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National Water Availability and Use Program

Consumptive Water Use in the Great Lakes Basin

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

Introduction

Great Lakes state agencies and organizations view understanding consumptive water use as a critical component in water-resource management. To assist them in developing a better understanding of the factors involved in consumptive use (table 1), the U.S. Geological Survey (USGS) has completed an inventory of consumptive-use coefficients for the Great Lakes Basin.

For the purposes of this report, the Great Lakes Basin (fig. 1) is delineated based on surface-water divides and includes states and provinces that are entirely or partially within the basin. Because the rate of consumptive use depends on how water is used, consumptive-use information for the Great Lakes Basin was compiled and statistically analyzed by water-use category (table 2; Shaffer and Runkle, 2007). For comparison, the statistics for the climatically similar areas (fig. 1) to the Great Lakes Basin are included (table 2). These climatically similar areas have comparable patterns of temperature and precipitation, percent consumptive loss, and water use to the Great Lakes Basin. Details about consumptive water-use data and consumptive-use coefficients are available in Shaffer and Runkle (2007).

Computing Consumptive Use

Two common ways to estimate consumptive use are with a water-balance equation (that is, consumptive use = withdrawal (and deliveries from public suppliers) – return flow (and releases to sewers), fig. 2*A*) or by application of a consumptive-use coefficient (fig. 2*B*). Measurements or well-documented estimates of delivery, withdrawal, return flow, and release data are needed to use a water-balance equation. Consumptive-use coefficients are calculated by dividing the amount of water removed from the environment and not returned (consumptive use) by the total amount of water withdrawn. Consumptive-use coefficients are commonly reported as a percentage.

Consumptive Use by Water-Use Category and Geographic Area

Water-use categories used to compile and organize consumptive-use coefficients are listed and defined in table 1. The summary statistics listed in table 2 show the considerable variability in consumptive-use coefficients by category due to the different water-use processes involved. The summary statistics in table 2 include

- the median—the value for which 50 percent of the values are higher and 50 percent are lower,
- the 25th and 75th percentiles—which together bracket half of the values used in the statistical analysis, and
- *N*—the number of values used in the statistical analysis.

The median consumptive-use coefficients for the Great Lakes Basin by water-use category are graphed in fig. 3. The coefficient statistics in table 2 are a starting point for estimating consumptive use and return flow (fig. 2). For example, the Great Lakes Basin median consumptive-use coefficients (table 2) were used to estimate the 2000 consumptive use for the Great Lakes States (table 3). The water withdrawals and estimated consumptive use for the Great Lakes states in 2000 are shown in figures 4 and 5, respectively.

