ESTIMATION, ANALYSIS, SOURCES, AND VERIFICATION OF CONSUMPTIVE WATER USE DATA IN THE GREAT LAKES - ST. LAWRENCE RIVER BASIN

By Deborah S. Snavely

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who prefer metric (International System) units rather than the inch-pound units used in this report, the following conversion factors may be used:

Multiply inch-pound unit	by	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic mile (mi^3)	4.165	cubic kilometer (km^3)
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
million gallons per day	0.04381	cubic meter per second (m^3/s)
(Mgal/d)	3785	cubic meter per day (m^3/d
	1.3816×10^6	cubic meter per year (m^3/y)
Ton	907.1847	kilogram (kg)

Other Conversions and Expressions

watt (W)	1000	kilowatt (kW)
kilowatt (kW)	1000	megawatt (MW)
kilowatt hour (kW·h)	3.600×10^6	Joule (J)

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Abstract

The Great Lakes - St. Lawrence River basin provides water for drinking, power generation, industry, navigation, recreation, and wildlife habitat. In 1986, the United States and Canada requested the International Joint Commission (IJC) to report on methods of alleviating adverse effects of fluctuating water levels in the basin. One task was to review consumptive water-use data of the International Great Lakes Diversions and Consumptive Uses Study Board (Study Board), the IJC, and the U.S. Geological Survey and to assess the magnitude and effects of consumptive water uses under present and projected economic and hydraulic conditions.

As a part of this effort, the U.S. Geological Survey analyzed the data, calculated a range of consumptive water-use estimates within the United States for the period 1980 to 2000, and developed methods of obtaining consumptive water-use data. Examination of consumptive water-use data for 1975 and 1980 as well as projected values indicated two methods of computation that represent minimum and maximum estimates for the year 2000:

1. Use the Geological Survey's 1985 estimate of consumptive water use in the United States part of the basin and apply the IJC's rate of increase of 115.6 ft^3/s (cubic feet per second) per year; adding to this the Study Board's projection for Canada gives a total of 6,520 ft^3/s.

2. Use the Geological Survey's 1980 estimate and apply a rate of increase of 292 ft^3/s per year during 1980-85 for the United States part of the basin; adding to this the Study Board's projection for Canada gives a total of 9,170 ft^3/s.

Discrepancies among consumptive water-use estimates by the Study Board, the IJC, and the Geological Survey reflect differences in (1) the methods by which base-year values were developed, including which facilities were inventoried, whether the data were estimated or reported, which methods of estimation and constants were used, the size of sampled areas, whether data were obtained directly from the water users or supplied by government agencies, and how often the data base is updated; and (2) methods or models that were used to project consumptive use to the future and the equations used in these models.

If a consumptive-use data base is developed for a different base year, for example, 1990, one of the following methods may be used:

1. Acquire data from the Great Lakes Regional Water-Use Data Base, housed at the Great Lakes Commission in Ann Arbor, Mich.

2. Develop a new set of projection data from the Institute for Water Resources - Municipal and Industrial Needs model of the U.S. Army Corps of Engineers or the Water Use Analysis Model of the Inland Waters Directorate, Environment Canada.

3. Acquire data directly from State and Federal agencies and Province ministries or from the water users.

Water-use categories of greatest interest are manufacturing, power, and public supply. If the major users can be identified, the first priority would be to obtain their withdrawal and consumptive water-use data. If questionnaires or surveys are used, voluntary responses and data accuracy need to be monitored. Data may be acquired from regulatory agencies or ministries having legal mandate to collect metered water-use data. In States or Provinces that lack such legislation, questionnaires can be used and coefficients developed. Coefficients have been found to vary greatly among industries producing the same product, however; therefore, the States and Provinces may be encouraged to develop legislation that allows for collection of water-use data.

INTRODUCTION

The Great Lakes, their connecting channels and streams, and the St. Lawrence River together represent a vast natural resource to the United States and Canada. With a surface area of about 95,170 mi^2 (square miles), the Great Lakes form the largest volume of unfrozen freshwater in the world. This water resource is used for many purposes, including public supply, industry, power generation, navigation, and recreation; it also provides habitat for a large variety of fish and wildlife.

The drainage area of the Great Lakes-St. Lawrence River basin above Cornwall, Ontario, covers about 299,000 mi^2 (fig. 1). It encompasses parts of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Ontario, Pennsylvania, and Wisconsin. From Cornwall, the St. Lawrence River flows northeastward into the Province of Quebec.

The water resources of the Great Lakes basin exert a vital economic role in Canada and the United States. For example, the lakes provide public water supply for about 26 million people (McAvoy, 1985, p. 2), and the Great Lakes-St. Lawrence Seaway Navigation System is a major international shipping lane. In 1983 alone, more than 100 million tons of iron ore, coal, and grain were shipped through this seaway (Pope, 1984, p. 37). The Great Lakes Fishery Commission estimates that anglers from the eight Great Lakes States and Ontario spend $755 million a year (Milliken, 1984, p. 16). Also, 20 billion kilowatt hours of electricity are generated by hydroelectric powerplants in Ontario annually by water flowing through the Great Lakes, and the value of the power generated on the Niagara and St. Lawrence Rivers is estimated to be $650 million annually (Pope, 1984, p. 37). The shores and waters of the Great Lakes support numerous mammal species, more than 20 reptile species, more than 100 bird species, and 100 fish species (International Joint Commission, 1985, p. 7).

The basin does not contain a vast surplus of water, however. When the lakes were originally formed, they were filled with glacial meltwater, but now only about 1 percent of their total volume is replenished annually (Loucks and others, 1987, p. 10). The loss of revenues for even a slight decline in lake levels would represent millions of dollars. For example, every inch of lake-level decline below the 27-foot navigation depth costs the navigation industry $2.5 million and results in $10-million loss in hydropower (Milliken, 1984, p.

14-15). For this reason, the effect of lake-level change has been the subject of much concern and study.

In 1988, the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, reviewed consumptive-use data compiled by three different agencies as a part of an effort directed by the International Joint Commission (IJC) to resolve discrepancies among the data sets and assess the magnitude and effects of consumptive uses under present and future economic and hydraulic conditions. Objectives of this review were to:

1) Compare the International Great Lakes Diversions and Consumptive Uses Study Board's (hereafter referred to as the Study Board) and the IJC's projections of consumptive use of water with the Geological Survey's estimates for the United States part of the basin and, from available information, explain the discrepancies and describe ways to analyze these data in detail to discern the reasons for conflicting values;

2) present alternative methods for projections of consumptive use that incorporate the Geological Survey's 1980 and 1985 data; and

