Consumptive Water-Use Coefficients for the Great Lakes Basin and Climatically Similar Areas

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Abstract

Consumptive water use is the portion of water withdrawn (for a particular use) that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. This report, which is organized by water-use categories, includes consumptive-use coefficients for the Great Lakes Basin (including Canada) and for areas climatically similar to the Great Lakes Basin. This report also contains an annotated bibliography of consumptive water-use coefficients. Selected references are listed for consumptive-use data from elsewhere in the world.

For the industrial water-use category, the median consumptive-use coefficients were 10 percent for the Great Lakes Basin, climatically similar areas, and the world; the 25th and 75th percentiles for these geographic areas were comparable within 6 percent. The combined domestic and public-supply consumptive-use statistics (median, 25th and 75th percentiles) were between 10 to 20 percent for the various geographic areas. Although summary statistics were similar for coefficients in the livestock and irrigation water-use categories for the Great Lakes Basin and climatically similar areas, statistic values for the world on a whole were substantially lower (15 to 28 percent lower). Commercial and thermoelectric power consumptive-use coefficient statistics (median, 25th, and 75th percentile) also were comparable for the Great Lakes Basin and climatically similar areas, within 2 percent. References for other countries were not found for commercial and thermoelectric power water-use categories. The summary statistics for the mining consumptive-use coefficients varied, likely because of differences in types of mining, processes, or equipment.

Introduction

This report is part of a series of reports by the U.S. Geological Survey National Assessment of Water Availability and Use Program for the **Great Lakes Basin**[1], a program designed to gain a clearer understanding of water-use, land-use, and climatic trends in our Nation's water resources. Preliminary discussions with state agencies have indicated that refinement of consumptive-use data and coefficients is an area of great interest and value to water-supply managers (Grannemann and Reeves, 2005). These consumptive-use coefficients were compiled and an annotated bibliography was prepared for the Great Lakes Basin and **climatically similar areas**.

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 (water body, surface- or ground-water source, basin). Water-resource planners and managers use consumptive water use to understand the effect of human use of water on the hydrologic system. When the hydrologic system includes an area shared by two countries, as is the Great Lakes Basin, it is important to thoroughly understand how water is consumed and unavailable for use. It is equally important to understand the measures needed to document current levels of consumptive use and develop policies that will optimize the use and reuse of water as much as possible.

Two common methods of computing consumptive use are with a water-balance equation or a consumptive-use coefficient. Because more detailed data are needed to use a water-balance equation, consumptive use frequently is estimated with coefficients. A consumptive-use coefficient, as defined for this report, is the percentage of water removed from the immediate environment by **evaporation**, **transpiration**, incorporation into products or crops, or consumption by humans or livestock.

[1] Bolded terms are defined in the glossary.

Purpose and Scope

The purpose of this report is to present a compilation of consumptive-use coefficients for the Great Lakes Basin and climatically similar areas. The report can serve as a starting point for facility managers, water managers, and scientists to compute water consumption and **return flow**. The data and coefficients were assembled by **water-use category** to address the following questions:

- Within a given water-use category, is there a small range of coefficients reported in most references?
- How do the coefficients for the Great Lakes Basin and climatically similar areas compare to each other and to world coefficients?
- What methods and data were used in previous studies to calculate consumptive use?
- What consumptive-use data and coefficients are available?

The report contains

- consumptive-use coefficients for domestic and public-supply, industrial, industrial use by major **standard industrial classification codes**, thermoelectric power, irrigation, livestock, commercial, and mining water-use categories;
- a selected statistical analysis;
- summary tables by geographic area and water-use category;
- an annotated bibliography of references with consumptive-use coefficients; and
- an appendix with detailed consumptive-use coefficient tables from selected references

for the Great Lakes Basin and areas climatically similar to the Great Lakes Basin, and selected references for elsewhere in the world.

Overview of Report

The different parts of the report are designed to work together. Overall summaries of consumptive-use coefficients by geographic area (table 9) and water-use category (table 43) provide an overview of the coefficient ranges. More detailed discussions about the consumptive-use coefficients are in the water-use categories sections (domestic and public-supply, industrial, industrial use by major standard industrial classification codes, thermoelectric power, irrigation, livestock, commercial, and mining). The water-use categories sections include coefficient summary tables and boxplots showing the distribution of the coefficients. More information about the coefficients presented in each water-use category summary table can be found in the annotated consumptive-use bibliography, which contains about 100 references. Tables from references with multiple tables or references that are part of a series of publications are in the appendixes (a guide to the appendixes is shown in table 1).

The intent of this report is to 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.

Table 1. Appendix guide.

Appendix table(s)	Reference(s)	Water-use categories	Description
1-1 to 1-16	Murray, 1968 Murray and Reeves, 1972 Murray and Reeves, 1977 Solley and others, 1983 Solley and others, 1988 Solley and others, 1993 Solley and others, 1998	Domestic 1-1 and 1-2 Industrial 1-3 and 1-4 Thermoelectric 1-5 and 1-6 Irrigation 1-7 and 1-8 Livestock 1-9 and 1-10 Animal specialties 1-11, 1-12 Commercial 1-13, 1-14 Mining 1-15, 1-16	Consumptive-use coefficients from USGS 5-year compilation reports aggregated by water-use categories for the (1) Great Lakes Basin and Great Lakes States and (2) water resources regions and states climatically similar to the Great Lakes States
2-1 to 2-5	U.S. Bureau of Census, 1986	Industrial 2-1 to 2-5	Consumptive-use coefficients, and water use and consumptive use data from the 1983 Census of Manufacturing.
3-1 to 3-9	Pebbles, 2003b Great Lakes Commission, Annual Reports, 2005a	Public supply 3-1, 3-2, and 3-6 Domestic 3-1, 3-2, and 3-7 Industrial 3-1, 3-2, and 3-3 Thermoelectric 3-1, 3-2, 3-4, 3-5 Irrigation 3-1, 3-2, and 3-8 Livestock 3-1, 3-2, and 3-9	Consumptive-use coefficients by Great Lakes jurisdictions and water use and consumptive use data for annual reports 1998 to 2002.
4-1 to 4-2	Tate and Harris, 1999a	Public supply 4-2 Industrial 4-1 Thermoelectric power 4-2 Agriculture 4-2	Consumptive-use coefficients and water intake and consumption data for water-use categories in the Canadian portion of the Great Lakes Basin.
5-1 to 5-4	Water Resources Council (U.S.), 1978	Domestic 5-3 Industrial 5-2 Thermoelectric 5-2 Irrigation 5-1 Livestock 5-1 Commercial 5-3 Mining 5-4	Consumptive-use coefficients, and water intake and consumptive use data for water resources regions in the United States.

