condensing steam. According to Backus and Brown (1975), the amount of water for one megawatt (MW) of electric generation capacity can be calculated as:

$$L = \frac{6823(1-e)}{Te} \tag{3.1}$$

where:
L = amount of water flow in gallons per minute per MW of generating capacity;
T = temperature rise of the cooling water in °F; and
e = thermodynamic efficiency of the power plant, expressed as decimal fraction.

For example, in a coal-fired plant with thermal efficiency of 40 percent and the condenser temperature rise of 20 °F, the water flow rate obtained from Equation 3.1 would be 512 gallons per minute (gpm) per MW. For a typical 650 MW plant, operating at 90 percent of capacity, the theoretical flow rate would be nearly 300,000 gpm, or 431.3 million gallons per day. The daily volume of cooling water is equivalent to approximately 31 gallons per 1 kWh of generation.

According to Croley et al., (1975), in recirculating systems with cooling towers, theoretical make-up water requirements are determined using the following relationship:

$$W = E \cdot \frac{1}{\frac{c}{c_o} - 1} \tag{3.2}$$

where:
c/c_0 is the concentration ratio; and
E = evaporative water loss which for a typical mean water temperature of 80 °F can be calculated as:

$$E = (1.91145 \cdot 10^{-6}) \cdot aQ \tag{3.3}$$

where:
a = the fraction of heat dissipated as latent heat of evaporation (for evaporative towers a = 75% to 85%); and
Q = rate of heat rejection by the plant in Btu/hr, which can be calculated as:

$$Q = 3414426 \cdot P \cdot \frac{1-e}{e} \tag{3.4}$$

where:
P = the rated capacity of the plant in MW; and
e is thermodynamic efficiency of plant expressed as a fraction.

Again, for a typical 650 MW coal-fired plant with 40 percent efficiency, the heat rejection would be 3,329 million Btu/hour and the evaporative water loss would be 5,091 gpm. At the concentration ratio c/c_o of 0.25 the make-up water flow would be 6,788 gpm or 0.63 gallons per 1 kWh of generation.

Theoretical vs. Actual Water Use

While the theoretical (or minimum) water requirements for energy generation are similar for plants of the same type, the actual unit amounts of water withdrawn per kilowatt-hour of gross generation vary from plant to plant even when the same type of cooling is used and at the same level of thermal efficiency. Significant differences in unit water use per kilowatt-hour of electricity generation among different types of cooling systems were reported in previous studies (Harte and El-Gasseir, 1978; Gleick, 1993; Baum et al., 2003).

Some of the reasons for this variability are easily explained. For example, in “load-following” plants using once-through cooling systems, intake pumps continue to operate when the level of generation declines. This is often caused by the lack of control technologies to regulate flow to match the fluctuating load on generators. There is limited ability to close or open control valves on pipes between the pumps and the condenser, or regulate the operation of pumps.

Better measurement and control of flows is available on closed-loop systems with cooling towers. The make-up water is usually metered and its flow rate could be regulated automatically depending on the quality of the recirculating water. However, the level of control varies among plants and the amounts of intake water per kilowatt-hour of generation also vary. Without advanced technologies for water measurement and control, it is difficult to optimize system operations to minimize water intake as well as operational costs associated with maintaining the high efficiency of heat transfer in the condenser.

It is important to note that while the thermoelectric power generation sector usually requires large quantities of water, the overall consumptive use of water is small. In once-through cooling systems, as much as 99 percent of water withdrawn can be returned back to the source. Closed-loop systems with cooling towers require smaller withdrawals (on average approximately 5 percent or less of the volumes withdrawn by once through cooling systems), however, between 30 to 70 percent of that smaller volume could be consumed due to evaporation.

As shown in the formulas presented in the previous section, the amount of water required for the cooling process depends on the amount of “waste” heat being removed, which in turn depends on the amount of energy being generated. The amount of energy being generated at the power plant is measured as gross generation. The amount of energy leaving the power plant is referred to as net generation. Gross generation is the electrical output directly produced by a given generator or a set of generators. Net generation, as defined by the EIA, is “the amount of electric energy generated, measured at the generator terminals, less the total electric energy consumed at the generating station.” Power plants use part of the generated electricity to run auxiliary equipment such as water pumps, electric motors and pollution control equipment. Generally, the energy consumed by generating station ranges from 3 to 6 percent of plant’s gross output (although in some plants with extensive pollution control equipment it can reach 12 percent) (EPA, 1999).

Table 3.1 shows average rates of water withdrawals and evaporative losses in cooling plants obtained from national data (Dziegielewski et al., 2006). These estimates were derived from the data on water pumpage and discharges in thermoelectric power plants (based on Form EIA-767).

Table 3.1 National Average Rates of Cooling Water Demand
By Power Plants Based on EIA Data

Description	Withdrawals per Unit Generation (gallons/kWh)	Estimated Evaporative Loss (gallons/kWh)
Fossil fuel plants:		
Once-through systems	44.0	0.2
Recirculating systems with ponds	24.0	0.7
Closed-loop w/ cooling towers	1.0	0.7
Nuclear plants:		
Once-through systems	48.0	0.4
Recirculating systems with ponds	13.0	0.5
Closed-loop w/ cooling towers	2.6	0.8

Source: Dziegielewski and Bik, 2006.

The estimates in Table 3.1 were obtained by dividing total reported water withdrawals by the net generation in kilowatt-hours. The estimates show average amounts of water per kilowatt-hour (kWh) of net generation in different types of cooling systems for both fossil fuel and nuclear plants. The resultant values represent weighted (by the net generation) average rates of water withdrawals. Because the estimates are based on net generation they are slightly higher (by 3 to 6 percent) than the rates of water withdrawals which would be obtained by dividing water withdrawals by gross generation.

The average rates for once-through cooling and closed-loop cooling systems in fossil-fuel plants shown in Table 3.1 are consistent with the theoretically derived values which were calculated for typical plants in the previous section (i.e., 31 gallons/kWh in once-through systems and 0.63 gallons/kWh in systems with cooling towers).

WATER WITHDRAWALS AND ELECTRIC GENERATION

Reported County-Level Water Withdrawals

The USGS National Water Use Information Program reported thermoelectric withdrawals in four of the eleven counties in Northeastern Illinois which are included in the study area. Table 3.2 shows the USGS-reported withdrawals for these four counties during the past five data compilation years: 1985, 1990, 1995, 2000, and 2005.

Table 3.2 USGS Reported Thermoelectric Water Withdrawals
in Four Counties in Northeastern Illinois (1985 – 2005)

County	1985	1990	1995	2000	2005
Cook	580.8	409.6	409.2	598.0	718.2
Grundy	781.2	1,537.9	2,550.8	967.3	1,548.6
Lake	2,170.3	2,789.6	2,364.0	658.2	758.3
Will	1,757.0	3,561.1	3,838.0	2,027.9	2,552.4
NE Illinois Total	5,289.3	8,298.3	9,161.9	4,251.5	5,577.5

Source: USGS water use reports, various years. Values represent average annual withdrawals in million gallons per day (mgd).

The USGS reported data in Table 3.2 show a significant decline of total withdrawals between 1995 and 2000. This was primarily due to the change in reported withdrawals for plants located in Lake and Will counties. The change in reported withdrawals resulted from the switch in reporting by once-through plants with cooling ponds or canals from the volume being pumped through the condenser to the volume of makeup water being added to the cooling pond. Also, Lake County experienced a large drop in withdrawals with the retirement of Zion nuclear plant in 1998. The increase in withdrawals in Grundy County is likely a function of changes in the diversion of water from Kankakee River during the “in-direct” open-cycle flow operation of Dresden plant canal and cooling pond system.

After a decline of 4,910 mgd (53.6 percent) in the reported withdrawals between 1995 and 2000, the four-county total reported withdrawals have increased by 1,326 mgd or 31.2 percent between 2000 and 2005. However, further revisions of the plant-level data for 2005 performed for this study show the total withdrawals in the study area of 4,259.5 mgd.

Electric Generation

According to the inventory of electric generators maintained by the Energy Information Agency (EIA), there are 72 generation facilities in the 11-county area of Northeastern Illinois. Total nameplate capacity of the 72 plants is 18,560 MW (see Table A3.1 in Chapter 3 Annex). Of the total number of plants, there are 12 large plants which account for more than 95 percent of total generation. The capacity and generation data for the 12 large plants in the 11-county study area are listed in Table 3.3.

Total generation capacity (measured as gross capacity) of these 12 plants is 11,767 MW. The small generators in the study area do not represent large users of water for power generation and their water demand is included in the self-supplied commercial-industrial sector or public-supply sector. The estimates of future water needs for electric power generation are based on the generation and cooling water needs of the large plants which are self-supplied.

Reported Plant-Level Withdrawals

Table 3.4 compares water withdrawals and gross generation for 11 of the 12 large plants, which are self-supplied. One plant, Elgin Energy Center, is using public water supply and therefore is not included in the analysis.

The plants in Table 3.4 are separated into two groups: through flow (i.e. run-of-the-river) plants and makeup water intake plants. Once-through flow run-of-the-river plants pump water directly to the condensers and almost immediately return it back to the river or lake. Closed-loop makeup water plants withdraw water to replace losses and blowdown in cooling towers, or water losses and discharges from perched lakes or ponds. This separation of plants provides for a better consistency in representing non-consumptive and consumptive water withdrawals for power production. Water withdrawn by through flow plants represents non-consumptive use since nearly all water withdrawn is returned to the source. Withdrawals by makeup water plants represent a sum of both consumptive and non-consumptive use and are comparable with withdrawals by the industrial/commercial and agricultural sectors.

Table 3.4 shows water withdrawals for eight run-of-the-river plants and three makeup water intake plants. The 2005 withdrawals for the run-of-the-river plants totaled 4,207.2 mgd. Almost all of these withdrawals represent non-consumptive use because the water withdrawn is returned to the sources after passing through the condensers.

Total 2005 withdrawals by the three makeup water plants were 52.3 mgd. A large but undetermined portion of this volume represents consumptive use. The consumptive use portion represents water being evaporated during the cooling process.

Table 3.3 Capacity and Generation of Large Powers Plants Located in Northeastern Illinois

Plant Name (Owner)/ Water Source	Gross Capacity (MW)	2005 Gross Generation (MWh/year)	2005 Net Generation (MWh/year)	Net/Gross Generation (%)	2005 Capacity Factor (%)
1. Crawford Plant, Cook Co. (Midwest Generation EME LLC) -Chicago San./ Ship Canal	582	3,201,844	2,965,873	92.6	62.8
2. Fisk Street Plant, Cook Co. (Midwest Generation EME LLC) -Chicago River- S. Branch	342	1,603,949	1,496,937	93.3	53.5
3. Dresden Nuclear Plant, Grundy Co. -(Exelon Generation Co. LLC) Kankakee DesPlaines River	1,734	14,031,125	13,622,453	97.1	92.4
4. Waukegan Plant, Lake Co. (Midwest Generation EME LL)C -Lake Michigan	628	4,909,907	4,560,504	92.9	89.3
5. Zion Energy Center*, Lake Co. (Zion Energy LLC) -Lake Michigan	546	35,058	34,876	99.5	0.7
6. Joliet 29 Plant, Will Co. (Midwest Generation EME LLC) -DesPlaines River	1,088	5,767,994	5,500,330	95.4	60.5
7. Joliet 9 Plant, Will Co. (Midwest Generation EME LLC) -DesPlaines River	326	1,922,330	1,673,848	87.1	67.3
8. Will County/Romeoville, Will (Midwest Generation EME LLC) -Chicago Sanitary/ Ship Canal	1,154	5,658,996	5,293,858	93.5	56.0
9. Braidwood Nuclear Plant, Will Co. (Exelon Generation Co. LLC) Kankakee River/ Cooling Lake	2,330	20,390,274	19,796,383	97.1	99.9
10. Elwood Energy LLC*, Will Co. (Dominion Elwood Serv. Co.) -Groundwater well	1,409	437,285	435,737	99.6	3.5
11. Kendall Co. Gen. Facility, Kendall (Dynegy Midwest Gen. Inc.) -Illinois River	1,160	1,367,008	1,313,416	96.1	13.5
12. Elgin Energy Center*, Kane (Ameren Energy Generating Co.) -(city water)	468	35,227	35,224	99.9	0.9
Total/Average	11,767	59,360,997	56,729,439	95.6	57.6

Comments: (*) Denotes a peaking plant. Zion nuclear plant was decommissioned in February 1998; currently synchronous condensers are used at peaking time. Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report."

Table 3.4 Gross Generation and Water Withdrawals in Large Powers Plants Located in Northeastern Illinois

Plant Name (Owner)/ Water Source	2005 Gross Generation (MWh/year)	2005 Water Withdrawals (MGD)	2005 Rate of Withdrawals (Gal./kWh)
THROUGH FLOW PLANTS:	37,131,203	4,207.2	41.4
1. Crawford Plant (Midwest Generation EME LLC) Chicago San./ Ship Canal	3,201,844	503.3	57.4
2. Fisk Street Plant (Midwest Generation EME LLC) Chicago River- S. Branch	1,603,949	222.2	50.6
3. Dresden Nuclear Plant (Exelon Generation Co.) Kankakee/DesPlaines River	14,031,125	415.6	10.8
4. Waukegan Plant (Midwest Generation EME LL)C Lake Michigan	4,909,907	758.6	56.4
5. Zion Energy Center* (Zion Energy LLC) Lake Michigan	35,058	31.7	330.0
6. Joliet 29 Plant (Midwest Generation EME LLC) - DesPlaines River	5,767,994	942.6	59.6
7. Joliet 9 Plant (Midwest Generation EME LLC) - DesPlaines River	1,922,330	415.3	78.9
8. Will County/Romeoville Plant (Midwest Generation EME LLC) Chicago Sanitary/ Ship Canal	5,658,996	917.9	59.2
MAKEUP WATER PLANTS:	22,194,567	52.3	0.86
9. Braidwood Nuclear Plant (Exelon Generation Co. LLC) Kankakee River/ Cooling Lake	20,390,274	49.8	0.89
10. Elwood Energy LLC* (Dominion Elwood Serv. Co.) Groundwater well	437,285	0.003	0.003
11. Kendall Co. Gen. Facility (Dynegy Midwest Gen. Inc.) Illinois River	1,367,008	2.5	0.67
All Plants	59,325,770	--	--

Comments: (*) Denotes a peaking plant. Zion nuclear plant was decommissioned in February 1998; currently synchronous condensers are used at peaking time. Elwood Energy plant is air-cooled.
LM = Lake Michigan

WATER-DEMAND RELATIONSHIPS

A straightforward unit-coefficient method was used in this study to derive future quantities of water withdrawals. This method represents water demand as a product of total gross generation at the plant and the unit rate of water required in gallons per kilowatt-hour. The specific coefficients and relationship for the two main types of cooling systems are discussed below.

Once-through Cooling

Previous studies of water use in plants with once-through cooling systems show that total water withdrawals depend primarily on the level of generation in kWh per year and also vary depending on the operational efficiency (i.e., the percent of capacity utilization), thermal efficiency of the plant, the design temperature rise in the condenser at 100 percent capacity, fuel type, and other system design and operational conditions (Dziegielewski and Bik, 2006, Yang and Dziegielewski, 2007). However, the usefulness of the published water-use relationships is somewhat limited because the reported equations are estimated from the data derived from the EIA-767 Steam Electric Plant Operation and Design Report which includes only net electric generation. More precise estimation methods for cooling water withdrawals can be derived using gross generation.

The data in Table 3.4 includes water withdrawals and gross generation in eight once-through run-of-the-river plants in the study area. With the exception of one plant (Dresden Nuclear Plant) the plants pump water directly to the condensers. The Dresden plant uses a combination of open-cycle and close-cycle cooling and therefore is not directly comparable to the other seven plants. Figure 3.1 below shows a plot of the reported water withdrawals versus gross generation for the seven run-of-the-river plants from Table 3.4.

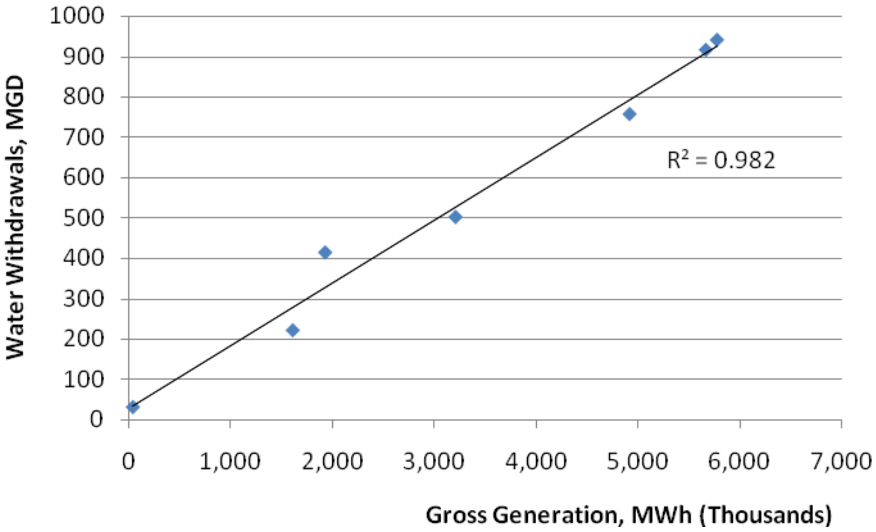

Figure 3.1 Relationship Between Total Water Withdrawals and Gross Generation for Seven Run-of-the-River Plants in Northeastern Illinois

The regression line which is fitted to the data points shows a correlation R^2 of 0.982. The R^2 coefficient indicates that 98.2 percent of variance in total withdrawals among the seven plants is explained by the values of gross generation. The relationship between the amount of generation and water withdrawals is also confirmed by previous studies of water withdrawals for power generation (Dziegielewski et al., 2002; Dziegielewski and Bik, 2006).

The slope of the regression line on Figure 3.1 is 56.7 gallons/kWh. This value represents the average incremental unit withdrawal per 1 kWh of gross generation. In deriving future estimates of water withdrawal for the eight run-of-the-river plants, the actual unit withdrawals at each plant which are shown in the last column of Table 3.4 were used.

Closed-loop Cooling

In the group of the three makeup water plants, two large plants, Kendall County and Braidwood Nuclear plants use closed-loop cooling systems. Elwood Energy is a gas-fired peaking plant with gas turbines which uses minimal quantities of water from a well near the plant.

The estimates of water withdrawals in the two closed-loop plants are 0.89 gallons/kWh and 0.67 gallons/kWh. These unit-values were used in determining future water withdrawals.

FUTURE DEMAND FOR ELECTRICITY

Future water withdrawals of the power generation sector will depend on the level of future generation and also on the type of generators and cooling systems. Before constructing the future scenarios for the thermoelectric sector, it is important to examine the future trends in demand for electricity in the study area. Because of the deregulation of electric power industry, the demand for electricity in any geographical area cannot be directly linked with local generation. However, the knowledge of the future demand for electricity is helpful in determining the future trends in generation.

It is reasonable to expect that the future demand for electricity within the 11-county study area will change because of population growth and the concomitant increase in economic activity. The current use of electricity within the study area is difficult to determine precisely. An approximate level of electricity usage per capita can be derived by comparing the current aggregate sales of electricity with population served.

Table 3.5 compares the available estimates of per capita energy consumption for different geographical areas. The data is derived by dividing total sales of electricity by estimated population served.

Using the data in Table 3.5, the estimate of 9.61 MWh per capita per year obtained from Commonwealth Edison appears to be the best approximation of electricity use in the 11-county study area. Because it is slightly lower than the statewide rates reported by the Illinois Commerce Commission (i.e., 10.14 MWh/capita/year) and the Energy Information Agency (10.77 MWh/capita/year), it was selected as a conservative estimate of future per capita use of electricity in the study area.

Table 3.5 Available Estimates of Per Capita Consumption of Electricity

Source and Data Year	Electricity Use MWh/capita/year	Comments
Commonwealth Edison, 2006	9.61	Based on total sales and number of customers
Illinois Commerce Commission (ICC), 2006	10.14	State-wide electricity sales and number of customers
Energy Information Agency (EIA), 2005	10.77	Illinois average
Energy Information Agency (EIA), 2005	12.33	U.S. average

According to the EIA, at the national level, total electricity sales to all sectors (i.e., residential, commercial, and industrial) are expected to increase from 3,660 billion kWh in 2005 to 5,168 billion kWh in 2030 (AEO2007 reference case, EIA, 2007). During the same time period the projected U.S. population is expected to increase from 296.94 million in 2005 to 364.94 million in 2030. This implies that at the national level, per capita use of electricity is expected to increase from the current level of 12.33 MWh/capita/year to 14.16 MWh/capita/year in 2030. This represents the annual growth in electricity consumption of 0.56% per year. Table 3.6 shows the estimates of demand for electricity in the 11-county study area.

Table 3.6 Population-based Estimates of Future Demand for Electricity in Northeastern Illinois Study Area

Year	Resident Population	Reference Electricity Demand[a] (MWh/year)	Electricity Demand with Growth[b] (MWh/year)
2005	8,743,866	84,028,552	84,028,552
2010	9,107,010	87,518,366	89,996,481
2015	9,444,014	90,756,975	95,969,370
2020	9,793,488	94,115,420	102,338,669
2025	10,155,895	97,598,151	109,130,686
2030	10,635,427	102,206,453	117,519,500
2035	10,921,437	104,955,010	124,096,954
2040	11,325,584	108,838,862	132,333,026
2045	11,744,685	112,866,423	141,115,709
2050	12,113,169	116,407,554	149,664,250

[a] The reference case electricity demand is obtained by multiplying the 11-county resident population by per capita use of electricity of 9.61 MWh per year.

[b] Demand with growth includes the annual growth factor in demand of 0.56%.

According to EIA (2007), the growth in demand for electricity at the national level “is expected to be potentially offset by efficiency gains in both residential and commercial sectors.”

WATER DEMAND SCENARIOS

The three future scenarios are designed to capture future conditions of water demand for electric power generation which would provide the future water withdrawals for this sector under three different sets of conditions. The scenarios include less resources intensive outcome, current trends (or baseline case), and more resource intensive outcome. The assumptions used in the formulation of each scenario are described below.

Scenario 1 – Current Trends (Baseline Case)

Under this baseline scenario, future generation of electricity in the 11-county study area would continue in the existing 12 power plants with the exception that the three electric generator units which are have been or are already scheduled to be retired because of limits on mercury emissions will be retired and not replaced within their respective plants. Table 3.7 shows the electric generation capacity of the three generator units to be shut down.

Table 3.7 Generators to be Shut Down Because of Mercury Emission Restrictions

County	*Plant Name/ Unit # to be Shut down*	*Expected Shutdown Date*	*Plant Gross Capacity (MW)*	*2005 Gross Plant Generation (MWh)*	*2005 Unit Gross Capacity (MW)*
Lake	Waukegan #6	12/31/2007	736	4,909,907	108
Will	Will Co./Romeoville #1	12/31/2010	1,154	5,658,996	167
Will	Will Co./Romeoville #2	12/31/2010	1,154	5,658,996	167
Total	--	--	--	--	442

Comments: Unit capacity obtained from Edison International, the parent company of Midwest Generations, which owns Waukegan and Will County/Romeoville plants (www.edison.com). Plant capacity and gross generation obtained from Federal data (EIA).

The three generator units represent total capacity of 442 MW. Their impact on generation is obtained by reducing the generation by the ratio of generation capacity of the generator units to total plant capacity. Accordingly, the generation of the Waukegan plant is reduced by (108/736)*4,909,907 or by 720,475 MWh/year after 2007. Similarly, the generation of the Will County plant will be reduced by (334/1154)*5,658,996 or by 1,637,872 MWh/year after 2010.

Based on power industry comments regarding the formulation of scenarios presented during the RWSPG meetings and reviews of the draft report, the CT scenario makes the assumption that all currently operating plants will remain in service using the existing cooling methods. Their annual gross generation will be maintained at the 2005 levels as shown in Table 3.3 above.

The specific assumptions for the current trends (CT) scenario are:

1. Future demand for electricity will grow in proportion to population growth at the rate of 9.61 MWH/capita/year plus an annual increase in per capita use of 0.56 percent, but the additional future demand will be met by power produced outside of the 11-county study area.

2. Future generation in the existing power plants will continue at the 2005 level of gross generation.

3. Three generator units (one in the Waukegan plant and two in the Will County plant) will be retired as scheduled and not replaced.

Scenario 2 – Less Resource Intensive Case

The intent of this scenario is to define future conditions which would lead to less water withdrawals by the power generation sector. Such an outcome would result if some of the existing plants would convert from once-through run-of-the-river cooling systems to closed-loop makeup water plants with cooling towers. This assumption is based on power industry comments regarding the formulation of scenarios presented during the RWSPG meetings and reviews of the draft report. The letter of April 21, 2008 from power industry suggested for one of the scenarios that "all current open cycle power plants in the region (less the two Will County units and one Waukegan unit) remain in service; but are required to be retrofit with closed cycle cooling systems (i.e. cooling towers)" (p.6). Because it seems unlikely that all once-through plants would be converted, a review of the current supply sources was conducted to determine which plants would possibly implement retrofits with cooling towers in the future. For the purpose of this scenario, two plants located on DesPlanes River were assumed to be possible candidates for retrofitting with cooling towers, namely, the Joliet 29 plant and the Joliet 9 plant. For the scenario construction purposes, the retrofits were assumed to take place within the next 10 years for Joliet 29 and within the next 20 years for Joliet 9.

The specific assumptions for the less resource intensive (LRI) scenario are:

1. Future increases in per capita consumption of electricity are offset by conservation and total demand for electricity will follow population growth with the rate of 9.61 MWh/capita/year (with no per capita growth rate).

2. The future increase in electricity consumptions will be met by importing electricity from outside the 11-county area.

3. Future generation in the existing power plants will continue at the 2005 level of gross generation.

4. Three generator units (one in the Waukegan plant and two in the Will County plant) will be retired as scheduled and not replaced (same as CT scenario).

5. Two power plants in Will County will be retrofitted with cooling towers: Joliet 29 by 2020, and Joliet 9 by 2030.

Scenario 3 –More Resource Intensive Case

The intent of this scenario is to define future conditions which would lead to higher water withdrawals by the power generation sector. Higher water withdrawals would result if additional power plants are built within the study area. According to the comments of the power industry representatives on the RWSPG there are no current plans for constructing any new power plants in the study area. Also, the opinion of power industry representatives is that if any new conventional power plants are built anywhere in the country they would be required to use closed-loop cooling systems in accordance with the USEPA Phase I 316(b) rule.

For the purpose of this scenario, an assumption is made that two clean coal power plants with gross capacity of 1200 MW each would be constructed within the 11-county study area during the later years of the planning horizon. For the purpose of constructing this scenario, it is assumed that one plant would be built in Kankakee County by 2025 and another in Grundy County by 2040. If the two plants are built, it was assumed that both plants would use river water as makeup water for closed-loop cooling system with cooling towers.

The specific assumptions for the more resource intensive (MRI) scenario are:

1. Future demand for electricity will grow in proportion to population growth at the rate of 9.61 MWH/capita/year plus an annual increase in per capita use of 0.56 percent.

2. Future generation in the existing power plants will continue at the 2005 level of gross generation.

3. Three generator units (one in the Waukegan plant and two in the Will County plant) will be retired as scheduled and not replaced (same as CT scenario).

4. Two new clean coal plants will be constructed within the 11-county study area during the later part of the study period: one by 2025, and one by 2040.

5. The new plants, if built, would be located near high-capacity transmission corridors, would use closed-loop cooling systems, and would likely be supplied with surface water from rivers in the western and southern parts of the study area.

SCENARIO RESULTS

The results of the assumptions for each of the three scenarios on water withdrawals are summarized in Table 3.8 below.

Under the baseline case (CT) scenario, the future water withdrawals for power generation would remain unchanged after the 3 generation units are retired by 2015. Total withdrawals would decrease by 377.0 mgd, from 4,259.5 mgd in 2005 to 3,882.5 by 2015, and remain constant during the 2015-2050 period. The 377.0 mgd decrease represents a reduction in through-flow withdrawals; makeup water withdrawals would remain unchanged.

Under the LRI scenario, total withdrawals would decline by 1,720.8 mgd, or 40.4 percent, when two plants with once-through cooling systems are retrofitted with cooling towers. Through-flow withdrawals would decrease by 1,734.9 mgd (or 41.2 percent). However, the conversion to cooling towers would increase makeup water withdrawals from 52.3 mgd to 66.4 mgd (a 27 percent increase).

Under the MRI scenario, total water withdrawals would decrease by 338.5 mgd (7.9 percent) because of the retirement of three generator units in 2007 and 2010 (as in CT scenario). However, water withdrawals by makeup water intake plants would increase by 38.4 mgd, or 73.5 percent, as two new closed-loop plants are added. The net effect would be a 338.5 mgd (or 7.9 percent) decrease in total withdrawals.

