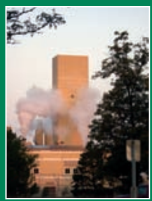
National Water Availability and Use Program

Variations in Withdrawal, Return Flow, and Consumptive Use of Water in Ohio and Indiana, with Selected Data From Wisconsin, 1999–2004








Scientific Investigations Report 2009–5096

U.S. Department of the Interior
U.S. Geological Survey

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By Kimberly H. Shaffer

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KEN SALAZAR, Secretary

U.S. Geological Survey
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Conversion Factors and Abbreviations

Multiply	By	To obtain
	Volume	
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
billion gallons (Ggal)	0.3785	cubic hectometer (hm^3)
	Rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
billion gallons per day (Ggal/d)	43.81	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C = (°F-32)/1.8

Electricity-generation rates are given in kilowatthours (kWh) and gigawatthours (GWh).

Additional abbreviations used in this report

GLC	Great Lakes Commission
HUC	Hydrologic Unit Code
IDNR	Indiana Department of Natural Resources
IJC	International Joint Commission
IQR	Interquartile range
ODNR	Ohio Department of Natural Resources
NAICS	North American Industrial Classification System
Nonmetallic mining	Mining and quarrying of Nonmetallic Minerals, except fuels
SIC	Standard Industrial Classification
Summer months	Months May through October
USGS	U.S. Geological Survey
Winter months	Months November through April

Variations in Withdrawal, Return Flow, and Consumptive Use of Water in Ohio and Indiana, with Selected Data From Wisconsin, 1999–2004

By Kimberly H. Shaffer

Abstract

This report contains an analysis of water withdrawal and return-flow data for Ohio and withdrawal data for Indiana and Wisconsin to compute consumptive-use coefficients and to describe monthly variability of withdrawals and consumptive use. Concurrent data were available for most water-use categories from 1999 through 2004. Average monthly water withdrawals are discussed for a variety of water-use categories, and average water use per month is depicted graphically for Ohio, Indiana, and Wisconsin (public supply only).

For most water-use categories, the summer months were those of highest withdrawal and highest consumptive use. For public supply, average monthly withdrawals ranged from 1,380 million gallons per day (Mgal/d) (November) to 1,620 Mgal/d (July) in Ohio, 621 Mgal/d (December) to 816 Mgal/d (July) in Indiana, and 515 Mgal/d (December) to 694 Mgal/d (July) in Wisconsin. Ohio and Indiana thermoelectric facilities had large increases in average monthly withdrawals in the summer months (5,520 Mgal/d in March to 7,510 Mgal/d in August for Indiana; 7,380 Mgal/d in February to 10,040 Mgal/d in July for Ohio), possibly because of increased electricity production in the summer, a need for additional cooling-water withdrawals when intake-water temperature is high, or use of different types of cooling methods during different times of the year. Average industrial withdrawals ranged from 2,220 Mgal/d (December) to 2,620 Mgal/d (August) in Indiana and from 707 Mgal/d (January) to 787 Mgal/d (August) in Ohio. The Ohio and Indiana irrigation data showed that most withdrawals were in May through October for golf courses, nurseries, and crop irrigation. Commercial water withdrawals ranged from 30.4 Mgal/d (January) to 65.0 Mgal/d (September) in Indiana and from 23.2 Mgal/d (November) to 49.5 Mgal/d (August) in Ohio; commercial facilities that have high water demand in Ohio and Indiana are medical facilities, schools, amusement facilities, wildlife facilities, large stores, colleges, correctional institutions, and national security facilities. Monthly livestock withdrawals were constant for Ohio but were more variable in Indiana and depended on whether the livestock facility operated on a seasonal schedule. Aquaculture withdrawals appeared to correlate with growing seasons and with aeration of ponds during the winter months. Mining withdrawals—specifically, those for nonmetallic mining—tended to be highest in April and may be related to dewatering.

Consumptive use and consumptive-use coefficients were computed by two principal methods in this study: the return-flow and withdrawal method (RW; Ohio only) and the winter-base-rate method (WBR; Ohio, Indiana and Wisconsin). The WBR method was not suitable for the thermoelectric, industrial, irrigation, livestock, aquaculture, and mining water-use categories. The RW method was not used for public-supply facilities. A third method, the Standard Industrial Classification code method (SIC), was used only for certain industrial facilities. The public-supply annual average consumptive-use coefficient derived by use of the WBR methods ranged from 6 to 8 percent among Ohio, Indiana, and Wisconsin; the summer average consumptive-use coefficient was considerably higher, ranging from 16 to 20 percent. The commercial annual consumptive-use coefficient for both Ohio and Indiana was 30 percent by the WBR method, which fell within the Ohio annual median (17 percent) and annual average (42 percent) by the RW method. Thermoelectric consumptive use differs greatly by the type of cooling the facility uses; the Ohio annual median consumptive-use coefficient (RW method) was 2 percent for all thermoelectric facilities and facilities with multiple types of cooling, but exclusively once-through-cooling facilities had a median of 0 percent and exclusively closed-loop-cooling facilities had a median of 25 percent. Industrial consumptive-use coefficients varied by type of industry, as reflected by SIC code; overall, the median annual consumptive-use coefficient for Ohio was 10 percent by the RW method and 11 percent for Indiana and 12 percent for Ohio by the SIC code method. Irrigation consumptive-use coefficients were computed for Ohio golf course irrigation (annual median of 77 percent) and nursery and crop irrigation (annual median of 78 percent), but the number of records available for analysis represented only a small proportion of the total number of facilities. The RW method was also used for livestock, aquaculture, and mining water-use categories—but again, only

relatively few records were available; the Ohio median annual consumptive-use coefficient for livestock was 76 percent (18 records), for aquaculture was 0 percent (33 records), and for mining was 10 percent (418 records).

In terms of maximum accuracy and minimal uncertainty, use of available withdrawal, return-flow, and consumptive-use data reported by facilities and data estimated from similar facilities are preferable over estimates based on data for a particular water-use category or groups of water-use categories. If monthly withdrawal, return flow, and consumptive use data are few and limited, monthly patterns described in this report may be used as a basis of estimation, but the level of uncertainty may be a greater than for the other estimation methods.

Introduction

Refinement of consumptive-use data and coefficients for estimating consumptive use is an area of great interest and value to water-supply managers in the United States and in the **Great Lakes Basin**[1] in particular (Grannemann and Reeves, 2005). **Consumptive use** is that part of water withdrawn that is no longer available because of **evaporation, transpiration, product incorporation**, incorporation into crops, human consumption, **livestock consumption** or is otherwise removed from the immediate water environment (such as a specific water body, a regional surface or groundwater source, or an entire basin). Water-resource planners and managers, who use data on **withdrawal, return flows**, and consumptive water use to understand the effect of human use of water on the hydrologic system, seek to further understand how they can use this information and what studies could be done to refine and remove some of the uncertainty about consumptive-use coefficients—thus resulting in improved management of water use.

This report is one in a series by the U.S. Geological Survey's National Water Availability and Use Program, a program designed to gain a better understanding of the water-use, land-use, and climatic trends that affect our Nation's water resources. Patterns uncovered in this report for consumptive use and seasonal variations of withdrawals may be used where data on consumptive use or other estimation procedures are lacking. A previous report in the series (Shaffer and Runkle, 2007) summarized previously published consumptive-use coefficients for the Great Lakes States and climatically similar states. In this report, information in databases of water-resource agencies in Ohio, Indiana, and Wisconsin was used to examine monthly variation in consumptive use. All three states have collected monthly water-use data to some extent for facilities that have the capacity to withdraw at least 100,000 gal/d (fig. 1). Ohio and Indiana have collected data in multiple water-use categories, whereas the Wisconsin data are for public supply only. In addition, Ohio has collected return-flow data as part of a statewide water-withdrawal monitoring program, making it possible to directly estimate consumptive-use coefficients from withdrawal and return-flow data. Consumptive-use coefficients determined/estimated in this report are compared to those of Shaffer and Runkle (2007) for the Great Lakes Basin (Appendix 1).

Two common methods of estimating consumptive use are application of a **water-balance** equation in which measured return flow is subtracted from measured withdrawals (**return-flow and withdrawal method**) and application of a **consumptive-use coefficient** if return-flow data are not available (fig. 1). Shaffer and Runkle (2007) noted that a third method, the **winter base-rate method**, has been used in a few studies to estimate domestic consumptive use, and that method was used in this study where data were sufficient for its application.

[1] Bolded terms defined in the glossary.

Consumptive use is water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from an immediate water environment.

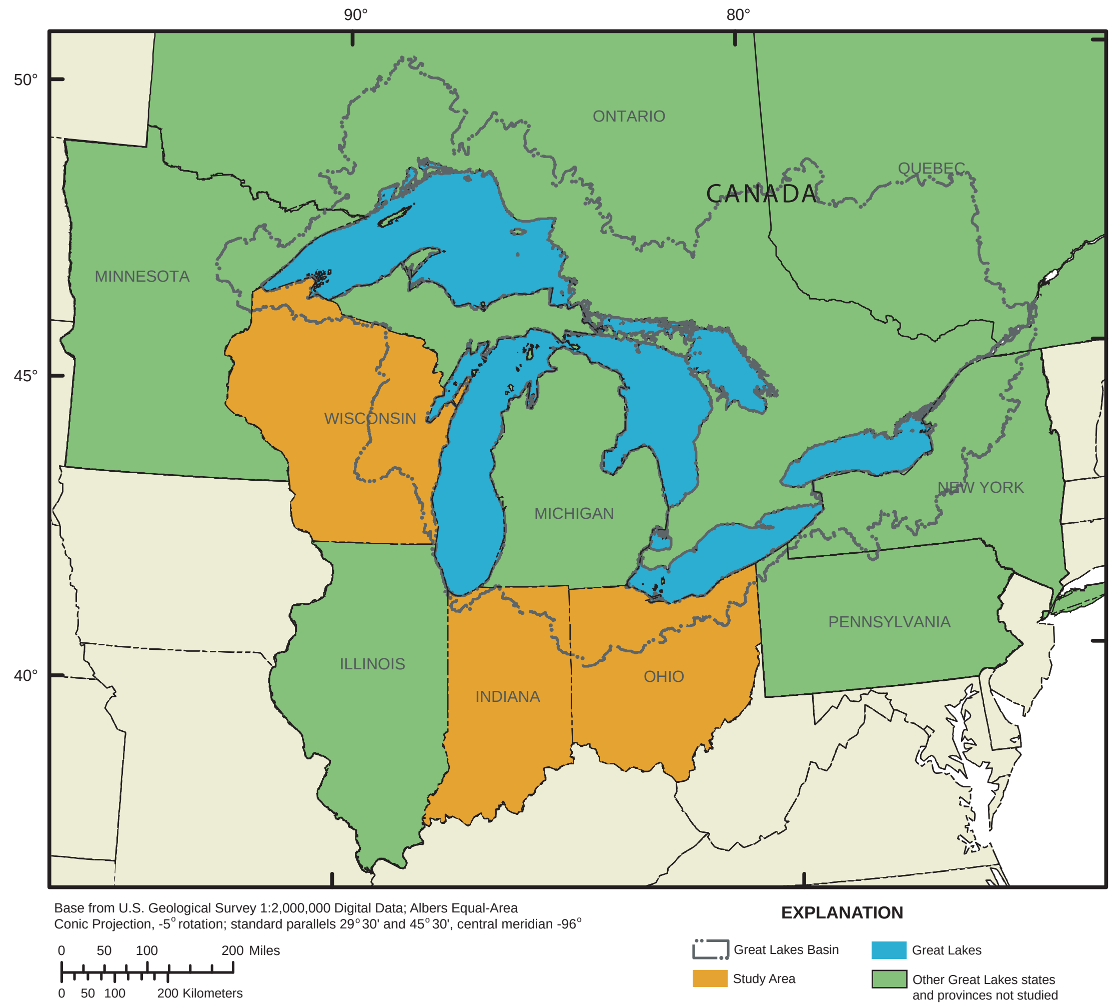


Figure 1. Indiana, Ohio, and Wisconsin study area and the Great Lakes surface-water basin.

Purpose and Scope

The purpose of this report is to examine available data in the Great Lakes States to better understand monthly water use and consumptive use. Specifically, this report

- summarizes variations in water withdrawal by water-use category or groups of similar industries
- compares estimated consumptive-use coefficients derived from the return-flow and withdrawal method in Ohio to the estimated consumptive-use coefficients derived from the winter-base-rate method used in Indiana, Ohio, and Wisconsin
- lists consumptive-use coefficients derived from water-withdrawal and return-flow data for Ohio
- summarizes the variability of consumptive use for water-use categories or groups of similar industries by month

Monthly water withdrawal data were compiled from Ohio, Indiana, and Wisconsin (public supply only) for 1999–2004. Monthly water return-flow data were compiled from Ohio for 1999 to 2004. Commercial, industrial, public-supply, thermoelectric-power, irrigation, livestock, aquaculture, and mining withdrawal data were available for Ohio and Indiana. Data on self-supplied domestic water use for the study area are scarce and therefore were insufficient for analysis and discussion in this report. Instead, a brief discussion on previous domestic studies is included. In addition, consumptive-use coefficients estimated in this report are compared to those given in other reports (Appendix 1).

Data availability—one of the limitations on assessing water-use trends in the Great Lakes States and in the Nation—also is discussed. Understanding the data-collection processes and limitations of data is important when documenting current levels of withdrawals, return flows, and consumptive use and developing policies to optimize the use and reuse of water.

Consumptive Use

The water-use process begins when water is diverted or withdrawn from surface-water or groundwater sources and conveyed to a place of use. A place of use can be a domestic, industrial, thermoelectric power, irrigation, livestock, commercial, or mining facility. Once the facility is done with the water, the remaining water is released and returned to a surface-water or groundwater source (fig. 2). The section "Public Supply" contains information on calculating consumptive use for public-supply facilities. For self-supplied users (who discharge to a stream and not to a wastewater-treatment plant), consumptive use can be calculated by use of the simplified equation

$$\textit{Consumptive use} = \textit{Withdrawals} - \textit{Return Flows} \tag{1}$$

Consumptive use and water withdrawals vary by the water-withdrawal purpose and the time of year. There are three basic withdrawal and consumption patterns:

1. *Constant consumptive-use rate and amount year round.* An example would be an industrial plant that maintains constant production of the same product throughout the year. The withdrawals would be constant throughout the year.

2. *Increase in total consumptive use due to an increase in water demand but not an increase in the consumption-to-withdrawal ratio.* Examples are a bottling plant that increases production in order to meet summer demand, or a seasonal vegetable-processing plant. The withdrawals would increase to meet demand as well, and the consumptive-use coefficient would be the same, but the overall consumptive use would increase because of increased water withdrawals.

3. *Increase in total consumptive use due to both an increase in demand and an increase in rate of consumptive use.* An example is domestic use: outdoor water use increases the water withdrawals in the summer, and the consumptive-use coefficient for outdoor use also increases because of evaporation and transpiration.

Data availability, time and areal variability aspects, water transfer, and **water-quality aspects** can make consumptive use complex. When consumptive-use data (often estimated by withdrawal and return-flow data) are not available, consumptive-use coefficients are necessary to determine consumptive use. Depending on water availability, the amount of consumptive use could indicate potential water-shortage areas or areas of water-quality stress on aquatic life. These periods tend to be in the summer and early fall, when water temperatures are at maximum and streamflows and groundwater levels are at minimum. Across states, water-withdrawal programs vary by what data are collected, how the data are organized, and how often the data are collected. This makes comparing data across state and basin boundaries difficult. For example, of the three states examined in this study, only Ohio collects return-flow data; therefore, only the Ohio dataset could be used to determine consumptive use by employing the return-flow and withdrawal method.

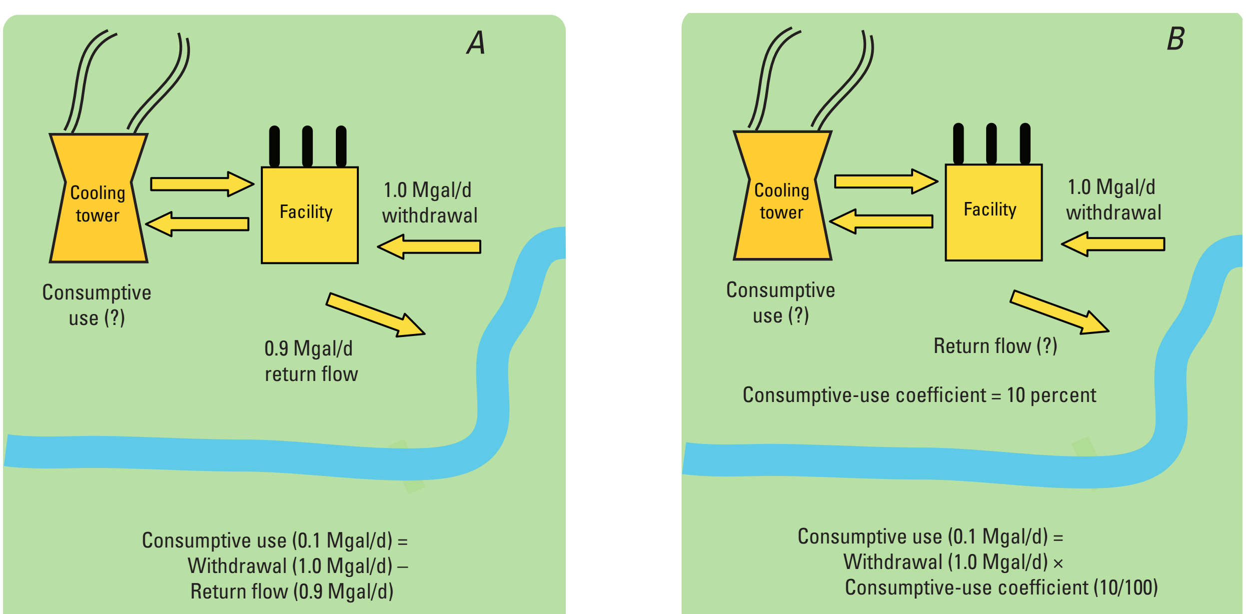


Figure 2. Examples of consumptive use by a single facility. *A*, Consumptive use is equal to withdrawal minus return flow (Mgal/d, million gallons per day). *B*, Consumptive use is equal to withdrawal multiplied by consumptive-use coefficient.

Table 1. State database sources and methods used to estimate consumptive-use coefficients.

State	Data source	Methods
Indiana	Indiana Department of Natural Resources, 2007	Winter base-rate method SIC Code method (Industrial)
Ohio	Ohio Department of Natural Resources, 2008	Return flow method Seasonal method SIC code Method (Industrial)
Wisconsin	Wisconsin Public Service Commission, 2006	Winter base-rate method

Methods and Data Requirements

Indiana and Ohio data from 1999–2004 were used because self-supplied comparable data were available for all three states and the timeframe included years in which cities in Ohio experienced notable highs and lows for June, July and August precipitation. Wisconsin public supply data were also available and used. Data sources and methods used are listed in table 1. Data were divided into water-use categories according to **Standard Industrial Classification code** (SIC code). Commercial and industrial water-use data were further divided by major groups by SIC code for analysis. For each water-use category or industrial subcategory with a representative number of facilities, data were analyzed for monthly variability of water withdrawals and consumptive-use coefficients. Summary tables and figures are in the "Findings" section of this report. Tables and figures that compare consumptive-use coefficients in this report to findings of Shaffer and Runkle (2007) are in the appendixes, as are statistical tables on the percentage of annual water withdrawn by month and other extensive tables.

As data were analyzed, they were selectively quality controlled to make sure that a facility was in the correct water-use category based on USGS methods and that withdrawal and return-flow data seemed reasonable. Questionable data or classifications were discussed with state water-use specialists. Estimates in this report are based on individual registration data, which could vary in accuracy among the individual registered facilities depending on their estimation methods.

The three state databases provided monthly data. These monthly data were used to (1) graph the average monthly water withdrawals (aggregated) and (2) compute statistics for the percentage of annual water withdrawn per month (individual facilities and years). This identifies periods of increased withdrawal for each water-use category and can identify periods of potential water shortages or stresses to aquatic life. The average water withdrawals were based on summing each month's withdrawals and dividing the total by 6 (number of years of data). Six years of data were unavailable for some recently inactive, new, or nonreporting facilities. The monthly percentage of annual withdrawals was computed (eq. 2) and listed on the series of average monthly water withdrawal (aggregated data) figures.

$$\textit{Percentage of the annual withdrawals per month}\ (\%) = (\textit{Monthly withdrawal} \div \textit{Annual withdrawal}) \times 100 \qquad (2)$$

Each combination of year and facility constituted an individual value for statistical purposes when computing monthly statistics. The statistics were calculated by taking each individual record (record) and computing the percentage of annual withdrawals per month for each individual record. Then the **average** (statistical mean), **25th** and **75th** percentiles and **median** were calculated for all the individual records and listed in figures and Appendix 2.

The withdrawal data were also used to determine how much water is used by facilities by percentile. Records were compiled for Ohio and Indiana and divided by percentiles. The annual withdrawals were divided into facility size categories based on percentiles: small facilities were those at the 33d percentile and below, medium facilities were those between the 33d and 66th percentiles, and large facilities were between the 66th and 90th percentiles. The top 10 percent of withdrawal records for a water-use category were subdivided into the categories of extra large (the top 2 percent, or 98th percentile and above) and very large (90th to 98th percentile). Results of these categorizations are listed in the "Findings" section, and for more specific commercial and industrial facility groups, the "Commercial" and "Industrial" sections.

The Ohio Water Withdrawal Facilities Registration Program is not mandated to collect return-flow data, but facilities have the option to report this data element. Facilities that report return-flow data for Ohio vary by year. For those facilities that choose to report, it is not always known if the return-flow data are measured (by a meter) or estimated. The monthly return-flow and withdrawal data are reported for the facility on the same annual form used by facilities that have the capacity to withdraw 100,000 gal/d. A comparison of return flow-data provided to the Ohio Water Withdrawal Facilities Registration Program maintained by the Ohio Department of Natural Resources (ODNR) and to the National Pollutant Discharge Elimination System (NPDES) maintained by the Ohio Environmental Protection Agency (Ohio EPA) in 2005 showed that the data were the same or similar for many facilities. Because these agencies have different program requirements, a facility that may be in ODNR's database may not be in Ohio EPA's database.

For this report, three methods were used to estimate consumptive use and consumptive-use coefficients:

1. In the first method, withdrawal and return-flow data for self-supplied facilities (Ohio only) are used to determine consumptive use and consumptive-use coefficients (**return flow and withdrawal method,** noted as **RW** in Appendix 1). Only facilities with return-flow data available were used. The level of data accuracy varies by facility. A consumptive-use coefficient was computed by using the following equation for withdrawal and return-flow data for self-supplied facilities:

$$\textit{Consumptive-use coefficient (\%)} = [(\textit{Water withdrawn} - \textit{Water returned}) \div \textit{Water withdrawn}] \times 100 \quad (3)$$

   The RW method was used for all the water-use categories except public supply. (See the "Public Supply" section for more information why this method was not used.)

2. The second method—the **winter base-rate method (WBR)** uses monthly withdrawal data to compute consumptive-use coefficients (Ohio, Indiana, Wisconsin). LaTour (1991), in a water-use study in Illinois, found that the WBR method produced the most reasonable results out of three methods to determine domestic consumptive use. The winter base-rate method focuses on outdoor water uses (lawn watering, landscape and garden irrigation, car washing, and swimming pool filling), which LaTour assumed made up most of domestic consumptive use. It is unknown how much of the water used for outdoor use is returned, the elapsed time between withdrawal and return, or the water quality of this returned water. Because there is no scientific information to the contrary, it is assumed that 100 percent of this water is consumed.

   Three WBR equations were applied to the following datasets to determine consumptive-use coefficients:

   - Annual (eq. 4)
   - Summer, fall, and spring (eq. 5)
   - Summer monthly (eq. 6).

$$\textit{Annual consumptive-use coefficient } (\%) = [(\textit{Sum of all monthly withdrawals} \div 12) - (\textit{Sum of winter-month withdrawals} \div 3)] \div (\textit{Sum of all monthly withdrawals} \div 12) \times 100 \quad (4)$$

"All months" are January through December, and "winter months" are December through February.

$$\textit{Summer consumptive-use coefficient } (\%) = [(\textit{Sum of } \textbf{summer} \textit{ monthly withdrawals} - \textit{Sum of winter monthly withdrawals}) \div \textit{Sum of summer monthly withdrawals}] \times 100 \quad (5)$$

"Summer months" are June through August. This basic equation is also used to estimate coefficients for spring (March through May) and fall (September through November).

$$\textit{Monthly consumptive-use coefficient } (\%) = [(\textit{Monthly withdrawals}) - (\textit{Sum of winter monthly withdrawals}) \div 3] \div (\textit{Monthly withdrawals}) \times 100 \quad (6)$$

"Monthly" refers to an individual summer months: May, June, July, August, September or October. "Winter months" are December through February.

In the WBR method, one assumes that, for certain water-use categories, the seasonal increase (fig. 3*B*) is outdoor use and therefore consumptive use. For WBR, the following procedures and a decision diagram (fig. 4) were used to determine whether the method would work for the water-use category:

- *Graph*—Each water-use category or subcategory with a representative number of facilities and monthly withdrawal data was graphed to assess monthly variation in water use.
- *Group*—Water-use patterns were grouped as follows: (a) approximately constant water use throughout the year, and (b) water use throughout the year, with specific months having greater water use than others. Examples of these water-use patterns are shown in figure 3. Figure 3*B* illustrates the seasonal increase.
- *Decide*—The decision diagram was used to determine whether the WBR method was appropriate for a specific water-use category. In general, water-use patterns similar to that in figure 3*A* were assigned constant consumptive-use coefficients for the year, and water-use patterns similar to that in figure 3*B* were further investigated to see whether the seasonal increase was due to outdoor use. The percentage of withdrawals in the summer had to be 0.5 percent higher than the percentage of withdrawals in the winter to be considered pattern 3*B*.

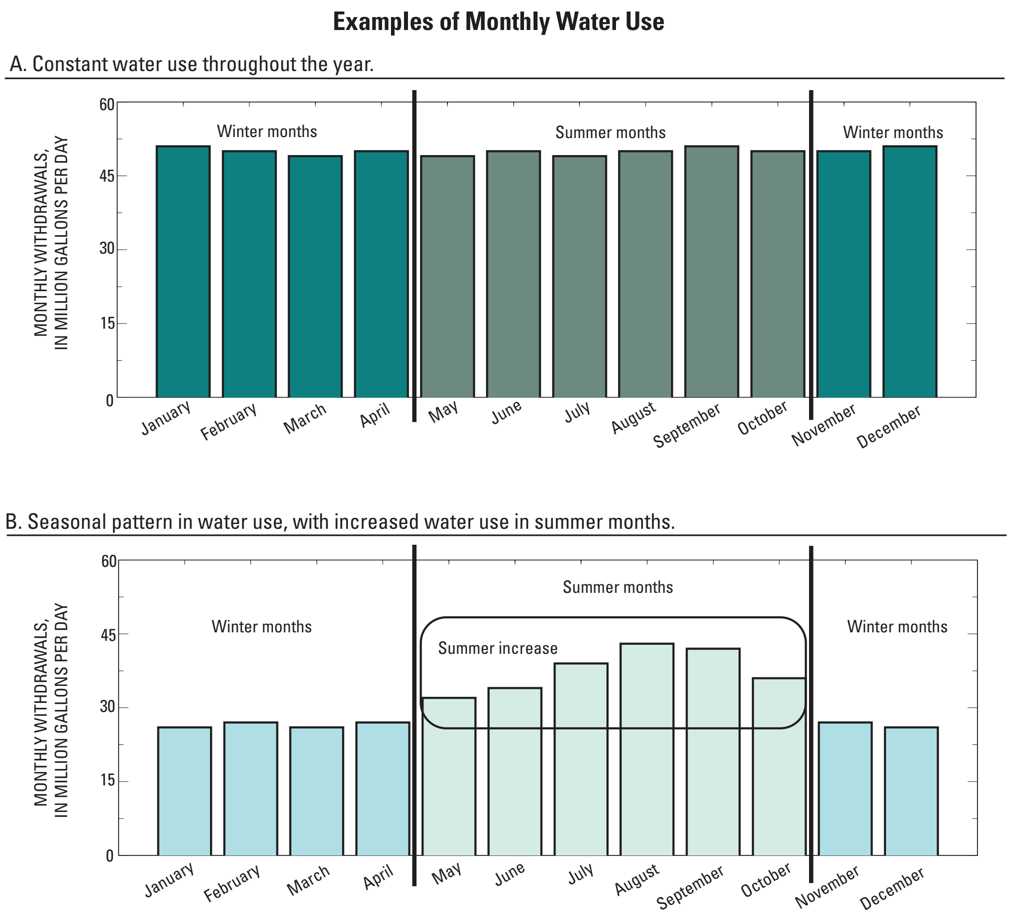


Figure 3. Examples of different types of monthly water use.

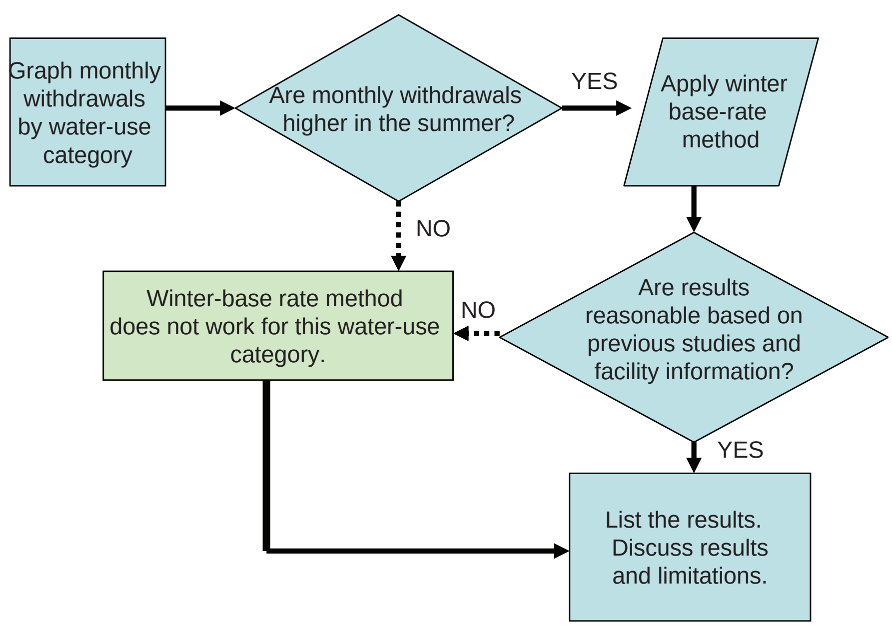


Figure 4. Winter base-rate method, decision diagram for consumptive-use coefficients.

Aquaculture, livestock, and mining water-use categories showed constant water withdrawals throughout the year or increases in withdrawals during nonsummer months, when outdoor use and evaporation is usually lowest, so the WBR method was not used for these categories. Industrial and Thermoelectric power water-use categories showed an increase in summer withdrawals similar to that in figure 3*B*. However, the WBR method was not used for the industrial category because it was unknown whether the summer withdrawal increase was from consumptive use, an increase in demand, or both. The WBR method also was not used for thermoelectric power. The WBR method was tested on the Ohio and Indiana thermoelectric datasets and was adjusted for increased power production in the summer. The resulting consumptive-use coefficient was much higher than that found in previous studies and was therefore rejected. Two factors may contribute to the significant increase in withdrawals in the summer besides consumptive use and increased power protection:

- During the summer, the influent water is warming, and withdrawals must increase in order to produce the same amount of electricity and cool the reactors and condensers.
- Thermoelectric power withdrawals and consumptive use also depend on the type of cooling at a facility, but many facilities use different types of cooling during different times of the year. One Indiana facility has even brought in portable cooling towers to use on a temporary basis (Donald Arvin, U.S. Geological Survey, written commun., [March] 2008).

Irrigation water withdrawals were predominantly in the summer months, so the WBR was not used because the winter-base rate is questionable. Winter withdrawals by irrigation facilities may reflect commercial activities in the clubhouse (golf-course irrigation), nursery buildings, or farm buildings.

Both Commercial and Public Supply water-use categories showed withdrawal patterns similar to that in figure 3*B* and outdoor water use, and the WBR was suitable for these two categories. (See those sections for more details.)

3. The third method—the **Standard Industrial Classification** (SIC) code method (Industrial only)—involves applying a consumptive-use coefficient (Shaffer and Runkle, 2007; Appendix table 2–5) based on the SIC for each facility in a state. These consumptive-use coefficients were applied to water withdrawn from facilities in Indiana and Ohio from 1999 to 2004. If the SIC codes did not match up (because of revisions to SIC codes), the sites were matched by facility name and type of facility. If the particular SIC consumptive-use coefficient was not available because of Census masking (an approach to ensure the confidentiality of all respondents in a dataset), the industrial group consumptive-use coefficient was used.

Analysis of Variation in Monthly Water Withdrawals, Return Flow, and Consumptive Use

Facilities were divided by water-use categories to compare variation in monthly water withdrawals. The water-withdrawal, return-flow, and consumptive-use data were used to determine consumptive-use coefficients per month. Because public-supply withdrawals are delivered to domestic, commercial, and industrial customers, the public-supply section follows the domestic, commercial and industrial sections.

An ethanol plant is an example of a water-withdrawal facility that has a fairly high consumptive-use coefficient.

Domestic

Domestic water use is water withdrawn for indoor household purposes (such as drinking, food preparation, bathing, washing clothes and dishes, and flushing toilets) and outdoor purposes (such as watering lawns and gardens). Water for domestic use can be self-supplied or be delivered by a public-supply facility (see the "Public Supply" section). Three USGS studies have used the WBR method to estimate domestic consumptive use: LaTour (1991), Mullaney (2004), and Horn and others (2008). These studies also estimated domestic per capita water demand.

LaTour (1991) estimated domestic per capita use and domestic consumptive use for the Rockford and Kankakee areas in Illinois. The per capita use ranged from 67.2 to 71 gal/d for publicly supplied domestic use (average 69.2 gal/d) and 24.4 to 51 gal/d for self-supplied domestic use (average 37.7 gal/d). The annual consumptive-use coefficient ranged from 3 to 14 percent and averaged 7 percent. The increase in summer withdrawals was from lawn watering, and rainfall was found to affect water use; monthly withdrawals increased during dry periods and decreased during wet periods, and returns increased during periods of increased rainfall because of groundwater and surface runoff entering the sewer systems.

Mullaney (2004) estimated water-use data and a consumptive-use coefficient for the Greenwich area in Connecticut and New York. The water-demand coefficient was dependent on the type of development: areas with less than a 1-acre lot size had per capita rates of 113 gal/d or less, whereas areas with larger lots had per capita rates as high as 416 gal/d. Mullaney also looked at seasonal variation (April through September in contrast to October through March) and found that larger residential properties showed a greater difference between warm-weather and cold-weather household demand. For residential properties less than 0.5 acre, median household water use was 230 gal/d in April through September and 204 gal/d in October through March; for properties larger than 4 acres, median water use was 1,389 gal/d in April through September and 848 gal/d in October through March. Mullaney estimated consumptive use to be equal to outdoor water (lawn or landscape watering, filling swimming pools, and washing vehicles because these uses generally are consumptive uses—water is transpired by plants into the atmosphere or water evaporates directly from surfaces). Indoor water use was estimated to be the winter water use. Consumptive use was estimated by subtracting the winter water-use data from the average daily water use. For the Greenwich area in 2000, the average consumptive use was 20 percent, the median was 19 percent, and the interquartile range was 3 to 39 percent.

Horn and others (2008) used a per capita water-demand model to determine annual, summer, and winter per capita water-demand coefficients and an annual domestic consumptive-use coefficient for the seacoast region in southeastern New Hampshire. Summer per capita water demand corresponded to June, July, and August, when outdoor water demand and consumptive use are high because of evaporation. Winter per capita water demand corresponded to December, January, and February, when virtually all household use is indoor where little evaporation is occurring (with the exception of humidifiers, which can account for up to 1 percent of per capita water demand). The town mean annual per capita water demand coefficient ranged from 62.3 to 111.4 (gal/d) with an average of 74.6 gal/d. The town mean summer per capita water demand coefficient ranged from 74.7 to 151.8 gal/d, with an average of 92.3 gal/d. The town mean winter per capita water demand ranged from 50.9 per 77.6 gal/d, with an average of 62.7 gal/d. The domestic annual consumptive-use coefficient ranged from 12 to 30 percent, with an average of 16 percent. The summer consumptive-use coefficient ranged from 26 to 49 percent, with an average of 39 percent.

Self-supplied domestic use includes water withdrawn from a groundwater or surface-water source by a user rather than being obtained from a public supply facility. Domestic water withdrawals are used for indoor household purposes like drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and such outdoor purposes as watering lawns and gardens.