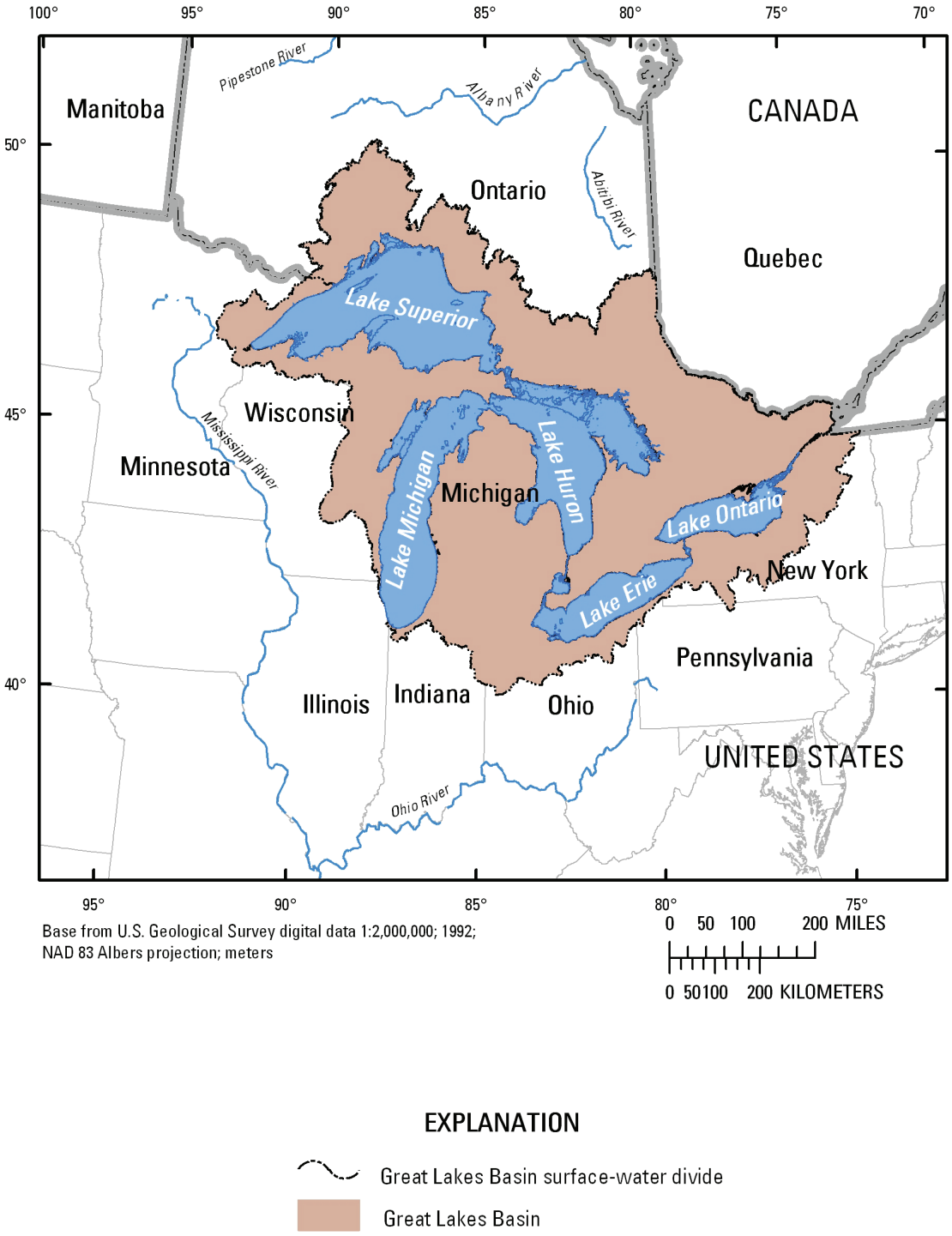
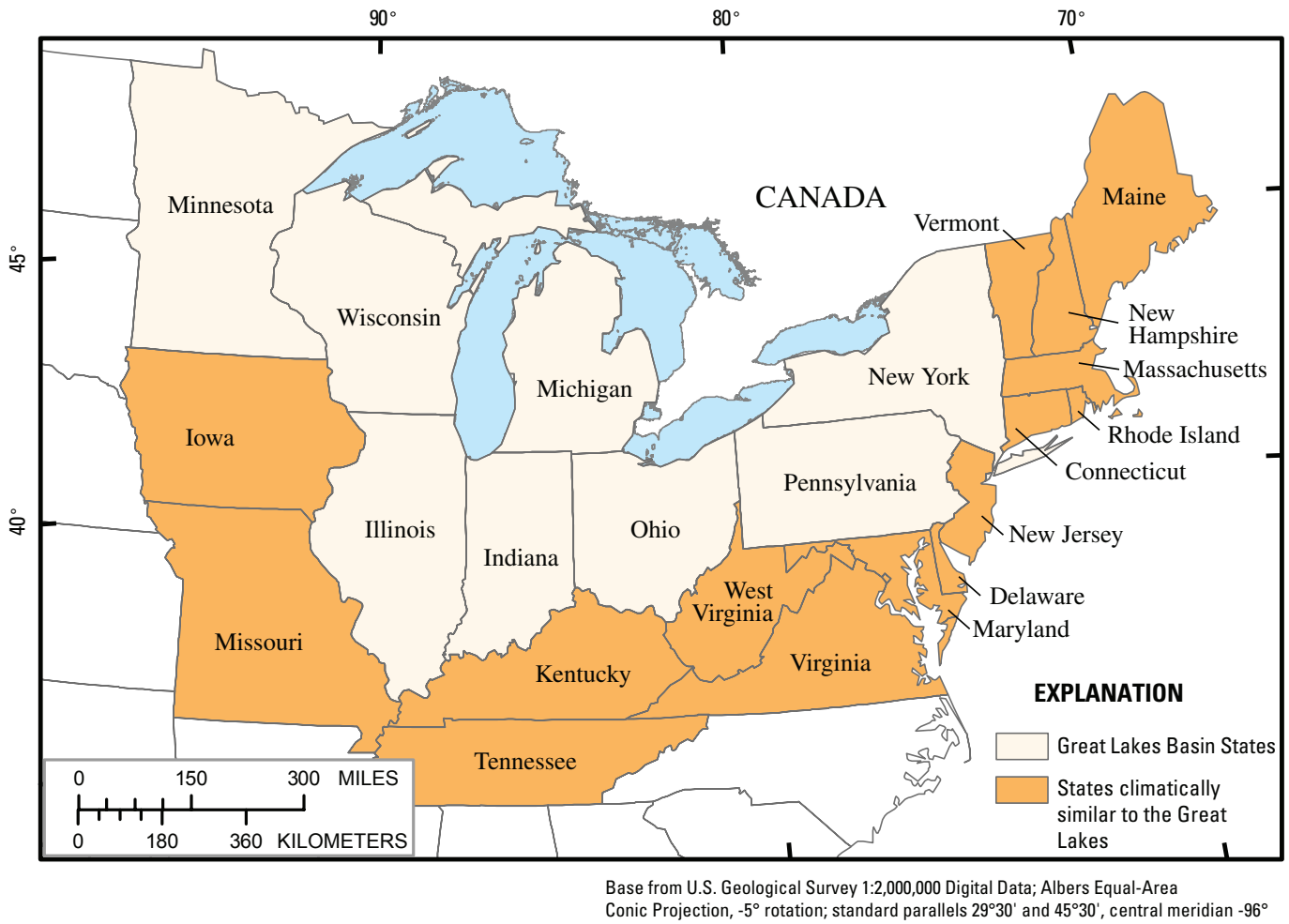