Table 3.8 Electric Power Generation and Water Demand Scenarios in Northeastern Illinois

Year	Through-flow Plants		Makeup Water Plants		All plants	
	Generation MWh/year	Withdrawals MGD	Generation MWh/year	Withdrawals MGD	Generation MWh/year	Withdrawals MGD
CT – Current Trends Scenario (Baseline Case)						
2005	37,134,492	4,207.2	22,194,567	52.3	59,329,059	4,259.5
2010	36,413,906	4,095.9	22,194,567	52.3	58,608,473	4,148.2
2015	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2020	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2025	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2030	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2035	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2040	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2045	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2050	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2005-50 Change	-2,358,458	-377.0	0.0	0.0	-2,358,458	-377.0
2005-50, %	-6.4	-9.0	0.0	0.0	-4.0	-8.9
LRI – Less Resource Intensive Scenario						
2005	37,134,492	4,207.2	22,194,567	52.3	59,329,059	4,259.5
2010	36,413,906	4,095.9	22,194,567	52.3	58,608,473	4,148.2
2015	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2020	29,004,862	2,887.6	27,962,561	62.9	56,969,669	2,950.5
2025	29,004,862	2,887.6	27,962,561	62.9	56,969,669	2,950.5
2030	27,082,532	2,472.3	29,884,891	66.4	56,969,257	2,538.7
2035	27,082,532	2,472.3	29,884,891	66.4	56,969,257	2,538.7
2040	27,082,532	2,472.3	29,884,891	66.4	56,969,257	2,538.7
2045	27,082,532	2,472.3	29,884,891	66.4	56,969,257	2,538.7
2050	27,082,532	2,472.3	29,884,891	66.4	56,969,257	2,538.7
2005-50 Change	-10,051,960	-1,734.9	7,690,324	14.1	-2,359,802	-1,720.8
2005-50, %	-27.1	-41.2	34.6	26.9	-4.0	-40.4
MRI – More Resource Intensive Scenario						
2005	37,134,492	4,207.2	22,194,567	52.3	59,329,059	4,259.5
2010	36,413,906	4,095.9	22,194,567	52.3	58,608,473	4,148.2
2015	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2020	34,776,034	3,830.2	22,194,567	52.3	56,970,601	3,882.5
2025	34,776,034	3,830.2	32,706,567	71.5	67,482,601	3,901.7
2030	34,776,034	3,830.2	32,706,567	71.5	67,482,601	3,901.7
2035	34,776,034	3,830.2	32,706,567	71.5	67,482,601	3,901.7
2040	34,776,034	3,830.2	43,218,567	90.8	77,994,601	3,921.0
2045	34,776,034	3,830.2	43,218,567	90.8	77,994,601	3,921.0
2050	34,776,034	3,830.2	43,218,567	90.8	77,994,601	3,921.0
2005-50 Change	-2,358,458	-377.0	21,024,000	38.4	18,665,542	-338.5
2005-50, %	-6.4	-9.0	94.7	73.5	31.5	-7.9

CHAPTER 3 ANNEX

Table A3.1 Listing of Power Generators in the 11-County Area of Northeastern Illinois

No.	Plant Name	County	Name Plate MW	No.	Plant Name	County	Name Plate MW
1	Braidwood Generation Station	Will	2,452.0	37	Hoffer Plastics	Kane	7.2
2	Dresden Generating Station	Grundy	1,824.0	38	General Mills West Chicago	DuPage	6.4
3	Elwood Energy LLC	Will	1,728.0	39	CID Gas Recovery	Cook	6.0
4	Joliet 29	Will	1,320.0	40	Wells Manufacturing Dura Bar Division	McHenry	6.0
5	Aurora	DuPage	1,275.0	41	Devonshire Power Partners LLC	Cook	5.5
6	Will County	Will	1,268.8	42	Nalco	DuPage	4.7
7	Kendall County Generation Facility	Kendall	1,256.0	43	Biodyne Lyons	Cook	4.5
8	Waukegan	Lake	914.7	44	Morris Genco LLC	Grundy	4.2
9	Lincoln Generating Facility	Will	692.0	45	Aventis Behring LLC	Kankakee	4.2
10	Fisk Street*	Cook	662.8	46	Little Company of Mary Hospital	Cook	3.8
11	Crawford	Cook	597.4	47	IVEX Packaging	Will	3.8
12	Zion Energy Center	Lake	596.7	48	M&M Mars Chicago	Cook	3.5
13	Elgin Energy Center	Kane	540.0	49	Bunge Oil	Kankakee	3.5
14	PPL University Park Power Project	Will	540.0	50	Avon Energy Partners LLC	Cook	3.3
15	Rocky Road Power LLC	Kane	418.9	51	MPEA Energy Center	Cook	3.3
16	Southeast Chicago Energy Project	Cook	407.2	52	Stickney Water Reclamation Plant	Cook	3.0
17	Calumet Energy Team LLC	Cook	386.0	53	Rock-Tenn	Kane	2.9
18	Joliet 9	Will	360.4	54	Evanston Township High School	Cook	2.4
19	Crete Energy Park	Will	356.0	55	Phelps Dodge Chicago Rod	Cook	2.4
20	University Park Energy LLC	Will	342.0	56	Saint Mary of Nazareth Hospital	Cook	2.4
21	Morris Cogeneration Plant	Grundy	179.0	57	Thornwood High School	Cook	2.4
22	University of Illinois Cogen Facility	Cook	59.9	58	Fox Metro Water Reclamation District	Kendall	2.2
23	Corn Products Illinois	Cook	54.6	59	Biodyne Lansing	Cook	2.0
24	ExxonMobil Oil Joliet Refinery	Will	39.6	60	Mooseheart Power House	Kane	1.8
25	Winnetka	Cook	33.4	61	St Francis Hospital	Cook	1.6
26	New Heights Recovery and Power LLC	Cook	26.0	62	South Barrington Electric	DuPage	1.6
27	Mallard Lake Electric	Du Page	25.0	63	Sherman Hospital	Kane	1.6
28	Lockport Powerhouse	Will	16.0	64	Woodland Landfill Gas Recovery	Kane	1.6
29	Biodyne Congress	Cook	15.0	65	Kankakee Gas Recovery	Kankakee	1.6
30	Greene Valley Gas Recovery	DuPage	9.9	66	Klein Tools Chicago	Cook	1.5
31	Lake Gas Recovery	Cook	9.0	67	Woodridge Greene Valley Treatment Plant	DuPage	1.5
32	Countyside Genco LLC	Lake	8.4	68	Art Institute of Chicago	Cook	1.4
33	Alsip Paper Condominium Association	Cook	8.3	69	Duraco Products	Cook	1.4
34	BP Naperville Cogeneration Facility	DuPage	8.3	70	Panduit Tinley Park	Cook	1.4
35	Koopers Chicago Plant	Cook	7.5	71	Kankakee Hydro Facility	Kankakee	1.2
36	Illinois Institute of Tech Cogen Fac	Cook	7.4	72	Riverside Resource Recovery LLC	Will	1.1

Total nameplate capacity in 72 plants = 18,560 MW (summer capacity = 15,962 MW). Gross capacity is used for the 12 large plants used in the analysis (see Table 3.3). Fisk station is no longer operating at the capacity shown.
Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report."

Table A3.2 Water Withdrawals for Thermoelectric Generation by County
For Three Scenarios (in MGD)

County	*2005*	*2010*	*2015*	*2020*	*2025*	*2030*	*2035*	*2040*	*2045*	*2050*
CT	*Current Trends (Baseline Case) Scenario*									
Boone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cook	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5
DeKalb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DuPage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grundy	415.6	415.6	415.6	415.6	415.6	415.6	415.6	415.6	415.6	415.6
Lake	790.3	679.0	679.0	679.0	679.0	679.0	679.0	679.0	679.0	679.0
Kane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kankakee	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kendall	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
McHenry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Will	2,325.6	2,325.6	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9
Total area	4,259.5	4,148.2	3,882.5	3,882.5	3,882.5	3,882.5	3,882.5	3,882.5	3,882.5	3,882.5
LRI	*Less Resource Intensive Scenario*									
Boone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cook	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5
DeKalb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DuPage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grundy	415.6	415.6	415.6	415.6	415.6	415.6	415.6	415.6	415.6	415.6
Lake	790.3	679.0	679.0	679.0	679.0	679.0	679.0	679.0	679.0	679.0
Kane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kankakee	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kendall	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
McHenry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Will	2,325.6	2,325.6	2,059.9	1,127.9	1,127.9	716.1	716.1	716.1	716.1	716.1
Total area	4,259.5	4,148.2	3,882.5	2,950.5	2,950.5	2,538.7	2,538.7	2,538.7	2,538.7	2,538.7
MRI	*More Resource Intensive Scenario*									
Boone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cook	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5	725.5
DeKalb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DuPage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grundy	415.6	415.6	415.6	415.6	415.6	415.6	415.6	434.8	434.8	434.8
Lake	790.3	679.0	679.0	679.0	679.0	679.0	679.0	679.0	679.0	679.0
Kane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kankakee	0.0	0.0	0.0	0.0	19.2	19.2	19.2	19.2	19.2	19.2
Kendall	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
McHenry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Will	2,325.6	2,325.6	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9	2,059.9
Total area	4,259.5	4,148.2	3,882.5	3,882.5	3,901.7	3,901.7	3,901.7	3,921.0	3,921.0	3,921.0

CHAPTER 4

INDUSTRIAL AND COMMERCIAL WATER DEMAND

BACKGROUND

Industrial, commercial and institutional water demand represents self-supplied or purchased (i.e., delivered by public system) water by industrial, commercial, and other nonresidential establishments. The industrial sub-sector includes water used for "industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining," and the commercial sub-sector includes water used for "motels, hotels, restaurants, office buildings, other commercial facilities, and institutions" (Avery, 1999).

This chapter focuses on self-supplied water withdrawals by industrial, commercial (and institutional) establishments within the 11-county study area in Northeastern Illinois. However, for analytical purposes, the sum of both self-supplied and publicly delivered supplies are considered in order to correlate future water withdrawals in this sector with the projections of the main driver variable – total employment in each of the 11 counties.

Historical Water Withdrawals

Because self-supplied industrial and commercial water withdrawal points (i.e., wells and surface water intakes) are distributed throughout the study area, the geographical areas of analysis are individual counties. County-level self-supplied withdrawals have been compiled and reported by the USGS since 1985. Table 4.1 shows the results of five periodic USGS compilations.

Table 4.1 Historical Industrial and Commercial Water Demand
as Reported by the USGS (In MGD)

County	1985	1990	1995	2000	2005
Boone	1.37	0.07	0.41	0.47	0.57
Cook	316.97	235.55	143.10	95.53	123.73
DeKalb	0.72	0.67	0.78	0.18	2.54
DuPage	5.65	6.43	4.95	5.48	0.96
Grundy	7.14	6.31	6.80	7.07	6.99
Kane	3.18	2.50	2.05	1.57	4.34
Kankakee	0.21	0.17	0.18	0.16	5.09
Kendall	0.83	0.33	0.31	0.29	0.78
Lake	7.33	13.12	16.95	20.61	13.88
McHenry	3.39	4.02	3.92	4.92	6.58
Will	16.01	22.04	15.71	11.96	24.97
Totals.	362.80	291.21	195.16	148.23	190.43

Source: Published by the USGS National Water Use Information Program, various years.
The data are based on the ISWS Illinois Water Information Program. MGD = million gallons per day.

The data in Table 4.1 show some variability of the reported withdrawals at the county level across the data years. The variability of the reported withdrawals can be partially attributed to the method in which the self-supplied withdrawals are inventoried. For example, higher estimates for Cook County in 2005 as compared to 2000 are a result of adding one additional facility with comparatively large withdrawals to the Illinois Water Inventory Program (IWIP) database. One additional facility was also added for DeKalb County. The reduction in DuPage County is a result of one large facility reporting reduced withdrawals. Detailed explanations of USGS methodology for data compilations and quality assurance are available from a USGS document entitled *Narrative for 2005 Water-Use Compilation* (USGS, 2008).

Although the accuracy of the data in Table 4.1 may be limited, the long term trends in total industrial and commercial (I&C) water withdrawals are readily apparent. For the entire 11-county study area in Northeastern Illinois, total self-supplied I&C withdrawals (including mining) have been gradually decreasing during the last two decades from 362.80 mgd in 1985 down to 190.43 mgd in 2005. During the last reporting period for the individual counties, between 2000 and 2005, both increases and decreases of withdrawals are reported. The combined effect of these changes is a net increase in total reported withdrawals although part of this increase is the result of adding new facilities to the data inventory.

Data Preparation

The data on self-supplied I&C withdrawals as well as on water deliveries to I&C establishments by public suppliers were obtained directly from the Illinois Water Inventory Program of the ISWS. County-level estimates of self-supplied commercial and industrial water withdrawals from both surface and groundwater sources were obtained for 1985, 1990, 1995, 2000, and 2005. The data reported by the USGS for 1985, 1990, 1995, and 2000 were used only to confirm the estimates derived by the project team from the ISWS data. However, the provisional USGS data for 2005 were used preferentially over the IWIP data. These data on water withdrawals were matched with public deliveries to I&C establishments in order to obtain total water withdrawals and purchases by I&C sector.

The data on I&C water withdrawals plus public system deliveries for each county were supplemented with data on employment and weather conditions. County-level employment data were obtained from several sources and were used during modeling. The most detailed county-level employment data (at the 2-digit SIC level) were those obtained from County Business Patterns and from the Illinois Department of Employment Security (IDES).

WATER-DEMAND RELATIONSHIPS

Water withdrawals and purchases for industrial and commercial purposes are most often explained in economic terms, where water is treated as a factor of production. Ideally, econometric models of I&C water demand could be developed based on a comparison of the outputs and the price of water and other inputs. Unfortunately, such data are rarely collected at the county level, or are not publicly available because of their proprietary nature. An alternative approach that has been commonly used is to estimate water demand based upon the size and type of products or services produced by the firm. This can be accomplished by using unit-use coefficients. Because the size of the firm is frequently represented by its number of employees, total water demand estimates for the I&C sector are frequently calculated in terms of the quantity of water per employee, for a specified type of business enterprise.

The types of firms can be determined by their Standard Industrial Classification (SIC) code, a system which is now converted into the North American Industry Classification System (NAICS). Several SIC/NAICS categories, especially those in the manufacturing sector, are commonly associated with high-levels of water withdrawals. The ready availability of data on the number of employees by SIC/NAICS categories at the county level has led to the widespread use of sectoral employment as the primary driver variable in I&C water demand studies (Davis, et al., 1987).

The variability of self-supplied I&C water withdrawals per employee for different SIC categories tend to be very high and therefore it is difficult to develop a model at the aggregate level of water-demand data. Table 4.2 compares the reported 2005 self-supplied commercial and industrial withdrawals for the 11 counties in the study area. The last column of Table 4.2 shows the unit withdrawals which are obtained by dividing the self-supplied withdrawals by the reported total employment in self-supplied firms. The unit rates show great variability across the counties. The per-employee withdrawal rates range from 87.1 gallons per employee per day (gped) in DuPage County to 32,420.4 gped in Kankakee County. Because it would be difficult to develop water-demand models which explain such great variability, the combined total self-supplied and purchased I&C water quantities were used as the dependent variable in deriving water-use relationships.

Table 4.2 Estimates of <u>Self Supplied</u> County-Level Industrial and Commercial Water Demand in 2005

County	Self-Supplied Withdrawal (MGD)	Employment in Self-supplied Establishments	Unit Self-Supplied Withdrawals Per Employee (GPED)
Boone	0.57	1,200	475.0
Cook	123.73	22,364	5,532.6
DeKalb	2.54	4,025	631.1
DuPage	0.96	11,024	87.1
Grundy	6.99	656	10,655.5
Kane	4.34	6,329	685.7
Kankakee	5.09	157	32,420.4
Kendall	0.78	5,229	149.2
Lake	13.88	19,495	712.0
McHenry	6.58	8,515	772.8
Will	24.97	13,727	1,819.0
Total/Ave.	190.43	92,721	2,053.8

MGD= million gallons per day, GPED = gallons per employee per day
Source: ISWS IWIP database

Table 4.3 shows the data on per-employee water demand at the county level for combined self-supplied and purchased quantities of I&C water for 2005. It shows that the per-employee rates of total water demand (self-supplied and purchased) show much less variability (ranging from 25 gped to 319 gped) than per-employee rates of self-supplied withdrawals in the subset of self-supplied firms as illustrated in Table 4.2.

Table 4.3 Estimates of Combined Self-Supplied and Purchased Industrial and Commercial County-Level Water Demand in 2005

County	Total County Employ-ment	Self-Supplied Withdrawal (MGD)	Public-supply Deliveries to C&I (MGD)	Total C&I Water Demand (MGD)	Unit Withdrawal Per Employee (GPED)
Boone	17,428	0.57	1.40	1.97	113.0
Cook	2,420,303	123.73	302.60	426.33	176.1
DeKalb	51,069	2.54	0.93	3.47	67.9
DuPage	677,073	0.96	25.05	26.01	38.4
Grundy	21,975	6.99	0.02	7.01	319.0
Kane	237,175	4.34	14.09	18.43	77.7
Kankakee	49,889	5.09	2.19	7.28	145.9
Kendall	42,608	0.78	0.28	1.06	24.9
Lake	357,871	13.88	14.02	27.90	78.0
McHenry	160,222	6.58	4.09	10.67	66.6
Will	319,603	24.97	9.39	34.36	107.5
Total/Avg.	4,355,216	190.43	374.06	564.49	129.6

MGD = million gallons per day, GPED = gallons per employee per day

A log-linear model similar to the public-supply model shown in Equation 3 in Chapter 1 was applied to capture the relationship between average water quantity per employee (for combined self-supplied and delivered water) and explanatory variables.

The independent (i.e., explanatory) variables included two weather variables (cooling degree-days and total precipitation) during the 5-month (May-September) summer season, and several variables representing the structure of employment within each county, which was captured as the percentage fraction of employment in 1-digit SIC categories. These included: manufacturing, manufacturing except food processing, mining, construction, wholesale trade, retail trade, finance/insurance/real estate, transportation, transportation/warehousing & utilities, and food and kindred products. Two of these ten categories were found to be statistically significant.

Also, a variable was included in the data to provide some measure of the allocation of publicly supplied and self-supplied commercial and industrial water demand in each county. This "percent of self-supplied I&C" withdrawal variable was calculated as the quantity of self-supplied I&C withdrawals divided by sum of publicly supplied and self-supplied I&C water.

Two types of binary variables were tested during model development. County binaries were added to the model to account for county specific characteristics that were not accounted for by other variables in the model. Outlier binary variables were added to the model to account for county/year observations that are far outside the expected range of values.

A "conservation trend" variable was included in the model to account for unspecified influences that are assumed to be affecting water demand over time, and represent general trends in water demand. Water demand per employee can be expected to change over time, and the conservation trend variable is intended to capture some of the rate of change in water demand due to gains in efficiency in production processes. The values of the trend variable were specified as zero for 1985, 5 for 1990, 10 for 1995, 15 for 2000, and 20 for the year 2005. The estimated structural regression with key explanatory variables is shown in Table 4.3. A detailed description of the model development procedure and a complete set of estimated coefficients including binary county intercepts and binary spike variables is included in the Annex to this chapter.

Table 4.4 Structural Log-linear Regression Model of Combined Per Employee Commercial and Industrial Water Demand

Term	Estimated Regression Coefficient	t Ratio	Prob. >|t|
Intercept	2.1137	1.84	0.0749
Summer cooling degree-days (ln)	0.3298	2.19	0.0361
Summer precipitation (ln)	-0.0896	-1.16	0.2541
Manufacturing employment (%)	0.0279	9.58	<.0001
Transportation & utilities employment (%)	-0.1077	-6.53	<.0001
Self-supplied I&C use, (%)	0.0032	2.60	0.0139
Conservation trend	-0.0074	-2.37	0.0239

Depended variable = natural logarithm (ln) of gallons per employee per day of total industrial and commercial (withdrawals plus purchases) water use.

The estimated coefficients of logarithmically transformed variables (as indicated by "ln" in Table 4.4) represent constant elasticities of the dependent variables with respect to per-employee water demand. For example, the elasticity of summer precipitation variable of -0.0896 indicates that a 1.0 percent increase in summer precipitation would result in a 0.0896 percent decrease in per-employee water demand. The same but opposite effect would result from a 1.0 percent decrease of summer precipitation. The coefficient of conservation trend variable indicates that per-employee water use is decreasing at the rate of 0.74 percent per year.

FUTURE WATER DEMAND

Future Employment

The main driver of future water demand in the industrial and commercial sector is the future level of production of goods and services as measured by total county employment. The future output of goods and services will also depend on labor productivity, and total future employment should be adjusted for productivity. The long-term growth in labor productivity in Illinois between 1977 and 2000 was 1.3 percent per year as reported by the U.S. Bureau of Labor Services of the U.S. Department of Labor (http://www.clevelandfed.org/Research/commentary/2005/June.pdf). However, no information was available on the projections of future growth in productivity and, for the purpose of this study; a long-term rate in productivity increases was assumed to be 1.0 percent per year. The adjustments for productivity gains were made across all three scenarios. The assumption of 1.0 percent per year makes the estimates of future self-supplied I&C withdrawals conservative. Higher future increases in productivity would be translated into higher physical output per employee, and result in higher withdrawals.

The projections of future employment were provided by CMAP. Table 4.5 shows the historical and projected total employment for each of the 11 counties in the study area. Between 2000 and 2030, total employment is projected to increase by 1,485,302 employees or by 34.3 percent. An additional increase in employment of 996,879 employees is projected for the 2030-2050 period.

Table 4.5 Historical and Projected Employment in the Study Area

County	1990	2000	2030	2050	2000-2050 Change	2000-2050 Change, %
Boone	15,804	20,965	22,737	28,127	7,162	34.2
Cook	2,776,033	2,818,334	3,305,003	3,675,291	856,957	30.4
DeKalb	41,323	49,401	64,447	77,632	28,231	57.1
DuPage	436,136	511,994	830,394	977,696	465,702	91.0
Grundy	15,588	19,985	34,095	50,087	30,102	150.6
Kane	145,205	206,107	352,208	499,298	293,191	142.3
Kankakee	43,905	49,984	74,329	104,169	54,185	108.4
Kendall	21,343	31,290	85,774	150,123	118,833	379.8
Lake	228,606	352,582	463,509	562,842	210,260	59.6
McHenry	97,057	105,118	168,573	175,568	70,450	67.0
Will	174,505	165,556	415,549	512,664	347,108	209.7
NE Illinois	3,995,505	4,331,316	5,816,618	6,813,497	2,482,181	57.3

Source: Projected employment estimates for 2030 were provided by CMAP.
The 2050 values were interpolated from the 2000-2030 employment projections.

Future Values of Explanatory Variables

The future values of weather variables (i.e., cooling degree-days and precipitation) were assumed to be at normal weather conditions. Because the cooling-degree data were available only for the period from 1985 to 2000, that 16-year period was used to approximate normal values. The rainfall data are based on the 1971-2000 observations.

The shares of employment in the two SIC/NAICS categories used in the regression model were determined based on county-level projections for 2004-2014 obtained from the Illinois Department of Employment Security, Economic Information and Analysis Division. Table 4.6 shows the projected growth rates for the two I&C employment categories. They show a decline of manufacturing employment in all counties except Boone, and projected growth of employment in transportation and utilities in all counties except Kane.

Table 4.6 Projected 2004-2014 Employment Growth Rates
for NAICS Categories (Annual Compound Growth Rate – Percent)

County	Manufacturing	Transportation
Boone	0.98	1.39
Cook	-0.79	0.73
DeKalb	-0.83	0.66
DuPage	-0.83	1.01
Grundy	-0.97	-0.63
Kane	-0.66	0.59
Kankakee	-0.94	0.55
Kendall	-0.50	1.82
Lake	-0.61	0.92
McHenry	-0.94	0.59
Will	-0.81	0.40

Source: Illinois Department of Employment Security.
Negative values indicate decline in employment.

Finally, because the percentage fraction of self-supplied I&C water is used as one of the independent variables, the future values of the self-supplied share of water had to be determined. The historical fractions of the self-supplied I&C withdrawals are shown in Table 4.7.

The future values were assumed, after examination of the historical shares of self-supplied withdrawals, by comparing the historical averages for the entire data period (1985-2005) and the most recent period (1995-2005).The future shares of self-supplied withdrawals were set as rounded percentage (to the nearest 5 percent) of total I&C demand (i.e., the sum of both self-supplied water and water delivered by public systems). The assumed shares were reviewed by the ISWS and by Mr. Patrick Mills – the State Coordinator of the National Water Use Information Program (NWUIP) in the USGS Illinois Water Science Center. The final percentage shares shown in the last column of Table 4.7 were considered the best estimates of the future values.

These assumed percentage fractions were also used in calculating self-supplied withdrawals from the future estimates of total I&C water use.

Table 4.7 Historical and Assumed Percentage Fractions of Self-Supplied I&C Water Demand

County	1985	1990	1995	2000	2005	1985-2005 Average	1995-2005 Average	Assumed 2010-2050
Boone	52.9	5.2	31.5	6.8	28.9	25.1	22.4	25.0
Cook	57.1	50.2	29.7	24.6	29.0	38.1	27.8	30.0
DeKalb	29.3	25.7	76.8	51.5	73.2	51.3	67.2	65.0
DuPage	22.8	24.9	23.0	21.9	3.7	19.3	16.2	20.0
Grundy	96.6	99.3	99.3	99.4	99.7	98.9	99.5	99.0
Kane	25.4	12.3	18.2	8.4	23.5	17.6	16.7	20.0
Kankakee	3.1	18.7	2.2	44.2	69.9	27.6	38.8	40.0
Kendall	63.4	36.0	42.2	46.1	73.6	52.3	54.0	55.0
Lake	55.4	23.3	65.3	60.8	49.7	50.9	58.6	50.0
McHenry	64.8	76.6	78.6	66.8	61.7	69.7	69.0	70.0
Will	69.9	90.5	81.2	87.6	72.7	80.4	80.5	80.0

Groundwater vs. Surface Water Withdrawals

The allocation of the future self-supplied I&C demand between groundwater and surface water withdrawals is assumed to remain at the 2005 share for each county. Table 4.8 shows the estimated fractions of surface water and groundwater for each county as reported in 2005.

Table 4.8 Percentage Allocation of I&C Surface Water and Groundwater Withdrawals in 2005

County	Groundwater %	Surface Water, %	Source of Surface Water (where available)
Boone	78.9	21.1	--
Cook	4.5	95.5	Lake Michigan
DeKalb	35.0	65.0	--
DuPage	51.0	49.0	--
Grundy	90.7	9.3	--
Kane	37.8	62.2	Fox River
Kankakee	67.0	33.0	--
Kendall	57.7	42.3	--
Lake	6.8	93.2	Lake Michigan
McHenry	23.4	76.6	--
Will	33.5	66.5	Illinois R. / S&S Canal

Source: USGS Provisional data for 2005. -- = specific information about surface source was not available, however significant quantities of surface water withdrawals in Boone, DeKalb, Grundy, Kankakee and McHenry counties are associated with mining. These withdrawals represent dewatering as well as washing or processing of mined materials.

Water Demand Under Three Scenarios

The three future scenarios define future conditions which would result in different levels of self-supplied commercial and industrial water use. The specific assumptions used in each scenario are described below.

Scenario 1- Current Trends (Baseline Case)

This scenario defines future conditions in terms of recent trends in demand drivers and explanatory variables. The main demand driver is total county employment as projected by CMAP. The assumptions pertaining to the values of explanatory variables and other parameters are described below:

1. Total county employment will follow the 2030 and 2050 projections, developed by CMAP.
2. Fractions of employment in manufacturing and transportation will follow employment growth rates as projected by the Illinois DES until 2050.
3. Self-supplied portion of I&C water demand for each county will remain at the percentage levels observed in 2005 (as shown in the last column in Table 4.7).
4. The proportion of groundwater in total self-supplied I&C withdrawals will remain at the percent fraction as reported for the year 2005.
5. Future conservation will follow the estimated historical trend of annual reduction of approximately 0.7 percent in water use per-employee per year.
6. Summer season cooling degree-days and total precipitation will remain at normal weather values.

Scenario 2 – Less Resource Intensive

This scenario defines conditions which would result in lower self-supplied I&C water withdrawals. Under this scenario, population growth and employment would concentrate more in the most densely urbanized areas of Cook and DuPage Counties, and less employment growth in the collar counties of Kane, Kendall, and McHenry.

The magnitude of the shift in employment was assumed at 30 percent of the CMAP projected growth of employment in Kane, Kendall, and McHenry Counties. The actual shifts of employment growth are shown in Table 4.9.

Table 4.9 Shifts of Employment Growth
for Less Resource Intensive Scenario

County	2030 Shift	Revised 2030 Employment	2050 Shift	Revised 2050 Employment
Cook	+55,002	3,360,005	+98,689	3,771,786
DuPage	+27,503	857,895	+49,344	1,025,943
Kane	-43,830	308,378	-87,957	411,341
Kendall	-19,638	66,136	-38,942	114,473
McHenry	-19,037	149,537	-21,134	154,433

The specific assumptions pertaining to the values of explanatory variables and other parameters are described below:

1. Total county employment will shift from Kane, Kendall, and McHenry Counties (30 percent of employment growth) toward Cook and DuPage Counties.

2. Future employment in manufacturing will follow growth rates as projected by the Illinois DES until 2050. The future share of employment in transportation will remain constant at the 2005 level.

3. Self-supplied portion of I&C water demand for each county will remain at the percentage levels observed in the past (as shown in the last column in Table 4.7).

4. The proportion of groundwater in total self-supplied I&C withdrawals will remain at the percent fraction as reported for the year 2005.

5. The annual rate of future conservation will be 50 percent higher than the estimated historical trend rate.

6. Summer season cooling degree-days and total precipitation will remain at normal weather values.

Scenario 3 – More Resource Intensive

This scenario defines conditions which would result in higher self-supplied I&C water withdrawals. Under this scenario, population growth and employment would concentrate more in the less densely urbanized areas in the collar counties of Kane, Kendall, and McHenry, and less employment growth would occur in Cook and DuPage counties. The magnitude of the shift in employment was assumed at 30 percent of the CMAP projected growth of employment in Cook and DuPage counties. The actual shifts of employment growth are shown in Table 4.10.

Table 4.10 Shifts of Employment Growth
for More Resource Intensive Scenario

County	2030 Shift	Revised 2030 Employment	2050 Shift	Revised 2050 Employment
Cook	-146,000	3,159,002	-257,087	3,418,204
DuPage	-54,121	776,272	-98,312	879,384
Kane	66,707	418,915	118,466	617,763
Kendall	66,707	152,481	118,466	268,588
McHenry	66,707	235,280	118,466	294,033

The specific assumptions pertaining to the values of explanatory variables and other parameters are described below:

1. Total county employment will shift from Cook and DuPage Counties (30 percent of employment growth) toward Kane, Kendall, and McHenry Counties.

2. Employment growth in manufacturing will retain a greater share of total employment than under the Illinois DES projected rates, and transportation will follow employment growth rates as projected by the Illinois DES until 2050.

3. Self-supplied portion of I&C water demand for each county will remain at the assumed percentage levels observed in the past (as shown in the last column in Table 4.7).

4. The proportion of groundwater in total self-supplied I&C withdrawals will remain at the percent fraction as reported for the year 2005.

5. No additional water conservation will be achieved in the future – the historical trend of average annual reduction in per employee use will not continue beyond 2005.

6. Summer season cooling degree-days and total precipitation will remain at normal weather values.

SCENARIO RESULTS

The estimated future water withdrawals under each of the three scenarios for the entire 11-county study area are summarized in Table 4.11.

Under the current trends (or baseline) scenario, self-supplied commercial, industrial (including mining) withdrawals are projected to increase from the weather adjusted value of 162.4 mgd in 2005 to 296.1 mgd in 2050. This represents an increase of 129.3 mgd, or 79.6 percent. The total self supplied withdrawals in 2050 would be 69.5 mgd (24%) lower under the LRI scenario, and 99.8 mgd (34%) higher under the MRI scenario.

In the CT scenario, there is a gradual increase in the rate of per employee water withdrawals (and purchases). This is a result of both the declining share of manufacturing employment and increasing labor productivity, as well as the continuing effects of the conservation trend in the future years.

The conservation trend has a non-linear effect of 0.74 percent reduction of per-employee rates per year with the greatest reductions in per-employee withdrawals (plus purchases) applied during the earlier part of the 2005-2050 period. Without the conservation trend, per-employee rates under the CT scenario would increase over time.

Under the LRI scenario, per-employee rates of water withdrawals would gradually decrease from the normal weather-adjusted value of 109.3 gped in 2005 to 90.6 gped in 2050 (a 17.2% decrease)

Finally under the MRI scenario, per employee rates would increase from 109.3 gped in 2005 to 155.2 gped in 2050 (a 41.9% increase).

Scenario values for total self-supplied industrial and commercial withdrawals as well as withdrawals by supply sources for individual counties are included in Tables A4.2 to A4.4 in the Annex to this chapter.