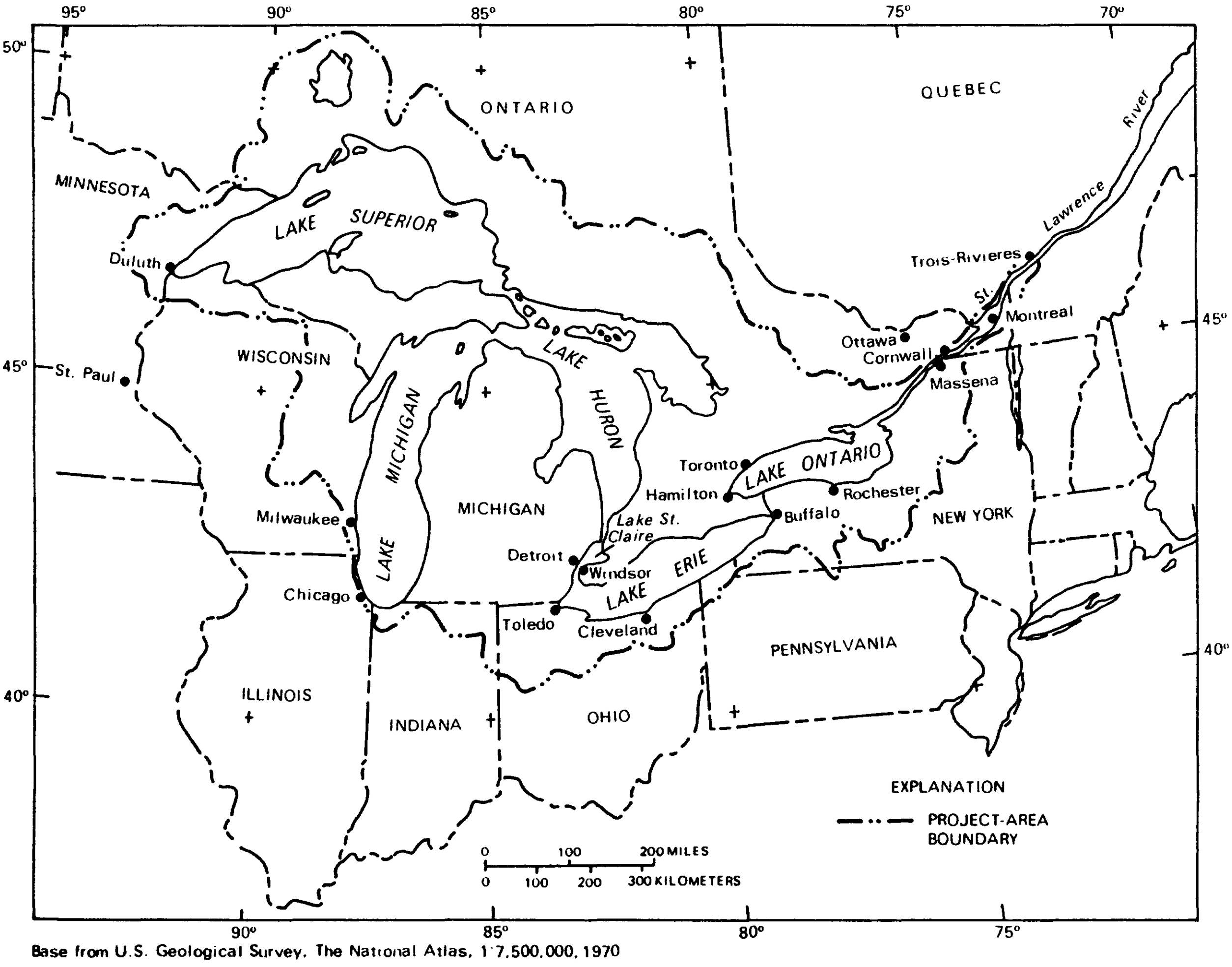


Figure 1.-- Major geographic features of the Great Lakes - St. Lawrence River basin.

3) describe methods to derive or collect consumptive-use data with improved reliability and accuracy.

Purpose and Scope

This report presents results of the three tasks listed above. The first part presents the Study Board's base-year values of consumptive water use and compares them with the U.S. Geological Survey's 1975, 1980, and 1985 estimates for the United States part of the basin; this part also (1) describes the methods used by the Study Board and the IJC to project consumptive use to the year 2000, and (2) discusses the assumptions and initial values on which the projections are based, (3) compares projections provided by the Study Board with those of the IJC, and (4) presents two alternative methods of projection that use Geological Survey values to narrow the range of the estimates for year 2000. The second part describes methods of data analysis. The third part describes sources of data and methods by which data collection could be improved, including use of available data bases, computerized models, and direct acquisition of data.

The project area is the entire Great Lakes basin, including the drainage areas for Lakes Superior, Huron, Michigan, Erie, and Ontario, their connecting channels and tributaries, and the international and Canadian reaches of the St. Lawrence River downstream to Trois-Rivieres, Quebec (fig. 1).

Acknowledgments

Thanks are extended to Dr. Benedykt Dziegielewski, Planning and Management Consultants, Carbondale, Ill., and Dr. Donald Tate, Environment Canada, Ottawa, Ont., for their suggestions and assistance.

LEGISLATION LEADING TO PRESENT STUDY

The dependence of the basin's population upon the quantity and quality of the water resource has prompted many local and national agencies to adopt measures to protect and conserve this resource. For example,

1) The Council of Great Lakes Governors is a nonprofit, private corporation founded in 1982 to work on common public-policy issues in the States of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. New York and Pennsylvania have the right to vote on water-related issues, and the governments of Quebec and Ontario are closely involved with the Council in management of the basin's water resources. In November 1983, the Council passed a resolution declaring that protection of Great Lakes water levels and flows is in the national interest (Great Lakes Governors Task Force on Water Diversion and Great Lakes Institutions, 1985, p. 38). The resolution also created a task force to evaluate and propose institutional arrangements that would strengthen the Great Lakes States' and Provinces' ability to manage or regulate diversions from the basin.

2) The Great Lakes Governors Task Force on Water Diversion and Great Lakes Institutions recommended to the governors and premiers that they sign and participate in the Great Lakes Charter, a basinwide, international water-management plan for assessing and regulating new or increased diversions and consumptive uses of Great Lakes basin water resources. The governors of the Great Lakes States and the premiers of the Provinces signed the Charter in February 1985.

3) The International Joint Commission (IJC) published a report concerning diversions and consumptive uses of Great Lakes water in 1985 in response to a Reference from the governments of Canada and the United States, dated February 21, 1977, that requested the IJC to examine and report on specific matters as they affect water levels, flows, and uses of the Great Lakes - St. Lawrence River basin (International Joint Commission, 1985, p. 1). Among the matters studied were (a) present diversions, (b) proposed or changed diversions, and (c) present and foreseeable patterns of consumptive use of Great Lakes waters.

4) The International Great Lakes Diversions and Consumptive Uses Study Board (herein referred to as the Study Board) was established in 1977 to conduct the technical investigations required for the three items listed above. The Study Board submitted its final report to the IJC in September 1981. Subsequently the IJC conducted further investigations and included the Study Board's findings, conclusions, and recommendations together with its own subsequent analyses in a report by the IJC (1985).

5) Hydraulic, Hydrology, and Climate Group (herein referred to as the HHC Group). On August 1, 1986, the governments of the United States and Canada presented a "Great Lakes Levels Reference" to the IJC requesting them to examine and report on methods of alleviating adverse effects of fluctuating water levels in the Great Lakes - St. Lawrence River basin. On April 10, 1987, the IJC issued a directive outlining the study it planned in response to the Reference.

   As a part of that effort, the IJC established a four-tiered management structure for the proposed study: the governance level, IJC steering committee, project-management team, and functional study groups. One of these, the HHC group, was organized to develop the water-level component of the study. This group plans to use several Great Lakes hydraulics and hydrologic models to determine how diversions, consumptive uses, and climatological factors will influence the lake levels and flows. Present and future scenarios can be simulated to determine the effects of proposed water-related projects and changes in climate.

One task assigned to the HHC group was to review the consumptive water-use data presented in reports by the Study Board (1981) and the IJC (1985) and to assess the magnitude and effects of consumptive uses under present and future economic and hydraulic conditions (International Joint Commission, 1988, p. 11). In reviewing the availability and accuracy of the consumptive water-use data, the HHC group found that the Study Board, the IJC's subsequent analyses, and the U.S. Geological Survey had differing base-year data and forecast estimates for consumptive use. As a result, the IJC arranged with the Geological Survey to conduct the study described herein.

ESTIMATION OF CONSUMPTIVE WATER USE

Current (1975) Consumptive Water Use

The Study Board and the U.S. Geological Survey estimated the consumptive use of water in the Great Lakes basin for 1975. These estimates are discussed and compared below.

Study Board Estimates

As explained previously, the IJC established the Study Board and requested that it conduct the required technical investigations to estimate consumptive uses for the base year 1975 and project future consumptive uses in the Great Lakes basin. The Study Board defined consumptive use as

> ... that portion of water that has been withdrawn or withheld from the Great Lakes for various uses such as power generation, manufacturing and so on, and is either known or assumed to be lost due to evaporation during use, leakage, or incorporation into manufactured products, or for other reasons has not been returned.

(International Joint Commission, 1985, p. 4.)

The Study Board estimated total withdrawals from the Great Lakes, tributaries, and ground water in the entire basin to be 75,620 ft^3/s (cubic feet per second), 6.6 percent of which was consumptive water use in 1975. The Study Board's withdrawal and consumptive water-use data and the percentage of total withdrawal that represents consumptive use in each water-use category in the United States part of the basin are given in table 1. (The Study Board

Table 1.--Withdrawal, consumptive water use, and consumptive use as percentage of withdrawal during 1975 for the United States part of the Great Lakes basin as reported by the International Great Lakes Diversions and Consumptive Uses Study Board and the U.S. Geological Survey.

[Partial figures may not add to totals because of independent rounding. Water-use values in cubic feet per second.]