Figure 1. The Great Lakes surface-water basin.

This report compares 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.

In many publications, consumptive-use values or coefficients have been 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.



Base from U.S. Geological Survey 1:2,000,000 Digital Data; Albers Equal-Area Conic Projection, -5° rotation; standard parallels 29°30' and 45°30', central meridian -96°

Figure 2. States considered climatically similar to the Great Lakes States.

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 (fig. 3), and water use in the state. Hutson and others (2004b) found that six water-resources regions (Great Lakes, mid-Atlantic, New England, Ohio, Tennessee, and Upper Mississippi) had comparable percent consumptive losses (fig. 4).

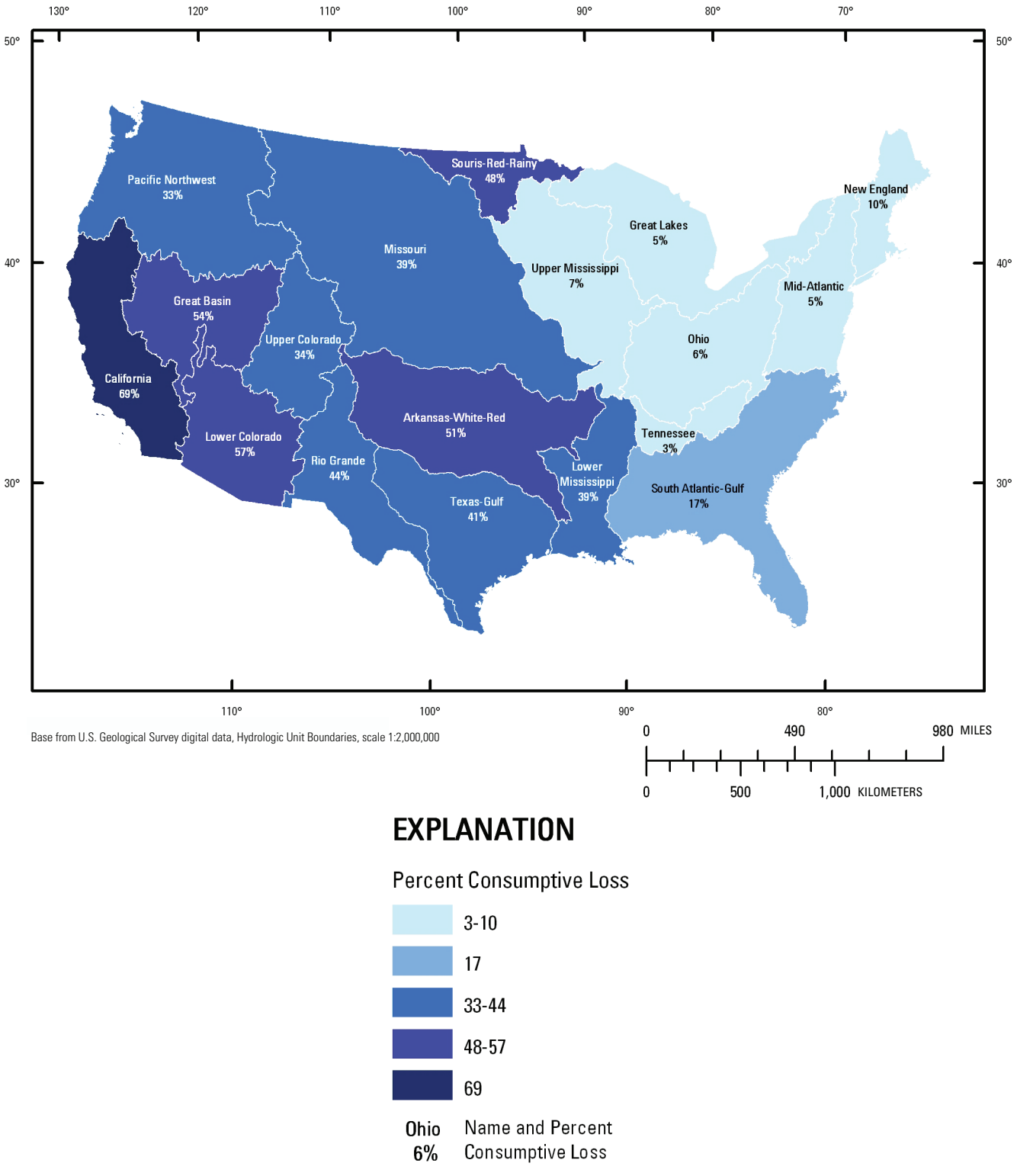


Figure 3. Percent consumptive loss in the conterminous United States, by water-resources region, in 1995. (From Hutson and others, 2004b and Solley and others, 1996)