Commercial

Commercial water use is water used at restaurants, motels, hotels, office buildings, ski slopes, and other commercial facilities. Processes that contribute to commercial consumptive use are lawn and landscaping watering, sidewalk and car washing, food preparation by restaurants, cooling towers for large air-conditioning units, fountains, aquariums and water-theme parks, laundromats, snow making, toilet use by customers, and whirlpools used in rehabilitation facilities and hospitals. Indiana, and Ohio commercial monthly withdrawal data from 1999 to 2004 were analyzed to determine the percentage distribution of annual withdrawals by month. Monthly water withdrawals for commercial facilities in Indiana and Ohio are graphed in fig 5. Average monthly water withdrawals increased during the summer months (Indiana, 30.4 Mgal/d in January to 62.3 and 65.0 Mgal/d in August and September; Ohio, 23.2 Mgal/d in November to 49.5 Mgal/d in August). The percent of annual withdrawals per month is listed on each monthly bar in fig. 5 and was calculated by use of equation 2.

Figure 6 and appendix tables 2–1, 2–2, and 2–3 show the statistics of monthly withdrawals for commercial facilities expressed as a percentage of annual withdrawals. Figure 6 shows that withdrawals are typically higher in May through September than in October through April.

Commercial water withdrawal data and consumptive-use coefficients were aggregated by SIC code and by similar water-use groups. Data were aggregated both ways because SIC codes are not always available. The commercial water-withdrawal data list the amount of water facilities withdrawals, whereas the consumptive-use coefficients help managers better understand what percentage of the water withdrawn is or is not available for reuse. Although the Ohio and Indiana water-use registration programs include facilities that have the capacity to withdrawal 100,000 gal/d, commercial facilities vary in their water withdrawals (table 2 and 3). Commercial median water withdrawals are displayed in two tables: table 3 includes groups that may be classified as community water-supply systems, and table 2 lists groups that typically would not be classified as community water-supply systems. Wildlife establishments, stores, medical facilities, amusement facilities, schools, colleges, correctional institutions, and national security facilities had some of the largest median withdrawals (tables 2 and 3). A list of commercial facility types by SIC code is in Appendix 3.

Commercial water withdrawals include recreational facilities like this manmade stream used for water sport activities.

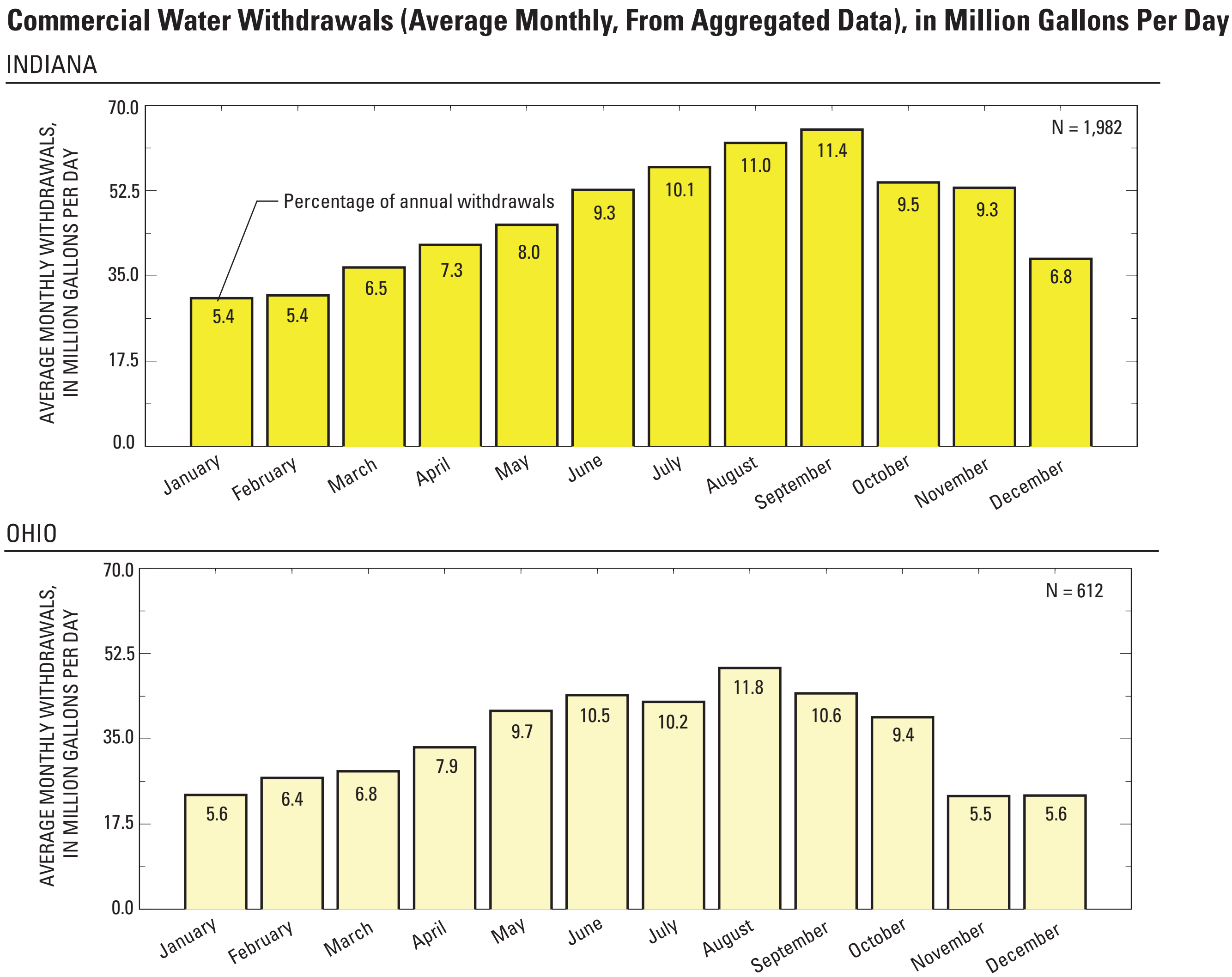


Figure 5. Indiana and Ohio monthly commercial water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

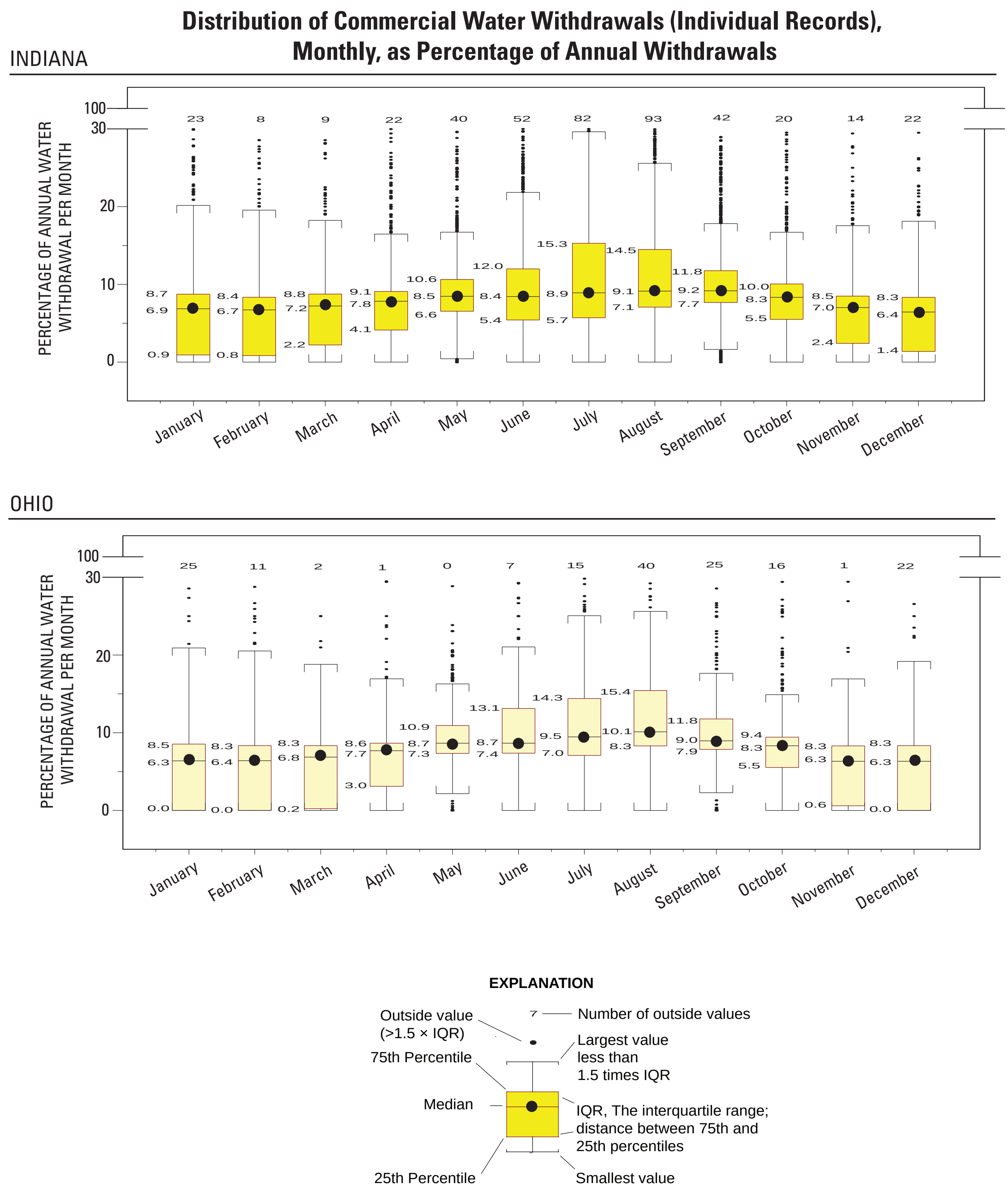


Figure 6. Indiana and Ohio commercial water withdrawals, monthly, as a percentage of annual withdrawals for 1999–2004.

Table 2. Median withdrawals, by commercial group, for Ohio and Indiana, 1999–2004.

[Facility size was computed by percentiles of all commercial facilities; “small” denotes less than 33d percentile, “medium” is from the 33d to 66th percentiles, “large” is from the 66th to 90th percentiles, and “very large” is from the 90th percentiles and above. Median withdrawals are rounded to three significant figures.]

Description of group type	Subgroup based on withdrawals at facility	Number of records	Median water withdrawals, in gallons per day
Agriculture services[1]	Small	10	1,670
	Medium	18	16,800
	Large	2	41,600
Wildlife establishments[2]	Small	43	1,860
	Medium	35	7,100
	Large	39	95,900
	Very large	25	770,000
Stores[3]	Small	70	1,970
	Medium	35	11,000
	Large	30	131,000
	Very large	5	1,640,000
Restaurants	Small	12	2,140
	Medium	6	16,700
Offices	Small	21	1,020
	Medium	36	15,300
	Large	29	57,500
	Very large	21	551,000
Hotels[4]	Small	43	2,250
	Medium	39	18,600
	Large	48	64,000
	Very large	11	305,000
Cleaners	Medium	7	15,400
	Large	11	48,000
Car washes	Small	12	220
	Medium	6	10,900
Businesses	Small	204	263
	Medium	38	7,890
	Large	57	68,600
	Very large	15	362,000
Amusement facilities	Small	17	1,420
	Medium	68	12,300
	Large	45	89,000
	Very large	38	850,000
Healthcare facilities	Small	14	1,600
	Medium	21	16,700
	Large	26	54,300
Medical facilities	Small	17	227
	Medium	16	18,500
	Large	22	97,800
	Very large	11	2,470,000
Schools	Small	307	2,570
	Medium	398	9,150
	Large	39	49,900

[1] Agriculture services includes SIC codes 0711, 0723, 0721, and 0782.

[2] Wildlife establishments are SIC codes 0971 and 9512.

[3] Stores include wholesale and retail.

[4] Hotels include hotels that are connected with a ski resort that have most withdrawals during November–March. It is unknown if this is because water withdrawals are used for hotel seasonal operations and/or snow making.

Table 3. Median withdrawals, by commercial group, for facilities that may be classified as community water systems in Ohio and Indiana, 1999–2004.

[Facility size was computed by percentiles of all commercial facilities; "small" denotes less than 33d percentile, "medium" is from the 33d to 66th percentiles, "large" is from the 66th to 90th percentiles, and "very large" is from the 90th percentiles and above. Median withdrawals are rounded to three significant figures.]

Description of group type	Subgroup based on withdrawals at facility	Number of records	Median water withdrawals, in gallons per day
Operators of real estate[1]	Small	17	3,120
	Medium	59	14,300
	Large	110	49,800
	Very large	19	330,000
Colleges	Small	14	2,550
	Medium	19	7,400
	Large	52	114,000
	Very large	40	651,000
Homeowner, tenant, and condominium associations	Small	20	1,750
	Medium	61	13,700
	Large	88	55,700
	Very large	14	349,000
Correctional institutions	Small	1	548
	Medium	11	12,400
	Large	1	64,500
	Very large	45	677,000
National-security facilities	Small	12	1,330
	Medium	-	-
	Large	19	79,900
	Very large	12	2,160,000

[1] Operators of real estate include operators of apartment buildings or mobile home parks, real estate agents and managers, and land subdividers and developers.

The RW method (tables 4 and 5) and the WBR method (table 6) were both used to determine consumptive use for commercial facilities. Facility data were more scarce for the RW method. Therefore, the RW data were aggregated in two ways; by SIC code (table 4) and by commercial groups with similar water uses (table 5, which is more comparable to table 6). Table 4 lists the SIC code, number of individual records reported, and the computed consumptive-use coefficient median for Ohio sites with return-flow data; the data should be used with caution because they are representative of only a few facilities. Table 5 lists consumptive-use coefficients based on Ohio RW method for commercial groups with similar water uses. The median annual consumptive-use coefficient was 17 percent for all facilities with return-flow data, but the average was 42 percent. Amusement parks and colleges had some of the higher median consumptive-use coefficients. The averages were typically higher than the median consumptive-use coefficients because many of the facilities with higher withdrawals had higher consumptive use.

The WBR method results for commercial water use are in table 6, which is organized by group types and by state and year. Summer consumptive-use coefficients were the highest for all the categories, as is evident in table 6. Homeowners, tenant and condominium associations, medical facilities, offices, and colleges were categories with some of the higher consumptive-use coefficients. For many of the facilities in these categories, withdrawals increased significantly in the summer. For all commercial facilities the annual consumptive-use coefficient was 30 percent for both Ohio and Indiana (WBR method). This falls within the average and median consumptive-use coefficient (42 and 17, respectively) found for the RW method. The wide spread between the average and median (RW method) is because facilities making large withdrawals in Ohio tended to have high consumptive use, thus making the average high; however, more facilities had less consumptive use. All three numbers, (17, 30, and 42 percent) are higher than most commercial consumptive-use coefficients found in the survey by Shaffer and Runkle (2007). This may because many previous commercial consumptive-use coefficients were estimated and not based on studies.

The computed commercial consumptive-use coefficients were higher than expected, but a review of the water uses of commercial facilities listed in the ODNR database (2008) showed that outdoor use and evaporation have a significant part in commercial water use. A facility may have a single use or multiple uses. Listed in table 7 is a compilation of types of water uses and the corresponding number of commercial individual records with any percentage (1–100 percent) listed as part of its use. Many commercial facilities use water for miscellaneous purposes (see table 7, footnote 1) or other purposes that lead to considerable outdoor use, evaporation, and consumptive use (for example, recreation/amusement, nursery/turf/landscaping, livestock, and so forth). The commercial consumptive-use coefficient will vary by how the water is used at each facility; facilities that use water in ways such that most water is evaporated and transpired will have a high consumptive-use coefficient.

Table 4. Standard Industrial Classification codes for records used in the return-flow and withdrawal method.

[Median consumptive-use coefficient and withdrawal range are rounded to nearest whole number. Mgal/yr, million gallons per year.]

SIC code	SIC description	Number of records	Median consumptive-use coefficient	Description of when withdrawn and returned	Annual withdrawal range (Mgal/yr)
0971	Hunting and trapping[1]	10	32	Water was withdrawn July through October, but returns were January through May.	16–97
4011	Railroads, line-haul operating	6	40	Withdrawals and returns were April through December.	92–105
4581	Airports, flying fields, and airport terminal services	6	80[2]	Withdrawals and returns were for the whole year, but withdrawals were higher in the summer months.	1-2
4931	Electric and other service combined	3	0	Withdrawals and returns varied by record.[3]	2–3
5032	Brick, stone, and related construction material	3	1	Withdrawals and returns were fairly even for the entire year.	1–4
5171	Petroleum blue stations and terminals wholesale distribution	4	0	Withdrawals and returns varied by record.[4]	2-–70
5541	Gasoline service stations	6	0	Withdrawals and returns were fairly even for the entire year.	5–12
6515	Operators of residential mobile home sites	2	5	Withdrawals and returns were fairly even for the entire year.	7–14
7011	Hotels and motels (ski resort)	4	14	Withdrawals and returns were significant in Dec. and Jan. (11–18 gal/d), smaller in Nov. and Feb (1–4 gal/d). and nominal in Mar.–Oct. (<0.22 gal/d).	35–39
7213	Linen supply	6	45	Withdrawals and returns were fairly even for the entire year.	14–19
7299	Misc. personal services[5]	4	0	For three records, withdrawals and returns were fairly even for the entire year. One record had data for Jan. through March.	3–13
7996	Amusement parks	18	30	All records showed higher withdrawals in the summer. Two facilities reported that much of the water withdrawn was not returned (20 to 91 percent), whereas a third facility reported that all of the water withdrawn was returned.	135–1,180
7999	Amusement/Recreation services[6]	24	36	With exception of snow skiing areas, these records had most withdrawals and returns during May–Sept.; some records also had higher withdrawals in April and October.	1–323
8051	Skilled nursing care facilities	2	20	Withdrawals and returns were fairly even for the entire year.	1–2
8052	Intermediate care facilities	5	5	Withdrawals and returns were fairly even for the entire year.	5–6
8062	General medical and surgical hospitals	1	0	Withdrawals and returns were throughout the year, but they were higher April through November and highest July–September.	700–800
8069	Specialty hospitals	6	0	Withdrawals and returns for the most part are for the entire year, but they were sometimes higher in the summer months.	122–2,760

Table 4. Standard Industrial Classification codes for records used in the return-flow and withdrawal method.

[Median consumptive-use coefficient and withdrawal range are rounded to nearest whole number. Mgal/yr, million gallons per year.]

SIC code	SIC description	Number of records	Median consumptive-use coefficient	Description of when withdrawn and returned	Annual withdrawal range (Mgal/yr)
8211	Elementary and secondary schools	22	18	Withdrawal and returns were for the entire year with slightly larger withdrawals September–June.	1–9
8221	Colleges and universities	17	23[2]	Withdrawals and returns were for the entire year, but some records showed more withdrawals in the summer, others showed more withdrawals during the school year (Sept.–June), and one was fairly steady throughout the year.	35–170
8249	Vocational schools	1	1	Withdrawals and returns were for the entire year.	3–4
8322	Individual and family social services	4	26	Withdrawals and returns were fairly even for the entire year.	1–6
8361	Residential care	1	0	Withdrawals and returns were fairly even for the entire year.	23–24
8422	Arboreta and botanical or zoological gardens	3	83	Withdrawals and returns were for the entire year, but more in the summer months.	75–82
8661	Religious organizations	6	88[7]	Withdrawals and returns were for the entire year.	132–203
8742	Management consulting services	5	0	Withdrawals and returns were for the entire year.	40–102
9223	Correctional institutions	4	4	Withdrawals and returns were fairly even for the entire year.	618–787
9511	Air and water resource and sold waste management	6	0	Withdrawals and returns were for the entire year.	48–83
9512	Land, mineral, wildlife, and forest conservation	1	10	Water was withdrawn in August, but returns were April and May.	40–60
9532	Admin. of urban and community development	3	0	Water was withdrawn and returned in the same month, but each record was different on which months.	157–276
9711	National security	11	80	Water was withdrawn and returned throughout the year, with a slight increase in withdrawals in July and August.	25–1,430

[1] Facilities primarily engaged in commercial hunting and trapping, or in the operation of game preserves.

[2] Facilities noted as having greater than 85 percent community water. These large consumptive-use coefficients are probably overinflated because the return flow reported may not indicate all the actual return flows (return flows to a nearby wastewater-treatment plant).

[3] One record showed withdrawals and returns in April through September. The second one showed withdrawals and returns in October only. The third record showed withdrawals and returns in July through September.

[4] Two records showed withdrawals and returns all year. A third record showed withdrawals and returns in March through December. The fourth record showed withdrawals and returns January, February, August, and October–December. Withdrawals in some months were in the 0.01- to 12.36-gal/d range.

[5] These records are for service areas that probably have restrooms.

[6] This includes parks, a waterpark, a mill, snow-skiing areas, and a waterfall. The records showed varied consumptive-use coefficients; 0–78 percent for parks, 0–40 percent for the water park, 0–0.4 percent for the mill, 6–56 percent for the skiing areas, and zero percent for the waterfall.

[7] This is a youth center.

Table 5. Ohio commercial monthly consumptive-use coefficients statistics based on withdrawal and return-flow data for 1999–2004.

[Statistics are in percent and are rounded to the nearest whole number. The median and 25th and 75th percentiles are based on computing the consumptive-use coefficient for each record and analyzing for these statistics. Monthly consumptive-use coefficient average is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. The average is computed by taking the total withdrawals for all records and subtracting the record return flows, then dividing this number by the record total withdrawals. There were 196 records.]

Statistic	Jan	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mobile homes/Correctional facilities/National security (N=22)													
25th percentile	0	0	0	0	1	2	3	3	0	0	0	0	1
Median	15	20	16	15	20	20	20	19	16	15	7	9	14
75th percentile	76	77	77	80	78	80	85	81	83	82	79	78	80
Average	57	56	58	60	59	62	63	63	63	58	56	56	59
Businesses (N=24)													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	0	0	0	1	0	0	0	0	1
75th percentile	50	50	50	55	56	56	45	54	49	50	48	50	53
Average	36	33	33	16	31	43	45	52	37	31	43	38	37
Hospitals/Skilled nursing care facilities/Intermediate care facilities/Social services (N=19)													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	5	4	4	4	4	5	5	5	5	4	3	5	5
75th percentile	24	20	20	22	20	24	20	24	20	20	19	20	21
Average	19	32	28	23	20	20	18	19	19	13	15	18	20
Amusement parks (N=23)													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	20	20	20	20	22	20	21	21	22	20	20	16	20
75th percentile	25	25	34	56	85	89	91	92	87	86	34	20	75
Average	25	24	29	39	40	41	41	40	39	41	27	24	36
Amusement/Recreation services (N=23)													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	1	0	1	0	0	0	0	0	0
75th percentile	72	68	71	69	83	77	65	69	70	82	79	73	75
Average	71	67	70	67	67	73	69	64	59	76	77	76	69
Colleges (N=18)													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	4
Median	0	15	4	15	27	35	35	42	43	27	14	0	21
75th percentile	93	92	94	94	94	94	92	94	93	95	95	94	94
Average	14	21	20	26	25	28	27	32	39	37	23	13	26
Schools (N=22)													
25th percentile	12	7	11	10	17	3	0	5	6	6	15	8	13
Median	18	17	24	23	27	17	10	18	23	24	22	20	18
75th percentile	75	39	66	56	47	50	28	65	59	60	74	46	46
Average	40	33	40	40	38	21	13	43	38	35	40	37	36
All commercial facilities (N=196)													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	4	4	5	7	7	7	8	19	17	16	3	4	17
75th percentile	44	50	50	55	56	56	50	73	78	78	48	47	56
Average	33	42	37	36	38	43	44	48	48	45	40	38	42

Table 6. Monthly, seasonal, and annual commercial consumptive-use coefficients for Ohio and Indiana, by commercial category and by year, computed by use of the winter-base-rate method.

[Consumptive-use coefficients are rounded to nearest whole number]

Category or year	N	Monthly consumptive-use coefficient						Seasonal consumptive-use coefficient			Annual
		May	June	July	Aug.	Sept.	Oct.	Spring	Summer	Fall	
By category (Indiana and Ohio)											
Stores	140	25	18	19	27	25	8	15	21	13	13
Restaurants	18	10	11	14	14	11	11	6	13	9	7
Offices	107	54	58	56	59	51	45	47	58	36	41
Hotels[1]	115	21	42	51	48	34	18	7	46	19	23
Cleaners	18	0	7	11	16	10	0	4	8	4	4
Businesses	314	22	48	52	50	47	22	13	50	30	28
Amusement facilities	168	41	45	44	43	32	25	19	44	16	23
Healthcare facilities	61	12	21	18	14	17	0	9	18	7	9
Medical facilities	66	63	68	70	68	66	44	54	69	48	52
Schools	744	6	22	19	29	33	14	0	23	16	10
Operators of real estate	205	7	28	36	27	4	0	5	30	0	9
Colleges	125	39	47	52	50	45	31	24	50	32	31
Homeowner, tenant, and condominium associations	183	72	81	85	84	80	69	70	84	72	71
Correctional institutions	58	2	4	6	5	2	0	1	5	0	2
National-security facilities	43	5	8	13	17	13	3	2	13	6	6
Indiana, by year											
1999	332	29	47	57	53	51	32	19	52	40	33
2000	323	49	45	50	62	65	55	38	53	58	44
2001	319	29	38	38	47	55	32	19	41	47	31
2002	322	9	53	60	61	60	44	9[2]	58	50	38
2003	331	48	50	47	53	53	54	42	50	54	42
2004	337	35	38	38	47	54	50	26	41	48	33
1999–2004	1,964	31	40	45	50	52	42	24	45	45	33
Ohio, by year											
1999	104	41	44	46	55	46	27	38	49	29	33
2000	103	42	52	43	45	37	32	28	47	25	29
2001	97	24	27	25	49	35	35	9[2]	36	26	20
2002	94	37	41	39	43	43	30	27	41	28	27
2003	89	46	47	49	58	48	49	31	52	40	36
2004	99	53	56	55	58	60	54	42	57	47	42
1999–2004	586	42	47	45	53	47	41	31	48	34	32

[1] Excludes facilities at ski areas.

[2] These numbers are low because withdrawals in March and April were less than withdrawals in winter months (Dec.–Feb.).

Table 7. Ohio commercial facilities type of water use, in decreasing order of number of facilities reporting type of water use (Ohio Department of Natural Resources, 2008).

[As part of the Ohio Water Withdrawal Registration Program, facilities are asked to estimate the percentage of total water withdrawal that goes to each type of water use. A facility may have multiple types of water or just one.]

Type of water use	Number of commercial records reporting listed use
Miscellaneous other[1]	360
Public supply, noncommunity	282
Public supply, community	217
Heating/cooling	126
Recreation/Amusement	90
Nursery/Turf/Landscaping	60
Dewatering	36
Livestock	36
Industrial, cooling water	36
Domestic	30
Remediation	24
Industrial, process water	18
Golf Course	17
Thermoelectric	6
Crop	6

[1] "Miscellaneous other" includes specified uses in database noted by the facilities: "fill pond and water plants, waterfowl, hydrostatic testing, research, waterfall, mill, backwash, pipe test, fire, hydro test, line test, dust control, marsh management, fire protection, truck wash, fire department, utility installation, groundwater remediation, yard irrigation, pond, resident camp, equipment wash, car wash, horserace, racetrack, hospital, wet lands, wash bay, fire fighting, cleaning."

Industrial

Industrial water use is water used for industrial fabrication, washing, processing, and cooling and includes industries such as chemical and allied products, paper and allied products, steel, and petroleum refining (Hutson, Barber, and others, 2004). Industrial consumptive use is the water that is not returned to the hydrologic system or to a wastewater treatment plant because it is incorporated into a product, evaporated, or removed from the immediate environment for reuse for other purposes.

The type of industrial facility (defined by the SIC code or the North American Industrial Classification (NAICS) code), the type of processes, and the age of equipment in an industrial facility all affect the amount of water consumed. Industrial consumptive-use coefficients are either typically associated with a specific SIC code or with a geographical area. These general industrial coefficients are based on a mixture of industrial facility types (SIC codes) that are in a particular geographical area. A consumptive-use coefficient based on one geographical area may be very different from that for another area based on the mix of industrial facilities, the water use, and the consumptive use.

Figure 8 shows the average monthly industrial water use for Indiana and Ohio for 1999–2004, and table 16 lists statistics for the monthly percentage of the total water used. Withdrawals in Indiana were higher than those in Ohio (2,400 Mgal/d in Indiana and 807 Mgal/d for Ohio in 2000). The average monthly water withdrawals are larger in the summer months than in other months (fig. 8 and table 2–2). Indiana withdrawals ranged from 2,220 Mgal/d in December to 2,620 Mgal/d in August, and those in Ohio ranged from 707 Mgal/d in January to 787 Mgal/d in August (fig. 8).

The RW and the SIC code method were both used in this study to estimate industrial consumptive-use coefficients. Some industrial groups were not used in the SIC code analysis because either a consumptive-use coefficient was not available or the U.S. Bureau of Census (1986) listed water discharge greater than water intake. SIC codes not used in the SIC code method and the reasons they were excluded are listed in table 8.

An example of industrial water withdrawals and consumptive use.

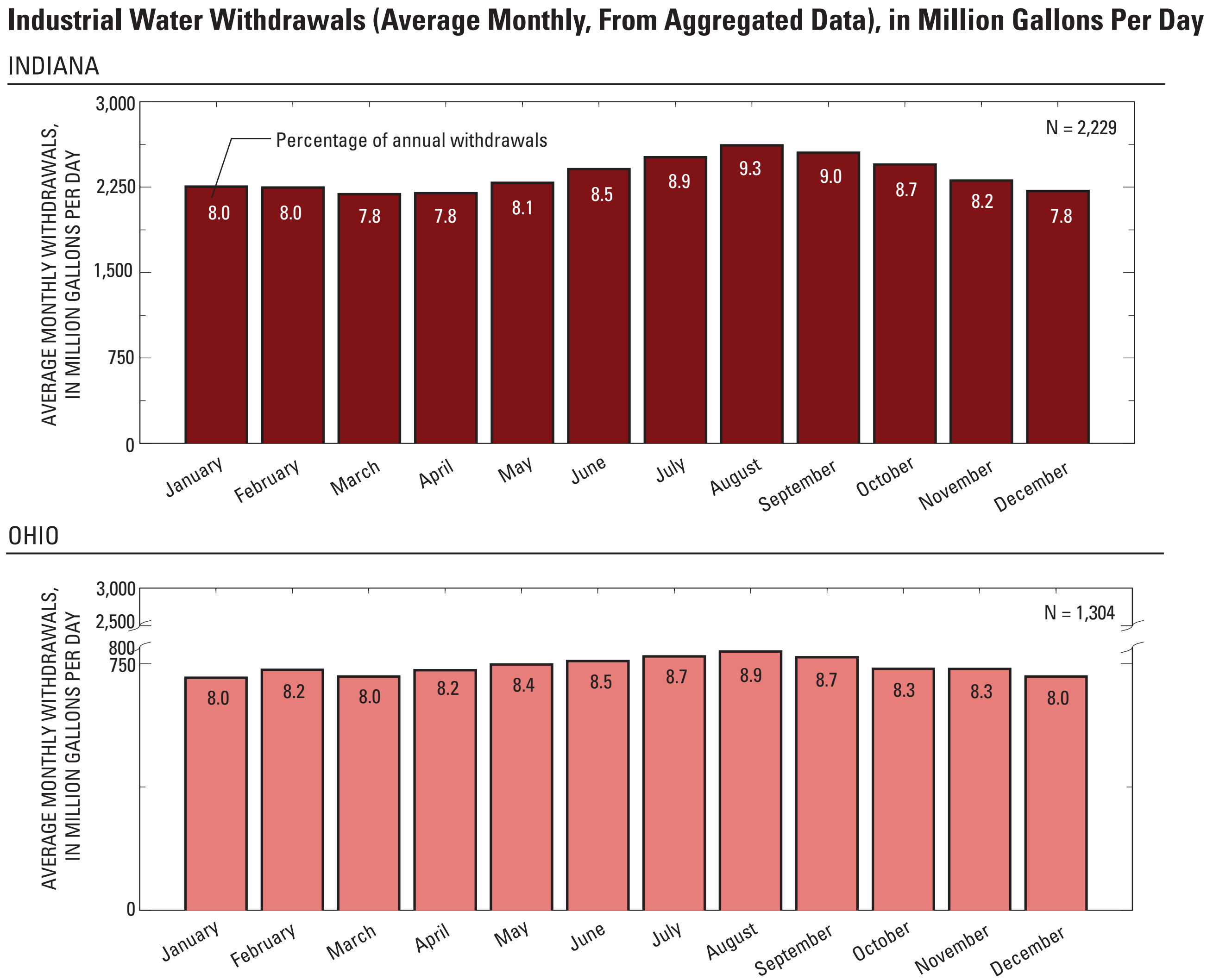


Figure 7. Indiana and Ohio monthly industrial water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

Table 8. Standard Industrial Classification codes (SIC) not used in the SIC-code method for estimating consumptive use.

SIC	Description	Reason not used in SIC method
1521	General contractor-single family houses	No data available from U.S. Bureau of Census (1986)
1611	Highway and street construction, except elevated highways	No data available from U.S. Bureau of Census (1986)
1711	Plumbing, heating, and air-conditioning	No data available from U.S. Bureau of Census (1986)
1770	Concrete work	No data available from U.S. Bureau of Census (1986)
1781	Water-well drilling	No data available from U.S. Bureau of Census (1986)
2732	Book printing	No data available from U.S. Bureau of Census (1986)
2754	Commercial printing	No data available from U.S. Bureau of Census (1986)
2759	Commercial printing, not elsewhere classified	No data available from U.S. Bureau of Census (1986)
2875	Fertilizers, mixing only	No data available from U.S. Bureau of Census (1986)
2951	Asphalt paving mixtures and blocks	Water discharged was greater than water intake
3295	Minerals and earths, ground or otherwise treated	Water discharged was greater than water intake
3531	Construction machinery and equipment	Water discharged was greater than water intake
3621	Motors and generators	Water discharged was greater than water intake

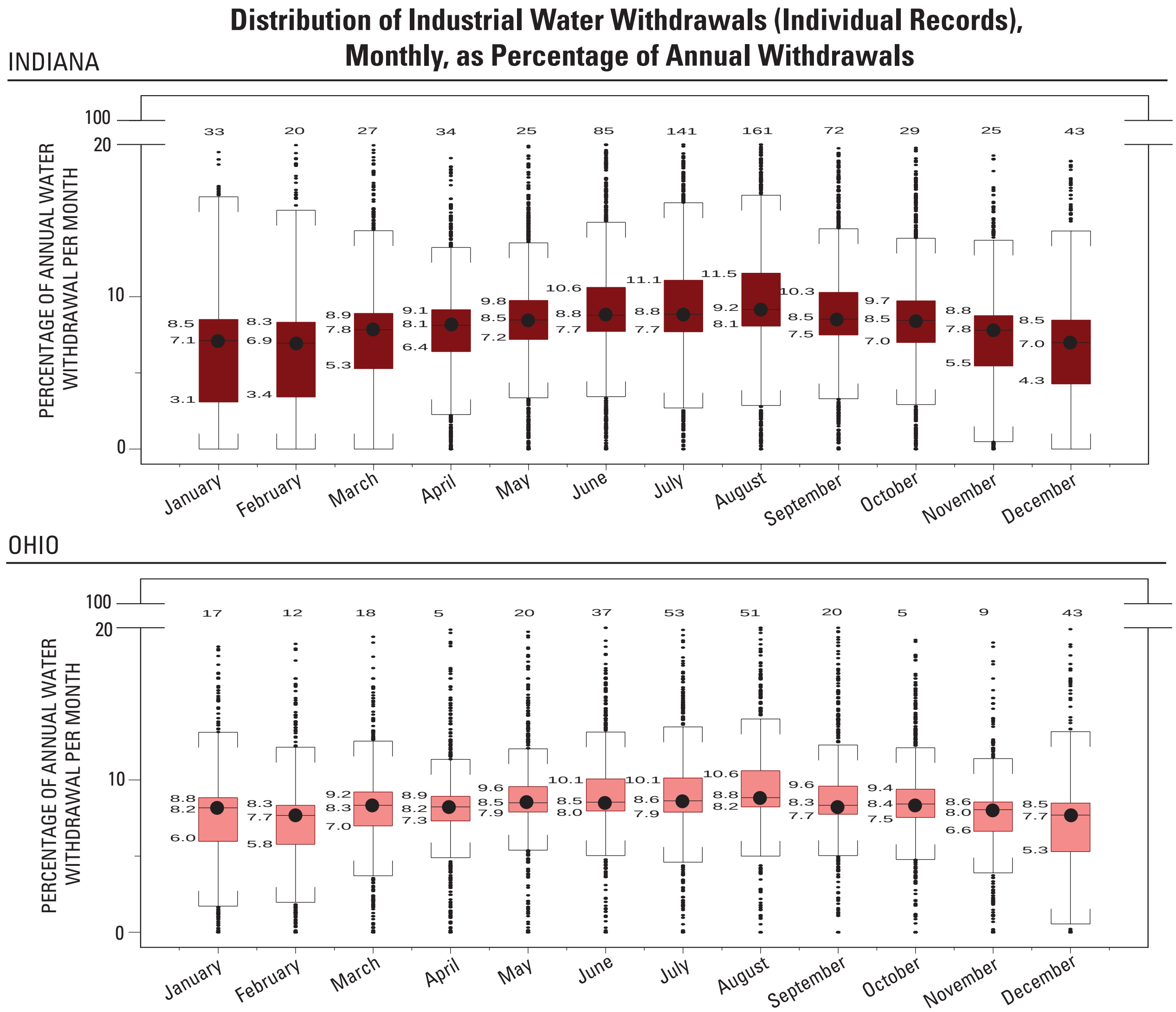


Figure 8. Indiana and Ohio industrial water withdrawals, monthly, as a percentage of annual withdrawals for 1999–2004 (see fig. 6 for explanation).