Water-use category[1]	Study Board Values[2]			U.S. Geological Survey Values[3]		
	With-drawal	Consumptive use	Consumptive use as percentage of withdrawal	With-drawal	Consumptive use	Consumptive use as percentage of withdrawal
Manufacturing	20,450	2,270	11	11,760	760	6.5
Public water supply	6,130	680	11	4,800	630	13
Thermoelectric power	33,470	420	1.2	38,680	80	0.21
Irrigation	350	260	74	150	140	95
Domestic	500	300	60	450	90	21
Livestock	130	130	100	130	120	93
TOTAL	61,030	4,060	6.6	55,970	1,830	3.3

1 The Study Board included mining as a category in 1975, but the Geological Survey did not.
2 Data from International Joint Commission (1985).
3 Data from Murray and Reeves (1977).

estimated total withdrawals in Canada in 1975 to be 13,510 ft^3/s and consumptive use to be 640 ft^3/s, but assessment of the estimates for Canada was beyond the scope of this study.)

Study board estimates shown in table 1 indicate that:

1) 34 percent of the withdrawals and 56 percent of the consumptive use occurred in the manufacturing sector;

2) 55 percent of the withdrawals are made by thermoelectric powerplants.

3) Manufacturing, publicly supplied users, and thermoelectric powerplants together account for 83 percent of the consumptive uses.

Although not indicated in table 1, the Study Board also estimated that:

- The industries that consume the most water are primary metals, paper manufacturing, and chemical production.

- 53 percent of these consumptive uses are in Michigan and Ohio;

- The States of Michigan, Ohio, New York, and Indiana collectively account for 79 percent of the consumptive use in the United States part of the basin (International Joint Commission, 1985, p. 29).

- About 82 percent of withdrawals and 87 percent of consumptive use for the entire basin in 1975 occurred in the United States part of the basin (International Joint Commission, 1985, p. 27-28).

U.S. Geological Survey Estimates

The Geological Survey has been publishing estimates of water use in the United States every 5 years since 1950. Because the individual States' methods of data collection differ widely, Congress in 1977 authorized the Survey to develop a program to collect, store, and disseminate uniform and reliable water-use information. This program, known as the National Water-Use Information Program (NWUIP), became part of the Survey's joint-funding program with the States. Responsibilities for gathering, analyzing, storing, and publishing water-use data are shared among local and State agencies and the Geological Survey's offices in each State.

The first U.S. Geological Survey publication of nationwide water-use data under the NWUIP presents data for 1980 (Solley and others, 1983). A report by the IJC (1985) compares data from that report with those prepared by the Study Board, which represent 1975. To avoid disparity resulting from the differing base years, Geological Survey data for 1975 (Murray and Reeves, 1977) are used herein for comparison with the Study Board's 1975 data. (See table 1.)

The definition of consumptive use recognized in Murray and Reeves (1977) is virtually the same as that used by the Study Board. The Geological Survey estimated consumptive use to represent 3.3 percent of withdrawals.

U.S. Geological Survey estimates shown in table 1 indicate that:

1) 21 percent of the withdrawals and 42 percent of the consumptive use occurred in the manufacturing sector;

2) 69 percent of the withdrawals are made by thermoelectric powerplants.

3) manufacturing, publicly supplied users, and thermoelectric powerplants collectively accounted for 80 percent of the consumptive uses.

Comparison of Study Board Estimates with U.S. Geological Survey Estimates

Although the U.S. Geological Survey's total withdrawal value in table 1 is more than 91 percent of the Study Board's value, the Geological Survey's total consumptive-use estimate is only 45 percent of the Study Board's estimate. The Geological Survey's consumptive-use estimate is 3.3 percent of the total withdrawal, whereas that of the Study Board is 6.6 percent of the total withdrawal. Most of this difference is in the manufacturing sector, where the Study Board's withdrawal value is almost twice that of the Survey's and nearly twice the Survey's ratio of consumptive use to withdrawal. Another notable difference is that the Study Board's estimate of consumptive use in the domestic category is 60 percent of withdrawal, whereas the Geological Survey's estimate is only 21 percent.

Reasons for Difference.--One reason for the discrepancy in the manufacturing-withdrawal data is that the Study Board is reporting both self-supplied and publicly supplied industries in manufacturing, whereas the Geological Survey reports self-supplied industries alone. This does not explain why the Survey's withdrawal estimates for public supply are lower than the Study Board's estimate, however. The reason the Geological Survey's withdrawal estimate for irrigation is less than half the Study Board's estimate is that the Survey considered only farmland irrigation in 1975, whereas the Study Board included irrigation of recreational land, such as golf courses.

Methods of Analyzing Differences.--Because nearly 69 percent of the difference between the Study Board's and the Geological Survey's consumptive-use values for the United States part of the basin is in the manufacturing sector (table 1), resolution of the differences in this category is essential. One reason may be that the Study Board used data published by the U.S. Water Resources Council (1978), which represented information on 9,300 large manufacturing plants that was gathered in a 1971 survey of all manufacturing establishments that were using more than 10 Mgal (million gallons) of water per year (U.S. Water Resources Council, 1980, p. 314). Presumably these plants accounted for about 98 percent of the water used by 312,000 manufacturing establishments in 1970. This data source also contains technical coefficients related to recirculation and consumption rates. The data base was presumably national in scope but gives no indication as to how many of these establishments are in the Great Lakes basin.

One way to compare the Study Board's Great Lakes manufacturing data with the Geological Survey's data would to be tabulate for each:

1) Number of facilities inventoried,

2) total withdrawals, by county or, at least, by State,

3) definitions of Standard Industrial Classification Codes (U.S. Office of Management and Budget, 1972) of the facilities included in the manufacturing sector, and

4) coefficients or percentages of consumptive use applied to each type of industry.

The tabulation by county (or State) would indicate whether the data discrepancies are geographical. If they are fairly uniform, the data-collection methods and coefficients would need to be examined.

This procedure probably would be more easily performed on the Study Board's data than the Geological Survey's data because, in 1975, the Survey was estimating water use every 5 years without the benefit of annual data from most States. A historical-trend analysis could be done for areas in which the State or local agency was routinely collecting data. In areas where that is impossible, an inspection of files might reveal equations or constants that were used. Such an analysis would probably reveal that many of the data were estimated from values reported 5 years earlier.

The method of analysis referred to here is to identify the facilities that represent 90 percent of the consumptive uses and determine how the data on withdrawals by these facilities were treated. For example, if a large paper mill were in an area for which the Geological Survey had reported a low industrial-withdrawal value, it probably was overlooked. If such facilities were not overlooked, however, and if the discrepancies are uniform and not geographical, then the methods of estimation must have differed. In that case, an analysis of methods would be required for both the base-year data and the forecast values. These methods are discussed in greater detail later in this report.

Projections of Consumptive Water Use

Study Board Projections

The Study Board estimated consumptive uses for 1975 to 2035, but the IJC concluded that projections beyond the year 2000 would be unreliable and therefore would not be used for planning and formulation of policy (International Joint Commission, 1985, p. 30). The Study Board estimated future water use and the distribution of demand from available base-year data, economic forecasts, and several assumptions related to conservation practices, improvements in technology, and political policy; it then produced high and low projections and estimated the one most likely to occur.

The Study Board used water-use projections of the U.S. Water Resources Council (1978) as a basis for projections for six of the water-use categories (manufacturing, mining, irrigation, livestock, rural-domestic, and public water supply) and generated its own projection for thermoelectric powerplants. The consumptive-use projections made by the Study Board and the IJC for the United States part of the basin for the year 2000 are presented in table 2.

Table 2.--Consumptive water use in the United States part of the Great Lakes basin in year 2000 as projected by the Study Board and the International Joint Commission.

[Data from International Joint Commission, 1985. Values are in cubic feet per second.]

Water-use category	Study Board projection	IJC projection
Manufacturing	4,050	3,500
Municipal	870	870
Thermoelectric power	2,260	1,550
Irrigation	500	500
Rural-Domestic	330	330
Mining	320	320
Livestock	130	130
TOTALS	8,460	7,200

Comparison of Study Board Projections with U.S. Geological Survey Current-Use Estimates

The Geological Survey obtained values for the consumptive use of water in the United States in 1975, 1980, and 1985 through a combination of data-collection activities by cooperating agencies and estimation techniques. The 1980 data are reported in Solley and others (1983), and the 1985 data are in Solley and others (1988). The Study Board's projections for 1980 and 1985 are shown in table 3 together with the Geological Survey's estimates. Comparison of these data reveals three major discrepancies between the Geological Survey's estimates of consumptive use and those of the Study Board:

1) The percentage of water withdrawn that is consumed, according to U.S. Geological Survey computations, increased from 3.3 percent in 1975 to 6.8 percent in 1985, which is is the same as the 1975 percentage reported by the Study Board. Either the percentage of water consumed has been increasing, the accuracy of the Survey's data is increasing, or both. Although the former is difficult to address, the accuracy of the data has improved since the initiation of the NWUIP. Before 1980, estimates were commonly made by category and county aggregations rather than by inventory of individual facilities. The accuracy of the data varied from State to State, depending on the type of data-collection programs. Since 1980, the NWUIP has done careful analysis of methods and obtained an increasing amount of reported data over estimated values.