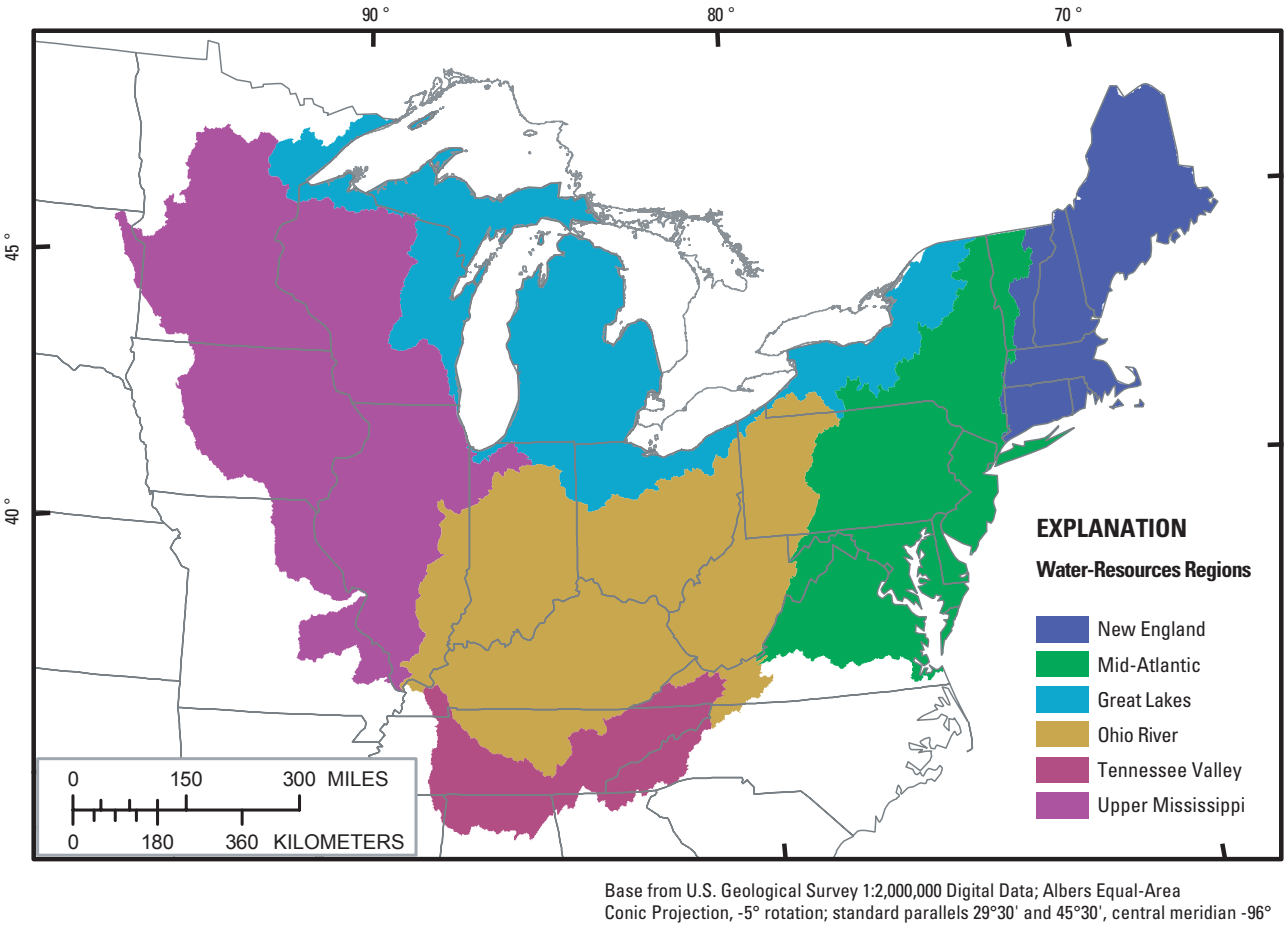


Figure 4. Water-resources regions used in selection of climatically similar States.

These water-resources regions (fig. 4) and the major states in these regions (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, 2006b) and many of these states reported irrigation as the primary water-use category (excluding thermoelectric power; Hutson and others, 2004a).

As part of this report, a search for world, continent, and country consumptive-use coefficients was conducted. 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 though 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.

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). Stream, lake, and reservoir evaporation losses were not addressed in this report.

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 geographic area and timeframe of the statistics.

Some publications use the words “consumptive use” to mean “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.

Methods

Table 2 includes consumptive-use definitions from multiple references. For the most part, these definitions show agreement that consumptive use is water that is evaporated, transpired, or incorporated into products or crops, consumed by humans or livestock or otherwise removed from an immediate water environment (water body, surface or ground water source, basin, Great Lakes Basin). The consumptive-use processes are described in greater detail in table 3.

Table 2. Consumptive-use definitions.

[Reference is the publication that contains the consumptive-use definition.]

Reference	Consumptive-use definition
Solley and others, 1998	That part of water withdrawn that is evaporated, transpired, or incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.
Great Lakes Commission, 2003	That portion of water withdrawn or withheld from the Great Lakes Basin and assumed to be lost or otherwise not returned to the Great Lakes Basin due to evapotranspiration, incorporation into products, or other processes.
International Joint Commission, 2004	That portion of water withdrawn which is evaporated, transpired from plants, incorporated into products, or otherwise lost, and thus is not available for further use in the basin.
Government of Canada and the U.S. Environmental Protection Agency, 1995	The permanent removal of water from a water body. Consumptive use may be due to evaporation or incorporation of water into a manufactured product.
Water Resources Council, 1978	Portion of surface or ground water withdrawn for off-stream uses that is lost by evapotranspiration or by incorporation into a manufactured product.

Table 3. Consumptive-use processes.

Consumptive-use processes	Definitions and examples
Evaporation	Water that is changed from a liquid form into a vapor state such as water evaporating from pools, large bodies of water, runoff from car washing or irrigation systems, evaporation through dehumidifiers, heating and cooling processes in industrial facilities and thermoelectric plants.
Transpiration	The process where 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.
Evapotranspiration	The collective term used to include water discharged to the atmosphere as a result of plant transpiration and evaporation from soil and surface-water bodies.
Product incorporation	Water is used to make industrial, food, and beverage products. A few examples are canned food, frozen food, soda, beer, wine, bottled water, juice, chemical and cleaning products, and pharmaceutical products.
Livestock and human consumption	Water that hydrates humans and livestock and is not returned. Livestock includes chickens, cows, horses, beef cattle, sheep, goats, pigs, and other animals.

Evaporation from heating and cooling processes in industrial facilities is an example of consumptive use.

Water-use activities begin when water is diverted or withdrawn from surface- or ground-water sources and conveyed to a place of use. A withdrawal is made by a self-supplied user or by a public supply facility (also known as a community water system).