Once the consumptive-use coefficient was assigned to each individual record, the minimum, median, maximum, and 25th and 75th percentile consumptive-use coefficients were computed from the full set of consumptive-use coefficients. To determine the average consumptive-use coefficient, the consumptive-use coefficients were multiplied by the water withdrawn for each individual record. The total consumptive use and total water withdrawn were computed, then the total consumptive use for all facilities was divided by the total withdrawals for all facilities (table 9). Half of the coefficients for individual records derived by the SIC code method were between 4 and 20 percent for Indiana and 7 and 20 percent for Ohio (table 9). Overall, the industrial median coefficients derived by the SIC code method for Indiana and Ohio were similar (11 and 12 percent, respectively). These are both representative of a large geographical area and a varied mix of industries.

Table 10 summarizes monthly and annual consumptive-use coefficients computed by the return-flow method. The overall percentage of consumptive use by month was steady throughout the year: medians ranged from 8 to 9 percent, and averages ranged from 11 to 12 percent (table 10). The annual median Ohio consumptive-use coefficient was 10 percent, and the average was 11 percent (table 10).

Withdrawal and return-flow data were analyzed by SIC code to determine consumptive-use statistics (table 11). Only SIC codes with 25 or more individual records were included in the analysis. The median and average for food and kindred products (SIC 20), paper and allied products (SIC 26), primary metal industries (SIC 33), and fabricated metal products (SIC 37) (table 24) were within 4 percent of the consumptive-use coefficients computed from the Census of Manufacturing (Shaffer and Runkle, 2007; table 2–5). The lower rubber and miscellaneous plastics coefficient may be from more industries

Table 9. Industrial consumptive-use coefficients based on SIC code method, 1999–2004.

[Statistics are in percent and are rounded to the nearest whole number. N is the number of records. Average consumptive-use coefficient is computed by adding annual estimated consumptive use and dividing by annual withdrawals.]

SIC code[1]	SIC title	Statistics						
		Minimum	25th percentile	Median	75th percentile	Maximum	Average	N
	Indiana							
20	Food and kindred products	2	7	13	21	45	8	250
24	Lumber and wood products	0	14	16	22	67	27	48
26	Furniture and fixtures	0	3	5	14	14	11	68
28	Chemical and allied products	1	1	8	14	19	8	106
29	Petroleum and coal products	15	15	15	15	15	15	37
30	Rubber and misc. plastic products	11	11	20	20	20	16	164
32	Stone, clay, and glass products	0	26	29	29	59	23	494
33	Primary metal industries	0	4	7	10	27	6	216
34	Fabricated metal products	0	3	4	6	18	8	176
35	Machinery, except electrical	0	0	2	8	35	6	107
36	Electronic equipment	0	0	1	9	12	9	93
37	Transportation equipment	3	7	10	12	12	10	131
38	Measuring, analyzing, and controlling equipment	0	7	7	9	10	7	32
20–39	All industrial	0	4	11	20	67	8	1,961[2]
	Ohio							
20	Food and kindred products	2	8	13	22	46	19	120
24	Lumber and wood products	22	22	22	42	42	36	17
26	Furniture and fixtures	0	5	5	14	14	6	83
28	Chemical and allied products	6	9	16	19	81	19	155
29	Petroleum and coal products	15	15	15	15	15	15	30
30	Rubber and misc. plastic products	11	11	18	18	18	17	87
32	Stone, clay, and glass products	0	14	29	29	59	34	253
33	Primary metal industries	2	7	10	10	27	10	180
34	Fabricated metal products	0	0	3	3	9	3	91
35	Machinery, except electrical	8	8	8	8	8	8	17
37	Transportation equipment	7	7	12	12	12	11	92
20–39	All industrial	0	7	12	20	81	10	1,149[2]

[1] Only SIC codes with 17 or more individual records are listed.

[2] The number of individual records for "all industrial" will be higher than the sum of individual records because only SIC codes with more than 17 individual records are listed.

in the Ohio dataset having lower consumptive-use coefficients: fabricated rubber products (11 percent) and rubber and plastics footwear (0 percent) (Shaffer and Runkle, 2007). The higher stone, clay, glass, and concrete products coefficient may be from more industries in the Ohio dataset having higher consumptive-use coefficients: structural clay products (50 percent), gypsum products (59 percent), and gaskets, packing, and sealing devices (50 percent) (Shaffer and Runkle, 2007; table 2–5). These differences may be due to not just the mix of facilities but also changes in the processes at facilities. These SIC code consumptive-use coefficients represent groups of similar industries, but even similar facilities can differ substantially in consumptive use. Thus, relying on available industrial consumptive-use data at the facility level is preferred over using industrial consumptive-use coefficients.

Industrial withdrawals vary considerably by SIC group and by size of facility within each group. Table 12 lists the median water withdrawals (gallons per day) for group and facility size. The primary metal industries and fabricated metal products had some of the highest median water withdrawals (63.5 and 67 Mgal/d, respectively). Other industries with high median water withdrawals for very large facilities (based on withdrawals) were food, paper, chemical, rubber, transportation, stone, clay, glass, concrete products, and petroleum refining.

Table 10. Ohio industrial monthly and annual consumptive-use coefficients statistics based on withdrawal and return-flow data from 1999 through 2004.

[Statistics are in percent and are rounded to the nearest whole number. Only major SIC codes with more than 20 individual records were compiled for this table. N is the number of records. "All facilities" statistics based on 471 records. The median and 25th and 75th percentile are based on computing the consumptive-use coefficient for each record and analyzing for these statistics. Monthly consumptive-use coefficient average is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. The annual average is computed by taking the total withdrawals for all records and subtracting the individual-record return flows, then dividing this number by the records' total withdrawals.]

SIC code or statistic	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual average	N
Facilities, by SIC code														
20	10	2	1	14	0	11	31	19	17	24	16	12	15	27
26	11	13	12	9	9	13	11	13	8	8	9	12	11	33
28	23	28	24	25	27	28	27	25	25	25	24	21	25	62
29	3	3	3	4	4	4	4	4	4	4	2	3	4	21
30	12	13	13	13	13	12	12	12	12	12	12	13	12	29
32	38	38	36	37	34	49	48	47	43	36	41	43	41	80
33	11	12	11	10	11	11	11	11	11	11	12	12	11	74
34	10	10	10	10	10	10	10	10	9	10	10	10	10	48
37	8	8	7	7	9	8	7	6	7	11	9	8	8	46
All facilities														
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0	471
Median	8	9	9	9	8	8	9	9	9	8	9	9	10	471
75th percentile	37	37	39	40	37	39	40	40	41	40	37	36	38	471
Average	11	12	11	11	11	12	12	12	11	11	12	12	11	471

Table 11. Annual Industrial consumptive-use coefficients, by Standard Industrial Classification (SIC) code computed by use of withdrawal and return-flow data.

[Statistics are in percent and are rounded to the nearest whole number. N is the number of records. Average consumptive-use coefficient is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. SIC code median consumptive-use coefficient is from Census of Manufacturing, 1986, noted in Shaffer and Runkle, 2007; table 2–5.]

Ohio statistics							National SIC code median consumptive-use coefficient
Min	25th percentile	Median	75th percentile	Max	Average	N	
SIC 20: Food and kindred products							
0	3	17	31	71	15	27	15
SIC 26: Paper and allied products							
0	4	7	20	80	11	33	7
SIC 28: Chemicals and allied products							
0	7	42	57	100	25	62	12
SIC 30: Rubber and miscellaneous plastics products							
0	3	6	25	88	12	29	18
SIC 32: Stone, clay, glass, and concrete products							
0	11	34	65	100	41	80	14
SIC 33: Primary metal industries							
0	0	8	25	62	11	74	11
SIC 34: Fabricated metal products							
0	0	0	9	24	10	48	6
SIC 37: Transportation equipment							
0	0	24	37	71	8	46	9

Table 12. Industrial withdrawals, by group, for Ohio and Indiana, 1999–2004.

[Facility size was computed by percentiles of all industrial facilities; “small” denotes less than 33d percentile, “medium” is from the 33d to 66th percentiles, “large” is from the 66th to 90th percentiles, and “very large” is from the 90th percentiles and above. Median withdrawals are rounded to three significant figures. Median withdrawals are rounded to three significant figures.]

Description of group type	Subgroup based on withdrawals at facility	Number of records	Median water withdrawals, in gallons per day
SIC 20: Food and kindred products	Small	70	6,170
	Medium	192	108,000
	Large	61	494,000
	Very large	42	4,260,000
SIC 22: Textile mill products	Small	12	9,620
	Medium	2	164,000
	Large	1	320,000
SIC 24: Lumber and wood products, except furniture	Small	23	3,330
	Medium	42	58,800
SIC 25: Furniture and fixtures	Small	6	2,630
	Medium	6	34,800
SIC 26: Paper and allied products	Small	16	6,980
	Medium	40	117,000
	Large	48	660,000
	Very large	39	7,290,000
SIC 27: Printing, publishing, and allied industries	Small	2	15,600
	Medium	20	104,000
	Large	6	653,000
SIC 28: Chemicals and allied products	Small	79	6,210
	Medium	44	138,000
	Large	87	771,000
	Very large	70	5,000,000
SIC 29: Petroleum refining and related industries	Small	38	5,420
	Medium	8	126,000
	Large	36	736,000
	Very large	12	73,600,000
SIC 30: Rubber and miscellaneous plastics products	Small	105	3,080
	Medium	76	71,200
	Large	61	454,000
	Very large	5	5,880,000
SIC 31: Leather and leather products	Small	6	14,500
	Medium	3	47,600
SIC 32: Stone, clay, glass, and concrete products	Small	297	4,260
	Medium	199	95,300
	Large	230	676,000
	Very large	37	4,300,000
SIC 33: Primary metal Industries	Small	71	852
	Medium	117	70,500
	Large	134	851,000
	Very large	76	63,500,000
SIC 34: Fabricated metal products	Small	77	7,690
	Medium	112	80,900
	Large	40	439,000
	Very large	24	67,000,000
SIC 35: Industrial and commercial machinery and computer equipment	Small	83	3,340
	Medium	56	105,000
	Large	26	708,000
	Very large	3	2,910,000
SIC 36: Electronic and other electrical equipment and components	Small	70	714
	Medium	34	80,700
	Large	7	1,630,000
SIC 37: Transportation equipment	Small	77	5,780
	Medium	94	82,500
	Large	30	829,000
	Very large	6	6,250,000
SIC 38: Measuring, analyzing, and controlling instruments	Small	17	12,000
	Medium	19	75,000
	Large	5	464,000
SIC 39: Miscellaneous manufacturing industries	Small	12	1,720

Public Supply

Public-supply water use is water withdrawn by private and public water suppliers and delivered to customers who, in turn, use the water for domestic, commercial, thermoelectric power, industrial, and public purposes (Solley and others, 1998). In this report, public supply includes public and private water systems that furnish water to at least 25 people or that have a minimum of 15 connections (Hutson, Barber, and others, 2004). In 2000, Ohio had a population of 11,400,000 people and public-supply withdrawals of 1,470 Mgal/d. These figures represent almost twice the population of Indiana (6,080,000 people) or Wisconsin (5,360,000 people) and more than twice the public-supply withdrawals in Indiana (670 Mgal/d) or Wisconsin (623 Mgal/d) (Hutson, Barber, and others, 2004).

The WBR method was used to estimate public-supply consumptive-use coefficients. The RW was not used for public supply in this report for the following reasons:

- The customer base for the water supplier and wastewater-treatment plant may not be the same. (For instance, a large municipal public supplier serves 100,000 people, but the municipal wastewater facility serves 125,000; the difference of 25,000 people results from a combination of small public-supply facilities and private wells.)
- Individual facilities may supplement public supply with self-supplied water. (A city has multiple large industrial facilities that use self-supplied water, but the facilities discharge large amounts of water into the municipal wastewater system.)
- Infiltration or inflows into sewer pipes may be misinterpreted as return flow, thus resulting in underestimation of consumptive use.
- There may be substantial public uses and conveyance losses that are not measured.

Ohio’s withdrawal and return-flow data could not be used to estimate consumptive use for public supply. Figure 9, an example from Darke County, Ohio, shows the types of problems typical of public-supply datasets. Wastewater return flow (fig. 9*B*) often exceeds withdrawal (fig. 9*A*) and is more similar to precipitation than to withdrawal in terms of the month-by-month pattern (fig. 9*C*, especially January and April). Figure 9 shows that withdrawals increase during the summer. Potentially, the increase in withdrawals in the summer compared to the winter may be attributed to consumptive use or an increase in demand not subjected to consumptive use. By using the WBR method, consumptive-use coefficients may be estimated for public-supply datasets, but there are limitations:

- A public-supply facility delivers water to domestic, commercial, industrial, irrigation, and thermoelectric users. The WBR method does not address the variability in public-supply deliveries to different users, but delivery data from Wisconsin made it possible to address this variability.
- The WBR method may not include consumptive use that is constant throughout the year (for example, product incorporation); it may result in zero or negative consumptive use in winter. Consumptive use may indeed be low in winter (depending on the uses of the water), typically much lower than in summer for domestic and commercial water uses. For industrial facilities, the consumptive use throughout the year will vary by facility.

Public-supply water withdrawals is water withdrawn by public and private water suppliers that furnish water to at least 25 people or have a minimum of 15 connections. Public suppliers provide water for a variety of uses, such as domestic, commercial, industrial, thermoelectric power, and public water use.

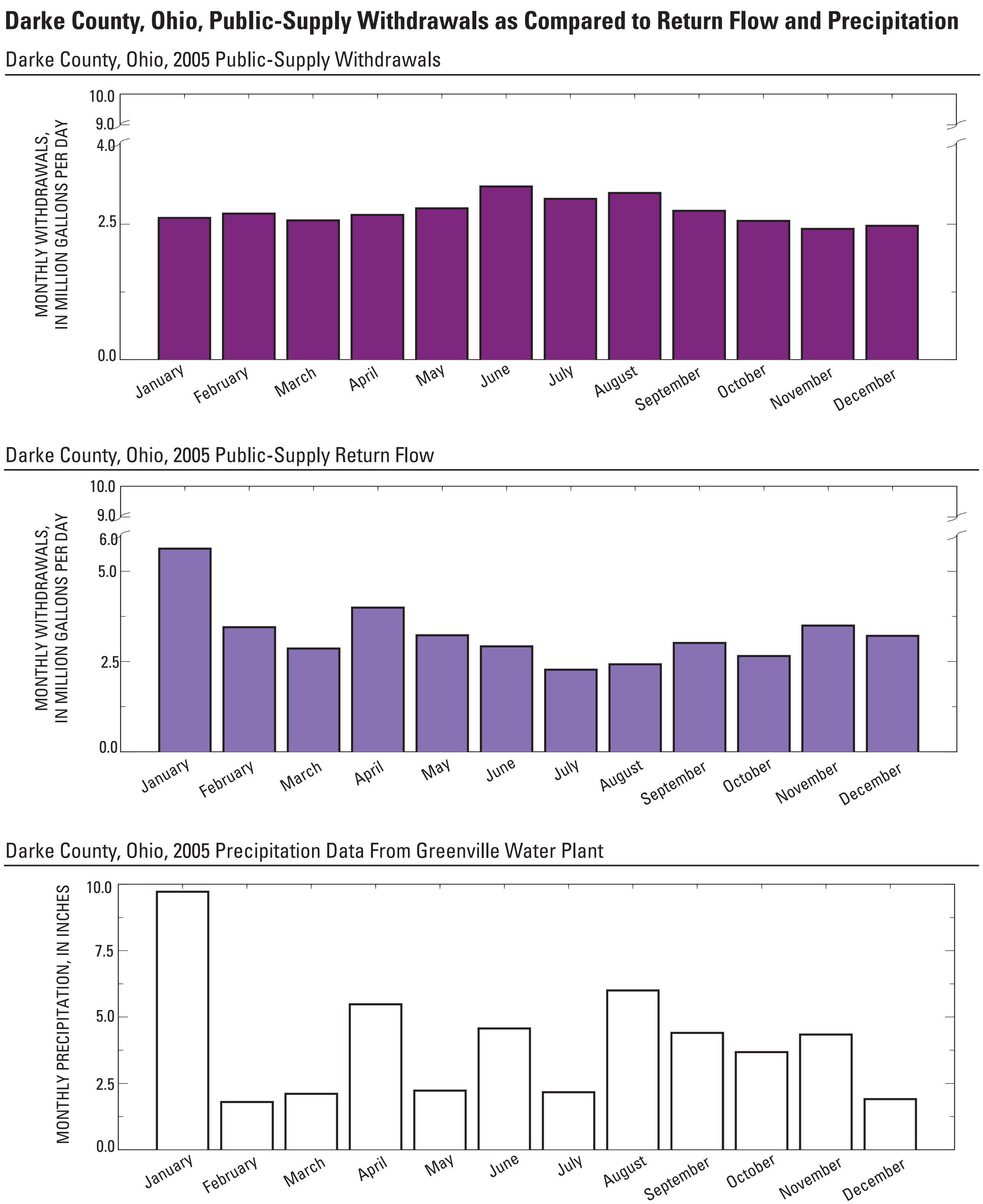


Figure 9. Public-supply withdrawals, public-supply return flow, and precipitation data for 2005, Darke County, Ohio. Withdrawal (Ohio Department of Natural Resources, 2008) and return flow (Ed Swindall, Ohio Environmental Protection Agency, written commun., 2008) are in million gallons per day. Precipitation data (National Climatic Data Center, 2005) are in inches.

Public-supply consumptive-use coefficients are based on water that is delivered to residential, commercial, industrial, and other users. Wisconsin's public-supply database, which includes metered and unmetered data from 1997 to 2005, classifies gallons sold to each of the categories residential, industrial, commercial and "other sales to public." Overall, 40.8 percent of the water withdrawals went to residential users, 28.7 percent went to industrial users, 24.5 percent went to commercial users, and 6.0 percent went to "other sales to public" during that period. The Wisconsin commercial use category includes businesses, apartments, and multifamily housing with four or more units (Cheryl Buchwald, U.S. Geological Survey, written commun., 2006). This categorization is important to note because delivery to apartment and multifamily housing is considered domestic water use by the USGS. Results from a telephone and email survey to Ohio public suppliers classifying the percentage of water withdrawn to residential, commercial, and industrial users and unaccounted-for use are listed in table 13. The unaccounted-for uses ranged from 0 to 40 percent. Public suppliers that noted no unaccounted-for use typically had new systems that were supplying only a few users. Some public-supply systems may have large percentages of unaccounted-for water because of specific public uses such as firefighting, system operation, public buildings, or leaky community swimming pools, all of which constitute large commitments of water to the public-use sector; misregistration of meters; lack of metering; or billing accounting procedures. The public suppliers that reported unaccounted-for uses greater than 30 percent noted these sorts of issues as contributing factors.

Average monthly water withdrawals for public suppliers in Indiana, Ohio, and Wisconsin are graphed in figure 10, which shows increases in monthly water withdrawals during the summer. Figure 11 and appendix tables 2–3, 2–4, and 2–5 show the statistical distributions of monthly public-supply withdrawals expressed as a percentage of annual withdrawals. Individual records from Wisconsin that included withdrawals sporadically or only for 3 months of the year were not used in the compilation of these statistics. Withdrawals in July and August were higher than in other months (figs. 10 and 11). In half of the Ohio records, 8.6 to 10.2 percent of the annual withdrawals were in July (fig. 11).

Some public suppliers in Ohio withdrew the greatest amounts in January and February because they were filling reservoirs (this, however is categorized as a water transfer). To reveal how these withdrawal practices affected the percentage of water withdrawn per month, statistics were compiled for (1) all facilities and (2) facilities where July withdrawals were equal to or greater than the February withdrawals (table 2–4).

Table 13. Percentage of water delivered to domestic, commercial, and industrial users and unaccounted-for uses for selected Ohio public suppliers in 2007.

[Minimum, median, maximum, 25th percentile, and 75th percentile are in percent and rounded to the nearest whole number. N is the number of references in the statistical analysis. For public suppliers who gave a range, the median of the range was used in the statistics. Reported percentages were not verified by the USGS.]

Water-use deliveries or unaccounted-for uses	Statistics					
	Minimum	25th	Median	75th	Maximum	N
Domestic deliveries	0[1]	41	49	71	99[2]	49
Commercial deliveries	1[2]	12	17	25	66	49
Industrial deliveries	0[2]	5	14	20	95[1]	46
Unaccounted-for uses	0	10	15	25	40	41

[1] The public supplier with a low percentage of residential deliveries and high percentage of industrial deliveries was a public supply where almost all of its water was used by industrial facilities.

[2] The public supplier with high residential deliveries had no industrial customers and supplied water to only a small number of commercial facilities.

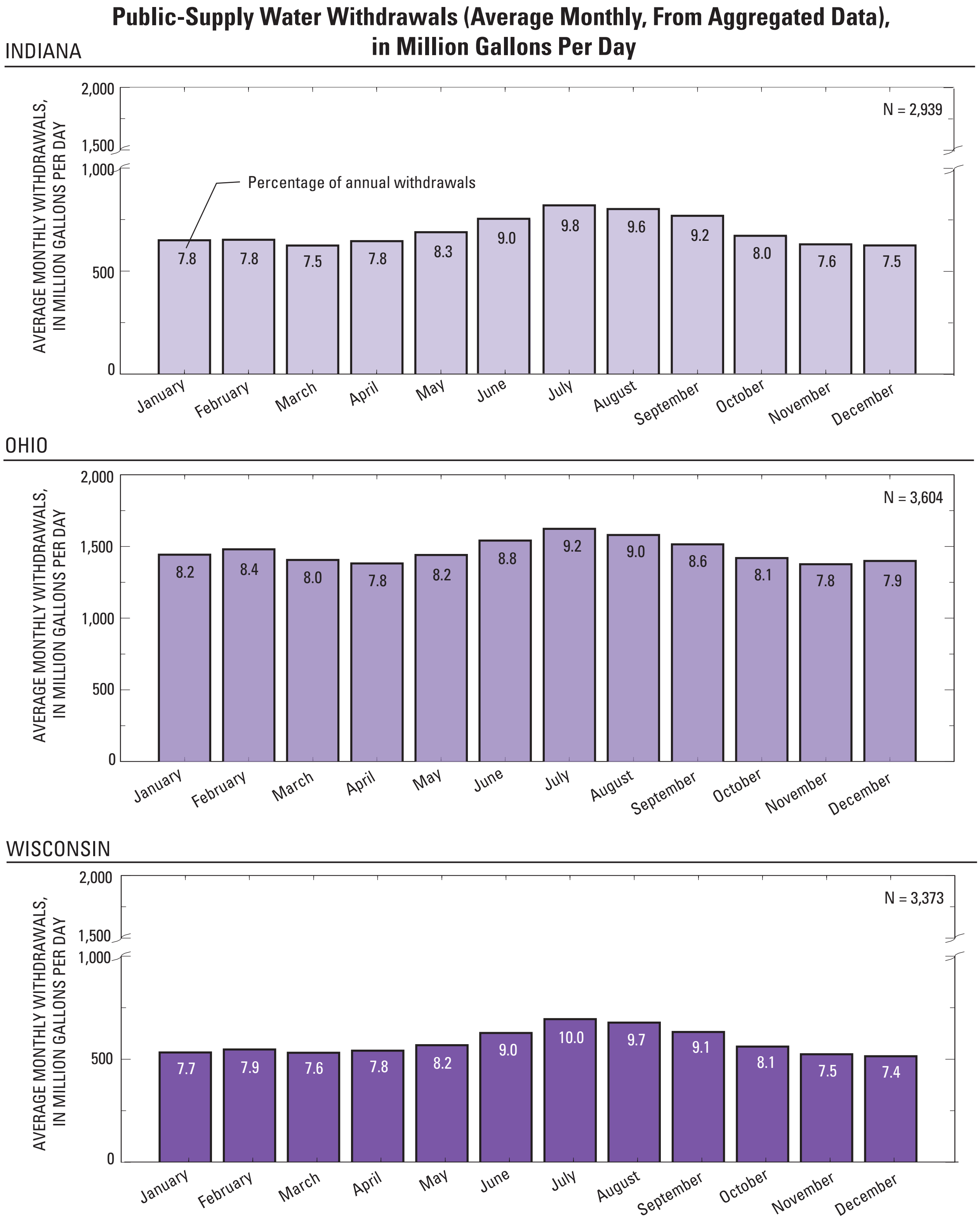


Figure 10. Indiana, Ohio, and Wisconsin monthly public-supply water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

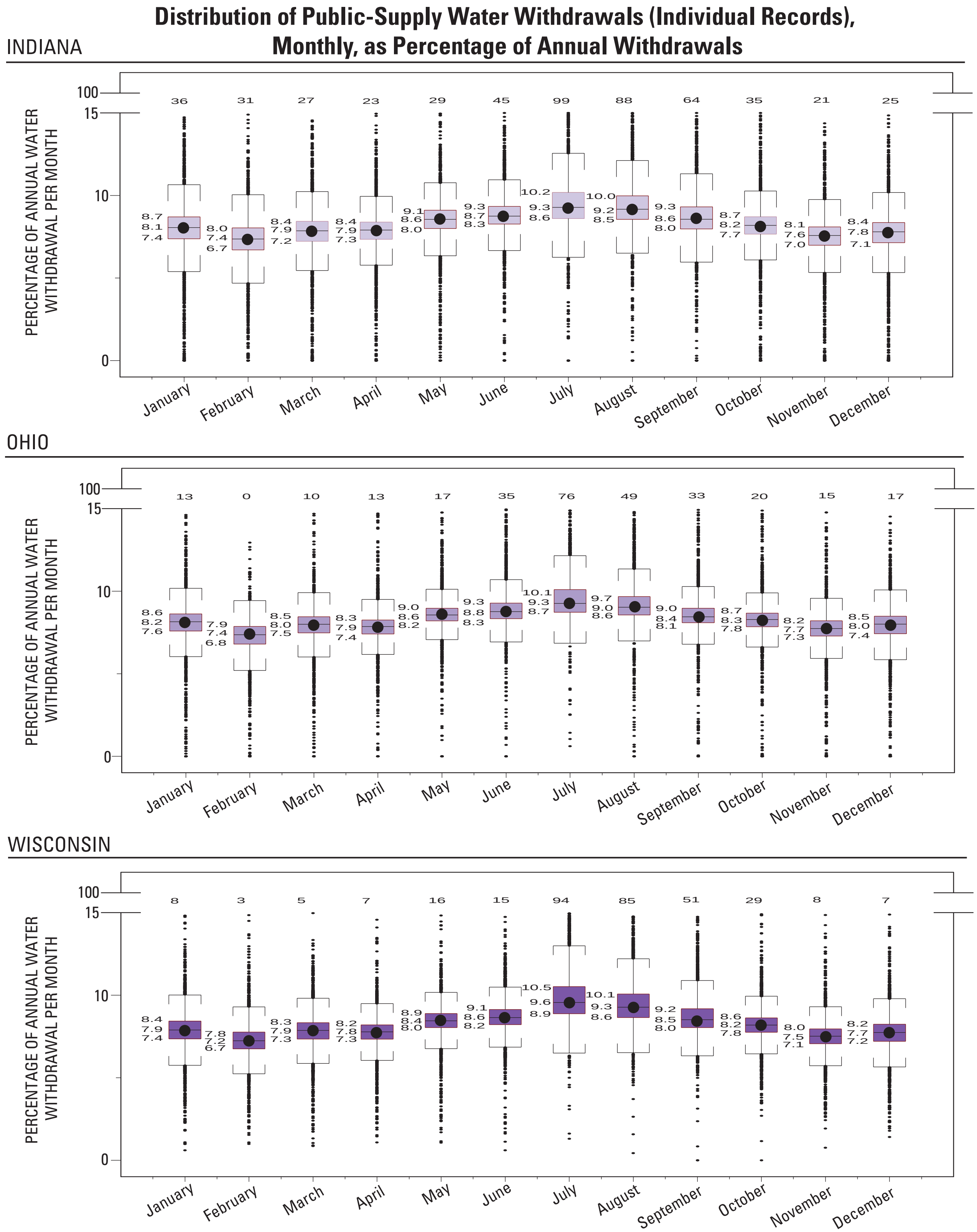


Figure 11. Indiana, Ohio and Wisconsin public-supply water withdrawals, monthly, as a percentage of annual withdrawals for 1999–2004 (see fig. 6 for explanation).

The Wisconsin data consist of two separate datasets for withdrawals and deliveries. The unaccounted-for uses (losses and public uses) were about 20 percent for Wisconsin during 1999 to 2004. Public-supply withdrawal records were organized by delivery data; specifically, by percentage of water delivered to residential customers. The withdrawals for each delivery group were divided by seasons. Summer was the season of the highest withdrawals for all residential categories (fig. 12), and public suppliers with higher withdrawals delivered 20 to 59 percent of their water to residential customers. Consumptive-use coefficients varied little by Wisconsin residential group (table 14), so Wisconsin withdrawals were then analyzed for three groups of public suppliers: those with residential deliveries greater than 85 percent, those with industrial deliveries greater than 50 percent, and those with commercial deliveries greater than 50 percent (fig. 13). The WBR consumptive-use coefficient was similar for each of the residential groups, and also for public suppliers with residential deliveries greater than 85 percent and public suppliers with industrial deliveries greater than 50 percent. The consumptive-use coefficients for public-supply facilities with residential deliveries of 0 to 29 percent were higher in spring and fall. Consumptive-use coefficients for the public-supply facilities with greater than 50 percent commercial deliveries were higher in the summer—43 percent—than for the other groups. This percentage is similar to those reported in the Commercial section: a 42-percent average coefficient from the RW method and coefficients of 42 percent Indiana for and 46 percent Ohio (1999–2004) from the WBR method. These elevated summer coefficients may be explained by commercial facilities characterized by a high proportion of outdoor withdrawals.

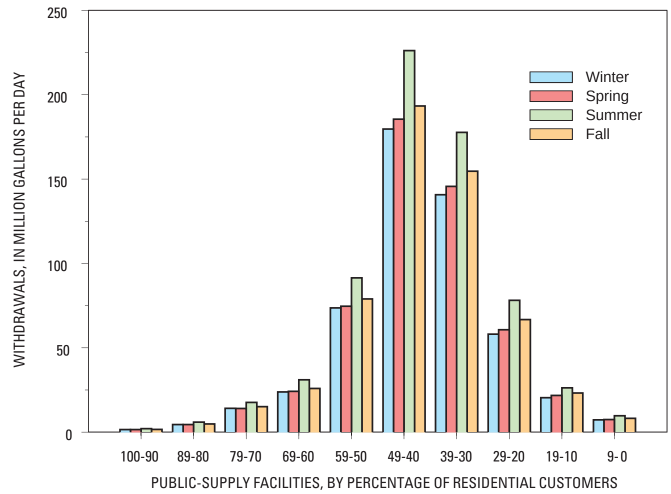


Figure 12. Wisconsin seasonal withdrawals for public-supply facilities, based on percentage of total withdrawals delivered to residential customers. (Winter, December–February; spring, March–May; summer, June–August; fall, September–November.)

Tables 15, 16, and 17 list the seasonal and annual consumptive-use coefficients for Ohio, Indiana, and Wisconsin, and table 18 lists the monthly consumptive-use coefficients for May through October. Overall, consumptive use was higher in July and August than in other months (table 17); summer consumptive use ranged from 10 to 26 percent (tables 14, 15, and 16). Table 19 lists the average monthly temperature and rainfall for the state and corresponds with table 18. Many of the higher consumptive-use coefficients (table 18) were found during periods of low rainfall and high temperatures (table 19).

Table 14. Wisconsin public-supply seasonal and annual consumptive-use coefficient, computed with the winter-base-rate method by delivery group for 1999–2004.

[Consumptive-use coefficient is in percent and is rounded to the whole number. N is the number of records. A range in the percentage of residential deliveries or delivery group denotes the percent range of the water delivered to residential customers (for example 100–90 are public suppliers that with 90 to 100 percent of their deliveries to residential customers. Res > 85 denotes public suppliers with 85 percent or more of their deliveries going to residential customers. Ind > 50 denotes public suppliers with 50 percent or more of their deliveries going to industrial customers. Com > 50 denotes public suppliers with 50 percent or more of their deliveries going to commercial customers.]

Percentage of residential deliveries or delivery group	Consumptive-use percentage				N
	Spring	Summer	Fall	Annual	
100–90	2	25	8	10	156
89–80	2	24	6	9	324
79–70	0	19	5	7	494
69–60	3	23	7	9	577
59–50	1	18	6	7	581
49–40	1	19	5	7	492
39–30	4	20	8	9	327
29–20	6	25	12	12	226
19–10	6	21	10	10	114
9–0	5	25	11	12	52
Res > 85	3	24	7	9	310
Ind > 50	4	21	11	10	333
Com > 50	10	43	15	21	94

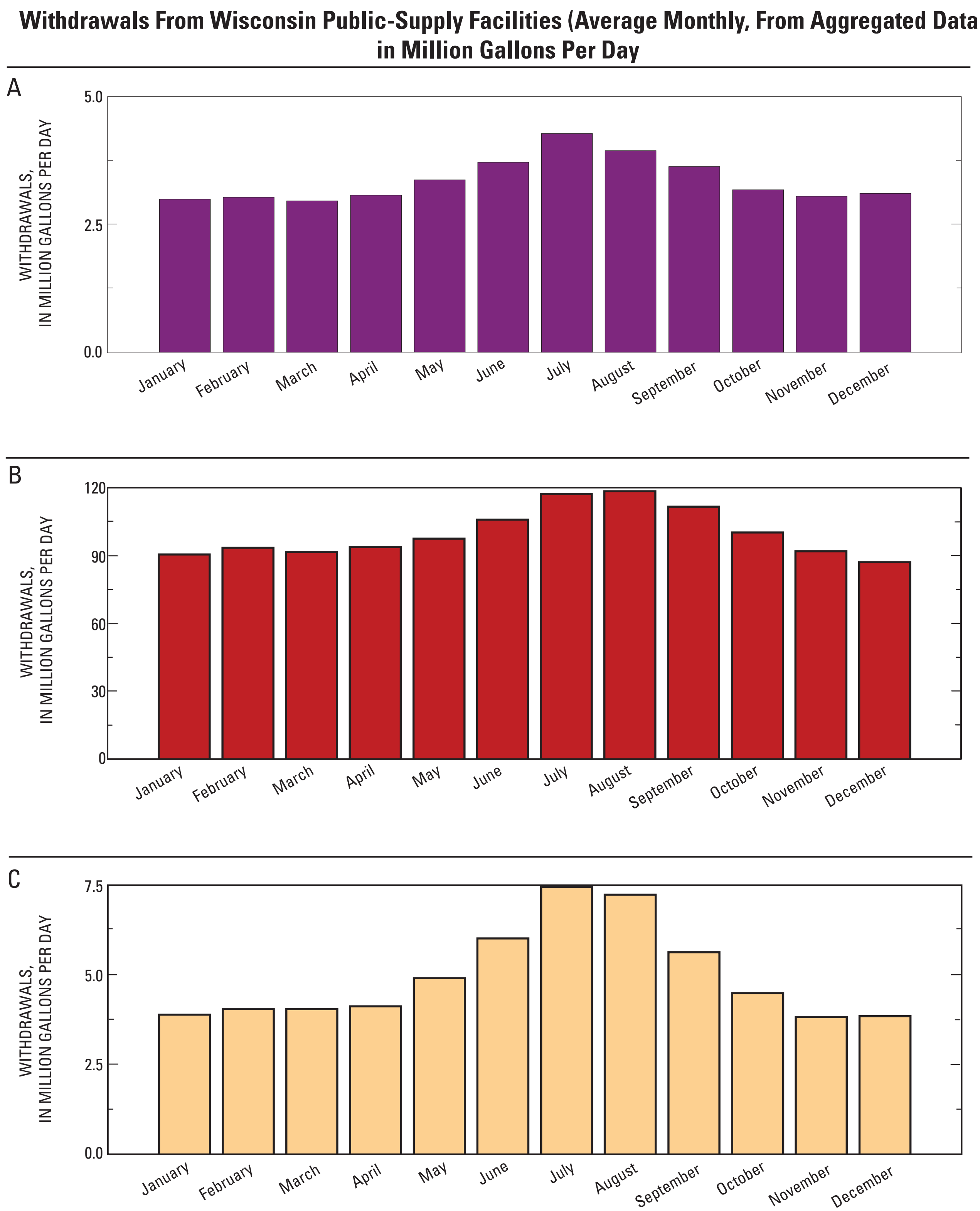


Figure 13. Wisconsin public-supply withdrawals, 1999–2004, for *A*, facilities delivering more than 85 percent of withdrawals to domestic customers; *B*, facilities delivering more than 50 percent of withdrawals to industrial customers; and *C*, facilities delivering more than 50 percent of withdrawals to commercial customers.

