An Analysis of Water Use In Minnesota

Report to the

Legislative Commission on Minnesota Resources

by the

Department of Natural Resources

Division of Waters

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Introduction

This report is a product of the Water Allocation and Management Program, a two-year project funded by the Legislative Commission on Minnesota Resources. The goal of this project was to develop a plan that will guide the allocation and management of water in Minnesota. Accomplishing this goal required a thorough understanding of the use of water in the state. This report describes the methods used to analyze Minnesota water use and the results which were obtained.

The results of this analysis were used as inputs to a computer simulation model of the Minnesota economy developed by the Department of Agricultural Economics of the University of Minnesota and the Natural Resources Research Institute at Duluth. This Interactive Policy Analysis Simulation System (IPASS) model (formerly SIMLAB) analyzes the economic value of water to the state and the impacts of changes in water supply on economic production.

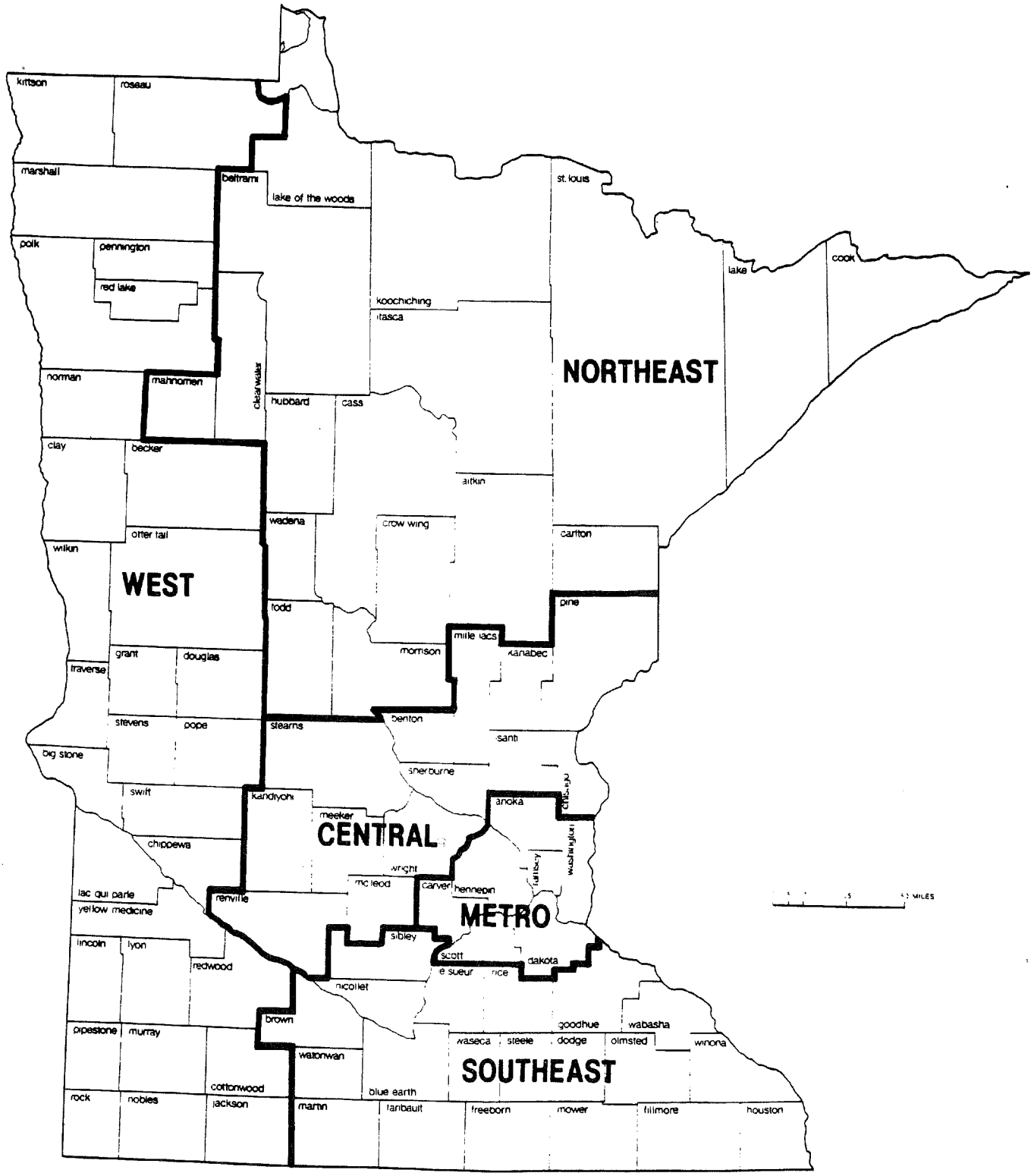
Objective

The primary objective of this analysis was to provide water use data for the water module used by IPASS. The requirements of the model strictly defined both the type of data collected and the format in which it was presented. All water use data had to be made compatible with the economic data of the model.

The IPASS model treats water as a necessary input for economic production. Each unit of output requires a specific volume of water as an input. The total water demand for each sector is determined by the average volume required per unit of production and the total number of units produced.

There are seventy-four economic sectors in the model; these sectors are aggregates of Standard Industrial Classifications (SIC's). IPASS actually includes six models: one state model and five sub-state regional models. The regional boundaries define the general economic subregions of the state (Figure 1). The base year of the models is 1982 - the most recent year for which complete economic data are available.

FIGURE 1. MINNESOTA ECONOMIC REGIONS



The water use data needed for the model were:

1. The total volumes of water withdrawn by each economic sector, by region, by resource (either surface or ground water) in 1982;

2. The volumes of water withdrawn for household use, by region, by resource, in 1982;

3. Any changes in withdrawal which would occur in response to various scenarios, such as a drought.

A second objective of this analysis was to aggregate the volumes of water withdrawn for each of the economic regions and for the thirty-nine principal watersheds in the state, so that comparisons could be made between withdrawals, volumes required for instream uses (for recreation, fish and wildlife habitat, navigation, waste assimilation, etc.), and total water supplies. This comparison did not utilize IPASS, since the computer simulation does not operate at the watershed level. These aggregations were completed using 1985 water use data in order to incorporate any possible changes in water use since 1982 and to make the most recent information on water withdrawals available to water resource managers.

For the purposes of the study, water withdrawal was defined as "water removed from the ground or diverted from a surface-water source for use" (Solley, Chase, and Mann, 1983). Water consumed is "water that is no longer available because it has been evaporated, transpired, incorporated into products or crops, consumed by man or livestock, or otherwise removed from the water environment" (Ibid). The acre-foot is used as the basic unit of water measurement. One acre-foot is the volume of water it takes to cover one acre of land with one foot of water, or 325,851 gallons.

Methodology

As the agency responsible for the regulation of water withdrawals, the Minnesota Department of Natural Resources (DNR) is the primary source of water use data in the State. The DNR Division of Waters collects and stores withdrawal data as part of its water appropriation permit program. Minnesota Statute 105.41 requires an appropriation permit for any withdrawal in excess of 10,000 gallons per day or 1,000,000 gallons per year. Only domestic use by fewer than twenty-five people is exempt from the permit requirement. Permit holders must submit annual reports of the volumes of water withdrawn. These pumpage data are stored on the State Water Use Database System (SWUDS), which is maintained by the DNR on a PRIME computer at the St. Paul office of the U.S. Geological Survey. For this project, SWUDS datafiles were modified and downloaded to an IBM-XT personal computer. Data were stored and analyzed using INFO, a database management system produced by Henco Software, Inc.

The procedures used to generate the water use data can be summarized as follows:

1. Code of all records of water use by Standard Industrial Classification (SIC).

2. Verify the accuracy of reported withdrawal data.

3. Estimate volumes of unreported water use.

4. Aggregate data by region into seventy-four economic sectors.

5. Disaggregate volumes of water withdrawn by municipal supply systems according to the end use among the sectors.

6. Estimate volumes of household water use from all sources.

7. Estimate volumes of water consumed based on volumes of water withdrawn and the type of use.

8. Estimate variations in water use in response to various scenarios.

Each step in this analysis will be described separately.

Standard Industrial Classifications

The IPASS model uses aggregations of data based on Standard Industrial Classifications (SIC's). Therefore each record of water use had to be codified by its SIC according to the Standard Industrial Classification Manual, 1972 edition. In some cases, this coding was complicated by the nature of the water use or the way in which some uses are evaluated by the model. Four uses which required special consideration were air conditioning, irrigation, lake level maintenance, and use by the 3M Company.

Circulating groundwater through cooling systems is a common method of air conditioning in Minnesota. Categorization of this use of water was based on the ownership of the building being cooled. Owner-occupied buildings were coded according to the SIC of the owner. Buildings owned by a real estate management firm but occupied by one or more other firms were coded under SIC 6512, "Operators of non-residential buildings".

Water used for irrigation of agricultural crops was coded under the general category 0100, "Agricultural production". Often, farmers rotate their crops, planting corn one year and soybeans the next, for example. Use of the general category acknowledges this fact, allowing the data to be applicable for more than one year. If it was known that only one crop was cultivated, the operation was classified accordingly. Thus, wild rice irrigators were coded as 0119, apple orchards as 0175, etc.

It was necessary to distinguish among the types of organizations that pump water to raise or lower the levels of lakes and wetlands. Public agencies were coded as 9511 or 9512, "Administration of environmental quality programs"; private organizations were usually coded as 6552, "Real estate subdividers and developers". Private organizations using water for wildlife management were coded as 0971, "Hunting and trapping, and game propagation".

Minnesota Mining and Manufacturing (3M Company) presented a special problem for coding because of the wide variety of its products and its numerous manufacturing plants. Determining the quantities of water used for each product at each plant was impractical. Therefore, reported water use for all 3M plants in the Minneapolis/St. Paul metropolitan area was arbitrarily assigned as shown in Table 1.

Table 1

Estimated Water Use - Minnesota Mining and Manufacturing Co.

SIC	Name	Appropriation (acre-feet)
2641	Paper coating and glazing	11,245
2899	Chemicals and chemical preparations	1,138
3079	Miscellaneous plastic products	949
3291	Abrasive products	1,462
3679	Electronic components	881
3861	Photographic equipment and supplies	307

Reported Water Use

All DNR water appropriation permit holders are required to monitor and report the volumes of water pumped during each calendar year. Rates of compliance with this provision of the permits are about 85% among agricultural irrigation water users and 95% among all other users. Although the volumes of water reported are required to be accurate to within 10%, no method of confirming this degree of accuracy is available. Flow meters are required only for pumping rates greater than 1500 gallons per minute. Most pumpage below that rate is estimated based on the capacity of the pump. Since the actual capacity of a pump generally declines over time, the accuracy of this estimation method is questionable at best. Skepticism regarding the accuracy of reported data must be tempered by the understanding that they are the best numbers available.

In an attempt to minimize the introduction of errors into the analysis, the computer datafiles containing pumpage data were compared to the original water use reports submitted by permit holders for all uses other than irrigation. This check was used to verify the accuracy of data entry and to locate and correct any arithmetic errors made by the permit holder. Irrigation reports

were not verified because of the large number of users (approximately 4,000) and the relatively small volumes of water used by each irrigation permit holder.

Estimated Water Use

For those uses where reported pumpage data were not available, it was necessary to estimate water withdrawal based on other sources of information. Uses for which data are not available at the DNR fall into three major categories: 1) appropriations of water below levels requiring a permit, 2) unauthorized appropriations of water in excess of minimum levels, 3) appropriation by valid permit holders who fail to report use. Different procedures were used to estimate pumpage volumes for each of these categories.

A DNR permit is required for the pumping of more than 10,000 gallons per day or one million gallons per year. The major uses excluded by these minimum levels are self-supplied residences and most livestock operations. Estimates of these uses were based on county level statistics and aggregated into regional and statewide totals. Methodologies for estimating residential water use are described later in this report.

The amounts of water used for raising livestock were taken from estimates made by the U.S. Geological Survey. County populations of twenty different livestock categories were multiplied by average daily water consumption per animal type. For the model, these county totals were then combined into dairy and poultry use (economic sector one) and meat and animal use (sector two). In accordance with the U.S. Geological Survey's estimates, it was assumed that 85% of all livestock operations use ground water for their drinking water supplies, except turkey farms, which are assumed to use ground water exclusively (Trotta).

It is difficult to determine the volumes of water used by non-permitted water appropriators in the state. The fact that these users have no permit means that the DNR is unaware of their water use or that their use is known and the DNR has been unable to bring them into compliance with the permit requirements. Where appropriate, other state agencies were consulted and their lists of water users were compared to lists of DNR permit holders. The Minnesota Pollution Control Agency, which regulates water discharge, was a source of information on uses of all types. The Minnesota Department of Health, which regulates drinking supply

systems, provided information on mobile home parks, apartment complexes, and campgrounds. Annual volumes of water were estimated based on the MPCA or MDH data available.

For those water users under permit who did not submit the required annual report of water use for 1982, estimates were made based on reports submitted in previous or subsequent years (where available), or on the volumes of water authorized to be taken under their permits. Estimates were not made for irrigation permits because farmers may not irrigate their crops every year. Some water appropriators who were operating without a permit in 1982 have since been brought under compliance. Estimates of their use were made based on their reported use in subsequent years or on their authorized appropriation amounts.