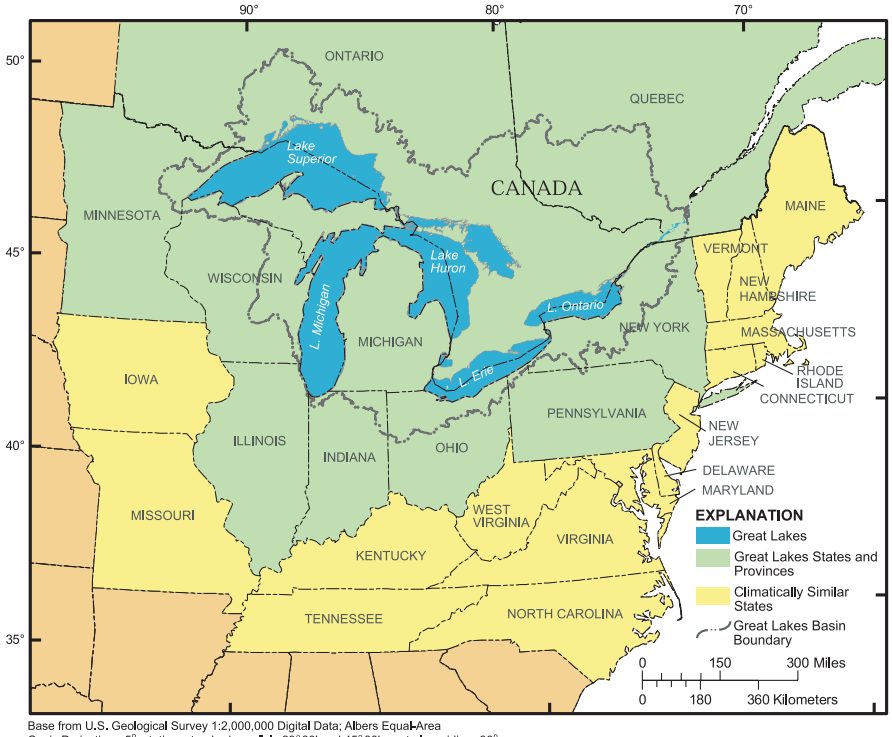

Figure 1. The Great Lakes Basin, the Great Lakes States and Provinces, and states considered climatically similar.

Table 1. Water-use categories, their definitions, and consumptive-use characteristics.

Water-use category	Definition	Consumptive-use characteristics
Domestic	Domestic water use is water that is used for household indoor and outdoor water purposes. Self-supplied domestic water use is water that is not obtained from a public-supply facility. Public-supplied domestic use is from a public-supply facility.	Domestic consumptive use (both self-supplied and publicly supplied) occurs primarily during outdoor watering of lawns and gardens, sidewalk and car washing, filling and maintaining pools, and to a lesser extent, during indoor cooking, cleaning, showering, and clothes washing (Marilee Horn, U.S. Geological Survey, written commun., February 2007).
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 purposes such as domestic, commercial, thermoelectric power, industrial, and public water use (Solley and others, 1998).	For details, see descriptions for other water-use categories. Public water consumptive use may be from evaporation and transpiration from firefighting, street washing, municipal parks maintenance and swimming pools.
Industrial	Industrial water use is water used for industrial fabrication, washing, processing, and cooling.	Industrial consumptive use may occur through product incorporation, evaporation from cooling and heating processes, cleaning, and groundskeeping.
Thermoelectric power	Thermoelectric-power water use is water used in the process of generating electric power.	Thermoelectric consumptive use is from evaporation during the condenser- and reactor-cooling process.
Irrigation	Irrigation water use is the application of water on lands to assist in the growing of crops, pastures, or nurseries or to maintain vegetative growth in recreational lands.	Irrigation consumptive use is from evapotranspiration (evaporation and transpiration from watering vegetation).
Livestock	Livestock water use is water used for stock watering, feedlots, dairy operations, fish farming, and other on-farm needs.	Livestock consumptive use occurs through processes such as stock watering and facility and animal cleaning.
Commercial	Commercial water use is water used in restaurants, motels, hotels, office buildings, military and nonmilitary institutions, snow making, and other commercial facilities.	Processes that contribute to commercial consumptive use are lawn and landscape 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, evaporation from offstream fish hatcheries, toilet use by customers, and whirlpools used in rehabilitation facilities and hospitals.
Mining	Mining water is the water withdrawn during the extraction of minerals.	Mining consumptive use is water consumed during quarrying, milling, and other operations associated with mining activities.

Domestic and Public Supply

Statistics for the domestic and public-supply categories were similar; more than half of the domestic and public-supply consumptive-use coefficients were between 10 and 15 percent (25th and 75th percentiles were the same for the two categories). The domestic category had a median coefficient of 15 percent, whereas the public-supply category had a median coefficient of 12 percent. The similarities in coefficients for domestic and public supply may be explained by the majority of deliveries from public suppliers going to domestic users.

Estimating public-supply consumptive use with a balancing equation (withdrawal minus return flow) most often is not feasible. The customer base and service areas for the water-supply withdrawals and wastewater discharges are usually different. Return flows may even exceed withdrawals in areas with (1) high water tables, because ground water can leak into sewers, or (2) combined storm and sanitary sewers, because runoff cannot be distinguished from return flows.

Unaccounted-for water (public uses and conveyance losses) may be unknown or removed from the public-supply system before it is actually subject to consumptive-use processes. Because of this, many public-supply reports use the term "unaccounted-for water" and quote rates between 10 and 25 percent of withdrawals.