Table 4.11 I&C Water Demand Scenarios for 11-County Study Area

Year	Total Employment	Use Per Employee GPED	Total I&C Use MGD	Total I&C Self-supplied MGD	Ground-water MGD	Surface Water MGD	Lake Michigan MGD
CT							
2005	4,355,216	130.6	568.7	191.6	30.4	161.2	13.3
2005N	4,355,216	109.3	476.1	162.4	24.5	137.8	10.9
2010	5,000,930	115.8	578.9	200.4	27.4	173.0	11.6
2015	5,189,948	116.4	603.9	209.7	29.3	180.4	12.3
2020	5,388,283	116.9	630.1	219.6	31.4	188.1	13.1
2025	5,596,566	117.5	657.7	229.9	33.7	196.3	13.9
2030	5,816,618	118.1	686.7	240.9	36.1	204.9	14.9
2035	6,045,775	118.6	717.1	252.5	38.8	213.7	15.7
2040	6,288,265	119.1	749.2	264.8	41.6	223.1	16.7
2045	6,543,846	119.6	783.0	277.8	44.8	233.0	17.8
2050	6,813,497	120.1	818.6	291.6	48.3	243.4	18.9
2005-50, Change	2,458,281	10.8	342.4	129.3	23.8	105.5	8.0
2005-50, %	56.4	9.9	71.9	79.6	96.9	76.5	73.9
LRI							
2005	4,355,216	130.6	568.7	191.6	30.4	161.2	13.3
2005N	4,355,216	109.3	476.1	162.4	24.5	137.8	10.9
2010	5,000,930	99.7	498.7	174.8	25.3	149.4	10.0
2015	5,189,948	98.6	511.6	179.8	26.6	153.2	10.5
2020	5,388,283	97.4	525.0	185.1	27.9	157.2	10.9
2025	5,596,566	96.3	538.8	190.6	29.4	161.2	11.4
2030	5,816,618	95.1	553.3	196.3	30.8	165.5	12.0
2035	6,045,775	94.0	568.3	202.3	32.5	169.8	12.4
2040	6,288,265	92.8	583.9	208.6	34.3	174.3	12.9
2045	6,543,846	91.7	600.1	215.2	36.1	179.0	13.5
2050	6,813,497	90.6	617.0	222.1	38.1	183.9	14.1
2005-50, Change	2,458,281	-18.8	140.9	59.7	13.6	46.1	3.2
2005-50, %	56.4	-17.2	29.6	36.8	55.6	33.4	29.6
MRI							
2005	4,355,216	130.6	568.7	191.6	30.4	161.2	13.3
2005N	4,355,216	109.3	476.1	162.4	24.5	137.8	10.9
2010	5,000,930	111.4	557.0	197.2	30.1	167.1	11.4
2015	5,189,948	116.1	602.4	214.3	33.7	180.6	12.6
2020	5,388,283	121.0	651.7	233.1	37.8	195.3	13.9
2025	5,596,566	126.1	705.5	253.7	42.5	211.3	15.4
2030	5,816,618	131.4	764.1	276.4	47.6	228.7	17.1
2035	6,045,775	137.0	828.0	301.2	53.7	247.5	18.8
2040	6,288,265	142.8	897.7	328.5	60.4	268.1	20.7
2045	6,543,846	148.8	973.9	358.4	68.0	290.5	22.9
2050	6,813,497	155.2	1057.3	391.4	76.6	314.8	25.3
2005-50, Change	2,458,281	45.8	581.1	229.1	52.1	177.0	14.4
2005-50, %	56.4	41.9	122.0	141.1	212.6	128.4	133.1

Note: 2005 and 2005N represent actual (reported) water withdrawals and model-derived weather-normalized withdrawals, respectively.

CHAPTER 4 ANNEX

Chapter 4 Annex - Part A

ADDITIONAL TABLES

Table A4.1 Historical Data on I&C Water Demand

County	Year	MGD	GPED	% SS	CDD	Precip.	Manuf.-%	Transp.-%
Boone	1985	2.59	190.9	52.9	675	17.27	43.79	2.34
	1990	1.85	116.8	5.2	791	26.85	32.00	2.06
	1995	1.74	89.6	31.5	994	18.06	31.36	2.31
	2000	1.48	89.7	6.8	690	30.79	33.28	2.20
	2005	1.98	113.4	28.9	1034	12.64	24.91	2.12
Cook	1985	555.20	231.3	57.1	839	15.79	21.64	5.64
	1990	493.70	177.8	50.2	942	24.13	17.20	5.66
	1995	409.05	163.7	29.7	1176	14.18	17.23	6.51
	2000	392.98	139.4	24.6	888	22.50	12.09	4.61
	2005	426.33	176.1	29.0	1210	12.21	10.17	5.01
DeKalb	1985	2.46	75.5	29.3	994	10.81	18.98	2.57
	1990	2.61	63.2	25.7	743	22.76	0.00	0.00
	1995	2.16	49.7	76.8	1051	18.16	19.70	1.85
	2000	3.30	66.8	51.5	692	22.93	14.15	1.48
	2005	3.47	67.9	73.2	1087	12.39	8.32	2.64
DuPage	1985	24.74	65.8	22.8	897	11.97	19.56	5.68
	1990	25.79	59.1	24.9	992	23.72	0.05	0.03
	1995	26.98	55.3	23.0	1221	16.32	17.72	6.75
	2000	30.96	60.5	21.9	1048	23.34	10.69	4.80
	2005	26.01	38.4	3.7	1225	10.88	9.18	4.10
Grundy	1985	7.39	515.4	96.6	702	13.82	14.87	0.00
	1990	6.88	441.5	99.3	842	24.82	0.00	0.00
	1995	6.36	374.6	99.3	1129	15.09	14.28	10.08
	2000	7.01	370.9	99.4	787	24.58	8.15	1.87
	2005	7.01	319.0	99.7	1170	17.46	7.55	3.65
Kane	1985	12.53	91.5	25.4	992	19.13	23.86	2.61
	1990	13.24	91.2	12.3	715	19.96	27.74	3.15
	1995	17.21	91.2	18.2	989	18.76	20.85	2.59
	2000	14.88	72.2	8.4	756	24.01	19.72	1.52
	2005	18.43	77.7	23.5	1167	10.08	13.88	1.78
Kankakee	1985	6.83	172.9	3.1	761	15.62	15.70	3.19
	1990	6.33	144.1	18.7	794	22.52	16.20	3.18
	1995	8.93	181.0	2.2	1142	18.10	14.49	2.45
	2000	7.91	177.8	44.2	942	20.82	14.77	2.32
	2005	7.28	146.0	69.9	1282	14.42	11.34	5.32
Kendall	1985	1.31	75.2	63.4	728	12.39	25.55	0.97
	1990	0.86	40.4	36.0	842	25.18	7.03	1.45
	1995	0.74	30.1	42.2	1037	18.34	11.33	1.77
	2000	0.64	31.7	46.1	680	20.34	13.55	3.73
	2005	1.24	29.1	73.6	1281	9.21	5.10	3.10

County	Year	MGD	GPED	% SS	CDD	Precip.	Manuf.-%	Transp.-%
Lake	1985	13.24	56.3	55.4	698	15.51	21.04	1.83
	1990	13.26	58.0	23.3	626	21.72	23.47	2.90
	1995	33.10	112.3	65.3	935	15.00	23.40	2.97
	2000	35.28	100.1	60.8	642	26.30	14.94	1.48
	2005	27.90	78.0	49.7	1020	10.47	12.88	1.75
McHenry	1985	5.23	69.0	64.8	698	15.51	27.34	1.72
	1990	9.20	94.8	76.6	672	25.94	23.02	1.74
	1995	9.07	74.7	78.6	1045	14.99	18.90	1.91
	2000	7.30	69.5	66.8	756	24.01	26.56	1.17
	2005	10.67	66.6	61.7	1027	12.11	13.23	1.07
Will	1985	22.90	145.0	69.9	702	12.85	11.74	4.05
	1990	24.13	138.3	90.5	842	23.33	11.30	3.68
	1995	21.56	104.1	81.2	1129	15.94	11.11	3.85
	2000	34.50	208.4	87.6	874	25.08	15.46	4.54
	2005	34.36	107.5	72.7	1114	14.65	6.63	3.15

Table A4.2 County-Level I&C Water Demand Scenarios of 11-County Study Area:
Self-Supplied Total Withdrawals (MGD)

County	2005	2005N	2010	2015	2020	2025	2030	2035	2040	2045	2050	2005-2050 Change
CT Scenario												
Boone	0.57	0.40	0.36	0.39	0.41	0.44	0.47	0.50	0.54	0.57	0.61	0.21
Cook	123.16	108.38	141.05	146.28	151.70	157.32	163.15	169.20	175.47	181.98	188.72	80.34
DeKalb	2.53	2.00	1.88	1.99	2.11	2.24	2.37	2.51	2.66	2.82	2.99	1.00
DuPage	0.98	0.42	2.39	2.51	2.64	2.77	2.92	3.07	3.23	3.39	3.57	3.15
Grundy	6.63	5.35	5.78	6.50	7.31	8.18	9.14	10.32	11.55	12.97	14.56	9.20
Kane	4.30	3.46	3.15	3.49	3.86	4.28	4.71	5.24	5.80	6.42	7.10	3.65
Kankakee	5.14	4.34	2.56	2.69	2.82	2.96	3.10	3.27	3.44	3.61	3.79	-0.55
Kendall	0.89	0.63	0.55	0.64	0.75	0.87	1.01	1.18	1.38	1.61	1.87	1.24
Lake	13.61	11.24	12.02	12.78	13.59	14.45	15.48	16.34	17.37	18.47	19.63	8.39
McHenry	6.46	5.30	6.13	6.25	6.37	6.49	6.62	6.75	6.88	7.01	7.15	1.85
Will	25.92	20.85	24.52	26.20	27.99	29.90	31.95	34.13	36.47	38.96	41.63	20.78
LRI Scenario												
Boone	0.57	0.40	0.32	0.33	0.35	0.37	0.38	0.40	0.42	0.44	0.46	0.07
Cook	123.16	108.38	120.28	122.78	125.35	127.98	130.66	133.43	136.27	139.19	142.18	33.80
DeKalb	2.53	2.00	1.63	1.69	1.76	1.82	1.90	1.97	2.05	2.13	2.21	0.21
DuPage	0.98	0.42	2.08	2.17	2.25	2.34	2.44	2.54	2.64	2.75	2.86	2.45
Grundy	6.63	5.35	6.06	6.60	7.19	7.83	8.48	9.28	10.11	11.00	11.98	6.63
Kane	4.30	3.46	2.68	2.82	2.97	3.13	3.30	3.51	3.71	3.94	4.19	0.73
Kankakee	5.14	4.34	2.32	2.50	2.69	2.90	3.12	3.37	3.63	3.91	4.21	-0.14
Kendall	0.89	0.63	0.45	0.50	0.55	0.60	0.67	0.74	0.82	0.92	1.03	0.39
Lake	13.61	11.24	10.42	10.87	11.34	11.84	12.43	12.88	13.44	14.02	14.62	3.38
McHenry	6.46	5.30	5.31	5.31	5.30	5.30	5.30	5.30	5.30	5.29	5.29	0.00
Will	25.92	20.85	23.19	24.24	25.33	26.48	27.67	28.92	30.23	31.59	33.02	12.17
MRI Scenario												
Boone	0.57	0.40	0.36	0.40	0.45	0.50	0.56	0.62	0.70	0.78	0.86	0.47
Cook	123.16	108.38	130.12	139.04	148.59	158.82	169.79	181.53	194.12	207.61	222.07	113.69
DeKalb	2.53	2.00	1.86	2.04	2.25	2.48	2.73	3.01	3.31	3.65	4.02	2.02
DuPage	0.98	0.42	2.32	2.50	2.70	2.91	3.14	3.38	3.65	3.94	4.26	3.84
Grundy	6.63	5.35	6.98	8.16	9.53	11.14	12.94	15.21	17.77	20.76	24.25	18.90
Kane	4.30	3.46	4.43	5.23	6.15	7.18	8.34	9.71	11.24	12.97	14.94	11.48
Kankakee	5.14	4.34	2.66	3.05	3.50	4.01	4.59	5.28	6.05	6.94	7.97	3.62
Kendall	0.89	0.63	0.78	0.95	1.15	1.40	1.68	2.02	2.42	2.89	3.45	2.82
Lake	13.61	11.24	11.88	13.12	14.49	16.00	17.80	19.51	21.54	23.78	26.26	15.02
McHenry	6.46	5.30	9.23	10.39	11.65	13.04	14.57	16.24	18.07	20.08	22.29	16.99
Will	25.92	20.85	26.52	29.43	32.67	36.26	40.25	44.67	49.58	55.03	61.08	40.23

Table A4.3 County-Level I&C Water Demand Scenarios of 11-County Study Area: Self-Supplied Groundwater Withdrawals (MGD)

County	2005	2005N	2010	2015	2020	2025	2030	2035	2040	2045	2050	2005-2050 Change
CT Scenario												
Boone	0.45	0.31	0.29	0.31	0.33	0.35	0.37	0.40	0.42	0.45	0.48	0.17
Cook	5.53	4.87	6.34	6.57	6.82	7.07	7.33	7.60	7.89	8.18	8.48	3.61
DeKalb	0.88	0.70	0.66	0.70	0.74	0.78	0.83	0.88	0.93	0.99	1.05	0.35
DuPage	0.50	0.21	1.22	1.28	1.35	1.42	1.49	1.57	1.65	1.73	1.82	1.61
Grundy	6.01	4.85	5.25	5.90	6.63	7.42	8.29	9.36	10.48	11.76	13.20	8.35
Kane	1.63	1.31	1.19	1.32	1.46	1.62	1.78	1.98	2.19	2.43	2.68	1.38
Kankakee	3.44	2.91	1.71	1.80	1.89	1.99	2.08	2.19	2.30	2.42	2.54	-0.37
Kendall	0.51	0.36	0.32	0.37	0.43	0.50	0.59	0.68	0.80	0.93	1.08	0.72
Lake	0.93	0.77	0.82	0.87	0.93	0.99	1.06	1.12	1.19	1.26	1.34	0.57
McHenry	1.51	1.24	1.43	1.46	1.49	1.52	1.55	1.58	1.61	1.64	1.67	0.43
Will	8.68	6.98	8.21	8.77	9.37	10.01	10.70	11.43	12.21	13.05	13.94	6.96
LRI Scenario												
Boone	0.45	0.31	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.35	0.37	0.05
Cook	5.53	4.87	5.41	5.52	5.63	5.75	5.87	6.00	6.12	6.25	6.39	1.52
DeKalb	0.88	0.70	0.57	0.59	0.62	0.64	0.66	0.69	0.72	0.75	0.77	0.08
DuPage	0.50	0.21	1.06	1.11	1.15	1.20	1.24	1.30	1.35	1.40	1.46	1.25
Grundy	6.01	4.85	5.50	5.99	6.52	7.10	7.69	8.42	9.17	9.98	10.87	6.01
Kane	1.63	1.31	1.01	1.07	1.12	1.18	1.25	1.32	1.40	1.49	1.58	0.28
Kankakee	3.44	2.91	1.56	1.68	1.81	1.94	2.09	2.26	2.43	2.62	2.82	-0.09
Kendall	0.51	0.36	0.26	0.29	0.31	0.35	0.38	0.43	0.47	0.53	0.59	0.23
Lake	0.93	0.77	0.71	0.74	0.78	0.81	0.85	0.88	0.92	0.96	1.00	0.23
McHenry	1.51	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	0.00
Will	8.68	6.98	7.76	8.11	8.48	8.86	9.26	9.68	10.12	10.58	11.05	4.07
MRI Scenario												
Boone	0.45	0.31	0.29	0.32	0.36	0.40	0.44	0.49	0.55	0.61	0.68	0.37
Cook	5.53	4.87	5.85	6.25	6.68	7.14	7.63	8.16	8.72	9.33	9.98	5.11
DeKalb	0.88	0.70	0.65	0.72	0.79	0.87	0.96	1.05	1.16	1.28	1.41	0.71
DuPage	0.50	0.21	1.19	1.28	1.38	1.48	1.60	1.73	1.86	2.01	2.17	1.96
Grundy	6.01	4.85	6.33	7.40	8.65	10.10	11.74	13.79	16.11	18.83	22.00	17.14
Kane	1.63	1.31	1.67	1.98	2.32	2.71	3.15	3.67	4.25	4.90	5.64	4.34
Kankakee	3.44	2.91	1.78	2.04	2.34	2.69	3.07	3.54	4.06	4.65	5.34	2.43
Kendall	0.51	0.36	0.45	0.55	0.67	0.81	0.97	1.16	1.39	1.67	1.99	1.63
Lake	0.93	0.77	0.81	0.90	0.99	1.09	1.22	1.34	1.47	1.63	1.80	1.03
McHenry	1.51	1.24	2.16	2.43	2.73	3.05	3.41	3.80	4.23	4.70	5.22	3.98
Will	8.68	6.98	8.88	9.85	10.94	12.14	13.48	14.96	16.60	18.43	20.45	13.47

Table A4.4 County-Level I&C Water Demand Scenarios of 11-County Study Area: Self-Supplied Surface Water Withdrawals (MGD)

County	2005	2005N	2010	2015	2020	2025	2030	2035	2040	2045	2050	2005-2050 Change
CT Scenario												
Boone	0.12	0.08	0.08	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.13	0.04
Cook	117.62	103.51	134.71	139.70	144.88	150.25	155.82	161.60	167.59	173.80	180.24	76.73
DeKalb	1.64	1.30	1.22	1.29	1.37	1.45	1.54	1.63	1.73	1.83	1.94	0.65
DuPage	0.48	0.20	1.17	1.23	1.29	1.36	1.43	1.50	1.58	1.66	1.75	1.54
Grundy	0.62	0.50	0.54	0.60	0.68	0.76	0.85	0.96	1.07	1.21	1.35	0.86
Kane	2.68	2.15	1.96	2.17	2.40	2.66	2.93	3.26	3.61	3.99	4.42	2.27
Kankakee	1.70	1.43	0.84	0.89	0.93	0.98	1.02	1.08	1.13	1.19	1.25	-0.18
Kendall	0.38	0.27	0.23	0.27	0.32	0.37	0.43	0.50	0.58	0.68	0.79	0.53
Lake	12.68	10.47	11.20	11.91	12.66	13.46	14.42	15.22	16.18	17.20	18.29	7.82
McHenry	4.95	4.06	4.69	4.78	4.88	4.97	5.07	5.17	5.27	5.37	5.47	1.42
Will	17.24	13.87	16.31	17.43	18.62	19.89	21.25	22.71	24.26	25.92	27.69	13.82
LRI Scenario												
Boone	0.12	0.08	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.10	0.01
Cook	117.62	103.51	114.88	117.27	119.72	122.23	124.79	127.44	130.15	132.93	135.79	32.28
DeKalb	1.64	1.30	1.06	1.10	1.14	1.19	1.23	1.28	1.33	1.38	1.44	0.14
DuPage	0.48	0.20	1.02	1.06	1.10	1.15	1.19	1.24	1.29	1.35	1.40	1.20
Grundy	0.62	0.50	0.56	0.61	0.67	0.73	0.79	0.86	0.94	1.02	1.11	0.62
Kane	2.68	2.15	1.67	1.75	1.85	1.95	2.05	2.18	2.31	2.45	2.60	0.45
Kankakee	1.70	1.43	0.77	0.83	0.89	0.96	1.03	1.11	1.20	1.29	1.39	-0.04
Kendall	0.38	0.27	0.19	0.21	0.23	0.25	0.28	0.31	0.35	0.39	0.43	0.17
Lake	12.68	10.47	9.71	10.13	10.57	11.02	11.58	12.00	12.52	13.06	13.62	3.15
McHenry	4.95	4.06	4.07	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.05	0.00
Will	17.24	13.87	15.43	16.12	16.85	17.61	18.41	19.24	20.11	21.01	21.96	8.09
MRI Scenario												
Boone	0.12	0.08	0.08	0.09	0.09	0.11	0.12	0.13	0.15	0.16	0.18	0.10
Cook	117.62	103.51	124.28	132.79	141.91	151.69	162.16	173.38	185.40	198.28	212.09	108.58
DeKalb	1.64	1.30	1.21	1.33	1.46	1.61	1.77	1.95	2.15	2.37	2.61	1.31
DuPage	0.48	0.20	1.14	1.23	1.32	1.42	1.54	1.66	1.79	1.93	2.08	1.88
Grundy	0.62	0.50	0.65	0.76	0.89	1.04	1.20	1.41	1.65	1.93	2.26	1.76
Kane	2.68	2.15	2.76	3.26	3.82	4.47	5.19	6.04	6.99	8.07	9.29	7.14
Kankakee	1.70	1.43	0.88	1.01	1.15	1.32	1.51	1.74	2.00	2.29	2.63	1.20
Kendall	0.38	0.27	0.33	0.40	0.49	0.59	0.71	0.85	1.02	1.22	1.46	1.19
Lake	12.68	10.47	11.07	12.22	13.50	14.90	16.58	18.17	20.06	22.16	24.47	13.99
McHenry	4.95	4.06	7.07	7.96	8.92	9.99	11.16	12.44	13.84	15.38	17.07	13.01
Will	17.24	13.87	17.64	19.58	21.73	24.12	26.77	29.72	32.98	36.61	40.63	26.76

Table A4.5 County-Level I&C Water Demand Scenarios of 11-County Study Area: Total Industrial and Commercial Employment by County

County	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2005-2050 Change
CT											
Boone	17,428	18,380	19,384	20,443	21,559	22,737	23,979	25,289	26,670	28,127	10,700
Cook	2,420,303	2,972,024	3,051,984	3,134,095	3,218,415	3,305,003	3,393,922	3,485,233	3,579,000	3,675,291	1,254,988
DeKalb	51,069	53,502	56,050	58,720	61,517	64,447	67,517	70,733	74,102	77,632	26,563
DuPage	677,073	705,287	734,675	765,288	797,177	830,394	864,997	901,040	938,586	977,696	300,623
Grundy	21,975	23,445	25,778	28,344	31,166	34,095	37,679	41,429	45,553	50,087	28,112
Kane	237,175	250,921	273,457	298,018	324,784	352,208	385,746	420,391	458,149	499,298	262,123
Kankakee	49,889	53,337	57,992	63,053	68,556	74,329	81,044	88,117	95,808	104,169	54,280
Kendall	42,608	49,008	56,369	64,835	74,573	85,774	98,657	113,475	130,519	150,123	107,515
Lake	357,871	376,338	395,757	416,179	437,654	463,509	483,987	508,961	535,224	562,842	204,971
McHenry	160,222	161,859	163,512	165,182	166,869	168,573	170,296	172,035	173,793	175,568	15,346
Will	319,603	336,832	354,990	374,126	394,295	415,549	437,951	461,560	486,442	512,664	193,061
Total	4,355,216	5,000,930	5,189,948	5,388,283	5,596,566	5,816,618	6,045,775	6,288,265	6,543,846	6,813,497	2,458,281
LRI											
Boone	17,428	18,380	19,384	20,443	21,559	22,737	23,979	25,289	26,670	28,127	10,700
Cook	2,420,303	2,975,654	3,060,873	3,148,767	3,239,452	3,332,761	3,429,705	3,529,549	3,632,743	3,739,454	1,319,151
DeKalb	51,069	53,502	56,050	58,720	61,517	64,447	67,517	70,733	74,102	77,632	26,563
DuPage	677,073	708,917	743,564	779,960	818,214	858,152	900,779	945,357	992,329	1,041,860	364,787
Grundy	21,975	23,445	25,778	28,344	31,166	34,095	37,679	41,429	45,553	50,087	28,112
Kane	237,175	246,339	261,363	277,737	295,581	313,864	336,222	359,319	384,491	411,924	174,749
Kankakee	49,889	53,337	57,992	63,053	68,556	74,329	81,044	88,117	95,808	104,169	54,280
Kendall	42,608	46,874	51,782	57,426	63,918	71,385	79,974	89,853	101,215	114,285	71,677
Lake	357,871	376,338	395,757	416,179	437,654	463,509	483,987	508,961	535,224	562,842	204,971
McHenry	160,222	161,313	162,415	163,529	164,654	165,789	166,938	168,098	169,269	170,453	10,231
Will	319,603	336,832	354,990	374,126	394,295	415,549	437,951	461,560	486,442	512,664	193,061
Total	4,355,216	5,000,930	5,189,948	5,388,283	5,596,566	5,816,618	6,045,775	6,288,265	6,543,846	6,813,497	2,458,281
MRI											
Boone	17,428	18,380	19,384	20,443	21,559	22,737	23,979	25,289	26,670	28,127	10,700
Cook	2,420,303	2,788,117	2,841,424	2,896,164	2,952,378	3,010,103	3,069,383	3,130,256	3,192,768	3,256,961	836,658
DeKalb	51,069	53,502	56,050	58,720	61,517	64,447	67,517	70,733	74,102	77,632	26,563
DuPage	677,073	695,882	715,475	735,883	757,143	779,287	802,356	826,385	851,415	877,489	200,415
Grundy	21,975	23,445	25,778	28,344	31,166	34,095	37,679	41,429	45,553	50,087	28,112
Kane	237,175	347,576	388,338	431,686	477,820	525,211	579,336	635,208	694,851	758,566	521,391
Kankakee	49,889	53,337	57,992	63,053	68,556	74,329	81,044	88,117	95,808	104,169	54,280
Kendall	42,608	68,339	79,345	91,569	105,180	120,375	137,375	156,439	177,860	201,977	159,369
Lake	357,871	376,338	395,757	416,179	437,654	463,509	483,987	508,961	535,224	562,842	204,971
McHenry	160,222	239,183	255,416	272,116	289,298	306,976	325,168	343,888	363,154	382,983	222,761
Will	319,603	336,832	354,990	374,126	394,295	415,549	437,951	461,560	486,442	512,664	193,061
Total	4,355,216	5,000,930	5,189,948	5,388,283	5,596,566	5,816,618	6,045,775	6,288,265	6,543,846	6,813,497	2,458,281

Table A4.6 County-Level I&C Water Demand Scenarios of 11-County Study Area: Combined Purchased and Self-Supplied Per Employee Water Use (GPED)

County	2005	2005N	2010	2015	2020	2025	2030	2035	2040	2045	2050	2005-2050 Change
CT Scenario												
Boone	97.0	78.6	75.6	72.7	69.9	67.2	64.7	62.2	59.9	57.6	55.4	-23.2
Cook	177.4	154.4	150.5	144.6	139.0	133.5	128.3	123.3	118.5	113.8	109.4	-45.0
DeKalb	63.5	53.4	51.4	49.5	47.6	45.8	44.1	42.5	40.9	39.4	37.9	-15.5
DuPage	39.8	16.7	16.1	15.5	14.8	14.3	13.7	13.2	12.6	12.1	11.7	-5.0
Grundy	332.0	244.3	237.1	230.7	224.5	217.4	211.2	205.3	198.8	193.1	187.6	-56.7
Kane	78.0	62.0	59.8	57.8	55.8	54.0	52.1	50.4	48.7	47.0	45.5	-16.6
Kankakee	143.9	124.5	119.9	115.9	111.9	108.1	104.4	100.9	97.5	94.1	90.9	-33.6
Kendall	25.5	20.1	19.4	18.7	18.0	17.4	16.8	16.2	15.6	15.0	14.5	-5.6
Lake	77.3	63.2	60.8	58.5	56.3	54.1	52.1	50.1	48.2	46.3	44.6	-18.6
McHenry	66.2	53.6	51.5	49.4	47.4	45.5	43.7	42.0	40.3	38.7	37.2	-16.4
Will	109.7	89.7	86.6	83.5	80.5	77.7	74.9	72.3	69.7	67.2	64.9	-24.9
LRI Scenario												
Boone	97.0	78.6	69.0	65.3	61.7	58.4	55.2	52.2	49.4	46.7	44.2	-34.4
Cook	177.4	154.4	134.7	127.2	120.1	113.4	107.1	101.1	95.5	90.2	85.1	-69.3
DeKalb	63.5	53.4	46.8	44.1	41.7	39.3	37.1	35.0	33.0	31.2	29.4	-24.0
DuPage	39.8	16.7	14.7	13.9	13.1	12.3	11.6	11.0	10.4	9.8	9.2	-7.4
Grundy	332.0	244.3	261.3	246.2	232.0	218.6	206.0	194.0	182.8	172.3	162.3	-82.0
Kane	78.0	62.0	54.4	51.3	48.4	45.7	43.1	40.7	38.4	36.2	34.1	-27.9
Kankakee	143.9	124.5	108.9	102.6	96.7	91.2	85.9	81.0	76.3	72.0	67.8	-56.7
Kendall	25.5	20.1	17.6	16.6	15.6	14.7	13.9	13.1	12.3	11.6	11.0	-9.2
Lake	77.3	63.2	55.4	52.3	49.4	46.6	44.0	41.5	39.2	37.0	34.9	-28.3
McHenry	66.2	53.6	47.0	44.4	41.9	39.6	37.4	35.4	33.4	31.5	29.8	-23.8
Will	109.7	89.7	86.1	81.2	76.6	72.3	68.2	64.4	60.7	57.3	54.1	-35.7
MRI Scenario												
Boone	97.0	78.6	79.0	79.4	79.9	80.3	80.8	81.2	81.7	82.2	82.6	4.0
Cook	177.4	154.4	155.6	155.2	154.8	154.5	154.1	153.7	153.4	153.0	152.7	-1.8
DeKalb	63.5	53.4	53.4	53.4	53.4	53.4	53.4	53.4	53.4	53.4	53.5	0.1
DuPage	39.8	16.7	16.7	16.7	16.6	16.5	16.5	16.4	16.4	16.3	16.3	-0.4
Grundy	332.0	244.3	300.9	304.2	307.6	311.0	314.3	317.9	321.4	324.9	328.5	84.3
Kane	78.0	62.0	63.7	64.1	64.4	64.8	65.0	65.3	65.6	65.9	66.1	4.1
Kankakee	143.9	124.5	124.6	125.1	125.6	126.0	126.5	127.0	127.4	127.9	128.4	3.8
Kendall	25.5	20.1	20.7	20.7	20.8	20.8	20.8	20.8	20.8	20.8	20.9	0.7
Lake	77.3	63.2	63.1	63.1	63.0	63.0	62.9	62.9	62.8	62.7	62.7	-0.5
McHenry	66.2	53.6	55.2	55.3	55.4	55.5	55.6	55.6	55.7	55.8	55.8	2.3
Will	109.7	89.7	98.4	98.6	98.8	99.0	99.2	99.4	99.6	99.8	100.0	10.3

Chapter 4 Annex – Part B

MODEL DEVELOPMENT PROCEDURES

The development of the water use equation for preparing future water withdrawals represented a significant challenge because of the aggregate nature of the data and the limited number of observations on historical water withdrawals. The total number of available cross-sectional and time series observations was 55 (i.e., 11 study areas representing counties times 5 time periods). The procedure for estimating the predictive water-use equation was similar to the procedure used in the public-supply sector (as described in Chapter 2 Annex). It consisted of three steps: (1) derivation of a "structural model", (2) compensating for fixed effects of study sites, and (3) examination of outliers on the estimated model coefficients. Each of these steps is described and illustrated with tables and figures below.

Structural Model

A preliminary analysis of the data revealed that total county employment in the study area explains 83 percent of the variability in the total county-level industrial and commercial water withdrawals (and purchases from public systems). Therefore, total county employment was used to express the dependent variable as average industrial and commercial water withdrawals (and purchases) per employee per day for each county (i.e., study area) and data year. If the per employee rate of water withdrawals in each study area can be predicted with sufficient accuracy, then total withdrawals (and purchases) can be obtained by multiplying the per employee use by total county employment, where the latter represents a driver of industrial and commercial demands. An important advantage of modeling the per employee use is that by expressing total withdrawals in per employee terms, the dependent variable is "normalized" across study sites and the heterogeneity associated with total withdrawals is reduced.