Aggregation into Economic Sectors

IPASS uses aggregates of data based on standard industrial classifications. The 74 economic sectors and their corresponding SIC's are listed in Table 2. Where a SIC is allocated among two or more sectors, the fraction allocated to each sector is given ("*" indicates multiplication). Each computer record of estimated and reported withdrawal is coded by SIC, source (either surface or ground water), and location. These data were aggregated into the appropriate sector using INFO software programming. Ground and surface withdrawals were totalled separately. All summations were done according to geographic region and then combined to yield a statewide total. Results are given in Tables 3 and 4. As will be explained below, these are not the final aggregations used in the IPASS model. In order to distinguish these results from other data, they will be referred to as the results of the "straight" method, because they come straight from reported water use data.

Disaggregation of Public Water Supply Withdrawals

The economic sector that withdraws water is not necessarily the same sector that actually uses the water to produce a unit of output. For instance, public water supply systems, which are included in Sector 61, provide water to almost all other sectors. In order for IPASS to evaluate the total water requirements for each sector, the water withdrawn by public water supply systems had to be broken down to reflect its end use among the seventy-four sectors, use by private

TABLE 2. ECONOMIC SECTORS USED BY IPASS

NO.	TITLE	SIC CODES
1	DAIRY & POULTRY	024,0251-0253,.5*0259,.25*0291,.167*0219 .25*0191
2	MEAT & ANIMAL PROD.	0211-0214,.5*0219,0271,0272,.5*0279,.25*0191,.167*0259 .25*0291
3	GRAINS	0111,0112,0115,.5*0119,7*0139,.25*0191,.167*0219, .167*0259,.25*0291
4	OTHER CROPS	.5*0119,0116,018,0173,0179,018,0131-0134,.3*0139, .25*0191,.167*0219,.25*0291,.166*0259, 0175
5	FOR. FISH. PROD.	081-084,091,097
6	AG.FOR.FISH.SERV.	0254,071,072,075,076,078,085,092,.5*0279
7	IRON ORE MINING	101,106
8	NONFERR. MINING	102-105,.5*108,109
9	COAL & PEAT	1111,1211,.5*1112,.5*1213
10	OIL & NAT. GAS	1311,1321
11	STONE,CLAY	141,142,144,145,.5*148,149
12	OTHER MINING	147
13	NEW CONSTRUCTION	.85*(15,16,17), .5*108,.5*1112,.5*1213,.33*138, .5*148,.5*6552
14	MAINT. & REPAIR	.15*(15,16,17),1215,.67*138
15	ORDN. & RELATED	348,3761,3795
16	MEAT PRODUCTS	201
17	DAIRY PRODUCTS	202
18	CANNED,FROZ.PROC.	203,2091,2092
19	GRAIN MILLING	204
20	BAKERY PRODUCTS	205
21	ALCH.BEV,SOFT DRNK	208
22	OTHER FOOD,TOBBACCO	206,207,2095,2097,2098,2099,21
23	TEXTILE GOODS	22 (EXCEPT FOR 225)
24	APPAREL,FABR.	225,23
25	LOGGING	241
26	SAWMILLS	242
27	OTHER WOOD PRODUCTS	243,244,2452,249
28	FURNITURE	25
29	PULP &PAPER	261-264,266
30	PAPERBOARD CONT.	265
31	PRINTING & PUBL.	27
32	CHEMICAL & ALLIED	28
33	PETR. REFINING	29
34	RUBBER PROD.	30
35	LEATHER PRODUCTS	31
36	GLASS,STONE,CLAY	32
37	PRIM. STEEL PRODUCTS	331
38	IRON & STL. FOUNDRY	332,339,3462
39	PRIMARY COPPER	3331,3351,3357,3362
40	OTHER PRIM. METALS	3332,3333,3334,3339,336(EXCEPT3362),3353-3356 3463,334
41	FABRICATED METALS	341-345,3465,3466,3469,347,349
42	FARM MACHINARY	352
43	MACHINE SHOPS	359
44	OTHER NONELECTRIC.	351,353-356
45	COMP.,OFF.MACHINES	357
46	SERV.,IND. MACHINES	358
47	ELECTRICAL MACHINES	36,3825
48	MOTOR VEHICLES	371(EXCL.3716)
49	OTHER TRANSPORT.	3716,372-375,3792,3799,2451,3764,3769
50	PROF., SCIENTIFIC	381,3822-3824,3829,384,387
51	OPT.OPHTH.,PHOTO.	383,385-386
52	MISC. MANUFACTURING	39
53	RAILROAD TRANSPORT.	40,474,.25*4789
54	LOCAL TRANSIT	.667*41
55	TRUCK TRANSIT	42,.25*4789
56	AIR TRANSPORTATION	45
57	OTHER TRANSPORT.	44,46,471,4723,4722,4782-4784,.5*4789
58	COMMUNICATIONS	48
59	ELECTRIC UTILITIES	491,.8*4931,.1*4932,.33*4939
60	GAS UTILITIES	492,.1*4931,.8*4932,.33*4939
61	WATER AND SANITATION	494-497, .1*4931,.1*4932,.33*4939
62	WHOLE TRADE	50,51
63	RETAIL TRADE	52-57,59,7396,8042
64	FINANCE,INSURANCE	60,61,62-64,67(EXCL.6732)
65	REAL ESTATE	65(EXCL.5*6552),66
66	HOTELS,ETC.	72,762-764,8361
67	BUSINESS SERVICES	731-737,7391-7395,7397,7399,769,81, 89(EXCEPT FOR 8922)
68	EAT & DRINK ESTABL.	58,70
69	AUTO REPS.	75
70	FILMS AND RECREATION	78,79
71	HEALTH SERVICES	80(EXCL.8042),074,
72	EDUC. NONPROFIT	6732,82,832,833,835,8399,84,86,8922
73	FED,STATE,LOCAL ENT.	.33*41,4311,.17*613
74	SCRAP,USED&SECOND	

TABLE 3. GROUND WATER WITHDRAWALS-STRAIGHT METHOD
(Acre-feet)

		NORTH	WEST	CENTRAL	METRO	SOUTH	TOTAL
		*****	****	*******	*****	*****	*****
1	DAIRY & POULTRY	3541.3	5214.6	6779.7	1255.6	6100.8	22892.0
2	MEAT & ANIMAL	3435.8	15496.7	6554.5	2699.0	16119.4	44305.4
3	FOOD/FEED GRAIN	13004.7	50046.2	33293.1	15731.4	5178.4	117253.8
4	OTHER CROPS	20.6	39.9	49.4	648.1	8.6	766.6
5	FOR/FISH PRODS	34.7	6.1	48.8	25.2	0.0	114.8
6	AG/FOR/FISH SER	1304.3	15.3	257.8	920.7	11699.8	14197.9
7	IRON ORE MINING	504.8	0.0	0.0	0.0	0.0	504.8
8	NONFERROUS MINE	0.0	0.0	0.0	0.0	0.0	0.0
9	COAL & PEAT	0.0	0.0	0.0	0.0	0.0	0.0
10	OIL & NAT. GAS	0.0	0.0	0.0	0.0	0.0	0.0
11	STONE & CLAY	140.6	1371.2	66.6	1139.5	60.2	2778.1
12	OTHER MINING	0.0	0.0	0.0	0.0	0.0	0.0
13	NEW CONSTRUCTN	0.3	0.0	0.0	161.7	0.0	162.0
14	MAINT. & REPAIR	0.0	0.0	0.0	28.5	0.0	28.5
15	ORDNANCE & REL	0.0	0.0	0.0	1828.4	0.0	1828.4
16	MEAT PRODUCTS	15.0	600.0	1055.1	276.2	3164.9	5111.2
17	DAIRY PRODUCTS	307.8	689.6	3128.1	1572.2	2979.3	8677.0
18	CANNED & FROZEN	0.0	224.0	772.7	465.6	3418.4	4880.7
19	GRAIN MILLING	16.9	1797.4	16.9	2852.5	70.3	4754.0
20	BAKERY PRODUCTS	0.0	0.0	15.3	30.1	0.0	45.4
21	BEVERAGES	0.0	0.0	59.5	10138.4	1043.4	11241.3
22	OTHER FOOD/TOB	18.4	15.3	56.8	2267.9	4112.6	6471.0
23	TEXTILE GOODS	0.0	0.0	0.0	0.0	171.6	171.6
24	APPAREL/FABRICS	0.0	0.0	0.0	0.0	0.0	0.0
25	LOGGING	0.0	0.0	0.0	0.0	0.0	0.0
26	SAWMILLS	0.0	0.0	0.0	0.0	0.0	0.0
27	WOOD PRODUCTS	6.1	0.0	0.0	664.4	0.0	670.5
28	FURNITURE	80.7	0.0	0.0	16.9	0.0	97.6
29	PULP & PAPER	2206.5	0.0	15.3	16265.1	21.2	18508.1
30	PAPERBOARD CONT	0.0	0.0	0.0	37.1	0.0	37.1
31	PRINT & PUBLISH	0.0	0.0	85.6	1194.4	0.0	1280.0
32	CHEMICAL/ALLIED	27.6	1282.8	0.0	3281.9	15.3	4607.6
33	PETROL REFINING	28.2	0.0	67.8	7215.9	0.0	7311.9
34	RUBBER PRODUCTS	0.0	0.0	128.3	3726.5	797.6	4652.4
35	LEATHER PRODUCT	0.0	0.0	0.0	0.0	484.6	484.6
36	CLAY/STONE/GLAS	1.2	156.8	34.4	2398.0	194.9	2785.3
37	PRIM STEEL PROD	4.3	0.0	0.0	529.1	0.0	533.4
38	IRON/STEEL FOUN	0.0	0.0	290.0	333.3	33.1	656.4
39	PRIMARY COPPER	0.0	0.0	0.0	0.0	0.0	0.0
40	OTHER METALS	0.0	0.0	0.0	69.0	0.0	69.0
41	FABRIC. METALS	81.6	0.0	0.0	3779.3	423.8	4284.7
42	FARM MACHINERY	0.0	0.0	0.0	227.1	16.9	244.0
43	MACHINE SHOPS	0.0	0.0	0.0	0.0	0.0	0.0
44	NONELECT MACH	0.0	0.0	0.0	403.6	0.0	403.6
45	COM/OFFICE MACH	0.0	0.0	0.0	708.3	80.4	788.7
46	SERV. IND. MACH	0.0	0.0	0.0	0.0	1.2	1.2
47	ELECTRIC MACH.	0.0	0.0	481.5	3636.0	509.4	4626.9
48	MOTOR VEHICLES	0.0	0.0	0.0	0.0	0.0	0.0
49	OTHER TRANSPORT	0.0	0.0	0.0	0.0	0.0	0.0
50	PROF/SCIENTIFIC	0.0	0.0	0.0	3414.4	16.6	3431.0
51	OPT.OPHTH.PHOT.	0.0	0.0	0.0	306.9	0.0	306.9
52	MISC.MANUFACTUR	0.0	0.0	0.0	372.6	0.0	372.6
53	RAILROAD TRANS	1.5	0.0	16.9	93.3	0.3	112.0
54	LOCAL TRANSIT	0.0	0.0	0.0	0.0	0.0	0.0
55	TRUCK TRANSIT	0.0	15.3	15.3	926.2	1.2	958.0
56	AIR TRANSPORT.	0.0	0.0	0.0	2178.0	0.0	2178.0
57	OTHER TRANS.	0.0	0.0	0.0	0.0	0.0	0.0
58	COMMUNICATIONS	0.0	0.0	0.0	593.2	0.0	593.2
59	ELECTRIC UTIL.	595.1	28.5	573.6	801.3	21587.2	23585.7
60	GAS UTILITIES	0.0	1.2	0.0	167.9	0.0	169.1
61	WATER & SANIT.	23418.4	29722.5	25906.9	142558.4	61305.0	282911.2
62	WHOLESALE TRADE	0.0	87.5	0.0	68.7	102.5	258.7
63	RETAIL TRADE	0.0	4.6	0.0	1602.3	15.3	1622.2
64	FINANCE/INSUR.	0.0	0.0	0.0	3203.6	0.0	3203.6
65	REAL ESTATE	238.8	251.3	443.5	9466.9	520.2	10920.7
66	HOTELS/SERVICES	105.9	84.4	42.4	1860.4	37.4	2130.5
67	BUSINESS SERV.	4.0	33.1	6.1	0.0	71.5	114.7
68	EAT/DRINK ESTBL	0.0	0.0	4.6	0.0	14.1	18.7
69	AUTO REPAIRS	0.0	0.0	0.0	0.0	0.0	0.0
70	FILM/RECREATION	133.5	179.2	577.9	3970.2	413.4	5274.2
71	HEALTH SERVICES	222.5	17.8	264.2	4961.2	824.9	6290.6
72	EDUC/NON-PROFIT	62.9	9.8	803.4	634.0	648.5	2158.6
73	GOVERNMENT	752.2	43.6	450.8	5937.1	22.7	7206.4
74	SCRAP	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	50316.2	107434.7	82362.8	269643.5	142286.9	652044.1

TABLE 4. SURFACE WATER WITHDRAWALS-STRAIGHT METHOD
(Acre-feet)