The median consumptive-use coefficient for the Great Lakes Basin was 12 percent for the domestic and public-supply categories combined. Great Lakes States withdrawals for the public-supply category were 10,200 million gallons per day (Mgal/d), the second largest withdrawals in 2000 (table 3, fig. 4); estimated consumptive use was 1,200 Mgal/d, the largest estimated consumptive use in the Great Lakes States.

Table 2. Consumptive-use coefficient statistics for the Great Lakes Basin and climatically similar areas, by water-use category (from Shaffer and Runkle, 2007).

[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. References are only from publications after 1975 (mining and commercial), 1980 (industrial, irrigation, thermoelectric, livestock), or 1985 (domestic and public supply).]

Geographical area	Summary statistics of consumptive-use coefficients, by indicated water-use category					
	Min	25th	Median	75th	Max	*N*
Domestic and Public Supply						
Great Lakes Basin	0	10	12	15	74	161
Climatically similar areas	6	10	15	20	70	68
Industrial						
Great Lakes Basin	0	7	10	14	35	122
Climatically similar areas	0	4	10	13	34	97
Thermoelectric						
Great Lakes Basin	0	1	2	2	21	141
Climatically similar areas	0	0	2	4	75	75
Irrigation						
Great Lakes Basin	70	90	90	96	100	95
Climatically similar areas	37	90	100	100	100	75
Livestock						
Great Lakes Basin	0[1]	80	83	90	100	85
Climatically similar areas	10[2]	86	100	100	100	73
Commercial						
Great Lakes Basin	4	8	10	15	26	29
Climatically similar areas	3	8	10	13	33	61
Mining						
Great Lakes Basin	0	7	10	25	58	58
Climatically similar areas	0	10	14	20	86	83

[1] The livestock minimum coefficient (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 minimum coefficient is 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.

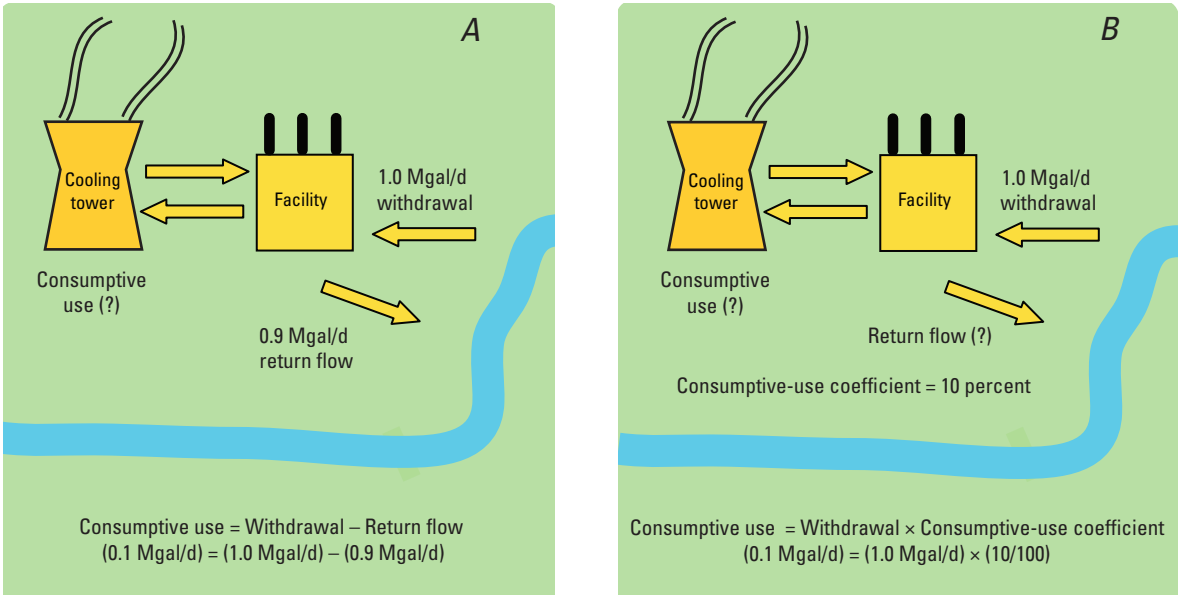

Figure 2. Computation of consumptive use by a single facility: A, using a water-balance equation; B, applying a consumptive-use coefficient (Mgal/d, million gallons per day).