Water use by a self-supplied user can be from a single user, or aggregate of users (group of users in a specific geographic area), and it refers to water that is actually used for a specific purpose, such as irrigation, industrial processing, or domestic activities in a household (such as drinking or bathing) to name a few. All the water-use categories except public supply are for self-supplied users. Public-supply facilities typically need a more complex equation to calculate consumptive use depending on the withdrawals, transfers (imports and exports), unaccounted-for water, return flow, infiltration and inflow. Consumptive use for self-supplied users (typically) can be calculated using the simple equation (fig. 5):

$$\textit{Consumptive use} = \textit{Withdrawal} - \textit{Return flows} \quad (1)$$

This is a condensed version of the equation from LaTour (1991):

$$\begin{aligned}&\textit{Consumptive use} = \\ &(\textit{Deliveries} + \textit{self-supplied withdrawals}) \\ &- (\textit{Releases to sewage-treatment plants} \\ &+ \textit{direct returns to surface- and ground-water sources}) \end{aligned} \quad (2)$$

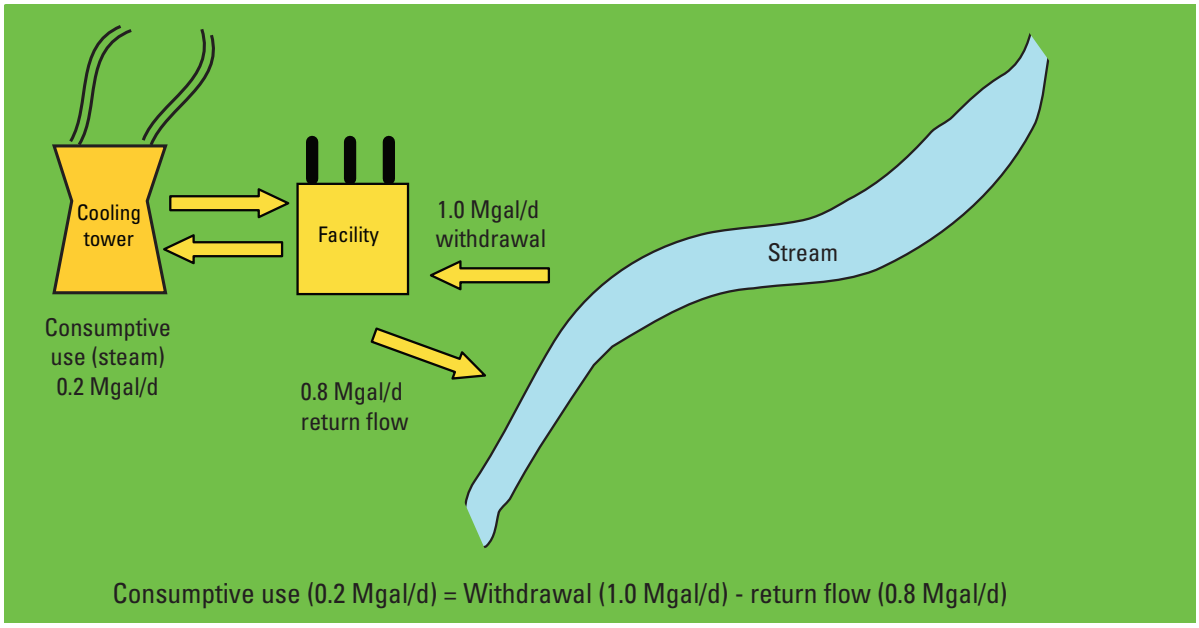
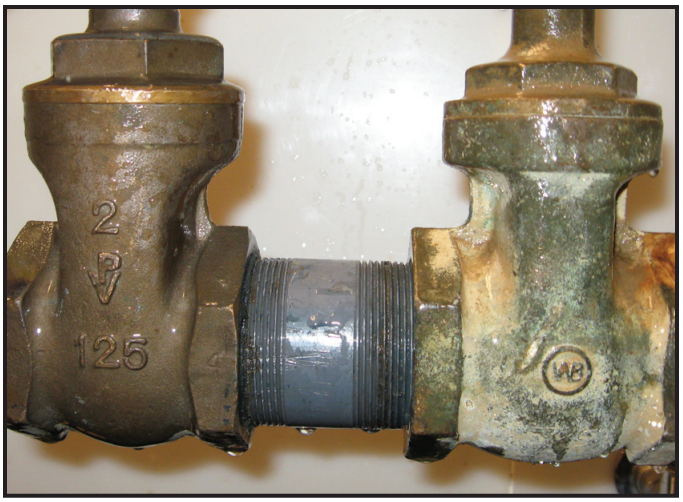


Figure 5. Representation of consumptive use by a single facility where consumptive use is equal to withdrawal minus return flow. (Mgal/d, million gallons per day)

LaTour (1991) also assumed that "**conveyance losses** or gains" (unaccounted-for water or inflow and infiltration) were zero for self-suppliers.

Consumptive use can be computed as a measurement at a self-supplied facility using these equations, or more commonly, is based on a coefficient that is a percentage of the withdrawal rates. Table 4 lists methods to determine consumptive use—the accuracy decreases and uncertainty increases by the methods down the table.

The availability and quality of data limit the use of the balancing equations and limit the research and refinement of consumptive-use coefficients. Additional complexities of consumptive use are discussed in table 5.



Unaccounted-for water includes conveyance losses and public uses.

Table 4. Consumptive-use computation methods.

Consumptive-use computation methods	Explanation
Facility level	Consumptive use is calculated at the facility level by subtracting return flow and release to the sewer system from withdrawal and delivery from a community water system.
Similar facilities	Consumptive use can be estimated by applying information such as meter readings and observations from a few facilities to an entire group of facilities (for example, car washes) to determine a consumptive-use coefficient.
Water-use categories	Consumptive use can be estimated by water-use category, such as commercial use, by applying a very general consumptive-use coefficient.
Groups of water-use categories	Consumptive use can be estimated by groups of water-use categories, such as public supply, which is a combination of domestic, commercial, industrial, and unaccounted-for water.

Table 5. Consumptive-use complexities.

Consumptive-use complexities	Explanation
Data availability	By jurisdictions, water use data and the data quality differ significantly. This hinders the ability to compare data by jurisdictions and truly analyze water availability and consumptive use.
Time and area	Water is in the hydrologic cycle in different locations on earth as liquid, precipitation, or condensation. Water 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?
Water transfer	Water that is withdrawn might be returned to a different water body, or basin (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 elsewhere (water was transferred).
Water quality	The degradation of quality of the returned water could also limit its reuse.

Two methods are commonly used to compute consumptive use. The first is by using a balancing equation (fig. 6). Withdrawal and return flow data are needed to use this balancing equation. The second method to compute consumptive use is to use consumptive-use coefficients (table 6).