The first step of model development was to identify the relevant explanatory variables, which would explain the variability of per employee withdrawals across the 11 counties and the 5 time periods. These variables were selected based on information from previous studies of water use. Several combinations of explanatory variables were examined prior to selecting the best "structural" model which explained the variability of historical water quantities in the data in terms of known determinants of industrial and commercial water demand.

Table A4.7 shows the estimated log-liner regression equation of the structural model. The equation includes six relevant explanatory variables. The expected signs (positive or negative) and magnitudes of the regression coefficients in the structural model are based on economic theory and on the underlying physical relationships as well as on the results of the previous studies of industrial and commercial demand. The expected signs are positive for temperature (as measured by cooling degree-days) and negative for precipitation and for time/conservation trend. However, the prior knowledge about the sign and magnitude of the coefficients of the two variables which capture the shares of employment in manufacturing and transportation and the variable representing the share of self-supplied use is limited.

Table A4.7 Structural Log-Linear Model of Per Employee Water Demand in Industrial and Commercial Sector (ln GPED)

Variables	Estimated Coefficient	t Ratio	Probability >|t|
Structural Model			
Intercept	1.3853	0.29	0.7730
Summer cooling degree-days (ln)	0.2073	0.33	0.7415
Summer precipitation (ln)	0.4187	1.28	0.2073
Manufacturing employment (%)	0.0040	0.35	0.7257
Transportation & utilities employment (%)	0.0787	1.60	0.1162
Self-supplied I&C use, (%)	0.0100	3.35	0.0016
Conservation trend	-0.0154	-1.10	0.2761
N=55, R^2=0.262, Mean Y=4.616; Root MSE=0.607			

The results in Table A4.7 show that only two of the six regression coefficients are statistically significant at approximately 10 percent level. Also, the coefficient of the precipitation variable is positive, which is opposite to the expected sign.

The low significance of the four variables and the inconsistent sign of cooling degree-days coefficient are likely a result of the small data sets (n = 55) and possible data errors in some of the observations on the dependent and independent variables. To address this problem, alternative model specification had to be considered and each data point needed to be examined in some detail.

Model with Fixed Effects of Study Sites

The next step in model development was to extend the structural model from Table A4.7 by including the binary variables designating individual counties. A regression of the key structural variables along with the county binary variables to compete for a significant share of the remaining model variance was estimated. This was accomplished by using a stepwise regression procedure through which binary variables are added to the structural model to account for each county. The binary county variables with statistically significant regression coefficients were kept in the model. This extended, fully-specified model is presented in Table A4.8 below. In addition to the six structural model variables, it includes six binary variables which designate individual counties. All six binary variables have regression coefficients which are statistically significant. These coefficients can be considered as representing county specific “intercept adjustors” because they increase or decrease the main intercept of the regression equation.

Table A4.8 Re-estimated Log-Linear Model of Per Employee Water Demand With Study Site Binaries (ln GPED)

Variables	Estimated Coefficient	t Ratio	Probability >|t|
Structural model			
Intercept	4.2262	2.52	0.0156
Summer cooling degree-days (ln)	-0.0260	-0.12	0.9060
Summer precipitation (ln)	-0.0415	-0.36	0.7234
Manufacturing employment (%)	0.0253	5.69	<.0001
Transportation & util. employment (%)	-0.0567	-2.79	0.0078
Self-supplied I&C use, (%)	0.0021	1.28	0.2060
Conservation trend	-0.0017	-0.34	0.7366
County intercepts			
Cook	1.0882	9.05	<.0001
Grundy	1.8164	11.3	<.0001
Kankakee	0.9477	8.83	<.0001
Kendall	-0.5664	-5.09	<.0001
McHenry	-0.2215	-1.82	0.0754
Will	0.7635	5.44	<.0001
N=55, R^2=0.922, Mean Y=4.616; Root MSE=0.211;			

The structural part of the model in Table A4.8 still shows a lack of statistical significance of regression coefficients for four of the six variables. Also, five out of six coefficients have the expected sign. The coefficients of summer cooling degree-days variable is insignificant and has the wrong sign.

One concern regarding the data was that the year 2005 was a drought year (with a moderate drought in terms of precipitation deficits) and that its inclusion in the data could bias the estimated regression coefficients of the structural variables. In order to determine if this was the case, a time period binary variable which designates the year 2005 was added to the extended model (from Table A4.8). However, its regression coefficient was found to be insignificant. Because of the lack of statistical significance of the four regression coefficients the next step in model building was undertaken.

Effects of Outliers on Model Coefficients

The model shown in Table A4.8 was examined for the effects of possible outliers on the magnitudes and statistical significance of the estimated coefficients. The procedure which was used to examine the effects of outliers on the estimated model without removing any suspected observation from the data is described in Chapter 2 Annex.

Using the above procedure, the effects of outliers on the coefficients of the model in Table A4.8 are analyzed and are presented in Table A4.9 and are graphed in Figures A4.1 to A4.6. For some variables these effects appear to be minor. Significant shifts on the regression coefficients were obtained only for the two weather variables: cooling degree-days and precipitation.

Table A4.9 Effects of Adding Binary Study Area and Spike Dummies on Estimated Regression Coefficients of the Structural I&C Model.

Step	Model specification/ Outliers	Inter-cept	CDD	Precipi-tation	Manuf. Empl. %	Trans. Empl. %	Self-Supp. %	Conser-vation Trend
0	Structural model only	1.385	0.207	0.419	0.004	0.079	0.010	-0.015
1	W/ 6 study site effects	4.226	-0.026	-0.042	0.025	-0.057	0.002	-0.002
	Binary Spike Variables:							
2	DeKalb-1995	2.846	0.147	0.022	0.027	-0.065	0.004	-0.004
3	Lake-1985	3.442	0.079	-0.013	0.026	-0.065	0.005	-0.006
4	Will-2000	3.668	0.072	-0.060	0.025	-0.068	0.005	-0.007
5	Grundy-1995	3.574	0.099	-0.065	0.025	-0.098	0.005	-0.007
6	Kendall-1995	3.046	0.168	-0.040	0.025	-0.102	0.005	-0.007
7	Boone-1995	2.474	0.242	-0.021	0.027	-0.108	0.005	-0.007
8	McHenry-1990	2.418	0.261	-0.043	0.028	-0.111	0.005	-0.007
9	Lake-2000	1.893	0.344	-0.056	0.029	-0.112	0.004	-0.008
10	*DuPage-2005*	*2.114*	*0.330*	*-0.090*	*0.028*	*-0.108*	*0.003*	*-0.007*
11	DeKalb-1985	2.038	0.359	-0.119	0.028	-0.109	0.003	-0.009
12	Lake-1990	2.835	0.248	-0.131	0.027	-0.103	0.003	-0.008
13	Will-1995	2.159	0.338	-0.110	0.028	-0.106	0.003	-0.009
14	Kendall-2005	1.889	0.388	-0.133	0.028	-0.107	0.003	-0.009

Note: Coefficients of the selected model are shown in Italic

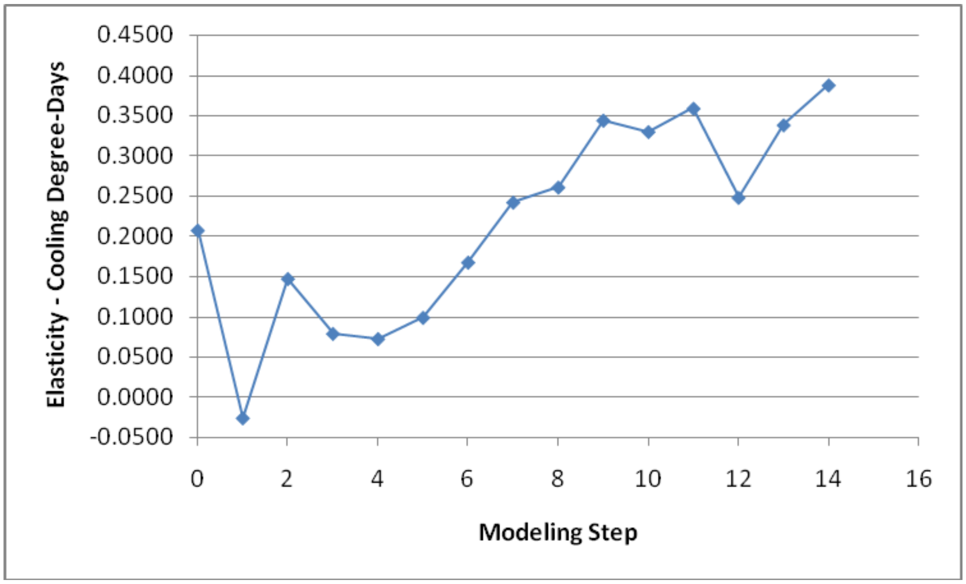

Figure A4.1 Effects of Binary Site Variables and Spike Dummies on Estimated Elasticity of Cooling Degree-Days

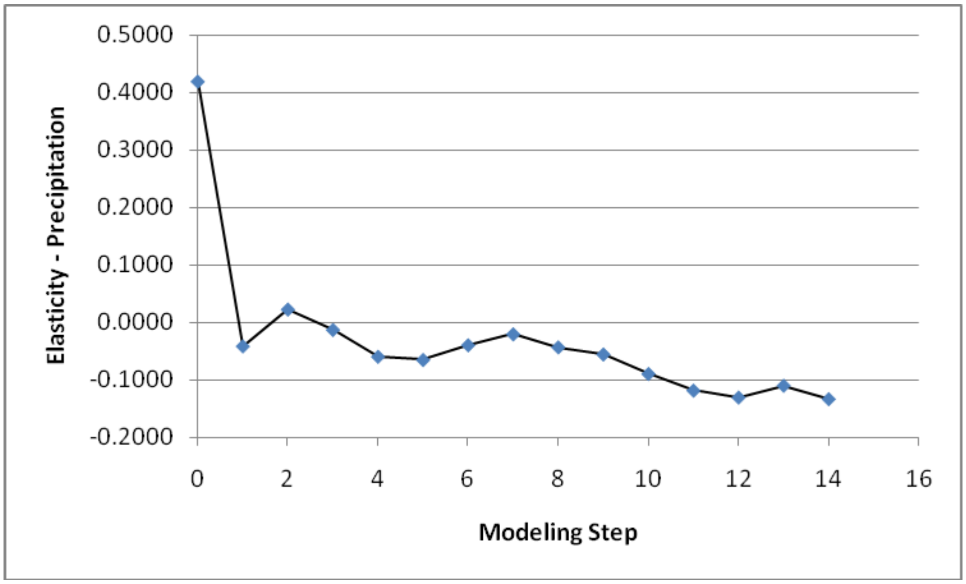

Figure A4.2. Effects of Binary Site Variables and Spike Dummies on Estimated Elasticity of Precipitation

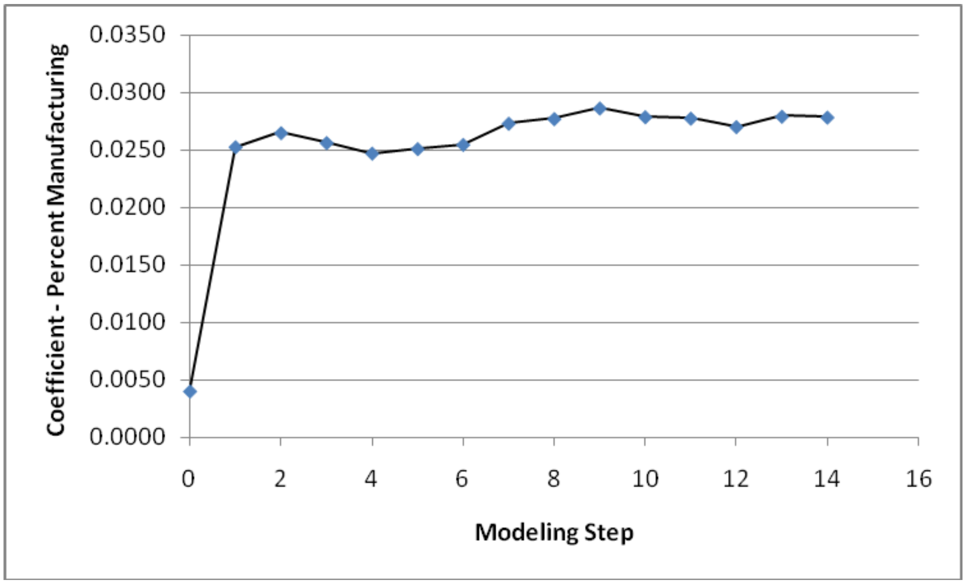

Figure A4.3 Effects of Binary Site Variables and Spike Dummies
on Estimated Coefficient of Percent Employment in Manufacturing

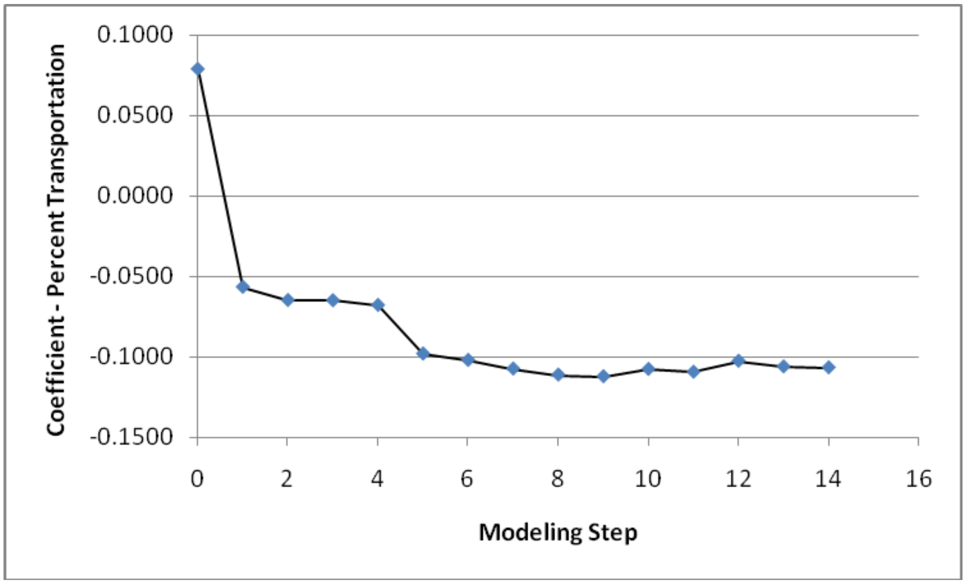

Figure A4.4 Effects of Binary Site Variables and Spike Dummies
on Estimated Coefficient of Employment in Transportation and Utilities

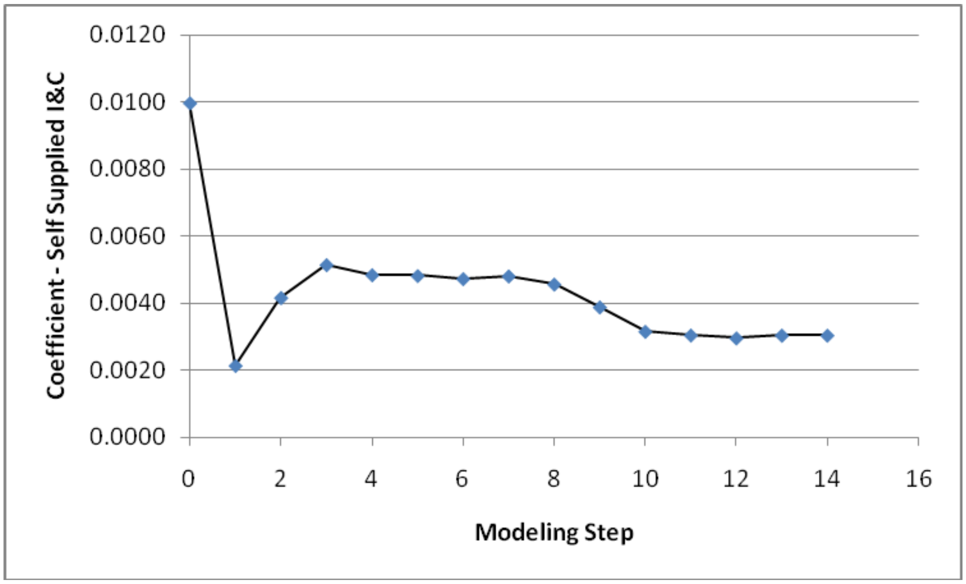

Figure A4.5 Effects of Binary Site Variables and Spike Dummies on Estimated Coefficient of Percent Self-Supplied I&C Water Use

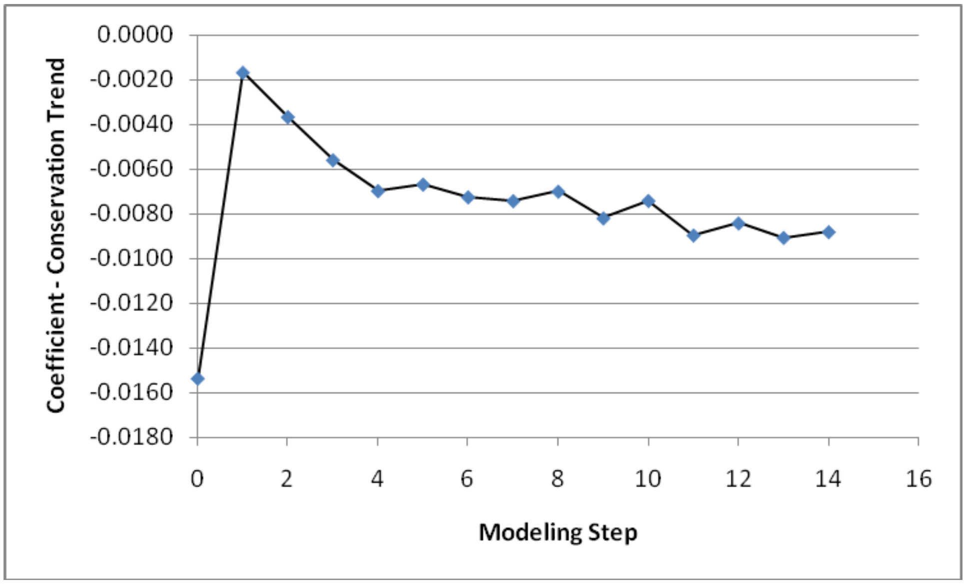

Figure A2.6 Effects of Binary Site Variables and Spike Dummies on Estimated Coefficient of Conservation Trend Variable

Final Regression Model

After examining the effects of model outliers on the estimated regression coefficients of the structural model, nine binary outlier variables were added to the model from Table A4.7, thus removing their effects on the estimated coefficients of the structural model. The re-estimated regression equation with the nine outlier variables is shown in Table A4.10 below.

Table A4.10 Final Log-Linear Model of Per Employee Water Demand in Industrial and Commercial Sector (ln GPED)

Variables	Estimated Coefficient	t Ratio	Probability >|t|
Structural model			
Intercept	2.1137	1.84	0.0749
Summer cooling degree-days (ln)	0.3298	2.19	0.0361
Summer precipitation (ln)	-0.0896	-1.16	0.2541
Manufacturing employment (%)	0.0279	9.58	<.0001
Transportation & util. employment (%)	-0.1077	-6.53	<.0001
Self-supplied I&C use, (%)	0.0032	2.60	0.0139
Conservation trend	-0.0074	-2.37	0.0239
County intercepts			
Cook	1.1371	14.4	<.0001
Grundy	1.6271	14.1	<.0001
Kankakee	0.9136	13.95	<.0001
Kendall	-0.5818	-7.54	<.0001
McHenry	-0.4218	-4.97	<.0001
Will	0.6189	6.42	<.0001
Spike Binaries			
Boone-1995	-0.2861	-2.09	0.0448
DeKalb-1995	-0.7610	-5.23	<.0001
DuPage-2005	-0.2741	-1.91	0.0644
Kendall-1995	-0.3424	-2.35	0.0249
Lake-1985	-0.5619	-4.09	0.0003
Lake-2000	0.3152	2.17	0.0373
McHenry-1990	0.3451	2.36	0.0245
Will-2000	0.5542	3.77	0.0006
Grundy-1995	0.5580	2.92	0.0062

N=55, R^2=0.978, Mean Y=4.616; Root MSE=0.125; MAPE= 7.5%,
Model specification tests(statistic and significance): Ramsey power 2 = 0.3485 (0.5591), Ramsey power 3 = 0.9534(0.3965), Ramsey power 4 = 0.9460 (0.4308)
Heteroscedasticity tests (statistic and significance):
White's test = 55.0 (0.4365), Breusch-Pagan test =15.77 (0.7825)

The results in Table A4.10 show that the significance of the regression coefficients has increased to the 10 percent level for all variables with the exception of precipitation. Also, the magnitudes of all six regression coefficients are within the expected levels. Model diagnostics tests shown at the bottom of the table indicate that the model is free from specification error and heteroscedasticity (i.e., non-constant error problems).

In-Sample Prediction Errors

The accuracy of the predictive models shown in Table A4.6 was evaluated by the mean absolute percentage error (MAPE) by using the regression equation to estimate the historical values of water use in the data.

The criterion of the MAPE error of less than 10 percent was used in selecting the final regression model. The value of 10 percent ensures that the absolute percentage error for individual predictions is not excessive (i.e., generally not exceeding 20 to 30 percent for some of the individual observations).

The regression model from Table A4.10 has the MAPE value for in-sample predictions of 7.5 percent. The actual and predicted values of per capita water use in the data and the absolute percentage errors are shown in Table A4.11 below.

Table A4.11 Actual and Predicted Values of Per Employee Water Use in Historical Data

County Name	Year	Actual GPED	Predicted GPED	Difference	Error (%)
Boone	1985	190.9	172.5	-18.3	9.6
Boone	1990	116.8	107.6	-9.2	7.9
Boone	1995	89.6	90.3	0.7	0.8
Boone	2000	89.7	96.8	7.0	7.8
Boone	2005	113.4	98.8	-14.6	12.9
Cook	1985	231.3	223.3	-8.0	3.5
Cook	1990	177.8	185.5	7.7	4.3
Cook	1995	163.7	172.6	8.9	5.5
Cook	2000	139.4	152.3	12.8	9.2
Cook	2005	176.1	158.0	-18.1	10.3
DeKalb	1985	75.5	92.7	17.2	22.7
DeKalb	1990	63.2	58.3	-4.9	7.7
DeKalb	1995	49.7	50.1	0.4	0.8
DeKalb	2000	66.8	72.5	5.7	8.6
DeKalb	2005	68.0	68.8	0.9	1.3
DuPage	1985	65.8	63.3	-2.5	3.8
DuPage	1990	59.1	63.6	4.5	7.7
DuPage	1995	55.3	53.5	-1.8	3.2
DuPage	2000	47.6	48.0	0.4	0.8
DuPage	2005	38.4	38.7	0.3	0.8
Grundy	1985	515.4	598.5	83.1	16.1
Grundy	1990	441.5	387.1	-54.4	12.3
Grundy	1995	374.6	377.6	3.0	0.8
Grundy	2000	370.9	361.2	-9.8	2.6
Grundy	2005	319.1	332.2	13.0	4.1
Kane	1985	91.5	99.2	7.8	8.5

County Name	Year	Actual GPED	Predicted GPED	Difference	Error (%)
Kane	1990	91.2	86.2	-4.9	5.4
Kane	1995	91.2	83.1	-8.1	8.9
Kane	2000	72.2	75.5	3.3	4.6
Kane	2005	77.7	78.6	0.9	1.2
Kankakee	1985	172.9	161.0	-11.9	6.9
Kankakee	1990	144.1	162.2	18.1	12.6
Kankakee	1995	181.0	176.1	-4.9	2.7
Kankakee	2000	177.8	183.4	5.7	3.2
Kankakee	2005	146.0	144.3	-1.7	1.1
Kendall	1985	75.2	73.4	-1.8	2.4
Kendall	1990	40.4	36.2	-4.2	10.4
Kendall	1995	30.1	30.3	0.2	0.8
Kendall	2000	31.7	30.9	-0.8	2.4
Kendall	2005	29.1	35.1	6.1	20.9
Lake	1985	56.3	56.7	0.4	0.8
Lake	1990	58.0	77.3	19.3	33.3
Lake	1995	112.3	99.4	-12.9	11.5
Lake	2000	100.1	100.8	0.8	0.8
Lake	2005	78.0	79.4	1.5	1.9
McHenry	1985	69.0	81.1	12.1	17.5
McHenry	1990	94.8	95.5	0.7	0.8
McHenry	1995	74.7	69.8	-5.0	6.6
McHenry	2000	69.5	74.8	5.3	7.7
McHenry	2005	66.6	58.2	-8.4	12.6
Will	1985	145.0	119.7	-25.3	17.4
Will	1990	138.3	127.3	-11.0	8.0
Will	1995	104.1	132.7	28.6	27.5
Will	2000	208.4	210.0	1.6	0.8
Will	2005	107.5	114.5	7.0	6.5
Average	--	127.9	128.7	--	**7.5**

CHAPTER 5

IRRIGATION, ENVIRONMENTAL AND AGRICULTURAL WATER DEMAND

BACKGROUND

The irrigation and agricultural (IR&AG) sector includes self-supplied withdrawals of water for irrigation of cropland, turfgrass-sod farms, and golf courses, as well as water for livestock and environmental purposes. In the USGS inventories of water demand, the designation of "irrigation" water withdrawals includes "all water artificially applied to farm and horticultural crops as well as self-supplied water withdrawal to irrigate public and private golf courses" (Solley et al., 1998).

Agricultural livestock water demand includes water for animals, feedlots, dairies, fish farms, and other on-farm needs. The categories of livestock water demand include water used to care for all cattle, sheep, goats, hogs, and poultry, including such animal specialties as horses, rabbits, bees, pets, fur-bearing animals in captivity, and fish in captivity (Avery, 1999).

The irrigation and agricultural sector represents a significant component of total water demand, especially in the counties with large proportions of land in agricultural use. Boone, DeKalb, Kankakee, and Kendall Counties all have more than three fourths of county land area in cropland. In the urbanized counties of Cook, DuPage, and Lake, only small fractions of land area are in agricultural use.

HISTORICAL WATER DEMAND

The Illinois Water Inventory Program includes agricultural withdrawals for only large agricultural irrigation systems and urban irrigation landscapes such as parks and golf courses. Therefore, the reported data on water withdrawals are based on the inventory of the total acreage of irrigated area within each county. Similarly, water withdrawals for livestock are based on the reported numbers of livestock by type. A review of the historical data on irrigation and agriculture is presented in the following sections.

Irrigated Land and Reported Withdrawals

The data on irrigated land are collected and reported by the U.S. Department of Agriculture. Table 5.1 shows the data on irrigated land which were reported in the four most recent years of the U.S. Censuses of Agriculture. The reported census data show that in the 11-county area of Northeastern Illinois, a total of 29,543 acres of land were under irrigation in 2002. The largest share of irrigated land, totaling 13,695 acres, was reported for Kankakee County. This is followed by McHenry County, where the reported irrigated land totaled 7,040 acres.

Table 5.1 Irrigated Land (in Acres) in Northeastern Illinois Counties

County	Irrigated Land (Acres)			
	1987	1992	1997	2002
Boone	673	1,017	1,766	1,632
Cook	647	590	412	134
DeKalb	249	--	633	1,022
DuPage	65	48	101	380
Grundy	436	404	66	60
Kane	871	1,848	1,935	2,089
Kankakee	7,822	17,297	13,833	13,695
Kendall	196	491	499	520
Lake	401	365	278	680
McHenry	7,647	9,543	8,058	7,040
Will	3,261	3,715	4,152	2,540
Total	22,268	35,318	31,733	29,792

Sources: http://agcensus.mannlib.cornell.edu; http://www.nass.usda.gov/

The data in Table 5.1 represent irrigation of agricultural land including harvested cropland, pasture and other land. However, according to the census data, in the 11 counties shown in Table 5.1 all irrigated land represents harvested cropland.

The amount of water applied for irrigation is a function of the number of acres of cropland which are irrigated during the growing season. The estimates of historical irrigation water demand are prepared by USGS by interpolating the census data on irrigated acres for the reporting years (i.e., 1985, 1990, 1995, 2000, and 2005) and then by determining irrigation withdrawals based on the rainfall deficit during the growing season. Table 5.2 shows the USGS estimates of irrigation withdrawals for the five reporting years. The years 1995, 2000, and 2005 also include irrigated acreage of golf courses.

Table 5.2 Estimated Irrigation Water Withdrawals 1985 – 2005

County	Irrigation Water Withdrawals				
	1985	1990	1995*	2000*	2005*
Boone	0.10	0.06	0.76	0.25	1.94
Cook	0.00	0.00	0.08	0.02	6.31
DeKalb	0.17	0.00	0.69	0.30	1.60
DuPage	2.46	2.36	1.00	0.46	3.64
Grundy	0.05	0.00	0.35	0.02	0.19
Kane	0.66	0.65	1.67	0.86	3.71
Kankakee	1.73	3.76	11.89	6.19	12.92
Kendall	0.03	0.11	0.44	0.15	0.74
Lake	1.35	1.27	1.58	0.53	3.88
McHenry	1.29	1.13	8.79	2.18	9.24
Will	1.02	0.16	3.33	1.30	4.56
Total 11 counties	8.86	9.50	30.58	12.26	48.73

* Data includes agriculture and golf course irrigation (USGS combines agricultural and golf course irrigation data since 1995). Source: USGS estimates of irrigation withdrawals

The reported irrigation data can be broken down into cropland irrigation and golf course irrigation. Sod farm irrigation is an additional category included separately in this study.

Cropland Irrigation in 2005

According to the USGS data compilation for 2005, the 11 counties of Northeastern Illinois had withdrawn an estimated 30.44 mgd of water for irrigation of cropland (Table 5.3). The largest withdrawals were reported for Kankakee County (12.45 mgd) followed by McHenry County (7.86 mgd). The lowest county-level water withdrawals for cropland irrigation were reported for Cook and Grundy Counties.

Table 5.3 Cropland Areas under Irrigation and Estimated Water Demand in 2005

County	Irrigated Cropland (acres)	Withdrawals and Demand (MGD)		
		Ground-water	Surface Water	Total Withdrawals
Boone	1,632	1.80	0.00	1.80
Cook	134	0.21	0.00	0.21
DeKalb	1,022	0.85	0.35	1.20
DuPage	380	0.41	0.00	0.41
Grundy	60	0.05	0.00	0.05
Kane	2,089	2.47	0.00	2.47
Kankakee	13,695	10.85	1.60	12.45
Kendall	520	0.60	0.00	0.60
Lake	680	0.71	0.00	0.71
McHenry	7,040	7.80	0.06	7.86
Will	2,540	1.81	0.87	2.68
Total	29,792	27.56	2.88	30.44

Source: US Geological Survey, Illinois Water Science Center

Golf Course Irrigation in 2005

Golf courses need a significant amount of water for irrigation. The amount of water applied for golf course irrigation is a function of the number of acres of golf courses which are irrigated during the growing season. According to the USGS data, approximately 12,688 acres of golf course area were irrigated in 2005, using 18.29 mgd surface and ground water (Table 5.4).