Industrial

Literature on industrial consumptive-use coefficients describes either general industrial consumptive-use coefficients (based on a variety of industries) or coefficients for specific industrial groups defined by their standard industrial classification (SIC) code. Table 2 lists the general industrial consumptive-use coefficient median for the Great Lakes Basin (10 percent), which compares closely with the 1983 Census of Manufactures consumptive-use coefficient for all manufacturing industries (11 percent) (U.S. Bureau of the Census, 1986; Shaffer and Runkle, 2007).

In 1983, approximately 93 percent of the industrial water withdrawals for the U.S. part of the Great Lakes Basin were from six major SIC code groups (U.S. Bureau of the Census, 1986). The medians for these six SIC-code groups are listed in table 4.

Table 5 is a more detailed compilation of SIC-code industry groups with comparatively large consumptive-use coefficients (U.S. Bureau of the Census, 1986); specifically, industries with consumptive-use coefficients of 50 percent or more, and industries with consumptive-use coefficients of 20 percent or more and with withdrawals of more than 5.5 billion gallons in 1983.

Since this major study in the 1980s, the bottled-water and ethanol-fuel industries have become and are still becoming much more noteworthy in terms of water withdrawal and consumptive use. The bottled-water industry has a high consumptive-use coefficient (97–100 percent), whereas the ethanol-fuel industry currently (2008) has a median consumptive-use coefficient of 77 percent, excluding water used in irrigating the ethanol source crops. Recent references also indicate that consumptive-use coefficients for the transportation industry may be increasing from 8 percent to 29 percent, perhaps because of recycling of water at individual plants. Knowing the type of industrial facilities in a geographic area is important; if withdrawals are increasingly by facilities such as those listed in table 5, use of a consumptive-use coefficient higher than 10 percent might be more representative and appropriate.

In 2000, industrial water-use withdrawals in the Great Lakes States were 6,380 Mgal/d (fig. 4 and table 3), the third largest water-use withdrawal category in the Great Lakes States. Estimated industrial consumptive use for 2000 was 640 Mgal/d (fig. 5) and was lower than that for public-supply, thermoelectric, or irrigation consumptive use.

Thermoelectric power

Thermoelectric power consumptive-use coefficients differ by type of cooling at each facility, age of the facility, water availability, and type of fuel used. A facility with a once-through cooling system uses water only once in the cooling process before returning the water to a surface-water source. Once-through cooling requires large amounts of water, but evaporation is small (usually less than 3 percent) (Solley and others, 1998). A closed-loop or recirculation thermoelectric plant uses cooling towers or cooling ponds to recycle water repeatedly for condenser and reactor cooling; although water withdrawal is less, consumptive use is higher. Facilities that combine once-through cooling with cooling towers and cooling ponds have consumptive-use coefficients somewhat higher than for once-through systems.

Table 3. Estimated consumptive use for Great Lakes States in 2000, based on median consumptive-use coefficients (from Shaffer and Runkle, 2007).

[The 2000 withdrawals are from Hutson and others (2004, table 2) for the Great Lakes States and are rounded to three significant figures. Withdrawals for domestic, industrial, thermoelectric power, irrigation, livestock, and mining are self-supplied. The median consumptive-use coefficients are from Shaffer and Runkle (2007, table 43) for the Great Lakes Basin. Consumptive use is calculated by multiplying the coefficient by withdrawals and dividing by 100 and is rounded to two significant figures. Mgal/d, million gallons per day.]