		NORTH *****	WEST ****	CENTRAL *******	METRO *****	SOUTH *****	TOTAL *****
1	DAIRY & POULTRY	0.0	0.0	0.0	0.0	0.0	0.0
2	MEAT & ANIMAL	133.8	0.0	0.0	0.0	0.0	133.8
3	FOOD/FEED GRAIN	18937.5	11520.0	4047.9	1126.9	3947.5	39579.8
4	OTHER CROPS	11.0	13.2	8.3	35.3	16.6	84.4
5	FOR/FISH PRODS	0.0	145.8	0.0	0.0	0.0	145.8
6	AG/FOR/FISH SER	776.4	0.0	1263.8	0.0	0.0	2040.2
7	IRON ORE MINING	250917.1	0.0	0.0	0.0	0.0	250917.1
8	NONFERROUS MINE	0.0	0.0	0.0	0.0	0.0	0.0
9	COAL & PEAT	0.0	0.0	0.0	0.0	0.0	0.0
10	OIL & NAT. GAS	0.0	0.0	0.0	0.0	0.0	0.0
11	STONE & CLAY	1268.7	555.5	543.5	21883.9	4752.2	29003.8
12	OTHER MINING	0.0	0.0	0.0	0.0	0.0	0.0
13	NEW CONSTRUCTN	1238.3	27.3	0.0	0.9	11.4	1277.9
14	MAINT. & REPAIR	0.9	4.6	0.0	0.0	1.8	7.3
15	ORDNANCE & REL	0.0	0.0	0.0	6.1	0.0	6.1
16	MEAT PRODUCTS	0.0	11.7	0.0	0.0	214.5	226.2
17	DAIRY PRODUCTS	0.0	175.5	1729.6	0.0	0.0	1905.1
18	CANNED & FROZEN	0.0	0.0	0.0	0.0	0.0	0.0
19	GRAIN MILLING	0.0	0.0	0.0	0.0	0.0	0.0
20	BAKERY PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0
21	BEVERAGES	0.0	0.0	0.0	0.0	0.0	0.0
22	OTHER FOOD/TOB	0.0	1212.8	4.6	0.0	0.0	1217.4
23	TEXTILE GOODS	0.0	0.0	0.0	0.0	0.0	0.0
24	APPAREL/FABRICS	0.0	0.0	0.0	0.0	0.0	0.0
25	LOGGING	0.0	0.0	0.0	0.0	0.0	0.0
26	SAWMILLS	0.0	0.0	0.0	0.0	0.0	0.0
27	WOOD PRODUCTS	6.4	0.0	0.0	0.0	0.0	6.4
28	FURNITURE	0.0	0.0	0.0	0.0	0.0	0.0
29	PULP & PAPER	72483.1	0.0	5038.8	0.0	0.0	77521.9
30	PAPERBOARD CONT	0.0	0.0	0.0	0.0	0.0	0.0
31	PRINT & PUBLISH	0.0	0.0	0.0	0.0	0.0	0.0
32	CHEMICAL/ALLIED	399.0	0.0	0.0	0.0	0.0	399.0
33	PETROL REFINING	0.0	0.0	0.0	0.0	0.0	0.0
34	RUBBER PRODUCTS	0.0	0.0	0.0	0.0	0.0	0.0
35	LEATHER PRODUCT	0.0	0.0	0.0	0.0	0.0	0.0
36	CLAY/STONE/GLAS	304.7	69.4	197.3	0.0	0.0	571.4
37	PRIM STEEL PROD	53019.0	0.0	0.0	0.0	0.0	53019.0
38	IRON/STEEL FOUN	0.0	0.0	0.0	0.0	0.0	0.0
39	PRIMARY COPPER	0.0	0.0	0.0	0.0	0.0	0.0
40	OTHER METALS	0.0	0.0	0.0	0.0	0.0	0.0
41	FABRIC. METALS	0.0	0.0	0.0	0.0	260.9	260.9
42	FARM MACHINERY	0.0	0.0	0.0	0.0	0.0	0.0
43	MACHINE SHOPS	0.0	0.0	0.0	0.0	0.0	0.0
44	NONELECT MACH	0.0	0.0	0.0	0.0	0.0	0.0
45	COM/OFFICE MACH	0.0	0.0	0.0	0.0	0.0	0.0
46	SERV. IND. MACH	0.0	0.0	0.0	0.0	0.0	0.0
47	ELECTRIC MACH.	0.0	0.0	0.0	0.0	0.0	0.0
48	MOTOR VEHICLES	0.0	0.0	0.0	191.5	0.0	191.5
49	OTHER TRANSPORT	0.0	0.0	0.0	0.0	0.0	0.0
50	PROF/SCIENTIFIC	0.0	0.0	0.0	0.0	0.0	0.0
51	OPT.OPHTH.PHOT.	0.0	0.0	0.0	0.0	0.0	0.0
52	MISC.MANUFACTUR	0.0	0.0	0.0	0.0	0.0	0.0
53	RAILROAD TRANS	3.7	0.0	0.0	0.0	0.0	3.7
54	LOCAL TRANSIT	0.0	0.0	0.0	0.0	0.0	0.0
55	TRUCK TRANSIT	0.0	0.0	0.0	0.0	0.0	0.0
56	AIR TRANSPORT.	0.0	0.0	0.0	0.0	0.0	0.0
57	OTHER TRANS.	26.4	0.0	0.0	0.3	0.0	26.7
58	COMMUNICATIONS	0.0	0.0	0.0	0.0	0.0	0.0
59	ELECTRIC UTIL.	152485.4	68143.1	279840.2	502155.3	390805.6	1393429.6
60	GAS UTILITIES	10.7	0.0	0.0	0.0	8.6	19.3
61	WATER & SANIT.	33593.3	9694.9	5410.8	181367.6	1964.4	232031.0
62	WHOLESALE TRADE	0.0	0.0	0.0	0.0	0.0	0.0
63	RETAIL TRADE	0.0	0.0	0.0	0.0	0.0	0.0
64	FINANCE/INSUR.	0.0	0.0	0.0	0.0	0.0	0.0
65	REAL ESTATE	0.0	0.0	0.0	142.4	0.0	142.4
66	HOTELS/SERVICES	157.4	0.0	1.8	0.0	0.0	159.2
67	BUSINESS SERV.	0.0	0.0	0.0	0.0	0.0	0.0
68	EAT/DRINK ESTBL	0.0	0.0	0.0	0.0	0.0	0.0
69	AUTO REPAIRS	0.0	0.0	0.0	0.0	0.0	0.0
70	FILM/RECREATION	231.7	385.8	184.7	334.8	116.3	1253.3
71	HEALTH SERVICES	0.0	0.0	0.0	0.0	0.0	0.0
72	EDUC/NON-PROFIT	64.8	2.8	18.7	15.3	0.0	101.6
73	GOVERNMENT	214.8	58.0	9715.2	1022.6	877.4	11888.0
74	SCRAP	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	586284.1	92020.4	308005.2	708282.9	402977.2	2097569.8

households, and use at the treatment plants operated by the utilities themselves.

The first step in this procedure was to survey all public water supply systems in the state (See Appendix) to determine:

1. the amount of water supplied for residential, commercial, industrial, recreation, and treatment use, and

2. more detailed information regarding the large water users supplied by the utility.

A similar survey was sent to all DNR appropriation permit holders who use water for any purpose other than public water supply or irrigation. This survey (See Appendix) requested information regarding:

1. the product or service provided by the user (to determine or confirm the assigned standard industrial classification),

2. the use to which the water is put,

3. the volumes purchased from a public supply system (if any),

4. the percent of water withdrawn which is consumed, and

5. the water disposal method.

The response rate for both surveys was fair. Forty percent of municipal survey forms were returned, while thirty percent of the industrial surveys were returned. A limited effort was made to follow up on non-respondents. Cities with populations greater than 10,000 were contacted by telephone or through a second letter. The three largest electric utilities in the state (Northern States Power, Minnesota Power, and Ottertail Power) were contacted a second time by letter, but no response was received.

Survey forms were not sent to the cities of Minneapolis and St. Paul. Instead, DNR staff contacted the water utilities of these cites directly to obtain meter readings for all municipal water supply connections using more than 100,000 cubic feet per month (approximately nine million gallons per year). St. Paul provided monthly data for 1985; Minneapolis provided readings for 1982.

Neither the DNR permit records nor the surveys could provide water use data for the majority of businesses in the state which purchase water from municipal utilities. Estimation of their use required the identification of secondary data sources that could serve as indicators of the volumes of water needed for each sector. For the purpose of the IPASS simulation model, it was not necessary to estimate these volumes for each municipality. Only aggregate data for five regions and the state are required.

When choosing a secondary data source, it is important to select a variable which displays a high correlation with water withdrawal. Two IPASS variables, total output and employment, have this characteristic. If output or employment is known, then total water use for each sector can be estimated based on an average volume of water per unit of output or per employee, as follows:

Equation I

$$\text{Total Sector } \mathbf{OUTPUT} \times \frac{\text{Average } \mathbf{WATER\ USE}}{\text{Unit of } \mathbf{OUTPUT}} = \text{Total Sector } \mathbf{WATER\ USE}$$

Equation II

$$\text{Total Sector } \mathbf{EMPLOYMENT} \times \frac{\text{Average } \mathbf{WATER\ USE}}{\text{Employee}} = \text{Total Sector } \mathbf{WATER\ USE}$$

Equations I and II assume that there is a linear relationship between output and water use or between employment and water use. As output or employment increases, so does water use, and vice versa. In addition, the amount of water required for production does not change over time or with the size or location of the firm. This assumption greatly simplifies the analysis and is consistent with the way all other variables are treated in IPASS.

Equation I is particularly significant because IPASS uses this equation to calculate total water demand based on the total dollar value of output produced by each sector. The ratio of water use to output, crucial to this equation, cannot be calculated for individual firms, however, because output per firm is always proprietary information. This constraint is circumvented for IPASS by aggregating both water use and output to the regional level, then dividing output by water use to obtain the needed ratio. This technique is not applicable at this point in the analysis, however, because an indicator of water use by individual businesses is required.

While output data for individual firms are not available, employment data per firm (for Equation II) are available using the Minnesota Directory of Manufacturers. This source lists the number of employees at each manufacturing plant in the state. Thus, for those plants where the total water use is known, an average water use per employee can be calculated. This technique was used to calculate average employee water use for all economic sectors for which data were available. Where data for more than one facility were available for a sector, the average water withdrawal was weighted according to the number of employees at each facility.

Employment or water use data for individual facilities were not available for some sectors, however, making applicability impossible in every case. In these instances, other methods were required. For sectors dominated by large numbers of very small firms, such as bakery products, an average volume of water per facility was estimated, and total water for the sector was calculated based on the number of facilities in the state or region. More complex methods were required for some sectors, though.

Use of water among most of the service-oriented sectors is generally limited to personal use among employees and small volumes required for office cleaning. For these sectors, a minimum water use was arbitrarily set at 7300 gallons per

year per employee. In a few sectors, water use was expected to be greater than this minimum value but no data were available to determine an average consumption. Average use per employee in these instances was assumed to be the same as the amounts used by employees in sectors which involved similar activities. Thus, for example, non-ferrous mining was assumed to require the same amount of water as sand and gravel operations. Finally, no average water use per employee was estimated for those sectors not expected to use municipal water supplies (such as irrigation) or for which total water use was accounted for based on reported and estimated use for individual facilities (such as electric utilities).

Table 5 shows the method used to calculate the total water use and the average water use per employee for each IPASS sector. The following descriptions summarize the estimation methods used:

Gallons per Animal:	Total water use was calculated based on an average water use per animal times the total number of animals in each region.
Reported plus Estimated:	Total water use was assumed to be the sum of all water use reported by permitted users and estimates for known but non-reporting users.
Reported:	Total water use was assumed to be the sum of all water use reported by permitted users. Assumes all users are covered by permit.
No Water Use:	IPASS economic datafiles indicate no output for these sectors, therefore no water use was estimated.
Minimum Gallons per Employee:	Assumes all water use for these sectors is for personal use by employees and for office cleaning. Average annual employee use derived from sample data.

Average Gallons per Employee: Average annual water withdrawal per employee calculated using the formula:

$$\frac{\text{Sum of Volume of water withdrawn by sample firms}}{\text{Sum of Number employees in sample firms.}}$$

This number was then multiplied by the total number of employees in that sector to obtain an estimate of total water use.

Number of Firms in Sector: An average volume of water used by firms in this sector was derived from sample data. Total water use was estimated by multiplying this average by the total number of firms listed in the Minnesota Directory of Manufacturers.

Similar to (X): Sample data were not available for these sectors, therefore average water use was assumed to be the same as that of Sector (X) with similar operations.

Reported plus a Minimum Gallons per Employee: It is assumed that for most firms in these sectors, the only water used is for personal use by employees and for office cleaning. However, some firms in these sectors use water for purposes not directly related to production. These uses include circulation of water through coolant systems for air conditioning, lawn watering, irrigation of golf courses, and snow making for skiing facilities. Reported water use by permit holders was added to minimum water use per employee to estimate total water use.

