Chapter 3

Self-supplied Power Generation (PG)

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3.1 Background

Water withdrawn by power plants is classified by the United States Geological Survey (USGS) as thermoelectric generation water use.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.

3.1.1 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 (sensible heat is heat energy transferred between the surface and air when there is a difference in temperature between them). 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 a 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 a somewhat higher 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 a 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 lake, 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.

In wet closed-loop cooling systems, although water *consumption* is higher than in once-through cooling systems, the total volume of water *withdrawals* is reduced by nearly 95 percent as compared to the water withdrawals required for once-through cooling (Harte, 1978). 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 or consumed in the process. The cooled water is collected at the bottom of the tower and is then pumped back to the condenser for reuse. Cooling towers have increasingly been used because they require much lower water withdrawals than once-through cooling systems. However, the total consumptive use of water in closed-loop systems is substantially higher than in once-through systems.

3.1.2 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:

$$L = \frac{6,823\,(1-e)}{Te} \tag{3.1}$$

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 (L) 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 kilowatt hour (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:

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

where

$\frac{c}{c_o}$ = 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:

$$Q = 3,414,426 \cdot P \cdot \frac{1-e}{e} \tag{3.4}$$

where

P = the rated capacity of the plant in MW; and

e = thermodynamic efficiency of plant expressed as a fraction.

3.1.3 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 are left on 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 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 Energy Information Administration (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.

Table 3.1: Average withdrawal rates and evaporative loss rates of cooling water based on Energy Information Administration data.

Description	Withdrawals per unit (gallons/kWh)	Evaporative loss (gallons/kWh)
Once-through systems	44.0	0.2
Recirculating system with ponds	24.0	0.7
Closed-loop w/ cooling towers	1.0	0.7

Source: Dziegielewski and Kiefer, 2006. The values represent weighted (by net generation) average water demand rates.

Generally the energy consumed by generating stations 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 systems of fossil fuel 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).

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. 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).

3.2 Generation and water withdrawals in East-Central Illinois

The USGS National Water Use Information Program reported significant thermoelectric withdrawals from six plants in five of the fifteen counties in East-Central Illinois (Figure 3.1). Table

Table 3.2: Thermoelectric water withdrawals in East-Central Illinois (1990-2005).

County	Water withdrawals (MGD)			
	1990	1995	2000	2005
DeWitt	493.2	709.4	628.3	934.6
Mason	102.8	61.2	84.2	109.4
Sangamon	204.6	307.1	314.3	371.2
Tazewell	765.4	16.3*	38.7*	25.9*
Vermilion	2.8	1.5	2.2	2.7
Total	1,568.8	1,095.5	1,067.7	1,443.8

Source: USGS water reports, various years. Values represent average annual withdrawals in MGD (million gallons per day).
* Values revised by industry to reflect withdrawal from source.
All withdrawals are from surface water sources.

3.2 shows the estimated withdrawals for these five counties during the past four data compilation years: 1990, 1995, 2000 and 2005. Although, relative to the other water sectors, the volume of water withdrawals for power generation is large, it is important to note that much of the water is returned to the source and is available for re-use by others. All of the reported withdrawals for cooling water are from surface water bodies, not groundwater resources. Some of the power plants also have groundwater wells at their facilities, but these are not typically used for cooling water purposes.

The USGS data in Table 3.2 show a significant decline in reported withdrawals between 1990 and 1995 in Tazewell County. This was primarily due to the change in how the withdrawals were reported for the closed-cycle plant located in this county. In 1990, the total amount of water flowing through the condensers was reported. Beginning in 1995, only the amount of make-up water added to the cooling pond from the source water was reported. This more accurately represents the withdrawals and consumptive use for this plant.

The other historical variation in water withdrawals is due to the fluctuation of energy production and the rate of usage (gal/kWh) from year to year.

3.2.1 Electric generation

According to the inventory of electric generators maintained by the EIA, there are 31 generation facilities in the 15-county area of East-Central Illinois (Appendix C). This number includes six

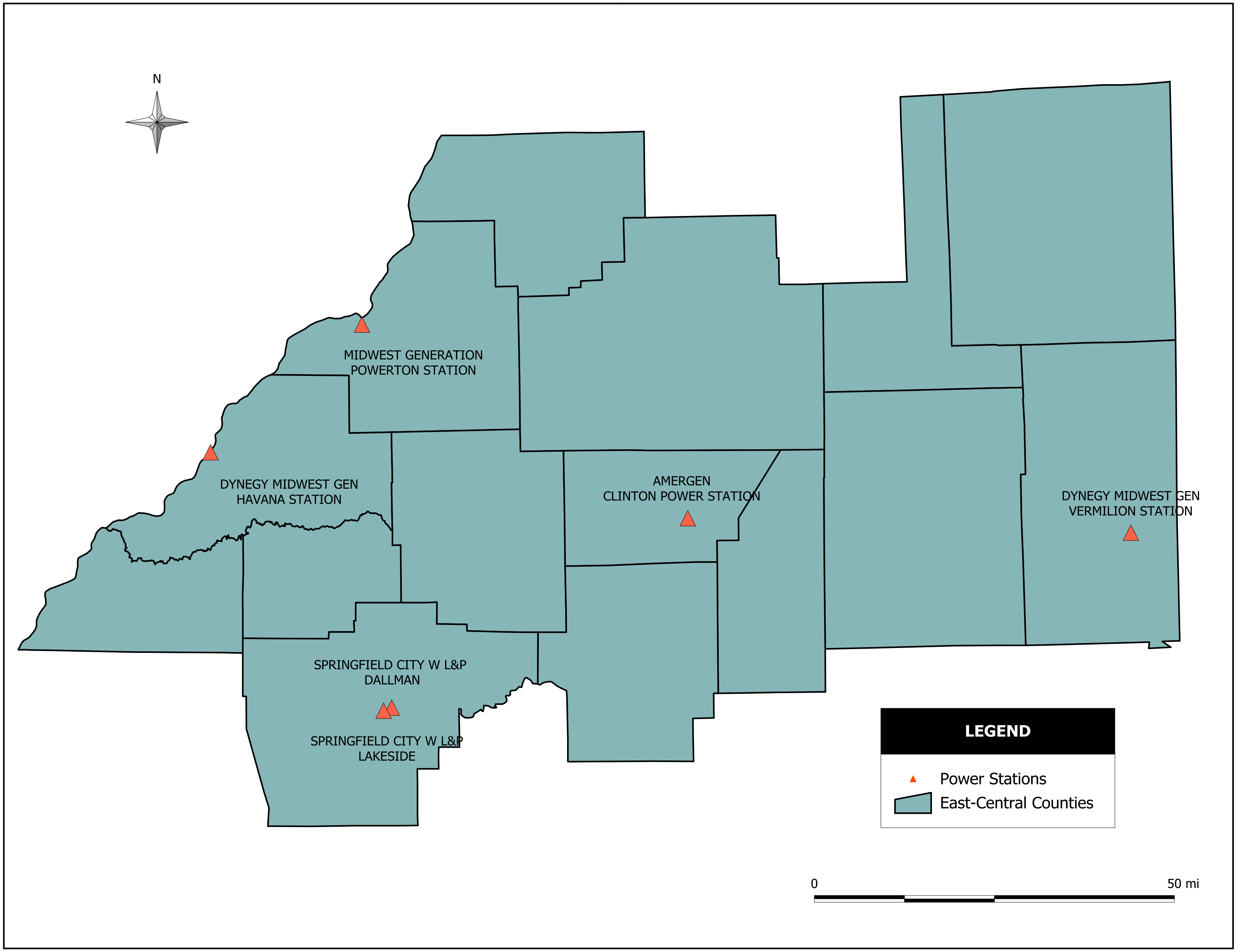


Figure 3.1: Location of six significant thermoelectric power generating plants within the 15-county East-Central Region.