Water-use category	2000 withdrawals for the Great Lakes States (Mgal/d)	Median consumptive-use coefficients (percent)	Estimated consumptive use (Mgal/d)
Public supply	10,200	12	1,200
Self-supplied domestic	1,080	12	130
Industrial	6,380	10	640
Thermoelectric power	53,700	2	1,100
Irrigation[1]	960	90	860
Livestock[2]	235	83	200
Mining[3]	941	10	94

[1] If a more conservative irrigation consumptive-use coefficient of 78 percent (Shiklomanov and Rodda, 2003) is used, the estimated consumptive use would be 750 Mgal/d.

[2] Livestock withdrawals do not include New York and Pennsylvania.

[3] Mining withdrawals do not include Illinois, Michigan, New York, and Wisconsin.

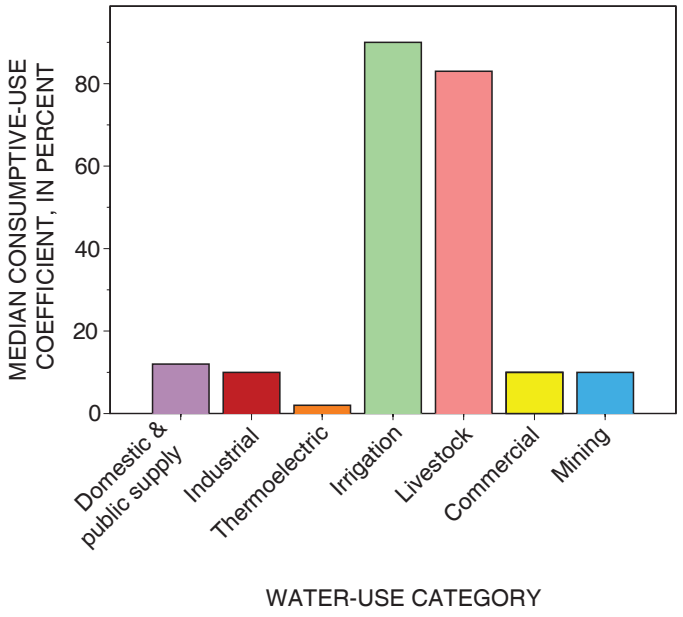

Figure 3. Median consumptive-use coefficients for the Great Lakes Basin, by water-use category (from Shaffer and Runkle, 2007).

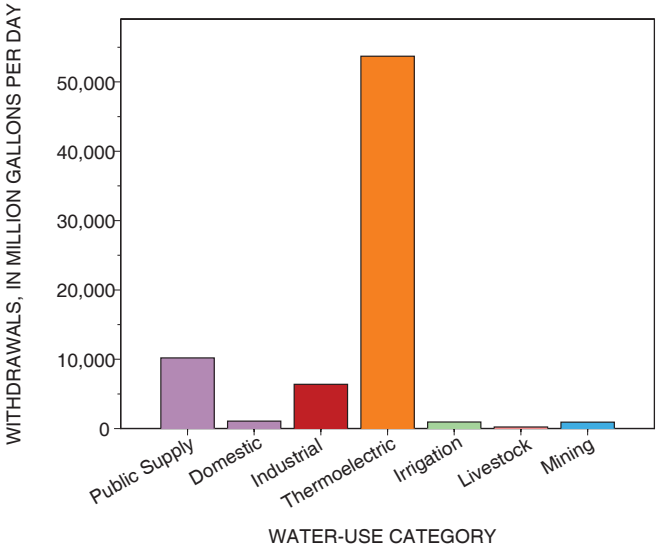

Figure 4. Withdrawals in 2000 for the Great Lakes States, by water-use category (from Hutson and others, 2004).