Table 5.4 Golf Course Area under Irrigation and Estimated Water Withdrawals in 2005

County	Golf Course Irrigation (Acres)	Water Withdrawals (MGD)		
		Ground-water	Surface Water	Total Withdrawals
Boone	99	0.07	0.07	0.14
Cook	4,177	4.58	1.52	6.10
DeKalb	257	0.2	0.20	0.40
DuPage	2,091	1.62	1.61	3.23
Grundy	121	0.07	0.07	0.14
Kane	802	0.93	0.31	1.24
Kankakee	403	0.24	0.23	0.47
Kendall	99	0.07	0.07	0.14
Lake	2,300	2.38	0.79	3.17
McHenry	995	0.69	0.69	1.38
Will	1,343	1.41	0.47	1.88
Total NE Illinois	12,688	12.26	6.03	18.29

Source: US Geological Survey, Illinois Water Science Center

Turfgrass Sod Irrigation in 2005

Through the process of data verification it was determined that irrigated sod farms were not included in the acreage of harvested cropland. Therefore, for 2005, turfgrass sod acreage was estimated using turfgrass sod irrigation withdrawals in 2005 (Table 5.5) from the IWIP data and independent estimates of irrigated acreage in Kane and McHenry counties provided by the RWSPG (McCann, 2008).

Table 5.5 Turfgrass-sod Under Irrigation Water Use in 2005

County	Reported Water Withdrawals (MGD)	Assumed Irrigated Turfgrass Sod (Acres)
Boone	0.64	470
Cook	0.00	0
DeKalb	0.01	0
DuPage	0	0
Grundy	0.00	0
Kane	0.55	2,000
Kankakee	3.33	3,200
Kendall	3.03	2,700
Lake	0.00	0
McHenry	0.90	3,000
Will	0.40	670
Total	8.86	12,046

Source: IWIP database and independent estimates.

Livestock Water Use

The U.S. Census of Agriculture also collects information on livestock. Table 5.6 shows the estimates of five categories of livestock for the data year 2000, and Table 5.7 shows the historical water withdrawals for livestock which were reported by the USGS.

Table 5.6 Estimated Numbers of Livestock in NE Illinois Study Area in 2000

County	Number of beef cows	Number of dairy cows	Number of hogs	Number of horses	Number of sheep
Boone	9,110	590	13,300	402	400
Cook	(D)	(D)	(D)	1,173	(D)
DeKalb	33,435	2,165	169,100	596	1,800
DuPage	(D)	(D)	(D)	272	(D)
Grundy	3,099	201	10,100	161	400
Kane	10,895	705	55,900	1,602	400
Kankakee	6,656	344	21,000	449	400
Kendall	2,630	170	23,300	452	400
Lake	1,127	73	(D)	1,692	400
McHenry	16,900	5,300	44,330	2,337	400
Will	4,790	310	11,700	1,224	400
Total	88,642	9,858	348,730	10,360	5,000

Source: Data were interpolated based on the 1997 & 2002 Census of Agriculture
D = Numbers withheld due to data disclosure limitations.

Table 5.7: Estimated Water Withdrawals for Livestock 1985 – 2005 (MGD)

County	1985	1990	1995	2000	2005
Boone	0.48	0.44	0.33	0.19	0.27
Cook	0.03	0.07	0.03	0.01	0.01
DeKalb	1.15	1.12	1.01	1.24	1.23
DuPage	0.02	0.03	0.01	0.00	0.01
Grundy	0.15	0.15	0.11	0.09	0.07
Kane	0.69	0.61	0.35	0.40	0.29
Kankakee	0.27	0.28	0.22	0.18	0.16
Kendall	0.31	0.31	0.19	0.14	0.18
Lake	0.12	0.17	0.07	0.04	0.06
McHenry	1.00	0.97	0.82	0.59	0.51
Will	0.37	0.42	0.16	0.13	0.16
Total NE Illinois	4.59	4.57	3.30	3.01	2.95

*Source: USGS National Water Use Information Program, various years.

The historical estimates of irrigated acreage and livestock counts for 2005 were used as the base year values while preparing future water demands for the irrigation and agriculture sector. The relationships between the two demand-driver variables and water withdrawals are described in the following section.

Water Withdrawals for Environmental Purposes

In addition to the irrigation and livestock watering uses of water, a relatively small quantity of water is withdrawn for environmental purposes such as forest and prairie preserves, park districts, game farms, and other uses.

Table 5.8 shows the 2005 reported withdrawals by the users available in the IWIP database. The total reported amount in the 11-county study area was 0.379 mgd.

Table 5.8 Reported Environmental Water Withdrawals

County	*2005 Withdrawals in MGD*
Cook	0.119
DeKalb	0.000
DuPage	0.091
Grundy	0.000
Kane	0.000
Kankakee	0.004
Kendall	0.002
Lake	0.149
McHenry	0.003
Will	0.013
Total	0.379

Although the total withdrawals are small, the historical data show a significant rate of increase in this subsector. The past rates of growth range from 2 to 6 percent per year.

WATER DEMAND RELATIONSHIPS

Estimation of Irrigation Demand

The future demand for irrigation water is determined using the following formula:

$$Q_t = \frac{325{,}851}{12 \cdot 365} A_t \cdot d_t \qquad (5.1)$$

where:

Q_t = annual (seasonal) volume of irrigation water withdrawals in million gallons per day (mgd) in year t;

A_t = irrigated land area in acres in year t;
d_t = depth of water application in inches in year t;
and the conversion factors represent: 325,851 gallons/acre-foot, 12 inches/foot, and 365 days/year.

The total seasonal application depth is determined according the ISWS/USGS method which is based on weekly precipitation records for the growing season from May 1 to August 31. This growing season in irrigation estimates is shorter than the growing season used in the public-supply and industrial-commercial sector because crop irrigation requirements in September are minimal (and can be omitted in the calculations of rainfall deficit).

Rainfall deficit is calculated by accumulating weekly deficits or surpluses over the consecutive weeks of the growing season as follows:

(1) If more than 1.25 inches of rain falls during the first week of the growing season, one-half the amount of rain exceeding 1.25 inches is added to the rain amount during the following week.

(2) If less than 1.25 inches of rain falls during the first week, the difference between the actual rainfall and 1.25 inches is the rainfall deficit that is assumed to be the quantity of water, in inches, applied by irrigation that week.

(3) For each subsequent week during the growing season, one-half of the cumulative rainfall during the previous week in excess of 1.25 inches is added to the rainfall amount for the week.

(4) If the cumulative rainfall amount for a week is less than 1.25 inches, then the difference between the actual rainfall and 1.25 inches is the rainfall deficit that is assumed to be the quantity of water, in inches, applied by irrigation that week.

(5) The rainfall deficits for each week are then added to determine the total irrigation water use during the growing season.

This procedure can be expressed as follows:

If the total rainfall in the first week r_1 is less than 1.25 inches, then

$$d_1 = r_1 - 1.25 \tag{5.2}$$

If the total rainfall in the first week r_1 is greater than 1.25 inches, then

$$\begin{aligned} d_1 &= 0 \\ r_2^e &= r_2 + (r_1 - 1.25)/2 \\ d_2 &= r_2^e - 1.25 \end{aligned} \tag{5.3}$$

where:
r_2^e = effective rainfall in week 2.

In week 2, again, the precipitation deficit will be zero if r_2^e is greater than 1.25 inches, and the one-half of the precipitation surplus will carry to the next week.

The total seasonal rainfall deficit for the 18 weeks (i.e., 4 months) which make up the irrigation season is calculated as:

$$d_t = \sum_{i=1}^{18} d_i \tag{5.4}$$

Table 5.9 shows the values of summer season precipitation deficit which were used to prepare estimates of historical water use (as previously reported in Table 5.2). The values of precipitation deficit represent the total depth of water application in inches during the growing season.

Table 5.9 Actual and Estimated Rainfall Deficits
for 1985 – 2005 Growing Seasons (May – August)

	Precipitation Deficit (inches)				
County	1985	1990	1995	2000	2005
Boone	-4.16	5.34	-9.76	-12.46	-18.36
Cook	-2.77	0.28	-9.96	-9.58	-18.75
DeKalb	-2.14	-5.68	-14.58	-7.28	-21.18
DuPage	-0.88	8.2	0.23	2.12	-11.30
Grundy	-4.73	-1.91	-4.71	-10.11	-16.51
Kane	-0.97	9.39	1.02	-1.72	-15.05
Kankakee	-6.73	2.52	-5.38	-7.88	-13.98
Kendall	*-1.46	*2.90	*-5.25	*-4.96	*-15.06
Lake	-8.56	7.34	-3.90	2.9	*-14.35
McHenry	-1.24	7.74	-12.58	-6.9	-16.28
Will	-0.65	9.30	-3.23	-1.25	-8.01

*Estimated not actual data. Source: Provisional USGS data for 2005.

Precipitation Deficits during Normal Weather Year

The demand for irrigation water during future years will depend on the precipitation deficit during the growing season (May 1 to August 31). For future years, the estimates of irrigation water are based on a “normal” rainfall deficit which depends on the distribution of weekly precipitation during the summer irrigation season of approximately 18 weeks. Table 5.10 shows the estimates of irrigation deficit for two locations in Northeastern Illinois: Cook County (based on four stations with daily precipitation data), and the City of DeKalb (based on DeKalb station data).

Table 5.10 "Normal" Year Precipitation Deficit for Two NE Illinois Locations

Year	Summer Precipitation	Irrigation Deficit	Summer Precipitation	Irrigation Deficit
	Cook County		DeKalb	
1990	22.76	-4.51	--	--
1991	11.94	-11.75	--	--
1992	10.40	-13.90	10.83	-13.89
1993	22.68	-6.88	18.20	-8.45
1994	14.56	-10.90	15.87	-12.35
1995	13.76	-11.14	14.01	-11.99
1996	19.82	-9.41	23.65	-8.14
1997	14.61	-9.41	10.18	-13.32
1998	16.48	-8.61	15.10	-9.93
1999	13.58	-10.70	13.24	-10.43
2000	14.72	-9.72	15.25	-10.41
2001	16.46	-8.80	8.06	-15.23
2002	15.09	-9.66	14.28	-11.23
2003	16.92	-8.88	11.66	-12.63
2004	17.58	-8.03	14.72	-10.16
2005	7.76	-15.99	8.82	-15.84
2006	15.92	-8.66	10.48	-13.25
2007	18.22	-9.80	--	--
Est. Normal Deficit		-9.82		-11.82

The average rainfall deficits included in the last row of Table 5.10 show the deficit of 9.82 inches for Cook County and 11.82 inches for DeKalb. These values are assumed to approximate "normal" weather year deficits for these locations.

Because daily precipitation data for weather stations in all 11 counties were not available, a regression procedure was used to estimate the relationship between total summer precipitation and the rainfall deficit. Table 5.11 shows the estimated relationship between the total summer precipitation during the four summer months and the rainfall deficit.

Table 5.11 Estimated Relationship between Summer Precipitation and Rainfall Deficit

Term	Estimate	t Ratio	Prob.>|t|
Intercept	-19.476	-27.44	<.0001
Summer Precipitation	0.562	11.66	<.0001
Cook Co. (binary)	0.809	2.14	0.0406
N=33, R^2=0.847, Root MSE= 1.040 inches			

The relationship in Table 5.11 was used to estimate the rainfall deficit in the nine remaining counties of the study area. The estimated values are shown in Table 5.12.

Table 5.12 Estimated May-August "Normal" Precipitation Deficit for 12 Weather Stations Used in the Study.

Station No.	Location	County	Normal May-Aug. Precipitation (inches)	Estimated Deficit (inches)
110338	Aurora	Kane	17.02	-9.91
111497	Chicago Botanical Garden	Cook	15.79	-10.60
111577	Chicago Midway	Cook	15.75	-10.62
112223	DeKalb	DeKalb	17.40	-11.82
112736	Elgin	Kane	16.51	-10.20
114530	Joliet Brandon	Will	16.25	-10.34
114603	Kankakee	Kankakee	16.47	-10.22
114837	Lake Villa	Lake	14.16	-11.52
115326	Marengo	McHenry	16.99	-9.93
116616	Park Forest	Cook	16.70	-10.09
117382	Rockford	For Boone	17.14	-9.84
119221	Wheaton	DuPage	16.42	-10.25

Water Demand by Livestock

Livestock water demand in each county is estimated by multiplying the total county population of each type of farm animal by an estimate of the amount of water consumed per animal. The estimated daily demand of water by each animal type for the year 2000, based on the USGS inventory, is shown in Table 5.13.

Table 5.13 Estimated Amount of Unit Water Demand by Animal Type

Animal Type	Estimated Water Demand, Gallons per Day per Animal
Dairy Cows	35.0
Beef Cattle	12.0
Horses and Mules	12.0
Hogs	4.0
Goats	3.0
Sheep	2.0
Turkeys	0.12
Chickens	0.06
Rabbits	0.05
Mink	0.03

Source: Avery, 1999

In estimating the county-level livestock water demand in Illinois, the USGS accounted only for five of the ten animal types listed in Table 5.6: hogs, beef-cattle, dairy cows, horses, and sheep. Therefore, only these five categories of livestock were used in preparing future water demands for livestock.

FUTURE IRRIGATION AND AGRICULTURAL WATER DEMAND

The future acreage of irrigated land is separated into cropland, golf courses, and turfgrass sod farms. The estimates of future water demand in the irrigation and agriculture sector are a function of the future estimates of irrigated area and summer rainfall deficit. The assumptions about the future changes in irrigated acreage are discussed below.

Cropland Irrigation

The future number of irrigated cropland acres can change as a larger or smaller proportion of the available cropland is irrigated. Table 5.14 compares the availability of cropland for future irrigation in the 11 counties of Northeastern Illinois.

The data in Table 5.14 show that in the 11-county region of Northeastern Illinois, 18.6 percent of total land area is in urban use, 48.9 percent is in cropland, and only 0.77 percent is in irrigated cropland. In the highly urbanized counties of Cook and DuPage, only a small percent of area is in cropland. In Cook County, 62.2 percent of total land is in urban use, 3.1 percent is cropland, and irrigated cropland represents only 0.02 percent of total county land area.

Table 5.14 Total Land Area, Urban Area, Cropland and Irrigated Cropland in Northeastern Illinois Counties

County	County Land area (acres)	Urban area (acres)	Urban (percent)	Cropland (acres) 2002	Cropland (percent)	Irrigated. Cropland (acres) 2002	Irrigated Cropland (percent)
Boone	180,013	3,725	2.1	135,203	75.1	1,632	0.91
Cook	605,235	376,624	62.2	18,781	3.1	134	0.02
DeKalb	405,862	10,125	2.5	345,795	85.2	1,022	0.25
DuPage	213,510	99,257	46.5	6,129	2.9	380	0.18
Grundy	268,736	7,016	2.6	200,125	74.5	60	0.02
Kane	333,082	41,260	12.4	184,769	55.5	2,089	0.63
Kankakee	433,120	15,858	3.7	333,821	77.1	13,695	3.16
Kendall	205,171	6,080	3.0	161,129	78.5	520	0.25
Lake	286,438	75,705	26.4	33,476	11.7	680	0.24
McHenry	386,246	28,573	7.4	212,319	55.0	7,040	1.82
Will	535,642	53,795	10.0	253,270	47.3	2,540	0.47
Total	3,853,056	718,018	18.6	1,884,817	48.9	29,792	0.77

Sources: http://www.nass.usda.gov/Census/; http://www.dnr.state.il.us; http://quickfacts.census.gov/

The data in Table 5.14 also indicate that, as of 2002, only 1.6 percent of total cropland was irrigated (i.e., 29,792 acres out of 1,884,817 acres of cropland). The historical estimates of irrigated cropland acres in each county (as reported in Table 5.1) represent only a small percentage of total cropland, and do not show a consistent decreasing trend over time. Therefore, the number of irrigated cropland acres for each county was not considered in terms of diminishing total cropland because of increasing urbanization.

Golf Course Irrigation

Golf courses represent another irrigation sub-sector. Table 5.15 shows that there are 352 golf courses in the study area, as compared to the estimated total of about 750 golf courses in the State of Illinois (Golfwebguide.com).

The existing national golf course inventories show that there were approximately 15,990 golf courses in the U.S. as of the beginning of 2006, up from 12,846 golf courses in 1990 (Chicagolandgolf.com.). However, a recent national inventory of golf courses prepared by National Golf Foundation (NGF) revealed that there was a negative net growth in golf facilities in 2006, with the number of golf courses closed (146) greater than the number of openings (119) (Chicagolandgolf.com). The Chicago area inventory shows that 147 new courses were built between 1990 and 2006 seasons in the Chicago market.

Table 5.15 Number of Golf Courses Built Per Decade in NE Illinois

County	Boone	Cook	De-Kalb	Du-Page	Grun-dy	Kane	Kan-kakee	Ken-dall	Lake	Mc-Henry	Will	Total
1890s	0	7	1	2	0	0	0	0	3	0	0	13
1900s	0	9	0	0	0	3	1	0	0	0	1	14
1910s	1	14	1	2	0	1	1	0	5	1	0	26
1920s	0	28	1	16	0	4	1	1	14	2	6	73
1930s	0	5	1	3	0	4	0	0	1	1	1	16
1940s	0	3	0	0	0	0	0	0	3	0	1	7
1950s	0	2	0	4	0	0	0	0	6	1	2	15
1960s	0	12	3	12	0	2	3	1	11	2	2	48
1970s	0	9	2	5	1	2	2	0	8	2	7	38
1980s	0	4	0	11	0	3	0	0	2	6	6	32
1990s	1	19	0	4	1	6	2	1	13	7	12	66
2000s	0	2	0	0	0	1	0	1	0	0	0	4
Total	2	114	9	59	2	26	10	4	66	22	38	352

Source: http://www.golfguideweb.com/illinois/illinois.html

The future water demand by golf courses is a function of the future estimates of irrigated golf course area and summer rainfall deficit. The average size of the irrigated golf course area is 40 acres (Leonard, 1983). The USGS water use inventories utilize the average irrigated area of 40 acres per golf course. In addition, a study conducted by Golf Course Superintendent Association of America confirmed the average size of irrigated area in golf courses to be approximately 40 acres. Therefore, assuming the average size of an irrigated golf course to be 40 acres, the total future irrigated golf course area is estimated by assuming the number of golf-courses that will be built per decade in each county. An analysis of new golf courses opened in the Chicagoland market from 2003 – 2006 shows that 2-4 new golf courses are being built per year (Table 5.16).

Table 5.16 New Golf Course Opening and Construction in U.S. and Chicagoland Market

Year	United states Total	Chicagoland Market			
		Public	Municipal	Private	Total
1990	-	1	1	2	4
1991	158	0	4	3	7
1992	206	4	4	2	10
1993	229	3	6	4	13
1994	244	6	6	2	14
1995	391	6	5	2	13
1996	267	6	3	1	10
1997	261	9	0	1	10
1998	298	7	2	1	10
1999	295	5	3	2	10
2000	292	9	1	1	11
2001	202	5	6	0	11
2002	138	7	4	1	12
2003	72	3	1	0	4
2004	56	1	1	0	2
2005	-5	2	2	0	4
2006	-62	1	0	1	2
Total		75	49	23	147

Source: Chicago Golf Publishing Co., 2007

Turfgrass Sod Irrigation

Besides the irrigation of cropland, golf courses, turfgrass sod production is an important agricultural sector for irrigation water withdrawals. The turfgrass sod industry has experienced high growth since 1960. In the 1960s, there were about 1,000 turfgrass-sod farms nationwide encompassing 105,000 acres (Adrian et al., 2004). In 1992, according to the national data, there were approximately 2,124 turfgrass-sod farms covering some 386,504 acres in production (Agricultural Census, 2002).

The agricultural censuses for 1987, 1992, and 1997 also showed an increasing trend for sod production in Northeastern Illinois. According to the agricultural Census data, in 1997, four counties in Northeastern Illinois harvested 8,196 acres of sod, as compared to 7,257 acres in 1987, and 6,993 acres in 1992 (Table 5.16). The data for three consecutive censuses show an average annual growth rate of turfgrass-sod acreage in the study area of approximately 1.2 percent.

Table 5.17 Agricultural Census Data on Sod Harvest
in Northeastern Illinois

Counties		Sod Harvested (Acres)		
	2002	1997	1992	1987
Kankakee Total	2,476	2,875	3,014	1,170
Will	D	2,136	1,394	3,095
Kane	D	1,070	670	525
McHenry	747	2,115	1,915	2,467
Total	D	8,196	6,993	7,257

Source: http://agcensus.mannlib.cornell.edu/area_to_county.php

Water Demand under Three Scenarios

The future water demand for agriculture and irrigation can change depending on the future changes in demand drivers as well as assumptions about future gains in water-use efficiency. The following three scenarios are designed to capture future conditions of water demand in this sector. Like other sectors, the three scenarios are: Current Trends, Less Resource Intensive and More Resource Intensive. All three scenarios use normal weather conditions.

Scenario 1- Current Trends (CT)

- This current trends or baseline scenario assumes constant acreage of the irrigated cropland. For the CT scenario, the irrigated cropland is assumed constant. This is because the historical estimates of irrigated acres in each county represent only a small percentage of cropland, and do not show a consistent trend over time. Therefore, the number of irrigated cropland acres for each county was not considered in terms of diminishing total cropland because of increasing urbanization.

- Future demand for golf course irrigation is assumed to be a function of the rate of construction of new golf courses. For the current trend scenario, an increasing acreage of golf course irrigation is assumed at the rate of 20 new golf courses per decade (which is equivalent to the compounded growth rate of 0.63 percent per year).

- The current trends scenario also assumes increasing acreage of turfgrass-sod irrigation. The historical data on sod harvest acreage from 1987 – 1992 shows an increasing trend at the rate of 1.2 percent per year. For the CT scenario, turfgrass-sod farm acreage is assumed to increase by 1.2 percent per year.

- For the CT scenario, the baseline rates of growth in livestock are assumed to be as projected by the USDA Economic Research Service. The livestock growth rates are reduced by one-third between 2015 and 2030, and by one-half between 2030 and 2050.

Scenario 2 – Less Resource Intensive (LRI)

- This scenario assumes decreasing acreage of the irrigated cropland acreage.

- The LRI scenario also assumes an increasing trend for constructing golf courses. This scenario assumes the national level rate of building new golf courses. Therefore, the LRI scenario assumes an increasing acreage of golf course irrigation at the rate of 0.4 percent per year.

- An increasing trend of turfgrass-sod acreage in LRI scenario is assumed. Turfgrass-sod acreage will follow the growth rate of golf course acreage (0.4 percent per year).

- The LRI scenario assumes the state-wide rate of growth in livestock. It also includes a trend in water efficiency of 0.3 percent demand reduction per year.

Scenario 3 – More Resource Intensive (MRI)

- This scenario assumes constant acreage of the irrigated cropland.

- An increasing acreage of golf course irrigation is assumed in the MRI scenario. Following the growth trend of building new golf courses in Northeastern Illinois area (Table 5.15), we assume an increase at the rate of 1.3 percent per year (40 new golf courses per decade), under the MRI scenario. This assumption is close to the national level compound annual growth (1.4 percent) from 1990 – 2006.

- An increasing acreage of turfgrass-sod irrigation is also assumed in the MRI scenario. Following the growth trend golf course acreage in the 11-country area in the MRI scenario, is assumed that turfgrass-sod acreage will increase at the rate of 1.3 percent.

- The state-wide rate of growth in livestock will be followed in the MRI scenario.

SCENARIO RESULTS

The results of the assumptions for each of the three scenarios are summarized in Table 5.18, below. Additional detailed information is included in Tables A4.1 to A4.3 in the Annex to this Chapter.

Under the CT scenario, total withdrawals would increase from 44.6 mgd in 2005 (adjusted for weather conditions) to 55.4 mgd in 2050. Under the LRI scenario, total withdrawals would slightly decline by 0.8 mgd (or 1.8%). Under the MRI scenario, total withdrawals would increase by 16.1 mgd (or 36.1%).

Table 5.18 Scenario Results for Water Withdrawals
in Irrigation and Agricultural Sector

Year	Cropland (MGD)	Golf Course (MGD)	Turfgrass-sod (MGD)	Livestock (MGD)	Environmental (MGD)	Total AG/E&I (MGD)
CT						
2005 (Reported)	31.0	14.6	13.1	2.9	0.4	62.0
2005 (Normal)	22.6	9.7	9.0	2.9	0.4	44.6
2010	22.6	9.9	9.6	3.1	0.5	45.6
2015	22.6	10.0	10.1	3.3	0.6	46.7
2020	22.6	10.2	10.8	3.3	0.7	47.6
2025	22.6	10.4	11.4	3.5	0.8	48.7
2030	22.6	10.5	12.1	3.6	1.0	49.9
2035	22.6	10.7	12.9	3.6	1.2	51.0
2040	22.6	10.9	13.7	3.7	1.5	52.3
2045	22.6	11.1	14.5	3.8	1.8	53.8
2050	22.6	11.2	15.4	3.9	2.2	55.4
2005-50, Change	0.0	1.5	6.4	1.0	1.8	10.8
LRI						
2005 (Reported)	31.0	14.6	13.1	2.9	0.4	62.0
2005 (Normal)	22.6	9.7	9.0	2.9	0.4	44.6
2010	22.2	9.6	9.2	3.1	0.4	44.6
2015	21.9	9.4	9.4	3.3	0.5	44.5
2020	21.6	9.3	9.6	3.3	0.5	44.3
2025	21.3	9.2	9.8	3.5	0.6	44.2
2030	20.9	9.0	9.9	3.6	0.6	44.2
2035	20.6	8.9	10.1	3.6	0.7	43.9
2040	20.3	8.8	10.4	3.7	0.8	43.9
2045	20.0	8.6	10.6	3.8	0.8	43.8
2050	19.7	8.5	10.8	3.9	0.9	43.8
2005-50, Change	-2.9	-1.2	1.8	1.0	0.5	-0.8
MRI						
2005 (Reported)	31.0	14.6	13.1	2.9	0.4	62.0
2005 (Normal)	22.6	9.7	9.0	2.9	0.4	44.6
2010	22.6	10.0	9.6	3.1	0.5	45.9
2015	22.6	10.4	10.2	3.3	0.7	47.2
2020	22.6	10.7	10.9	3.3	0.9	48.4
2025	22.6	11.0	11.7	3.5	1.2	50.0
2030	22.6	11.4	12.4	3.6	1.6	51.7
2035	22.6	11.7	13.3	3.6	2.2	53.3
2040	22.6	12.1	14.1	3.7	2.9	55.4
2045	22.6	12.5	15.1	3.8	3.9	57.9
2050	22.6	12.9	16.1	3.9	5.2	60.7
2005-50, Change	0.0	-3.2	7.1	1.0	4.8	16.1

CHAPTER 5 ANNEX

Table A5.1 Scenario Assumptions for Irrigated Land (Acres)

Year	Cropland (Acres)	Golf Course (Acres)	Turfgrass-sod (Acres)	Total (Acres)
CT Scenario				
2005	29,792	12,689	12,046	54,527
2010	29,792	12,893	12,786	55,472
2015	29,792	13,101	13,572	56,465
2020	29,792	13,312	14,406	57,510
2025	29,792	13,526	15,292	58,610
2030	29,792	13,744	16,231	59,767
2035	29,792	13,965	17,229	60,986
2040	29,792	14,190	18,288	62,270
2045	29,792	14,419	19,412	63,622
2050	29,792	14,651	20,605	65,048
2005-50, Change	0	1,962	8,559	10,521
2005-50, %	0	15.5	71.0	19.3
LRI Scenario				
2005	29,792	12,689	12,046	54,527
2010	29,792	12,689	12,046	54,527
2015	29,792	12,689	12,289	54,770
2020	29,792	12,689	12,537	55,018
2025	29,792	12,689	12,789	55,270
2030	29,792	12,689	13,047	55,528
2035	29,792	12,689	13,310	55,791
2040	29,792	12,689	13,579	56,060
2045	29,792	12,689	13,852	56,333
2050	29,792	12,689	14,132	56,613
2005-50, Change	0	0	2,086	2,086
2005-50, %	0	0	17.3	3.8
MRI Scenario				
2005	29,792	12,689	12,046	54,527
2010	29,792	13,094	12,850	55,735
2015	29,792	13,511	13,707	57,010
2020	29,792	13,942	14,621	58,356
2025	29,792	14,387	15,597	59,776
2030	29,792	14,846	16,637	61,275
2035	29,792	15,320	17,747	62,859
2040	29,792	15,808	18,931	64,531
2045	29,792	16,313	20,194	66,299
2050	29,792	16,833	21,541	68,166
2005-50, Change	0	4,144	9,495	13,639
2005-50, %	0.0	32.7	78.8	25.0

Table A5.2 Estimated Numbers of Livestock Under Three Scenario

Year	Beef Cows	Dairy Cows	Hogs	Horses	Seeps
2005 (Reported)	88,642	9,858	348,730	10,360	5,000
2010	94,789	10,831	369,979	10,360	5,000
2015	101,362	11,900	392,523	10,360	5,000
2020	101,393	11,895	392,420	10,360	5,000
2025	106,038	12,663	408,167	10,360	5,000
2030	110,897	13,481	424,547	10,360	5,000
2035	108,626	13,091	416,039	10,360	5,000
2040	112,370	13,725	428,457	10,360	5,000
2045	116,243	14,389	441,247	10,360	5,000
2050	120,250	15,086	454,418	10,360	5,000
2005-50, %	35.7	53.0	30.3	0.0	0.0

Table A5.3 Total Irrigation Water Withdrawals (MGD) in Northeastern Illinois Counties

Counties	2005 Reported	2005 Normal	2010	2015	2020	2025	2030	2035	2040	2045	2050
CT											
Boone	3.20	1.80	1.84	1.87	1.90	1.94	1.97	2.00	2.04	2.08	2.12
Cook	5.26	3.28	3.36	3.44	3.53	3.63	3.73	3.86	3.99	4.15	4.33
DeKalb	2.69	2.30	2.39	2.47	2.48	2.55	2.61	2.59	2.65	2.71	2.77
DuPage	3.05	1.98	2.03	2.08	2.13	2.20	2.27	2.35	2.44	2.55	2.68
Grundy	0.25	0.23	0.24	0.24	0.25	0.25	0.26	0.26	0.26	0.27	0.27
Kane	6.35	4.27	4.44	4.62	4.78	4.99	5.21	5.44	5.71	6.02	6.37
Kankakee	15.91	13.34	13.51	13.68	13.86	14.05	14.26	14.46	14.69	14.94	15.19
Kendall	3.92	2.59	2.72	2.86	3.00	3.15	3.32	3.48	3.67	3.86	4.07
Lake	3.52	2.74	2.80	2.88	2.96	3.05	3.16	3.28	3.42	3.58	3.77
McHenry	12.99	8.75	8.94	9.14	9.31	9.52	9.74	9.92	10.16	10.41	10.67
Will	4.99	3.53	3.60	3.66	3.72	3.79	3.87	3.94	4.03	4.12	4.23
LRI											
Boone	3.20	1.80	1.80	1.80	1.79	1.79	1.79	1.78	1.78	1.77	1.77
Cook	5.26	3.28	3.25	3.22	3.18	3.16	3.13	3.11	3.09	3.07	3.06
DeKalb	2.69	2.30	2.36	2.43	2.41	2.46	2.50	2.46	2.49	2.53	2.56
DuPage	3.05	1.98	1.96	1.94	1.93	1.92	1.90	1.89	1.89	1.88	1.88
Grundy	0.25	0.23	0.23	0.24	0.23	0.24	0.24	0.23	0.24	0.24	0.24
Kane	6.35	4.27	4.31	4.36	4.38	4.42	4.47	4.49	4.54	4.60	4.66
Kankakee	15.91	13.34	13.24	13.15	13.04	12.95	12.86	12.76	12.68	12.60	12.53
Kendall	3.92	2.59	2.63	2.67	2.71	2.75	2.79	2.83	2.87	2.92	2.97
Lake	3.52	2.74	2.72	2.70	2.68	2.67	2.65	2.64	2.64	2.64	2.64
McHenry	12.99	8.75	8.75	8.75	8.71	8.71	8.71	8.66	8.66	8.66	8.66
Will	4.99	3.53	3.51	3.49	3.47	3.45	3.43	3.40	3.38	3.37	3.35
MRI											
Boone	3.20	1.80	1.84	1.88	1.91	1.95	1.99	2.02	2.07	2.11	2.16
Cook	5.26	3.28	3.42	3.57	3.75	3.95	4.19	4.48	4.83	5.26	5.80
DeKalb	2.69	2.30	2.39	2.48	2.50	2.57	2.65	2.64	2.71	2.79	2.88
DuPage	3.05	1.98	2.06	2.16	2.27	2.40	2.56	2.75	2.99	3.30	3.69
Grundy	0.25	0.23	0.24	0.25	0.25	0.26	0.27	0.27	0.28	0.28	0.29
Kane	6.35	4.27	4.47	4.70	4.94	5.23	5.58	5.97	6.48	7.10	7.88
Kankakee	15.91	13.34	13.52	13.72	13.92	14.14	14.37	14.61	14.88	15.16	15.47
Kendall	3.92	2.59	2.73	2.89	3.04	3.21	3.40	3.58	3.79	4.01	4.25
Lake	3.52	2.74	2.85	2.99	3.14	3.34	3.57	3.86	4.23	4.69	5.29
McHenry	12.99	8.75	8.96	9.19	9.39	9.63	9.88	10.10	10.38	10.68	11.00
Will	4.99	3.53	3.62	3.71	3.80	3.90	4.02	4.14	4.29	4.47	4.67

CHAPTER 6

SENSITIVITY TO CLIMATE CHANGE AND DROUGHT

CLIMATE CHANGE EFFECTS

The estimates of future water withdrawals presented in the previous chapters assume normal weather conditions. Specifically, the values of air temperature and precipitation, which are used as explanatory variables in water-use models, represent long-term averages based on the 30 year record from 1971 to 2000. Because the period of analysis for water demand scenarios extends until the year 2050, the average weather conditions may change in response to regional and global climate change.