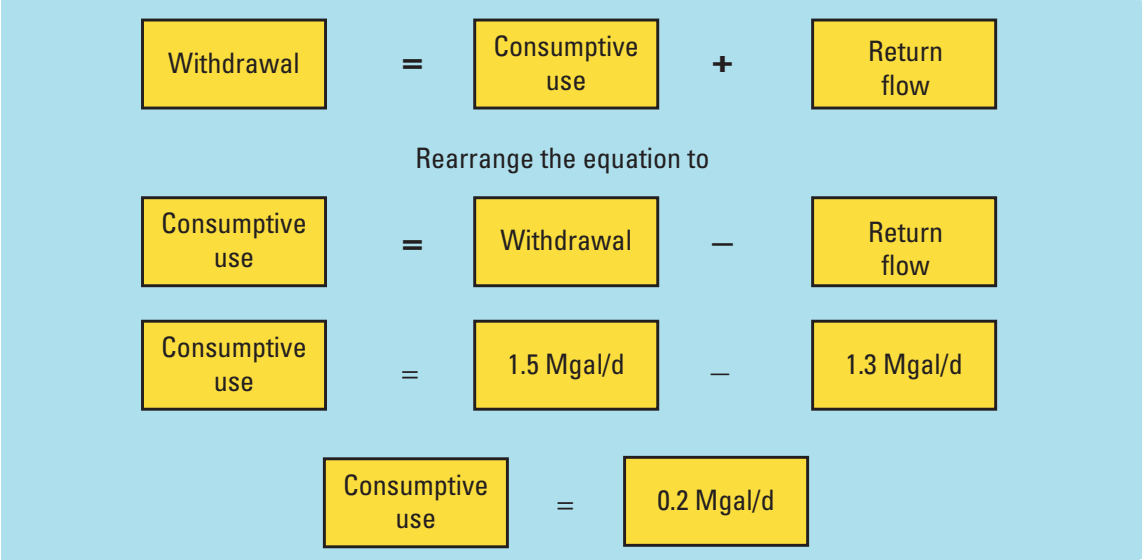


Figure 6. An example of calculating consumptive use with a water-use balancing equation. (Mgal/d, million gallons per day)

Table 6. Examples of calculating consumptive use and return flow using a consumptive-use coefficient for self supplied facilities.

[Consumptive use is calculated by multiplying the coefficient times withdrawals and dividing by 100. Return flow is calculated by subtracting the consumptive use from the withdrawals. Mgal/d, million gallons per day]

Water-use category	Consumptive-use coefficients (in percent)	Withdrawals (Mgal/d)	Consumptive use (Mgal/d)	Return flow (Mgal/d)
Irrigation	90	1.60	1.44	0.16
Domestic	15	3.20	.48	2.72
Industrial	10	2.22	.22	2.00

Data availability, time and areal aspects, water transfers, and water quality make understanding and computing consumptive use complex. For example, the mobility of livestock, limited data, and animals' impact on water quality make livestock water use difficult to assess.

The consumptive-use coefficients compiled in this report were determined by three techniques:

- The first technique is to find references listing a consumptive-use coefficient, identified by "coefficient" in the "Coefficient or other" column in the water-use category summary tables. The summary tables are explained in figure 7. Coefficients listed as ratios rather than percentages are multiplied by 100 for presentation in this report. In many references, this coefficient was used to estimate consumptive use by multiplying it by total withdrawals of a geographic area. The origins of the consumptive-use coefficients or data (withdrawals, consumptive use, and (or) return flow) were not always known or reported by the author(s). If the author referenced another source, that source is listed in the annotated bibliography. Some of these coefficients were derived in consumptive-use studies, whereas other coefficients were assumed in order to calculate consumptive use. References with consumptive-use analysis are discussed in more detail in the water-use categories sections of this report.

- The second technique uses references listing withdrawal data and consumption data, indicated by a "CW" in the "Coefficient or other" column in the water-use category summary tables in this report (fig. 7). From those data, a consumptive-use coefficient is computed using the following equation:

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

- The third technique uses references having withdrawal and return flow data for self-supplied facilities indicated by a "RW" in the "Coefficient or other" column in the water-use category summary tables in this report (fig. 7). This technique was not used for public-supply facilities because of the complexities of service areas, unaccounted-for use, and inflows and infiltration. For the withdrawal and return-flow data for self-supplied facilities, a consumptive-use coefficient was computed by use of the following equation:

$$\textit{Consumptive-use coefficient}\ (\%) = [(\textit{Water withdrawn} - \textit{Water returned}) \div \textit{Water withdrawn}] \times 100 \quad (4)$$

In the water-use category summary tables, each reference is listed as one of the following:

- A **primary source** indicates the authors of the referenced work did most of the compilation, analysis, and computation of data. Often the primary source publication was completed in cooperation with multiple agencies, but the publication was the main product for the multiple agency effort.

- A **secondary source** is a publication primarily completed by some other person or organization, but the data or consumptive-use coefficient was used to discuss or estimate consumptive use for the current report.

- An **unknown source** indicates the source of the coefficient or data was not described in the reference.

After references were annotated and the coefficients determined,

- the coefficients were organized by water-use category, domestic and public supply were compiled together for analytical purposes;

- coefficients were compiled in water-use category summary tables;

- summary statistics of the more recent consumptive-use coefficients were computed (**Minimum**, **maximum**, **25th percentile**, **75th percentile**, and **median** statistics were computed. The median and 25th and 75th percentiles are in this report because they are less affected by data outliers than other statistical measures (minimums, means, and maximums).);

- boxplots were prepared for data in each water-use category to show the distributional characteristics of consumptive-use coefficients;

- the number of consumptive-use coefficients used in the statistical computations (N), are noted in the water-use summary tables, the boxplots, and the summary tables by geographic area and water-use category; and

- summary statistics are tabulated for references with multiple coefficients (Statistics include minimum, median, maximum, 25th percentile and 75th percentile. Some reference series had multiple years of data and multiple coefficients for different geographic areas, each of which were compiled by different people using different methods. Each observation was considered independent by geographic location and by year of compilation and used in the statistical computation.).

Reference listed alphabetically by author and publication year(s). Detailed information about reference is in the annotated bibliography.

Water-use term used in the reference for public-supply or domestic water-use categories.

Geographic area defines the lakes, states, provinces, countries, continents, and the world for the consumptive coefficient information listed.

Coefficients are in percent. Coefficients for references with multiple coefficients are in the appendix.

The **single coefficient** is listed if a reference reported only one coefficient.

The **median coefficient** is listed if the reference reported multiple coefficients.

N is the number of coefficients used in computing the statistical values shown in summary statistics tables and boxplots.

Statistics area lists whether the geographic area is in the Great Lakes Basin, in climatically similar areas (Clim sim), or neither (Other).

Used in statistics indicates whether the coefficient(s) were used in the statistical analysis.

Coefficient or other lists if the coefficient was reported in the reference or if the coefficient was derived from consumptive-use and withdrawal data (CW) or return flow and withdrawal data (RW).

Data source lists whether the coefficient was computed from data or through analysis (Primary), from another source (Secondary), or from a source that was not noted in the reference (Unknown).