   The Study Board reports an increase in consumptive use as a percentage of total withdrawn from 6.6 percent in 1975 to 7.8 percent in 1985.

2) The percentage of total withdrawals represented by consumptive use in the domestic category increased during 1975-85, according to Geological Survey records, and the Survey's 1985 value for domestic use (74 percent) exceeds the Study Board's estimate for 1975 (60 percent). This discrepancy occurs because the Geological Survey's 1985 data represent the consumptive use of self-supplied and publicly supplied water, whereas the 1975 and 1980 data represent consumptive use of self-supplied water alone. This is true for all categories.

Table 3.--Withdrawal, consumptive use, and consumptive use as percentage of withdrawal in the United States part of the Great Lakes basin, as reported and compiled by the U.S. Geological Survey and the Study Board for 1980 and 1985.

[Individual values may not add to totals because of independent rounding. Water-use values in cubic feet per second. A dash indicates no data.]

	Study Board 1980			Geological Survey 1980			Study Board 1985			Geological Survey 1985		
Water-use category	With-drawal	Consump-tive use	Consumptive Use as percentage of with-drawal	With-drawal	Consump-tive use	Consumptive use as percentage of with-drawal	With-drawal	Consump-tive use	Consumptive use as percentage of with-drawal	With-drawal	Consump-tive use	Consumptive use as percentage of with-drawal
Manufacturing (includes mining)	21,950	2,770	13	8,890	580	6.5	22,420	3,050	14	7,220	680	9.4
Public-water Supply	6,520	720	11	6,050	480	8	6,890	750	11	6,310	110*	--
Thermoelectric Power	36,630	610	1.7	41,950	140	.34	39,930	830	2.1	34,720	1,700	4.9
Irrigation	410	310	76	473	473	100	460	370	80	420	420	100
Domestic	520	330	64	410	110	27	530	330	62	440	330	74
Livestock	130	130	100	130	120	92	130	130	100	120	110	88
Totals	66,160	4,870	7.4	57,910	1,900	3.3	70,360	5,460	7.8	49,240	3,360	6.8

*Consumptive use for industrial and domestic public-water-supply deliveries are included in those categories; 110 cubic feet per second is consumptive use for public-water-supply delivery to commercial users.

The Study Board's estimate of the percentage of domestically used water that represents consumptive use during 1975-85 ranges between 60 and 64 percent.

3) The Geological Survey's estimate of consumptive water use in the thermoelectric-powerplant category was higher in 1985 than 1980 because the Survey's data probably represent nuclear powerplants that went into operation during 1980-85, and because the accounting of powerplants and the amount of water used were more accurate than before. The Study Board also shows a slight increase in the percentage of water consumed by thermoelectric plants.

International Joint Commission Projections

The IJC maintains that any water-use projection should be reevaluated periodically; for that reason the Study Board's consumptive-use projections were analyzed in relation to newer data (International Joint Commission, 1985, p. 33). The IJC adjusted the Study Board's data in two ways: (1) revision of assumptions regarding factors that control the rate of change in consumptive use, and (2) designation of a different base year and set of base-year values from which to project consumptive use to the year 2000.

Adjusment of Assumptions.--Two primary assumptions that affected the consumptive-use projections for the United States part of the basin were that (1) present uses of energy in the mid-1970's would continue, and (2) consumptive use by industry would increase through recycling in response to the stringent water-quality requirements for industrial discharges mandated by the Clean Water Act of 1977 (Public Law 92-500). Both assumptions were revised and the Study Board's projections altered as described below.

1) *Energy*. The assumption that the rate of energy use in base year 1975 would continue was reassessed for two reasons. The first was that energy prices and political instability in some energy-rich nations have prompted energy-conservation measures in the United States and Canada. The Study Board had assumed an average annual growth rate of 4.1 percent for power generation in the United States part of the basin for 1975-80 and 4.7 percent to the year 2000 (International Joint Commission, 1985, p. 33), whereas the U.S. North American Electric Reliability Council issued an average annual growth-rate estimate of approximately 2.5 percent to the year 2000. The other reason was that the percentage of energy supplied by nuclear plants relative to that supplied by fossil-fuel plants is not increasing at the rate the Study board had assumed. The Study Board had estimated that nuclear plants would supply 39 percent of the electricity by the year 2000, as contrasted to a 28-percent estimate by the IJC. Because consumptive water use for nuclear plants is about 35 percent greater than fossil-fuel plants, the projection of consumptive use has been lowered accordingly (International Joint Commission, 1985, p. 33).

In regard to the power industry's future water demands, the Congressional Research Service of the Library of Congress (1980, p. 256) restated the General Accounting Office position that"

- estimates of increased demand for electric energy are now lower than previously anticipated;

- consumptive water use per megawatt of capacity in steam powerplants is much less than expected;

- numerous methods are now used to conserve, reuse, or recycle water supplies.

Together these factors resulted in a downward revision of the projected consumptive use by the power category to 1,550 ft^3/s in the year 2000 (table 2).

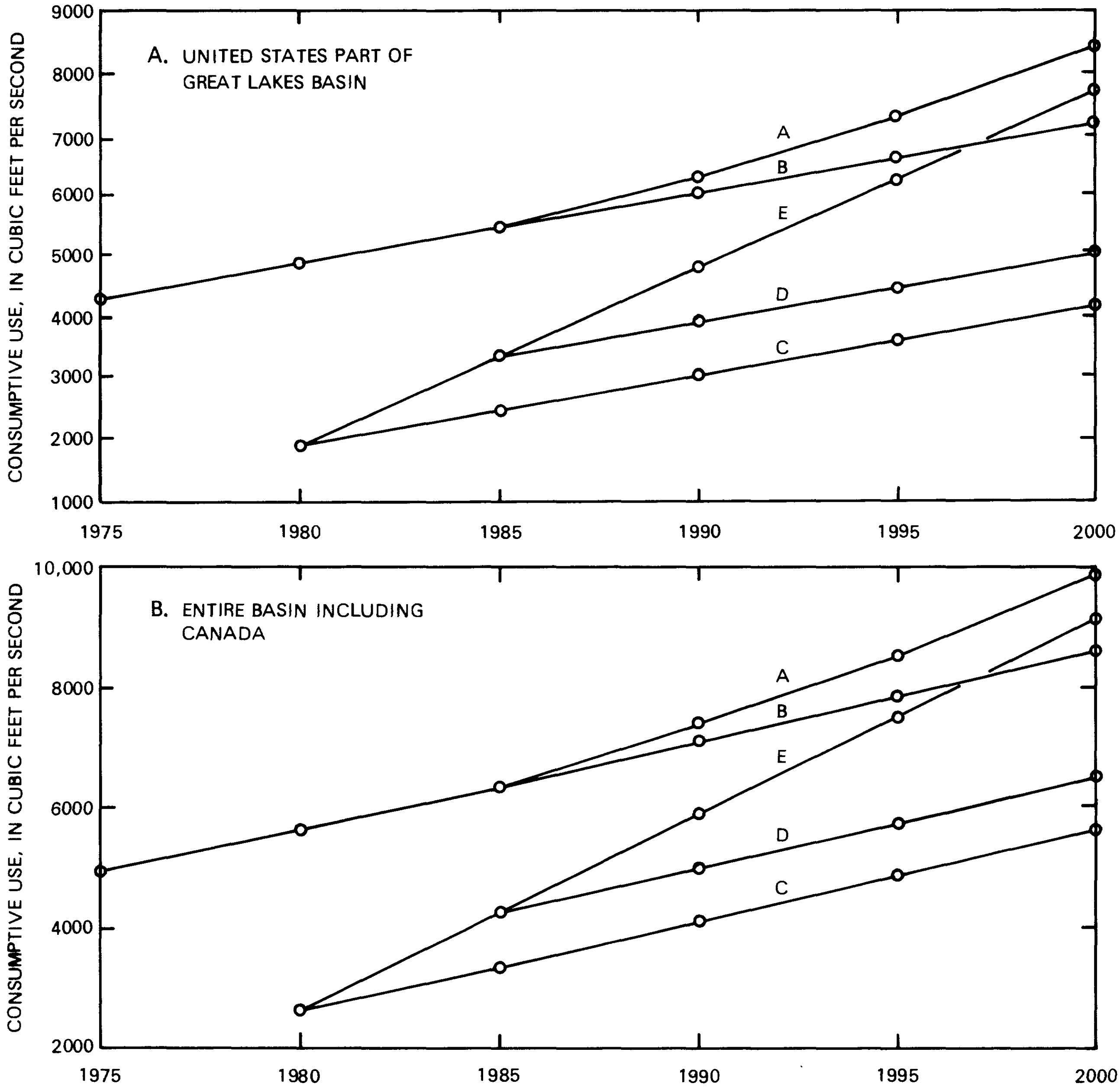
2) *Industry.* With regard to the assumption that industrial consumptive water use would increase as a result of recycling, the General Accounting Office believed the requirements of Public Law 92-500 may be modified and that industry may find it cheaper to continue using once-through methods and treat the wastewater than to construct recycling operations. This would tend to lower the estimates of future industrial consumptive use because recycling decreases total withdrawals but greatly increases the percentage of consumptive water use.