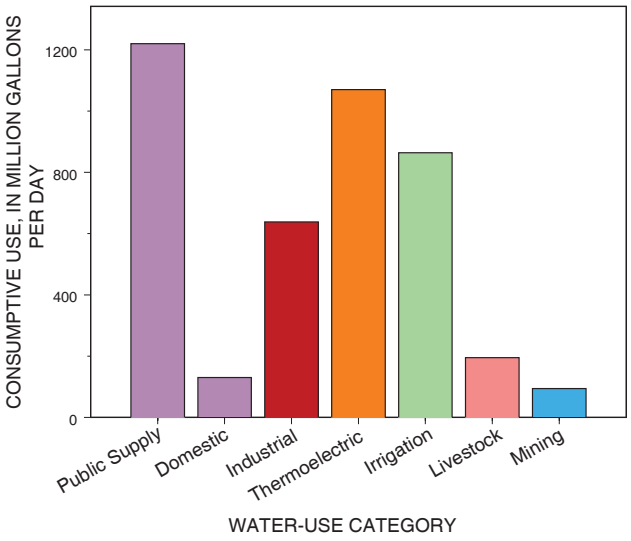

Figure 5. Estimated consumptive use in 2000 for the Great Lakes States, by water-use category (from Hutson and others, 2004; Shaffer and Runkle, 2007).

Table 4. Median consumptive-use coefficients for six major Standard Industrial Classification (SIC) code industrial groups.

[The median consumptive-use coefficient is in percent.]

SIC code	Industrial group	Median consumptive-use coefficient
20	Food and kindred products	12
26	Paper and allied products	9
28	Chemical and allied products	6
32	Stone, clay, and glass products	12
33	Primary metal industries	8
37	Transportation equipment	8

Table 5. Industries with a consumptive-use coefficient of (a) 50 percent and more or (b) 20 percent and more with over 5.5 billion gallons of water used in 1983.

[Modified from U.S. Bureau of the Census, 1986]

SIC code	Industry	Coefficient
	Industries with a consumptive-use coefficient of 50 percent or more	
2992	Lubricating oils and greases	50
325	Structural clay products[1]	50
3293	Gaskets, packing, sealing devices	50
3764	Air and gas compressors	50
3332	Primary lead[2]	57
3275	Gypsum products (like sheetrock)	59
2435	Hardwood, veneer, and plywood	67
2895	Carbon black[3]	81
	Industries with a consumptive-use coefficient of 20 percent or more	
2032	Canned specialties	23
2043	Cereal breakfast foods	36
2061	Raw cane sugar	24
2063	Beet sugar	34
2082	Malt beverages	22
2086	Bottled and canned soft drinks	45
2221	Weaving mills, manmade fiber and silk	20
2436	Softwood veneer and plywood	43
249	Misc. wood products[1]	24
2813	Industrial gases	36
284	Soaps, cleaners, and toilet goods[1]	40
2873	Nitrogenous fertilizers	36
2874	Phosphatic fertilizers	34
3079	Misc. plastics products	20
3296	Mineral wool	29
3321	Gray iron foundries	27
3351	Copper rolling and drawing	20
3356	Nonferrous rolling and drawing	26
351	Engines and turbines[1]	35

[1] Industrial group used due to "census masking," a policy of selected data release to protect individual privacy and confidentiality in data collection and analysis.

[2] "Primary lead" is the smelting and refining of lead.

[3] Often used as a pigment and reinforcement in rubber and plastic products.

The Department of Energy reports site-specific facility data for thermoelectric plants, including the average annual rate of cooling-water withdrawals, the average annual rate of cooling-water discharge, and the average annual rate of cooling-water consumption (U.S. Department of Energy, 2004). Analysis of this Department of Energy thermoelectric power data can be found in a report by Dziegielewski and others (2006).

For the Great Lakes States in 2000, the thermoelectric-power water-use withdrawal category had the largest withdrawals at 53,700 Mgal/d (fig. 4); but because of the low median consumptive-use coefficient (2 percent), the estimated consumptive use was 1,100 Mgal/d, a little less than that for public supply and only a little more than that for irrigation (fig. 5).

Irrigation

Although three-fourths of the references examined by Shaffer and Runkle (2007) for the Great Lakes Basin reported irrigation consumptive-use coefficients between 90 and 100 percent, this range was higher than that estimated for the world, which was 65 to 78 percent (Shaffer and Runkle, 2007).

Irrigation consumptive-use coefficients may vary because of differences in irrigation methods, inconsistencies in research and data availability, varied ways of defining irrigation consumptive use, and atmospheric factors affecting transpiration and evaporation (such as temperature, relative humidity, wind and air movement, soil-moisture availability, and plant type). For example, estimated consumptive-use coefficients are 30 to 40 percent for flood irrigation and 90 percent for drip irrigation (Cosgrove and others, 2000).