Reference	Water-use term	Geographic area	Single coefficient	Median coefficient	N	Statistics area	Used in statistics	Coefficient or other	Data source
Barlow, 2003[1]	Domestic use	Rhode Island, Massachusetts	15		1	Clim sim	Yes	Coefficient	Secondary
Brill and others, 1977	Municipal water consumption	Illinois, Indiana, Kentucky, and Ohio	20		-	Clim sim	No	Coefficient	Primary
College of Exploration, 2006	Domestic	World	17		-	Other	No	CW	Unknown
Cosgrove and Rijsberman, 2000	Municipal water use	World							
1900			25		-	Other	No	CW	Secondary
1950			17		-	Other	No	CW	Secondary
1995			14		-	Other	No	CW	Secondary
Delaware River Basin Commission, 2005	Public-water-supply facilities	Delaware River Basin (Pennsylvania, Delaware, New Jersey)	10		1	Clim sim	Yes	Coefficient	Primary
Endreny, 2004	Domestic	New York	5		1	Great Lakes	Yes	CW	Secondary
European Environmental Agency, 2005	Domestic	Europe	20		-	Other	No	Coefficient	Primary
Great Lakes Commission, Annual Reports, 1998-2002[1]	Self-supply domestic	Great Lakes Basin		11	50	Great Lakes	Yes	CW	Secondary
	Public supply			10	45	Great Lakes	Yes	CW	Secondary
Government of Canada and the U.S. Environmental Protection Agency, 1995	Municipal	By Country and Great Lake							
		Canada, Lake Superior	25		1	Great Lakes	Yes	CW	Secondary
		Canada, Lake Huron	17		1	Great Lakes	Yes	CW	Secondary
		Canada, Lake Erie	16		1	Great Lakes	Yes	CW	Secondary
		Canada, Lake Ontario	15		1	Great Lakes	Yes	CW	Secondary
		United States, Lake Superior	14		1	Great Lakes	Yes	CW	Secondary
		United States, Lake Michigan	6		1	Great Lakes	Yes	CW	Secondary
		United States, Lake Huron	55		1	Great Lakes	Yes	CW	Secondary
		United States, Lake Erie	10		1	Great Lakes	Yes	CW	Secondary
		United States, Lake Ontario	18		1	Great Lakes	Yes	CW	Secondary
Horn and others, 1994	Domestic	Rhode Island	15		1	Clim sim	Yes	Coefficient	Secondary
Horn, 2000	Domestic	Massachusetts	15		1	Clim sim	Yes	Coefficient	Primary
Hutson, 1998	Domestic	Tennessee	10		1	Clim sim	Yes	CW	Primary
Hutson, and others, 2004	Public supply	Tennessee	43		1	Clim sim	Yes	RW	Primary

Figure 7. Schematic of the summary tables of consumptive-use coefficients for the Great Lakes Basin, climatically similar areas, and the world.

Consumptive-Use Coefficients by Water-Use Category

The four water-use categories with the largest water withdrawals for the United States part of the Great Lakes in 1995 were (in decreasing order) thermoelectric, industrial, domestic and public supply, and commercial (table 7, fig. 8). However, the largest consumptive-use categories were industrial, thermoelectric, irrigation, and domestic and public supply (fig. 8). These four largest consumptive-use categories accounted for 89 percent of the total consumptive use for the U.S. part of the Great Lakes Basin (Solley and others, 1998) but differed in consumptive-use coefficients.

In comparison, the Great Lakes Commission (GLC) (2005a) compiled water-use and consumptive-use data for both the U.S. and Canadian parts of the Great Lakes Basin in 2002 (table 8, fig. 8). The Great Lakes Commission (2005a) and Solley and others (1998) did not define water-use categories identically. The Great Lakes Commission (2005a) included the mining and commercial categories as part of other water-use categories, whereas the USGS (Solley and others, 1998) considered them individual categories. The Great Lakes Commission (2005a) reported separate withdrawals and consumptive use for both the self-supplied domestic and public-supply categories whereas Solley and others (1998) reported only the consumptive use for self-supplied domestic and publicly-supplied domestic water combined. Even with these differences, the same four water-use categories were highest in consumptive use, but their rankings differed (fig. 8). These four categories for the GLC represented 95 percent of the total consumptive use (mining was included in industrial).

Table 7. Water use and consumptive use in the U.S. part of the Great Lakes Basin in 1995.

[Modified from Solley and others (1998). Withdrawals and deliveries and consumptive use are in million gallons per day. Consumptive-use coefficients are in percentage of withdrawal and are rounded]

Water-use category	Withdrawals and deliveries	Consumptive use	Consumptive-use coefficient
Industrial	4,950	436	9
Thermoelectric power	22,800	429	2
Irrigation	315	295	94
Domestic	1,760	248	14
Commercial	752	82	11
Livestock	70	55	79
Mining	398	37	9

Table 8. Water use and consumptive use in the Great Lakes Basin in the United States and Canada, 2002.

[Modified from Great Lakes Commission (2005a). Withdrawals and consumptive use are in million gallons per day. Consumptive-use coefficients are in percent and are rounded. Self-supplied domestic and public-supply data are combined in one category]

Water-use category[1]	Total withdrawals	Consumptive use	Consumptive-use coefficient
Public supply and domestic	6,450	660	10
Thermoelectric power	30,820	390	1
Irrigation	510	380	94
Industrial	4,380	370	8
Livestock	140	90	64

[1] The Great Lakes Commission document does not include mining or commercial as independent water-use categories. Mining is included in industrial. Commercial facilities, depending on the facility, could be under multiple water-use categories, the most likely of which is public supply or self-supplied domestic. Also, the domestic, thermoelectric power, irrigation, industrial, and livestock categories are only from self-supplied facilities, and the public-supply category includes all the withdrawals regardless of how the water is being used (domestic, commercial, industrial, etc.).