In addition, the Study Board assumed that the primary metals industry would be the principal component of consumptive water use to the year 2000, whereas the IJC believes that steel industry's withdrawals are unlikely to increase to the levels built into the Study Board's projections. For these reasons, the IJC revised the Study Board's consumptive water-use estimate in the manufacturing sector from 4,050 ft^3/s to 3,500 ft^3/s (table 2).

Reassessment of Base-Year Values.--Another assessment made by the IJC was an analysis of base-year values, including the Geological Survey's consumptive-use values reported for 1980 in Solley and others (1983). After adjusting the Study Board's values for the thermoelectric-power and industrial categories and using the Geological Survey's 1980 data as a new base year, the IJC projected a consumptive-use value of 7,200 ft^3/s for the United States part of the basin in the year 2000, a reduction of 1,260 ft^3/s (table 2).

Comparison of Study Board Projections with International Joint Commission Projections

The consumptive-use projections made by the Study Board and the IJC for the United States part of the Great Lakes basin are plotted in figure 2A. The Study Board estimate for 1975-2000 (line A) indicates that the greatest rate of increase will occur during 1990-95 and 1995-2000. The overall projected increase in consumptive water use from 1975 through 2000 is about 4,150 ft^3/s.



EXPLANATION

Line A = Study Board estimate

Line B = International Joint Commission (IJC) revision of Study Board estimate

Line C = IJC revision based on U.S. Geological Survey (USGS) base-year 1980 data and IJC's rate of increase, 115.6 ft^3/s.

Line D = First alternative (USGS base-year 1985 data and IJC's rate of increase, 115.6 ft^3/s per year)

Line E = Second alternative (USGS base-year 1980 and 1985, with 292 ft^3/s as annual rate of increase)

Figure 2.--Projections of consumptive water use in the Great Lakes basin from 1975 to the year 2000:
A. United States part of basin only.
B. Entire basin, including Canada.
Sources of data are given in footnote to table 4.

Table 4.--Consumptive-use estimates for Great Lakes basin

[Values are plotted in fig. 2. IJC = International Joint Commission. USGS = U.S. Geological Survey. Water-use values are in cubic feet per second (ft^3/s). Dash indicates no data.]

A. UNITED STATES PART ONLY (fig. 2A)

Year	Data source and corresponding line in figure 2				
	Line A (Study Board)	Line B (IJC)	Line C (IJC and USGS)	Line D (First alternative)	Line E (Second alternative)
1975	4,310	4,310	-	-	-
1980	4,870	4,890	1,900	-	1,900
1985	5,460	5,470	2,480	3,360	3,360
1990	6,320	6,040	3,060	3,940	4,820
1995	7,320	6,620	3,630	4,520	6,280
2000	8,460	7,200	4,210	5,090	7,740

B. ENTIRE BASIN INCLUDING CANADA (fig. 2B)

Year	Canada only (Study Board)	Data source and corresponding line in figure 2				
		Line A (Study Board)	Line B (IJC)	Line C (IJC and USGS)	Line D (First alternative)	Line E (Second alternative)
1975	640	4,950	4,950	--	--	--
1980	750	5,620	5,640	2,650	--	2,650
1985	900	6,360	6,370	3,380	4,260	4,260
1990	1,060	7,380	7,100	4,120	5,000	5,880
1995	1,240	8,560	7,860	4,870	5,760	7,520
2000	1,430	9,890	8,630	5,640	6,520	9,170

Data for the United States part of the Great Lakes basin (part A) from:

Line A. International Great Lakes and Consumptive Uses Study Board, 1981, Annex F.
Line B. International Joint Commission, 1985.
Line C. International Joint Commission, 1985. Based on USGS base-year 1980 data and IJC's rate of increase, 115.6 ft^3/s per year.
Line D. Based on USGS base-year 1985 data and IJC's rate of increase, 115.6 ft^3/s per year.
Line E. Based on Geological Survey's base year 1980 and 1985 data and the Survey's rate of increase 292 ft^3/s per year.

Data for the Canadian part of the Great Lakes basin (part B) from International Great Lakes and Consumptive Uses Study Board, 1981, Annex F.

The IJC's update of the Study Board's projection, based on revised consumptive-use data for the manufacturing and power categories (line B), indicates a constant increase of 115.6 ft^3/s per year and a consumptive-use value of 7,200 ft^3/s for the year 2000. When the IJC used the latter rate of increase but began the projection with the Geological Survey's 1980 value of 1,900 ft^3/s, the projected consumptive-use value for year 2000 was 4,210 ft^3/s (line C).

Two Alternative Projections

Two additional projections of consumptive use were considered. The first uses a base-year value of 3,360 ft^3/s (the Geological Survey's estimate of consumptive use in the United States part of the basin in 1985) and applies the rate of increase that the IJC used (about 115.6 ft^3/s per year) to obtain a consumptive-use value of 5,090 ft^3/s for the year 2000 (fig. 2A, line D). The second alternative uses the 1980 and 1985 Geological Survey values for consumptive use and applies that rate of increase (292 ft^3/s per year) to obtain a projected consumptive-use value of 7,740 ft^3/s in the year 2000 (fig. 2A, line E).

The latter projection (line E) is justified only if the rate of increase of consumptive use is equal to the Geological Survey's 1980-85 data. Assumptions regarding population growth, industrial development, water conservation, recycling, air- and water-pollution regulations, the amount of manufacturing done and energy generated, and the type of thermoelectric plants used in the future, are all subject to change, which would influence the future consumptive use of water. The approach here is to use an intermediate range of consumptive-use values that lies between the IJC's rate of increase (about 115.6 ft^3/s per year) for 1985-2000 (fig. 2A, line D), and the Geological Survey's rate (about 292 ft^3/s per year, line E). This process narrows the range of possibilities and alleviates some of the concerns that the IJC noted about the Study Board's assumptions that generated the higher values. The estimated values used in all projections are listed in table 4A, which refers only to the United States part of the basin. The assumptions and data used to generate the projections for the Canadian part of the basin could be analyzed in a similar fashion when data or estimates become available.

The data and projections for the entire basin, including the Study Board's values of consumptive use for Canada, are given in table 4B and figure 2B. These data could be apportioned into the Great Lakes subbasins from the Study Board's compilations, which are available by subbasin. The Geological Survey's data were compiled by subbasin and by county in 1985, and these subbasin proportions could be easily compiled by water-use category. The IJC's reassessment of consumptive use in the manufacturing and thermoelectric-power categories could also be apportioned into subbasins.

Two further steps could be taken to explain the discrepancies among the projected values of the Study Board, those of the IJC, and those of the Geological Survey and to develop a more consistent data base of consumptive-use estimates. The first would be to research in detail the inventories that were used by the Study Board, the IJC, and the Geological Survey to generate the estimates; the second would be to undertake a new program to collect consumptive-use data and to perform field measurements on a selected random sample.

METHODS OF ANALYZING CONSUMPTIVE-WATER-USE DATA

The disparity among consumptive-use estimates, both for the present and the year 2000, indicates a need to examine the methods by which the data were collected and used for compilation. This section describes two approaches that could be used to analyze the original data.