Table 5. Aggregation Techniques for End Use Method

Sector	Name	Average Water Use per Employee (gallons/year)	Estimation Method Used
1	Dairy & Poultry	N.A.	Gal./Animal
2	Meat & Animal	N.A.	Gal./Animal
3	Food/Feed Grain	N.A.	Rep. + Est.
4	Other Crops	N.A.	Rep. + Est.
5	Forest/Fish Products	7,300**	Rep.
6	Agri./Forest/Fish Services	1,112,800**	Rep.
7	Iron Ore Mining	9,407,000**	Rep.
8	Non-ferrous Mining	N.A.	No Water Use
9	Coal & Peat Mining	N.A.	No Water Use
10	Oil & Natural Gas Mining	7,300	Min. Gal./Emp.
11	Stone & Clay Mining	7,059,441**	Rep.
12	Other Mining	N.A.	No Water Use
13	New Construction	7,300	Rep.
14	Maintenance & Repair	7,300	Min. Gal./Emp.
15	Ordnance & Related	107,140	Gal./Emp.
16	Meat Products	252,060	Gal./Emp.
17	Dairy Products	612,570	Gal./Emp.
18	Canned & Frozen	420,870	Gal./Emp.
19	Grain Milling	1,089,700	Gal./Emp.
20	Bakery Products	220,133**	No. of Firms
21	Beverages	1,036,800	Gal./Emp.
22	Other Food/Tobacco	2,107,605**	No. of Firms
23	Textile Goods	234,874	Gal./Emp.
24	Apparel/Fabrics	7,300	Min. Gal./Emp.
25	Logging	7,300	Min. Gal./Emp.
26	Sawmills	7,300	Min. Gal./Emp.
27	Wood Products	68,054	Gal./Emp.
28	Furniture	56,121	Gal./Emp.
29	Pulp and Paper	1,193,000	Gal./Emp.
30	Paperboard Containers	192,000	Gal./Emp.
31	Printing & Publishing	204,570	Gal./Emp.

Table 5 (cont.)

Sector	Name	Average Water Use per Employee (gallons/year)	Estimation Method Used
32	Chemical & Allied	500,310	Gal./Emp.
33	Petroleum Refining	2,427,800	Gal./Emp.
34	Rubber Products	385,540	Gal./Emp.
35	Leather Products	188,780	Gal./Emp.
36	Glass, Stone, Clay	170,340	Gal./Emp.
37	Primary Steel Products	14,461,000	Gal./Emp.
38	Iron & Steel Foundary	537,000	Gal./Emp.
39	Primary Copper	537,000	Similar to 38
40	Other Primary Metals	300,000	Gal./Emp.
41	Fabricated Metals	646,650	Gal./Emp.
42	Farm Machinery	141,960	Gal./Emp.
43	Machine Shops	7,300	Gal./Emp.
44	Other Nonelectric Machines	26,964	Gal./Emp.
45	Computers, Office Mach.	24,855	Gal./Emp.
46	Service Industry Machines	13,285	Gal./Emp.
47	Electrical Machines	132,430	Gal./Emp.
48	Motor Vehicles	121,430	Gal./Emp.
49	Other Transportation	66,512	Gal./Emp.
50	Professional, Scientific Equip.	81,973	Gal./Emp.
51	Optical, Ophthalmic, Photographic	81,973	Similar to 50
52	Miscellaneous Manufacturing	81,973	Similar to 50
53	Railroad Transportation	8,500*	Gal./Emp.
54	Local Transit	7,300	Min. Gal./Emp.
55	Truck Transit	7,300	Min. Gal./Emp.
56	Air Transportation	86,212*	Gal./Emp.
57	Other Transportation	7,300	Min. Gal./Emp.
58	Communications	37,820*	Gal./Emp.
59	Electric Utilities	46,532,000**	Rep. + Est.

Table 5 (cont.)

Sector	Name	Average Water Use per Employee (gallons/year)	Estimation Method Used
60	Gas Utilities	25,000*	Gal./Emp.
61	Water & Sanitation	599,161**	No. of Firms
62	Wholesale Trade	68,000	Rep. + Min. Gal./Emp.
63	Retail Trade	96,471	Rep. + Min. Gal./Emp.
64	Finance & Insurance	90,484	Rep. + Min. Gal./Emp.
65	Real Estate	7,300	Rep. + Min. Gal./Emp.
66	Hotels, Etc.	161,890	Rep. + Min. Gal./Emp.
67	Business Services	7,300	Rep. + Min. Gal./Emp.
68	Eating & Drinking Establishments	40,000	Rep. + Min. Gal./Emp.
69	Auto Repair	11,000	Rep. + Min. Gal./Emp.
70	Film & Recreation	N.A.	Rep. + Min. Gal./Emp.
71	Health Services	26,183	Rep. + Min. Gal./Emp.
72	Education & Non-profit	28,000	Rep. + Min. Gal./Emp.
73	Government	7,300	Rep. + Min. Gal./Emp.
74	Scrap	N.A.	N.A.

*Employment data obtained from telephone survey of sample firms.

**Average water use was calculated for this table, but was not used to estimate total water use for the sector.

These methods were used to calculate the total volumes of water used per sector for each of the five economic regions of the state. The results were then compared to the total water use based on the "straight method" (Tables 2 and 3). For each sector, if the reported water use was greater than the estimates based on average employee use, then the reported volume was used as the final water use estimate. If the estimated use was larger than the reported, then the difference was assumed to be the water supplied by public utilities.

The next step in the analysis was to apportion these volumes of water supplied by public utilities into the amounts withdrawn from ground and surface water sources. Since these were regional totals, there was no direct method of determining the exact source of water for any sector. The only available data were the total amounts of ground and surface waters withdrawn by municipalities in each region. Therefore, for the portion of total sector water withdrawals that was supplied by public utilities, the ratio of ground to surface water use was assumed to be the same as the average ratio of ground to surface withdrawals by municipalities in the region.

In summary, the following equation was used to reapportion total water use in each sector according to its end use:

For each sector in each region:

Average Water use Per Employee	*	Total Number of Employees	-	Reported Water Use	=	Water Supplied by Municipalities

Water Supplied by Municipalities	*	Percent of Region's municipal Water supplies Coming From Ground water	=	Ground water Supplied by Municipalities

The amount of surface water supplied by municipalities is the remainder after subtracting the ground water from the total for each sector.

This process, which shall be referred to as the "end use" method, was used to calculate total water use for each region. The state total is the sum of all regional totals. These results were used for the IPASS model (Tables 6 and 7).

TABLE 6. GROUND WATER WITHDRAWALS-END USE METHOD
(Acre-feet)

		NORTH *****	WEST ****	CENTRAL *******	METRO *****	SOUTH *****	TOTAL *****
1	DAIRY & POULTRY	3436.5	5214.6	6780.0	1255.6	6101.2	22787.9
2	MEAT & ANIMAL	3436.5	15496.7	6554.8	2699.0	16119.0	44306.0
3	FOOD/FEED GRAIN	8734.6	41501.5	32365.6	12400.4	3271.2	98273.3
4	OTHER CROPS	4290.7	8584.6	49.4	3979.1	1915.8	18819.6
5	FOR/FISH PRODS	34.7	6.1	48.8	25.2	0.0	114.8
6	AG/FOR/FISH SER	1304.3	15.3	257.8	920.7	11699.8	14197.9
7	IRON ORE MINING	504.8	0.0	0.0	0.0	0.0	504.8
8	NONFERROUS MINE	1724.7	0.0	0.0	0.0	0.0	1724.7
9	COAL & PEAT	0.0	0.0	0.0	0.0	0.0	0.0
10	OIL & NAT. GAS	0.0	0.0	0.0	0.0	0.0	0.0
11	STONE & CLAY	140.6	1371.2	66.6	1139.5	60.2	2778.1
12	OTHER MINING	0.0	0.0	0.0	0.0	0.0	0.0
13	NEW CONSTRUCTN	1.8	2.8	4.0	173.7	5.8	188.1
14	MAINT. & REPAIR	9.2	12.6	24.2	88.0	32.2	166.2
15	ORDNANCE & REL	0.0	0.0	0.0	2823.0	0.0	2823.0
16	MEAT PRODUCTS	139.0	1028.4	1429.5	397.7	4429.0	7423.6
17	DAIRY PRODUCTS	369.2	1236.8	3664.5	1997.2	4051.0	11318.7
18	CANNED & FROZEN	397.1	589.5	1199.6	904.1	4318.8	7409.1
19	GRAIN MILLING	111.7	2495.9	995.3	11382.5	3579.3	18564.7
20	BAKERY PRODUCTS	50.3	22.1	186.5	496.3	118.8	874.0
21	BEVERAGES	66.0	166.3	129.5	10753.1	1304.6	12419.5
22	OTHER FOOD/TOB	437.9	9570.6	2071.2	8616.2	4306.6	25002.5
23	TEXTILE GOODS	16.6	0.0	0.0	51.1	117.5	185.2
24	APPAREL/FABRICS	2.1	0.0	9.5	26.6	27.2	65.4
25	LOGGING	8.9	0.0	0.3	0.0	0.3	9.5
26	SAWMILLS	11.0	0.3	0.9	0.3	2.5	15.0
27	WOOD PRODUCTS	217.5	130.1	160.8	812.0	110.2	1430.6
28	FURNITURE	82.5	0.0	9.5	133.8	246.4	472.2
29	PULP & PAPER	2472.0	3.7	15.3	18387.2	45.1	20923.3
30	PAPERBOARD CONT	0.0	0.0	0.0	947.9	68.4	1016.3
31	PRINT & PUBLISH	676.7	590.1	1007.2	7837.9	3820.5	13932.4
32	CHEMICAL/ALLIED	79.5	1325.8	0.0	5737.9	720.2	7863.4
33	PETROL REFINING	28.2	46.6	67.8	9279.4	0.0	9422.0
34	RUBBER PRODUCTS	154.1	40.8	1719.2	5536.8	1134.6	8585.5
35	LEATHER PRODUCT	0.0	0.0	0.0	126.1	848.0	974.1
36	CLAY/STONE/GLAS	56.1	247.6	184.5	2553.9	391.3	3433.4
37	PRIM STEEL PROD	8.0	0.0	0.0	651.9	77.3	737.2
38	IRON/STEEL FOUN	160.8	0.0	290.0	1208.5	346.4	2005.7
39	PRIMARY COPPER	6.8	0.0	0.0	317.0	0.0	323.8
40	OTHER METALS	0.0	0.0	0.0	681.5	243.7	925.2
41	FABRIC. METALS	1099.9	1720.7	4509.4	14397.3	5146.8	26874.1
42	FARM MACHINERY	3.1	297.7	174.3	525.7	550.0	1550.8
43	MACHINE SHOPS	1.8	6.1	12.3	54.9	16.6	91.7
44	NONELECT MACH	30.1	35.3	51.7	866.7	203.8	1187.6
45	COM/OFFICE MACH	11.4	47.3	22.4	1453.1	598.4	2132.6
46	SERV. IND. MACH	0.3	0.6	0.0	102.5	33.7	137.1
47	ELECTRIC MACH.	0.0	181.4	694.5	5541.8	1719.2	8136.9
48	MOTOR VEHICLES	4.3	14.7	49.1	319.2	206.2	593.5
49	OTHER TRANSPORT	58.0	52.2	33.1	58.6	78.3	280.2
50	PROF/SCIENTIFIC	2.1	0.0	121.8	4403.2	67.5	4594.6
51	OPT.OPHTH.PHOT.	3.1	0.0	129.2	404.2	15.3	551.8
52	MISC.MANUFACTUR	61.7	21.5	64.8	874.1	0.0	1022.1
53	RAILROAD TRANS	29.4	19.0	30.7	126.4	13.8	219.3
54	LOCAL TRANSIT	6.4	10.1	19.0	47.3	33.1	115.9
55	TRUCK TRANSIT	35.9	73.3	59.2	1089.8	95.1	1353.3
56	AIR TRANSPORT.	13.8	6.8	0.0	2498.1	43.3	2562.0
57	OTHER TRANS.	5.8	2.1	1.2	26.4	5.5	41.0
58	COMMUNICATIONS	91.8	138.1	124.6	1012.4	263.9	1630.8
59	ELECTRIC UTIL.	595.1	28.5	573.6	801.3	21587.2	23585.7
60	GAS UTILITIES	2.1	2.7	6.4	195.8	15.3	222.3
61	WATER & SANIT.	295.5	154.1	356.3	491.3	579.4	1876.6
62	WHOLESALE TRADE	54.9	185.7	124.3	806.8	270.1	1441.8
63	RETAIL TRADE	263.0	417.1	472.9	2538.9	807.4	4499.3
64	FINANCE/INSUR.	107.4	221.3	159.3	3467.8	418.0	4373.8
65	REAL ESTATE	57.5	94.2	71.5	8406.6	149.8	8779.6
66	HOTELS/SERVICES	148.9	141.2	88.4	2084.7	172.7	2635.9
67	BUSINESS SERV.	41.4	57.0	52.1	733.2	118.1	1001.8
68	EAT/DRINK ESTBL	100.4	163.3	164.5	610.4	330.8	1369.4
69	AUTO REPAIRS	5.2	9.8	9.8	85.6	26.4	136.8
70	FILM/RECREATION	146.4	204.4	600.9	4104.6	458.5	5514.8
71	HEALTH SERVICES	580.6	689.3	686.5	5268.7	2138.4	9363.5
72	EDUC/NON-PROFIT	196.7	209.6	974.3	1591.8	1102.1	4074.5
73	GOVERNMENT	776.4	68.2	483.9	6116.9	80.7	7526.2
74	SCRAP	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	34000.8	94973.3	70214.3	185447.2	106858.3	491494.0

Table 8. Residential Water Use
(acre-feet)

	Municipal Supplies	Non-Municipal Supply Systems	Self-Supplied	Total Ground Water	Total Surface* Water	Total
West	22,757.6	224.5	20,920.5	38,304.2	5,598.4	43,902.6
Northeast	30,707.0	237.6	19,030.1	31,882.1	18,092.6	49,974.7
Central	17,791.3	443.1	21,850.8	37,010.9	3,074.3	40,085.2
Metro	213,330.9	1,760.8	63,982.2	159,629.9	119,444.0	279,073.9
Southeast	38,451.3	519.8	18,606.1	56,385.2	1,172.0	57,577.2
State	323,038.1	3,185.8	144,389.7	323,212.3	147,381.3	470,593.6

*Note: Virtually all surface water use for residential purposes comes from municipal water supplies.