large plants and 25 smaller plants. Total nameplate capacity of the 31 plants is 6,000 MW. Because the smaller plants are not self-supplied, but have water supplied to them by municipalities or other utilities, their water withdrawals are not analyzed in this section of the report but are accounted for within the Public Water Supply Chapter.

The six large power generation plants within the study area have total generation capacity of approximately 4,000 MW. The capacity and generation data for the six large plants in the 15-county study area are listed in Table 3.3. The capacity utilization (also referred to as operational efficiency) is the ratio of the average load on a generating unit to its capacity rating during a specified period of time. In 2005, the capacity utilization ranged from 39 to 96 percent among the individual plants. Average capacity utilization for all six plants was approximately 70 percent.

3.2.2 Reported plant-level withdrawals

Table 3.4 compares gross electricity generation and water withdrawals for the six large power plants. In 2005, the reported water withdrawals totaled 1,315.4 MGD. The 2005 values reported in Table 3.4 differ from the values reported by the USGS in Table 3.2. The values in Table 3.4 reflect the revisions of the plant-level data for 2005 performed for this study. The revisions were made in collaboration with industry representatives and ISWS. The values shown in Table 3.4 are the values used for future estimation of water withdrawals.

The plants in Table 3.4 are separated into two groups: once-through open cycle and closed-loop make-up water intake plants. Once-through flow plants pump water directly to the condensers and almost immediately return it back to the river or lake. Closed-loop make-up water plants withdraw water to replace losses and blowdown in cooling towers and/or water losses 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 once-through plants represents non-consumptive use since nearly all water withdrawn is returned to the source. Withdrawals by closed-loop make-up 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 2005 withdrawals for the once-through flow plants totaled 1,236.71 MGD. Almost all of these withdrawals represent non-consumptive use because the water withdrawn is returned to the source after passing through the condensers.

Total 2005 withdrawals by the three closed-loop make-up water plants were 78.64 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: Capacities and generation in large power plants located in East-Central Illinois.

Plant name/ (Owner)/ Water source	County	Gross capacity (MWe)	2005 Gross generation (MWh/year)	2005 Net generation (MWh/year)	Net/gross generation (%)	Capacity utilization (%)
1. Clinton Plant (Amergen) Clinton Lake	DeWitt	1,030	9,014,690	8,692,074	96.4	96.3
2a. Havana Plant (Dynegy Midwest) Illinois River	Mason	675	3,228,853	2,934,856	90.9	54.6
3. Dallman Plant (City of Springfield) Sangamon River	Sangamon	352	2,328,492	2,084,105	89.5	75.5
4. Lakeside Plant (City of Springfield) Sangamon River	Sangamon	66	229,452	208,452	90.8	39.7
5. Vermilion Plant (Dynegy Midwest) Station Reservoir	Vermilion	177	702,950	633,258	90.1	45.3
6. Powerton Plant (Midwest Generation) Illinois River to Pond	Tazewell	1,697	10,120,133	9,468,947	93.6	68.1
Total/Average		3,977	25,624,570	24,0021,692	93.7	73.2

Comments: Plant capacity and gross and net generation data were obtained from the Energy Information Administration.

Table 3.4: Generation and water withdrawals of large power plants located in East-Central Illinois.

Plant name/ (Owner)/ Water source	County	2005 Gross generation (MWh/year)	2005 Water withdrawals (MGD)	Estimate 2005 rate of usage (gal/kWh)
ONCE-THROUGH PLANTS				
1. Clinton Plant (Amergen) Clinton Lake	DeWitt	9,014,690	810.44	32.8
2a. Havana Plant #1-5 (Dynegy Midwest) Illinois River	Mason	33,960	55.00	591.1
3. Dallman Plant (City of Springfield) Sangamon River	Sangamon	2,328,492	328.10	51.4
4. Lakeside Plant (City of Springfield) Sangamon River	Sangamon	229,855	43.17	68.6
	Total/average	11,606,997	1,236.71	38.9
CLOSED-LOOP PLANTS				
2b. Havana Plant #6 (Dynegy Midwest) Illinois River	Mason	3,194,890	50.00	5.71
5. Vermilion Plant (Dynegy Midwest) Station Reservoir	Vermilion	702,950	2.76	1.43
6. Powerton Plant (Midwest Generation) Illinois River to Pond	Tazewell	10,120,133	25.88	0.93
	Total/average	14,017,973	78.64	2.18
ALL PLANTS TOTALS		25,624,970	1,315.35	–

Sources: Water withdrawals are based on self-supplied water quantities reported to the Illinois State Water Survey. Gross generation data were obtained from Energy Information Administration.

As shown in Table 3.4, the ratios of annual withdrawals to gross electricity generation ranged from 32.8 to 591.1 gallons/kWh for once-through cooling plants. For closed-loop systems, the ratios ranged from 0.93 to 5.7 gallons/kWh.

The estimates of future water demands for electric power generation in the 15-county study are based on the generation ability and cooling water needs of the six large plants shown in Table 3.4. The method of future estimation and the assumptions used are discussed in more detail in Section 3.4.

3.3 Water-withdrawal relationships

A straightforward unit-coefficient method was used in this study to derive future quantities of water withdrawals. This method represents cooling 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.

3.3.1 Once-through cooling systems

Previous studies of water demand 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 et al., 2006, Xiaoying and Dziegielewski, 2007). However, for the purpose of this study, the usefulness of the published water-use relationships is somewhat limited because the water-use equations are derived from the data reported on the EIA-767 Steam Electric Plant Operation and Design Report which include only net electric generation. More precise estimation methods for cooling water withdrawals can be derived using gross generation. The relationship between gross generation and water withdrawals is described below.

The data in Table 3.4 include water withdrawals and gross generation in four plants with once-through open-loop systems in the study area. Figure 3.2 shows a plot of the reported water withdrawals versus gross generation for seven once-through open loop plants in Northeastern Illinois together with the four plants in East-Central Illinois. The seven Northeastern plants were included in order to examine a general relationship between water withdrawals and gross generation.