Table 15. Indiana public-supply seasonal and annual consumptive-use coefficients computed by use of the winter-base-rate method.

[Consumptive-use coefficient is in percent and is rounded to the whole number. N is the number of facilities.]

Year or statistic	Consumptive use (percent)				N
	Spring	Summer	Fall	Annual	
1999	2	23	11	10	485
2000	0	11	4	4	486
2001	6	18	3	7	482
2002	0	26	9	10	487
2003	1	18	6	7	498
2004	2	14	7	6	501
25th	0	14	4	6	-
Median	2	18	7	7	-
75th	2	23	9	10	-
1999–2004 average	2	19	7	7	2,971

Table 16. Ohio public-supply seasonal and annual consumptive-use coefficients computed by use of the winter-base-rate method.

[Consumptive-use coefficient is in percent and is rounded to the whole number. N is the number of records.]

Year or statistic	Facilities with July withdrawals ≥ February withdrawals				
	Consumptive use (percent)				N
	Spring	Summer	Fall	Annual	
1999	0	19	7	7	559
2000	0	10	2	3	485
2001	2	16	6	7	531
2002	0	22	11	9	531
2003	6	12	2	5	456
2004	0	12	2	3	436
25th	0	12	2	3	-
Median	0	14	4	6	-
75th	2	19	7	7	-
1999–2004	1	16	5	6	2,998

Table 17. Wisconsin public-supply seasonal and annual consumptive-use coefficients computed by use of the winter-base-rate method.

[Consumptive-use coefficient is in percent and is rounded to the whole number. N is the number of records.]

Year or statistic	Consumptive use (percent)				N
	Spring	Summer	Fall	Annual	
1999	3	21	9	9	561
2000	3	16	6	6	562
2001	3	22	5	8	562
2002	3	24	8	10	563
2003	3	22	8	9	562
2004	2	15	8	7	563
25th	3	16	6	7	-
Median	3	22	8	8	-
75th	3	22	8	9	-
1999–2004	3	20	7	8	3,373

Table 18. Monthly consumptive-use coefficients for Wisconsin, Ohio, and Indiana public supply computed by use of the winter-base-rate method.

[Consumptive-use coefficient is in percent and is rounded to the whole number. N is number of records.]

Year or statistic	Consumptive-use coefficient (percent)						
	N	May	June	July	August	September	October
Indiana							
1999	485	9	19	26	22	24	6
2000	486	4	8	14	12	12	2
2001	482	13	15	20	20	9	3
2002	487	3	17	31	28	21	4
2003	498	4	15	19	21	14	3
2004	501	7	13	15	14	16	6
25th percentile	-	4	13	15	14	12	3
Median	-	6	15	20	20	15	4
75th percentile	-	9	17	26	22	21	6
Ohio[1]							
1999	559	7	19	22	16	15	3
2000	485	4	9	12	10	7	1
2001	531	6	11	20	18	9	6
2002	531	1	14	27	24	19	8
2003	456	8	12	13	12	7	0
2004	436	5	9	15	11	8	0
25th percentile	-	4	9	13	11	7	0
Median	-	6	12	18	14	8	2
75th percentile	-	7	14	22	18	15	6
Wisconsin							
1999	561	7	23	22	19	19	5
2000	562	9	11	17	19	11	6
2001	562	7	13	30	22	9	5
2002	563	7	16	31	23	17	6
2003	562	5	17	21	28	20	5
2004	563	4	10	18	18	19	5
25th percentile	-	5	11	18	19	11	5
Median	-	7	14	22	20	18	5
75th percentile	-	7	17	30	23	19	6
Indiana, Ohio[1], Wisconsin (1999–2004)							
25th percentile	-	4	11	15	14	9	3
Median	-	6	14	20	19	14	5
75th percentile	-	7	17	26	22	19	6

[1] Ohio data are for facilities with withdrawals in July that are greater or equal to withdrawals in February.

Table 19. Monthly state-averaged precipitation and temperature data for Wisconsin, Ohio, and Indiana for 1999–2004.

[Monthly state-averaged precipitation is in inches, and temperature is in degrees Fahrenheit. Precipitation and temperature data from Midwestern Regional Climate Center (2008).]

Year	Data type	Monthly state-averaged precipitation and temperature data					
		May	June	July	August	September	October
Indiana							
1999	Precipitation	3.14	3.98	2.76	2.35	1.36	2.04
	Temperature	63.4	71.9	77.7	71.1	65.5	53.4
2000	Precipitation	4.54	6.30	3.81	4.46	4.58	2.21
	Temperature	64.1	70.3	71.8	72.0	64.3	57.2
2001	Precipitation	4.27	4.23	5.60	4.02	3.84	7.72
	Temperature	63.8	68.9	73.7	73.8	63.5	53.6
2002	Precipitation	7.00	3.25	2.76	2.85	3.76	2.83
	Temperature	58.4	72.9	77.0	74.8	69.3	52.3
2003	Precipitation	6.64	3.30	8.47	3.50	6.21	2.47
	Temperature	60.5	67.3	73.2	74.0	63.4	52.8
2004	Precipitation	7.27	4.64	5.17	4.96	0.76	4.26
	Temperature	65.8	69.5	72.1	68.6	67.0	54.6
Ohio							
1999	Precipitation	2.23	2.10	3.80	3.12	1.87	2.19
	Temperature	62.0	71.2	76.9	70.0	64.7	52.4
2000	Precipitation	4.82	4.76	3.98	3.81	3.83	2.22
	Temperature	62.8	69.9	70.0	69.7	63.1	55.7
2001	Precipitation	5.45	3.09	3.79	3.64	3.12	4.61
	Temperature	61.4	68.4	72.0	72.9	62.1	53.6
2002	Precipitation	5.18	3.62	2.75	2.09	4.17	3.09
	Temperature	56.9	71.5	75.9	74.2	68.3	52.0
2003	Precipitation	6.89	4.11	6.67	5.17	6.02	2.61
	Temperature	59.6	66.2	71.9	72.6	62.7	50.8
2004	Precipitation	6.99	4.64	4.54	4.21	4.50	2.77
	Temperature	64.4	67.9	71.4	68.3	65.8	53.1
Wisconsin							
1999	Precipitation	5.02	4.29	7.75	3.25	2.17	1.30
	Temperature	58.1	65.3	72.5	65.9	58.0	45.6
2000	Precipitation	4.28	6.62	4.53	3.83	3.78	0.90
	Temperature	56.8	62.7	67.6	67.5	58.1	50.3
2001	Precipitation	4.86	4.85	2.67	4.59	4.05	2.44
	Temperature	56.7	64.3	69.9	69.8	57.2	46.0
2002	Precipitation	3.01	5.60	3.63	4.47	4.58	3.97
	Temperature	50.6	66.1	72.7	67.5	61.5	41.9
2003	Precipitation	4.78	3.32	3.39	2.07	3.18	1.39
	Temperature	53.4	62.8	68.5	70.1	59.3	46.4
2004	Precipitation	7.64	4.61	3.33	3.21	2.16	3.58
	Temperature	52.7	61.8	66.8	62.1	62.8	47.8

Thermoelectric Power

Thermoelectric-power water use is water used in the process of generating electric power. Most of the consumptive use is from evaporation during condenser and reactor cooling, and a smaller amount is consumed by scrubbers and facility maintenance. The two basic types of thermoelectric facilities are **once-through thermoelectric power** facilities (also called open-loop cooling) and **other-than-once-through thermoelectric power facilities** (also called closed-loop or recirculating cooling). A once-through thermoelectric power facility uses water only once in the condenser- and reactor-cooling process before returning the water to a surface-water source. An other-than-once-through thermoelectric power facility uses cooling towers or cooling ponds to recycle water repeatedly for condenser and reactor cooling. Figure 14 shows thermoelectric water withdrawal by month for Ohio and Indiana in million gallons per day. Figure 15 shows water withdrawal by month as a percentage of the annual withdrawal, and table 2–6 lists the statistics for the percentage of annual water withdrawn per month. Ohio's thermoelectric average monthly withdrawals ranged from 7,380 to 10,000 Mgal/d, and Indiana's thermoelectric average monthly withdrawals ranged from 5,520 to 7,510 Mgal/d (fig. 14). July and August were the months of the greatest monthly median percentage of annual withdrawals: 10.6 and 10.4 percent for Indiana and 9.5 and 9.4 for Ohio (fig. 15). Cooling type, and operational and regulatory requirements can influence monthly water use and consumptive use. Cooling-type information is available from the U.S. Department of Energy and has been used in this study and other studies to estimate consumptive use by cooling type. Dziegielewski and others (2006) list benchmarks of weighted-average use rates of cooling water for thermoelectric plants; the percentage consumptive use for once-through systems is less than 1 percent, whereas closed-loop systems with cooling towers consume 70 percent for fossil-fuel plants and 30 percent for nuclear plants; recirculating systems with ponds consume 3 to 4 percent.

Thermoelectric-power withdrawals increase in the summer (fig. 14 and table 2–6). On the basis of Ohio withdrawal and return-flow data on sites that reported those data, the annual consumptive-use coefficient was between 0 and 10 percent for half of the facilities. The median consumptive-use coefficient was 2 percent (table 20), which is the same as that found by Shaffer and Runkle (2007) and very close to that found by Torcellini and others (2003), who estimated a consumptive-use coefficient of 2.5 percent nationwide for the United States.

The U.S. Department of Energy (2004) compiles data for consumptive use by thermoelectric powerplants. The 2005 U.S. Department of Energy water datasets for Ohio and Indiana (aggregated by Nancy Barber, U.S. Geological Survey, August 2006) include consumptive-use data for four types of plants: (1) once-through freshwater, (2) recirculating pond/canal, (3) recirculating draft tower (forced, induced, and natural-draft towers), and (4) plants that combine cooling types 1, and 2, and/or 3. Thermoelectric self-reported consumptive-use coefficients are listed in table 21. Facilities with once-through cooling and recirculating ponds and/or canals estimated 0 percent consumptive use (median, table 26). Facilities with recirculating draft towers estimated 22 to 100 percent consumptive use for Ohio and Indiana, with medians of 80 percent (Indiana) and 79 percent (Ohio) (table 21). Plants with recirculating draft towers have higher consumptive-use coefficients but much lower withdrawals than once-through cooling plants.

Example of a thermoelectric powerplant.

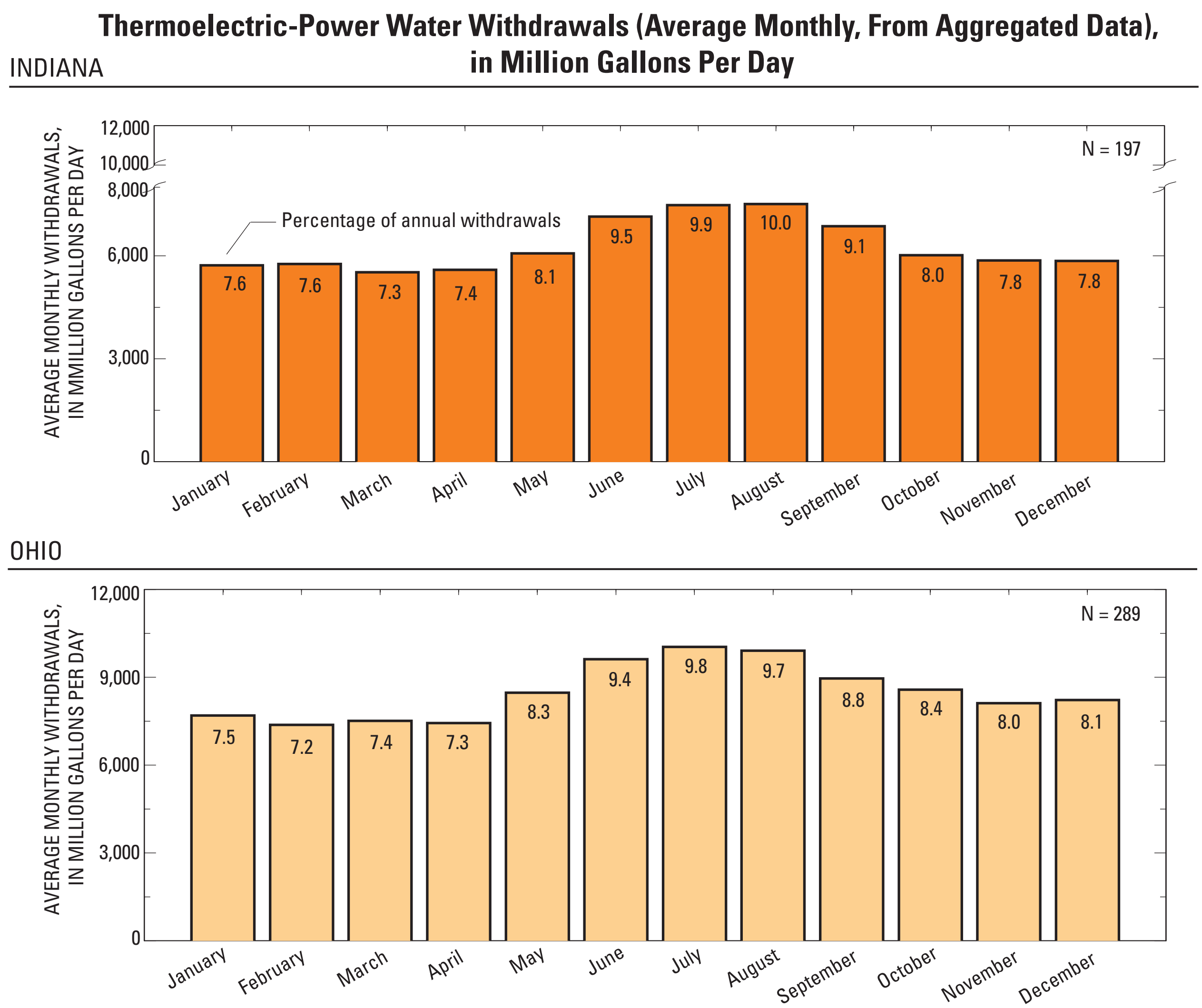


Figure 14. Indiana, and Ohio monthly thermoelectric-power water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

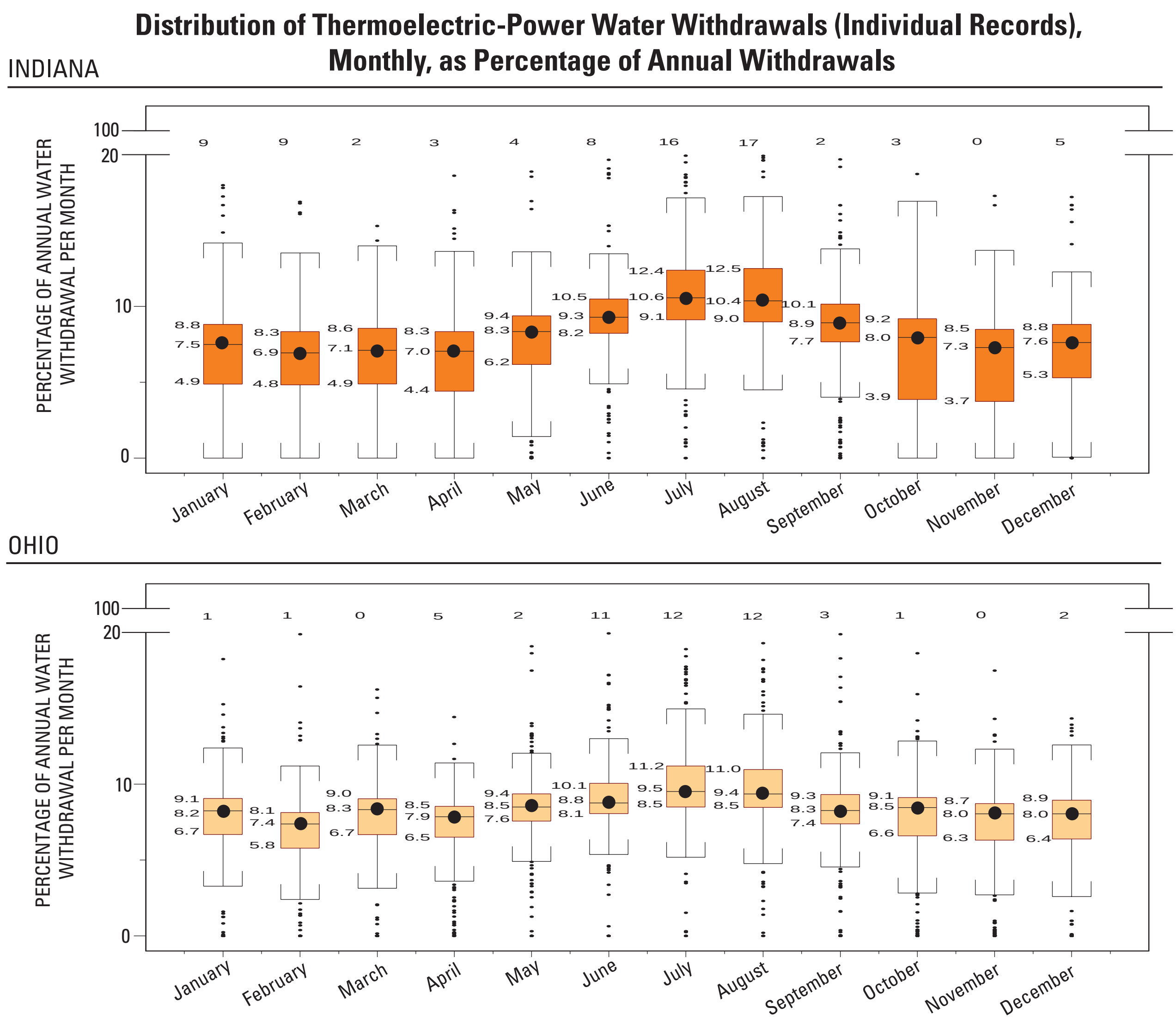


Figure 15. Indiana and Ohio thermoelectric-power water withdrawals, monthly, as percentage of annual water withdrawals for 1999–2004 (see fig. 6 for explanation).

Table 20. Ohio thermoelectric monthly consumptive-use coefficients statistics based on withdrawal and return-flow data for 1999–2004.

[Statistics are in percent and are rounded to the nearest whole number. Statistics based on 289 records. The median and 25th and 75th percentiles based on computing the consumptive-use coefficient for each record and analyzing for these statistics. Monthly consumptive-use coefficient average is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. The average is computed by taking the total withdrawals for all records and subtracting the individual-record return flows, then dividing this number by the individual-records' total withdrawals.]

Statistic	Jan	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Individual records with both types of cooling													
25th percentile	1	1	1	1	1	1	1	1	1	1	1	1	1
Median	1	2	1	3	2	5	3	3	2	2	2	2	2
75th percentile	5	6	3	5	5	6	6	8	5	5	3	5	5
Average	3	3	2	2	2	3	4	4	3	2	3	3	3
Individual records with closed-loop cooling													
25th percentile	6	5	6	3	6	7	7	12	6	5	6	6	9
Median	26	29	30	23	25	29	28	33	24	21	27	26	24
75th percentile	59	65	75	65	75	72	75	75	71	49	63	65	74
Average	23	23	24	22	25	24	24	25	25	25	24	24	24
Individual records with once-through cooling													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	0	0	0	0	0	0	0	0	0
75th percentile	1	1	2	2	2	1	1	1	1	2	1	2	2
Average	3	2	3	2	4	4	3	3	3	3	3	3	3
All records													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	1	1	1	1	1	1	1	1	1	1	1	1	2[1]
75th percentile	7	8	8	6	10	12	15	16	7	7	8	13	16
Average	4	4	4	4	5	5	5	5	4	4	4	5	5

[1] Annual calculation includes more records than monthly records.

Table 21. Indiana and Ohio thermoelectric consumptive-use coefficients computed from data for 2005.

[Consumptive-use coefficient is in percent and is rounded to the whole number. Consumptive-use coefficient was computed by dividing the average rate of consumption in million gallons per day by the average rate of withdrawal in million gallons per day. N is the number of cooling systems for each type of cooling; some plants have multiple systems. Data originally from U.S. Department of Energy, Energy Information Administration, aggregated by Nancy Barber, U.S. Geological Survey, in 2006.]

Type of cooling plant	Statistics					
	Minimum	25th percentile	Median	75th percentile	Maximum	N
Indiana						
Once-through, freshwater	0	0	0	0	100	30
Recirculating, pond/canal	0	0	0	0	0	6
Recirculating, draft tower	24	69	80	100	100	7
Plants with both once-through fresh-water and recirculating draft tower	0	0	0	0	96	11
Ohio						
Once-through, fresh water	0	0	0	0	0.03	29
Once-through cooling, pond/canal	0	0	0	0	0	1
Recirculating, draft tower	0	22	79	100	100	11
Plants with both once-through fresh and once-through cooling pond/canal	0	0	0	0	0	4

Irrigation

Irrigation water use is the application of water on lands to assist in the growing of crops, pasture grasses, and nursery plants or to maintain vegetative growth in recreational lands such as parks and golf courses. Irrigation consumptive use is from evapotranspiration (the combination of evaporation and transpiration from watering vegetation). Evaporation is water lost to the atmosphere during application of water and the ground surface. Transpiration is the release of water vapor through the leaves of a plant and varies in response to temperature, relative humidity, wind, soil type, soil-moisture availability, land slope, sunlight availability and intensity, and type of plant. Return flow after all types of irrigation occurs through groundwater recharge and, after furrow irrigation, to surface water as well.

Irrigation can be subdivided into three categories: golf-course (fig. 16), nursery and turf, and crop irrigation (fig. 17). Over the period 1999–2004, numbers of irrigation sites in the Indiana dataset ranged from 233 to 261 for golf course sites, 16 to 18 for nurseries and turf-irrigation facilities, and 1,288 to 1,402 for crop-irrigation sites per year. No return-flow data were available from Indiana. The Ohio dataset includes more than 400 self-supplied golf course facilities (approximately 79 percent of which were 18-hole golf courses, according to 2005 data), 97 to 122 nursery and turf-irrigation sites, and 54 to 87 crop-irrigation sites per year. Return-flow data from Ohio were available for only 5 percent of golf courses. No irrigation withdrawal or return-flow data were available from Wisconsin.

Golf-course irrigation withdrawal can also include a proportion of water for clubhouse use, restaurants, toilets, sinks, showers, and cleaning of equipment. The withdrawal occurs primarily from May through October for Ohio and Indiana (fig 18; table 2–7). The average withdrawals shown in fig. 12 do not include sites that reported no withdrawals in a given year. Even though Indiana has 38 percent of the golf courses among the two states, it accounts for 44 percent of the golf course withdrawals, primarily because facilities in Indiana irrigated more. Return-flow data for golf courses in Ohio may represent irrigation activity, discharges after commercial activities in the clubhouse, or a combination of both.

Withdrawal for nursery and turf irrigation can occur year round, but it peaks in May through August (fig. 19; table 2–8). Return flows for nurseries occur during the months of withdrawals. Ohio had more nursery farms, nursery irrigated farms, square feet under glass or other protection, acres in the open, and irrigated acres in the open for nurseries than Indiana (U.S. Department of Agriculture, 2008; tables 22 and 23).

Drip hoses supply irrigation water to day lilies at a western Ohio nursery.

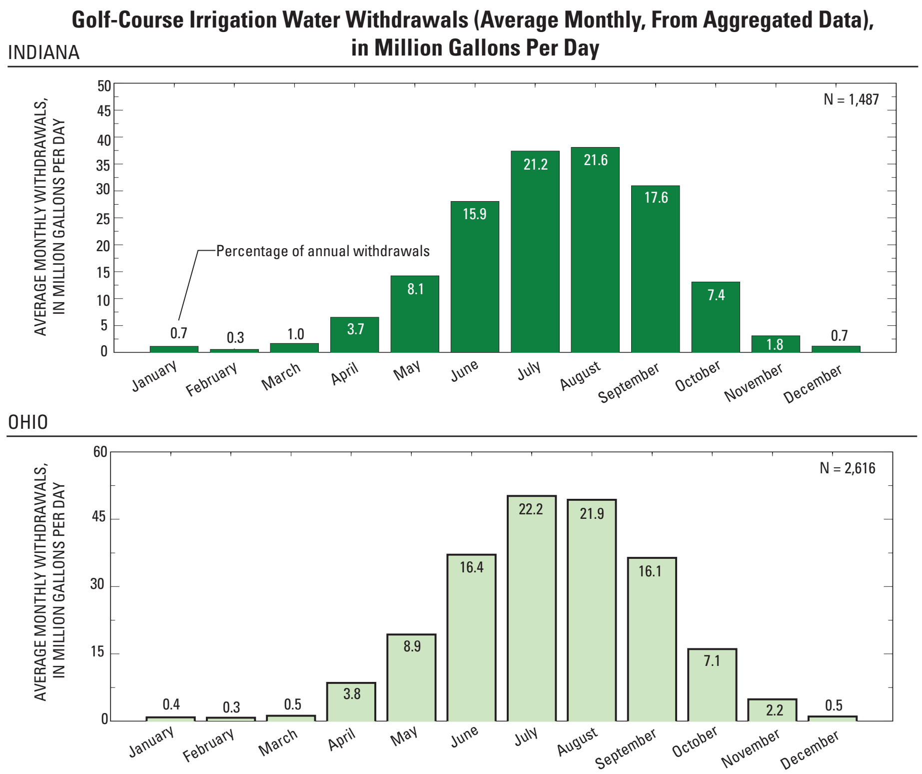


Figure 16. Indiana and Ohio monthly golf-course irrigation water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

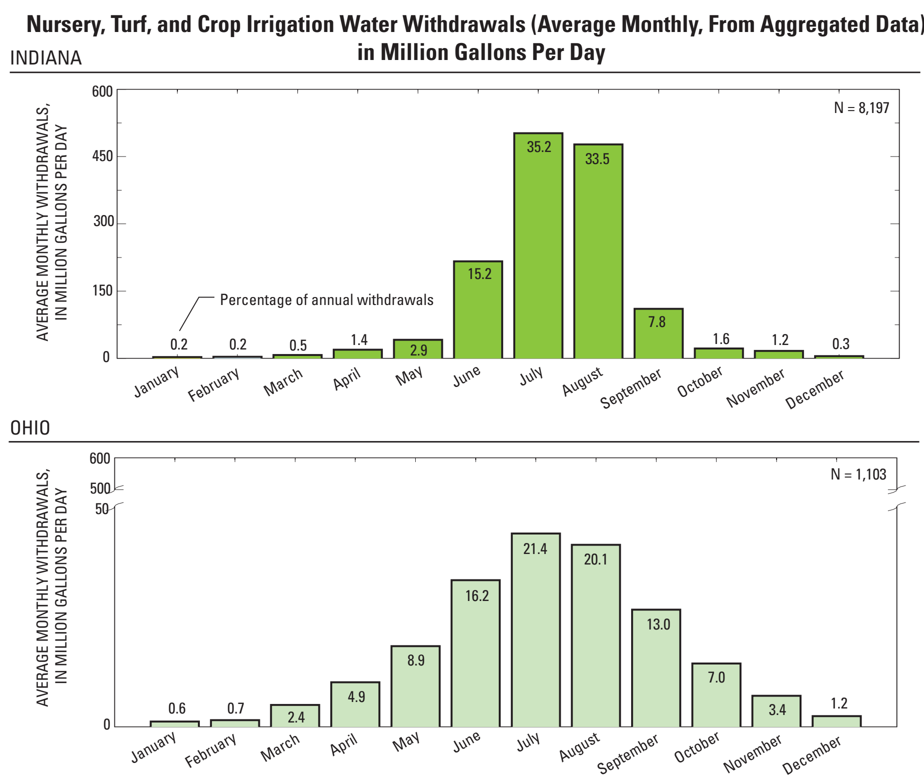


Figure 17. Indiana and Ohio monthly nursery, turf, and crop irrigation water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

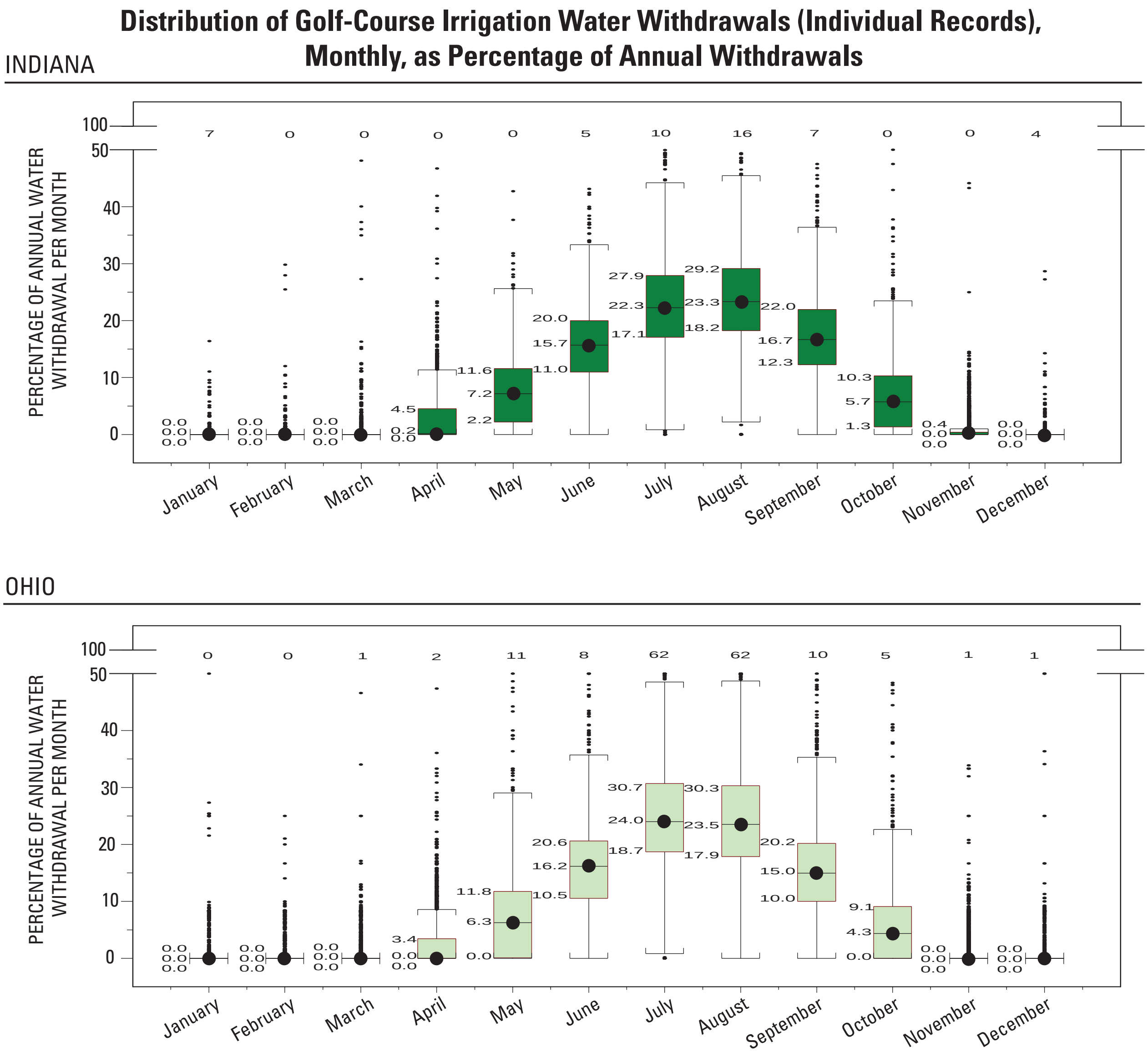


Figure 18. Indiana and Ohio golf-course-irrigation water withdrawals, monthly, as percentage of annual water withdrawals for 1999–2004 (see fig. 6 for explanation).

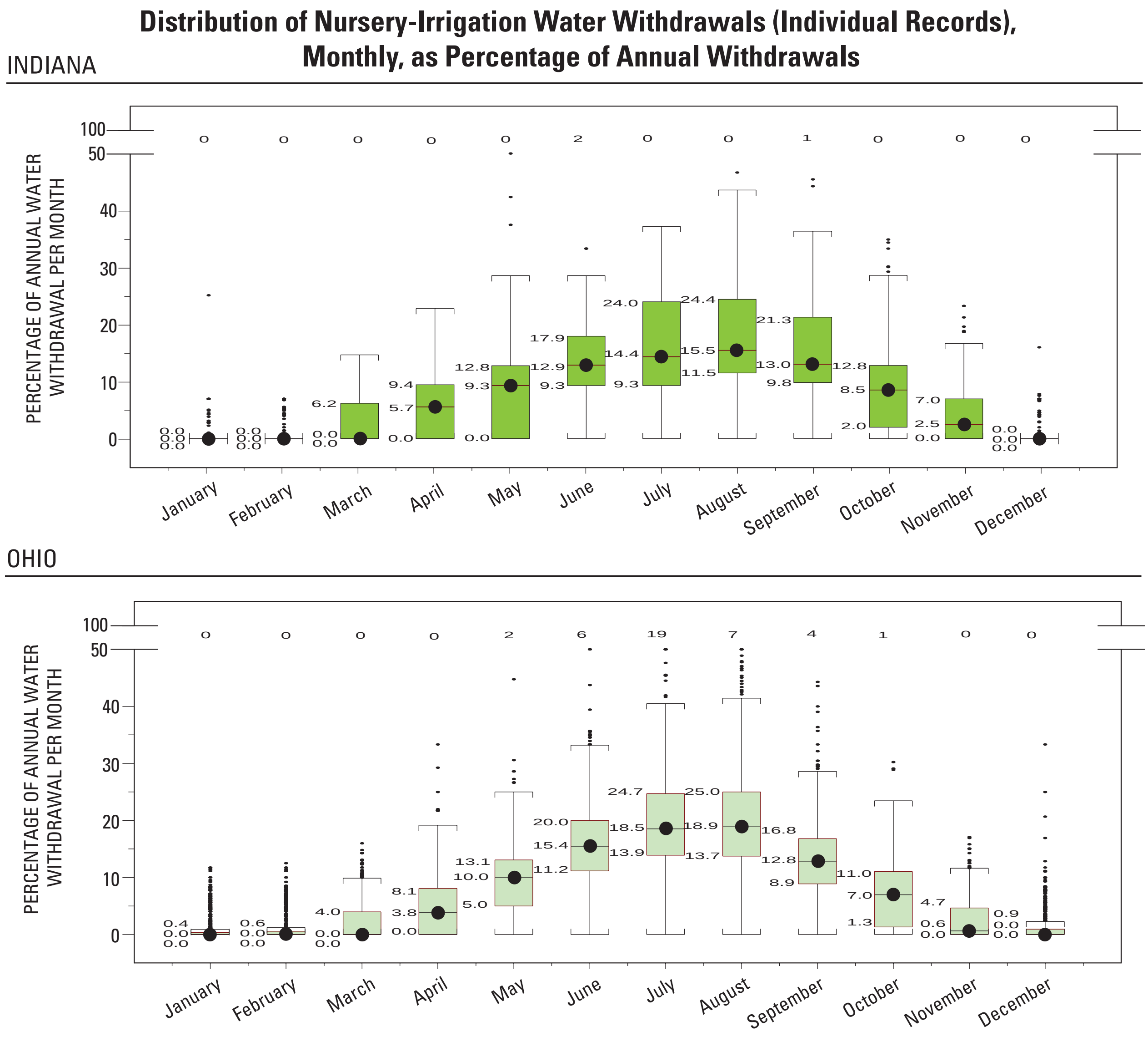


Figure 19. Indiana and Ohio nursery-irrigation water withdrawals, monthly, as percentage of annual withdrawals for 1999–2004 (see fig. 6 for explanation).

Table 22. Agricultural irrigation data for Ohio and Indiana in 2002.

[Data from the U.S. Department of Agriculture, 2008; (D), withheld to avoid disclosing data for individual farms; NR, not reported.]