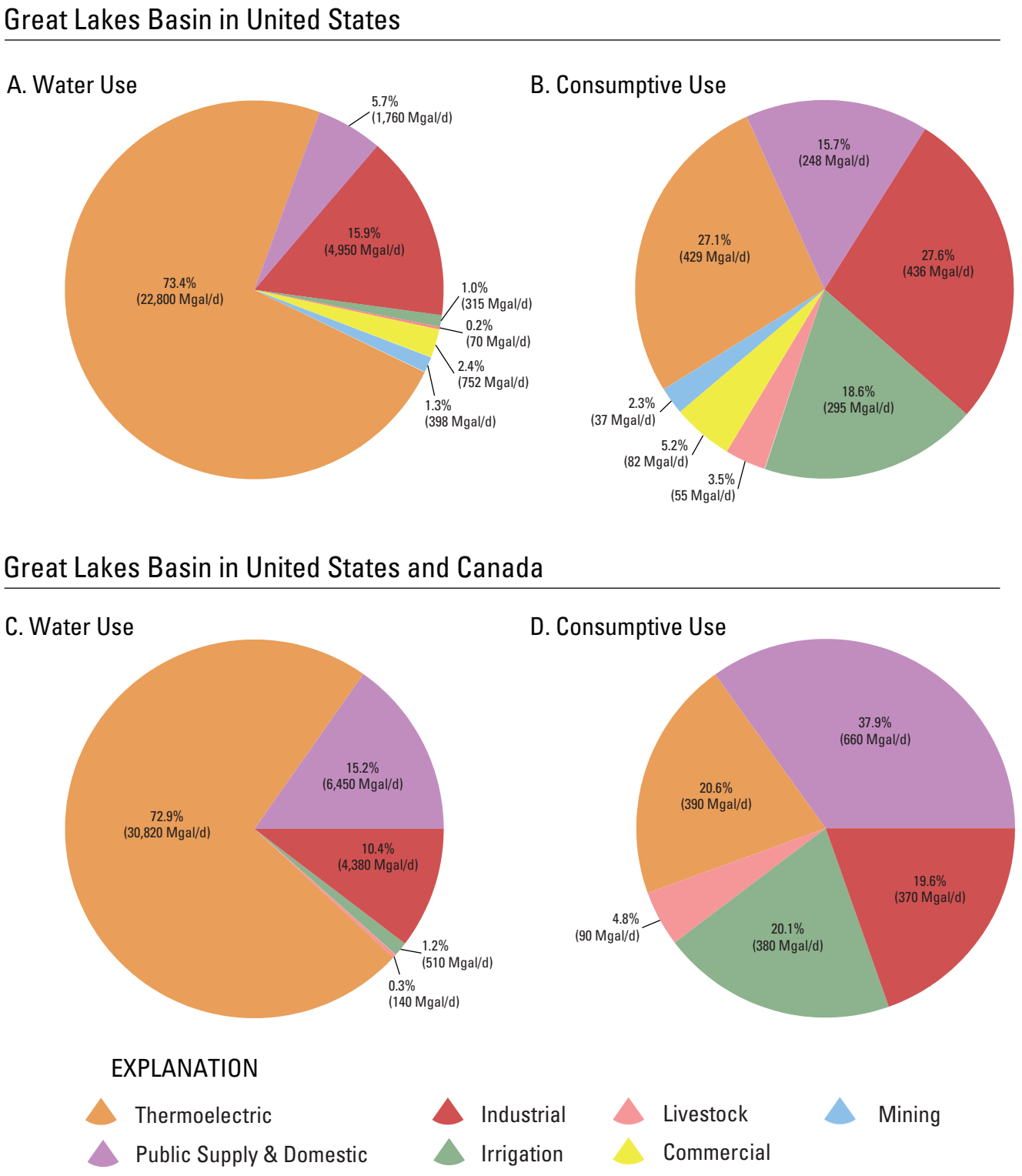


Figure 8. *A*, Water use, and *B* consumptive use in the United States part of the Great Lakes Basin in 1995 (adapted from Solley and others, 1998). *C*, Water use, and *D* consumptive use in the United States and Canadian parts of the Great Lakes Basin in 2002 (adapted from the Great Lakes Commission, 2005). Category percentages may not add to 100 percent because of independent rounding; Mgal/d, million gallons per day.

As evident from tables 7 and 8, consumptive-use coefficients ranged from 1 to 94 percent, depending on the water-use category. Although the consumptive-use coefficients varied widely between water-use categories, the coefficients were similar within water-use categories for Solley and others (1998) and the GLC (2005) (irrigation, both 94 percent; industrial, 9 and 8 percent; thermoelectric power, 2 and 1 percent; domestic, 14 and 10 percent (tables 7 and 8)). Because consumptive-use coefficients were similar within water-use categories, the references were compiled and summarized by water-use category. The water-use category coefficients in more recent references are statistically summarized by four groups in table 9:

- The **Great Lakes Basin** includes the eight U.S. states and two Canadian provinces that are either all or partly in the Great Lakes Basin. Data also may be included for areas in the eight states and two provinces but outside the Great Lakes Basin (fig. 1).
- **Climatically similar areas** are basins and states that have climates similar to the Great Lakes Basin (figs. 2 and 4).
- **Great Lakes Basin and climatically similar areas** combined include the data for Great Lakes Basin references and the climatically similar area references together (figs. 1, 2, and 4).
- **World** represents single coefficients that have worldwide applicability for particular water-use categories.

Table 9. Consumptive-use coefficient statistics for water-use categories for the Great Lakes Basin, climatically similar areas, and the world.

[Great Lakes Basin refers to basins, parts of states, and states in the Great Lakes Basin. Climatically similar areas are basins and states that are climatically similar in the Great Lakes Basin but not in 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 the Canada coefficients, all the United States coefficients, or continent coefficients because these include areas that are not climatically similar to the Great Lakes. Minimum (min), median, maximum (max), the 25th percentile, and the 75th percentile are in percent. N is the number of references used in the statistical analysis]

Water-use category	Statistics					
	Min	25th	Median	75th	Max	N
Great Lakes Basin						
Domestic and Public Supply	0	**10**	**12**	**15**	74	161
Industrial	0	**7**	**10**	**14**	35	122
Thermoelectric Power	0	**1**	**2**	**2**	21	141
Irrigation	70	**90**	**90**	**96**	100	95
Livestock	0[1]	**80**	**83**	**90**	100	85
Commercial	4	**8**	**10**	**15**	26	29
Mining	0	**7**	**10**	**25**	58	58
Climatically similar areas						
Domestic and Public Supply	6	**10**	**15**	**20**	70	68
Industrial	0	**4**	**10**	**13**	34	97
Thermoelectric Power	0	**0**	**2**	**4**	75	75
Irrigation	37	**90**	**100**	**100**	100	75
Livestock[2]	10[2]	**86**	**100**	**100**	100	73
Commercial	3	**8**	**10**	**13**	33	61
Mining	0	**10**	**14**	**20**	86	83
Great Lakes Basin and climatically similar areas						
Domestic and public supply	0	**10**	**13**	**15**	74	229
Industrial	0	**6**	**10**	**13**	35	219
Thermoelectric power	0	**1**	**2**	**3**	75	216
Irrigation	37	**90**	**91**	**100**	100	170
Livestock[1,2]	0[1,2]	**80**	**90**	**100**	100	158
Commercial	3	**8**	**10**	**13**	33	90
Mining	0	**8**	**13**	**22**	86	141
World						
Domestic and public supply	14	**16**	**16**	**18**	19	4
Industrial	9	**10**	**10**	**11**	11	4
Agriculture	65	**65**	**68**	**72**	78	4

[1] The livestock low coefficient minimum (0 percent) is from Great Lakes Commission (2005a) 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 be the result of their adding animal specialties, including fish farming, into the livestock water-use category. In previous and subsequent USGS reports, fish farming was in different water-use categories.