The regression line which is fitted to the 11 data points shows a correlation of 0.993 (and R^2 of 0.986). The R^2 coefficient indicates that 98.6 percent of variance in total withdrawals among the

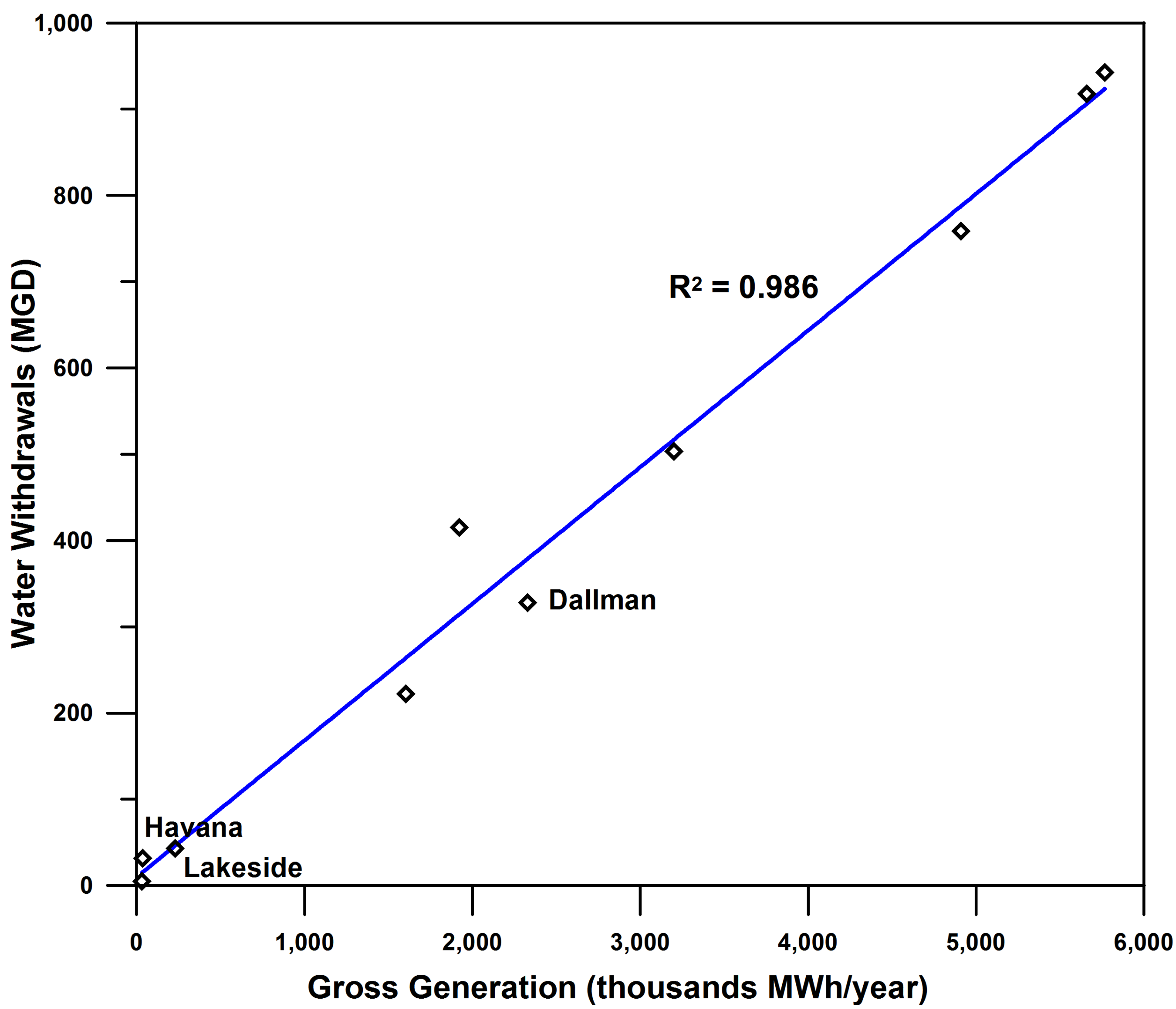


Figure 3.2: Relationship between total water withdrawals and gross generation for eleven once-through plants in East-Central and Northeastern Illinois

11 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 (e.g., Dziegielewski et al., 2002; Dziegielewski and Bik, 2006).

The slope of the regression line on Figure 3.2 is 57.8 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 four once-through plants, the actual unit withdrawals shown on Table 3.4 were used.

3.3.2 Closed-loop cooling systems

In the group of closed-loop make-up water plants, three plants (Havana #6, Vermilion and Powerton), use closed-loop cooling systems. The estimates of water withdrawals in these closed-loop plants are 5.71, 1.43, and 0.93 gallons/kWh, respectively. These unit-values were used in determining future water withdrawals.

3.4 Future demand for electricity

It is reasonable to expect that the future demand for electricity within the 15-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. There is no accurate or predictable correlation between local demand for power and local generation, both now and in the future, due to the nature of the electric power market. Increasing future electric demand may not be met by the six plants currently within the study area. The demand may be met with power generated outside the study area, or with power generated inside the study area by alternate means, such as gas turbines, wind turbines, solar, etc. As such, there is no way to predict or estimate where additional sources of power to serve the 15-county area will come from in the next five, let alone the next 42 years (2050). New and developing technologies will likely play a large part in how electric demand will be handled, but there are no current plans from which to develop any plausible scenarios regarding future water demand by the industry. All told, these unknowns make the development of likely future water demand scenarios involving the electric power industry difficult to specify or even generally conceptualize. Regardless of the difficulty in determining future power demand in East-Central Illinois and the sources for that power, it is necessary for the purpose of water-supply planning to account for current withdrawals and to estimate future withdrawals for the power generation sector. In this report, using the data available, we provide three possible scenarios for future power generation water withdrawals. The assumptions for these scenarios are provided in the following sections.

For the purposes of this report, 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 Illinois and the U.S. The data is derived by dividing total sales of electricity by estimated population served.

Using the data in Table 3.5, the estimate of 10.77 MWh per capita per year was chosen as the best approximation of electricity use in the 15-county study area. This estimate is lower than the nation-wide rates reported by the EIA (12.33 MWh/capita/year for the U.S.) yet higher than the per capita reported by the Illinois Commerce Commission (ICC).

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. For developing future scenarios both the constant rate and increasing annual growth rate of 0.56% were assumed in deriving estimates of future demand for electricity within the 15-county study area. The estimates of the future demand for electricity during the 2005-2050 period are shown in Table 3.6.

The baseline estimates in Table 3.6 indicate that total demand for electricity would be expected to increase from 11,284,548 MWh/year in 2005 to 14,466,542 MWh in 2050. Assuming increasing per capita demand, by 2050, total demand for electricity would increase by 7,314,968 MWh or by 65 percent above the 2005 level.

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." The assumption related to energy conservation is incorporated in the "less resource intensive" scenario.

3.5 Scenarios

The three future scenarios are designed to capture future conditions of water withdrawals for electric power generation under three different sets of conditions. The scenarios include a baseline scenario, a less resource intensive outcome, and a more resource intensive outcome. The assump-

Table 3.5: Estimation of per capita generation and consumption of electricity.