Base-Year Analysis

The consumptive-use data generated by projections are partly dependent upon the initial (base-year) values from which the projection begins. This section describes the development of a base-year data base by the Study Board and the Geological Survey and ways to study these data sets.

Because the Study Board used data published by the U.S. Water Resources Council (hereafter referred to as the Council) in 1978 as its initial data values for 1975, analysis of the Council's methods would be necessary to interpret the Study Board's estimates. The Geological Survey also estimated consumptive use for 1975 (as well as for 1980 and 1985). Three questions pertaining to both the Council's and the Survey's data for withdrawals and consumptive use each year are:

1) Which facilities' (if any) water-use values were gathered as site-specific data points in each of the water-use categories. (For example, individual industries and powerplants may have been considered, whereas individual households are unlikely to have been).

2) Which methods (such as questionnaires, site visits, acquisition of reported data, published data, and so forth) were used to obtain data from individual facilities.

3) Which methods and constants were used to estimate values for each category. (This aspect is especially important because much of the data base consists of estimates).

This information would need to be collected for each State, Province, and subbasin individually. The States and Provinces with the higher volumes of withdrawal and consumptive use would be targeted first, as would the larger users, such as thermoelectric powerplants, industries, and public-water suppliers. Comparison of the Council's data with the Geological Survey's data for the United States part of the basin by county would be facilitated by the fact that the Council divided the basin into areas that approximate county boundaries where possible (Moody, D., U.S. Geological Survey, written commun., 1986). An additional check would be to compare the base-year values with any other available data, published or stored elsewhere, as a means of comparison.

Projection Analysis

The assumptions that influenced the Study Board's projections (which were reevaluated by the IJC as described previously) could be reanalyzed in light of more recent information, especially with regard to (1) the rate of consumptive-use increase, and (2) whether consumptive use is increasing relative to withdrawals. The Study Board projected a marked increase in consumptive use for 1990-2000, which the IJC revised downward to a more constant increase from 1980-2000. The rate of increase indicated by the Survey's data for 1980-85 is greater than that of the IJC (fig. 2A); therefore, an analysis of the rates would address the primary assumptions.

The increase in consumptive use also would be analyzed in relation to withdrawals. Consumptive use can increase or decrease independently of withdrawals, depending upon the percentage of water returned. An economic projection of the types of industries that are expected to grow and those that are expected to decline would be useful for such an analysis. Useful also would be a range of estimates as to the amount of recycling predicted for each type of industry.

Another factor to consider is the possible effect of legislation to discourage or prohibit major new consumptive-use projects. Even when Great Lakes water levels are above normal, basinwide water-resource management guidelines (such as the Great Lakes Charter) are tending toward water conservation and preservation, although this may not have been apparent when the Council and the Study Board made their projections. Another check would be to compare the projections with any other available projections for the region or for a specified subbasin or even a specified State.

The IJC has repeatedly cautioned against forecasting too far ahead (International Joint Commission, 1985), as has the Congressional Research Service of the Library of Congress (1980, p. 6):

> ... a review of many factors impacting water use trends discloses the fragile nature of these estimates and the need to accept them in this light. In general, the older the estimate the more likely it is to be off-target because of influences unrecognized at the time it was made or due to understatement or overstatement of other conditions.

Another alternative to long-range forecasting would be to direct efforts toward renewed data collection to establish a reliable base year of data from which to project values.

SOURCES AND VERIFICATION OF CONSUMPTIVE-USE DATA

Compilation of consumptive-use data would include the categories of manufacturing, thermoelectric powerplants, and public-water-supply deliveries because, in the United States part of the basin, these categories are estimated to represent 78 to 91 percent of the total consumptive use. Large changes within the other categories (irrigation, rural-domestic, mining, livestock) would have little effect on the total consumptive water use (Pinsak, 1984a, p. 1-2). The following paragraphs describe sources and methods of acquiring consumptive-use data for the major categories.

Great Lakes Regional Water-Use Data Base

As a result of the Great Lakes Charter, the Great Lakes Regional Water-Use Data Base (hereafter referred to as the data base) was designed by the Geological Survey and translated into computer language by Acres International Ltd.[1] of Niagara Falls, Ont. The data base is maintained and operated by the Great Lakes Commission in Ann Arbor, Mich., and is described in Snavely (1986). The designated agency in each State and ministry in each Province will transmit data annually; the coding sheet is illustrated in figure 3.

Each State and Province will transmit data for the water-use categories listed on the coding sheet and complete one coding sheet for each Great Lakes or St. Lawrence River subbasin in that State or Province. Withdrawal data are entered for each of three water sources in each category: Great Lakes, surface water other than Great Lakes, and ground water. Indications as to level of accuracy and sources of data are also specified for each data entry. Consumptive use is entered for each withdrawal in compliance with the Great Lakes Charter mandate to document diversions and consumptive uses as losses from the region. Intrabasin and interbasin diversions are documented also.

One method of acquiring withdrawal and consumptive-use data for further studies would be to interrogate the data base for annual data. In this manner, data to the subbasin level of definition could be used to compare with data of the Study Board, the IJC, and the Geological Survey. One caution is that the data-collection methods and threshold levels (withdrawals below which data are not collected) differ from place to place; another is that, because many agencies and ministries are estimating the consumptive-use component, their methods of estimation and the facilites inventoried would need to be documented to assess the reliability of the data. Many of these methods are described in Snavely (1986).

Forecasting Models

Institute for Water Resources - Municipal and Industrial Needs Forecasting Model

The Institute for Water Resources - Municipal and Industrial Needs (IWR-MAIN) forecasting model could be used to examine the Study Board's and the IJC's projections and the Geological Survey's estimates. The values generated by IWR-MAIN would not be more definitive than other projections but could provide additional values with which to define the most likely projection.

The original MAIN model was updated and modified for use on personal computers by the Institute for Water Resources of the U.S. Army Corps of Engineers; thereafter the name was changed to IWR-MAIN. This model takes into account several factors that influence the level of future water use, such as changes in prices for water and sewer services, household income, type of housing, and the relative proportion of water used for industrial, commercial, and other nonresidential uses of water (Planning and Management Consultants, Ltd., 1987, p. 1). Information regarding these factors (such as the price of

[1] The use of company names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Great Lakes Regional Water-Use Data Base — Water-Use Data Input Sheet

Basin ________ Jurisdiction/Agency ________ / ________ Year of Data ________

WATER-USE CATEGORIES
1. Public Supply - Domestic (Residential, Commercial, Institutional)
2. Public Supply - Industrial
3. Self Supply - Domestic (Residential, Commercial, Institutional)
4. Self Supply - Irrigation
5. Self Supply - Livestock
6. Self Supply - Industrial (Manufacturing and Mining)
7. Self Supply - Thermoelectric Power—Fossil-Fuel Plants
8. Self Supply - Thermoelectric Power—Nuclear Plants
9. Self Supply - Hydroelectric Power
10. Other (Navigation, Sanitation, Environmental)

WITHDRAWAL/ DISCHARGE TYPE
1. Great Lakes Surface Water
2. Other Surface Water
3. Groundwater

BASIN
1. Lake Superior
2. Lake Michigan
3. Lake Huron
4. Lake Erie
5. Lake Ontario
6. St. Lawrence River

JURISDICTION
1. Illinois
2. Indiana
3. Michigan
4. Minnesota
5. New York
6. Ohio
7. Ontario
8. Pennsylvania
9. Quebec
10. Wisconsin

UNITS
1. ML/d
2. Mgal(US)/d

LEVEL OF ACCURACY
1. Measured Withdrawal Amount
2. Partially (>50%) Measured Withdrawal Amount
3. Calculated or Estimated Withdrawal Amount

LEVEL OF AGGREGATION
1. Site-Specific Source of Withdrawal Data (>50% of Amount)
2. Aggregated Source of Withdrawal Data (>50% of Amount)

Water Use Category	Withdrawal/ Discharge Type (in Basin)	Basin (1-6)	Jurisdiction (1-10)	Year of Data	Units (1 or 2)	ALL FACILITIES*				Level of Accuracy (1-3)	Level of Aggreg. (1 or 2)	No. of Principal Facilities**	PRINCIPAL FACILITIES**			
						Withdrawal Amount	Intrabasin Diversion Amount***	Interbasin Diversion Amount***	Consumptive Use				Withdrawal Amount	Intrabasin Diversion Amount***	Interbasin Diversion Amount***	Consumptive Use
1	1 2 3															
2	1 2 3															
3	1 2 3															
4	1 2 3															
5	1 2 3															
6	1 2 3															
7	1 2 3															
8	1 2 3															
9	1 2 3															
10	1 2 3															

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* Facilities covered by jurisdiction criteria for water-use data recording and compilation.
** Facilities withdrawing in excess of Great Lakes Charter uniform trigger level of 100,000 US gal/d (380,000 L/d) average in any 30-day period.
*** Outgoing diversions positive, incoming diversions negative.