Climate models indicate that by 2050, there may be a possible average annual temperature departure of up to +6 °F from the 1971-2000 long-term normal in Illinois. Climate models also indicate a possible departure from 1971-2000 normal annual precipitation in Illinois in a range from -5 inches to +5 inches per year. Figures 6.1 and 6.2 below show the predictions of global climate model scenarios, grouped into three families (A1, A2, and B1).

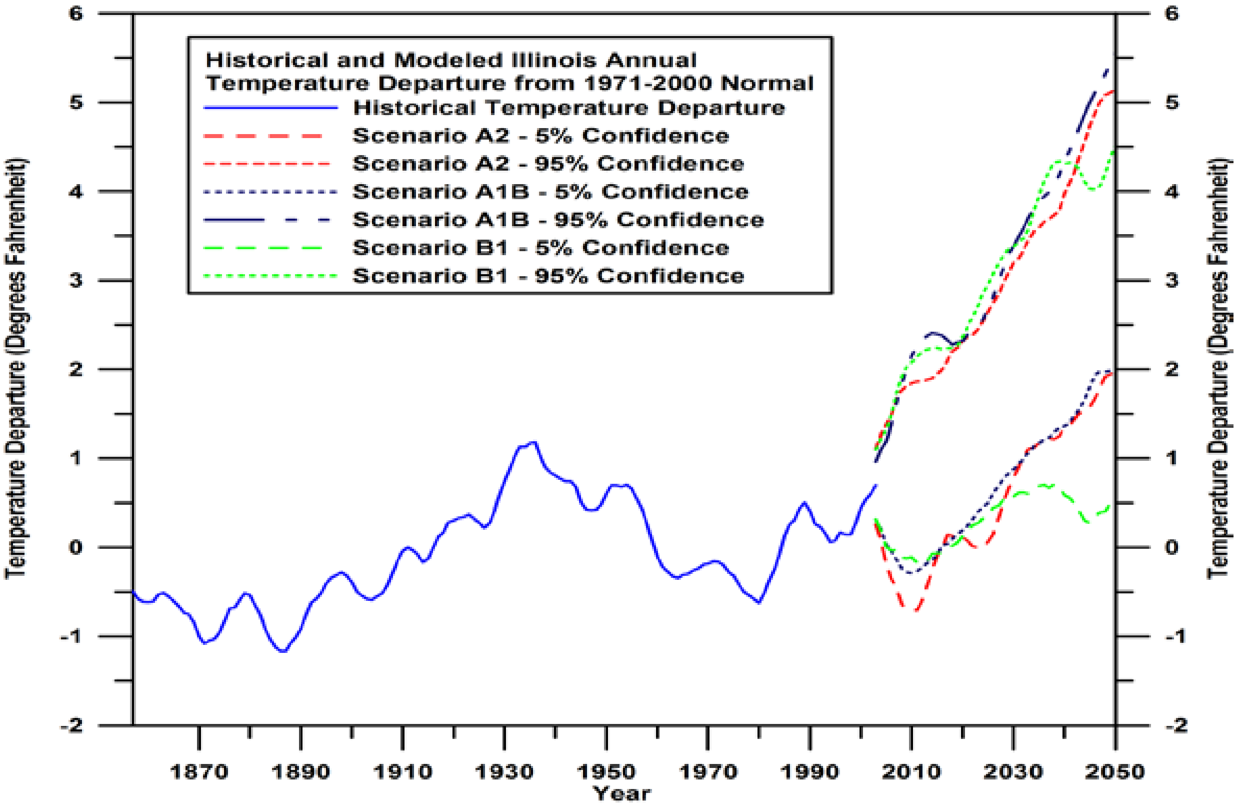

Figure 6.1 Global Climate Model Scenarios on Expected Departures from Normal Annual Temperature: 2005-2100. (Source: ISWS 2007b)

In both figures, scenario A1 assumes very rapid economic growth, a global population peak in mid-century, and rapid introduction of new and more efficient technologies. Scenario A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change. Scenario B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structure toward a service and information economy. Each scenario family is divided into two groups – 5th percentile and 95th percentile. The percentiles designate values which were exceeded 5 percent and 95 percent, respectively (IPCC, 2007).

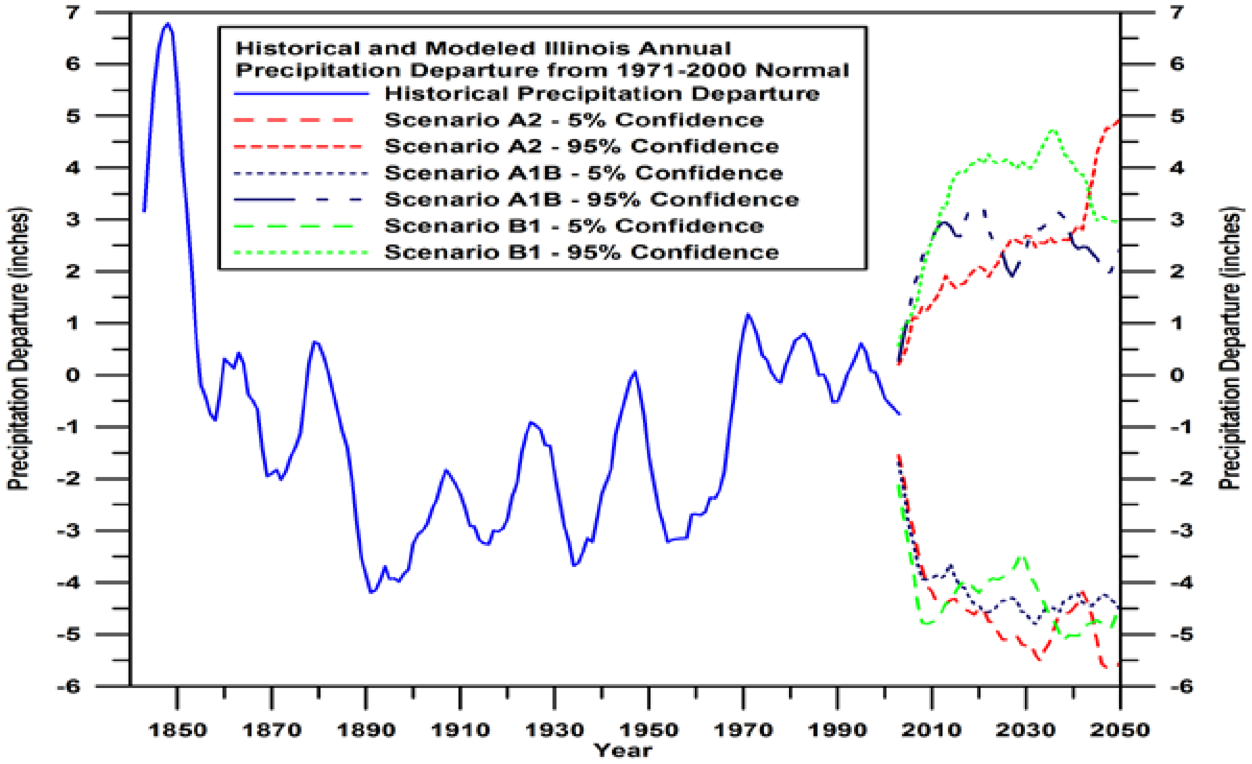

Figure 6.2 Global Climate Model Scenarios on Expected Departures from Normal Annual Precipitation: 2005-2100.
(Source: ISWS 2007b)

Future withdrawals may be affected by these temperature and precipitation scenarios. Furthermore, the changes in annual temperature and precipitation also result in changes during the growing season. The temperature increase of 6 °F will also apply to the summer growing season. The distribution of precipitation is expected to range from +2.5 inches to -3.5 inches during the growing season. The effects of these changes will vary by user sector, depending on each sector's sensitivity of water withdrawals to air temperature and precipitation. The following sections identify the specific assumptions about the changes in weather variables, discussed separately for each of the major sectors of water users.

PUBLIC WATER SUPPLY SECTOR

The sensitivity of public-supply withdrawals to weather conditions is captured by two variables: average maximum-daily temperatures, and average total precipitation during the five month growing season from May to September. This five month growing season is used based on summer precipitation. The estimated constant elasticity of the temperature variable is +1.095, indicating that per capita water withdrawals (plus purchases) would be expected to increase by 1.095 percent in response to a 1.0 percent increase in temperature. The estimated constant elasticity of summer season precipitation is -0.095, indicating that average annual per capita water withdrawals (plus purchases) would be expected to decrease by 0.095 percent in response to a 1.0 percent increase in precipitation.

Effects of Climate Change

Given the 6 °F increase in annual average temperature by 2050, the summer growing season maximum daily temperature is assumed to increase by the same amount of 6 °F. According to the graph in Figure 6.1, there is approximately a linear increase in temperature departure between 2005 and 2050. Therefore, the temperature is increased linearly from zero in 2005 to an additional increase of 6 °F in 2050.

The annual range in precipitation scenario is ±5 inches. The winter, fall, and spring ranges are within -1.5 to +2.5 inches, and the summer season range is +2.5 to -3.5 inches. The graph on Figure 6.2 indicates that the precipitation change will take place early during the 2005-2050 period. Therefore, for the sensitivity analysis it is assumed that departure from precipitation will reach the +2.5 inches and -3.5 inches by 2015. The effects of the combinations of temperature and precipitation changes during the growing season are shown in Tables 6.1 to 6.3.

Table 6.1 Impact of Air Temperature Increase
on Total Public-Supply Withdrawals (based on CT Scenario)

Year	Total Normal Weather Withdrawals MGD	Total Withdrawals (+6°F, +0”) MGD	Change MGD	Change %
2005	1,189.2	1,189.2	0.0	0.0
2010	1,219.8	1,231.2	11.5	0.9
2015	1,254.4	1,277.7	23.4	1.9
2020	1,294.5	1,330.8	36.3	2.8
2025	1,340.1	1,390.3	50.2	3.7
2030	1,392.4	1,457.4	65.1	4.7
2035	1,430.8	1,511.2	80.4	5.6
2040	1,473.8	1,570.5	96.7	6.6
2045	1,519.8	1,612.2	92.4	6.1
2050	1,570.2	1,702.7	132.4	8.4

Total normal weather withdrawals represent the Current Trends (CT) scenario.
(+6°F, +0”) means increase in summer temperature and no increase in summer precipitation

Table 6.1 (above) shows the effects of a gradual temperature increase on total water withdrawals in the public supply sector under the current trends (CT) scenario. By 2050, the 6 °F increase in air temperature would increase total public-supply withdrawals by 132.4 mgd (or 8.4 percent) relative to unchanged normal weather demand.

Table 6.2 Impact of Changes in Summer Precipitation on Total Public-Supply Withdrawals

Year	Total Withdrawals MGD	Total Withdrawals (+0°F, +2.5”) MGD	Change MGD	Change %	Total Withdrawals (+0°F, -3.5”) MGD	Change MGD	Change %
2005	1,189.2	1,189.2	0.0	0.0	1,189.2	0.0	0.0
2010	1,219.8	1,211.2	-8.6	-0.7	1,230.8	11.0	0.9
2015	1,254.4	1,240.0	-14.4	-1.1	1,278.3	24.0	1.9
2020	1,294.5	1,279.7	-14.8	-1.1	1,319.2	24.7	1.9
2025	1,340.1	1,324.7	-15.4	-1.1	1,365.7	25.6	1.9
2030	1,392.4	1,376.6	-15.8	-1.1	1,418.7	26.4	1.9
2035	1,430.8	1,414.5	-16.4	-1.1	1,458.2	27.3	1.9
2040	1,473.8	1,456.9	-16.9	-1.1	1,501.9	28.1	1.9
2045	1,519.8	1,502.4	-17.4	-1.1	1,548.8	29.0	1.9
2050	1,570.2	1,552.3	-18.0	-1.1	1,600.2	30.0	1.9

Total withdrawals represent the Current Trends (CT) scenario. Two climate change conditions are: (1) no temperature increase and precipitation increase (+0°F, +2.5”), and (2) no temperature increase and precipitation decrease (+0°F, -3.5”)

Table 6.3 Impact of Combined Air Temperature and Precipitation Changes on Total Public-Supply Withdrawals

Year	Total Withdrawals MGD	Total Withdrawals (+6°F, +2.5”) MGD	Change MGD	Change %	Total Withdrawals (+6°F, -3.5”) MGD	Change MGD	Change %
2005	1,189.2	1,189.2	0.0	0.0	1,189.2	0.0	0.0
2010	1,219.8	1,222.5	2.8	0.2	1,242.3	22.6	1.9
2015	1,254.4	1,263.1	8.7	0.7	1,302.2	47.8	3.8
2020	1,294.5	1,315.6	21.1	1.6	1,356.2	61.7	4.8
2025	1,340.1	1,374.4	34.3	2.6	1,416.8	76.8	5.7
2030	1,392.4	1,440.9	48.5	3.5	1,485.0	92.7	6.7
2035	1,430.8	1,493.9	63.0	4.4	1,540.0	109.2	7.6
2040	1,473.8	1,552.5	78.7	5.3	1,600.4	126.6	8.6
2045	1,519.8	1,593.8	73.9	4.9	1,643.0	123.2	8.1
2050	1,570.2	1,683.2	112.9	7.2	1,735.1	164.9	10.5

Total withdrawals represent the Current Trends (CT) scenario. Two climate change conditions are: (1) 6 °F temperature increase and 2.5” precipitation increase (+6°F, +2.5”), and (2) 6 °F temperature increase minus 3.5” and precipitation decrease (+6°F, -3.5”).

Table 6.2 shows the impact of changes in summer precipitation without the temperature increase. The 2.5 inch increase in precipitation by 2050 would decrease withdrawals by 18.0

mgd (or 1.1 percent) relative to normal weather withdrawals. The 3.5 inch decrease in precipitation would increase withdrawals by 30.0 mgd (or 1.9 percent).

The combined effects of changes in both air temperature and precipitation are presented in Table 6.3. The results indicate that, by 2050, the 6 °F increase in temperature, when combined with a 2.5 inches increase in precipitation, would result in a 112.9 mgd increase in demand (a 7.2 percent increase). The demand would increase by 164.9 mgd (or 10.5 percent) when the 6 °F increase in temperature would be combined with a 3.5 inches decrease in precipitation.

More detailed information about the climate impacts on per capita public supply withdrawals and shares of withdrawals from different sources is shown in Tables A6.1, A6.2, and A6.4 in the annex to this chapter.

Effects of Drought

Another type of climate impact on water demand is the effect of periodic droughts. In the future, even in the absence of possible changes in the mean long-term annual temperature and precipitation, it can be expected that periodic droughts will occur. While the severity and duration of future droughts is not known, their impact on water demand in the public supply sector can be determined by examining the historical climate records. The most severe historical droughts in Illinois took place in the 1930s and 1950s. These were multiyear droughts which were associated with growing season precipitation deficits during the driest year of approximately 40 percent below normal. For the purpose of this analysis, it was assumed that during future droughts the 1971-2000 precipitation for the growing season would be reduced by 40 percent to represent a worst-case historical drought. Table 6.4 shows the results for average-day water demand in the public-supply sector under the conditions of a worst-case historical drought.

Table 6.4 Impact of Drought-induced Precipitation Deficit on Total Public-Supply Withdrawals (compared to CT Scenario)

Year	Total Normal Weather Withdrawals MGD	Total Withdrawals During Drought MGD	Change MGD	Change %
2005	1,189.2	1,248.7	59.5	5.0
2010	1,219.8	1,281.3	61.5	5.0
2015	1,254.4	1,317.6	63.2	5.0
2020	1,294.5	1,359.7	65.2	5.0
2025	1,340.1	1,407.6	67.5	5.0
2030	1,392.4	1,461.9	69.6	5.0
2035	1,430.8	1,502.9	72.0	5.0
2040	1,473.8	1,548.0	74.2	5.0
2045	1,519.8	1,596.3	76.5	5.0
2050	1,570.2	1,649.2	79.0	5.0

Total normal weather withdrawals represent the Current Trends (CT) scenario.
Summer precipitation deficit during a drought year is 40 percent of normal.

The results in Table 6.4 indicate that during a drought year (represented by the worst historical drought) total public supply withdrawals would increase by 5 percent. This percentage increase would be equivalent to additional 61.5 mgd by 2010, and 79.0 mgd by 2050.

INDUSTRIAL AND COMMERCIAL SECTOR

The sensitivity of industrial and commercial (I&C) sector's water withdrawals to weather conditions are captured by two variables: total cooling degree-days and total precipitation during the five month summer season from May to September. The estimated constant elasticity of the cooling degree-days variable is 0.330, indicating that per employee water withdrawals (plus purchases) would be expected to increase by 0.330 percent in response to a 1.0 percent increase in cooling degree-days. The same size but opposite effect would result from a 1.0 percent decrease in cooling degree-days. The estimated constant elasticity of summer season precipitation is -0.090, indicating that average annual per employee water withdrawals would be expected to decrease by 0.090 percent in response to a 1.0 percent increase in precipitation. The same size but opposite effect would result from a 1.0 percent increase in precipitation.

Effects of Climate Change

The 6 °F increase in annual average temperature by 2050 will translate into higher values for cooling degree-days during the summer season. The increase in cooling degree-days is approximated by the rational relationship developed by Thom (1954). Using the normal average monthly temperature for the five summer months, and the standard deviation of the monthly average temperature, the change in cooling degree days for the DeKalb station was estimated at 369 degree-days by 2050. This value was used to estimate the impact of an air temperature increase on industrial and commercial water use. The cooling degree-day values were linearly increased for the 2010-2050 period.

Table 6.5 Impact of Changes in Cooling Degree-Days
on Self-Supplied I&C Withdrawals (compared on CT Scenario)

Year	Total Normal Weather Withdrawals, MGD	Total Withdrawals CDD Only MGD	Change MGD	Change %
2005	162.4	162.4	0.0	0.0
2010	200.4	203.5	3.1	1.6
2015	209.7	216.1	6.4	3.1
2020	219.6	229.5	9.9	4.5
2025	229.9	243.6	13.7	6.0
2030	240.9	258.6	17.7	7.3
2035	252.5	274.5	22.0	8.7
2040	264.8	291.3	26.5	10.0
2045	277.8	309.2	31.4	11.3
2050	291.6	328.3	36.7	12.6

Table 6.5 (above) shows the effects of a gradual temperature increase (resulting in a gradual increase in cooling degree-days) on total water withdrawals in the I&C sector under the CT scenario. By 2050, the increase in cooling degree-days would increase total withdrawals by 36.7 mgd (or 12.6 percent) relative to unchanged normal weather demand.

Table 6.6 Impact of Precipitation Changes on Self-Supplied I&C Withdrawals

Year	Total Withdrawals MGD	Total Withdrawals (+2.5") MGD	Change MGD	Change %	Total Withdrawals (-3.5") MGD	Change MGD	Change %
2005	162.4	162.4	0.0	0.0	162.4	0.0	0.0
2010	200.4	199.0	-1.4	-0.7	202.5	2.1	1.0
2015	209.7	207.0	-2.7	-1.3	214.4	4.7	2.2
2020	219.6	216.7	-2.9	-1.3	224.4	4.9	2.2
2025	229.9	226.9	-3.0	-1.3	235.0	5.1	2.2
2030	240.9	237.8	-3.2	-1.3	246.3	5.4	2.2
2035	252.5	249.2	-3.3	-1.3	258.1	5.6	2.2
2040	264.8	261.3	-3.5	-1.3	270.7	5.9	2.2
2045	277.8	274.2	-3.6	-1.3	284.0	6.2	2.2
2050	291.6	287.8	-3.8	-1.3	298.1	6.5	2.2

Table 6.6 (above) shows the impacts of changes in summer season precipitation on self-supplied commercial water withdrawals as compared to the CT scenario under normal weather conditions. Table 6.7 (below) gives a summary of the impacts on I&C withdrawals due to changes in cooling degree-days and precipitation. The results in Table 6.7 show that by 2050 the I&C withdrawals would increase by 32.4 mgd (or 11.1 percent) if the increase in temperature is associated with a 2.5 inch increase in precipitation. If the temperature increase is associated with a 3.5 inch decrease in precipitation, self-supplied withdrawals would increase by 44.0 mgd (or 15.1 percent).

Table 6.7 Impact of Combined Air Temperature and Precipitation Changes on Self-Supplied I&C Withdrawals

Year	Total Withdrawals MGD	Total Withdrawals (+CDD, +2.5") MGD	Change MGD	Change %	Total Withdrawals (+CDD, -3.5") MGD	Change MGD	Change %
2005	162.4	162.4	0.0	0.0	162.4	0.0	0.0
2010	200.4	202.1	1.7	0.9	205.6	5.2	2.6
2015	209.7	213.3	3.6	1.7	220.9	11.2	5.3
2020	219.6	226.5	6.9	3.2	234.6	15.0	6.8
2025	229.9	240.4	10.5	4.6	249.0	19.1	8.3
2030	240.9	255.2	14.3	5.9	264.4	23.4	9.7
2035	252.5	270.9	18.4	7.3	280.6	28.1	11.1
2040	264.8	287.5	22.7	8.6	297.8	33.0	12.5
2045	277.8	305.2	27.4	9.9	316.1	38.3	13.8
2050	291.6	324.0	32.4	11.1	335.6	44.0	15.1

The sensitivity analysis results for the five combinations of climatic factors on total and self-supplied commercial and industrial withdrawals, which are also separated by source of water supply, are shown in Tables A6.4 to A6.6 in the annex to this chapter.

Effects of Historic Drought

Water withdrawals in the self-supplied industrial and commercial sector will also be affected by periodic droughts in the future. For the purpose of this analysis, it was assumed that during future droughts, the 1971-2000 precipitation for the growing season would be reduced by 40 percent, representing a worst-case historical drought.

Table 6.8 shows the results for average-day water demand in the public-supply sector during a worst-case historical drought.

Table 6.8 Impact of Drought-induced Precipitation Deficit
on Self-Supplied Commercial and Industrial Withdrawals (CT Scenario)

Year	Total Normal Weather Withdrawals MGD	Total Withdrawals During Drought MGD	Change MGD	Change %
2005	162.4	162.4	8.9	5.5
2010	200.4	211.5	11.1	5.5
2015	209.7	221.4	11.6	5.6
2020	219.6	231.8	12.2	5.6
2025	229.9	242.7	12.8	5.6
2030	240.9	254.4	13.4	5.6
2035	252.5	266.6	14.1	5.6
2040	264.8	279.6	14.8	5.6
2045	277.8	293.3	15.5	5.6
2050	291.6	308.0	16.3	5.6

Total normal weather withdrawals represent the Current Trends (CT) scenario.
Summer precipitation deficit during a drought year is 40 percent of normal.

The results in Table 6.8 indicate that during a drought year (represented by the worst historical drought), self-supplied I&C withdrawals would increase by 5.6 percent. This percentage increase would be equivalent to additional 11.1 mgd by 2010, and 16.3 mgd by 2050.

IRRIGATION AND AGRICULTURAL SECTOR

For the purpose of sensitivity analysis with respect to climate change scenarios, future estimates of water demand for irrigation were further adjusted for the effects of decreased or increased precipitation, and the effect of increased temperature on evapotranspiration. The effect of the change in normal precipitation was translated into change in the precipitation deficit. The change was calculated using the equation from Table 5.9 in Chapter 5. This relationship is:

$$d_t = -19.476 + 0.562 \cdot P_n \tag{6.1}$$

where d_t = precipitation deficit during summer season, and P_n = normal precipitation during the irrigation season, increased by 2.5 inches or decreased by 3.5 inches.

The correction for the departure of average temperature is based on the analysis of potential evapotranspiration and monthly temperature by Dr. Ken Kunkel and his staff at ISWS. It is approximated using the adjustment of 0.1 inches/degree F:

$$d_t^c = d_t + 0.1 \cdot (T_a - T_n) \tag{6.2}$$

where d_t^c is the corrected total application depth during the growing season, T_a is average monthly air temperature for May through August, and T_n = average of normal monthly temperatures during the four month growing season.

In arriving at this relationship, Dr. Kunkel analyzed the soil moisture model data in order to examine the year-to-year variability in the ratio of actual to potential evapotranspiration (ET/PET) for each month of the growing season. In July and August, there are years when the model-estimated ratio is 1.0, thus indicating that the use of PET as actual ET is appropriate. In June, the highest ET/PET values were in the range of 0.90 to 0.95. In May, the highest ET/PET values were near or slightly above 0.70. The average value for May was 0.50. Assuming that a stretch of 1-2 weeks of dry weather in May would concern a farmer enough to irrigate, the higher value of 0.70 would be appropriate for May.

Because the development of a weighted coefficient for ET/PET ratio would require monthly data (while seasonally aggregated data are used in this study), no downward adjustment for actual ET was introduced (this means assuming the ET/PET value of 1.0 for all months of the irrigation season). This assumption contributes to slightly overestimated effects of temperature on irrigation water demand.

Effects of Climate Change

The effects of climate change on total water withdrawals in agricultural and irrigation sector are shown in Tables 6.9 to 6.11. By 2050, the gradual increase in air temperature during the growing season and the resultant increase in actual evapotranspiration would increase agricultural demand by 2.9 mgd (or 5.3 percent).

Table 6.9 Impact of Changes in Air Temperature on Irrigation and Agricultural Withdrawals (based on CT Scenario)

Year	Total Normal Weather Withdrawals, MGD	Total Withdrawals (+6°F Only) MGD	Change MGD	Change %
2005	44.6	44.6	0.0	0.0
2010	45.6	45.9	0.3	0.6
2015	46.7	47.2	0.6	1.2
2020	47.6	48.4	0.9	1.8
2025	48.7	49.9	1.2	2.4
2030	49.9	51.4	1.5	3.0
2035	51.0	52.8	1.8	3.6
2040	52.3	54.5	2.2	4.1
2045	53.8	56.3	2.5	4.7
2050	55.4	58.3	2.9	5.3

Table 6.10 shows the effect of changes in summer precipitation on agricultural and irrigation withdrawals. A 2.5 inch increase in precipitation by 2050 would decrease water withdrawals by 6.8 mgd (or 12.3 percent). A 3.5 inch decrease in summer precipitation would result in an increase in withdrawals of 9.5 mgd (or 17.2 percent).

Table 6.10 Impact of Change in Precipitation on Total Agricultural and Irrigation Withdrawals

Year	Total Withdrawals MGD	Total Withdrawals (+2.5 in.) MGD	Change MGD	Change %	Total Withdrawals (-3.5 in.) MGD	Change MGD	Change %
2005N	44.6	44.6	0.0	0.0	44.6	0.0	0.0
2010	45.6	42.7	-2.9	-6.4	49.7	4.1	8.9
2015	46.7	40.8	-5.9	-12.6	54.9	8.3	17.7
2020	47.6	41.6	-6.0	-12.6	56.0	8.4	17.7
2025	48.7	42.6	-6.1	-12.6	57.3	8.6	17.6
2030	49.9	43.6	-6.2	-12.5	58.6	8.7	17.5
2035	51.0	44.6	-6.4	-12.5	59.9	8.9	17.5
2040	52.3	45.8	-6.5	-12.4	61.4	9.1	17.4
2045	53.8	47.1	-6.6	-12.4	63.1	9.3	17.3
2050	55.4	48.6	-6.8	-12.3	64.9	9.5	17.2

Total withdrawals represent the Current Trends (CT) scenario. Two climate change conditions are: (1) temperature increase plus precipitation increase, and (2) temperature increase plus precipitation decrease

By 2050, the 6 °F increase in air temperature combined with a 2.5 inches increase in precipitation would decrease total agricultural withdrawals by 3.9 mgd (or 7.0 percent) relative to unchanged normal weather (Table 6.11). When the 6 °F increase in air temperature is combined with a 3.5 inches decrease in precipitation, the 2050 withdrawals increase by 12.4 mgd (or 22.4 percent) relative to normal weather withdrawals.

Table 6.11 Impact of Climate Change on Total Agricultural and Irrigation Withdrawals (compared to CT Scenario)

Year	Total Withdrawals MGD	Total Withdrawals (+6°F, +2.5 in.) MGD	Change MGD	Change %	Total Withdrawals (+6°F, -3.5 in.) MGD	Change MGD	Change %
2005N	44.6	44.6	0.0	-0.1	44.6	0.0	-0.1
2010	45.6	43.0	-2.6	-5.7	49.9	4.3	9.5
2015	46.7	41.3	-5.3	-11.4	55.5	8.8	18.9
2020	47.6	42.4	-5.2	-10.8	56.8	9.3	19.5
2025	48.7	43.7	-5.0	-10.2	58.4	9.7	20.0
2030	49.9	45.1	-4.8	-9.5	60.1	10.2	20.5
2035	51.0	46.4	-4.6	-8.9	61.7	10.7	21.1
2040	52.3	48.0	-4.3	-8.3	63.6	11.3	21.6
2045	53.8	49.6	-4.1	-7.7	65.6	11.8	22.0
2050	55.4	51.5	-3.9	-7.0	67.8	12.4	22.4

Total withdrawals represent the Current Trends (CT) scenario. Two climate change conditions are: (1) temperature increase plus precipitation increase, and (2) temperature increase plus precipitation decrease

More detail information of the climate impacts on water withdrawals in all three agricultural subsectors are shown in Tables A6.7 and A6.8 in the annex to this chapter.