Agricultural product	Indiana				Ohio			
	Harvested		Irrigated		Harvested		Irrigated	
	Farms	Acres	Farms	Acres	Farms	Acres	Farms	Acres
Selected crops harvested	44,298	11,937,370	2,122	311,963	58,577	10,041,416	2,561	39,881
Corn for grain[1]	24,156	5,123,291	767	180,305	23,898	2,869,951	26	3,387
Sorghum for grain	94	9,950	3	(D)	21	996	-	-
Wheat for grain	5,907	299,873	30	2,862	14,340	796,085	1	(D)
Barley for grain	75	1,255	-	-	489	5,745	-	-
Buckwheat	3	76	-	-	22	1,615	-	-
Canola	2	(D)	-	-	1	(D)	-	-
Emmer and spelt	25	268	-	-	297	4,125	-	-
Oats for grain	914	11,015	1	(D)	3,865	55,151	2	(D)
Popcorn	273	69,207	40	9,791	353	67,378	2	(D)
Proso millet	-	-	-	-	1	(D)	-	-
Rye for grain	91	1,070	-	-	270	3,521	2	(D)
Sunflower seed, all	30	307	2	(D)	31	849	-	-
Triticale	1	(D)	-	-	5	51	-	-
Dry edible beans, excluding limas	19	1,016	-	-	44	3,988	-	-
Potatoes	131	2,491	29	2,090	314	4,865	23	1,067
Sweet potatoes	12	5	4	2	46	13	6	1
Sugarbeets	-	-	-	-	21	1,530	1	(D)
Soybeans[2]	25,212	5,761,363	558	84,571	26,327	4,718,690	12	1,478
Tobacco	1,282	4,034	57	317	1,845	5,764	10	90
Field and grass seeds	14	249	-	-	178	3,941	-	-
All hay and forage[3]	22,196	625,898	77	2,928	33,939	1,271,137	16	530
All haylage, grass silage, and greenchop	937	34,869	17	826	2,648	130,327	1	(D)
Corn for silage or greenchop	2,875	116,939	41	5,222	5,503	255,359	7	548
Sorghum for silage or greenchop	56	1,020	-	-	110	1,861	-	-
Land used for vegetables [4]	1,139	37,682	374	16,892	2,323	43,909	655	16,654
Land in orchards	613	5,354	47	268	1,654	13,144	192	922
Fruits and nuts	1,159	5,314	NR	NR	3,472	13,149	NR	NR
Land in berries	311	1,226	102	602	772	1,555	278	878
Cut christmas trees	373	5,630	-	-	1,105	16,625	-	-
Maple syrup	128	-	-	-	594	-	-	-
Nursery, floriculture, etc.[5]	1,123	14,095	305	4,341	2,700	38,439	660	12,787

[1] Indiana counties with more than 2,500 acres of irrigated corn for grain were Bartholomew, Elkhart, Fulton, Jasper, Knox, Kosciusko, LaGrange, Lake, La Porte, Marshall, Newton, Noble, Porter, Posey, Pulaski, St. Joseph, Starke, and Sullivan. No Ohio counties had more than 2,500 acres of irrigated corn for grain; the highest amount was in Fulton County with 1,105 acres.

[2] Indiana counties with more than 2,500 acres irrigated for soybeans were Elkhart, Fulton, Jasper, Knox, Kosciusko, LaGrange, La Porte, Porter, Posey, Pulaski, St. Joseph, Starke, and Sullivan. There were no Ohio counties with more than 2,500 acres irrigated for soybeans.

[3] "All hay and forage" includes land used for all hay and all hayage, grass silage, and greenchop.

[4] Indiana counties with more than 1,000 acres of irrigated land used for vegetables were Knox, LaGrange, Lake, La Porte, and Sullivan. Ohio counties with more than 1,000 acres of irrigated land used for vegetables were Huron and Lucas; in Fulton, Mahoning, Meigs, and Putnam counties more than 600 acres were irrigated.

[5] Harvested numbers are for nursery, greenhouse, floriculture, aquatic plants, mushrooms, flower seeds, vegetable seeds, and sod harvested, total farms and acres in the open. Irrigation numbers are for nursery, floriculture, vegetable and flower seed crops, sod harvested, etc., grown in the open, irrigated. Indiana Counties with more than 230 acres irrigated were Hamilton, Lake, and St. Joseph. Ohio Counties with more than 230 acres irrigated were Butler, Clark, Delaware, Franklin, Fulton, Hamilton, Lake, Lorain, Pickaway, Stark, Union, Warren, and Wayne.

Table 23. Nursery data for Ohio and Indiana in 2002.

[Data from the U.S. Department of Agriculture, 2008; (D), withheld to avoid disclosing data for individual farms; (X), Not applicable).]

Nursery product	Indiana			Ohio		
	Farms	Square feet under glass or other protection	Acres in the open	Farms	Square feet under glass or other protection	Acres in the open
State total	1,123	16,215,460	14,095	2,700	39,708,263	38,439
Nursery, floriculture, vegetable and flower seed crops, sod harvested, etc., grown in the open, irrigated	305	(X)	4,341	660	(X)	12,787
Bedding/Garden plants	599	9,471,681	300	1,196	24,215,599	801
Cut flowers and cut florist greens	73	461,610	85	144	1,346,649	216
Foliage plants	101	1,054,042	20	109	790,018	52
Potted flowering plants	251	3,642,120	95	405	6,818,842	101
Aquatic plants	15	(D)	4	48	146,108	17
Bulbs, corms, rhizomes, and tubers – dry	17	13,306	(D)	40	115,930	36
Flower seeds	7	(D)	(D)	16	25,288	5
Greenhouse vegetables	49	384,632	(X)	139	1,151,891	(X)
Mushrooms	5	(D)	(X)	11	23,719	(X)
Nursery stock	442	470,108	8,210	1,267	4,229,895	26,963
Sod harvested	38	(X)	5,076	62	(X)	9,434
Vegetable seeds	18	8,418	1	35	134,452	60
Other nursery and greenhouse crops	27	118,850	133	85	710,412	756

Withdrawal for crop irrigation in Indiana (fig. 17) was almost 7 times that in Ohio, and the irrigated acreage in Indiana was almost 7 times that in Ohio. The threshold requirement for reporting water withdrawal is the same for Indiana and Ohio (a capacity to withdraw 100,000 gal/d). Most Indiana withdrawals are in June, July, and August (fig. 20). Table 22 lists the irrigated farms and acreage in 2002 for Ohio and Indiana (U.S. Department of Agriculture, 2008), and figure 21 shows 2002 irrigated acreage. Indiana had more irrigated farms and irrigated acreage for corn (for grain) and soybean crops than Ohio. A reported 2 to 3 percent of corn and soybean farms in Indiana irrigated their crops, whereas the proportion in Ohio was less than 0.1 percent. Irrigated vegetable acreage in the two states was similar (U.S. Department of Agriculture, 2008). Approximately two-thirds of crop farm withdrawal occurs in July and August in Indiana, as does half of the annual withdrawal in Ohio (table 2–8).

Improving the understanding of consumptive use in irrigation would require field studies measuring groundwater recharge, runoff, and, where flood irrigation is used, measuring the return flow from the field. By definition in Ohio, consumptive use is 100 percent.

Instructions for the Ohio Water Withdrawal Facility Registration tell facilities to assume 100 percent consumptive use for irrigation (golf, crop, nurseries) (Paul Spahr, Ohio Department of Natural Resources, written commun., 2008). The ODNR database for 1999–2004 includes more than 2,000 golf course records, but only 94 of them furnished return-flow data. Most sites did not report return flow, but it is not known whether the nonresponse was because (1) return-flow data are not required, (2) the form implies that return flow will not occur (100 percent consumption is assumed), or (3) course managers have actually observed that 100 percent (or most) of the water withdrawn is evaporated or transpired. The 94 records that reported return-flow data can be put in the two categories consumptive use of less than 40 percent or greater than or equal to 40 percent. Results of an analysis of the sites with consumptive use greater than or equal to 40 percent are listed in table 24. On the basis of withdrawals and return flows, the median consumptive-use coefficient for golf courses was 77 percent (annually), but 80 to 84 percent from June through September, when most of the withdrawals occur. This 77 percent may not reflect the hydrology of all golf courses because it does not include facilities that did not report return-flow data.

For other irrigation (primarily crop and nursery irrigation), the Ohio Water Withdrawal Facility Registration Program listed more than 1,700 individual records, but only 66 included return flow. Reasons for nonresponse are unknown but may be the same as those suspected for golf courses. Four sites with return-flow data were not included in statistical analyses because all withdrawals or return flows were in one month or the facility reported zero consumptive use. Of the remaining 62 records, 20 were for crop irrigation and 42 were nursery irrigation. The median consumptive-use coefficient was 78 percent for the entire year (table 24) but 80 to 82 percent for June through September, when most withdrawals occur. The averages for the months in table 24 were similar to the median consumptive-use coefficient in table 25.

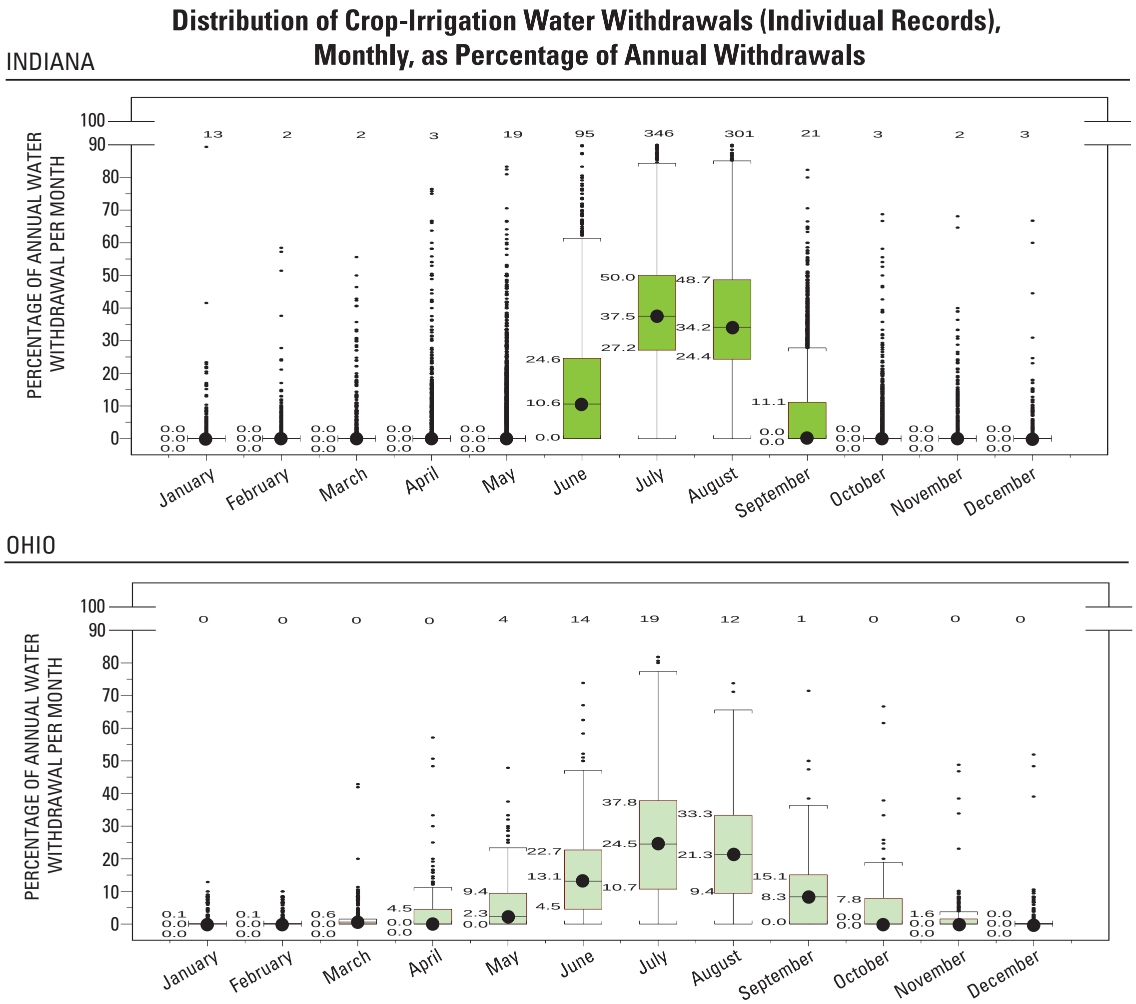


Figure 20. Indiana and Ohio crop-irrigation water withdrawals, monthly, as percentage of annual withdrawals for 1999–2004 (see fig. 6 for explanation).

Table 24. Monthly average consumptive-use coefficients for golf course and nursery and crop irrigation based on Ohio withdrawal and return-flow data for 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Average consumptive-use coefficient is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. – indicates that withdrawals were less than return flows for the month. Golf-course irrigation numbers are based on 59 records. Other irrigation based on 62 records (20 crop and 42 nursery).]

Month or statistic	Average consumptive-use coefficient	
	Golf-course irrigation	Nursery and crop irrigation
January	51	21
February	47	30
March	43	80
April	43	82
May	70	82
June	75	80
July	76	80
August	79	79
September	86	77
October	89	73
November	86	76
December	51	41
Annual, 25th percentile	63	65
Annual, median	77	78
Annual, 75th percentile	97	89
Annual, average	78	78

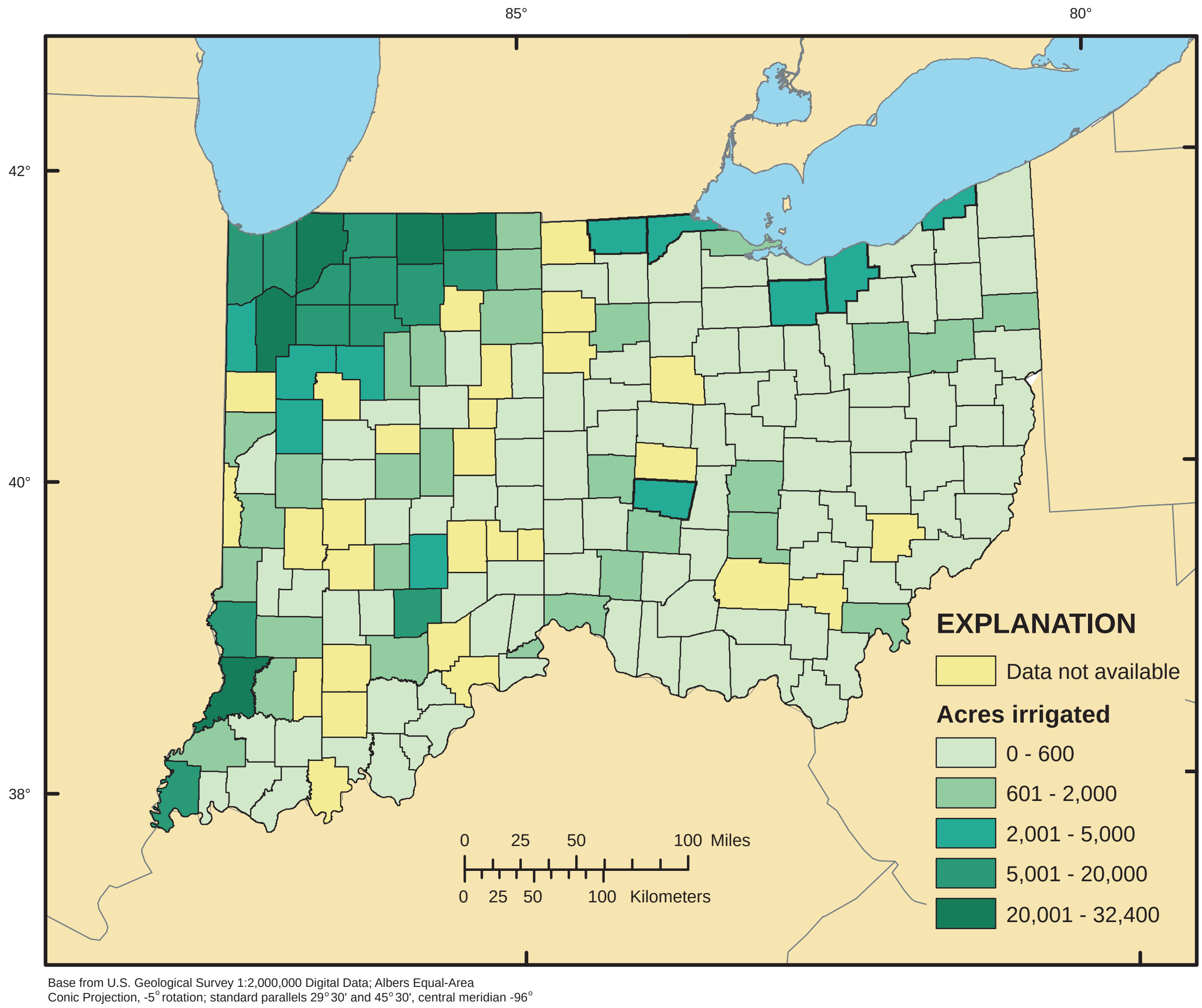


Figure 21. Irrigated land acreage in Indiana and Ohio for 2002 (National Agricultural Statistics Service, 2008).

Table 25. Ohio irrigation monthly consumptive-use coefficient statistics, based on withdrawal and return-flow data for 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Average consumptive-use coefficient is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. – indicates that withdrawals were less than return flows for the month. Golf-course irrigation numbers based on 59 records. Other irrigation based on 62 records (20 crop irrigation and 42 nursery irrigation).]

Statistic	Consumptive-use coefficient							
	April	May	June	July	August	September	October	November
Golf-course irrigation								
25th percentile	1[1]	42	65	67	68	68	37	0[1]
Median	71	75	82	80	84	82	75	3[1]
75th percentile	99	98	98	95	98	99	98	94
Crop and nursery irrigation								
25th percentile	67	68	65	68	66	60	56	37
Median	79	78	82	80	80	81	81	70
75th percentile	93	91	90	90	93	92	90	84

[1] These numbers are low because many of the facilities had no withdrawals or return flows in these months.

Livestock

Livestock water use is water associated with livestock watering, feedlots, dairy operations, and other on-farm needs (Hutson, Barber, and others, 2004); consumptive use occurs during stock watering—by which water is incorporated into the product (milk, eggs, growth of livestock) or evaporates—and facility and animal cleaning—during which water evaporates. Some water used for stock watering may be returned to the hydrologic environment, but water quality and location of the return may limit if and when this water is available for reuse. Only livestock facilities that have the capacity to withdraw 100,000 gal/d are required to report withdrawals to Ohio and Indiana. Much of the livestock withdrawals in Ohio and Indiana may be from facilities that have a capacity of less than 100,000 gal/d. This is why Census of Agriculture data frequently are used to estimate livestock water use (Hutson, Barber, and others, 2004). Therefore, figure 22 may not be representative of all the livestock withdrawals in Ohio and Indiana.

Livestock facilities can be categorized as those that withdraw continuously throughout the year and those that withdrawal seasonally, most likely from the start to end of a livestock production schedule (animals born in the spring and sold off in the fall). Figure 22*A* shows livestock water use for all the reporting Indiana sites, and figure 22*B* shows the water use for Ohio facilities.

Ohio withdrawals are fairly constant (fig. 23), whereas Indiana monthly percentages appear to be much more affected by seasonal withdrawals. Table 2–9 lists the percentage of annual withdrawals for Indiana and Ohio sites, and table 2–10 lists the summary statistics for Indiana broken out by seasonal facilities and all-year facilities. Statistics for all-year facilities in Ohio (table 2–9) and Indiana (table 2–10) are similar, but withdrawals at the Indiana seasonal sites are highly concentrated in June through September. Among 18 individual records with return flow from Ohio, the consumptive-use coefficients ranged from 12 to 100 percent, with a median of 76 percent. The facility with a 12 percent consumptive-use coefficient reported to ODNR (2008) that 50 percent of groundwater withdrawals was used as process water and 50 percent was for cooling water, which would explain the low consumptive-use coefficient. Because the records are so few, the median consumptive-use coefficient should be viewed with caution.

Livestock water use is water associated with livestock watering, feedlots, dairy operations, and other on-farm needs.

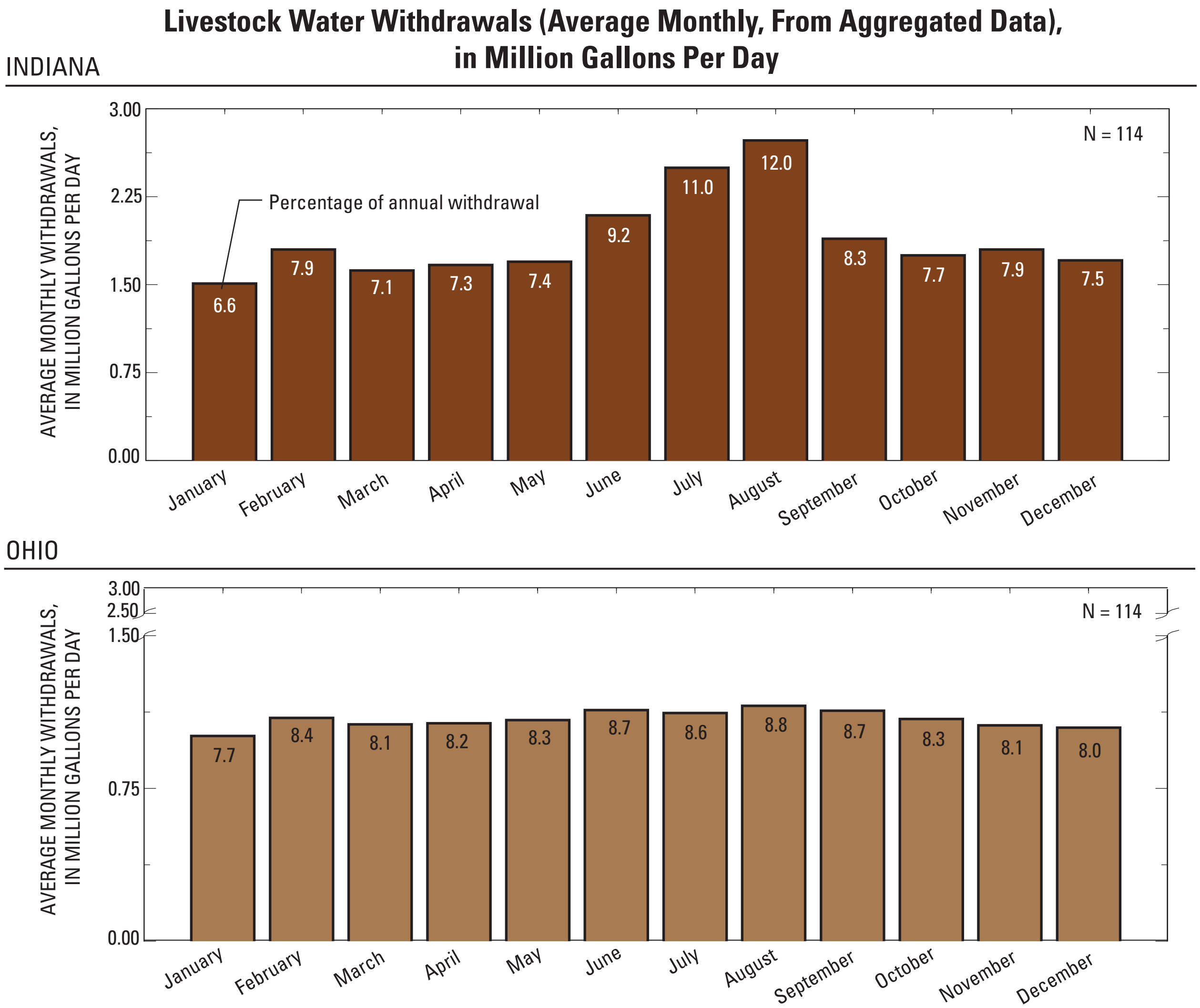


Figure 22. Indiana and Ohio monthly livestock water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

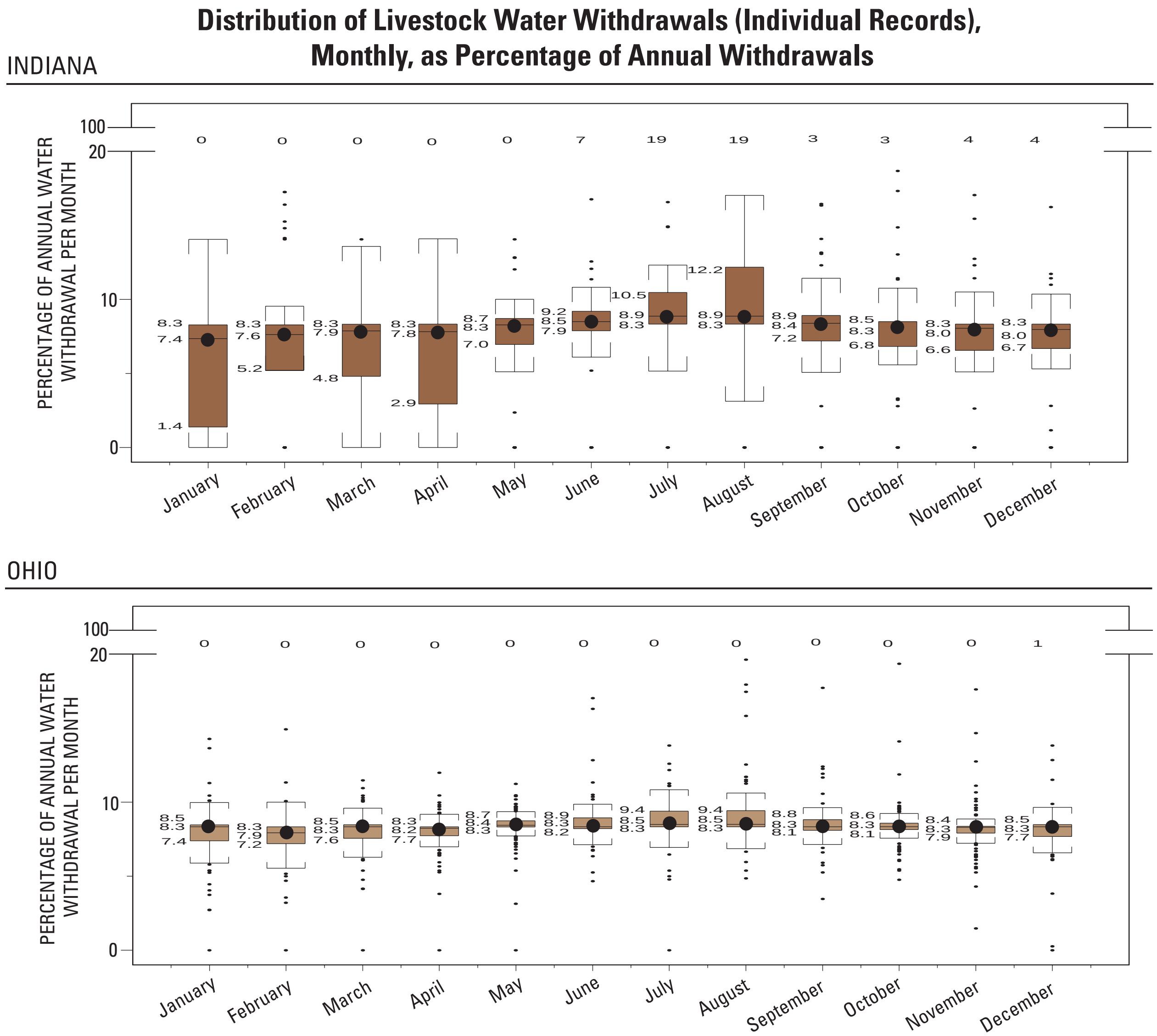


Figure 23. Indiana and Ohio livestock water withdrawals, monthly, as percentage of annual withdrawals for 1999–2004 (see fig. 6 for explanation).

Aquaculture

Aquaculture water use is water associated with raising organisms that live in water and includes fish-farming and fish-hatchery activities. Aquaculture production includes controlled feeding, sanitation, and harvesting procedures primarily in ponds, flowthrough raceways, and, to a lesser extent, cages, net pens, and closed-recirculation tanks (Hutson, Barber, and others, 2004). There were 11 aquaculture sites in Indiana and 8 sites in Ohio with data between 1999 and 2004. The average monthly withdrawals are graphed in figure 24. Many of the Indiana and Ohio facilities had specific months during which no water was withdrawn (tables 2–11).

The months that tend to have highest withdrawals (March through June) correspond with fish-hatchery life cycles for cool-water species, which end in late May when the fish are stocked as fingerlings (John Tertuliani, U.S. Geological Survey, oral commun., 2008). The water withdrawals tend to correspond with production times of each species of fish; water withdrawals may be higher when ponds are filled before production and after production (after the pond has been drained after production). Higher withdrawals in December and January may be to prevent ponds from freezing by pumping water to aerate the pond (a frozen-over pond would limit photosynthesis). The type of aquaculture facility may also affect withdrawals and consumptive use:

1. *Raceways*—Typically the water flows through the raceways, and only a small percentage of water is evaporated.

2. *Ponds*—Typically, ponds have high levels of evaporation and therefore consumptive use (especially during the summer months). Water for hatcheries that use ponds might fill up the pond 3 to 5 months before the pond is drained, thus making it difficult to quantify evaporation and consumptive use because of the time lag.

There were 65 individual aquaculture records for Ohio between 1999 and 2004. For Ohio aquaculture, fewer than 35 individual records included return-flow and withdrawal data. The consumptive-use coefficients from the return-flow method ranged from 0 to 100 percent, with half (IQR) of the coefficients between 0 and 2 percent. The average consumptive-use coefficient for the individual records was higher (5 percent, table 26).

Fish hatcheries represent a major form of aquaculture in the United States. (Photograph from the Oregon Department of Fish and Wildlife, reproduced with permission.)

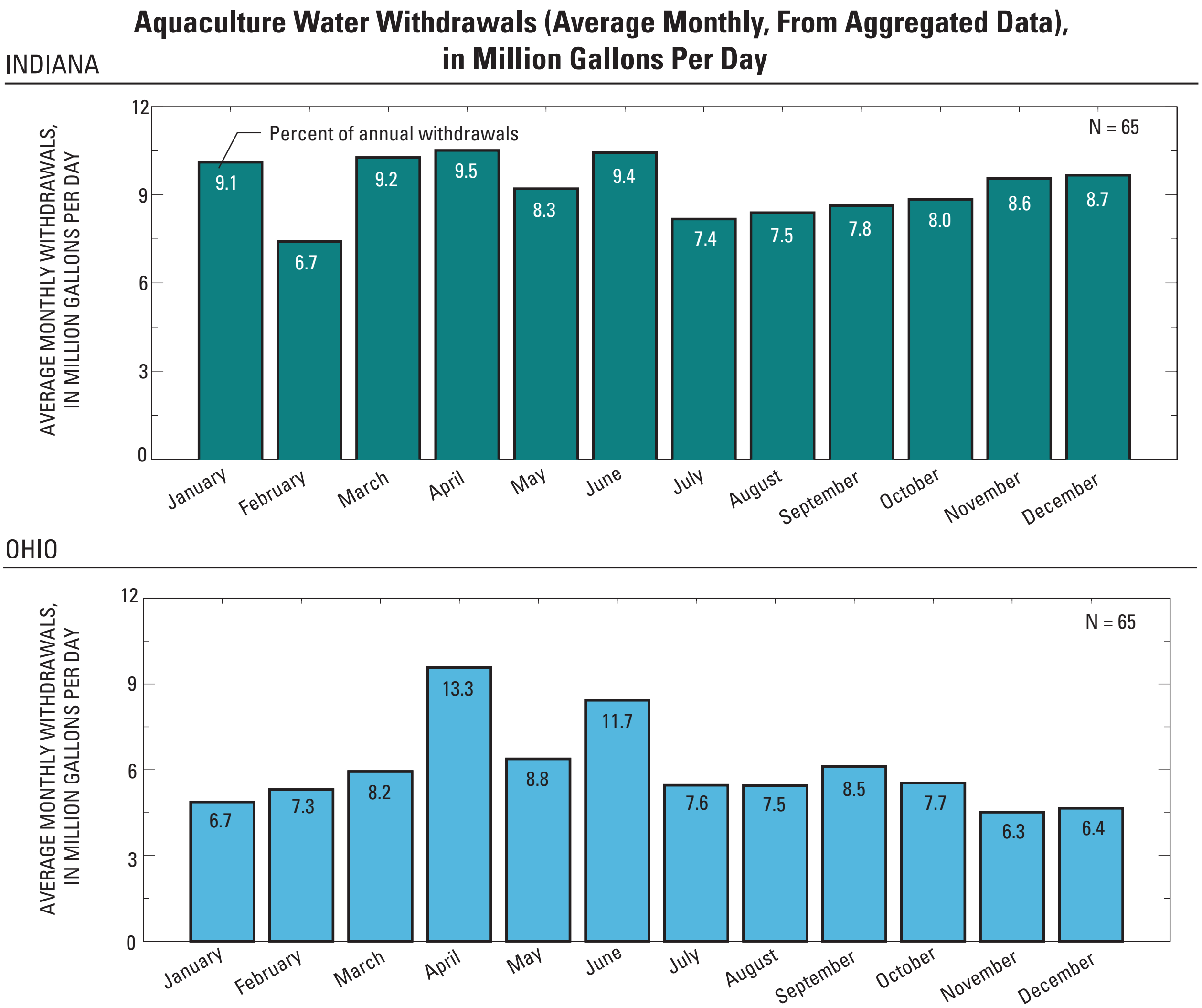


Figure 24. Indiana and Ohio monthly aquaculture water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

Table 26. Ohio aquaculture monthly consumptive-use coefficient statistics, based on withdrawal and return-flow data for 1999–2004.

[Statistics are in percent and are rounded to the nearest whole number. The median and 25th and 75th percentiles are based on computing the consumptive-use coefficient for each record and analyzing for these statistics. Monthly consumptive-use coefficient average is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. The average is computed by taking the total withdrawals for all records and subtracting the individual-record return flows, then dividing this number by the individual-records total withdrawals. Statistics based on 33 records.]

Statistic	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	0	0	0	0	0	0	0	0	0
75th percentile	0	0	0	0	4	9	5	5	5	0	0	0	2
Average	4	3	7	8	5	9	5	5	6	3	2	1	5

Mining

Mining water is water withdrawn during the extraction of minerals, and the corresponding consumptive use is water consumed during quarrying, milling, and other operations. Ohio and Indiana have two major types of mining: coal mining (SIC 12) and mining and quarrying of nonmetallic minerals, except fuels (**nonmetallic minerals**, SIC 14, includes dimension stone, crushed and broken limestone, sand and gravel, construction sand and gravel, and industrial sand, among other products). Figure 18 is the average monthly mining withdrawals during 1999–2004 for Ohio and Indiana. The May–October monthly withdrawals were typically higher than November–March withdrawals. The April withdrawals (for coal mining and nonmetallic mining) were either similar to or greater than summer withdrawals (figs. 26 and 27). Although the USGS does not consider dewatering a mining withdrawal, dewatering is included in the ODNR and IDNR registration programs and could not be separated out for this report. Thus, the increased April withdrawals may be from dewatering caused by high water tables in the spring. Table 2–12 and figure 28 also show increased withdrawals beginning in April and continuing through November.

Although the median mining coefficient for 1999–2004 was 10 percent (from the return-flow method), the average was higher (30 percent) (table 27). For the return-flow analysis, the mining facilities were separated by type of mining. Both the coal mining (SIC 12) and nonmetallic minerals (SIC 14) had the same minimums (0), medians (10), and 25th and 75th percentiles (0 and 30, respectively) but different maximums (80 percent, coal; 100 percent, nonmetallic minerals).

An alternative method for estimating consumptive use (not attempted in this study) is based on quantity of product mined. For example, CHM2HILL (2003) includes net water consumption by mining operation in gallons per ton and stated that one coal surface-mine operator found that dust control consumed about 5.2 gal of water per ton of coal produced. Another alternative method would be to use return-flow data from reporting facilities to estimate a consumptive-use coefficient for facilities with no data, depending on activities at those facilities (mining, mineral preparation, both**)**. For example, as part of a recent study in Pennsylvania, Stuckey (2008) examined registered mining withdrawals for a corresponding return flow. If no discharges were found, a consumptive-use coefficient of 8 percent was used. For mining operations involving only mineral preparation, a consumptive-use coefficient of 17 percent was used.

This sand and gravel mining and processing facility is typical of many such facilities throughout the Great Lakes States.