If a utility did not respond to the survey, then information regarding the percentage of water used by households was taken from DNR permit files. This information is requested from water utilities during the permit application process. If neither source of information was available, then the percent of water for residential use was estimated based on population served and reported or permitted use. These estimates assumed an average withdrawal of 88 gallons per person per day.

Private community water supply systems are required to have a DNR water appropriation permit if they serve more than 25 people. It was assumed that all of the water withdrawn by these systems was used for domestic purposes, so the 1982 reported volumes were simply aggregated by region and statewide to account for this water use.

A number of private community supply systems are not covered by a DNR appropriation permit, either because they serve fewer than 25 people or because they are appropriating in violation of statute. In order to identify these users, the list of DNR permits was compared to the Minnesota Department of Health's (MDH) list of non-municipal community systems. For those systems without a DNR permit, the Minnesota Department of Health estimate of annual water withdrawals was used.

Good sources of data regarding self-supplied residential use do not exist. The only way to estimate this use is by a process of elimination. Total county populations are known, as are the populations served by municipal and private community supply systems. It was assumed that the remaining populations in each county have their own water supplies. Therefore, the difference between the county populations and the known population served was multiplied by the standard estimate of average domestic water use employed by the U.S. Geological Survey (88 gallons per person per day, or 32,120 gallons per year) to estimate total self-supplied residential water use for each county. These numbers were then aggregated into regional and statewide totals.

Consumptive Water Use

Any computer simulation model uses sets of numbers and equations to describe a real-world system. These numbers and equations, by necessity, are simplifications of the real system they represent. Of all the assumptions built into the way IPASS analyzes water, the most significant is the decision to use the volumes of water withdrawn as a measure of the amounts of water required for the production of each unit of output in the economy.

For an individual production facility, withdrawal data are the most accurate reflection of the total amount of water required for production. However, aggregations of withdrawals by more than one facility over-estimate water requirements because they do not account for water which is returned to the source and then re-used by another production facility. For example, an electric power generation station uses very large quantities of water for cooling, but may return more than 97% of the total water withdrawn back into the stream from which it came.

An alternative to the use of withdrawal data in IPASS is the use of the volumes of water consumed by each sector. Aggregations of consumptive water use reflect the total amount of water which is no longer available for use downstream. However, consumption data underestimate total water needs; the fact that cooling water is returned to a river or lake does not diminish its value to the production facility. Analysis of consumptive use is also hampered by a lack of primary data. These volumes must be estimated from withdrawal data, adding another level of uncertainty to their accuracy.

After weighing the two alternatives, the DNR chose to use withdrawal data because doing so increases the likelihood that IPASS would identify situations where the amount of water available is not sufficient to meet the demands placed upon it. This decision follows the conservative approach used by DNR throughout this project. Moreover, the impacts of the choice are less significant for appropriations of ground water, since we assume that only a small percentage of ground water withdrawal is returned to the aquifer source from which it came.

Despite its decision to use withdrawal data for the IPASS simulations, the DNR chose to proceed with an analysis of the consumptive use of water, believing that the data would be valuable as an information source for water resource management. Like withdrawal data, consumptive water use data were evaluated two different ways. The "straight" method was based on reported water use from DNR appropriation permit holders and estimates of unreported use. Water use was correlated to the facility making the withdrawal of water from the surface or ground water source. All water withdrawn by municipalities was assigned to IPASS sector 59, water utilities. The "end use" method assigned all water withdrawals according to their end use among the 74 sectors or to residential use. Estimates of consumptive use were then made based on withdrawal volumes.

For the "straight" method, a consumption coefficient was assigned to each appropriation of water based on its standard industrial classification and type of use. This consumption coefficient was simply an estimate of the percent of the water withdrawn which was consumed. For all manufacturing uses, the consumption coefficient was taken from the U.S. Department of Commerce, Bureau of the Census, 1982 Census of Manufactures, "Water Use in Manufacturing". In most cases, a coefficient was calculated for each three digit SIC code. If the three digit coefficient was not available, the more general two digit coefficient was used. For non-manufacturing sectors, the value assigned for the consumption coefficient was based on the end use of the water. These values were taken from a variety of sources (See Table 9). The coefficients were multiplied by the 1982 pumpage data to obtain the estimated consumptive use for each facility. These amounts were then aggregated by economic sector for each region and the state.

Table 9. Consumption Assumptions

D.N.R. Use Code	S.I.C.	Use Type	% Consumed	Information Source Key
80-95	100-199	Irrigation except Wild Rice	90	a
96	119	Wild Rice Irrigation	85	a
9	200-299	Livestock	100	a
72	279,921	Hatcheries & Fisheries	10	a
43	1000-1099	Mineral Processing (Metals)	36.8	b
44	1400-1499	Mineral Processing (Sand & Gravel)	13.1	b
51	1500-1799	Construction (not dewatering)	99	a
52	1500-1799	Construction (dewatering)	0	a
40-49	2000-3999	Industrial	varies	c
20-25	4911	Electric Power Generation	varies	d
53	4920,4610	Pipeline and Tank testing	3	a
10-16	4941,etc.	Waterworks (municipal & private)	10	e
40	7210	Laundry, Cleaning, Garment Services	12	f
73	7999	Snow Making	80	a
30-32	various	Air Conditioning	3	f
33-34	various	Heating, Coolant pumps	3	f
35	various	District Heating	3	f
54	various	Landscape Watering (temporary)	80	a
60-69	various	Water Level Maintenance	0	a
55,71	various	Pollution Confinement	0	a

a. First order approximation.
b. The Nation's Water Resources, 1975-2000.
c. 1982 Census of Manufactures, Water Use in Manufacturing.
d. Westinghouse Hanford Co., Unpublished.
e. Solley, Chase, and Mann, 1983.
f. Results of DNR telephone survey of individual businesses.

TABLE 10. GROUND WATER CONSUMPTION-STRAIGHT METHOD
(Acre-feet)

		NORTH	WEST	CENTRAL	METRO	SOUTH	TOTAL
		*****	****	*******	*****	*****	*****
1	DAIRY & POULTRY	3541.30	5214.60	6779.70	1255.60	6100.80	22892.00
2	MEAT & ANIMAL	3435.80	15496.70	6554.50	2699.00	16119.40	44305.40
3	FOOD/FEED GRAIN	12354.42	47551.49	31636.55	14942.72	4920.04	111405.22
4	OTHER CROPS	19.64	38.05	46.95	616.85	5.83	727.32
5	FOR/FISH PRODS	32.84	0.00	46.34	0.00	0.00	79.18
6	AG/FOR/FISH SER	130.43	15.34	33.45	92.07	1183.67	1454.96
7	IRON ORE MINING	83.17	0.00	0.00	0.00	0.00	83.17
8	NONFERROUS MINE	0.00	0.00	0.00	0.00	0.00	0.00
9	COAL & PEAT	0.00	0.00	0.00	0.00	0.00	0.00
10	OIL & NAT. GAS	0.00	0.00	0.00	0.00	0.00	0.00
11	STONE & CLAY	18.41	179.53	8.59	149.76	7.67	363.96
12	OTHER MINING	0.00	0.00	0.00	0.00	0.00	0.00
13	NEW CONSTRUCTN	0.31	0.00	0.00	6.14	0.00	6.45
14	MAINT. & REPAIR	0.00	0.00	0.00	0.92	0.00	0.92
15	ORDNANCE & REL	0.00	0.00	0.00	240.91	0.00	240.91
16	MEAT PRODUCTS	1.23	46.03	81.02	21.18	243.98	393.44
17	DAIRY PRODUCTS	23.02	51.56	236.00	117.85	224.95	653.38
18	CANNED & FROZEN	0.00	25.78	89.00	55.55	393.43	563.76
19	GRAIN MILLING	0.92	112.94	0.92	122.14	3.99	240.91
20	BAKERY PRODUCTS	0.00	0.00	5.22	10.13	0.00	15.35
21	BEVERAGES	0.00	0.00	13.50	2317.62	238.76	2569.88
22	OTHER FOOD/TOB	0.61	2.46	11.97	355.68	625.44	996.16
23	TEXTILE GOODS	0.00	0.00	0.00	0.00	21.79	21.79
24	APPAREL/FABRICS	0.00	0.00	0.00	0.00	0.00	0.00
25	LOGGING	0.00	0.00	0.00	0.00	0.00	0.00
26	SAWMILLS	0.00	0.00	0.00	0.00	0.00	0.00
27	WOOD PRODUCTS	0.92	0.00	0.00	274.36	0.00	275.28
28	FURNITURE	2.46	0.00	0.00	0.61	0.00	3.07
29	PULP & PAPER	124.60	0.00	0.92	1233.08	0.61	1359.21
30	PAPERBOARD CONT	0.00	0.00	0.00	3.99	0.00	3.99
31	PRINT & PUBLISH	0.00	0.00	6.75	65.06	0.00	71.81
32	CHEMICAL/ALLIED	2.15	429.64	0.00	685.90	5.22	1122.91
33	PETROL REFINING	3.99	0.00	9.82	3285.86	0.00	3299.67
34	RUBBER PRODUCTS	0.00	0.00	25.47	695.10	155.90	876.47
35	LEATHER PRODUCT	0.00	0.00	0.00	0.00	31.92	31.92
36	CLAY/STONE/GLAS	0.61	27.31	13.81	400.49	43.89	486.11
37	PRIM STEEL PROD	0.31	0.00	0.00	53.71	0.00	54.02
38	IRON/STEEL FOUN	0.00	0.00	73.96	84.09	8.59	166.64
39	PRIMARY COPPER	0.00	0.00	0.00	0.00	0.00	0.00
40	OTHER METALS	0.00	0.00	0.00	8.29	0.00	8.29
41	FABRIC. METALS	8.29	0.00	0.00	176.77	39.28	224.34
42	FARM MACHINERY	0.00	0.00	0.00	6.75	0.61	7.36
43	MACHINE SHOPS	0.00	0.00	0.00	0.00	0.00	0.00
44	NONELECT MACH	0.00	0.00	0.00	16.27	0.00	16.27
45	COM/OFFICE MACH	0.00	0.00	0.00	21.18	2.46	23.64
46	SERV. IND. MACH	0.00	0.00	0.00	0.00	0.00	0.00
47	ELECTRIC MACH.	0.00	0.00	19.95	232.93	39.90	292.78
48	MOTOR VEHICLES	0.00	0.00	0.00	0.00	0.00	0.00
49	OTHER TRANSPORT	0.00	0.00	0.00	0.00	0.00	0.00
50	PROF/SCIENTIFIC	0.00	0.00	0.00	276.51	9.82	286.33
51	OPT.OPHTH.PHOT.	0.00	0.00	0.00	28.23	0.00	28.23
52	MISC.MANUFACTUR	0.00	0.00	0.00	24.86	0.00	24.86
53	RAILROAD TRANS	0.31	0.00	1.84	9.21	0.00	11.36
54	LOCAL TRANSIT	0.00	0.00	0.00	0.00	0.00	0.00
55	TRUCK TRANSIT	0.00	0.61	0.61	30.08	0.00	31.30
56	AIR TRANSPORT.	0.00	0.00	0.00	822.15	0.00	822.15
57	OTHER TRANS.	0.00	0.00	0.00	0.00	0.00	0.00
58	COMMUNICATIONS	0.00	0.00	0.00	17.80	0.00	17.80
59	ELECTRIC UTIL.	120.74	0.92	407.86	368.57	360.02	1258.11
60	GAS UTILITIES	0.00	0.00	0.00	4.91	0.00	4.91
61	WATER & SANIT.	2336.34	2974.67	2590.14	13899.60	6093.58	27894.33
62	WHOLESALE TRADE	0.00	0.00	0.00	5.83	0.00	5.83
63	RETAIL TRADE	0.00	0.61	0.00	98.51	1.53	100.65
64	FINANCE/INSUR.	0.00	0.00	0.00	120.91	0.00	120.91
65	REAL ESTATE	23.63	24.55	45.11	502.68	54.32	650.29
66	HOTELS/SERVICES	32.84	11.35	4.91	156.21	3.68	208.99
67	BUSINESS SERV.	0.00	3.38	0.61	0.00	7.37	11.36
68	EAT/DRINK ESTBL	0.00	0.00	0.61	0.00	0.92	1.53
69	AUTO REPAIRS	0.00	0.00	0.00	0.00	0.00	0.00
70	FILM/RECREATION	126.75	158.05	464.32	3241.97	363.97	4355.06
71	HEALTH SERVICES	22.40	1.84	26.39	175.54	56.77	282.94
72	EDUC/NON-PROFIT	21.79	1.23	56.77	131.66	73.35	284.80
73	GOVERNMENT	48.79	1.84	45.73	250.73	2.15	349.24
74	SCRAP	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	22519.02	72370.48	49339.29	50414.52	37445.61	232088.92