Source and data year	Electrical use (MWh/capita/year)	Comments
Illinois Commerce Commission (ICC), 2006	10.14	State-wide electricity sales and number of customers served
Energy Information Administration (EIA), 2005	10.77	Illinois average
Energy Information Administration (EIA), 2005	12.33	U.S. average

Table 3.6: Population-based estimates of future demand for electricity in East-Central Illinois.

Year	Resident population in 15-County Area	Estimated electricity demand[a] (MWh/year)	Electricity demand with growth[b] (MWh/year)
2005	1,047,776	11,284,548	11,284,548
2010	1,085,502	11,690,857	12,021,887
2015	1,123,080	12,095,572	12,790,250
2020	1,165,718	12,554,783	13,651,745
2025	1,199,724	12,921,027	14,447,821
2030	1,221,729	13,158,021	15,129,417
2035	1,250,916	13,472,361	15,929,482
2040	1,280,879	13,795,067	16,772,897
2045	1,311,641	14,126,378	17,662,063
2050	1,343,226	14,466,542	18,599,516

[a]The estimated electricity demand is obtained by multiplying the 15-county resident population by per capita use of electricity of 10.77 MWh per year.

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

Note: Due to the nature of the market, local electricity demand is not related to local energy production.

tions used in the formulation of each scenario are described below.

As discussed in Section 3.4, due to the nature of the power generation market, there is no accurate or predictable correlation between local demand and local energy production. Therefore, in all scenarios, it is assumed that the plants will remain at their 2005 rates of usage (with the stated exceptions).

3.5.1 Scenario 1 - Baseline (BL)

Under the baseline scenario (BL), future generation of electricity in the 15-county study area will continue in the existing six power plants with the exception that the electric generator units which are scheduled to be retired will be retired. One new plant, Dallman 4, with a capacity of 200 MW will be completed by 2010 in Springfield, Illinois and will replace the Lakeside Plant to be retired, which has a capacity of only 76 MW. The new Dallman 4 Plant will use pulverized coal and a cooling system with cooling towers instead of once-through cooling.

Based on power industry comments regarding the formulation of scenarios presented in the reviews of the draft report, the BL 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 3.4.

New demands for electricity within the study area are assumed to be met by higher utilization of the locally generated power in the five existing plants plus Dallman 4 as well as importing electricity from outside of the study area. For example, the Springfield City Water Light and Power (CWLP) has already entered into two 10-year contracts with FPL Energy for the purchase of 120 megawatts (MW) of wind power, which will be produced at FPL's Hancock and Osceola Wind Farms located in Northern Iowa. With the capacity factor for wind turbine plants in the range of 20 to 40 percent, the total amount of energy at the midpoint capacity of 30 percent would be 315,360 MWh per year.

For the purpose of the BL scenario it is assumed that no new thermoelectric plants will be built to meet the future increases in demand for electricity.

The specific assumptions for the Baseline Scenario are:

1. Future demand for electricity in the study area will grow in proportion to population growth at the rate of 10.77 MWh/capita/year plus an annual increase in per capita use of 0.56 percent.

2. Two generating units in the Lakeside Plant will be retired as scheduled and replaced by the newly constructed Dallman 4 Plant.

3. New demand for electricity will be met by obtaining more power from the existing five plants plus the new Dallman 4 Plant and also importing some power from outside the 15-county study area.

3.5.2 Scenario 2 - Less resource intensive (LRI)

The intent of this scenario is to define future conditions which would lead to less water withdrawals by power generation sector. Such an outcome would result if some of the existing plants would convert from once-through open-cycle cooling systems to closed-loop water plants with cooling towers (although this would result in higher overall water *consumption*). However, a review of the current supply sources to determine which of the two once-through plants might implement retrofits with cooling towers showed that neither plant is a realistic candidate for such a conversion. Therefore, we assumed, for this scenario, that in the future some of the older generator units may be used less because of the high cost of their operation.

We chose the oldest of all of the generators and assumed that in the future they would be put on standby. The oldest generators in the region are Units #1 through #5 at the Havana Plant built between 1947 and 1950 and Units #1 and #2 at the Vermilion Plant built in 1955 and 1956. These units are assumed to fall into the high operating cost category. Therefore, water withdrawals by these 7 generating units were assumed to decline as the units would possibly be placed on standby in the future. It should be noted here that none of the companies have current plans to change their operations of existing units; these reductions are assumed for the sole purpose of formulating the LRI scenario. The generators were chosen specifically due to their age, not any other reason.

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 demand for electricity will follow population growth at the rate of 10.77 MWh/capita/year.

2. The future increase in electricity consumption not provided by local plants will be met by importing electricity from outside the 15-county area.

3. Two generating units in the Lakeside Plant will be retired as scheduled and replaced by the newly constructed Dallman 4 Plant.

4. The generation in the existing five plants will maintain production at the current levels of capacity utilization with the exception of the five older units at Havana Plant and two older units at Vermilion Plant. The one new plant, Dallman 4, will be run at a capacity utilization of 75%.

5. The five older units at the Havana Plant (Units #1 to #5) were assumed to be gradually put on standby between 2020 and 2040.

6. The two older units at Vermilion Plant were assumed to by placed on standby by 2020 (Unit #1) and by 2035 (Unit #2).

3.5.3 Scenario 3 - More resource intensive (MRI)

The intent of the MRI scenario is to define future conditions which would lead to more water withdrawals by the power generation sector. Higher water demand in terms of water withdrawals will result if new power plants are built in the 15-county study area.

According to the comments of the power industry representatives, there are no current plans for constructing new power plants, other than Dallman 4, 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 one clean coal power plant with gross capacity of 650 MW would be constructed within the 15-county study area during the later years of the planning horizon. The new plant could be built in Woodford County on the Illinois River or in another county with a large cooling/storage pond that would receive make-up water from the Sangamon River, Salt Creek, or lower Mackinaw River. For this scenario, we assumed the new plant will be built in Woodford County on the Illinois River and will use river water only as make-up 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 10.77 MWH/capita/year plus an annual increase in per capita use of 0.56 percent.

2. Two generating units in the Lakeside Plant will be retired as scheduled and replaced by the newly constructed Dallman 4 Plant.

3. The generation in existing five plants will continue at the current levels of capacity utilization. The one new plant, Dallman 4, will be run at a capacity utilization of 75%.

4. New demand for electricity will be met by constructing one new clean coal power plant with a closed-loop cooling system in Woodford County with gross capacity of 650 MW.

3.6 Results

Figure 3.3 summarizes the total historical and estimated future water withdrawals for each of the scenarios. The historical fluctuation in water withdrawals is due to differences in energy production and rates of water usage from year to year. Future withdrawals were estimated using the 2005 rate of usage (gal/kWh) along with the previously discussed assumptions. The overall change in the Baseline Scenario, -3.0%, is due to the replacement of the Lakeside Plant with the Dallman 4 Plant in Sangamon County. This change also occurs in the LRI and MRI Scenarios. The LRI Scenario, additionally decreases due to the older generation units being put on standby (total of -7.4% change). The MRI Scenario, increases by 2.0% with the addition of a new plant in Woodford County.

It is important to note that while the thermoelectric power generation sector 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.