For Jurisdiction/Agency

Prepared by ________ Date ________ Checked by ________ Date ________

For Great Lakes Commission

Checked by ________ Date ________ Entered by ________ Date ________

GREAT LAKES COMMISSION
GREAT LAKES REGIONAL WATER-USE DATA BASE
WATER-USE DATA INPUT SHEET

Figure 3.--Data-input sheet for the Great Lakes Regional Water-Use Data Base.

water and the number of employees in specified manufacturing sectors) are entered for a base year for which water-use data are available. After calibration to these values, water use can be projected through several model options. Water use is estimated separately for residental, commercial/institutional, industrial, and public/unaccounted categories. Data can be generated for average daily use, winter season, summer season, and peak-day use (Planning and Management Consultants, Ltd., 1987, p. 6). The data also can be spatially disaggregated, depending upon the level of detail required (Davis and others, 1987, p. viii).

The difficulties with this approach are that (1) the model is calibrated to base-year data whose values are currently being studied, and (2) these projections are no more verifiable than other projections. Yet, because the type of data used to estimate base-year values differs from the type used by the Geological Survey, the resulting IWR-MAIN estimates for 1975, for example, could be compared with those of the Study Board and those of the Survey. Also the projected rate of increase of withdrawal and consumptive use generated by IWR-MAIN could be evaluated and compared with the rates estimated by the Study Board, IJC, and Geological Survey. This could first be done for one subbasin to determine the feasibility of extending the technique.

Water Use Analysis Model

Another alternative is to apply the Water Use Analysis Model (WUAM) of the Inland Waters Directorate, Environment Canada, to the United States part of the basin. This model was used to generate the Study Board projections for Canada but was not used for the United States. If this model is rerun for Canada with updated assumptions and base-year values, it could be extended to the United States to compare those projections with the original Study Board values.

Direct Data Compilation

A third method of obtaining or verifiying consumptive-use data would be to collect data either directly from agencies and ministries that have the legal mandate to collect such data or collect data directly from the facilities. Both are subject to restrictions imposed by privacy considerations and the agencies' or facilities' willingness to participate in the project. The availability of data and the accuracy, format, and characteristics of information from public agencies are discussed in Snavely (1986).

Manufacturing and Thermoelectric Power Generation

The following steps could be followed for manufacturing plants, then for thermoelectric powerplants and public-water suppliers:

1) Contact the State agency, Province ministry, or Geological Survey office that is the primary water-use data-collecting office in each State and Province and compile a list of major water users in each area. (Include withdrawals and consumptive-use values.) In some places this may require contact with more than one office.

2) For each user, tabulate:

   a. withdrawal
   b. return flow
   c. manufacturing-plant characteristics, such as number of employees, age of facility, amount of product produced, amount of recirculation, type of processing used, and so forth.
   d. powerplant characteristics, such as power generated (daily and monthly average), age of plant, type of cooling, amount of recirculation, and so forth.

   This information can be used to calculate the amount of water withdrawn and the consumptive use and can be keyed to specific plant and process characteristics. If return data are not readily available, some information may be acquired through discharge-permitting programs operated by State agencies.

   In areas where reporting of withdrawals is not mandated by law, individual inventory through questionnaires could be considered. Caution is needed in such a survey, however, because voluntary response may be poor, and the data reported may be skewed in a direction favorable to the respondent.

3) Calculate consumptive use for as many plants as possible and develop coefficients for each type of plant. A variety of coefficients can be calculated, such as number of gallons used per employee or per ton of product, and compared with similar coefficients generated for other years and other areas. Statistical sampling techniques can then be applied to other industries. The major facilities would be addressed first.

   Caution also is needed in generating and applying coefficients. Burt (1983, p. 17) discovered that "... different data bases produced coefficients that differ widely for similar industries, in some cases by an order of magnitude." His study indicated such a wide variability in plant processes and characteristics that reliable coefficients could not be developed for industrial water use. His approach is to inventory the major users--those that together account for 90 percent of the withdrawal in the category. Self-metering and voluntary reporting, legislatively mandated metering and reporting, or the installation of project instrumentation would be alternatives. Metered withdrawals and return data (as opposed to estimated or calculated values) would be desirable.

   If metered data cannot be acquired, survey questionnaires and techniques of estimation through use of coefficients, or a range of coefficients, could be used.

4) Apply the above procedures to the manufacturing category and the thermoelectric-power category and compare the resulting withdrawal and consumptive-use values with those of the Study Board, the IJC, and the Geological Survey for 1985 or 1990, depending upon when the study is done. This would help to verify the accuracy of the data bases and would provide new base-year data for projections.

Public Supply

The public-supplied (municipal) category could also be analyzed, but with a different procedure:

1. Identify the public suppliers that are the major distributors of water in each State and Province and acquire their withdrawal data. This would be relatively simple because most are legally mandated to monitor withdrawals for public supplies.

2. Determine water deliveries from billing records and organize them by water-use category.

3. Calculate conveyance loss, unaccounted-for water and public uses, and the difference between withdrawals and deliveries.

4. Calculate the amount of water delivered and consumptive use by the major industries and powerplants receiving public water by the procedures detailed earlier for determining manufacturing and thermoelectric powerplant water use.

Data Storage and Retrieval

The data collected or estimated for individual facilities could be stored and retrieved from a water-use data base such as the State Water-Use Data System of the Geological Survey. This computer program stores point data by location of facility and measurement points, including those for withdrawal, delivery, release, and return of water. Quantities at each measurement point can be stored, and the relations among the facilities are tied together programmatically.

Another possibility is to use a geographic information system, which allows the user to locate a facility and store any number of characteristics about that facility, such as Standard Industrial Classification Code, number of employees, and so forth.

Data Verification

One way to decrease the range of withdrawal and consumptive-use values that the HHC group will use would be to generate a new set of base-year values for comparison with the previous estimates and projections. If this effort were completed between 1989 and 1991, the Geological Survey's data base of water use in 1990 would also be available for comparison.

Another method of verification would be to rerun the Study Board models for 1985, for example, but to replace certain assumptions, such as number of nuclear powerplants, with documented data. If the resulting water-use values are closer to the IJC's or Geological Survey's data than previously, some of the higher projections could be eliminated.

SUMMARY AND CONCLUSIONS

The Hydraulics, Hydrology and Climate group, formed by the International Joint Commission in 1987, has been delegated the task of reviewing the consumptive-use values previously generated by the International Great Lakes Diversions and Consumptive Uses Study Board, the IJC, and the U.S. Geological Survey and assessing the magnitude and effects of consumptive water uses under present and future economic and hydraulic conditions; it also wishes to narrow the range of consumptive water-use projections from the 5,640- to 9,890-ft^3/s range presented by the IJC for the year 2000. The procedure introduced in this report results in a range of consumptive water-use projections of 6,520 to 9,170 ft^3/s for the year 2000.

Two alternative projections have been calculated from more recent base-year data through projection by (1) a rate of increase calculated by the IJC, and (2) a rate of increase indicated by the Geological Survey's 1980-85 data. In addition to the many assumptions that are inherent in a projection model, the assumption applied in the first alternative is that the IJC's rate of increase will remain constant, even with a new base-year (1985) value. This assumption may or may not be valid because initial values do affect model output. Therefore, a further refinement would be to rerun the water-use forecast models from the new base-year value rather than apply a predefined rate of increase to a new base-year value.

The second alternative applies a rate of increase per year that is defined by only two data points--1980 and 1985. This rate also is suspect if the Geological Survey's estimates for 1980 are too low. This rate could be reexamined after the Geological Survey publishes data for 1990; then three data points would be available. (Geological Survey data for 1975 are published, but the methods used to generate the estimates were inconsistent among the States and were undocumented in many States.)

The alternative projections apply only to the United States part of the basin, but similar analysis could be done with Canadian data if data are available now that were unavailable when the Study Board and IJC made their projections.