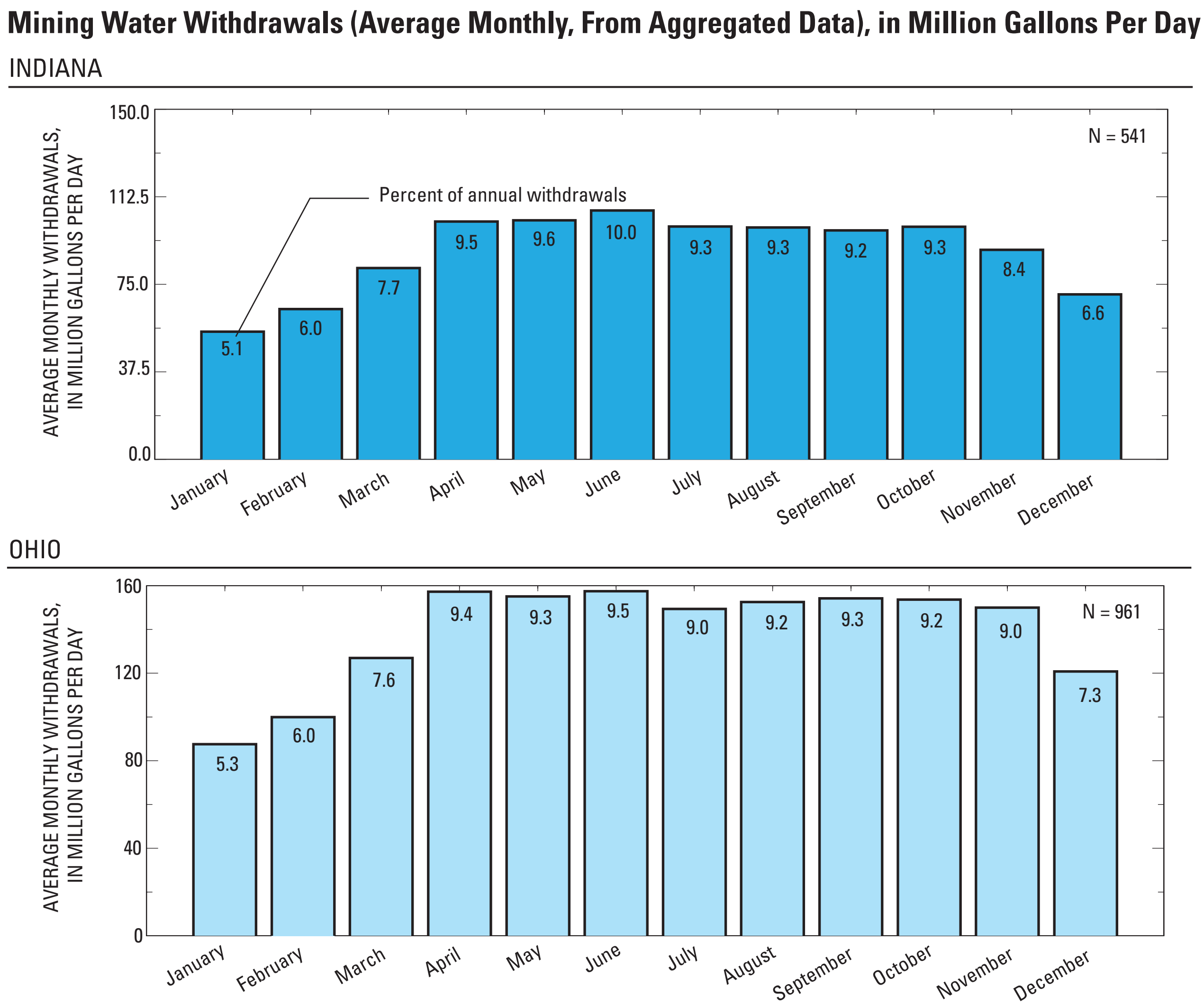


Figure 25. Indiana and Ohio monthly mining water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

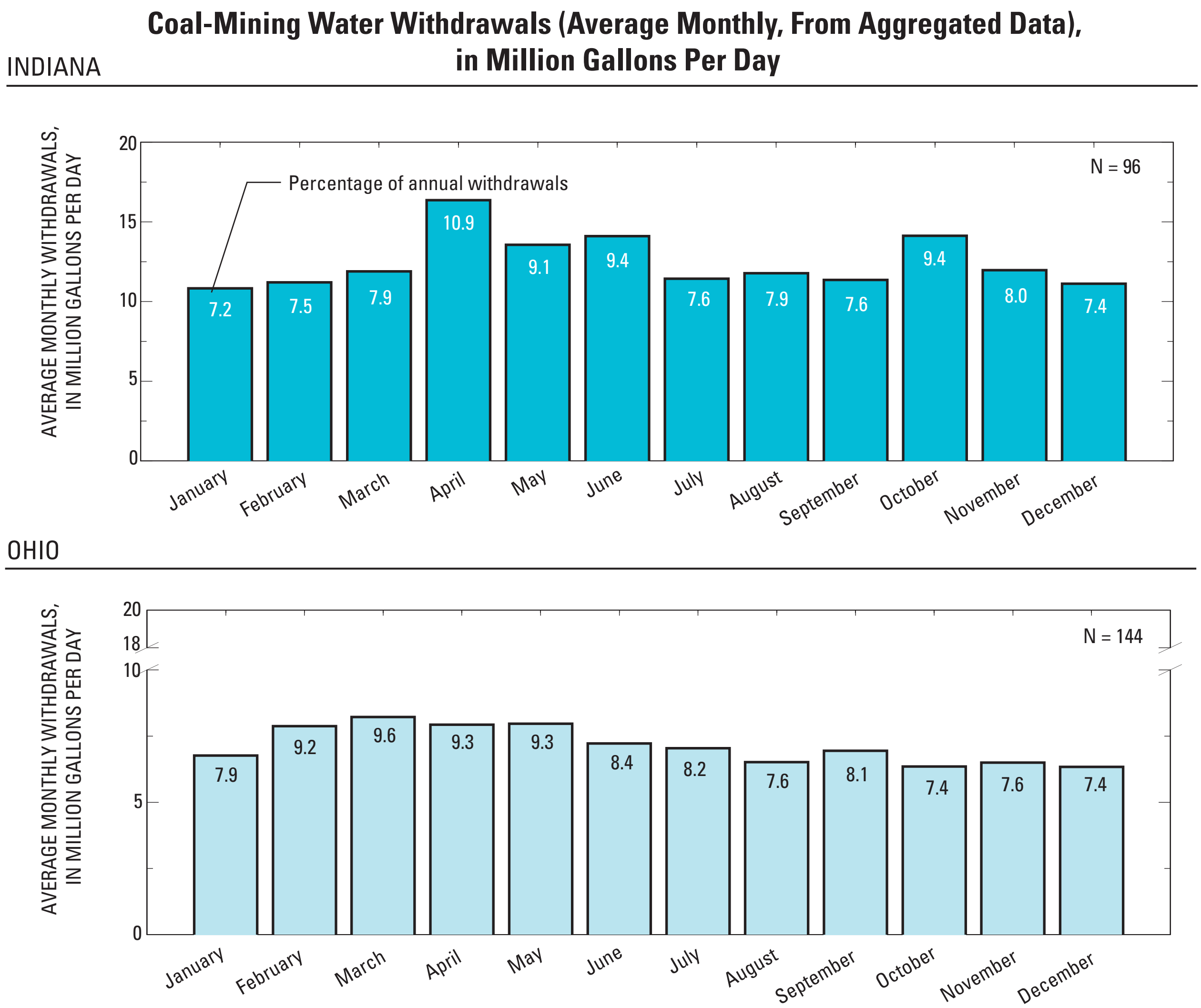


Figure 26. Indiana and Ohio monthly coal-mining water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

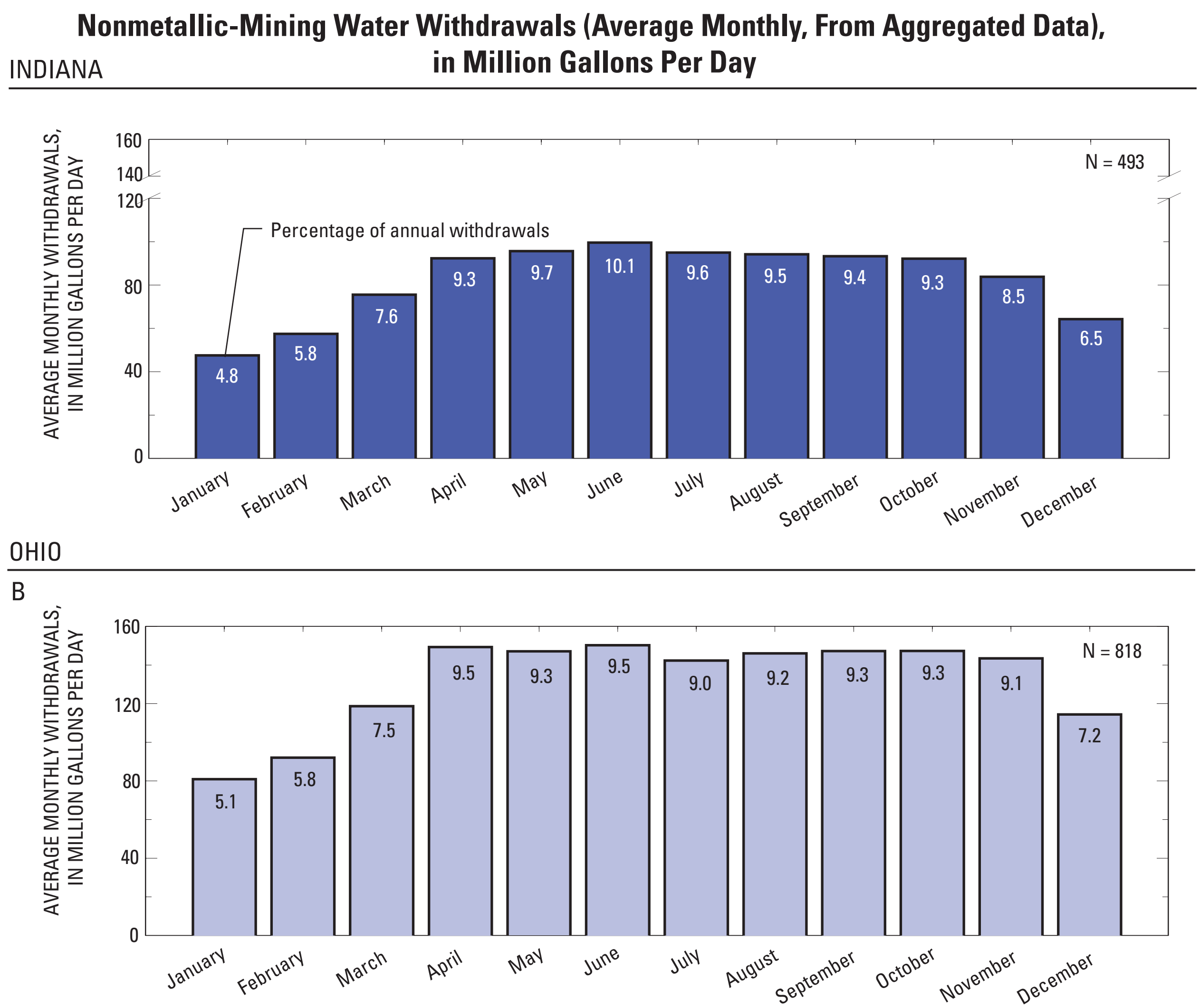


Figure 27. Indiana and Ohio monthly nonmetallic-mining water withdrawals, aggregated for 1999–2004. Monthly percentages of annual withdrawals may not add up to 100 percent because of independent rounding. N is the number of records.

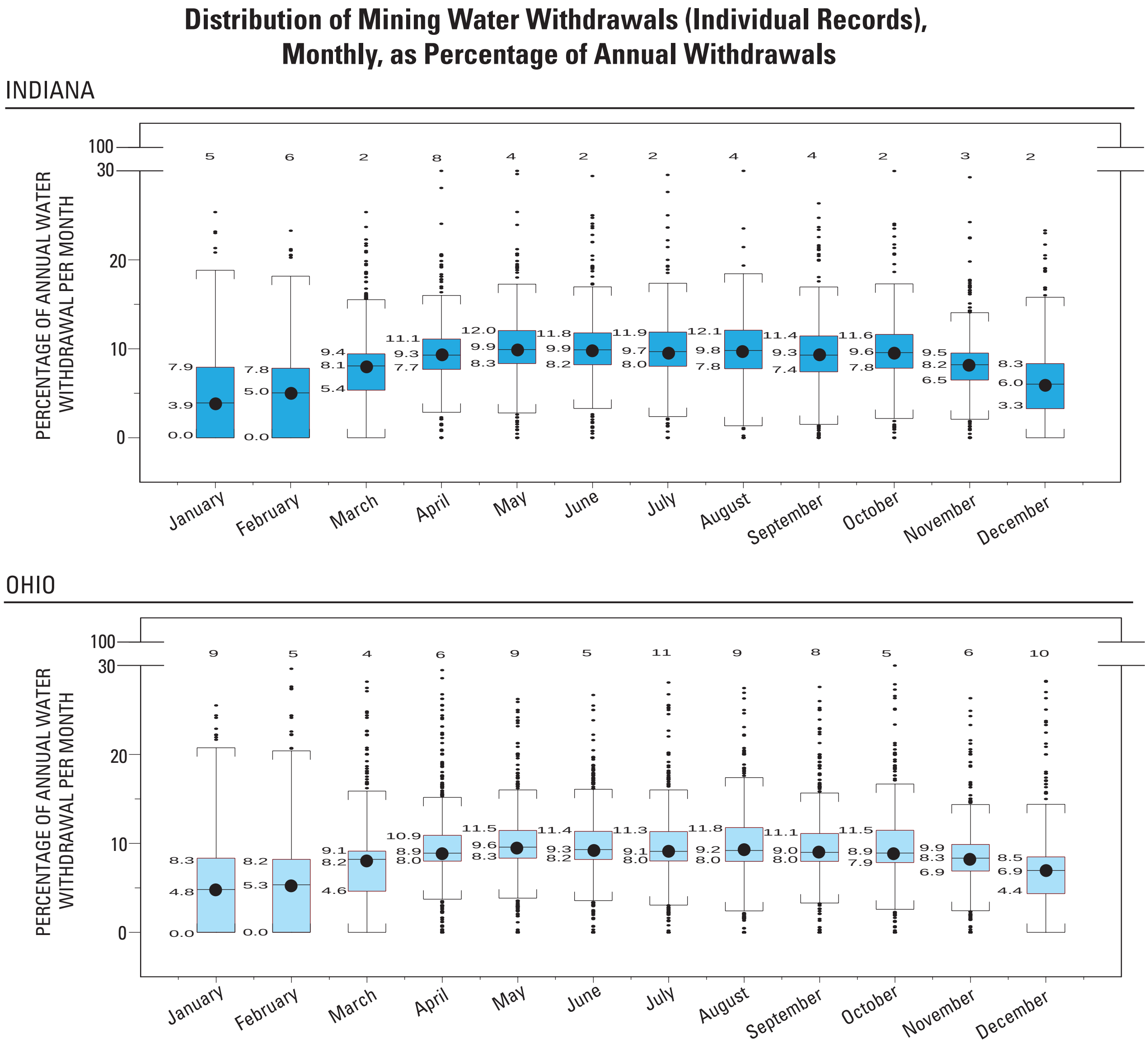


Figure 28. Indiana and Ohio mining water withdrawals, monthly, as percentage of annual withdrawals for 1999–2004 (see fig. 6 for explanation).

Table 27. Ohio mining monthly consumptive-use coefficient statistics, based on withdrawal and return-flow data for 1999–2004.

[Statistics are in percent and are rounded to the nearest whole number. The median and 25th and 75th percentiles are based on computing the consumptive-use coefficient for each record and analyzing for these statistics. Monthly consumptive-use coefficient average is computed by subtracting monthly return flows from monthly withdrawals and dividing by monthly withdrawals. The average is computed by taking the total withdrawals for all records and subtracting the individual-record return flows, then dividing this number by the individual-record total withdrawals. The number of records is 418.]

Statistic	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	3	5	10	10	10	10	10	10	10	10	10	10	10
75th percentile	30	30	30	30	30	30	30	30	30	30	30	30	30
Average	29	30	30	30	30	29	28	31	30	31	31	31	30

Findings

Consumptive-use coefficients, monthly withdrawal variations, and methods used in this report can be used in future studies to assist water managers and planners in estimating monthly data where reported data from facilities—the preferred and generally most accurate datasets—are not available. Estimation of withdrawal, return flow, and consumptive use on the basis of data from similar facilities is generally the next best option to reported data in terms of maximizing accuracy and minimizing uncertainty, but estimates based on water-use categories or groups of water-use categories may be necessary if similar-facility data are not available.

If monthly data are not available, water-resource planners must rely on other methods to estimate monthly water withdrawal, return flow, and consumptive use. Monthly water withdrawals can be computed by multiplying annual withdrawal by the monthly percentage of annual withdrawals (figs. 5, 7, 10,14, 16, 17, 22, 24, 25, 26, and 27) or the monthly median percentage of annual withdrawals (figs. 6, 8, 11, 15, 18, 19, 20, 23, 24, and 28 or Appendix 2). If annual withdrawal data are not available, water withdrawals may be estimated by using median withdrawal rates based on water-use categories, groups, or SIC codes (tables 2, 3, 12, 30, and 3–1) and multiplying the median water withdrawal rate by 365 days to get an estimated annual withdrawal. Return-flow and consumptive-use estimates can be computed by multiplying the monthly withdrawal by an annual, seasonal, or monthly consumptive-use coefficient.

Study methods and major findings are summarized in table 28. The return-flow and withdrawal (RW) method of calculating consumptive-use coefficients was used for all water-use categories except public supply, subject to data availability. The winter-base-rate (WBR) method was used for commercial and public-supply water-use categories. Table 28 also lists the changes in monthly withdrawals per season. Public-supply, industrial, thermoelectric, irrigation, and commercial withdrawals were higher during May through October than during November through April. Ohio livestock withdrawals were fairly constant, but Indiana withdrawals were heavily influenced by facilities that operated only seasonally. Aquaculture withdrawals may relate to the seasonal life cycle of fish and aeration of ponds during the winter. Mining withdrawals, specifically for nonmetallic mining, were high in April, perhaps a result of dewatering.

Table 29, figure 29 and figure 30 summarize average withdrawals for 1999–2004 for Indiana and Ohio by water-use category. Thermoelectric power was the category of highest withdrawals for both states (fig. 29). Industrial and public-supply withdrawals were second and third highest (Indiana with more industrial withdrawals and Ohio with more public-supply withdrawals; fig. 30). The remainder of the water-use categories made up less than 3 percent of the total withdrawals for Ohio or Indiana. Crop and nursery irrigation withdrawals in Indiana were highest from June through August and were between 29 to 61 percent of the average public-supply withdrawals of that month for the State. Crop irrigation withdrawals were higher in Indiana than Ohio because more corn and soybean farms irrigated land in Indiana (U.S. Department of Agriculture, 2008). Overall, June and July were the months of heaviest withdrawals for combined categories (9.6 to 10.1 percent), whereas January, February, and March were the months of the least combined withdrawals (7.3 to 7.6 percent) (fig. 29).

Water-use category withdrawals are divided by facility size in table 30. Facility size was determined by percentile of withdrawals, and then median withdrawal for each facility size group was computed. The thermoelectric-power water-use category had the largest median withdrawals for all of the facility size groups in comparison to other water-use categories. After thermoelectric power, industrial had the highest median withdrawal for the "extra large and very large" facility sizes, and public supply had the highest median withdrawals for "small, median, and large" facility sizes. The top 10 percent of many water-use categories accounted for most of the withdrawals in that category: industrial, 95 percent of withdrawals; public supply, 76 percent; commercial, 86 percent. Livestock and aquaculture withdrawals were not included because insufficient data were available on type and number of livestock and aquaculture counts per facility.

Table 31 lists the results from the return-flow method for computing consumptive-use coefficients. For industrial facilities and thermoelectric plants with once-through cooling, consumptive-use coefficient averages and medians were fairly constant for the entire year. Consumptive-use coefficients (average and/or medians) for commercial facilities were highest during the summer and fall (June–October). Coefficients were highest for golf course irrigation from June through September and from crop and nursery irrigation from June through October. Mining consumptive-use coefficients (from the return-flow method) were fairly constant except for January and February, which had lower medians.

Table 32 lists the consumptive-use coefficients computed by use of the WBR method for commercial and public-supply facilities for Ohio, Indiana, and Wisconsin. Consumptive use was highest from June through September. Rainfall and temperature may affect water withdrawals and consumptive use, but it was outside the scope of this study to determine to what extent.

Table 28. Summary of methods and major findings.

Water-use category	Return-flow and withdrawal method	Winter-base-rate method	Monthly withdrawals
Public supply	Should not be used to compute consumptive use. See the "Public Supply" section for more information and exceptions.	Can be applied to estimate consumptive use but is based on the assumptions that (1) public-supply deliveries are going to mostly domestic customers and (2) the summer increase is outdoor water use and therefore is evaporated or transpired.	Increased withdrawals in the summer—some of the January and February withdrawals may be for filling reservoirs.
Industrial	Can be used to compute consumptive use but is limited by data availability and types of industries.	Should not be used because the increase in summer withdrawals may be from increase in production, not consumptive use .[1]	Increased withdrawals in the summer (this increase was greater in Indiana than Ohio).
Thermoelectric	Can be used to compute consumptive use but is limited by data availability. Type of cooling used at the plant affects consumptive use.	Should not be applied because in the summer; the same amount of electrical production will result in higher withdrawals due to warmer influent water.	Increased in summer, possibly because more intake water is needed for cooling in the summer in response to higher water temperatures and increased thermoelectric power production in the summer versus the winter.
Irrigation, golf course	Can be used to compute consumptive use but is limited by data availability.	Should not be applied because the withdrawals in the winter are most likely for the clubhouse uses, not irrigation.	Increased withdrawals in the summer.
Irrigation, other	Can be used to compute consumptive use but is limited by data availability.	Should not be applied because most withdrawals occur in the summer.	Increased withdrawals in the summer. Indiana had many more registered facilities than Ohio, but Ohio had more nurseries than Indiana.
Livestock	Can be used to compute consumptive use but is limited by data availability.	Should not be used to estimate consumptive use.	Withdrawals were fairly constant in Ohio, but varied by facility in Indiana.
Mining	Can be used to compute consumptive use but is limited by data availability.	Because mining activities vary widely by facility, this method should not be used to estimate consumptive use.	Dewatering my be a factor during spring months.
Commercial	Can be used to compute consumptive use, but is limited by data availability. Types of facilities and outdoor water use affect consumptive use.	Can be applied to estimate consumptive use but is based on the assumption that the summer increase is outdoor water use and therefore is evaporated or transpired. Does not apply to snow-skiing facilities.	Increased withdrawals in the summer.

[1] A better method may be the SIC code method. For more information see the "Industrial" section.

Table 29. Average water withdrawals for Ohio and Indiana, 1999–2004.

[Numbers are million gallons per day rounded to three significant figures.]

Water-use category	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Indiana												
Public supply	651	653	625	646	690	752	817	802	766	669	631	622
Industrial	2,250	2,250	2,190	2,200	2,290	2,410	2,510	2,620	2,550	2,450	2,310	2,220
Thermoelectric	5,720	5,760	5,520	5,590	6,070	7,140	7,480	7,510	6,860	6,020	5,870	5,850
Golf-course irrigation	1.15	0.57	1.67	6.54	14.2	28.1	37.4	38.1	31.0	13.1	3.11	1.18
Irrigation, other	2.98	3.52	7.50	19.4	41.4	216	502	477	110	22.1	16.7	4.98
Livestock	1.51	1.80	1.62	1.67	1.70	2.09	2.50	2.73	1.89	1.75	1.80	1.71
Aquaculture	10.1	7.41	10.3	10.5	9.21	10.4	8.18	8.40	8.64	8.85	9.56	9.67
Commercial	30.4	31.0	36.7	41.4	45.5	52.6	57.3	62.3	65.0	54.2	53.1	38.5
Mining	58.4	68.7	87.5	109	109	114	106	106	105	106	95.8	75.3
Ohio												
Public supply	1,440	1,480	1,410	1,380	1,440	1,540	1,620	1,580	1,510	1,420	1,380	1,400
Industrial	707	732	711	730	748	758	772	787	770	734	734	711
Thermoelectric	7,690	7,380	7,510	7,440	8,470	9,620	10,040	9,910	8,960	8,580	8,110	8,220
Golf-course irrigation	.86	.77	1.20	8.54	19.3	37.1	50.2	49.3	36.4	16.1	4.86	1.05
Irrigation, other	1.21	1.52	4.97	10.1	18.3	33.3	43.9	41.3	26.6	14.4	7.06	2.43
Livestock	1.01	1.10	1.06	1.07	1.09	1.13	1.12	1.16	1.13	1.09	1.06	1.05
Aquaculture	4.87	5.30	5.94	9.57	6.38	8.43	5.46	5.45	6.12	5.53	4.52	4.66
Commercial	23.5	27.0	28.3	33.3	40.7	44.0	42.6	49.5	44.3	39.4	23.2	23.4
Mining	87.7	100	127	157	155	157	149	152	154	154	150	121

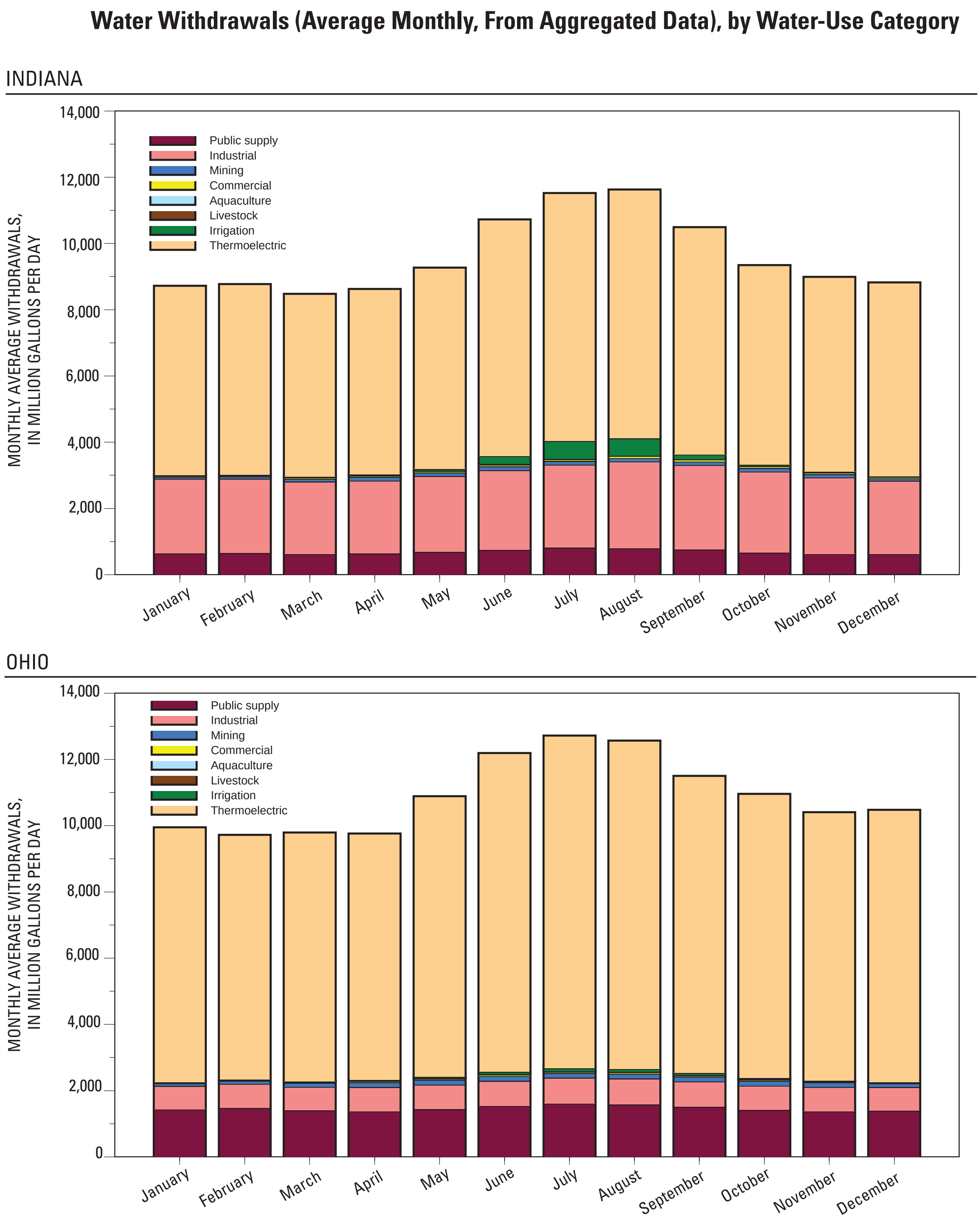
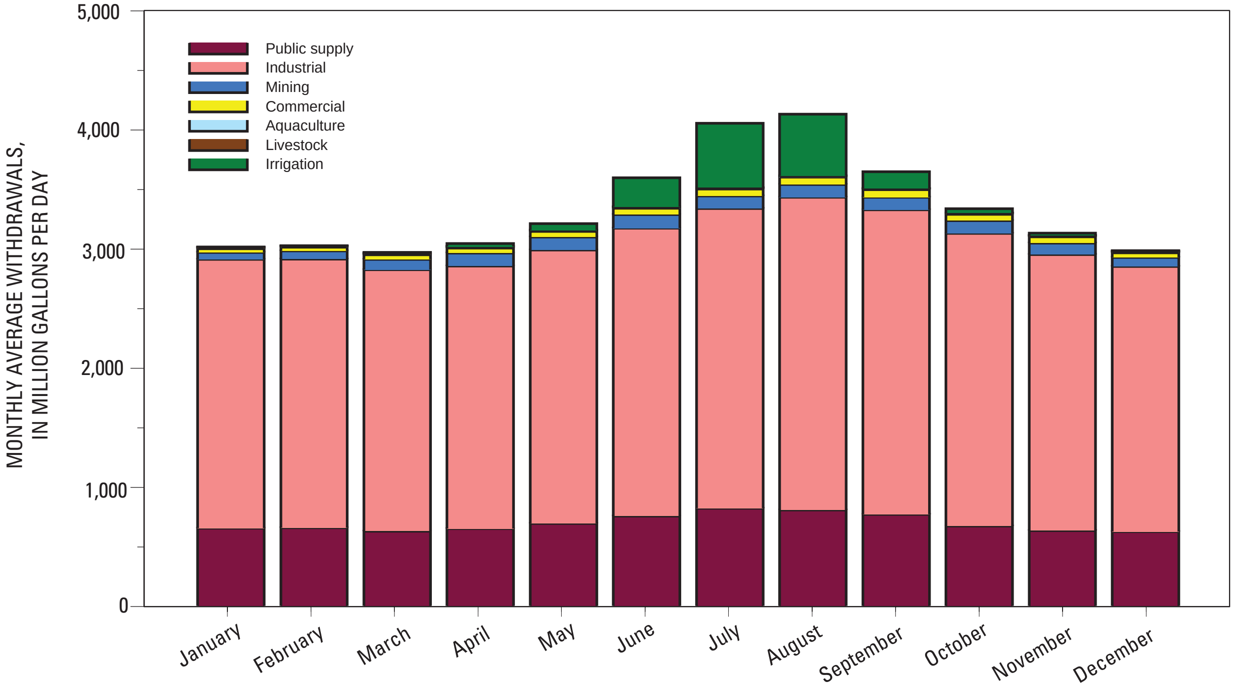


Figure 29. Indiana and Ohio monthly water withdrawals, aggregated for 1999–2004, by water-use category.

Water Withdrawals (Average Monthly, From Aggregated Data), by Water-Use Category, Excluding Thermoelectric Power Production

INDIANA



OHIO

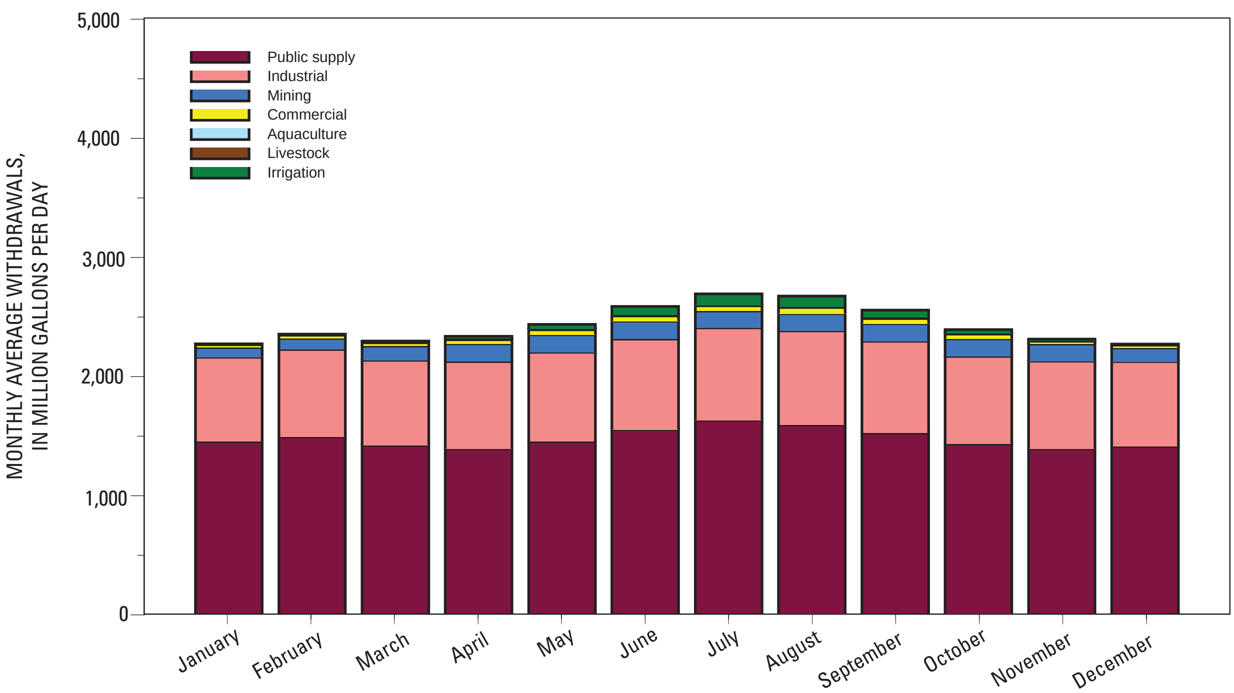


Figure 30. Indiana and Ohio monthly water withdrawals, aggregated for 1999–2004, by water-use category, excluding thermoelectric power production.

Table 30. Water demand by water-use category and facility size for Ohio and Indiana, 1999–2004.

[Facility size was computed by percentiles of withdrawals for records; “small” denotes less than 33d percentile, “medium” is from the 33d to 66th percentiles, “large” is from the 66th to 90th percentiles,” very large” is from the 90th to 98th percentiles, and “extra large” is greater than the 98th percentile. Mgal/d, million gallons per day. N, number of records. Due to rounding, the sum of “Percent of total withdrawals” may not equal 100.]

Water-use category	Facility size	N	Median withdrawal (Mgal/d)	Percent of total withdrawals (in percent)
Public supply	Small	2,157	0.07	1
	Medium	2,160	0.28	5
	Large	1,570	1.27	18
	Very large	524	5.32	27
	Extra large	131	40.4	49
Industrial	Small	1,078	0.004	<1
	Medium	1,078	0.09	1
	Large	784	0.65	4
	Very large	261	5.46	11
	Extra large	66	130	84
Thermoelectric power	Small	161	0.15	<1
	Medium	160	24.5	6
	Large	116	301	44
	Very large	39	777	36
	Extra large	10	1,230	14
Irrigation, golf	Small	1,354	0.006	4
	Medium	1,356	0.03	19
	Large	918	0.07	33
	Very large	327	0.14	24
	Extra large	82	0.31	19
Irrigation, nursery	Small	260	0.01	2
	Medium	258	0.03	12
	Large	188	0.11	29
	Very large	63	0.42	38
	Extra large	16	0.81	20
Irrigation, crop	Small	2,822	0.01	5
	Medium	2,037	0.05	18
	Large	682	0.10	28
	Very large	171	0.24	24
	Extra large	171	0.74	24
Commercial	Small	858	0.002	<1
	Medium	855	0.01	2
	Large	624	0.06	11
	Very large	206	0.47	28
	Extra large	51	3.65	59
Mining[1]	Small	496	0.02	1
	Medium	495	0.39	14
	Large	360	1.12	33
	Very large	120	3.26	30
	Extra large	31	9.42	22

[1] Mining numbers may include dewatering.

Table 31. Monthly consumptive-use coefficients for Ohio, 1999–2004, computed by use of the return-flow and withdrawal method.