The results for each of the three scenarios on water withdrawals are also summarized in Tables 3.7-3.9. Under the baseline scenario, the future water withdrawals for power generation would decline by 39.8 MGD in 2010 when the Lakeside Plant is retired and the new Dallman 4 Plant comes on line (Table 3.7). After 2010, total withdrawals would remain unchanged as the level of generation in the existing plants and utilization of existing capacity remain unchanged. Because the Lakeside Plant with once-through cooling system would be replaced with the Dallman 4 Plant with a cooling tower, total once-through withdrawals would decline by 43.2 MGD and closed-loop make-up water withdrawals would increase by 3.4 MGD (for a net change of 39.8 MGD). Overall, between 2005 and 2050, under the BL scenario, total withdrawals would decline by 39.8 MGD or 3.0 percent.

In the LRI scenario, following the decline in 2010 when the Lakeside Plant is retired and the new Dallman 4 Plant comes online, the level of once-through water withdrawals would additionally decline by 57.7 MGD after the older Havana (Units #1-5) and Vermilion (Units #1-2) units are put on stand by (Table 3.8). Between 2020 and 2040, the total water withdrawals are reduced approximately 11-13 MGD per 5-year increment due to the units put on stand by. Overall, between 2005 and 2050, under the LRI scenario, total withdrawals would decline by 97.6 MGD or 7.4 percent.

In the MRI scenario, the assumed addition of one clean coal plant with closed-loop cooling

Table 3.7: Electric power generation and water withdrawals for Baseline (BL) Scenario in East-Central Illinois.

Year	Once-through plants		Closed-loop water plants		All plants	
	Generation (MWh/year)	Withdrawals (MGD)	Generation (MWh/year)	Withdrawals (MGD)	Generation (MWh/year)	Withdrawals (MGD)
2005	11,606,997	1,236.7	14,017,973	78.6	25,624,970	1,315.4
2010	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2015	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2020	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2025	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2030	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2035	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2040	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2045	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2050	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
Difference from 2005 to 2050						
Unit	-229,855	-43.2	1,314,000	3.4	1,084,145	-39.8
Percent %	-2.0	-3.5	9.4	4.3	4.2	-3.0

MWh/year = mega watt hour per year; MGD = million gallons per day

would increase make-up water demand by 66.8 MGD in 2030 (Table 3.9). Once-through flow withdrawals would decline by 43.2 MGD after the retirement of Lakeside Plant by 2010 and would remain unchanged after 2010. The sum effect would be that the total withdrawals would increase by 26.9 MGD or 2.0 percent between 2005 and 2050.

Table 3.10 shows the future withdrawals for power generation for the five counties with power plants plus new generation (in the MRI scenario) in Woodford County. Figures 3.4-3.6 show the historical and future withdrawals for the power plants for the baseline scenario.

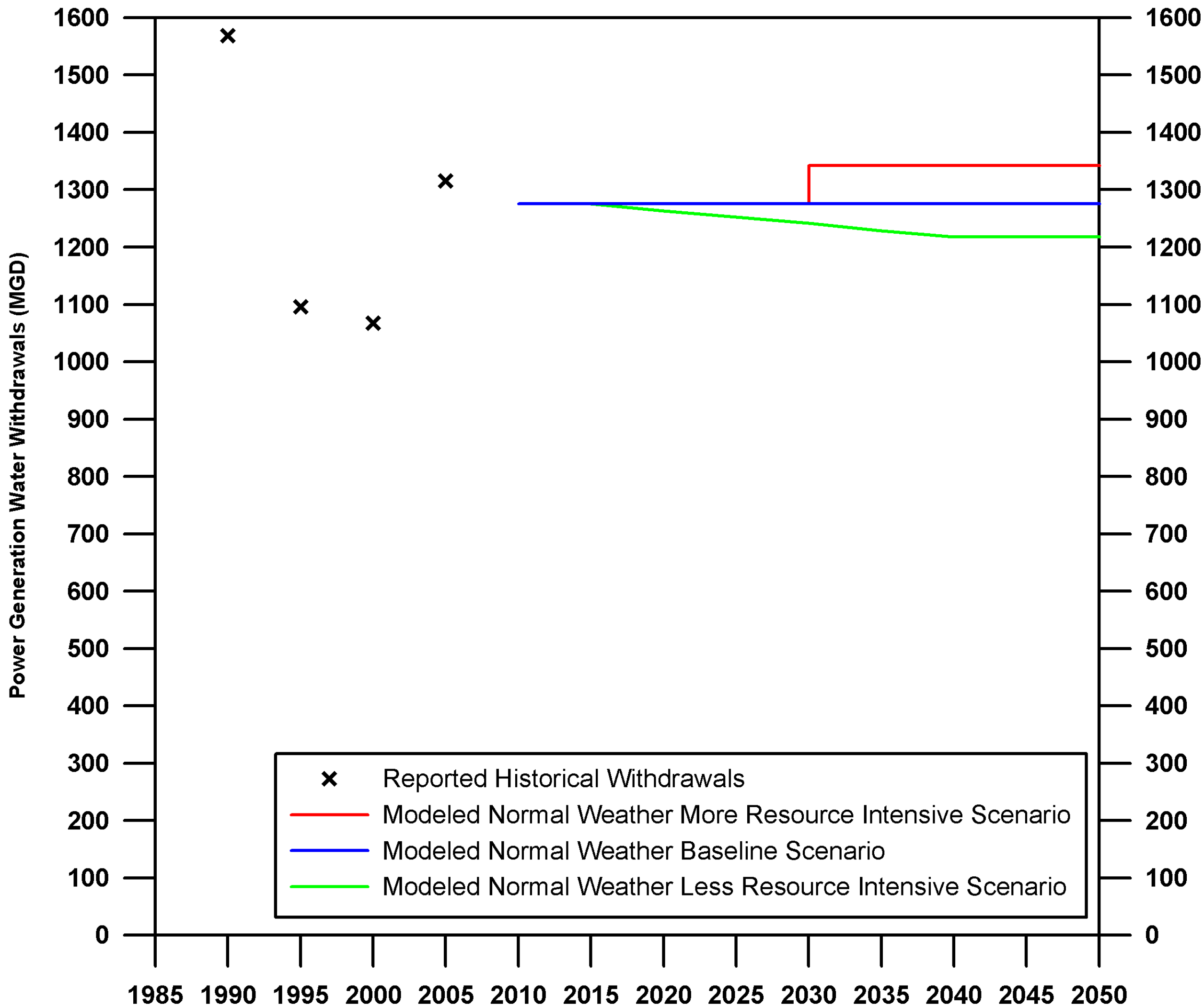


Figure 3.3: Historical and future thermoelectric water withdrawals for the baseline scenario, the less resource intensive scenario, and the more resource intensive scenario for East-Central Illinois.

Note: Future withdrawals were estimated using the 2005 rate of usage (gal/kWh). The historical fluctuation in water withdrawals is due to differences in energy production and rate of usage from year to year. Large discrepancy in withdrawals between 1990 and other years, in part, due to change in reporting from Tazewell County Plant in 1995. See Section 3.2 for further explanation.