TABLE 11. SURFACE WATER CONSUMPTION-STRAIGHT METHOD
(Acre-feet)

		NORTH	WEST	CENTRAL	METRO	SOUTH	TOTAL
		*****	****	*******	*****	*****	*****
1	DAIRY & POULTRY	0.00	0.00	0.00	0.00	0.00	0.00
2	MEAT & ANIMAL	13.50	0.00	0.00	0.00	0.00	13.50
3	FOOD/FEED GRAIN	15458.91	9170.14	3283.10	1070.73	735.61	29718.49
4	OTHER CROPS	10.74	12.58	7.98	33.45	15.65	80.40
5	FOR/FISH PRODS	0.00	0.00	0.00	0.00	0.00	0.00
6	AG/FOR/FISH SER	77.64	0.00	126.44	0.00	0.00	204.08
7	IRON ORE MINING	40044.07	0.00	0.00	0.00	0.00	40044.07
8	NONFERROUS MINE	0.00	0.00	0.00	0.00	0.00	0.00
9	COAL & PEAT	0.00	0.00	0.00	0.00	0.00	0.00
10	OIL & NAT. GAS	0.00	0.00	0.00	0.00	0.00	0.00
11	STONE & CLAY	4.91	72.43	35.29	232.93	256.56	602.12
12	OTHER MINING	0.00	0.00	0.00	0.00	0.00	0.00
13	NEW CONSTRUCTN	5.83	27.01	0.00	0.92	3.99	37.75
14	MAINT. & REPAIR	0.92	4.60	0.00	0.00	0.31	5.83
15	ORDNANCE & REL	0.00	0.00	0.00	0.00	0.00	0.00
16	MEAT PRODUCTS	0.00	0.92	0.00	0.00	16.57	17.49
17	DAIRY PRODUCTS	0.00	13.20	129.81	0.00	0.00	143.01
18	CANNED & FROZEN	0.00	0.00	0.00	0.00	0.00	0.00
19	GRAIN MILLING	0.00	0.00	0.00	0.00	0.00	0.00
20	BAKERY PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00
21	BEVERAGES	0.00	0.00	0.00	0.00	0.00	0.00
22	OTHER FOOD/TOB	0.00	249.19	0.61	0.00	0.00	249.80
23	TEXTILE GOODS	0.00	0.00	0.00	0.00	0.00	0.00
24	APPAREL/FABRICS	0.00	0.00	0.00	0.00	0.00	0.00
25	LOGGING	0.00	0.00	0.00	0.00	0.00	0.00
26	SAWMILLS	0.00	0.00	0.00	0.00	0.00	0.00
27	WOOD PRODUCTS	1.53	0.00	0.00	0.00	0.00	1.53
28	FURNITURE	0.00	0.00	0.00	0.00	0.00	0.00
29	PULP & PAPER	8304.10	0.00	256.87	0.00	0.00	8560.97
30	PAPERBOARD CONT	0.00	0.00	0.00	0.00	0.00	0.00
31	PRINT & PUBLISH	0.00	0.00	0.00	0.00	0.00	0.00
32	CHEMICAL/ALLIED	11.97	0.00	0.00	0.00	0.00	11.97
33	PETROL REFINING	0.00	0.00	0.00	0.00	0.00	0.00
34	RUBBER PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00
35	LEATHER PRODUCT	0.00	0.00	0.00	0.00	0.00	0.00
36	CLAY/STONE/GLAS	44.19	14.42	7.06	0.00	0.00	65.67
37	PRIM STEEL PROD	5252.09	0.00	0.00	0.00	0.00	5252.09
38	IRON/STEEL FOUN	0.00	0.00	0.00	0.00	0.00	0.00
39	PRIMARY COPPER	0.00	0.00	0.00	0.00	0.00	0.00
40	OTHER METALS	0.00	0.00	0.00	0.00	0.00	0.00
41	FABRIC. METALS	0.00	0.00	0.00	0.00	0.00	0.00
42	FARM MACHINERY	0.00	0.00	0.00	0.00	0.00	0.00
43	MACHINE SHOPS	0.00	0.00	0.00	0.00	0.00	0.00
44	NONELECT MACH	0.00	0.00	0.00	0.00	0.00	0.00
45	COM/OFFICE MACH	0.00	0.00	0.00	0.00	0.00	0.00
46	SERV. IND. MACH	0.00	0.00	0.00	0.00	0.00	0.00
47	ELECTRIC MACH.	0.00	0.00	0.00	0.00	0.00	0.00
48	MOTOR VEHICLES	0.00	0.00	0.00	19.64	0.00	19.64
49	OTHER TRANSPORT	0.00	0.00	0.00	0.00	0.00	0.00
50	PROF/SCIENTIFIC	0.00	0.00	0.00	0.00	0.00	0.00
51	OPT.OPHTH.PHOT.	0.00	0.00	0.00	0.00	0.00	0.00
52	MISC.MANUFACTUR	0.00	0.00	0.00	0.00	0.00	0.00
53	RAILROAD TRANS	3.68	0.00	0.00	0.00	0.00	3.68
54	LOCAL TRANSIT	0.00	0.00	0.00	0.00	0.00	0.00
55	TRUCK TRANSIT	0.00	0.00	0.00	0.00	0.00	0.00
56	AIR TRANSPORT.	0.00	0.00	0.00	0.00	0.00	0.00
57	OTHER TRANS.	0.92	0.00	0.00	0.00	0.00	0.92
58	COMMUNICATIONS	0.00	0.00	0.00	0.00	0.00	0.00
59	ELECTRIC UTIL.	17818.45	215.44	11291.35	1454.96	27233.80	58014.00
60	GAS UTILITIES	0.31	0.00	0.00	0.00	0.31	0.62
61	WATER & SANIT.	3359.51	962.10	541.04	18136.82	196.41	23195.88
62	WHOLESALE TRADE	0.00	0.00	0.00	0.00	0.00	0.00
63	RETAIL TRADE	0.00	0.00	0.00	0.00	0.00	0.00
64	FINANCE/INSUR.	0.00	0.00	0.00	0.00	0.00	0.00
65	REAL ESTATE	0.00	0.00	0.00	0.00	0.00	0.00
66	HOTELS/SERVICES	120.30	0.00	0.00	0.00	0.00	120.30
67	BUSINESS SERV.	0.00	0.00	0.00	0.00	0.00	0.00
68	EAT/DRINK ESTBL	0.00	0.00	0.00	0.00	0.00	0.00
69	AUTO REPAIRS	0.00	0.00	0.00	0.00	0.00	0.00
70	FILM/RECREATION	220.35	365.81	175.54	318.24	111.09	1191.03
71	HEALTH SERVICES	0.00	0.00	0.00	0.00	0.00	0.00
72	EDUC/NON-PROFIT	54.32	2.76	17.80	14.42	0.00	89.30
73	GOVERNMENT	6.44	3.68	0.00	3.07	0.00	13.19
74	SCRAP	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	90814.68	11114.28	15872.89	21285.18	28570.30	167657.33

TABLE 12. GROUND WATER CONSUMPTION-END USE METHOD
(Acre-feet)

		NORTH	WEST	CENTRAL	METRO	SOUTH	TOTAL
		*****	****	*******	*****	*****	*****
1	DAIRY & POULTRY	3436.5	5214.6	6780.0	1255.6	6101.2	22787.9
2	MEAT & ANIMAL	3436.5	15496.7	6554.8	2699.0	16119.0	44306.0
3	FOOD/FEED GRAIN	7424.4	35276.3	27510.8	10540.3	2780.5	83532.3
4	OTHER CROPS	3647.1	7296.9	42.0	3382.2	1628.4	15996.7
5	FOR/FISH PRODS	10.5	1.9	14.8	7.7	0.0	34.9
6	AG/FOR/FISH SER	133.0	1.6	26.3	93.9	1193.4	1448.2
7	IRON ORE MINING	80.8	0.0	0.0	0.0	0.0	80.8
8	NONFERROUS MINE	0.0	0.0	0.0	0.0	0.0	0.0
9	COAL & PEAT	0.0	0.0	0.0	0.0	0.0	0.0
10	OIL & NAT. GAS	0.0	0.0	0.0	0.0	0.0	0.0
11	STONE & CLAY	4.2	41.1	2.0	34.2	1.8	83.3
12	OTHER MINING	0.0	0.0	0.0	0.0	0.0	0.0
13	NEW CONSTRUCTN	0.1	0.1	0.1	5.4	0.2	5.8
14	MAINT. & REPAIR	1.7	2.4	4.6	16.6	6.1	31.4
15	ORDNANCE & REL	0.0	0.0	0.0	369.8	0.0	369.8
16	MEAT PRODUCTS	10.7	79.2	110.1	30.6	341.0	571.8
17	DAIRY PRODUCTS	27.7	92.8	274.8	149.8	303.8	848.9
18	CANNED & FROZEN	46.1	68.4	139.2	104.9	501.0	859.5
19	GRAIN MILLING	5.7	127.3	50.8	580.5	182.5	946.8
20	BAKERY PRODUCTS	17.0	7.5	63.0	167.7	40.2	295.4
21	BEVERAGES	15.1	38.1	29.7	2462.5	298.8	2844.1
22	OTHER FOOD/TOB	70.9	1550.4	335.5	1395.8	697.7	4050.4
23	TEXTILE GOODS	5.3	0.0	0.0	16.4	37.6	59.3
24	APPAREL/FABRICS	0.3	0.0	1.2	3.4	3.5	8.4
25	LOGGING	1.5	0.0	0.1	0.0	0.1	1.7
26	SAWMILLS	1.5	0.0	0.1	0.0	0.3	2.1
27	WOOD PRODUCTS	89.0	53.2	65.8	332.1	45.1	585.1
28	FURNITURE	2.6	0.0	0.3	4.1	7.6	14.6
29	PULP & PAPER	254.6	0.4	1.6	1893.9	4.6	2155.1
30	PAPERBOARD CONT	0.0	0.0	0.0	102.4	7.4	109.8
31	PRINT & PUBLISH	37.9	33.0	56.4	438.9	213.9	780.2
32	CHEMICAL/ALLIED	18.0	301.0	0.0	1302.5	163.5	1785.0
33	PETROL REFINING	12.7	21.0	30.6	4185.0	0.0	4249.3
34	RUBBER PRODUCTS	29.0	7.7	323.2	1040.9	213.3	1614.1
35	LEATHER PRODUCT	0.0	0.0	0.0	8.3	56.0	64.3
36	CLAY/STONE/GLAS	9.2	40.6	30.3	418.8	64.2	563.1
37	PRIM STEEL PROD	0.8	0.0	0.0	64.5	7.7	73.0
38	IRON/STEEL FOUN	40.8	0.0	73.7	307.0	88.0	509.4
39	PRIMARY COPPER	0.7	0.0	0.0	32.7	0.0	33.4
40	OTHER METALS	0.0	0.0	0.0	81.8	29.2	111.0
41	FABRIC. METALS	53.9	84.3	221.0	705.5	252.2	1316.8
42	FARM MACHINERY	0.1	8.9	5.2	15.8	16.5	46.5
43	MACHINE SHOPS	0.0	0.0	0.0	0.0	0.0	0.0
44	NONELECT MACH	2.0	2.4	3.5	58.9	13.9	80.8
45	COM/OFFICE MACH	0.3	1.4	0.7	43.6	18.0	64.0
46	SERV. IND. MACH	0.0	0.0	0.0	3.5	1.1	4.7
47	ELECTRIC MACH.	0.0	11.4	43.8	349.1	108.3	512.6
48	MOTOR VEHICLES	0.4	1.5	5.1	32.9	21.2	61.1
49	OTHER TRANSPORT	4.4	3.9	2.5	4.4	5.9	21.0
50	PROF/SCIENTIFIC	0.2	0.0	10.1	365.5	5.6	381.4
51	OPT.OPHTH.PHOT.	0.3	0.0	11.9	37.2	1.4	50.8
52	MISC.MANUFACTUR	4.1	1.4	4.3	58.6	0.0	68.5
53	RAILROAD TRANS	3.8	2.5	4.0	16.4	1.8	28.5
54	LOCAL TRANSIT	0.6	1.0	1.9	4.7	3.3	11.6
55	TRUCK TRANSIT	1.2	2.4	2.0	36.0	3.1	44.7
56	AIR TRANSPORT.	5.2	2.6	0.0	941.8	16.3	965.9
57	OTHER TRANS.	0.2	0.1	0.0	0.9	0.2	1.4
58	COMMUNICATIONS	2.8	4.1	3.7	30.4	7.9	48.9
59	ELECTRIC UTIL.	25.0	1.2	24.1	33.7	906.7	990.6
60	GAS UTILITIES	0.1	0.1	0.2	5.7	0.4	6.4
61	WATER & SANIT.	29.3	15.3	35.3	48.6	57.4	185.8
62	WHOLESALE TRADE	1.3	4.3	2.9	18.6	6.2	33.2
63	RETAIL TRADE	16.3	25.9	29.3	157.4	50.1	279.0
64	FINANCE/INSUR.	4.1	8.4	6.1	131.8	15.9	166.2
65	REAL ESTATE	3.4	5.6	4.2	496.0	8.8	518.0
66	HOTELS/SERVICES	21.4	20.3	12.7	300.2	24.9	379.6
67	BUSINESS SERV.	4.1	5.6	5.2	72.6	11.7	99.2
68	EAT/DRINK ESTBL	8.2	13.4	13.5	50.1	27.1	112.3
69	AUTO REPAIRS	0.5	1.0	1.0	8.6	2.6	13.7
70	FILM/RECREATION	124.4	173.7	510.8	3488.9	389.7	4687.6
71	HEALTH SERVICES	26.1	31.0	30.9	237.1	96.2	421.4
72	EDUC/NON-PROFIT	32.7	34.8	161.7	264.2	182.9	676.4
73	GOVERNMENT	2.3	0.2	1.5	18.4	0.2	22.6
74	SCRAP	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	19250.6	66220.9	43680.9	41566.3	33395.1	204113.9