Statistic	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual[1]
Commercial facilities													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	4	4	5	7	7	7	8	19	17	16	3	4	17
75th percentile	44	50	50	55	56	56	50	73	78	78	48	47	56
Average	33	42	37	36	38	43	44	48	48	45	40	38	42
Industrial facilities													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	8	9	9	9	8	8	9	9	9	8	9	9	10
75th percentile	37	37	39	40	37	39	40	40	41	40	37	35	38
Average	11	12	11	11	11	12	12	12	11	11	12	12	11
Thermoelectric-power records with both types of cooling													
25th percentile	1	1	1	1	1	1	1	1	1	1	1	1	1
Median	1	2	1	3	2	5	3	3	2	2	2	2	2
75th percentile	5	6	3	5	5	6	6	8	5	5	3	5	5
Average	3	3	2	2	2	3	4	4	3	2	3	3	3
Thermoelectric-power records with closed-loop cooling													
25th percentile	6	5	6	3	6	7	7	12	6	5	6	6	9
Median	26	29	30	23	25	29	28	33	24	21	27	26	25
75th percentile	59	65	75	65	75	72	75	75	71	49	63	65	74
Average	23	23	24	22	25	24	24	25	25	25	24	24	24
Thermoelectric-power records with once-through cooling													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	0	0	0	0	0	0	0	0	0	0	0	0	0
75th percentile	1	1	2	2	2	1	1	1	1	2	1	2	2
Average	3	2	3	2	4	4	3	3	3	3	3	3	3
All thermoelectric power records													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	1	1	1	1	1	1	1	1	1	1	1	1	2
75th percentile	7	8	8	6	10	12	15	16	7	7	8	13	16
Average	4	4	4	4	5	5	5	5	4	4	4	5	5
Golf-course irrigation													
25th percentile	-	-	-	1[2]	42	65	67	68	68	37	0[2]	-	-
Median	-	-	-	71	75	82	80	84	82	75	3[2]	-	-
75th percentile	-	-	-	99	98	98	95	98	99	98	94	-	-
Crop and nursery irrigation													
25th percentile	-	-	-	67	68	65	68	66	60	56	37	-	-
Median	-	-	-	79	78	82	80	80	81	81	70	-	-
75th percentile	-	-	-	93	91	90	90	93	92	90	84	-	-
Mining records													
25th percentile	0	0	0	0	0	0	0	0	0	0	0	0	0
Median	3	5	10	10	10	10	10	10	10	10	10	10	10
75th percentile	30	30	30	30	30	30	30	30	30	30	30	30	30
Average	29	30	30	30	30	29	28	31	30	31	31	31	30

[1] Annual calculation includes more records than monthly records.

[2] These numbers are low because many of the facilities had no withdrawals or return flows in these months.

Table 32. Monthly and seasonal consumptive-use coefficients for Ohio, Indiana, and Wisconsin, 1999– 2004, computed by use of the winter-base-rate method.

Category or year	N	Monthly consumptive-use coefficient						Seasonal consumptive-use coefficient			Annual
		May	June	July	Aug.	Sept.	Oct.	Spring	Summer	Fall	
Indiana commercial											
1999	332	29	47	57	53	51	32	19	52	40	33
2000	323	49	45	50	62	65	55	38	53	58	44
2001	319	29	38	38	47	55	32	19	41	47	31
2002	322	9	53	60	61	60	44	9[1]	58	50	38
2003	331	48	50	47	53	53	54	42	50	54	42
2004	337	35	38	38	47	54	50	26	41	48	33
1999–2004	1,964	31	40	45	50	52	42	24	45	45	33
Ohio commercial											
1999	104	41	44	46	55	46	27	38	49	29	33
2000	103	42	52	43	45	37	32	28	47	25	29
2001	97	24	27	25	49	35	35	9[1]	36	26	20
2002	94	37	41	39	43	43	30	27	41	28	27
2003	89	46	47	49	58	48	49	31	52	40	36
2004	99	53	56	55	58	60	54	42	57	47	42
1999–2004	586	42	47	45	53	47	41	31	48	34	32
Indiana public supply											
1999	485	9	19	26	22	24	6	2	23	11	10
2000	486	4	8	14	12	12	2	0	11	4	4
2001	482	13	15	20	20	9	3	6	18	3	7
2002	487	3	17	31	28	21	4	0	26	9	10
2003	498	4	15	19	21	14	3	1	18	6	7
2004	501	7	13	15	14	16	6	2	14	7	6
1999–2004 (median)	2,971	7	15	21	20	16	4	2	19	7	7
Ohio public supply[2]											
1999	559	7	19	22	16	15	3	0	19	7	7
2000	485	4	9	12	10	7	1	0	10	2	3
2001	531	6	11	20	18	9	6	2	16	6	7
2002	531	1	14	27	24	19	8	0	22	11	9
2003	456	8	12	13	12	7	0	6	12	2	5
2004	437	5	9	15	11	8	0	0	12	2	3
1999–2004	2,939	5	13	19	16	11	3	1	16	5	6
Wisconsin public supply											
1999	561	7	23	22	19	19	5	3	21	9	9
2000	562	9	11	17	19	11	6	3	16	6	6
2001	562	7	13	30	22	9	5	3	22	5	8
2002	563	7	16	31	23	17	6	3	24	8	10
2003	562	5	17	21	28	20	5	3	22	8	9
2004	563	4	10	18	18	19	5	2	15	8	7
1999–2004	3,373	6	15	23	22	16	5	3	20	7	8

[1] Spring of 2002 had low temperatures and high precipitation.

[2] Ohio data are for facilities with withdrawasl in July that are greater than or equal to withdrawals in Febuary.

Summary and Conclusions

State agencies with jurisdiction within the Great Lakes Basin have indicated that refinement of consumptive-use data and coefficients for all water-use categories were of interest and value to water-supply managers. As part of the USGS National Assessment of Water Availability and Use Pilot Program, this study took available datasets and analyzed monthly withdrawals and consumptive-use coefficients by month and season. Two principal methods, winter-base rate (WBR) and return-flow and withdrawal (RW), were used to estimate consumptive-use coefficients. The WBR method was used for commercial and public-supply facilities, and the RW method was used for all water-use categories except public supply. A third method based on Standard Industrial Classification codes (SIC code method) was used only to compute consumptive use for certain industrial facilities.

Commercial average monthly withdrawals increased significantly in the summer, particularly in August and September. The commercial average monthly withdrawals ranged from 30.4 to 65.0 Mgal/d for Ohio and 23.2 to 49.5 Mgal/d for Indiana—more than doubling at summer highs from winter lows. The consumptive-use coefficients were 30 percent (Ohio and Indiana annual coefficient, WBR method) and 17 and 42 percent (Ohio, median and average, RW method).

Industrial average monthly withdrawals were highest in the summer months in Ohio and Indiana. Indiana had almost three times the industrial withdrawals of Ohio. Indiana industrial withdrawals ranged from 2,220 to 2,620 Mgal/d, and Ohio industrial withdrawals ranged from 707 to 787 Mgal/d. The industrial consumptive-use coefficient varied by Standard Industrial Classification code. The overall industrial consumptive-use coefficient for Ohio was 10 percent (from the RW method) and 12 percent (Ohio) and 11 percent (Indiana) (from the SIC code method). These coefficients are based on large geographical areas and may not be representative of a particular geographical area based on the mix of industrial facilities and the processes at these facilities that affect the consumptive use. Shaffer (2008), Shaffer and Runkle (2007), and this report list variations in industrial consumptive-use coefficients. Many industrial facilities report withdrawal, return-flow, and consumptive-use data, such reported data are preferred, if available, over estimates based on general industrial consumptive-use coefficients.

Public-supply average withdrawals were higher in the summer months for Ohio, Indiana, and Wisconsin. Ohio's average monthly withdrawals ranged from 1,380 to 1,620 Mgal/d for 1999 to 2004 and were more than twice the public-supply withdrawals of Indiana (621 to 816 Mgal/d) or Wisconsin (515 to 694 Mgal/d). Ohio has almost twice the population of Indiana or Wisconsin (Hutson, Barber, and others, 2004). The public-supply annual average consumptive-use coefficient calculated by use of the WBR method ranged from 6 to 8 percent, and the summer consumptive-use coefficient ranged from 16 to 20 percent for Ohio, Indiana, and Wisconsin. Monthly precipitation and temperature affects consumptive-use, but it was beyond the scope of this study to determine to what extent.

Thermoelectric-power average monthly withdrawals were highest in the summer months for Ohio and Indiana. Ohio's average monthly withdrawals ranged from 7,380 to 10,040 Mgal/d and Indiana's ranged from 5,520 to 7,510 Mgal/d. Thermoelectric-power consumptive use varies by facility cooling type (0 to 25 percent median). Once-through cooling facilities have low consumptive-use coefficients (less than 2 percent), whereas closed-loop cooling has higher consumptive use (median of 25 percent). Facilities with both types of cooling and all facilities overall for Ohio had a median consumptive use coefficient of 2 percent. The U.S. Department of Energy collects consumptive-use rates from most thermoelectric-powerplants and, because the data are facility specific, may be less uncertain than estimates based on general consumptive-use coefficients.

Irrigation withdrawals were mostly in May through October. Indiana had about three times the withdrawals of Ohio, mostly as crop irrigation. More acres were irrigated for corn and soybean crops in Indiana in 2002 (284,876 acres) than in Ohio (4,865 acres) (National Agricultural Statistic Service, 2008). Of the many golf courses, nurseries, and farms in Ohio, irrigation consumptive-use coefficients were calculated from only 58 golf course records and 62 records, owing in part to possible confusion about State reporting requirements and instructions. The median golf-course irrigation coefficient was 77 percent, and the median nursery and crop irrigation coefficient was 78 percent; however, the June to September consumptive-use coefficients ranged from 80 to 84 percent. These coefficients should be used with caution until a more scientific basis is available for understanding the ranges of irrigation consumptive-use coefficients. Studies that determine the surface-water runoff and groundwater recharge after irrigation, could be used to compute irrigation consumptive-use coefficients. In addition, studies that document irrigation purposes, practices, methods, and environmental conditions in detail may assist in specifying better guidance on selecting ranges on irrigation consumptive-use coefficients.

Average monthly withdrawals for livestock, aquaculture, and mining water-use categories varied considerably throughout the year and differed somewhat between Ohio and Indiana. The livestock monthly withdrawals were virtually constant for Ohio but the monthly pattern was varied for Indiana and depended on the type of facility. Aquaculture withdrawals appeared to correlate with growing seasons and/or aeration of ponds during the winter months. Mining withdrawals were larger in April than expected, possibly because of dewatering. The RW method was used to calculate consumptive-use coefficients for livestock, aquaculture, and mining water-use categories, but the values should be used with caution because records for these categories were scarce. Median annual consumptive-use coefficients were 76 percent for Livestock, 0 percent for aquaculture, and 10 percent for mining.

Water-resource planners use water-withdrawal, return-flow, and consumptive-use data to understand the effects of human use of water on the hydrologic system. The availability of water-use data limits our ability to understand the effects of water use on the hydrologic system in real time. Among the many state agencies nationwide that are responsible for compiling water-use data, agency programs differ substantially regarding what data are collected, how data are organized, how often the data are collected, and when data are made available to the public. Monthly data are of great value for understanding the effect of human activity in areas where there may be potential water shortages or water-quality stress on aquatic life. These periods tend to be in the summer and early fall, when water temperatures are at maximum and streamflows and ground-water levels are at minimum. Summer months and early fall (June, July, August, and September) are also when water withdrawals for most water-use categories are at their highest (figs. 29 and 30).

In terms of maximum accuracy and minimal uncertainty, use of available withdrawal, return-flow, and consumptive-use data reported by facilities and data estimated from similar facilities is preferable over estimates based on data for a particular water-use category or groups of water-use categories. If monthly withdrawal, return flow, and consumptive use data are few and limited, monthly patterns described in this report may be used as a basis of estimation, but the level of uncertainty may be a greater than for the other estimation methods. Annual and monthly withdrawal data can be estimated by using median withdrawal rates and monthly percentages of annual withdrawals. Return flow and consumptive-use estimates can be estimated by using withdrawal data and consumptive-use coefficients.

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Glossary

The terms in this glossary were compiled from numerous sources. Some definitions have been modified specifically in reference to this report and are not the only valid ones for those terms.

25th percentile The value in a rank of values below which one-fourth (25 percent) of the values fall. The 25th and 75th percentile together bracket half of the values.

75th percentile The value in a rank of values below which three-fourths (75 percent) of the values fall. The 25th and 75th percentile together bracket half of the values.

average The statistical mean of a set of numbers.

climatically similar areas Basins, states, or countries that have climates similar to the Great Lakes Basin.

commercial water use Water for motels, hotels, restaurants, office buildings, other commercial facilities, military and nonmilitary institutions—and in USGS water-use circulars for 1990 and 1995, water for offstream fish hatcheries.

community water system A public water system that delivers water for human consumption through pipes and other constructed conveyances if such a system regularly serves at least 25 year-round residents or has at least 15 service connections used by year-round residents. Community water systems might serve towns, cities, military bases, apartment complexes, or mobile home parks (U.S. Environmental Protection Agency, 1999).

consumptive use Water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.

consumptive-use coefficient The percentage of water removed from the immediate environment by evaporation, transpiration, incorporation into products or crops, or consumption by humans or livestock.

conveyance loss Either positive or negative. A negative conveyance loss is water that is lost in transit from a pipe, canal, conduit, or ditch by leakage or evaporation. A positive conveyance loss represents water that infiltrates a wastewater collection (sewer) system and is usually water from a high water table.

data availability By jurisdictions, water use data and the data quality differs significantly. This hinders our ability to compare data by jurisdictions and truly analyze water availability and consumptive use.

domestic water use Water used for all such indoor household purposes as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and such outdoor purposes as watering lawns and gardens.

evaporation The change of water from a liquid form into a vapor state such as water evaporating from pools, large bodies of water, and runoff from car-washing or irrigation systems; also includes evaporation through humidifiers, heating and cooling processes in industrial facilities and thermoelectric plants.

evapotranspiration A collective term used to include water discharged to the atmosphere as a result of plant transpiration and evaporation from soil and surface-water bodies.

Great Lakes Basin In this report, the eight United States and two Canadian provinces that have all or part of their states or provinces in the Great Lakes Basin. It also includes any areas in the eight states and two provinces that may or may not be in the Great Lakes Basin.

industrial water use Water used for fabrication, processing, washing, and cooling, and includes such industries as chemical and allied products, food, mining, paper and allied products, petroleum refining, and steel.

irrigation water use Water that is applied by an irrigation system to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands such as parks and golf courses.

livestock consumptive use Water used for processes like stock watering and facility and animal cleaning that is evaporated (on the ground, or off the skin) or is incorporated into products (milk, eggs, the animal itself). Some livestock water withdrawals may be returned to the hydrologic environment, but water quality, areal, and time aspects may limit the reuse of this water.

maximum The largest number in a group of values.

median The point in a rank of values above and below which 50 percent of the values fall.

minimum The lowest number in a group of values.

mining water use Water used for the extraction of naturally occurring minerals including solids, such as coal, sand, gravel, and other ores; liquids, such as crude petroleum; and gases, such as natural gas. Also includes uses associated with quarrying, milling, and other preparations customarily done at the mine site or as part of a mining activity.

nonmetallic minerals Includes SIC 14 minerals like dimension stone, crushed and broken limestone, sand and gravel, construction sand and gravel, industrial sand among others.

once-through thermoelectric power facility A facility that uses water only one time in the condenser-and reactor-cooling process before returning the water to a surface-water source. Although once-through cooling requires substantial water withdrawals, the consumption is low—usually less than 3 percent (Solley and others, 1998).

other than once-through thermoelectric power facility A facility that uses cooling towers or cooling ponds to recycle water repeatedly for condenser and reactor cooling. This type of facility typically uses less water than a once-through facility but has a higher percentage of consumptive use (evaporation), typically greater than 60 percent (Solley and others, 1998).

product incorporation Inclusion of water as a component of industrial, food, and beverage products.

return flow Water that reaches a groundwater or surface-water source after release from the point of use and thus becomes available for further use.

return flow method Water withdrawal data and return flow data used to compute consumptive use. Return flow data is subtracted from water withdrawal data to compute consumptive use and then divided by the water withdrawal data to compute the consumptive use coefficient (multiplied by 100) for percent.

standard industrial classification (SIC) codes Four-digit codes established by the Office of Management and Budget, published in 1987, and used in the classification of establishments by type of activity in which they are engaged.

summer increase The amount of summer months' water withdrawals that is greater than the average winter rate of withdrawals.

summer months For this publication, refers to May through October.

thermoelectric-power water use Water used in the process of generating electricity with steam-driven turbine generators.

time and areal variability Water is found in the hydrologic cycle in different locations on earth as water, precipitation, or condensation. Water that is removed from an environment might take days, months, years, or millions of years to return to that location, if it ever returns. At what specific timeframe is the water considered "consumed" versus still being used and returnable for reuse.

transfer Conveyance of water that occurs during distribution or collection of water and sewage.

transpiration The process in which water is absorbed by plants, usually from the roots and evaporated into the atmosphere from the plant surface. Transpiration occurs in all types of plants including crops, grass (lawns, golf courses), landscaping plants, and nursery plants.

individual record A combination of facility and water.

water balance The mathematical equation of the inflows, outflows, and change in storage of water in a given area (*Inflows* = *Outflows* + *Change in storage*).

water-use category The type of specific use (facility or consumer) for which water is withdrawn (for example, public supply, irrigation, industrial, thermoelectric power).

water-quality aspects of consumptive use The degradation of water quality of the returned water limits the reuse of the water.

water transfer Water that is withdrawn might be returned to a different water body, or basin (this is a transfer). This becomes complex because the water is no longer available for use at the original environment (body of water, basin), but is available for use somewhere else (water is transferred).

withdrawal Removal of water from either a surface-water or groundwater source.

winter base-rate method Method used to estimate consumptive use and monthly consumptive-use coefficients.

winter months For this publication, refers to November through April.

Appendix 1

Tables

Figures

Table 1–1. Scope of work for initial U.S. Geological Survey study of consumptive-use coefficients in the Great Lakes and climatically similar areas (Shaffer and Runkle, 2007).

Scope of Work	Explanation
Validity of coefficients	The intent of Shaffer and Runkle (2007) was to simply compile consumptive-use coefficients from publications, rather than determine the validity of the coefficients. The information in the annotated bibliography describes the coefficients and presents some of the methods and assumptions used by the source to determine the coefficients. Many references did not include an approach or methodology for their consumptive-use data or coefficients.
Great Lakes Basin	Shaffer and Runkle (2007) compared two main areas: the Great Lakes Basin and climatically similar areas to the Great Lakes Basin in North America. The Great Lakes Basin (fig. 1) includes parts of Illinois, Indiana, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, the entire state of Michigan, and parts of Ontario and Quebec.
Geographic area	Shaffer and Runkle (2007) found that, in many publications, consumptive-use values or coefficients were determined for the entire state or province and not just the Great Lakes Basin portion. The coefficients from these publications were assumed to be representative of the Great Lakes Basin because they could not be separated by river basin or water-resources region. The state- or province-based coefficients were identified as such in the text, figures, and tables.
Climatically similar areas	Consumptive use and consumptive-use coefficients are a function of climate, economics, and culture. Choice of the climatically similar states (fig. 2) was based on patterns of temperature and precipitation (Prism Group, 2006a, b), water-resources regions (Solley and others, 1998), comparable percent consumptive loss for water-resources regions (Shaffer and Runkle, 2007; fig. 3), and water use in the state. Hutson, Koroa, and Murphree (2004) found that six water-resources regions (Great Lakes, Mid-Atlantic, New England, Ohio, Tennessee, and Upper Mississippi) had comparable percentages of consumptive losses (Shaffer and Runkle, 2007; fig. 4). These water-resources regions (fig. 4) and the major states in these regions (Shaffer and Runkle, 2007; fig. 2) are considered part of the scope of this report. These states have annual precipitation of 28–60 in. (1971–2000) and average minimum temperatures of 21 to 49°F (1971 to 2000; Prism Group, 2006a, b). States south of Missouri, Tennessee, and Virginia had average minimum temperatures greater than 49°F (Prism Group, 2006a). States west of Minnesota, Iowa, and Missouri have areas with annual precipitation of less than 24 in. (from 1971 to 2000; Prism Group, 2006b) and many of these states reported irrigation as the primary water-use category (excluding thermoelectric power; Hutson, Barber, and others, 2004).
World, continent, and country consumptive-use coefficients	As part of this report, a search for world, continent, and country consumptive-use coefficients was done. Only a few references were found, and they are included in this report as a basis of comparison with the coefficients of Great Lakes Basin and climatically similar areas. Most of these coefficients were geographically broad (large countries, continents, or the world), in areas of the world not climatically similar, and in countries with economic and cultural differences. Therefore, these references although not included with the climatically similar references, were kept in the report to broaden the understanding of the Great Lakes Basin and climatically similar areas consumptive-use coefficients.
Agriculture modeling	The terms “consumptive-use coefficient” and “consumptive crop irrigation coefficient” are used in relation to coefficients used in agriculture modeling to estimate evaporation and transpiration in crop irrigation (American Society of Civil Engineers, 1973; Kite and Droogers, 2000). These coefficients are not included in this document because almost all the references were in areas not climatically similar to the Great Lakes Basin and the primary water-use category for these areas was irrigation (excluding thermoelectric).
Evaporation losses	Stream, lake, and reservoir evaporation losses were not addressed in this report.
References	Many publications included consumptive-use coefficients derived from another reference. References not adding value to the understanding of consumptive-use coefficients were not included in the report. References using a coefficient from another reference or combination of other references to compute consumptive use were included in the report and statistical computations if they fit the geographical area and timeframe of the statistics.
Consumptive use and water use	Some publications use the words “consumptive use” to average “water use” (or water withdrawals). In this report, water use is defined as water that is withdrawn for a specific purpose like irrigation, industrial processing, public supply, or thermoelectric power.

Table 1–2. Consumptive-use coefficient statistics for Ohio, Indiana, Wisconsin, the Great Lakes Basin, climatically similar areas, and the world, by water-use category.

[Great Lakes Basin refers to basins, parts of states, and states in the Great Lakes Basin. Climatically similar areas are basins and states with climatically similar areas to the Great Lakes Basin. Great Lakes and climatically similar references are the combination of references from these two areas. References are only from publications after either 1975 (mining and commercial), 1980 (industrial, irrigation, thermoelectric, livestock), or 1985 (domestic and public supply) and do not include all of Canada coefficients, all of the United States coefficients, or continent coefficients (excluding Europe) because these have areas that are not climatically similar to the Great Lakes Basin. Minimum (min), median, maximum (max), 25th percentile, and 75th percentile are in percent and rounded to the nearest whole number. N is the number of references in the statistical analysis. "RW" means computed from return-flow and withdrawal data. "WBR" means computed from the winter-base-rate method. "SIC" means computed from Standard Industrial Classification code consumptive-use coefficients. WBR statistics are computed using only facilities with monthly annual average withdrawals greater than Dec.–Feb. monthly average withdrawals. Shaffer and Runkle (2007) coefficients are from table 43 on page 74.]

Geographical area	Reference or method	Min	25th	Median	75th	Max	N
Domestic and Public Supply							
Great Lakes Basin	Shaffer and Runkle, 2007	0	10	12	15	74	161
Climatically similar areas	Shaffer and Runkle, 2007	6	10	15	20	70	68
Great Lakes and climatically similar references	Shaffer and Runkle, 2007	0	10	13	15	74	229
World	Shaffer and Runkle, 2007	14	16	16	18	19	4
Indiana	WBR	0	5	8	14	100	2,339
Ohio[1]	WBR	0	3	7	12	100	2,672
Wisconsin	WBR	0	5	9	13	86	2,913
Industrial							
Great Lakes Basin	Shaffer and Runkle, 2007	0	7	10	14	35	122
Climatically similar areas	Shaffer and Runkle, 2007	0	4	10	13	34	97
Great Lakes and climatically similar references	Shaffer and Runkle, 2007	0	6	10	13	35	219
World	Shaffer and Runkle, 2007	9	10	10	11	11	4
Ohio	RW	0	0	10	38	100	471
Ohio	SIC	0	7	12	20	81	1,962
Indiana	SIC	0	4	11	20	67	1,149
Thermoelectric							
Great Lakes Basin	Shaffer and Runkle, 2007	0	1	2	2	21	141
Climatically similar areas	Shaffer and Runkle, 2007	0	0	2	4	75	75
Great Lakes and climatically similar areas	Shaffer and Runkle, 2007	0	1	2	3	75	216
Ohio	RW	0	0	2	16	100	289
Irrigation							
Great Lakes Basin	Shaffer and Runkle, 2007	70	90	90	96	100	95
Climatically similar areas	Shaffer and Runkle, 2007	37	90	100	100	100	75
Great Lakes and climatically similar References	Shaffer and Runkle, 2007	37	90	91	100	100	170
World	Shaffer and Runkle, 2007	65	65	68	72	78	4
Ohio, golf-course irrigation	RW	45	63	77	97	99	59
Ohio, nursery and crop irrigation	RW	23	65	78	89	99	62

Table 1–2. Consumptive-use coefficient statistics for Ohio, Indiana, Wisconsin, the Great Lakes Basin, climatically similar areas, and the world, by water-use category.—Continued

[Great Lakes Basin refers to basins, parts of states, and states in the Great Lakes Basin. Climatically similar areas are basins and states with climatically similar areas to the Great Lakes Basin. Great Lakes and climatically similar references are the combination of references from these two areas. References are only from publications after either 1975 (mining and commercial), 1980 (industrial, irrigation, thermoelectric, livestock), or 1985 (domestic and public supply) and do not include all of Canada coefficients, all of the United States coefficients, or continent coefficients (excluding Europe) because these have areas that are not climatically similar to the Great Lakes Basin. Minimum (min), median, maximum (max), 25th percentile, and 75th percentile are in percent and rounded to the nearest whole number. N is the number of references in the statistical analysis. "RW" means computed from return-flow and withdrawal data. "WBR" means computed from the winter-base-rate method. "SIC" means computed from Standard Industrial Classification code consumptive-use coefficients. WBR statistics are computed using only facilities with monthly annual average withdrawals greater than Dec.–Feb. monthly average withdrawals. Shaffer and Runkle (2007) coefficients are from table 43 on page 74.]

Geographical area	Reference or method	Min	25th	Median	75th	Max	N
			Livestock				
Great Lakes Basin	Shaffer and Runkle, 2007	0[1]	80	83	90	100	85
Climatically similar areas	Shaffer and Runkle, 2007	10[2]	86	100	100	100	73
Great Lakes and climatically similar areas	Shaffer and Runkle, 2007	0[1,2]	80	90	100	100	158
World (Agriculture)	Shaffer and Runkle, 2007	65	65	68	72	78	4
Ohio	RW	12	19	76	93	100	18
			Commercial				
Great Lakes Basin	Shaffer and Runkle, 2007	4	8	10	15	26	29
Climatically similar areas	Shaffer and Runkle, 2007	3	8	10	13	33	61
Great Lakes and climatically similar areas	Shaffer and Runkle, 2007	3	8	10	13	33	90
Ohio	RW	0	0	17	57	97	196
Ohio	WBR	0	9	36	100	100	612
Indiana	WBR	0	9	34	99	100	1,450
			Mining				
Great Lakes Basin	Shaffer and Runkle, 2007	0	7	10	25	58	58
Climatically similar areas	Shaffer and Runkle, 2007	0	10	14	20	86	83
Great Lakes and climatically similar areas	Shaffer and Runkle, 2007	0	8	13	22	86	141
Ohio	RW	0	0	10	30	100	418

[1] The livestock low coefficient minimum (0 percent) is from Great Lakes Commission (2005), in which Minnesota reported 0.25 Mgal/d total withdrawn in 1998 and 0.0 Mgal/d consumptive-use. The next lowest coefficient for the Great Lakes basin was 66 percent.

[2] The livestock low minimum coefficients are from Solley and others (1988) and may result from adding animal specialties (including fish farming) into the livestock water-use category. In USGS reports previous and subsequent to Solley and others, fish farming was in different water-use categories.

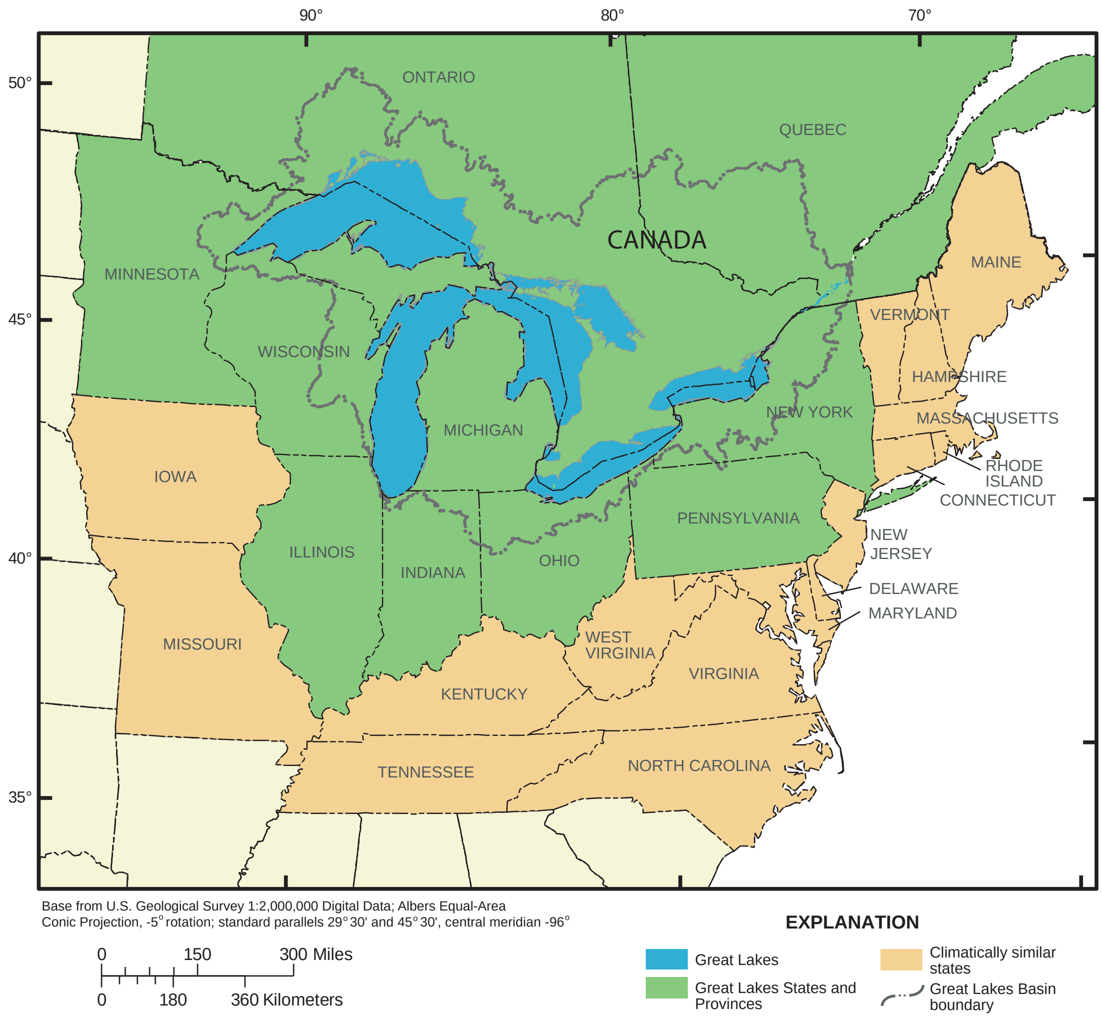
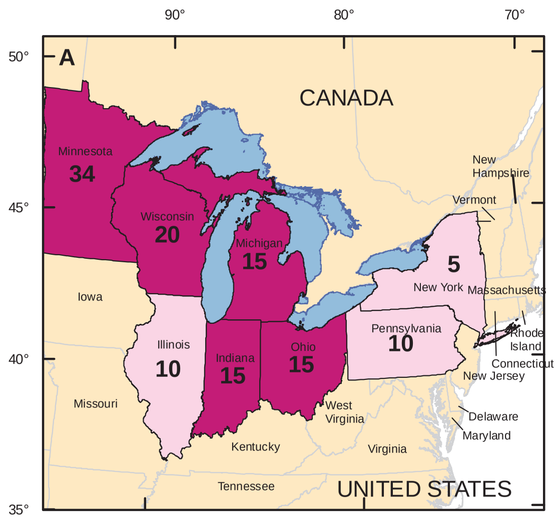
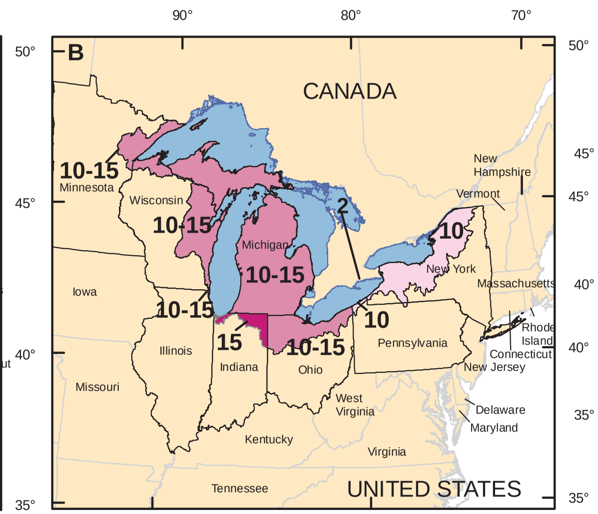


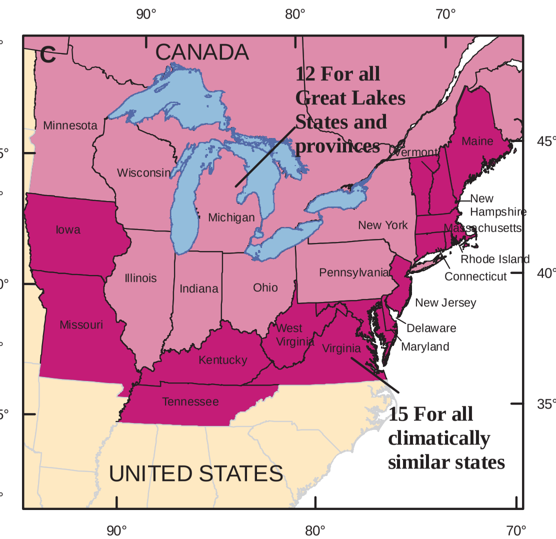
Figure 1–1. The Great Lakes surface-water basin, the Great Lakes States and Provinces, and states considered climatically similar.



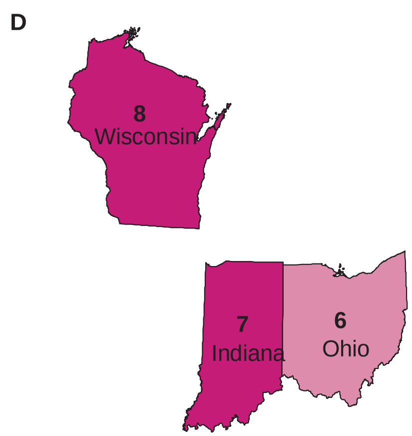
Data from Solley and others, 1998, Estimated use of water in the United States in 1995. (The consumptive-use coefficient is for the entire state for combined self-supplied and publicly-supplied domestic.)



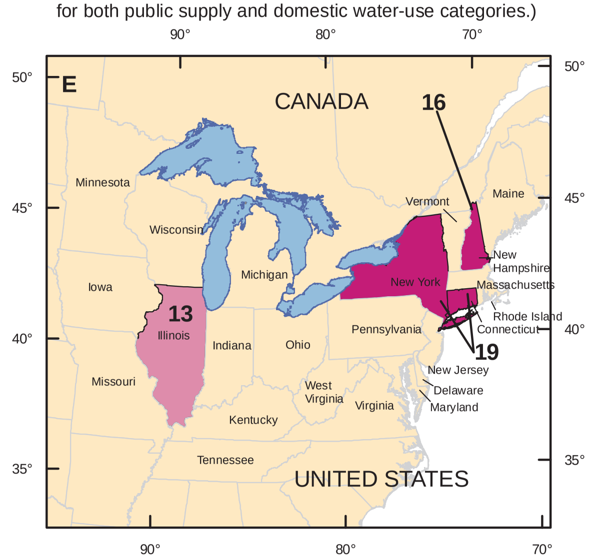
Data from Pebbles, 2003, Measuring and estimating consumptive use of the Great Lakes water. (The consumptive-use coefficient is for the Great Lakes Basin part of the state and is for both public supply and domestic water-use categories.)



Data from Shaffer and Runkle, 2007, Consumptive water-use coefficients for the Great Lakes Basin and climatically similar areas (medians). Consumptive-use coefficients are for domestic and public supply water-use categories.



Winter-base rate method; data from 1999-2004 water-withdrawal programs for Ohio, Indiana, and Wisconsin. Consumptive-use coefficient is for public supply water use. Summer consumptive-use coefficients are 19 (Indiana), 16 (Ohio), and 20 percent (Wisconsin).



Studies using the winter-base rate method in various areas and regions for domestic consumptive-use coefficients. (Horn and others, 2008; Latour, 1991; Mullaney, 2004).

Explanation

Consumptive-use coefficients (in percent)

Maps A, C, D, and E	Map B
5 - 10	5-10
11 - 14	10-15
15 - 34	15

Figure 1–2. Domestic and public supply consumptive-use coefficients from various sources for Great Lakes States.