Table 3.8: Electric power generation and water withdrawals for less resource intensive (LRI) scenario in East-Central Illinois.

Year	Once-through plants		Closed-loop water plants		All plants	
	Generation (MWh/year)	Withdrawals (MGD)	Generation (MWh/year)	Withdrawals (MGD)	Generation (MWh/year)	Withdrawals (MGD)
2005	11,606,997	1,236.8	14,017,973	78.6	25,624,970	1,315.4
2010	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2015	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2020	11,370,350	1,182.5	15,034,113	80.8	26,404,463	1,263.4
2025	11,363,558	1,171.5	15,034,113	80.8	26,397,671	1,252.4
2030	11,356,766	1,160.5	15,034,113	80.8	26,390,879	1,241.4
2035	11,349,974	1,149.5	14,629,023	79.2	25,978,997	1,228.8
2040	11,343,182	1,138.5	14,629,023	79.2	25,972,205	1,217.8
2045	11,343,182	1,138.5	14,629,023	79.2	25,972,205	1,217.8
2050	11,343,182	1,138.5	14,629,023	79.2	25,972,205	1,217.8
Difference from 2005 to 2050						
Unit	-263,815	-98.2	611,050	0.6	347,235	-97.6
Percent %	-2.3	-7.9	4.4	0.8	1.4	-7.4

MWh/year = mega watt hour per year; MGD = million gallons per day

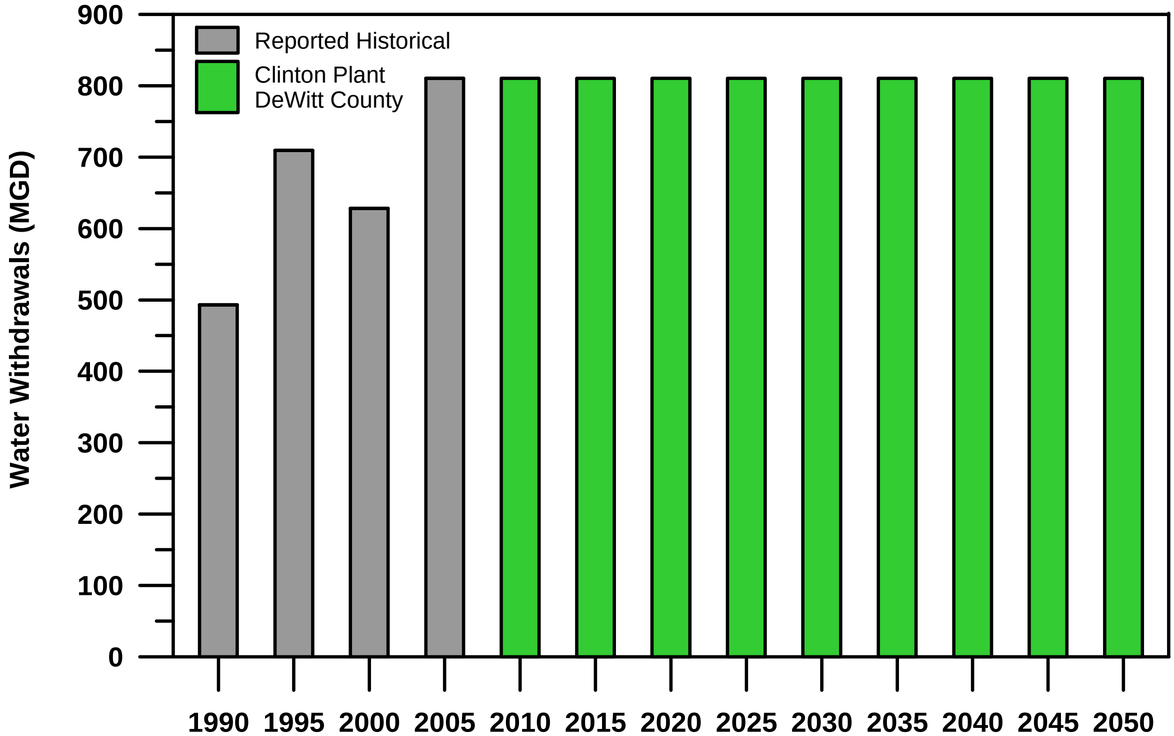
Table 3.9: Electric power generation and water withdrawals for more resource intensive (MRI) scenario in East-Central Illinois.

Year	Once-through plants		Closed-loop water plants		All plants	
	Generation (MWh/year)	Withdrawals (MGD)	Generation (MWh/year)	Withdrawals (MGD)	Generation (MWh/year)	Withdrawals (MGD)
2005	11,606,997	1,236.8	14,017,973	78.6	25,624,970	1,315.4
2010	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2015	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2020	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2025	11,377,142	1,193.5	15,331,973	82.0	26,709,115	1,275.5
2030	11,377,142	1,193.5	19,602,473	148.8	30,979,615	1,342.4
2035	11,377,142	1,193.5	19,602,473	148.8	30,979,615	1,342.4
2040	11,377,142	1,193.5	19,602,473	148.8	30,979,615	1,342.4
2045	11,377,142	1,193.5	19,602,473	148.8	30,979,615	1,342.4
2050	11,377,142	1,193.5	19,602,473	148.8	30,979,615	1,342.4
Difference from 2005 to 2050						
Unit	-229,855	-43.2	5,584,500	70.2	5,354,645	26.9
Percent %	-2.0	-3.5	39.8	89.3	20.9	2.0

MWh/year = mega watt hour per year; MGD = million gallons per day

Table 3.10: Electric power generation and water withdrawals in East Central Illinois.

County	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BL - Baseline Scenario										
DeWitt	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4
Mason	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
Sangamon	371.3	331.5	331.5	331.5	331.5	331.5	331.5	331.5	331.5	331.5
Tazewell	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
Vermilion	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Woodford	-	-	-	-	-	-	-	-	-	-
Total study area	1,315.4	1,275.5	1,275.5	1,275.5	1,275.5	1,275.5	1,275.5	1,275.5	1,275.5	1,275.5
LRI - Less Resource Intensive Scenario										
DeWitt	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4
Mason	105.0	105.0	105.0	94.0	83.0	72.0	61.0	50.0	50.0	50.0
Sangamon	371.3	331.5	331.5	331.5	331.5	331.5	331.5	331.5	331.5	331.5
Tazewell	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
Vermilion	2.8	2.8	2.8	1.6	1.6	1.6	0.0	0.0	0.0	0.0
Woodford	-	-	-	-	-	-	-	-	-	-
Total study area	1,315.4	1,275.5	1,275.5	1,263.4	1,252.4	1,241.4	1,228.8	1,217.8	1,217.8	1,217.8
MRI - More Resource Intensive Scenario										
DeWitt	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4	810.4
Mason	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
Sangamon	371.3	331.5	331.5	331.5	331.5	331.5	331.5	331.5	331.5	331.5
Tazewell	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
Vermilion	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Woodford	-	-	-	-	-	73.5	73.5	73.5	73.5	73.5
Total study area	1,315.4	1,275.5	1,275.5	1,275.5	1,275.5	1,342.4	1,342.4	1,342.4	1,342.4	1,342.4