TABLE 13. SURFACE WATER CONSUMPTION-END USE METHOD
(Acre-feet)

		NORTH	WEST	CENTRAL	METRO	SOUTH	TOTAL
		*****	****	*******	*****	*****	*****
1	DAIRY & POULTRY	0.0	0.0	0.0	0.0	0.0	0.0
2	MEAT & ANIMAL	133.8	0.0	0.0	0.0	0.0	133.8
3	FOOD/FEED GRAIN	15781.3	9075.5	3440.7	711.6	3214.4	32223.5
4	OTHER CROPS	325.0	727.8	75.6	276.3	155.0	1559.6
5	FOR/FISH PRODS	0.0	44.3	0.0	0.0	0.0	44.3
6	AG/FOR/FISH SER	79.2	0.0	128.9	0.0	0.0	208.1
7	IRON ORE MINING	40146.7	0.0	0.0	0.0	0.0	40146.7
8	NONFERROUS MINE	0.0	0.0	0.0	0.0	0.0	0.0
9	COAL & PEAT	0.0	0.0	0.0	0.0	0.0	0.0
10	OIL & NAT. GAS	0.0	0.0	0.0	0.0	0.0	0.0
11	STONE & CLAY	38.1	16.7	16.3	656.5	142.6	870.1
12	OTHER MINING	0.0	0.0	0.0	0.0	0.0	0.0
13	NEW CONSTRUCTN	38.5	0.9	0.0	0.5	0.4	40.2
14	MAINT. & REPAIR	2.7	1.6	0.9	14.3	0.5	20.1
15	ORDNANCE & REL	0.0	0.0	0.0	166.6	0.0	166.6
16	MEAT PRODUCTS	13.7	11.7	6.0	11.9	19.6	62.9
17	DAIRY PRODUCTS	6.6	26.6	138.1	40.6	2.6	214.5
18	CANNED & FROZEN	66.1	13.9	10.3	64.7	3.3	158.3
19	GRAIN MILLING	6.9	11.6	10.4	553.5	5.7	588.2
20	BAKERY PRODUCTS	24.4	2.4	12.0	200.5	1.3	240.6
21	BEVERAGES	21.7	12.4	3.4	179.1	1.9	218.5
22	OTHER FOOD/TOB	97.5	701.5	68.9	1308.4	1.0	2177.2
23	TEXTILE GOODS	7.6	0.0	0.0	44.9	6.6	59.1
24	APPAREL/FABRICS	0.4	0.0	0.3	4.1	0.0	4.8
25	LOGGING	2.2	0.0	0.0	0.0	0.0	2.2
26	SAWMILLS	2.2	0.0	0.0	0.1	0.0	2.3
27	WOOD PRODUCTS	126.6	17.3	13.8	76.7	1.4	235.9
28	FURNITURE	0.1	0.0	0.1	4.6	0.2	5.0
29	PULP & PAPER	7505.0	0.1	519.0	278.1	0.1	8302.3
30	PAPERBOARD CONT	0.0	0.0	0.0	125.2	0.2	125.4
31	PRINT & PUBLISH	54.4	10.8	10.8	473.3	6.8	556.1
32	CHEMICAL/ALLIED	107.5	3.2	0.0	709.3	5.1	825.1
33	PETROL REFINING	0.0	6.8	0.0	1184.1	0.0	1190.8
34	RUBBER PRODUCTS	41.5	2.5	62.5	432.9	2.0	541.5
35	LEATHER PRODUCT	0.0	0.0	0.0	10.6	0.8	11.3
36	CLAY/STONE/GLAS	62.9	16.3	37.5	32.6	1.0	150.2
37	PRIM STEEL PROD	5249.4	0.0	0.0	15.5	0.2	5265.1
38	IRON/STEEL FOUN	58.5	0.0	0.0	282.9	2.6	344.0
39	PRIMARY COPPER	1.0	0.0	0.0	41.5	0.0	42.5
40	OTHER METALS	0.0	0.0	0.0	93.5	0.9	94.5
41	FABRIC. METALS	71.5	27.5	46.1	661.9	20.2	827.3
42	FARM MACHINERY	0.1	2.9	1.1	11.4	0.5	16.0
43	MACHINE SHOPS	0.0	0.0	0.0	0.0	0.0	0.0
44	NONELECT MACH	2.9	0.8	1.8	40.0	0.4	46.0
45	COM/OFFICE MACH	0.5	0.5	0.1	28.4	0.5	30.0
46	SERV. IND. MACH	0.0	0.0	0.0	4.4	0.0	4.5
47	ELECTRIC MACH.	0.0	3.7	2.8	152.7	2.4	161.7
48	MOTOR VEHICLES	0.6	0.5	1.0	61.5	0.7	64.4
49	OTHER TRANSPORT	6.2	1.3	0.5	5.6	0.2	13.8
50	PROF/SCIENTIFIC	0.2	0.0	2.1	104.4	0.1	106.9
51	OPT.OPHTH.PHOT.	0.4	0.0	2.5	11.4	0.1	14.3
52	MISC.MANUFACTUR	5.9	0.5	0.9	42.7	0.0	50.0
53	RAILROAD TRANS	5.7	0.3	0.4	5.5	0.0	12.4
54	LOCAL TRANSIT	0.9	0.3	0.4	6.0	0.1	7.8
55	TRUCK TRANSIT	1.7	0.6	0.3	6.9	0.1	9.6
56	AIR TRANSPORT.	7.5	0.3	0.0	153.6	0.5	162.4
57	OTHER TRANS.	1.2	0.0	0.0	1.2	0.0	2.4
58	COMMUNICATIONS	3.9	1.4	0.8	16.0	0.2	22.3
59	ELECTRIC UTIL.	6404.4	2862.0	11753.3	21090.5	16413.8	58524.0
60	GAS UTILITIES	0.4	0.0	0.0	1.0	0.3	1.7
61	WATER & SANIT.	42.0	5.0	7.4	61.9	1.8	118.0
62	WHOLESALE TRADE	1.8	0.7	0.6	21.6	0.1	24.9
63	RETAIL TRADE	23.4	8.4	6.1	73.9	1.6	113.3
64	FINANCE/INSUR.	5.9	2.7	1.3	12.8	0.5	23.2
65	REAL ESTATE	4.8	1.3	0.9	61.0	0.3	68.2
66	HOTELS/SERVICES	31.6	2.7	1.6	41.1	0.6	77.6
67	BUSINESS SERV.	5.3	0.8	0.9	92.4	0.1	99.5
68	EAT/DRINK ESTBL	11.8	4.4	2.7	63.7	0.8	83.4
69	AUTO REPAIRS	0.7	0.3	0.2	10.9	0.1	12.2
70	FILM/RECREATION	212.6	335.0	161.2	429.8	100.1	1238.7
71	HEALTH SERVICES	23.1	9.9	4.0	17.6	1.9	56.4
72	EDUC/NON-PROFIT	42.6	11.3	9.0	204.8	2.4	270.1
73	GOVERNMENT	0.7	0.2	29.2	3.8	2.6	36.5
74	SCRAP	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	76921.8	13990.2	16594.7	31494.8	20129.2	159130.8

For the "end use" method, an average consumptive use for each sector was calculated by dividing the "straight" consumption by the "straight" withdrawal totals. This average was then multiplied by the "end use" withdrawal amounts. Use of this method assumes that the way in which water is used by permitted appropriators is representative of the water use of all firms in that economic sector. While this assumption is probably valid for manufacturing, it may not be applicable to those sectors which include permitted uses that consume abnormally large or small percentages of their withdrawals. For instance, permitted users in Sector 70, Films and Recreation, include golf courses and ski resorts. These uses consume large portions of the water withdrawn. Estimates of water use in Sector 70 by the "end use" method assume that the only water use for all other facilities is for personal use and office cleaning, processes which do not consume much water. Therefore, for those sectors in Table 5 whose withdrawals were estimated by combining reported use and minimum gallons per employee, consumption was determined by using average consumption for reported use plus ten percent of all water use estimated by the "end use" method. (This method assumes that ten percent of the water coming from municipal supplies is consumed.)

Variations in Water Use

Relatively large fluctuations in the volumes of water withdrawn are typical for most water users. Usually these fluctuations are cyclical. If a municipal utility monitors its water use hourly, it would notice a sudden increase in demand during the early morning hours, as residents rise, shower, flush toilets, and prepare breakfast. Demand usually peaks during the work day, tapers off in the evening, and becomes minimal during the late night and early morning hours.

Many water uses display seasonal fluctuations, with peaks generally occurring during the summer months. The demand for municipal water supplies increases in summer, primarily because of lawn watering. Agricultural irrigators typically water their crops during the hot months of July and August, using little if any water in May, June, or September. Use of water for air conditioning also peaks during the summer.

Fluctuations in water demand become an important concern for water resource managers when the peak demands create a constraint on available water supplies. The potential for a conflict over water supplies increases when the peak demands for several different users occur simultaneously. The recent availability of computerized water use datafiles at the DNR makes it possible to examine these changes in water demand. Analysis of monthly, seasonal, or annual fluctuations is possible for any combination of use types. Unfortunately, the IPASS model is only able to use annual data. Since seasonal fluctuations probably have the greatest impact on the water resource, this limitation greatly reduces the value of IPASS for the water resource manager.

Several factors can cause a change in annual water withdrawals. On a local level, the opening or closing of a manufacturing plant with large water requirements can have a significant impact on water demands. However, the impacts of such a change would probably not extend to the regional or state level, where the IPASS model would be able to evaluate its effect on the economy. An exception might be the decline in the iron ore mining industry in the Northeast, which has had a profound effect on the regional economy.

A period of economic growth or recession can cause a broader change in water use, as perhaps hundreds of plants are opened or closed. Since IPASS assumes a linear relationship between water use and output, a simulation of economic growth would result in a proportional increase in the demand for water. While the validity of this assumption is debatable, it is useful as a first approximation of changes in water demand.

From a water management perspective, an interesting topic is changes in water demand in response to climatological or hydrological changes. We know that water supply changes in response to changes in precipitation. Do water demands change as well? For instance, do specific industries use more water during a drought? The DNR chose to look at the impacts of drought conditions on three water uses: electric power generation, air conditioning, and irrigation.

The DNR was unable to obtain any substantial data regarding the impacts of drought on water use by electric power generation plants. Questionnaire's were mailed to the three largest utilities in the state, but no written responses were received. One utility representative responded by telephone, but he was

unwilling to provide any specific data. The representative was able to state that the use of mechanical air conditioners does create a large increase in electric demand during the summer. This increased use, however, is caused by high temperatures and humidity, rather than by a lack of precipitation (drought). Furthermore, there is little increase in water demand associated with an increase in electric demand, at least in the short term. Only the bringing on line of an additional plant would significantly affect the demand for water in the State. Finally, even if an unusually hot time period increased water demand, the impact of this change would be negligible compared to the annual water use for the sector.

Ground water is used to cool a significant number of buildings in the Twin Cities metropolitan area. The DNR used two different methods to analyze the impacts of drought on this water use. First, a telephone survey was conducted of four of the largest users of ground water air conditioning systems. According to these users, the difference between a normal use of water and an abnormal use caused by drought (or more likely, by high temperatures) would be less than ten percent. Second, statistical tests were conducted to determine whether there was any correlation between changes in reported water use and climatic events. This analysis found no significant difference in water use between 1976, a drought year, and 1981, 1982, or 1983, years of fairly normal precipitation. The analysis was limited by a small sample size and significant difference in time between the drought year and later years. Technological changes could have occurred between 1976 and 1981 which would have an effect on the volumes of water withdrawn.

In order to analyze the impacts of drought on water use for agricultural production, the DNR examined reported water use data from a sample of seventy-two irrigation permits in west central Minnesota. The results showed no significant difference in the amount of water applied for varying levels of rainfall. This was the case for both annual and May-to-September rainfall amounts. In all samples, however, more water was used during dry periods (precipitation levels less than fifteen inches) than during normal or wet periods. More importantly, since the total amount of irrigated crop land in the

state accounts for less than two percent of all cultivated acres, even a doubling of water use during a drought would have only a minimal impact on total crop production.

In this analysis of the three uses of water most likely to be affected by a drought, no significant differences in withdrawals were found, even in 1976, one of the four driest years of this century. Discussion with some water users indicated that some correlation may exist between high temperatures and increased water withdrawals. However, there may be no direct climatological or hydrological connection between high temperatures and low water availability, so it is difficult to determine the usefulness of an analysis relating the two. For the purpose of this study, the results of our analysis showed that the amounts of water required for production should not be adjusted for the IPASS simulation of drought conditions.