Effects of Drought

Water withdrawals by irrigation and agricultural sector will also be affected by periodic droughts in the future. Irrigation demands are very sensitive to the decreasing precipitation during the summer growing season. The assumption that during future droughts, the normal precipitation for the growing season would be reduced by 40 percent, representing a worst-case historical drought, would substantially increase the amount of water applied for crop and turf irrigation.

Table 6.12 shows the results for average-day water demand in the IR&AG sector during a worst-case historical drought.

Table 6.12 Impact of Drought-induced Precipitation Deficit on Irrigation and Agricultural Withdrawals (CT Scenario)

Year	Total Normal Weather Withdrawals MGD	Total Withdrawals During Drought MGD	Change MGD	Change %
2005	44.6	44.6	0.0	0.0
2010	45.6	68.2	22.6	49.7
2015	46.7	70.1	23.4	50.1
2020	47.6	71.3	23.7	49.7
2025	48.7	73.1	24.4	50.0
2030	49.9	75.0	25.1	50.2
2035	51.0	76.2	25.2	49.4
2040	52.3	78.2	25.9	49.5
2045	53.8	80.3	26.5	49.3
2050	55.4	82.6	27.2	49.1

Total normal weather withdrawals represent the Current Trends (CT) scenario.
Summer precipitation deficit during a drought year is 40 percent of normal.

The results in Table 6.12 indicate that during a drought year (represented by the worst historical drought), self-supplied IR&AG withdrawals would increase by approximately 50 percent. This percentage increase would be equivalent to additional 22.6 mgd by 2010, and 27.2 mgd by 2050.

DOMESTIC SELF-SUPPLIED SECTOR

The sensitivity of self-supplied domestic withdrawals to weather conditions is captured by two variables: average of maximum-daily temperatures and total precipitation during the five month growing season from May to September. The estimated constant elasticity of the temperature variable is +1.624, indicating that per capita water withdrawals would be expected to increase by 1.624 percent in response to a 1.0 percent increase in temperature. The estimated constant elasticity of summer season precipitation is -0.219, indicating that average annual per capita water withdrawals (plus purchases) would be expected to decrease by 0.219 percent in response to a 1.0 percent increase in precipitation.

Effects of Climate Changes

The effect of changes in temperature and precipitation are shown in Tables 6.13 to 6.15.

As shown in Table 6.13, by 2050, the gradual increase in air temperature during the growing season and would increase self-supplied domestic water withdrawals by 5.9 mgd (or 14.4 percent).

Table 6.13 Impact of Changes in Air Temperature on Self-Supplied Domestic Withdrawals (compared to CT Scenario)

Year	Total Normal Weather Withdrawals, MGD	Total Withdrawals (+6°F Only) MGD	Change MGD	Change %
2005	31.8	31.8	0.0	0.1
2010	33.4	33.9	0.5	1.5
2015	34.7	35.8	1.1	3.2
2020	35.9	37.6	1.7	4.8
2025	37.0	39.4	2.4	6.4
2030	38.1	41.1	3.0	7.8
2035	38.9	42.7	3.8	9.6
2040	39.7	44.2	4.5	11.2
2045	40.5	44.8	4.3	10.5
2050	41.2	47.1	5.9	14.4

Table 6.14 shows the effect of changes in summer precipitation on self-supplied domestic withdrawals. A 2.5 inch increase in precipitation by 2050 would decrease water withdrawals by 0.4 mgd (or 0.9 percent). A 3.5 inch decrease in summer precipitation would result in an increase in withdrawals of 2.6 mgd (or 6.3 percent).

Table 6.14 Impact of Change in Precipitation on Self-Supplied Domestic Withdrawals

Year	Total Withdrawals MGD	Total Withdrawals (+2.5 in.) MGD	Change MGD	Change %	Total Withdrawals (-3.5 in.) MGD	Change MGD	Change %
2005N	31.8	31.8	0.0	0.1	31.8	0.0	0.1
2010	33.4	33.0	-0.4	-1.2	34.2	0.8	2.5
2015	34.7	34.0	-0.7	-2.0	36.5	1.8	5.2
2020	35.9	35.3	-0.6	-1.8	37.8	1.9	5.4
2025	37.0	36.4	-0.6	-1.6	39.1	2.1	5.6
2030	38.1	37.5	-0.6	-1.6	40.2	2.1	5.6
2035	38.9	38.4	-0.5	-1.2	41.2	2.3	6.0
2040	39.7	39.2	-0.5	-1.1	42.1	2.4	6.1
2045	40.5	40.1	-0.4	-1.1	43.0	2.5	6.1
2050	41.2	40.8	-0.4	-0.9	43.8	2.6	6.3

Total withdrawals represent the Current Trends (CT) scenario. Two climate change conditions are: (1) temperature increase plus precipitation increase, and (2) temperature increase plus precipitation decrease

Table 6.15 Impact of Climate Change on Self-Supplied Domestic Withdrawals

Year	Total Withdrawals MGD	Total Withdrawals (+6°F, +2.5 in.) MGD	Change MGD	Change %	Total Withdrawals (+6°F, -3.5 in.) MGD	Change MGD	Change %
2005N	31.8	31.8	0.0	0.1	31.8	0.0	0.1
2010	33.4	33.4	0.0	0.1	34.7	1.3	3.9
2015	34.7	35.0	0.3	0.8	37.5	2.8	8.1
2020	35.9	36.7	0.8	2.3	39.4	3.5	9.8
2025	37.0	38.5	1.5	3.9	41.3	4.3	11.5
2030	38.1	40.1	2.0	5.3	43.0	4.9	13.0
2035	38.9	41.6	2.7	7.1	44.7	5.8	14.9
2040	39.7	43.1	3.4	8.6	46.3	6.6	16.5
2045	40.5	43.7	3.2	7.9	46.9	6.4	15.8
2050	41.2	46.0	4.8	11.7	49.4	8.2	19.8

Total withdrawals represent the Current Trends (CT) scenario. Two climate change conditions are: (1) temperature increase plus precipitation increase, and (2) temperature increase plus precipitation decrease

The 6 °F increase in air temperature combined with a 2.5 inches increase in precipitation would increase self-supplied domestic withdrawals by 4.8 mgd (or 11.7 percent) relative to unchanged normal weather (Table 6.15). When the 6 °F increase in air temperature is combined with a 3.5 inches decrease in precipitation, the 2050 withdrawals increase by 8.2 mgd (or 19.8 percent) relative to normal weather withdrawals.

Effects of Drought

Water withdrawals in the self-supplied domestic sector will also be affected by periodic droughts in the future. For the purpose of this analysis, it was assumed that during future droughts the 1971-2000 precipitation for the growing season would be reduced by 40 percent to represent a worst-case historical drought. Table 6.21 shows the results for average-day water demand in the self-supplied domestic sector during a worst-case historical drought.

The results in Table 6.15 indicate that during a drought year, which is characterized by a 40 percent deficit in summer precipitation, self-supplied domestic withdrawals would increase by 4.0 mgd (11.9 percent) in 2010 and by 5.6 mgd (13.5 percent) in 2050, as compared to normal year.

Additional scenario values for the self-supplied domestic sector are included in Table A6.9 to A6.12 in the annex to this chapter.

Table 6.16 Impact of Drought
on Self-Supplied Domestic Withdrawals
(Compared on CT Scenario)

Year	Total Normal Weather Withdrawals, MGD	Total Drought Withdrawals MGD	Change MGD	Change %
2005	31.8	31.8	0.0	0.1
2010	33.4	37.4	4.0	11.9
2015	34.7	39.0	4.3	12.3
2020	35.9	40.4	4.5	12.5
2025	37.0	41.7	4.7	12.7
2030	38.1	42.9	4.8	12.7
2035	38.9	44.0	5.1	13.1
2040	39.7	44.9	5.2	13.2
2045	40.5	45.9	5.4	13.3
2050	41.2	46.8	5.6	13.5

POWER GENERATION SECTOR

Higher air temperatures will have an impact on the quantity of water withdrawn for thermoelectric cooling. In once-through cooling systems, warmer intake water may lead to increased rates of withdrawals in order meet the limitations on thermal pollution. Also, the performance of cooling towers will be affected by higher air temperatures. However, the actual impacts on water withdrawals cannot be easily quantified and are not included in the sensitivity analysis conducted here.

SUMMARY OF CLIMATE EFFECTS

Table 6.17 summarizes the effects of climate changes on water withdrawals in four sectors.

The last column of Table 6.22 shows the changes in withdrawals relative to the withdrawals under the CT scenario. The largest change in total withdrawals by 2050 of 229.5 mgd would result from the combined effect of the temperature increase and decrease in summer precipitation.

Table 6.18 summarizes the increases in sectoral withdrawals during a reoccurrence of the worst historical drought.

Table 6-17 Effects of Possible Climate Change on Water Withdrawals in Northeastern Illinois (MGD)

Weather Scenario/ Sector	2005[1] Water With-drawals	2030 Water With-drawals	2005-2030 Change	2050 Water With-drawals	2005-2050 Change	Change from CT in 2050
CT Scenario						
Public supply	1,189.2	1,392.4	203.2	1,570.2	381.0	0.0
Self-supplied I&C	162.4	240.9	78.5	291.6	129.2	0.0
Self-supplied domestic	31.8	38.1	6.3	41.2	9.4	0.0
Irrigation and agriculture	44.6	49.9	5.3	55.4	10.8	0.0
All sectors (w/o power)	1,428.0	1,721.3	293.3	1,958.4	530.4	0.0
• *T +6°F only*						
Public Supply	1,189.2	1,457.4	268.2	1,702.7	513.5	132.5
Self-supplied I&C	162.4	258.6	96.2	328.3	165.9	36.7
Self-supplied domestic	31.8	41.1	9.3	47.1	15.3	5.9
Irrigation and agriculture	44.6	51.4	6.8	58.3	13.7	2.9
All sectors (w/o power)	1,428.0	1,808.5	380.5	2,136.4	708.4	178.0
+2.5" Rain only						
Public Supply	1,189.2	1,376.6	187.4	1,552.3	363.1	-17.9
Self-supplied I&C	162.4	237.8	75.4	287.8	125.4	-3.8
Self-supplied domestic	31.8	37.5	5.7	40.8	9.0	-0.4
Irrigation and agriculture	44.6	43.6	-1.0	48.6	4.0	-6.8
All sectors (w/o power)	1,428.0	1,695.5	267.5	1,929.5	501.5	-28.9
-3.5" Rain only						
Public Supply	1,189.2	1,418.7	229.5	1,600.2	411.0	30.0
Self-supplied I&C	162.4	246.3	83.9	298.1	135.7	6.5
Self-supplied domestic	31.8	40.2	8.4	43.8	12.0	2.6
Irrigation and agriculture	44.6	58.6	14.0	64.9	20.3	9.5
All sectors (w/o power)	1,428.0	1,763.8	335.8	2,007.0	579.0	48.6
• *T +6°F & +2.5" Rain*						
Public Supply	1,189.2	1,440.9	251.7	1,683.2	494.0	113.0
Self-supplied I&C	162.4	255.2	92.8	324.0	161.6	32.4
Self-supplied domestic	31.8	40.1	8.3	46.0	14.2	4.8
Irrigation and agriculture	44.6	45.1	0.5	51.5	6.9	-3.9
All sectors (w/o power)	1,428.0	1,781.3	353.3	2,104.7	676.7	146.3
• *T +6°F & -3.5" Rain*						
Public Supply	1,189.2	1,485.0	295.8	1,735.1	545.9	164.9
Self-supplied I&C	162.4	264.4	102.0	335.6	173.2	44.0
Self-supplied domestic	31.8	43.0	11.2	49.4	17.6	8.2
Irrigation and agriculture	44.6	60.1	15.5	67.8	23.2	12.4
All sectors (w/o power)	1,428.0	1,852.5	424.5	2,187.9	759.9	229.5

[1] 2005 water withdrawals are adjusted for normal weather conditions. • *T* = temperature increase. Small decimal value differences are due to independent rounding.

Table 6.18 Impacts of Drought Related Precipitation Deficit on Water Withdrawals In Northeastern Illinois

Weather Scenario/ Sector	2005[1] Water With-drawals	2030 Water With-drawals	2005-2030 Change	2050 Water With-drawals	2005-2050 Change	Change from CT in 2050
CT Scenario						
Public supply	1,189.2	1,392.4	203.2	1,570.2	381.0	0.0
Self-supplied I&C	162.4	240.9	78.5	291.6	129.2	0.0
Self-supplied domestic	31.8	38.1	6.3	41.2	9.4	0.0
Irrigation and agriculture	44.6	49.9	5.3	55.4	10.8	0.0
All sectors	1,428.0	1,721.3	293.3	1,958.4	530.4	0.0
Drought Year (40% precipitation deficit)						
Public Supply	1,189.2	1,461.9	272.7	1,649.2	460.0	79.0
Self-supplied I&C	162.4	254.4	92.0	308.0	145.6	16.3
Self-supplied domestic	31.8	42.9	11.1	46.8	15.0	5.6
Irrigation and agriculture	44.6	75.0	30.4	82.6	38.0	27.2
All sectors	1,428.0	1,834.2	406.2	2,086.6	658.6	128.1

[1] 2005 water withdrawals are for climate normal adjusted conditions. Small decimal value differences are due to independent rounding.

CHAPTER 6 ANNEX

Table A6.1 Estimated Effects of Temperature Increase on Water Demand in Public Supply Sector.

Year	Population Served	Per Capita GPCD	Total Withdrawals MGD	Ground-Water MGD	Surface Non-Lake Water MGD	Surface Lake Water MGD
CT						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	140.7	1,219.8	162.2	34.0	1,023.6
2015	9,000,551	139.4	1,254.4	177.5	35.5	1,041.3
2020	9,360,062	138.3	1,294.5	195.8	37.1	1,061.6
2025	9,751,671	137.4	1,340.1	217.0	39.0	1,084.1
2030	10,178,737	136.8	1,392.4	241.5	40.9	1,109.9
2035	10,514,026	136.1	1,430.8	257.7	43.1	1,130.1
2040	10,868,264	135.6	1,473.8	275.4	45.3	1,153.1
2045	11,241,979	135.2	1,519.8	294.8	47.7	1,177.4
2050	11,636,341	134.9	1,570.2	316.2	50.3	1,203.8
2005-50, %	39.1	-5.0	32.0	111.9	53.0	19.5
6°F • T-Only						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	142.0	1,231.2	163.7	34.4	1,033.2
2015	9,000,551	142.0	1,277.7	180.8	36.1	1,060.8
2020	9,360,062	142.2	1,330.8	201.2	38.2	1,091.4
2025	9,751,671	142.6	1,390.3	225.1	40.4	1,124.7
2030	10,178,737	143.2	1,457.4	252.7	42.8	1,161.9
2035	10,514,026	143.7	1,511.2	272.1	45.5	1,193.6
2040	10,868,264	144.5	1,570.5	293.4	48.2	1,228.9
2045	11,241,979	143.4	1,612.2	312.6	50.5	1,249.1
2050	11,636,341	146.3	1,702.7	342.7	54.5	1,305.4
2005-50, %	39.1	3.0	43.2	129.7	65.8	29.6

Table A6.2 Estimated Effects of Changes in Summer Precipitation on Water Demand in Public Supply Sector.

Year	Population Served	Per Capita GPCD	Total Withdrawals MGD	Ground-Water MGD	Surface Non-Lake Water MGD	Surface Lake Water MGD
CT						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	140.7	1,219.8	162.2	34.0	1,023.6
2015	9,000,551	139.4	1,254.4	177.5	35.5	1,041.3
2020	9,360,062	138.3	1,294.5	195.8	37.1	1,061.6
2025	9,751,671	137.4	1,340.1	217.0	39.0	1,084.1
2030	10,178,737	136.8	1,392.4	241.5	40.9	1,109.9
2035	10,514,026	136.1	1,430.8	257.7	43.1	1,130.1
2040	10,868,264	135.6	1,473.8	275.4	45.3	1,153.1
2045	11,241,979	135.2	1,519.8	294.8	47.7	1,177.4
2050	11,636,341	134.9	1,570.2	316.2	50.3	1,203.8
2005-50, %	39.1	-5.0	32.0	111.9	53.0	19.5
0°• T+2.5”Rain						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	139.7	1,211.2	161.0	33.8	1,016.3
2015	9,000,551	137.8	1,240.0	175.5	35.1	1,029.3
2020	9,360,062	136.7	1,279.7	193.6	36.7	1,049.4
2025	9,751,671	135.8	1,324.7	214.6	38.5	1,071.6
2030	10,178,737	135.2	1,376.6	238.9	40.5	1,097.2
2035	10,514,026	134.5	1,414.5	254.8	42.6	1,117.1
2040	10,868,264	134.1	1,456.9	272.3	44.8	1,139.9
2045	11,241,979	133.6	1,502.4	291.4	47.1	1,163.9
2050	11,636,341	133.4	1,552.3	312.6	49.7	1,189.9
2005-50, %	39.1	-6.1	30.5	109.5	51.3	18.1
0°• T-3.5”Rain						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	142.0	1,230.8	163.6	34.3	1,032.8
2015	9,000,551	142.0	1,278.3	180.9	36.1	1,061.3
2020	9,360,062	140.9	1,319.2	199.4	37.8	1,082.0
2025	9,751,671	140.0	1,365.7	221.1	39.7	1,104.9
2030	10,178,737	139.4	1,418.7	245.8	41.7	1,131.2
2035	10,514,026	138.7	1,458.2	262.5	43.9	1,151.8
2040	10,868,264	138.2	1,501.9	280.5	46.1	1,175.3
2045	11,241,979	137.8	1,548.8	300.3	48.5	1,200.0
2050	11,636,341	137.5	1,600.2	322.1	51.2	1,226.9
2005-50, %	39.1	-3.2	34.6	115.9	55.8	21.8

Table A6.3 Estimated Effects of Temperature and Precipitation Changes on Water Demand in Public Supply Sector.

Year	Population Served	Per Capita GPCD	Total Withdrawals MGD	Ground-Water MGD	Surface Non-Lake Water MGD	Surface Lake Water MGD
CT						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	140.7	1,219.8	162.2	34.0	1,023.6
2015	9,000,551	139.4	1,254.4	177.5	35.5	1,041.3
2020	9,360,062	138.3	1,294.5	195.8	37.1	1,061.6
2025	9,751,671	137.4	1,340.1	217.0	39.0	1,084.1
2030	10,178,737	136.8	1,392.4	241.5	40.9	1,109.9
2035	10,514,026	136.1	1,430.8	257.7	43.1	1,130.1
2040	10,868,264	135.6	1,473.8	275.4	45.3	1,153.1
2045	11,241,979	135.2	1,519.8	294.8	47.7	1,177.4
2050	11,636,341	134.9	1,570.2	316.2	50.3	1,203.8
2005-50, %	39.1	-5.0	32.0	111.9	53.0	19.5
6°• T+2.5”Rain						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	141.0	1,222.5	162.5	34.1	1,025.9
2015	9,000,551	140.3	1,263.1	178.8	35.7	1,048.6
2020	9,360,062	140.6	1,315.6	199.0	37.7	1,078.8
2025	9,751,671	140.9	1,374.4	222.6	40.0	1,111.8
2030	10,178,737	141.6	1,440.9	250.0	42.4	1,148.5
2035	10,514,026	142.1	1,493.9	269.0	45.0	1,179.9
2040	10,868,264	142.8	1,552.5	290.0	47.7	1,214.7
2045	11,241,979	141.8	1,593.8	309.1	50.0	1,234.7
2050	11,636,341	144.6	1,683.2	338.9	53.9	1,290.4
2005-50, %	39.1	1.8	41.5	127.1	64.0	28.1
6°• T-3.5”Rain						
2005	8,368,021	142.1	1,189.2	149.2	32.9	1,007.1
2010	8,670,432	143.3	1,242.3	165.1	34.7	1,042.5
2015	9,000,551	144.7	1,302.2	184.2	36.8	1,081.1
2020	9,360,062	144.9	1,356.2	205.0	38.9	1,112.4
2025	9,751,671	145.3	1,416.8	229.4	41.2	1,146.3
2030	10,178,737	145.9	1,485.0	257.3	43.6	1,184.2
2035	10,514,026	146.5	1,540.0	277.2	46.3	1,216.5
2040	10,868,264	147.3	1,600.4	298.9	49.1	1,252.4
2045	11,241,979	146.2	1,643.0	318.5	51.5	1,273.1
2050	11,636,341	149.1	1,735.1	349.2	55.5	1,330.5
2005-50, %	39.1	4.9	45.9	134.0	68.8	32.1

Table A6.4 Estimated Effects of Temperature Increase on I&C Water Withdrawals

Year	Total Employment	Use Per Employee GPED	Total I&C Use MGD	Total Self-supplied MGD	Ground-water MGD	Surface Water MGD	Lake Michigan (MGD)
CT							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	115.8	578.9	200.4	27.4	161.4	11.6
2015	5,189,948	116.4	603.9	209.7	29.3	168.1	12.3
2020	5,388,283	116.9	630.1	219.6	31.4	175.1	13.1
2025	5,596,566	117.5	657.7	229.9	33.7	182.4	13.9
2030	5,816,618	118.1	686.7	240.9	36.1	190.0	14.9
2035	6,045,775	118.6	717.1	252.5	38.8	198.0	15.7
2040	6,288,265	119.1	749.2	264.8	41.6	206.4	16.7
2045	6,543,846	119.6	783.0	277.8	44.8	215.2	17.8
2050	6,813,497	120.1	818.6	291.6	48.3	224.5	18.9
%	56.4	9.9	71.9	79.6	96.9	76.8	73.9
CDD Only							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	117.5	587.8	203.5	27.9	163.8	11.8
2015	5,189,948	119.9	622.1	216.1	30.3	173.1	12.8
2020	5,388,283	122.2	658.3	229.5	32.9	182.8	13.8
2025	5,596,566	124.4	696.3	243.6	35.7	192.9	15.0
2030	5,816,618	126.6	736.5	258.6	38.7	203.6	16.3
2035	6,045,775	128.8	778.7	274.5	42.2	214.8	17.5
2040	6,288,265	130.9	823.3	291.3	45.9	226.6	18.9
2045	6,543,846	133.0	870.5	309.2	50.0	238.9	20.4
2050	6,813,497	135.1	920.3	328.3	54.4	251.9	22.0
2005-50, %	56.4	23.6	93.3	102.2	122.0	98.4	102.3

Table A6.5 Estimated Effects of Precipitation Increase on I&C Water Withdrawals

Year	Total Employ-ment	Use Per Employee GPED	Total I&C Use MGD	Total Self-supplied MGD	Ground-water MGD	Surface Water MGD	Lake Michigan (MGD)
CT							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	115.8	578.9	200.4	27.4	161.4	11.6
2015	5,189,948	116.4	603.9	209.7	29.3	168.1	12.3
2020	5,388,283	116.9	630.1	219.6	31.4	175.1	13.1
2025	5,596,566	117.5	657.7	229.9	33.7	182.4	13.9
2030	5,816,618	118.1	686.7	240.9	36.1	190.0	14.9
2035	6,045,775	118.6	717.1	252.5	38.8	198.0	15.7
2040	6,288,265	119.1	749.2	264.8	41.6	206.4	16.7
2045	6,543,846	119.6	783.0	277.8	44.8	215.2	17.8
2050	6,813,497	120.1	818.6	291.6	48.3	224.5	18.9
2005-50,%	56.4	9.9	71.9	79.6	96.9	76.8	73.9
+2.5"							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	114.9	574.5	199.0	27.2	160.4	11.5
2015	5,189,948	114.6	595.0	207.0	28.8	166.0	12.1
2020	5,388,283	115.2	620.8	216.7	30.8	172.9	12.9
2025	5,596,566	115.8	647.9	226.9	33.0	180.2	13.7
2030	5,816,618	116.3	676.5	237.8	35.4	187.7	14.7
2035	6,045,775	116.9	706.5	249.2	38.1	195.6	15.5
2040	6,288,265	117.4	738.0	261.3	40.9	203.9	16.5
2045	6,543,846	117.9	771.3	274.2	44.0	212.6	17.5
2050	6,813,497	118.3	806.3	287.8	47.4	221.7	18.7
2005-50,%	56.4	8.2	69.3	77.3	93.4	74.6	71.9
-3.5"							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	117.1	585.8	202.5	27.9	163.0	11.7
2015	5,189,948	119.3	619.2	214.4	30.3	171.5	12.5
2020	5,388,283	119.9	646.1	224.4	32.5	178.6	13.3
2025	5,596,566	120.5	674.4	235.0	34.7	186.1	14.2
2030	5,816,618	121.1	704.2	246.3	37.2	193.9	15.2
2035	6,045,775	121.6	735.4	258.1	40.0	202.1	16.0
2040	6,288,265	122.2	768.3	270.7	43.0	210.7	17.0
2045	6,543,846	122.7	803.0	284.0	46.2	219.7	18.1
2050	6,813,497	123.2	839.6	298.1	49.8	229.1	19.3
2005-50, %	56.4	12.7	76.3	83.6	103.0	80.4	77.4

Table A6.6 Estimated Effects of Changes in Temperature and Precipitation on I&C Water Withdrawals

Year	Total Employ-ment	Use Per Employee GPED	Total I&C Use MGD	Total Self-supplied MGD	Ground-water MGD	Surface Water MGD	Lake Michigan (MGD)
CT							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	115.8	578.9	200.4	27.4	161.4	11.6
2015	5,189,948	116.4	603.9	209.7	29.3	168.1	12.3
2020	5,388,283	116.9	630.1	219.6	31.4	175.1	13.1
2025	5,596,566	117.5	657.7	229.9	33.7	182.4	13.9
2030	5,816,618	118.1	686.7	240.9	36.1	190.0	14.9
2035	6,045,775	118.6	717.1	252.5	38.8	198.0	15.7
2040	6,288,265	119.1	749.2	264.8	41.6	206.4	16.7
2045	6,543,846	119.6	783.0	277.8	44.8	215.2	17.8
2050	6,813,497	120.1	818.6	291.6	48.3	224.5	18.9
2005-50,%	56.4	9.9	71.9	79.6	96.9	76.8	73.9
CDD +2.5"							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	116.6	583.3	202.1	27.6	162.8	11.7
2015	5,189,948	118.1	612.9	213.3	29.7	171.0	12.6
2020	5,388,283	120.4	648.5	226.5	32.3	180.5	13.7
2025	5,596,566	122.6	686.0	240.4	35.0	190.6	14.8
2030	5,816,618	124.7	725.5	255.2	38.0	201.1	16.1
2035	6,045,775	126.9	767.2	270.9	41.4	212.2	17.3
2040	6,288,265	129.0	811.1	287.5	45.1	223.8	18.7
2045	6,543,846	131.0	857.5	305.2	49.1	236.0	20.1
2050	6,813,497	133.1	906.6	324.0	53.5	248.9	21.7
2005-50,%	56.4	21.7	90.4	99.6	118.1	96.0	99.9
CDD -3.5"							
2005	4,355,216	109.3	476.1	162.4	24.5	127.0	10.9
2010	5,000,930	118.9	594.7	205.6	28.3	165.4	11.9
2015	5,189,948	122.9	637.8	220.9	31.3	176.6	13.0
2020	5,388,283	125.3	674.9	234.6	34.0	186.5	14.1
2025	5,596,566	127.6	714.0	249.0	36.9	196.9	15.3
2030	5,816,618	129.8	755.2	264.4	40.0	207.7	16.6
2035	6,045,775	132.1	798.5	280.6	43.5	219.2	17.8
2040	6,288,265	134.3	844.3	297.8	47.3	231.2	19.3
2045	6,543,846	136.4	892.7	316.1	51.5	243.8	20.8
2050	6,813,497	138.5	943.9	335.6	56.1	257.1	22.4
2005-50, %	56.4	26.7	98.2	106.7	128.8	102.5	106.3

Table A6.7 Estimated Effects of Changes in Precipitation on Total Agricultural and Irrigation Withdrawals.

Year	Cropland MGD	Golf Course MGD	Sod MGD	Livestock MGD	Environ-mental MGD	Total AG&I MGD
2005N	22.6	9.7	9.0	2.9	0.4	44.6
2010	22.6	9.9	9.6	3.1	0.5	45.6
2015	22.6	10.0	10.1	3.3	0.6	46.7
2020	22.6	10.2	10.8	3.3	0.7	47.6
2025	22.6	10.4	11.4	3.5	0.8	48.7
2030	22.6	10.5	12.1	3.6	1.0	49.9
2035	22.6	10.7	12.9	3.6	1.2	51.0
2040	22.6	10.9	13.7	3.7	1.5	52.3
2045	22.6	11.1	14.5	3.8	1.8	53.8
2050	22.6	11.2	15.4	3.9	2.2	55.4
2005-50 Change	0.0	1.5	6.4	1.0	1.8	10.8
+2.5 Rain						
2005N	22.6	9.7	9.0	2.9	0.4	44.6
2010	21.0	9.2	8.9	3.1	0.5	42.7
2015	19.5	8.7	8.7	3.3	0.6	40.8
2020	19.5	8.8	9.3	3.3	0.7	41.6
2025	19.5	9.0	9.8	3.5	0.8	42.6
2030	19.5	9.1	10.4	3.6	1.0	43.6
2035	19.5	9.2	11.1	3.6	1.2	44.6
2040	19.5	9.4	11.8	3.7	1.5	45.8
2045	19.5	9.5	12.5	3.8	1.8	47.1
2050	19.5	9.7	13.2	3.9	2.2	48.6
2005-50 Change	-3.1	0.0	4.2	1.0	1.8	4.0
-3.5 Rain						
2005N	22.6	9.7	9.0	2.9	0.4	44.6
2010	24.8	10.8	10.5	3.1	0.5	49.7
2015	26.9	12.0	12.1	3.3	0.6	54.9
2020	26.9	12.2	12.9	3.3	0.7	56.0
2025	26.9	12.3	13.7	3.5	0.8	57.3
2030	26.9	12.5	14.5	3.6	1.0	58.6
2035	26.9	12.8	15.4	3.6	1.2	59.9
2040	26.9	13.0	16.3	3.7	1.5	61.4
2045	26.9	13.2	17.3	3.8	1.8	63.1
2050	26.9	13.4	18.4	3.9	2.2	64.9
2005-50 Change	4.3	3.7	9.4	1.0	1.8	20.3

2005-50 Change = Change in withdrawals in MGD between 2005 and 2050.

Table A6.8 Estimated Effects of Changes in Precipitation and Temperature on Total Agricultural and Irrigation Withdrawals.