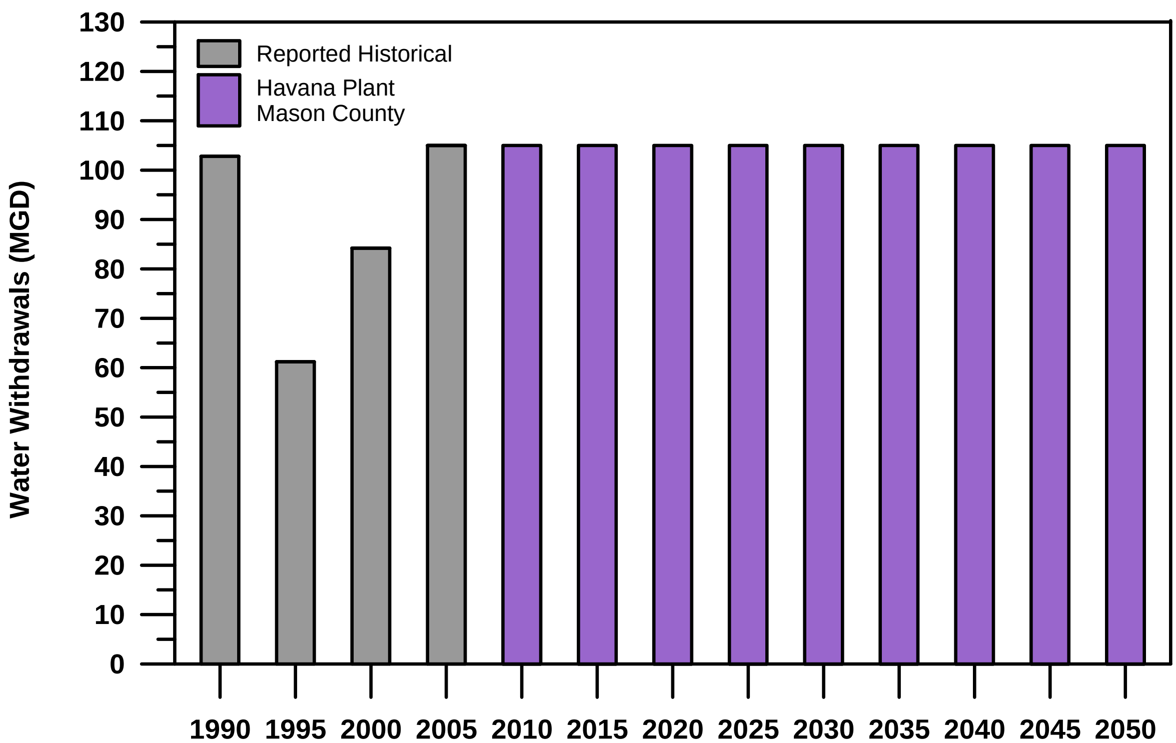
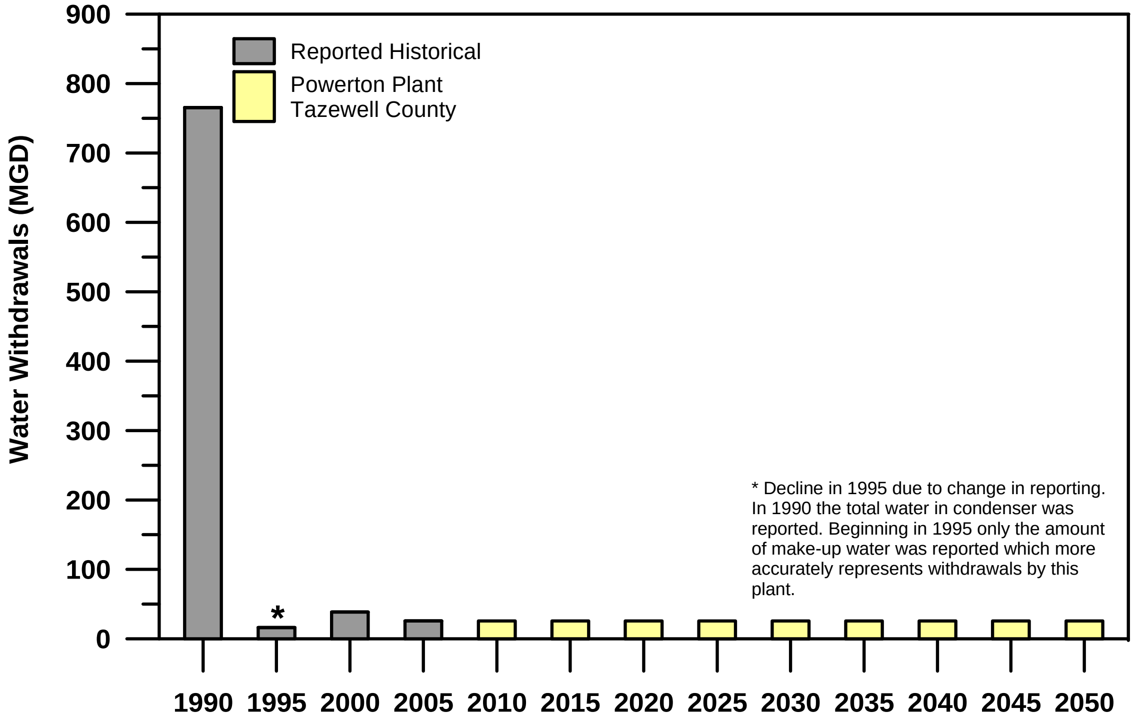


Figure 3.4: Historical and future power generation water withdrawals from the baseline scenario for the Clinton and Havana plants.