The primary difficulty in making any water-use projection is that assumptions need to be made in regard to socioeconomic conditions that can markedly change for unforeseen reasons. These can be due to political decisions, international situations, and changes in social and environmental laws. The IJC believes that projecting to longer than 20 or 25 years is too uncertain to be useful.

One alternative to consumptive-use forecasting is estimation of current conditions. This procedure identifies and characterizes the key water users and derives their consumptive use from coefficients. The coefficients can differ greatly from facility to facility, however, and the application of only one coefficient per type of industry can yield erroneous results.

Another alternative would be data collection. This may be done through direct inventory of users or direct acquisition of data from agencies or groups that collect reported data. One source of consumptive-use data or estimates for the basin is the Great Lakes Commission in Ann Arbor, Mich.;

another is the agencies and ministries that have the legal authority to issue permits and registrations or to collect water-use data. Alternatively, one may contact the water users directly by questionnaire, although some degree of inaccuracy and a poor rate of voluntary compliance are possible.

The most direct method of acquiring accurate data may be to obtain it directly from the agencies and ministries that receive reported data or through the Great Lakes Regional Water-Use Data Base. As a result of the Great Lakes Charter, areas that do not have the legal framework to collect water-use data (such as New York State) are introducing legislation to do so or to supplement current programs. The agencies or ministries that do not already collect data are generating estimates from sources such as the National Water-Use Information Program of the U.S. Geological Survey. These data and estimates are expected to become more accurate as the data-collection programs become more consistent and techniques more refined. These data can then be used to represent base years from which projections can be made.

Even while making projections to the year 2035, the Study Board concluded that consumptive uses need to be monitored periodically. The acquisition of reports of metered withdrawal and return data seems a logical long-range goal that could eventually eliminate the difficulties that this group is experiencing in obtaining consumptive-use values.

SELECTED REFERENCES

Burt, R. J., 1983, Problems in estimating self-supplied industrial water use by indirect methods--the California example: U.S. Geological Survey Water-Resources Investigations Report 83-4276, 20 p.

Congressional Research Service of The Library of Congress, 1980, State and National water use trends to the year 2000 [Prepared for the Committee on environment and public works, U.S. Senate]: Washington D.C., 297 p.

Croley, T. E., II, 1983, Great Lake basins (U.S.A.-Canada) runoff modeling: Journal of Hydrology, v. 64, p. 135-158.

----- 1987, The Great Lakes large basin runoff model, in Proceedings: American Society of Civil Engineers symposium, Engineering hydrology, Williamsburg, Va., p. 14-25.

Davis, W. Y., Rodrigo, D. M., Opitz, E. M., Dziegielewski, Bennedykt, and Boland, J. J., 1987, IWR-MAIN water use forecasting system, version 5.0, User's manual and system description: Carbondale, Ill., Planning and Management Consultants, Ltd., 214 p.

Donahue, M. J., Bixby, Alicia, and Siebert, David, 1985, Great Lakes diversion and consumptive use--the issue in perspective: Chicago, Ill., Center for the Great Lakes, 24 p.

SELECTED REFERENCES (continued)

Giusti, E. V., and Meyer, E. L., 1977, Water consumption by nuclear powerplants and some hydrological implications: U.S. Geological Survey Circular 745, 14 p.

Great Lakes Governors Task Force on Water Diversions and Great Lakes Institutions, 1985, Water diversion and Great lakes institutions: Madison, Wis., Council of Great Lakes Governors, 46 p.

Huber, A. L., Haws, F. W., Huges, T. C., Bagley, J. M., Hubbard, K. G., and Richardson, E. A., 1982, Consumptive use and water requirements for Utah: State of Utah, Department of Natural Resources, 92 p.

International Great Lakes Diversions and Consumptive Uses Study Board, 1981a, Great Lakes diversions and consumptive uses: International Joint Commission, 243 p.

______1981b, Great Lakes diversions and consumptive uses, Annex F, Consumptive water use: International Joint Commission, 151 p.

______ 1981c, Great Lakes diversions and consumptive uses, Annex G, Evaluation of diversion management scenarios and consumptive water use projections: International Joint Commission, 147 p.

International Joint Commission, 1985, Great Lakes diversions and consumptive uses: International Joint Commission, 82 p.

______ 1987, Plan of study-concerning the reference on fluctuating water levels in the Great Lakes - St. Lawrence River basin: International Joint Commission, 33 p.

______ 1988, Plan of study concerning the reference on fluctuating water levels in the Great Lakes-St. Lawrence River basin: International Joint Commission, 21 p.

Kammerer, J. C., 1976, Water quantity requirements for public supplies and other uses, in Gehm, H. W. and Bregman, J. I., Handbook of water resources and pollution control: New York, Van Nostrand-Reinhold, p. 44-83.

______1982, estimated demand of water for different purposed, in Water for human consumption, man and his environment, precongress-published papers: Buenos Aires, Argentina, IVth world Congress of the International Water Resources association, p. 141-172.

Loucks, E. D., Joeres, E. F., Potter, K. W., David, M. H., and Rosenthal, S. S., 1987, Diversion of Great Lake water, part 1, hydrologic effects: Madison, University of Wisconsin, Institute for Environmental Studies, 69 p.

McAvoy, P. V., 1985, The Great Lakes Charter--toward a basin-wide strategy for managing the Great Lakes: Chicago, Ill., Center for the Great Lakes, 24 p.

SELECTED REFERENCES (continued)

Milliken, W. G., 1984, Effects of the Great lakes on the regional economy, in Proceedings, Ontario water Resources Conference, Futures in water: Toronto, Ontario Government, p. 12-17.

Murray, C. R., and Reeves, E. B., 1977, Estimated water use in the United States in 1975: U.S. Geological Survey Circular 765, 37 p.

Oak Ridge National Laboratory, 1980, State water use and socioeconomic data related to the second national water assessment [Prepared for U.S. Water Resources Council]:, Oak Ridge, Tenn., 45 p.

Pinsak, A. P., 1984a, Effects of the energy crisis and economic downturn on the international Great Lakes diversions and consumptive uses study board consumptive water use projections: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 7 p.

_____ 1984b, Manufacturing water use model: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 36 p.

_____ 1985, Thermal-electric power generation water use model: U.S. Department of Commerce, National Oceanic and Atmospheric administration, 35 p.

Planning and Management Consultants, Ltd., 1987, Forecasting urban water use--the IWR-MAIN model; system description: Carbondale, Ill., Planning and Management Consultants, Ltd., 27 p.

Pope, A. W., 1984, Ontario's water resources, in Proceedings, Ontario Water Resources Conference, Futures in Water: Toronto, Ontario, Ontario Government, p. 34-39.

Schefter, J. E., and Moody, D. W., 1981, Water use data - who needs it?: Water Resources Bulletin, v. 17, no. 6, p. 978-986.

Shepherd, A. D., Hodgson, M. E., Stewart, J., and Hake, K. A., 1980, State water use and socioeconomic data related to the second national water assessment: U.S. Water Resources Council, 151 p.

Snavely, D. S., 1986, Water-use data-collection programs and regional data base of the Great Lakes - St. Lawrence River basin States and Provinces: U.S. Geological Survey Open-file report 86-546, 204 p.

Solley, W. B., Chase, E. B., and Mann, W. B., IV, 1983, Estimated use of water in the United States in 1980: U.S. Geological Survey Circular 1001, 56 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.

SELECTED REFERENCES (Continued)

Sugarman, R. J., 1985, Binding ties, tying bonds--international options for constraints on Great Lakes diversions: Chicago, Ill., Center for the Great Lakes, 34 p.

U.S. Office of Management and Budget, 1972, Standard industrial classification manual: Washington, D.C., Statistical Policy Division, 649 p.

U.S. Water Resources Council, 1978, The nation's water resources, 1975-2000, v. 1, summary: Washington, D.C., Second national water assessment by the U.S. Water Resources Council, 86 p.

Viessman, Warren Jr., and DeMoncada, Christine, 1980, State and national water use trends to the year 2000: Library of Congress, Congressional research service, 297 p.

Water Data Collection Task Force, 1985, Survey and preliminary evaluation of the present water use data collection systems in the Great Lakes States and Provinces: Ann Arbor, Mich., Great lakes Commission, 46 p.

Water Resources Management Committee (appointed by the governors and premiers of the Great Lakes States and Canadian Provinces), 1987, Managing the waters of the Great Lakes basin: Water Resources Management Committee, 47 p.

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