The amount of irrigation water withdrawn in 2000 for the Great Lakes States ranked fifth (960 Mgal/d) out of the seven water-use withdrawal categories, but the estimated consumptive use ranked third (860 Mgal/d). This irrigation consumptive use was estimated using the conventional 90-percent coefficient. If a more conservative consumptive-use coefficient of 78 percent were used (1995 assessment; Shiklomanov and Rodda, 2003), the estimated consumptive use for the Great Lakes States would be 750 Mgal/d. Additional research would be needed to refine irrigation consumptive-use data and consumptive-use coefficients.

Livestock

Three-fourths of the references examined by Shaffer and Runkle (2007) reported livestock consumptive-use coefficients between 80 and 100 percent. However, the documentation for these estimates was sparse. Among the seven water-use withdrawal categories, livestock withdrawals were smallest in 2000 for the Great Lakes States (235 Mgal/d), but estimated livestock consumptive use (200 Mgal/d) was larger than domestic or mining because livestock had a higher median consumptive-use coefficient, at 83 percent. Further research would be needed to refine livestock consumptive-use data and consumptive-use coefficients.

Mining

For mining water use, the consumptive-use coefficients varied widely by the type of mining activity. The commodity mined, the method used, and the hydrologic environment are factors that determine the consumptive-use coefficients. For example, metal-mining consumptive-use coefficients ranged from 1 (for lead) to 77 percent (for copper), and nonmetal-mining coefficients ranged from 0 (for magnesium) to 100 percent (for diatomite) (Quan, 1988). Among the seven water-use withdrawal categories, mining withdrawals were second lowest for 2000 for the Great Lakes States (941 Mgal/d), and the amount of estimated consumptive use in 2000 was the lowest (94 Mgal/d).

References

Cosgrove, W.J., and Rijsberman, F.R., 2000, The use of water today, *chap. 2 of* World wide vision, making water everybody's business: World Water Council, p. 4–21, accessed April 28, 2006, at *http://www.worldwatercouncil.org/fileadmin/wwc/Library/WWVision/Chapter2.pdf*

Dziegielewski, Ben; Bik, Thomas; Usama, Alqalawi; Mubako, Stanley; Eidem, Nathan; and Bloom, Shauna, 2006, Water use benchmarks for thermoelectric power generation: Accessed November 5, 2007, at *http://www.geog.siu.edu/geography_info/research/documents/ThermoReport.pdf*

Great Lakes Commission, 2005, Annual reports from the Great Lakes Regional Water Use Database Repository, representing 1998 to 2002 water-use data: Ann Arbor, Mich., accessed May 31, 2006, at *http://www.glc.org/wateruse/database/downloads.html*

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268, 46 p.

Quan, C.K., 1988, Water use in the domestic nonfuel minerals industry: U.S. Bureau of Mines Information Circular 9196, 62 p.

Shaffer, K.H., and Runkle, D.L., 2007, Consumptive water-use coefficients for the Great Lakes Basin and climatically similar areas: U.S. Geological Survey Scientific Investigations Report 2007–5197, 191 p.

Shiklomanov, I.A., and Rodda, J.C., 2003, World water resources at the beginning of the 21st century: Cambridge U.K., Cambridge University Press [for] UNESCO, 435 p.

Solley, W.B., Merk, C.F., and Pierce, R.R., 1988, Estimated use of water in the United States in 1985: U.S. Geological Survey Circular 1004, 82 p.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 71 p.

U.S. Bureau of the Census, 1986, 1982 Census of manufactures: Washington, D.C., Subject series, Water use in manufacturing, MC82–S–6, 72 p. [Reported data are for 1983.]

U.S. Department of Energy, 2004, Year 2004 annual steam-electric plant operation and design data: Department of Energy Form EIA-767 data file, accessed January 5, 2006, at *http://www.eia.doe.gov/cneaf/electricity/page/eia767.html*

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