Year	Cropland MGD	Golf Course MGD	Sod MGD	Livestock MGD	Environmental MGD	Total AG&I MGD
2005N	22.6	9.7	9.0	2.9	0.4	44.6
2010	22.6	9.9	9.6	3.1	0.5	45.6
2015	22.6	10.0	10.1	3.3	0.6	46.7
2020	22.6	10.2	10.8	3.3	0.7	47.6
2025	22.6	10.4	11.4	3.5	0.8	48.7
2030	22.6	10.5	12.1	3.6	1.0	49.9
2035	22.6	10.7	12.9	3.6	1.2	51.0
2040	22.6	10.9	13.7	3.7	1.5	52.3
2045	22.6	11.1	14.5	3.8	1.8	53.8
2050	22.6	11.2	15.4	3.9	2.2	55.4
2005-50 Change	0.0	1.5	6.4	1.0	1.8	10.8
T+2.5 Rain						
2005N	22.6	9.7	9.0	2.9	0.4	44.6
2010	21.2	9.3	9.0	3.1	0.5	43.0
2015	19.8	8.8	8.9	3.3	0.6	41.3
2020	19.9	9.0	9.5	3.3	0.7	42.4
2025	20.1	9.2	10.1	3.5	0.8	43.7
2030	20.2	9.4	10.8	3.6	1.0	45.1
2035	20.3	9.7	11.6	3.6	1.2	46.4
2040	20.5	9.9	12.4	3.7	1.5	48.0
2045	20.6	10.1	13.3	3.8	1.8	49.6
2050	20.8	10.4	14.2	3.9	2.2	51.5
2005-50 Change	-1.8	0.7	5.2	1.0	1.8	6.9
T-3.5 Rain						
2005N	22.6	9.7	9.0	2.9	0.4	44.6
2010	24.9	10.9	10.6	3.1	0.5	49.9
2015	27.2	12.1	12.3	3.3	0.6	55.5
2020	27.4	12.4	13.1	3.3	0.7	56.8
2025	27.5	12.6	14.0	3.5	0.8	58.4
2030	27.7	12.9	14.9	3.6	1.0	60.1
2035	27.8	13.2	15.9	3.6	1.2	61.7
2040	28.0	13.4	17.0	3.7	1.5	63.6
2045	28.1	13.7	18.1	3.8	1.8	65.6
2050	28.3	14.0	19.3	3.9	2.2	67.8
2005-50 Change	5.7	4.3	10.3	1.0	1.8	23.2

2005-50 Change = Change in withdrawals in MGD between 2005 and 2050.

Table A6.9 Estimated Effects of Temperature Increase on Self-supplied Domestic Withdrawals

Year	Self-Supplied Population	SS GPCD	SS-DOM MGD
CT			
2005	392,650	81.1	31.8
2010	410,485	81.3	33.4
2015	424,925	81.7	34.7
2020	437,100	82.2	35.9
2025	447,516	82.8	37.0
2030	456,522	83.4	38.1
2035	463,030	84.1	38.9
2040	468,202	84.8	39.7
2045	472,698	85.6	40.5
2050	476,621	86.4	41.2
2005-50 Change	83,971	5.3	9.4
2005-50 %	21.4	6.5	29.6
T Only			
2005	392,650	81.1	31.8
2010	410,485	82.6	33.9
2015	424,925	84.2	35.8
2020	437,100	86.1	37.6
2025	447,516	88.0	39.4
2030	456,522	90.0	41.1
2035	463,030	92.1	42.7
2040	468,202	94.3	44.2
2045	472,698	94.7	44.8
2050	476,621	98.9	47.1
2005-50 Change	83,971	17.8	15.3
2005-50 %	21.4	22.0	48.0

Table A6.10 Estimated Effects of Precipitation Changes on Self-supplied Domestic Withdrawals

Year	Self-Supplied Population	SS GPCD	SS-DOM MGD
CT			
2005	392,650	81.1	31.8
2010	410,485	81.3	33.4
2015	424,925	81.7	34.7
2020	437,100	82.2	35.9
2025	447,516	82.8	37.0
2030	456,522	83.4	38.1
2035	463,030	84.1	38.9
2040	468,202	84.8	39.7
2045	472,698	85.6	40.5
2050	476,621	86.4	41.2
2005-50 Change	83,971	5.3	9.4
2005-50 %	21.4	6.5	29.6
+2.5”R Only			
2005	392,650	81.1	31.8
2010	410,485	80.4	33.0
2015	424,925	80.1	34.0
2020	437,100	80.7	35.3
2025	447,516	81.4	36.4
2030	456,522	82.2	37.5
2035	463,030	83.0	38.4
2040	468,202	83.8	39.2
2045	472,698	84.7	40.1
2050	476,621	85.7	40.8
2005-50 Change	83,971	4.6	9.0
2005-50 %	21.4	5.7	28.3
-3.5”R Only			
2005	392,650	81.1	31.8
2010	410,485	83.4	34.2
2015	424,925	85.9	36.5
2020	437,100	86.6	37.8
2025	447,516	87.3	39.1
2030	456,522	88.1	40.2
2035	463,030	89.0	41.2
2040	468,202	89.9	42.1
2045	472,698	90.9	43.0
2050	476,621	91.9	43.8
2005-50 Change	83,971	10.8	12.0
2005-50 %	21.4	13.4	37.6

Table A6.11 Estimated Effects of Precipitation and Temperature Changes on Self-supplied Domestic Withdrawals

Year	Self-Supplied Population	SS GPCD	SS-DOM MGD
CT			
2005	392,650	81.1	31.8
2010	410,485	81.3	33.4
2015	424,925	81.7	34.7
2020	437,100	82.2	35.9
2025	447,516	82.8	37.0
2030	456,522	83.4	38.1
2035	463,030	84.1	38.9
2040	468,202	84.8	39.7
2045	472,698	85.6	40.5
2050	476,621	86.4	41.2
2005-50 Change	83,971	5.3	9.4
2005-50 %	21.4	6.5	29.6
T+2.5 Rain			
2005	392,650	81.1	31.8
2010	410,485	81.5	33.4
2015	424,925	82.3	35.0
2020	437,100	84.0	36.7
2025	447,516	85.9	38.5
2030	456,522	87.9	40.1
2035	463,030	89.9	41.6
2040	468,202	92.1	43.1
2045	472,698	92.4	43.7
2050	476,621	96.5	46.0
2005-50 Change	83,971	15.5	14.2
2005-50 %	21.4	19.1	44.5
T-3.5 Rain			
2005	392,650	81.1	31.8
2010	410,485	84.6	34.7
2015	424,925	88.3	37.5
2020	437,100	90.2	39.4
2025	447,516	92.2	41.3
2030	456,522	94.3	43.0
2035	463,030	96.5	44.7
2040	468,202	98.8	46.3
2045	472,698	99.2	46.9
2050	476,621	103.6	49.4
2005-50 Change	83,971	22.5	17.5
2005-50 %	21.4	27.8	55.1

Table A6.12 Estimated Effects of Drought on Self-supplied Domestic Withdrawals

Year	Self-Supplied Population	SS GPCD	SS-DOM MGD
CT			
2005	392,650	81.1	31.8
2010	410,485	81.3	33.4
2015	424,925	81.7	34.7
2020	437,100	82.2	35.9
2025	447,516	82.8	37.0
2030	456,522	83.4	38.1
2035	463,030	84.1	38.9
2040	468,202	84.8	39.7
2045	472,698	85.6	40.5
2050	476,621	86.4	41.2
2005-50 Change	83,971	5.3	9.4
2005-50 %	21.4	6.5	29.6
Drought			
2005	392,650	81.1	31.8
2010	410,485	91.1	37.4
2015	424,925	91.7	39.0
2020	437,100	92.4	40.4
2025	447,516	93.2	41.7
2030	456,522	94.1	42.9
2035	463,030	95.0	44.0
2040	468,202	96.0	44.9
2045	472,698	97.0	45.9
2050	476,621	98.1	46.8
2005-50 Change	83,971	17.0	14.9
2005-50 %	21.4	21.0	46.9

CHAPTER 7

PEAK-SEASON AND PEAK-DAY WITHDRAWALS

PURPOSE

This chapter describes the data and methods used in developing estimates of peaking factors for maximum rates of water withdrawal from wells and surface water intakes in the study area. The purpose of this analysis is to derive peaking factors which would permit estimation of maximum-season and maximum-day demands for water by the major sectors of users in the 11-county study area in Northeastern Illinois.

The future demands for the period 2005-2050 were determined for four major sectors of water users within geographical subdivisions of the 11-county area. The four major sectors include:

(1) public-supply municipal and industrial sector, and self-supplied domestic;
(2) self-supplied commercial and industrial sector (including mining);
(3) thermoelectric power generation sector; and
(4) agricultural irrigation, including golf course irrigation, environmental and livestock.

Definitions of study areas differ by user sector. For the self-supplied industrial and commercial, the self-supplied domestic, and the irrigation and agricultural sectors, the study areas were defined as individual counties. For the power generation sector, future demands were determined for individual power plants. For the public water supply sector, the 11-county area was subdivided into 26 service areas of dominant water supply systems, and 11 county remainder areas.

Three alternative levels of future demands were developed for each sector and study area. These alternative demands were derived by defining three future scenarios, each of which had a different set of assumed future conditions regarding the future values of demand drivers and explanatory variables. More detailed descriptions of the scenarios are included in previous chapters (Chapters 1 through 5).

The future demand scenarios developed estimates of total annual water withdrawals. The actual units used to express the annual volume of withdrawals were million gallons per day (mgd). For each future year and geographical area, this measure of water demand was calculated by dividing total annual volume of withdrawals by 365 days.

The analysis described here provides information on the pattern of water withdrawals throughout the year by determining the magnitude of water withdrawals during the growing season (i.e., the four peak months from May 1 to August 31) as well as the maximum daily withdrawals (i.e., peak-day during the year). The following sections discuss seasonal and maximum-day peaking factors for the four major sectors of water users.

SEASONAL PATTERNS OF WATER WITHDRAWALS

Public Water Supply Sector

The available data on monthly and seasonal patterns of water pumpage in a sample of public water supply systems in the study area are shown in Tables 7.1 to 7.4. These data were obtained from the ISWS and were originally included as accompanying submittals for the IWIP survey of annual withdrawals.

Table 7.1 shows monthly values of water withdrawals from Fox River and from wells by the City of Aurora for two calendar years: 2005 and 2006. The bottom rows in the table show water withdrawals during the four-month summer season (May 1 to August 31) and peak month withdrawals. For combined surface water and groundwater withdrawals, the four-month summer season accounts for approximately 40 percent of annual withdrawals (as compared to 33 percent that would be obtained under uniform distribution of withdrawals throughout the year).

Table 7.1. Monthly Distribution of Water Withdrawals by the City of Aurora, Illinois (Million Gallons - MG)

Month	2005			2006		
	Fox River	Ground Water	Total Withdrawal	Fox River	Ground Water	Total Withdrawal
January	245.296	232.268	477.564	187.535	310.676	498.211
February	209.681	221.157	430.838	158.516	292.274	450.790
March	236.734	235.862	472.596	155.033	319.448	474.481
April	247.644	210.792	458.436	219.935	270.267	490.202
May	264.381	279.349	543.730	301.951	269.158	571.109
June	371.601	380.438	752.039	340.621	282.622	623.243
July	305.895	399.121	705.016	337.787	350.321	688.108
August	254.773	384.975	639.748	314.667	345.557	660.224
September	183.703	387.925	571.628	269.260	260.875	530.135
October	190.339	343.612	533.951	264.349	239.300	503.649
November	213.293	256.960	470.253	236.030	241.729	477.759
December	234.666	263.250	497.916	260.113	240.155	500.268
Total MG	2,958.006	3,595.709	6,553.715	3,045.797	3,422.382	6,468.179
May-August, MG	1,196.650	1,443.883	2,640.533	1,295.026	1,247.658	2,542.684
May-August, %	40.5	40.2	40.3	42.5	36.5	39.3
4-month peak factor	1.20	1.19	1.20	1.26	1.08	1.17
Max. month, MG	371.601	399.121	752.039	340.621	350.321	688.108
1-month peak factor	1.53	1.31	1.40	1.36	1.21	1.25

Seasonal peaking factor shown at the bottom of Table 7.1 was calculated by dividing average daily water use during the four month period (123 days) by average daily use during the entire calendar year (365 days).

Table 7.1 shows that the seasonal (four-month) peaking factors for Aurora in 2005 and 2006 were, respectively, 1.20 and 1.17. In 2005 (a drought year), the seasonal peak factor for groundwater was approximately the same as the peak factor for surface water intake. In 2006, when weather was closer to normal, the groundwater peak was 1.08, and surface water was 1.26.

Monthly peaking factor was obtained by dividing the total use during the highest month by average monthly use (total annual use divided by 12). Approximately the same result would be obtained by dividing average daily water use during the peak month by average daily use during the entire calendar year. The one-month peaking factor for total pumpage in Aurora was 1.40 in 2005, and 1.25 in 2006.

Table 7.2 shows monthly pumpage by North Aurora during fiscal year 2004-05. During the four-month summer season groundwater withdrawals represented 37.1 percent of the annual volume. The corresponding 4-month peaking factor was 1.10. For one month duration, the highest withdrawals occurred in July and were 21 percent higher than average month withdrawals. The 1-month peaking factor was 1.21.

Table 7.2 Seasonal Groundwater Pumping By North Aurora
(Wells #3,4,5,6, in MG)

Month	FY 2004-2005
January	47.239
February	42.627
March	46.551
April	47.027
May	53.931
June	53.616
July	61.559
August	57.441
September	56.670
October	48.992
November	46.476
December	48.841
Total	610.970
May-August, MGD	226.547
May-August, %	37.1
4-month peak factor	1.10
Max. month, MGD	61.559
1-month peak factor	1.21

For the Village of Sleepy Hollow in 2004 (shown in Table 7.3), the corresponding factors were 1.08 (four-month seasonal peak) and 1.20 (monthly peak).

Table 7.3 Monthly Pumping by Village of Sleepy Hollow in 2004
(Two Pumping Stations, in Cubic Feet - CF)

Month	Randall Pump Station	McLean Pump Station	Both Stations
January	846,200	226,300	1,072,500
February	872,500	238,400	1,110,900
March	836,900	185,400	1,022,300
April	813,900	182,800	996,700
May	912,700	210,900	1,123,600
June	974,700	227,900	1,202,600
July	1,030,000	207,900	1,237,900
August	1,153,100	226,200	1,379,300
September	1,107,900	241,000	1,348,900
October	939,800	113,600	1,053,400
November	885,600	103,800	989,400
December	684,600	336,600	1,021,200
Total CF	11,057,900	2,500,800	13,558,700
May-August, CF	4,070,500	872,900	4,943,400
May-August, %	36.8	34.9	36.5
4-month peak factor	1.09	1.04	1.08
Max. month, CF	1,153,100	336,600	1,379,300
1-month peak factor	1.23	1.58	1.20

Table 7.4 shows seasonal and monthly peaking factors for four years (2001-2004) in the St. Charles Water Division. The four-month peaking factors were: 1.22, 1.18, 1.13, and 1.13. The one-month factors were: 1.50, 1.42, 1.22, and 1.28.

Table 7.4 Monthly Pumpage Records from St. Charles Water Division (in Gallons)

Month	2001	2002	2003	2004
January	118,336,000	120,746,000	123,340,000	120,833,000
February	106,852,000	105,767,000	105,182,000	113,724,000
March	118,054,000	115,908,000	122,795,000	116,864,020
April	120,699,000	119,512,991	120,502,000	126,616,000
May	140,523,000	133,185,000	141,118,000	142,097,000
June	150,504,000	159,396,000	149,654,000	142,982,000
July	202,127,000	189,860,000	157,942,000	170,234,000
August	177,383,000	163,713,000	160,066,000	161,571,000
September	136,370,000	154,440,000	152,119,000	164,771,000
October	128,342,000	133,849,000	134,941,000	130,434,000
November	117,444,000	118,048,000	113,270,000	110,793,000
December	119,168,640	115,227,000	116,798,000	116,294,000
Total, Gallons	1,635,802,640	1,629,651,991	1,597,727,000	1,617,213,020
May-August, Gal.	670,537,000	646,154,000	608,780,000	616,884,000
May-August, %	41.0	39.6	38.1	38.1
4-month peak factor	1.22	1.18	1.13	1.13
Max. month, Gal.	202,127,000	189,860,000	160,066,000	170,234,000
1-month peak factor	1.50	1.42	1.22	1.28

The four data tables show a certain level of consistency in seasonal peaking, thus indicating that it may be appropriate for the study to derive global seasonal peaking factors for all withdrawal points (i.e., the same ratios for all systems). Table 7.5 below compares the seasonal peaking factors for the data in Tables 7.1 to 7.4.

Table 7.5 Comparison of Seasonal Peaking Factors

System name	Data Year	Peaking Factor 4-month	Peaking Factor 1-month
Aurora	2005	1.20	1.40
	2006	1.17	1.25
North Aurora	2004-05	1.10	1.19
Sleepy Hollow	2004	1.08	1.20
St. Charles	2001	1.22	1.50
	2002	1.18	1.42
	2003	1.13	1.22
	2004	1.13	1.28
Weighted average	--	1.18	1.33

The four-month peak factor corresponds to the irrigation season (May 1 to August 31). In Table 7.5 it ranges from 1.08 to 1.22. An average seasonal factor, weighted by the volume of water pumped, is 1.18. Assuming that the four-month factor is a good approximation of the global factor for systems in the 11-county area, it could be used to obtain average daily demand during the four-month peak season by multiplying average annual values in mgd by 1.18.

The monthly peaking factor in Table 7.5 ranges from 1.19 to 1.50, with a weighted average of the nine observations of 1.33. Again, assuming that this factor is a good approximation of the global factor for the study area, it could be used to obtain average daily demand during the peak month by multiplying average annual values in mgd by 1.33.

Self-Supplied Industrial and Commercial Sector

No data on monthly withdrawals of self-supplied industrial and commercial establishments are collected by the IWIP. Therefore no seasonal and monthly peaking factors could be determined for this sector. However, data on maximum day withdrawals are reported to IWIP and are discussed in the section on maximum-day peaking factors.

Power Generation Sector

No data on monthly withdrawals of self-supplied power plants are collected by the IWIP. Therefore no seasonal and monthly peaking factors could be determined for this sector.

Agriculture and Irrigation Sector

In the irrigation and agriculture sector water withdrawals are estimated using the seasonal values of precipitation deficit during the four months of summer growing season from May 1 to August 31. Therefore, by assumption, the estimated irrigation water demand occurs during the four months, while it is zero during the remaining eight month of the year. This implies that the four-month seasonal peaking factor for this sector is 3.0. Accordingly, average daily demand during the peak season can be obtained by multiplying average annual values in mgd by 3.0. However, because the sector total withdrawals include some quantities of water used for livestock and environmental purposes, these amounts should be subtracted before the calculation of peak season demands.

For monthly peak, the peaking factor can be calculated using the maximum monthly precipitation deficit during the four-month irrigation season. Based on the long term data for Cook County, the average summer season precipitation deficit is 9.82 inches. The long-term average of the highest monthly deficits is 3.87 inches. This implies that the ratio of peak month to average month during the irrigation season is 1.58. Based on average annual usage in mgd, the monthly peaking factor is 4.7. Accordingly, average daily demand during the peak month can be obtained by multiplying average annual values in mgd by 4.7.

MAXIMUM-DAY (PEAK-DAY) FACTORS

Public Water Supply Sector

The IWIP database contains data on the reported maximum-day demands by public water supply systems as well as other water users. The available historical data on peaking factors are included in Tables 7.6 to 7.9.

Table 7.6 shows daily peaking factors for two of the four systems discussed in the previous section. As could be expected, the daily peaking factors are significantly higher than monthly factors and also show greater variability.

Table 7.6 Comparison of Maximum-Day Peaking Factors

System name	Data Year	Max-day
Aurora	2005	1.89
	2006	2.08
North Aurora	2004-05	--
Sleepy Hollow	2004	--
St. Charles	2001	2.06
	2002	1.88
	2003	1.52
	2004	1.67

Tables 7.7 to 7.9 show historical data on peaking factors for a sample of systems in the study area. The bottom two rows in Tables 7.7 to 7.9 show average peaking factors for all the available historical data and also for the years 2000-2004 (where available). The 2000-2004 average peaking factors could be used for individual systems to determine peak-day withdrawals.

Table 7.7 Maximum-day Peaking Factors for Systems in Cook County

	Evanston		Glencoe		Kenilworth		Northbrook		Wilmette		Winnetka	
Year	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF
1989	48.187	1.97	1.836	3.27	0.428	3.20	6.208	2.25	5.955	2.40	1.707	3.60
1990	46.183	1.61	1.547	--	0.443	2.00	5.857	1.87	5.786	1.83	1.594	3.88
1991	49.456	1.82	1.856	2.18	0.480	3.55	6.732	2.05	6.538	--	1.901	5.42
1992	47.631	--	1.743	3.05	0.447	2.94	6.078	2.20	5.632	--	1.665	7.39
1993	45.569	--	1.485	2.20	0.386	1.83	5.511	1.56	6.119	--	1.505	3.92
1994	48.032	--	1.816	2.84	0.458	3.23	5.958	2.29	6.779	--	1.872	5.58
1995	47.712	1.74	1.736	2.70	0.503	2.60	5.948	2.06	6.498	2.00	1.827	5.24
1996	46.629	1.75	1.660	2.50	0.472	2.32	5.807	2.19	6.148	2.00	1.648	5.46
1997	45.554	1.68	1.750	2.98	0.429	2.72	5.780	2.30	6.290	2.08	1.593	5.75
1998	47.184	1.75	1.868	--	0.555	2.16	6.472	1.98	6.064	1.95	3.601	2.40
1999	48.014	1.54	1.876	2.55	--	--	6.554	2.10	6.380	2.03	3.599	2.89
2000	46.333	1.73	1.743	2.66	0.455	2.38	5.857	1.73	6.205		3.309	2.34
2001	46.183	1.51	1.628	2.75	0.425	2.68	5.493	2.08	6.323	1.81	3.221	2.43
2002	45.971	1.65	1.812	2.65	0.474	2.54	5.970	--	6.406	2.18	3.445	--
2003	44.998	1.88	1.792	2.37	0.433	2.51	5.840	1.96	6.471	--	1.712	--
2004	43.704		1.597	2.19	0.426	2.05	5.607	--	6.298	--	1.665	3.85
2005	42.007	1.92	2.071	2.72	0.487	3.23	5.833	2.25	6.947	2.03	3.892	2.66
Peaking Factors:												
Ave. 1989-05		1.74		2.64		2.62		2.06		2.03		4.19
Ave. 2000-04		1.69		2.52		2.43		1.92		2.00		2.87

Source: Data from IWIP, raw processed by Mr. Ed Glatfelter

Table 7.8 Maximum-day Peaking Factors for Systems in Lake County

	Central Lake Co Joint Act Water Agency		Great Lakes Naval Training Station		Highland Park		Highwood		Lake County Public Water District		Lake Forest	
Year	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF	MGD-Ave.	PF
1989	--	--	4.872	1.48	4.619		--	--	2.558	1.29	2.289	5.52
1990	--	--	4.798	1.64	7.968	1.99	0.641	--	2.558	--	1.511	2.25
1991	--	--	4.294	1.71	9.084	2.70	0.667	1.41	2.381	1.71	2.550	5.69
1992	11.699	--	3.345	1.77	9.575	2.36	0.667	--	2.361	1.69	1.757	5.77
1993	14.884	1.38	3.138	1.58	9.740	2.21	0.618	--	2.394	1.30	1.435	4.52
1994	15.946	1.81	3.472	1.44	10.896	2.11	0.618	--	2.653	1.67	1.833	6.85
1995	16.405	1.77	3.838	1.78	10.170	2.48	0.618	--	2.729	1.66	1.701	5.62
1996	16.365	1.73	4.190	1.58	10.240	2.44	0.618	--	2.706	1.71	1.820	4.74
1997	16.488	1.76	4.077	1.50	9.064	2.35	0.623	1.31	2.732	1.50	1.876	2.60
1998	17.414	1.71	3.899	1.61	10.955	2.01	0.627	1.59	2.822	1.57	4.162	--
1999	18.620	1.80	3.982	1.91	11.408	2.17	0.619	2.26	3.011	1.74	4.263	--
2000	18.496	1.54	3.915	1.39	11.330	1.71	0.514	1.99	2.935	1.65	3.696	--
2001	19.177	1.73	4.102	--	10.829	2.11	0.583	2.02	2.977	1.80	3.714	--
2002	20.229	1.70	--	--	11.520	2.37	0.663	1.75	2.917	1.85	4.094	--
2003	19.655	1.61	3.529	1.58	11.196	2.04	0.662	1.62	2.992	1.50	4.016	--
2004	19.809	1.74	3.507	2.08	10.573		0.634	1.36	2.880	1.52	3.925	--
2005	21.581	1.88	2.656	1.95	12.056	2.17	0.657	1.68	3.034	1.90	4.885	--
Peaking Factors:												
Ave. 1989-05		1.71		1.67		2.21		1.70		1.63		4.84
Ave. 2000-04		1.67		1.68		2.06		1.75		1.67		--

Source: Data from IWIP, raw processed by Mr. Ed Glatfelter

Table 7.9 Maximum-day Peaking Factors for Systems in Kane, Kankakee and Lake Counties

	Aurora		Lake Shannon		Shadow Lakes II Association		Wilmington		Waukegan	
Year	Ave.-MGD	PF	Ave.-MGD	PF	Ave.-MGD	PF	Ave.-MGD	PF	Ave.-MGD	PF
1989	--	--	0.027	1.27	--	--	--	--	10.763	1.39
1990	--	--	0.030	1.20	--	--	0.567		11.243	
1991	--	--	0.028	1.00	--	--	0.594	1.92	11.420	1.52
1992	6.725	2.70	0.028	1.00	0.019	2.87	0.586	1.91	9.931	
1993	6.675	1.48	0.025	1.00	--	--	0.565	1.53	8.640	
1994	9.420	2.14	0.027	1.35	0.029	1.74	0.565	1.53	8.710	
1995	9.883	1.70	0.032	1.32	0.033		0.595	1.65	8.628	1.69
1996	9.548	1.60	0.040	1.31	0.030	2.98	0.617	2.16	8.963	1.37
1997	9.314	2.00	0.038	2.45	--	--	0.604	1.65	9.024	1.61
1998	8.852	2.15	--	--	--	--	0.621	1.54	9.060	1.48
1999	8.777	2.01	0.036	1.89	--	--	0.729	2.09	9.496	1.56
2000	9.317	1.73	0.044	1.81	--	--	0.735	1.63	9.216	1.36
2001	10.990	1.79	0.050	1.68	--	--	0.643	1.55	9.440	1.48
2002	9.716	2.29	0.047	2.15	--	--	0.687	1.28	9.433	1.61
2003	10.203	2.18	0.042	1.93	--	--	0.705	1.24	10.385	
2004	8.206	1.89	0.050	2.02	--	--	0.669	1.33	10.345	
2005	7.461	2.08	0.061	2.31	--	--	0.739	1.87	10.107	
Peaking Factors:										
Ave. 1989-05		1.98		1.61		2.53		1.66		1.51
Ave. 2000-04		1.98		1.92		--		1.41		1.48

Source: Data from IWIP, raw processed by Mr. Ed Glatfelter.

Because the peaking factors show high variability across systems and also vary by year, the best method of determining peak-day demands for public-supply systems would be to select a separate peaking factor for each system and apply it to the system's average day annual withdrawals.

A single global peaking factor for all systems would be less accurate but would provide a reasonable estimate of aggregate demands as long as the average peaking factor was weighted by the annual volume of water use. Table 7.10 shows the weighted peaks for systems from Tables 7.7 to 7.9, as well as a global weighted peaking factor.

Table 7.10 Weighted Maximum-day Peaking Factors

System name	Ave. - MGD	Peaking Factor
Evanston	46.49	1.73
Glencoe	1.76	2.65
Kenilworth	0.46	2.63
Northbrook	6.00	2.06
Wilmette	6.28	2.03
Winnetka	2.31	3.77
Central Lake	18.08	1.71
Great Lakes NTS	3.83	1.66
Highland Park	10.40	2.21
Highwood	0.62	1.69
Lake Co. PWD	2.76	1.63
Lake Forest	1.86	4.94
Aurora	8.93	1.97
Lake Shannon	0.04	1.70
Shadow Lakes II	0.03	2.49
Wilmington	0.64	1.66
Waukegan	9.54	1.50
Global (weighted) factor	--	1.91

The weighted maximum-day peaking factors in Table 7.10 range from 1.63 to 4.94. The global weighted peaking factor for all systems in the sample is 1.91. Assuming that this factor is a good approximation of the global factor for the study area, it could be used to obtain average daily demand during the peak day by multiplying average annual values in mgd by 1.91.

Self-Supplied Industrial and Commercial Sector

The ISWS collects data on maximum-day withdrawals of self-supplied industrial and commercial establishments under the IWIP. These data were used to derive maximum day peaking factors for this sector. Table 7.11 shows peaking factors for self-supplied I&C withdrawals which are aggregated at the county level. The data show large variability of peaking factors among the counties and also across the four years of the available data.

Table 7.11 Maximum-day Peaking Factors for Self-Supplied Industrial and Commercial Sector

County	Number of observations	1990	1995	2000	2005	1995-2005 Average
Boone	3	3.32	1.23	2.76	1.13	1.68
Cook	28	1.32	1.52	1.21	2.50	1.43
DeKalb	6	1.28	4.90	3.84	4.10	3.05
DuPage	14	2.21	2.92	1.92	6.95	2.36
Grundy	3	1.58	1.65	1.43	1.44	1.53
Kane	15	2.20	2.57	3.76	2.04	2.52
Kankakee	3	3.92	2.82	1.01	1.52	1.36
Kendall	3	3.23	2.13	2.92	4.47	3.20
Lake	11	1.81	3.54	2.79	2.60	2.95
McHenry	13	1.58	1.14	1.48	1.26	1.36
Will	23	1.77	1.31	1.11	1.75	1.46
Weighted Average	122	1.41	1.85	1.71	2.19	1.66

The weighted average peaking factor for all counties and data years is 1.66. However, because of large variability of peaking factors, the accuracy of the global peaking factor is limited. A better approach would be to use the weighted county-specific peaking factors which are shown in the last column of Table 7.11.

Power Generation Sector

No data on maximum-day withdrawals of self-supplied power plants are collected by the IWIP. Therefore no maximum-day peaking factors could be determined for this sector.

Agriculture and Irrigation Sector

Very limited data on maximum-day withdrawals are available in the IWIP database. The only available data are for golf courses, and country clubs with golf courses. The maximum-day peaking factors derived from the available data are shown in Table 7.12. The data show large variability across the 10 counties with available data.

Table 7.12 Maximum-day Peaking Factors
For Golf Courses and Country Clubs

County	Number of observations	Max-day Peaking Factor
Boone	1	4.06
Cook	33	5.91
DeKalb	1	4.06
Du Page	25	8.60
Grundy	8	3.13
Kane	15	7.31
Kankakee	3	4.35
Lake	58	7.76
McHenry	11	10.71
Will	23	5.22
Total	178	7.11

The weighted average peaking factor for golf course irrigation in all counties and data years is 7.11.

SUMMARY

The available data on seasonal, monthly and daily peaking are used in this chapter to derive peaking factors for major sectors of water use in the 11-county study area in Northeastern Illinois. Table 7.13 lists the global peaking factors which could be derived based on the available data.

Table 7.13 Recommended Global Peaking Factors

Sector	Seasonal Peaking Factor	Monthly Peaking Factor	Max-day Peaking Factor
Public-supply	1.18	1.33	1.91
Industrial and commercial	--	--	1.66
Irrigation and agriculture	3.0	4.7	7.11
Power generation	--	--	--

“ -- ” peaking data were not available.

The global peaking factors represent average peaking ratios which were weighted by water withdrawals of public water supply systems and other entities. These global peaking factors should provide reasonable approximation of future demands during seasons, months, and days of the highest water demand. More accurate estimates of peak demands can be obtained by deriving and applying peaking factors which are site-specific.

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