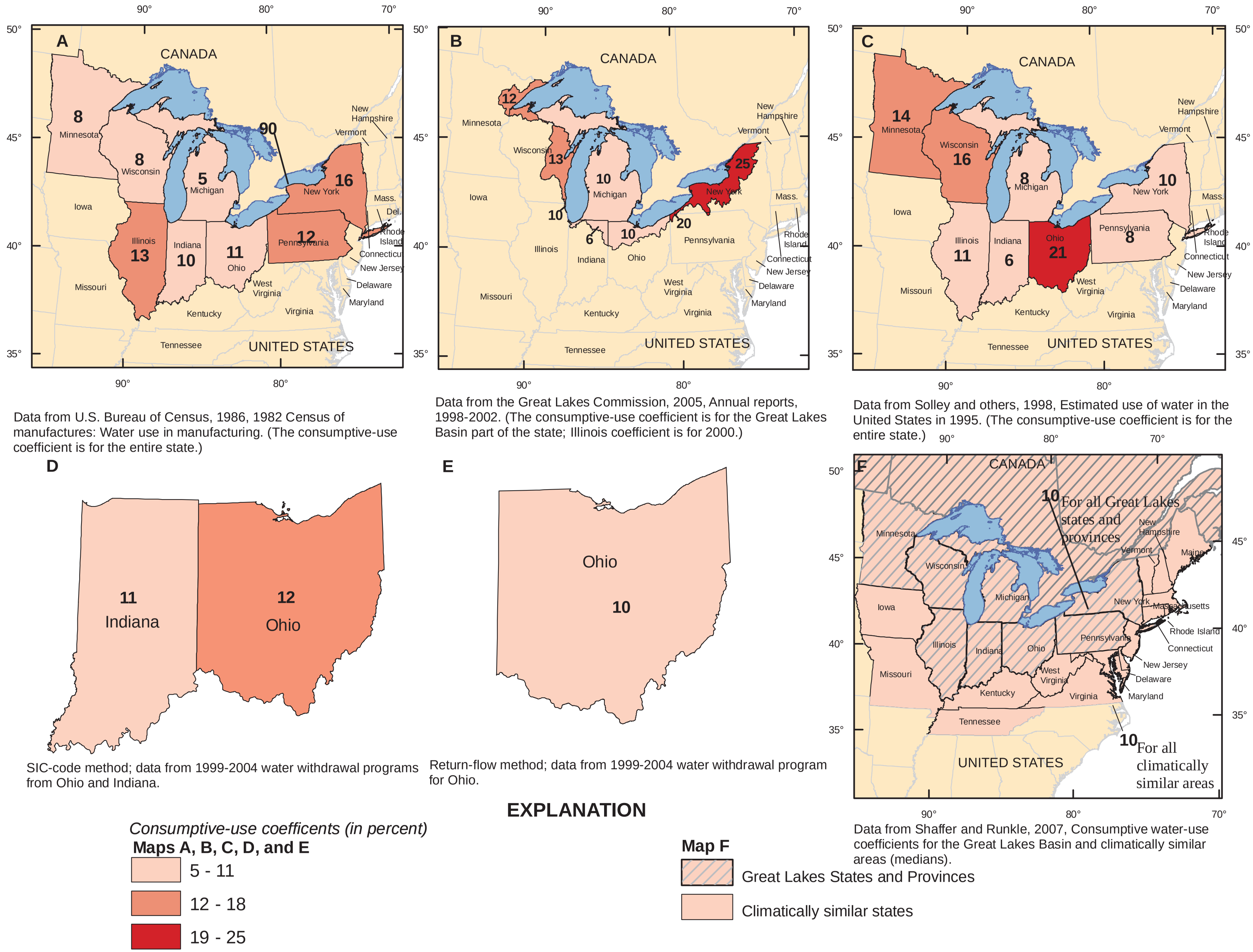


Figure 1–3. Industrial consumptive-use coefficients from various sources for Great Lakes States.

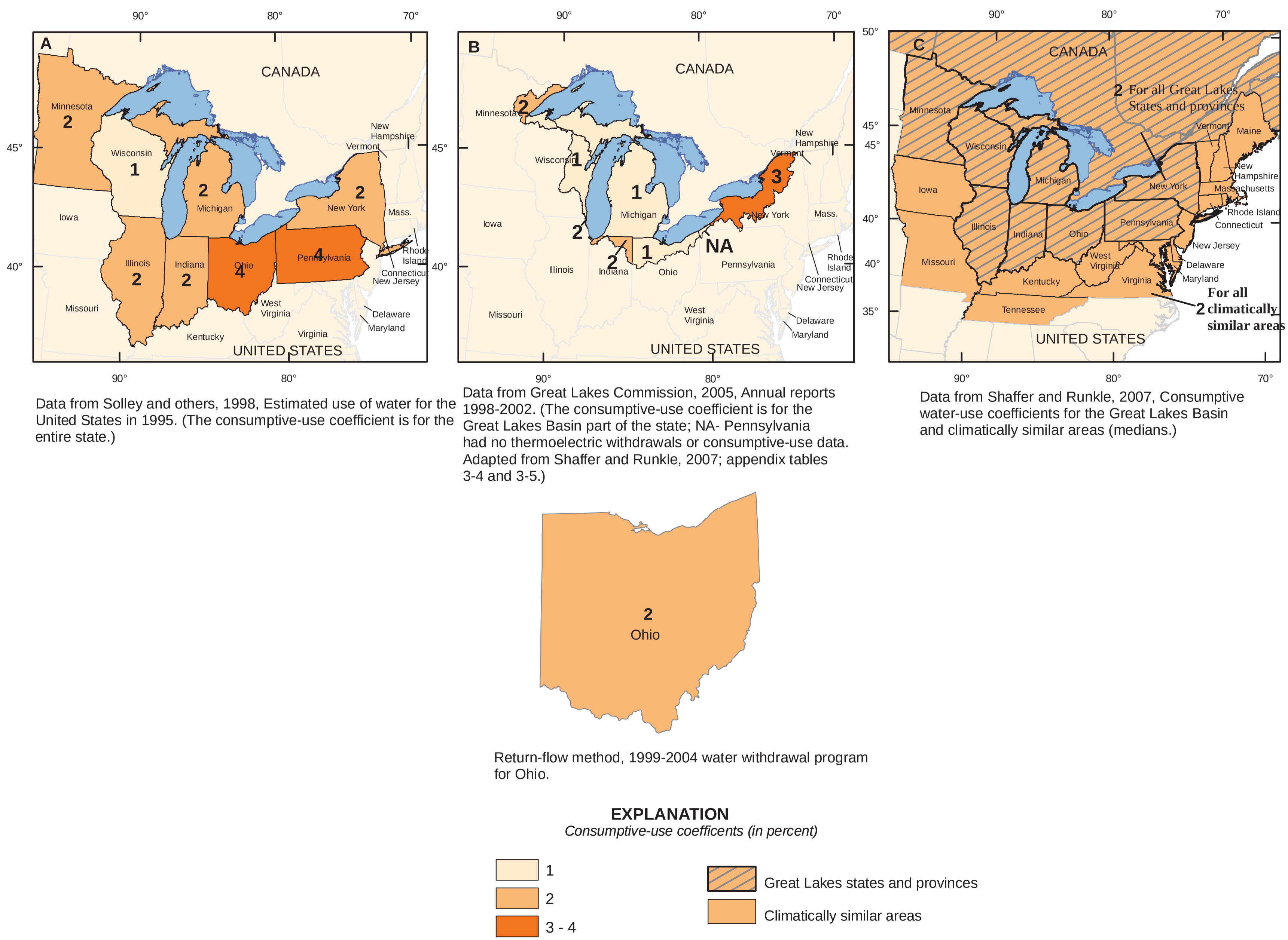


Figure 1–4. Thermoelectric power consumptive-use coefficients from various sources for Great Lakes States.

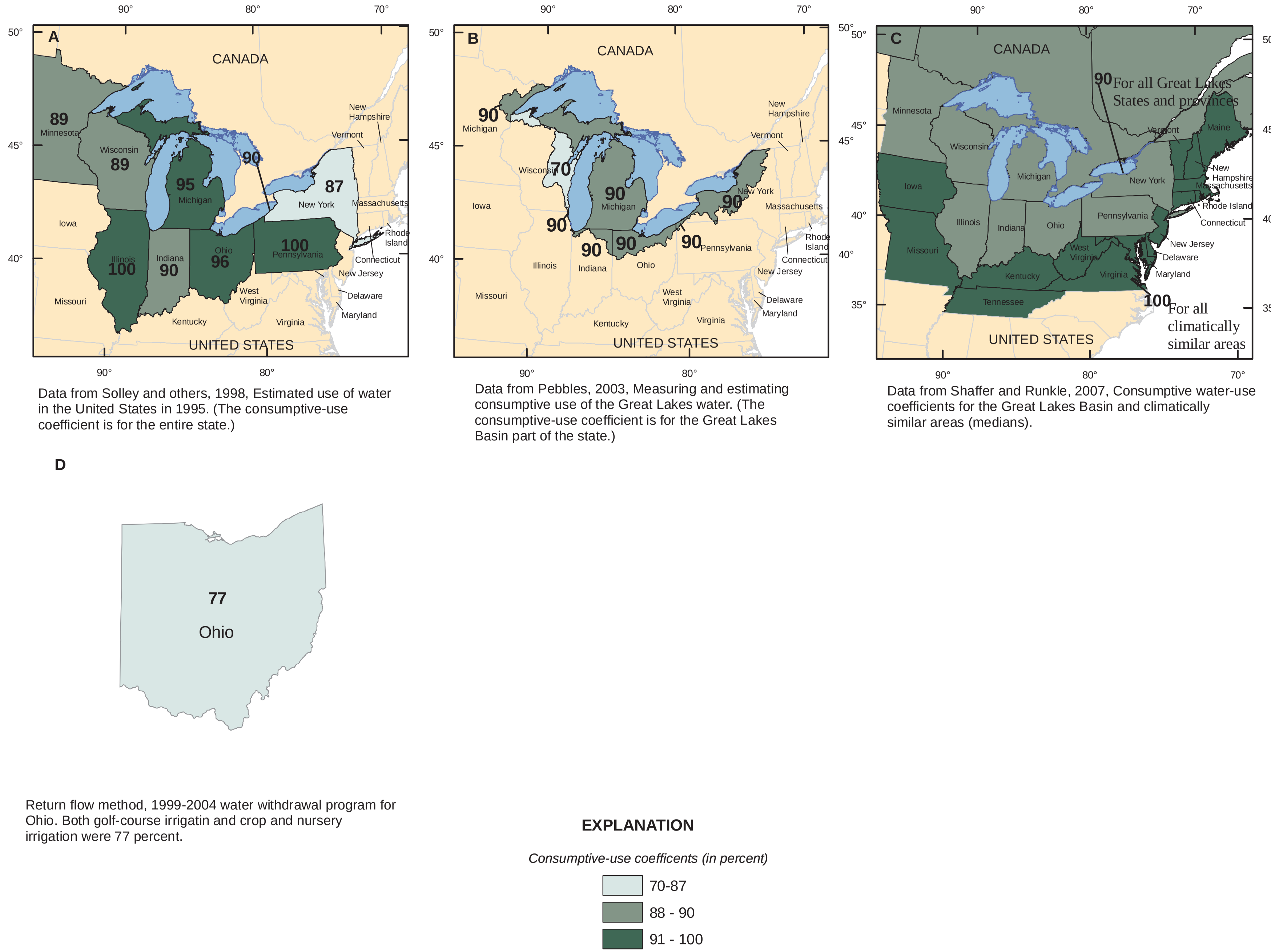


Figure 1–5. Irrigation consumptive-use coefficients from various sources for Great Lakes States.

Appendix 2

Tables

Table 2–1. Statistics for the percentage of annual water withdrawn per month for Indiana and Ohio commercial facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Statistics based on 1,981 records for Indiana and 612 records for Ohio.]

Month	Statistics					
	Indiana			Ohio		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	0.9	6.9	8.7	0	6.4	8.5
February	0.8	6.7	8.4	0	6.4	8.3
March	2.2	7.2	8.8	0.2	6.9	8.3
April	4.1	7.8	9.1	3.0	7.7	8.6
May	6.6	8.5	10.6	7.3	8.7	10.9
June	5.4	8.4	12.0	7.4	8.7	13.1
July	5.7	8.9	15.3	7.0	9.5	14.3
August	7.1	9.1	14.5	8.3	10.1	15.4
September	7.7	9.2	11.8	7.9	9.0	11.8
October	5.5	8.3	10.0	5.5	8.3	9.4
November	2.4	7.0	8.5	0.6	6.3	8.3
December	1.4	6.4	8.3	0	6.3	8.3

Table 2–2. Statistics for the percentage of annual water withdrawn per month by Indiana and Ohio industrial facilities, 1999– 2004.

[Statistics are in percent and are rounded to the nearest tenth. Statistics are based on 2,091 records for Indiana and 1,188 records for Ohio.]

Month	Statistics					
	Indiana			Ohio		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	3.1	7.1	8.5	6.0	8.2	8.8
February	3.4	6.9	8.3	5.8	7.7	8.3
March	5.3	7.8	8.9	7.0	8.3	9.2
April	6.4	8.1	9.1	7.3	8.2	8.9
May	7.2	8.5	9.8	7.9	8.5	9.6
June	7.7	8.8	10.6	8.0	8.5	10.1
July	7.7	8.8	11.1	7.9	8.6	10.1
August	8.1	9.2	11.5	8.2	8.8	10.6
September	7.5	8.5	10.3	7.7	8.3	9.6
October	7.0	8.5	9.7	7.5	8.4	9.4
November	5.5	7.8	8.8	6.6	8.0	8.6
December	4.3	7.0	8.5	5.3	7.7	8.5

Table 2–3. Statistics for the percentage of annual water withdrawn per month by Indiana public-supply facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Statistics are based on 2,939 records.]

Month	Statistics of monthly withdrawals, as a percentage of annual withdrawals		
	25th percentile	Median	75th percentile
January	7.4	8.1	8.7
February	6.7	7.4	8.0
March	7.2	7.9	8.4
April	7.3	7.9	8.4
May	8.0	8.6	9.1
June	8.3	8.7	9.3
July	8.6	9.3	10.2
August	8.5	9.2	10.0
September	8.0	8.6	9.3
October	7.7	8.2	8.7
November	7.0	7.6	8.1
December	7.1	7.8	8.4

Table 2–4. Statistics for the percentage of annual water withdrawn per month by Ohio public-supply facilities, 1999–2004, for all facilities and years and for facilities without records where February withdrawals were greater than July withdrawals.

[Statistics are in percent and are rounded to the nearest tenth. There are 3,604 records for all facilities and 2,998 facilities where July withdrawals are greater than or equal to February withdrawals.]

Month	Statistics					
	All facilities			Facilities where July withdrawals were greater than or equal to February withdrawals		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	7.6	8.2	8.8	7.6	8.2	8.6
February	6.9	7.5	8.2	6.8	7.4	7.9
March	7.5	8.1	8.6	7.5	8.0	8.5
April	7.4	7.9	8.3	7.4	7.9	8.3
May	8.1	8.5	9.0	8.2	8.6	9.0
June	8.2	8.7	9.2	8.3	8.8	9.3
July	8.5	9.1	9.9	8.7	9.3	10.1
August	8.4	8.9	9.6	8.6	9.0	9.7
September	7.9	8.4	8.9	8.1	8.4	9.0
October	7.7	8.2	8.7	7.8	8.3	8.7
November	7.2	7.7	8.2	7.3	7.7	8.2
December	7.4	8.0	8.5	7.4	8.0	8.5

Table 2–5. Statistics for the percentage of annual water withdrawn per month by Wisconsin public-supply facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Sites for which withdrawals were reported quarterly or annually were not included in the statistics. Statistics based on 3,373 records.]

Month	Statistics		
	25th percentile	Median	75th percentile
January	7.4	7.9	8.4
February	6.7	7.2	7.8
March	7.3	7.9	8.3
April	7.3	7.8	8.2
May	8.0	8.4	8.9
June	8.2	8.6	9.1
July	8.9	9.6	10.5
August	8.6	9.3	10.1
September	8.0	8.5	9.2
October	7.8	8.2	8.6
November	7.1	7.5	8.0
December	7.2	7.7	8.2

Table 2–6. Statistics for the percentage of annual water withdrawn per month for Indiana and Ohio thermoelectric facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Statistics based on 197 records for Indiana and 289 for Ohio.]

Month	Indiana			Ohio		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	4.9	7.5	8.8	6.7	8.2	9.1
February	4.8	6.9	8.3	5.8	7.4	8.1
March	4.9	7.1	8.6	6.7	8.3	9.0
April	4.4	7.0	8.3	6.5	7.9	8.5
May	6.2	8.3	9.4	7.6	8.5	9.4
June	8.2	9.3	10.5	8.1	8.8	10.1
July	9.1	10.6	12.4	8.5	9.5	11.2
August	9.0	10.4	12.5	8.5	9.4	11.0
September	7.7	8.9	10.1	7.4	8.3	9.3
October	3.9	8.0	9.2	6.6	8.5	9.1
November	3.7	7.3	8.5	6.3	8.0	8.7
December	5.3	7.6	8.8	6.4	8.0	8.9

Table 2–7. Statistics for the percentage of annual water withdrawn per month for Indiana and Ohio golf-course facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Statistics based on 1,487 records for Indiana and 2,616 for Ohio.]

Month	Statistics					
	Indiana			Ohio		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0.2	4.5	0	0	3.4
May	2.2	7.2	11.6	0	6.3	11.8
June	11.0	15.7	20.0	10.5	16.2	20.6
July	17.1	22.3	27.9	18.7	24.0	30.7
August	18.2	23.3	29.2	17.9	23.5	30.3
September	12.3	16.7	22.0	10.0	15.0	20.2
October	1.3	5.7	10.3	0	4.3	9.1
November	0	0	0.4	0	0	0
December	0	0	0	0	0	0

Table 2–8. Statistics for the percentage of annual water withdrawn per month for Indiana crop and nursery irrigation facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Statistics based on 8,196 records for Indiana and 1,103 for Ohio for Crop and nursery irrigation combined, 8,090 records for Indiana and 425 records for Ohio for crop irrigation, and 106 records for Indiana and 678 for Ohio for nursery irrigation.]

Month	Indiana			Ohio		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
Crop and nursery irrigation combined						
January	0	0	0	0	0	0.3
February	0	0	0	0	0	0.4
March	0	0	0	0	0	3.1
April	0	0	0	0	0.9	7.2
May	0	0	0	0	8.3	12.5
June	0	10.9	24.5	8.9	14.9	20.5
July	26.7	37.2	50	13.3	19.9	28.6
August	23.8	33.9	48.4	12.9	19.5	27.0
September	0	0	11.4	4.2	11.5	16.4
October	0	0	0	0	5.5	9.5
November	0	0	0	0	0	4.0
December	0	0	0	0	0	0.6
Crop irrigation						
January	0	0	0	0	0	0.1
February	0	0	0	0	0	0.1
March	0	0	0	0	0	0.6
April	0	0	0	0	0	4.5
May	0	0	0	0	2.3	9.4
June	0	10.6	24.6	4.5	13.1	22.7
July	27.2	37.5	50.0	10.7	24.5	37.8
August	24.4	34.2	48.7	9.4	21.3	33.3
September	0	0	11.1	0	8.3	15.1
October	0	0	0	0	0	7.8
November	0	0	0	0	0	1.6
December	0	0	0	0	0	0.1
Nursery irrigation						
January	0	0	0	0	0	0.4
February	0	0	0	0	0	0.6
March	0	0	6.2	0	0	4.0
April	0	5.7	9.4	0	3.8	8.1
May	0	9.3	12.8	5.0	10.0	13.1
June	9.3	12.8	17.9	11.2	15.4	20.0
July	9.3	14.3	23.9	13.9	18.5	24.7
August	11.5	14.9	23.8	13.7	18.9	25.0
September	9.8	12.9	21.3	8.9	12.8	16.8
October	2.0	8.6	12.8	1.3	7.0	11.0
November	0	2.5	7.0	0	0.6	4.7
December	0	0	0	0	0	0.9

Table 2–9. Statistics for the percentage of annual water withdrawn per month for Indiana and Ohio livestock facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Indiana livestock statistics are based on 114 records. Ohio livestock statistics are based on 114 records.]

Month	Statistics					
	Indiana			Ohio		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	1.4	7.4	8.3	7.4	8.3	8.5
February	5.2	7.6	8.3	7.2	7.9	8.3
March	4.8	7.9	8.3	7.6	8.3	8.5
April	2.9	7.8	8.3	7.7	8.2	8.3
May	7.0	8.3	8.7	8.3	8.4	8.7
June	7.9	8.5	9.2	8.2	8.3	8.9
July	8.3	8.9	10.5	8.3	8.5	9.4
August	8.3	8.9	12.2	8.3	8.5	9.4
September	7.2	8.4	8.9	8.1	8.3	8.8
October	6.8	8.3	8.5	8.1	8.3	8.6
November	6.6	8.0	8.3	7.9	8.3	8.4
December	6.7	8.0	8.3	7.7	8.3	8.5

Table 2–10. Statistics for the percentage of annual water withdrawn per month for Indiana livestock facilities, 1999–2004, seasonal facilities and all-year facilities.

[Statistics are in percent and are rounded to the nearest tenth. The number of records were 88 for all-year facilities and 26 for seasonal facilities.]

Month	Statistics					
	Seasonal facilities			All-year facilities		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	0	0	0	6.5	8.0	8.3
February	0	0	0	7.0	8.0	8.3
March	0	0	0	7.2	8.1	8.3
April	0	0	0	7.1	8.0	8.3
May	0	0	0	8.2	8.3	8.8
June	0	0	16.8	8.3	8.5	9.6
July	12.3	31.5	44.4	8.3	8.8	9.5
August	12.2	31.8	50.0	8.3	8.8	9.8
September	0	0	9.3	8.2	8.5	8.9
October	0	0	0	8.0	8.3	8.6
November	0	0	9.0[1]	7.6	8.2	8.3
December	0	0	0	7.5	8.1	8.3

[1] The seasonal facilities included sites where withdrawals concluded in November and sites where withdrawals began in November.

Table 2–11. Statistics for the percentage of annual water withdrawn per month for Indiana and Ohio aquacultural sites, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. The number of records is 65 for both Ohio and Indiana.]

Month	Statistics					
	Instances of no withdrawals	Minimum	25th percentile	Median	75th percentile	Maximum
Indiana						
January	11	0	6.2	8.4	9.3	30.7
February	12	0	4.7	7.5	8.2	12.1
March	2	0	7.5	8.5	10.8	42.0
April	0	4.0	8.2	9.9	13.3	35.2
May	3	0	5.7	8.5	9.7	20.8
June	0	5.0	8.1	9.0	13.6	32.6
July	6	0	5.0	7.2	8.5	24.5
August	6	0	6.7	7.5	8.5	16.9
September	0	2.4	6.1	7.8	8.3	14.9
October	0	2.8	6.1	7.8	8.7	14.9
November	3	0	5.7	7.8	8.5	20.0
December	9	0	4.6	8.3	8.8	19.3
Ohio						
January	13	0	4.4	6.8	8.7	22.0
February	13	0	4.4	6.7	7.9	21.7
March	0	2.3	6.6	8.4	11.1	94.0
April	0	0.9	8.1	8.8	12.2	41.2
May	1	0	6.9	8.7	9.2	18.3
June	0	0.9	8.0	8.8	12.2	40.1
July	0	1.1	5.3	7.8	9.2	11.3
August	4	0	5.3	8.1	9.4	12.2
September	0	0.9	7.4	8.5	9.7	13.5
October	4	0	7.6	8.5	8.8	11.7
November	10	0	4.4	7.3	8.5	15.3
December	11	0	4.4	7.2	8.5	31.5

Table 2–12. Statistics for the percentage of annual water withdrawn per month for Indiana and Ohio mining facilities, 1999–2004.

[Statistics are in percent and are rounded to the nearest tenth. Indiana statistics are based on 541 records, and Ohio statistics are based on 961 records.]

Month	Statistics					
	Indiana			Ohio		
	25th percentile	Median	75th percentile	25th percentile	Median	75th percentile
January	0.0	3.9	7.9	0	4.8	8.3
February	0.0	5.0	7.8	0	5.3	8.2
March	5.4	8.1	9.4	4.6	8.2	9.1
April	7.7	9.3	11.1	8.0	8.9	10.9
May	8.3	9.9	12.0	8.3	9.6	11.5
June	8.2	9.9	11.8	8.2	9.3	11.4
July	8.0	9.7	11.9	8.0	9.1	11.3
August	7.8	9.8	12.1	8.0	9.2	11.8
September	7.4	9.3	11.4	8.0	9.0	11.1
October	7.8	9.6	11.6	7.9	8.9	11.5
November	6.5	8.2	9.5	6.9	8.3	9.9
December	3.3	6.0	8.3	4.4	6.9	8.5

Appendix 3

Table 3–1. Commercial withdrawals by SIC code for Ohio and Indiana, 1999–2004.

[Median consumptive-use coefficient and withdrawal range are rounded to two significant figures. Mgal/yr, million gallons per year.]

SIC code	SIC description	Number of records	Median annual withdrawal (Mgal/yr)	Description of withdrawals	Annual withdrawal range (Mgal/yr)
0711	Soil preparation services	6	0.45	Withdrawals were from March to November.	0.08–0.70
0721	Crop planting, cultivating, and protecting	12	8.2	Withdrawals are mostly from March to October.	1.8–9.2
0723	Crop preparation services for market	6	1.5	Withdrawals are for July and August only.	0.97–17
0782	Lawn and garden services	6	5.9	Withdrawals varied by year but were usually June to October with occasional withdrawals in May, November, and December.	0.96–13
0971	Hunting and trapping[1]	34	86	Most of the withdrawals were concentrated August through November, even though some records listed withdrawals throughout the year.	6.0–880
4011	Railroads, line-haul operating	6	100	Withdrawals were April through December with higher withdrawals June through September.	92–105
4221	Farm product warehousing and storage	7	0.30	Withdrawals were March through December.	0.25–0.56
4225	General warehousing and storage	6	2.3	Withdrawals were for the entire year.	1.4–3.8
4231	Freight trucking terminals	6	0.64	Withdrawals were for the entire year.	0.57–0.68
4581	Airports, flying fields, and airport terminal services	22	0.36	Withdrawals were for the entire year.	0.03-82
4613	Refined petroleum pipelines	6	11	Withdrawals were for the entire year.	6.2–15
4833	Television broadcasting station	15	0.08	Withdrawals were for the entire year.	0.0–79
4922	Natural gas transmission	6	0.10	Withdrawals were for the entire year.	0.05–0.23
4923	Natural gas transmission and distribution	18	0.16	Withdrawals were for the entire year.	0.05–1.1
4924	Natural gas distribution	12	0.23	Withdrawals were for the entire year.	0.16–0.38
4931	Electric and other service combined	4	2.9	Withdrawals varied by record.[3]	2.0–7.3
4939	Combination utilities[2]	6	0.03	Withdrawals varied monthly by record.	0.02–0.04
5031	Lumber, plywood, millwork, and wood panels	6	1.2	Withdrawals were mostly throughout the entire year, with an increase in withdrawals July and August.	0.30–3.4
5032	Brick, stone, and related construction material	6	0.80	Withdrawals were fairly even for the entire year.	0.77–4.0
5082	Construction and mining machinery and equipment	6	3.7	Withdrawals were throughout the entire year.	3.0–4.6
5084	Industrial machinery and equipment	6	0.03	Withdrawals varied monthly by record. June through August withdrawals were highest.	0.02–0.06

Table 3–1. Commercial withdrawals by SIC code for Ohio and Indiana, 1999–2004.—Continued

[Median consumptive-use coefficient and withdrawal range are rounded to two significant figures. Mgal/yr, million gallons per year.]

SIC code	SIC description	Number of records	Median annual withdrawal (Mgal/yr)	Description of withdrawals	Annual withdrawal range (Mgal/yr)
5141	Groceries, general line	6	64	Withdrawals were throughout the entire year.	30–84
5171	Petroleum blue stations and terminals wholesale distribution	17	69	Withdrawals varied by record.	2.2–980
5191	Farm supplies	29	0.81	Some records had withdrawals throughout the year and others were seasonal.	0.12–9.9
5411	Grocery stores	6	1.8	Withdrawals were throughout the entire year.	1.4–2.4
5500	Automotive dealers and gasoline service Stations	5	51	Withdrawals were April through October.	51–52
5511	Motor vehicle dealers (new and used)	6	0.99	Withdrawals were throughout the entire year.	0.99–1.0
5541	Gasoline service stations	13	3.2	Withdrawals and returns were fairly even for the entire year.	0.72–12
5812	Eating places	24	3.4	Withdrawals were fairly even for the entire year.	0.61–55
6035	Savings institutions, federally chartered	10	16	Withdrawals varied by record. Some listed withdrawals throughout the year, and others listed withdrawals March through November.	0.26–21
6211	Security brokers, dealers, and flotation companies	9	8.6	Withdrawals were fairly even for the entire year.	0.89–66
6311	Life insurance establishments	6	500	Withdrawals were throughout the entire year but higher in June through September.	390–540
6500	Real estate establishments	6	0.72	Withdrawals were fairly even for the entire year.	0.66–0.72
6512	Operators of nonresidential buildings	11	0.81	Withdrawals varied by record. Some listed withdrawals throughout the year, and others listed withdrawals May through December.	0.01–18
6513	Operators of apartment buildings	42	62	Withdrawals were throughout the year, but higher June through September.	14–150
6515	Operators of residential mobile home sites	116	8.5	Withdrawals were throughout the entire year. A few records listed higher withdrawals in July and August.	0.10–150
6531	Real estate agents and managers	12	74	Withdrawals were throughout the entire year.	16–1,000
6552	Land subdividers and developers, except cemeteries	34	11	Withdrawals varied by record. Some listed withdrawals throughout the year, and others listed withdrawals May through October.	0.72–35
6553	Cemetery subdividers and developers	6	53	Withdrawals were throughout the entire year.	47–74

Table 3–1. Commercial withdrawals by SIC code for Ohio and Indiana, 1999–2004.—Continued

[Median consumptive-use coefficient and withdrawal range are rounded to two significant figures. Mgal/yr, million gallons per year.]

SIC code	SIC description	Number of records	Median annual withdrawal (Mgal/yr)	Description of withdrawals	Annual withdrawal range (Mgal/yr)
6710	Investment and holding offices	6	4.6	Withdrawals were May through October.	1.4–15
7011	Hotels and motels	87	10	Withdrawals for hotels and motels associated with a skiing area were highest November through February. Other hotels and motels either had fairly constant withdrawals throughout the year or some increase July through September.	0.46–140
7032	Sporting and recreational camps	16	0.56	Withdrawals varied by record. Some listed withdrawals throughout the year, and others listed withdrawals part of the year. Withdrawals typically increased during June through August.	0.19–1.7
7033	Recreation vehicle parks and campsites	32	7.7	Withdrawals varied by record. Some listed withdrawals throughout the year, and others listed withdrawals May through October. Withdrawals increased during June through August.	0.12–26
7213	Linen supply	6	18	Withdrawals were fairly even for the entire year.	14–19
7218	Industrial launderers	12	7.3	Withdrawals were fairly even for the entire year.	5.4–27
7299	Misc. personal services[5]	8	13	Most records listed withdrawals throughout the year with an increase in July and August.	3–23
7350	Misc. equipment rental and leasing	6	60	Withdrawals were June through September.	44–82
7370	Computer programming, data processing, and other computer related services	6	9.4	Withdrawals were for the entire year.	8.9–13
7389	Business services, not elsewhere classified	6	1.2	Withdrawals varied by record.	0.09–1.8
7532	Top, body, and upholstery repair shops and paint shops	6	0.05	Withdrawals varied by record.	0.01–0.09
7542	Carwashes	12	2.0	Withdrawals were for the entire year.	0.02–5.7
7941	Professional sports clubs and promoters	4	390	Withdrawals were for the entire year.	33–690
7948	Racing, including track operations	18	4.8	Withdrawals varied by record, with most facilities having higher withdrawals June through September.	0–48
7990	Miscellaneous amusement and recreation services	12	5.0	Withdrawals were April through November.	3.7–34
7991	Physical fitness facilities	5	990	Withdrawals were for the entire year with higher withdrawals December through June.	680–1,100

Table 3–1. Commercial withdrawals by SIC code for Ohio and Indiana, 1999–2004.—Continued

[Median consumptive-use coefficient and withdrawal range are rounded to two significant figures. Mgal/yr, million gallons per year.]

SIC code	SIC description	Number of records	Median annual withdrawal (Mgal/yr)	Description of withdrawals	Annual withdrawal range (Mgal/yr)
7996	Amusement parks	38	130	Withdrawals varied by record with more withdrawals May through September.	1.8–1,000
7999	Amusement/Recreation services[6]	87	4.9	Ski facilities had more withdrawals in winter months while other facilities had more withdrawals April through September.	0–1,500
8000	Health services	6	0.32	Withdrawals varied by month.	0.26–0.38
8051	Skilled nursing care facilities	36	14	Withdrawals were for the entire year.	0.72–34
8052	Intermediate care facilities	6	6.2	Withdrawals were for the entire year.	0.45–6.3
8059	Nursing and personal care facilities	19	1.5	Withdrawals were for the entire year.	0–44
8060	Hospitals	6	6.2	Withdrawals were for the entire year.	5.9–7.0
8062	General medical and surgical hospitals	49	10	Withdrawals varied by record, many had higher withdrawals April through October.	0–910
8069	Specialty hospitals	15	10	Withdrawals and returns for the most part are for the entire year but they were sometimes higher in the summer months.	7.1–2,800
8211	Elementary and secondary schools	755	1.9	Withdrawals varied by record with larger withdrawals September through June.	0–68
8221	Colleges and universities	125	46	Withdrawals varied by record with larger withdrawals September through June.	0.53–9,000
8249	Vocational schools	12	2.4	Withdrawals were for the entire year.	0.55–5.5
8322	Individual and family social services[7]	5	2.6	Withdrawals were for the entire year.	0.04–5.7
8361	Residential care	21	13	Withdrawals were for the entire year.	0.04–24
8422	Arboreta and botanical or zoological gardens	6	88	Withdrawals were for the entire year but greater in the summer months.	75–110
8641	Civic, social, and fraternal association	190	11	Withdrawals varied by record.	0–382
8661	Religious organizations	41	2.3	Withdrawals varied by record.	0.01–200
8731	Commercial physical and biological research	12	2.8	Withdrawals were for the entire year.	0–5.6
8734	Testing laboratories	9	2.3	Withdrawals were May through September.	0–6.9
8741	Management services	5	39	Withdrawals were for the entire year, with higher withdrawals May through September.	32–77
8742	Management consulting services	6	60	Withdrawals and returns were for the entire year.	40–100
8744	Facilities support management services	12	120	Withdrawals were for the entire year.	2.3–290
9199	General government	3	1,500	Withdrawals varied by record.	0.01–2,800

Table 3–1. Commercial withdrawals by SIC code for Ohio and Indiana, 1999–2004.—Continued

[Median consumptive-use coefficient and withdrawal range are rounded to two significant figures. Mgal/yr, million gallons per year.]

SIC code	SIC description	Number of records	Median annual withdrawal (Mgal/yr)	Description of withdrawals	Annual withdrawal range (Mgal/yr)
9223	Correctional institutions	52	220	Withdrawals were fairly even for the entire year.	0.20–790
9224	Fire protection	82	0.06	Withdrawals varied by record.	0–1.0
9511	Air and water resource and solid waste management	36	1.0	Withdrawals varied by record.	0–83
9512	Land, mineral, wildlife, and forest conservation	108	2.4	Withdrawals varied by record with many records having withdrawals August through December.	0–3,400
9531	Administration of housing programs	12	68	Withdrawals varied by record.	0.06–140
9532	Admin. of urban and community development	6	190	Withdrawals varied by record.	160–410
9621	Regulation of administration of transportation programs	30	8.2	Withdrawals were for the entire year.	0.37–21
9711	National security facilities	43	29	Withdrawals were for the entire year.	0.02–1,400
9999	Nonclassifiable establishments	18	13	Withdrawals varied by record.	0–300

[1] Facilities primarily engaged in commercial hunting and trapping or in the operation of game preserves.

[2] This is a fire department.

[3] One record listed withdrawals and returns in April through September. The second one listed withdrawals and returns in October only. The third record listed withdrawals and returns July through September.

[4] Two records listed withdrawals and returns all year. A third record listed withdrawals and returns March through December. The fourth record listed withdrawals and returns January, February, August, and October through December. In some months, withdrawals were 0.01 to 12.36 gal/d.

[5] These records are for service areas that probably has restrooms.

[6] This category includes parks, a water park, a mill, snow-skiing areas, and a waterfall. The records listed varied consumptive-use coefficients; 0–78 percent for parks, 0–40 percent for the water park, 0–0.4 percent for the mill, 6–56 percent for the skiing areas, and zero percent for the waterfall.

[7] This is a youth center.

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