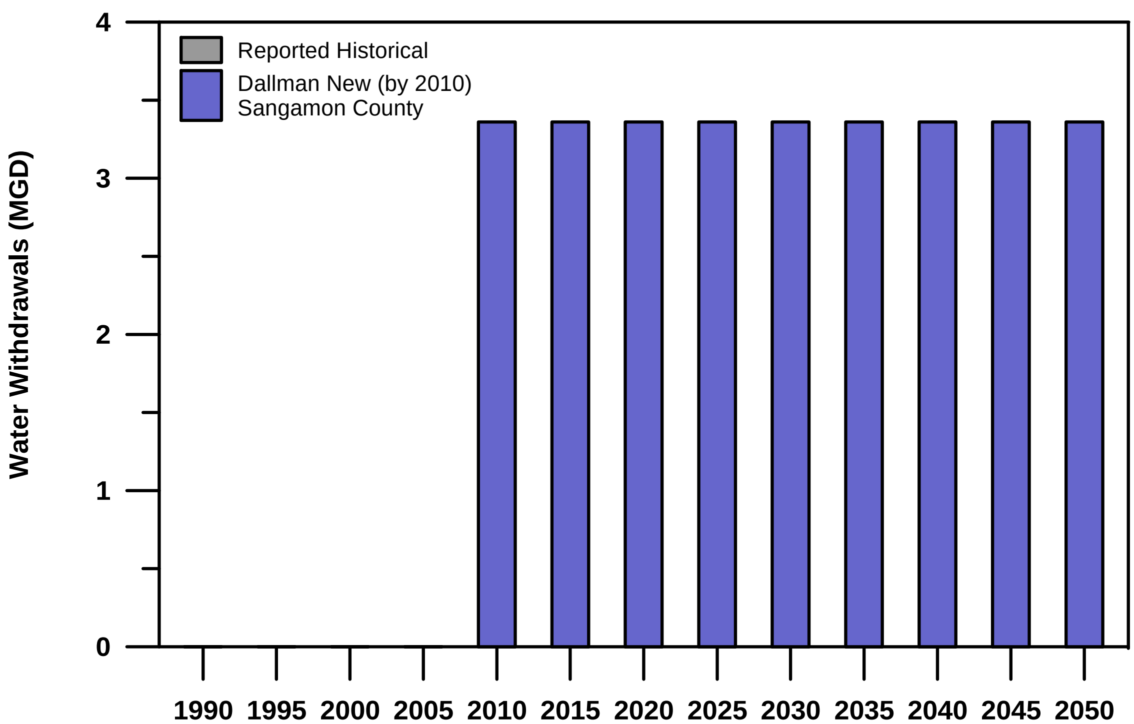
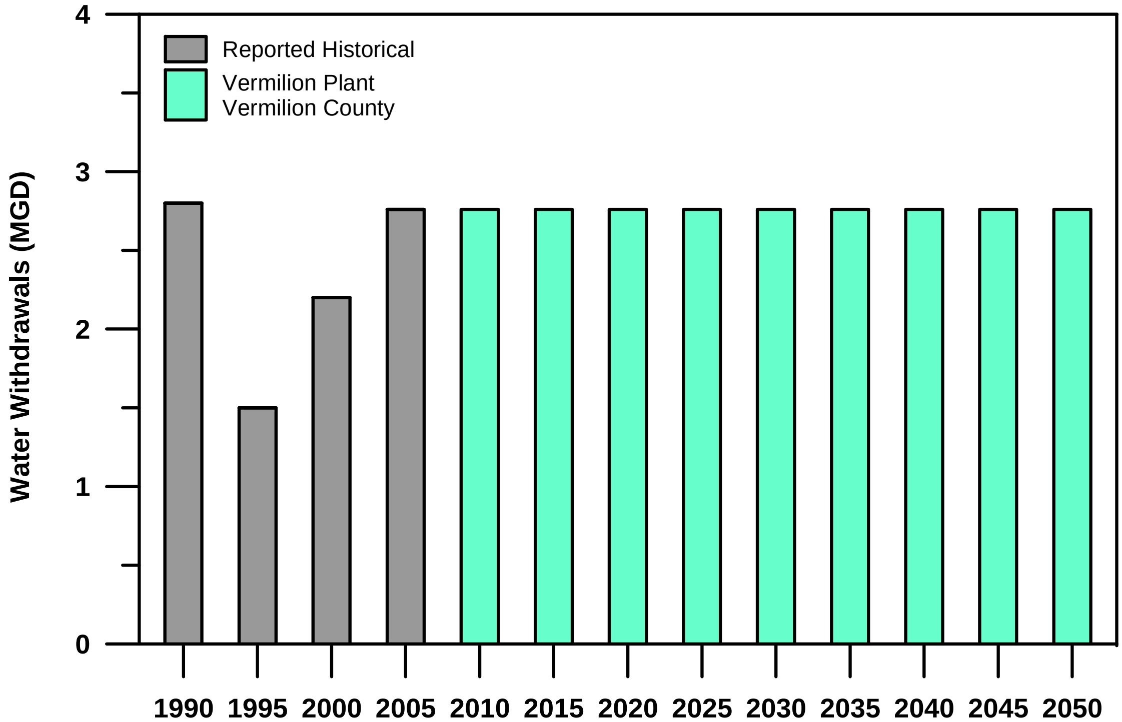


Figure 3.5: Historical and future power generation water withdrawals from the baseline scenario for the Powerton and Dallman (new) plants.



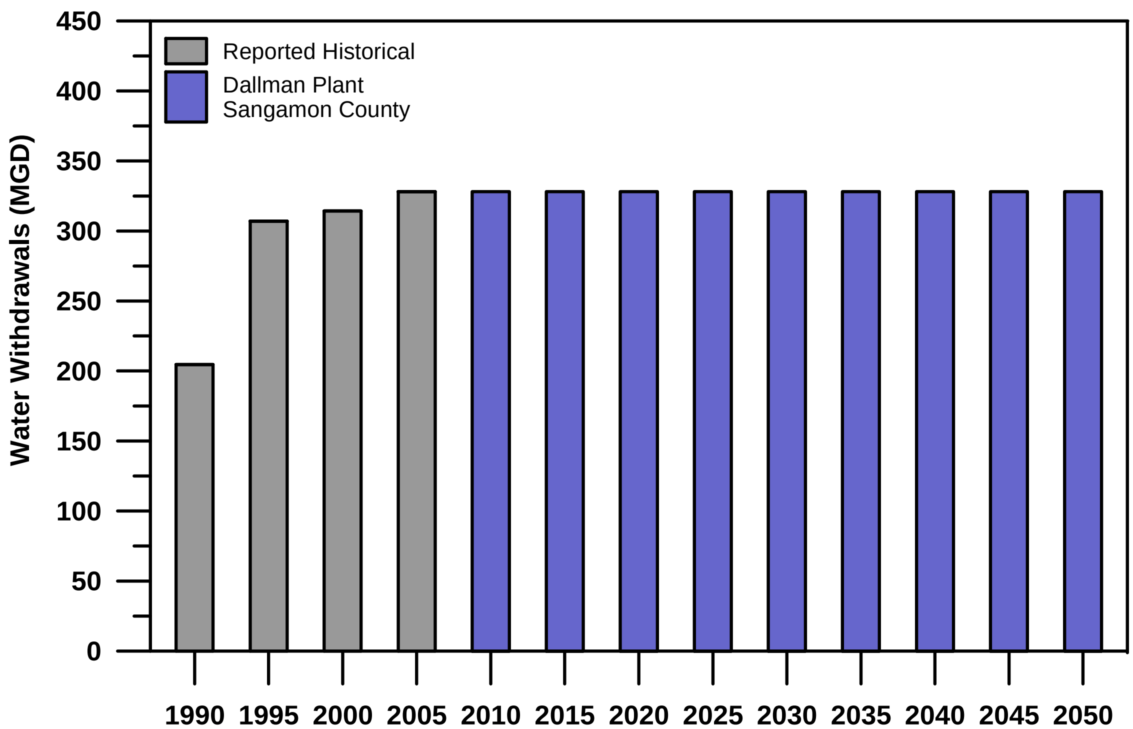


Figure 3.6: Historical and future power generation water withdrawals from the baseline scenario for the Vermilion and Dallman (existing) plants.

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