1985 Water Withdrawal Aggregations

The second objective of this analysis was to aggregate water withdrawal data by region and by principal watershed so that comparisons could be made between water use and available water supplies. If a comparison shows that the potential exists for a conflict over available supplies in certain geographic areas, then these areas can be targeted for more intensive water management activities. These comparisons are discussed in The Value of Water To Minnesota, Volume I of the Water Allocation and Management project report to the Legislative Commission on Minnesota Resources.

It was not necessary to itemize the water withdrawals by the seventy-four economic sectors used by IPASS, so the 1985 data were aggregated into eight major use categories (Tables 14-17). Withdrawals for mining operations were further broken down into mine processing and dewatering. Water use in manufacturing was broken down into seven subcategories of use.

The aggregation techniques used were similar to those used for the "straight method" of aggregation for the IPASS analysis. The volumes of water used were correlated with the entity which withdrew water, rather than the end user. Thus, the volumes of water withdrawn by public utilities are included under

"municipalities" and no attempt was made to determine whether this water was used by private households or any specific economic sector. The aggregations do not include estimates of the volumes of water withdrawn for rural domestic or livestock use because of the difficulty in estimating human and animal populations for individual watersheds. Watershed boundaries are shown in Figure 2.

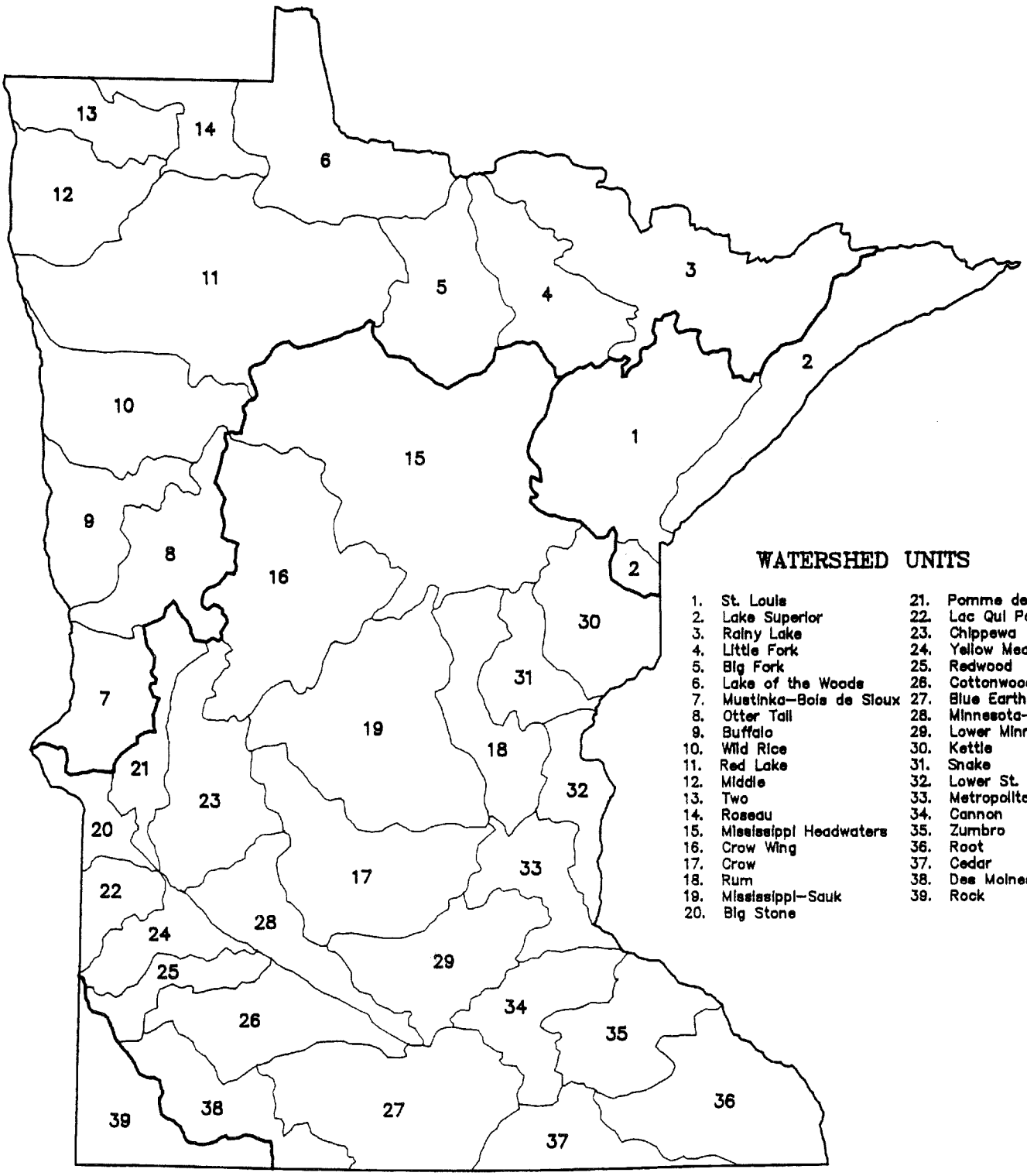
TABLE 14. 1985 GROUND WATER WITHDRAWALS BY REGION
(Acre-feet)

REGION	MINE MINING	MINE DEWATERING	IRRIGATION	MANUFACTURING FOOD	TEXTILES	WOOD	CHEMICAL	METAL	MACHINERY	OTHER	TOTAL	MUNICIPAL	ELECTRIC	COMMERCIAL	GOVERNMENT	OTHERS	TOTAL
WEST	0.0	0.0	42525.3	2804.3	15.3	0.0	12.6	0.0	0.0	0.0	2832.2	33219.5	4.3	467.4	18.7	19.6	79087.0
NORTHEAST	169.4	0.0	11438.1	776.4	0.0	2313.0	97.3	89.0	0.0	0.0	3275.7	20518.9	33752.5	453.3	833.2	1035.1	71476.2
CENTRAL	241.5	0.0	29190.3	4222.8	0.0	101.0	226.2	290.0	463.1	0.0	5303.1	24427.7	674.5	1473.7	498.1	87.8	61896.7
METRO	1202.7	0.0	20285.0	16553.9	0.0	24261.7	9491.1	4213.0	1872.6	2259.0	58651.3	139970.4	705.5	17907.9	2382.1	11725.9	252830.8
SOUTHEAST	64.8	0.0	6893.7	13443.3	195.2	21.2	1759.4	449.3	537.7	16.6	16422.7	72042.1	939.4	1973.0	67.8	11823.2	110226.7
TOTAL	1678.4	0.0	110332.3	37800.7	210.5	26696.9	11586.6	5041.3	2873.4	2275.6	86485.0	290170.6	36076.3	22275.2	3799.9	24691.7	575517.4

TABLE 15. 1985 SURFACE WATER WITHDRAWALS BY REGION
(Acre-feet)

REGION	MINE MINING	MINE DEWATERING	IRRIGATION	MANUFACTURING FOOD	TEXTILES	WOOD	CHEMICAL	METAL	MACHINERY	OTHER	TOTAL	MUNICIPAL	ELECTRIC	COMMERCIAL	GOVERNMENT	OTHERS	TOTAL
WEST	1514.2	0.0	10215.1R	2201.3	0.0	0.0	151.3	0.0	0.0	0.0	2352.6	11891.0	45974.4	4.6	16.6	91.8	72060.3
NORTHEAST	187378.9	54544.6	29777.1	0.0	0.0	85401.3	1315.9	47120.0	0.0	0.0	133837.2	38378.9	160585.4	1281.6	422.0	872.5	607078.2
CENTRAL	226.2	36.8	2584.3	245.2	0.0	11172.0	3087.6	0.0	0.0	0.0	14504.8	5472.7	389834.0	240.3	2611.9	1340.2	416851.2
METRO	917.0	24749.7	620.2	0.0	0.0	0.0	64.4	0.0	0.0	96.4	160.8	177085.2	448118.6	0.0	2172.5	0.0	653824.0
SOUTHEAST	1880.0	3624.0	1278.2	0.0	0.0	0.0	0.0	296.1	0.0	0.0	296.1	0.0	511154.2	0.0	2379.6	0.6	520620.7
TOTAL	191916.2	82955.1	44474.9	2446.5	0.0	96573.3	4619.3	47416.2	0.0	96.4	151151.7	232827.9	1555666.5	1526.5	7602.6	2313.0	2270434.4

FIGURE 2. MINNESOTA'S 39 PRINCIPAL WATERSHEDS



WATERSHED UNITS

1. St. Louis
2. Lake Superior
3. Rainy Lake
4. Little Fork
5. Big Fork
6. Lake of the Woods
7. Mustinka–Bois de Sioux
8. Otter Tail
9. Buffalo
10. Wild Rice
11. Red Lake
12. Middle
13. Two
14. Roseau
15. Mississippi Headwaters
16. Crow Wing
17. Crow
18. Rum
19. Mississippi–Sauk
20. Big Stone
21. Pomme de Terre
22. Lac Qui Parle
23. Chippewa
24. Yellow Medicine
25. Redwood
26. Cottonwood
27. Blue Earth
28. Minnesota–Hawk Creek
29. Lower Minnesota
30. Kettle
31. Snake
32. Lower St. Croix
33. Metropolitan
34. Cannon
35. Zumbro
36. Root
37. Cedar
38. Des Moines
39. Rock

TABLE 16. 1985 GROUND WATER WITHDRAWALS BY WATERSHED
(Acre-feet)

WATERSHED	MINE MINING	MINE DEWATERING	IRRIGATION	MANUFACTURING FOOD	TEXTILES	WOOD	CHEMICAL	METAL	MACHINERY	OTHER	TOTAL	MUNICIPAL	ELECTRIC	COMMERCIAL	GOVERNMENT	OTHERS	TOTAL
1 ST LOUIS	8.9	0.0	0.0	0.0	0.0	97.9	31.0	0.0	0.0	0.0	128.9	6363.6	33218.3	12.0	228.9	1.5	39962.1
2 LAKE SUPERIOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	8.9	0.0	0.0	18.7
3 RAINY LAKE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	262.7	0.0	9.5	8.0	0.0	280.2
4 LITTLE FORK	0.0	0.0	0.0	0.0	0.0	54.3	0.0	0.0	0.0	0.0	54.3	52.8	0.0	0.0	6.1	0.0	113.2
5 BIG FORK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.4	0.0	0.0	0.0	0.0	80.4
6 LAKE DE WOODS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	434.9	0.0	0.0	0.0	0.0	434.9
7 MUSTINKA -SIOUX	0.0	0.0	129.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	798.8	0.0	0.6	0.0	0.0	928.6
8 OTTER TAIL	0.0	0.0	6433.6	451.1	0.0	0.0	0.0	0.0	0.0	0.0	451.1	3291.7	3.4	27.3	2.5	0.0	10209.6
9 BUFFALO	0.0	0.0	846.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2735.3	0.0	7.1	9.2	0.0	3598.3
10 WILD RICE	0.0	0.0	34.1	69.4	0.0	0.0	0.0	0.0	0.0	0.0	69.4	1120.5	0.0	27.9	0.0	0.0	1251.8
11 RED LAKE	0.0	0.0	68.4	11.7	0.0	0.0	66.3	0.0	0.0	0.0	78.0	2150.1	0.0	26.4	0.0	1.2	2324.1
12 MIDDLE	0.0	0.0	123.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	754.9	0.0	0.0	0.0	0.0	878.0
13 TWO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	452.0	0.0	0.0	0.0	0.0	452.0
14 ROSEAU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	392.8	0.0	11.4	0.0	0.0	404.2
15 MISS HEADWATERS	0.0	0.0	272.5	3.7	0.0	107.7	0.0	35.3	0.0	0.0	146.7	7514.5	534.3	183.2	4.3	983.0	9638.5
16 CROW WING	160.5	0.0	11448.1	815.1	0.0	0.0	0.0	0.0	0.0	0.0	815.1	4321.3	0.9	97.9	4.9	50.6	16899.4
17 CROW	23.0	0.0	10091.7	2177.4	0.0	0.0	98.2	0.0	334.5	0.0	2610.1	9975.1	31.3	47.3	17.2	0.0	22795.7
18 RUM	143.3	0.0	825.8	293.7	0.0	0.0	17.2	397.1	0.0	0.0	708.0	4101.9	0.0	295.2	24.9	0.0	6099.1
19 MISS -SAUK	44.8	0.0	26840.2	1045.6	0.0	2154.1	20.9	298.0	0.0	0.0	3518.6	9460.8	643.2	935.1	907.8	1.5	42343.9
20 BIG STONE	0.0	0.0	1588.5	78.3	0.0	0.0	0.0	0.0	0.0	0.0	78.3	747.6	0.0	0.0	0.0	0.0	2414.3
21 POMME DE TERRE	0.0	0.0	8455.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1281.3	0.0	35.6	1.8	3.1	9777.2
22 LAC QUI PARLE	0.0	0.0	935.4	1559.3	0.0	0.0	0.0	0.0	0.0	0.0	1559.3	1022.6	0.0	8.0	0.0	0.0	3525.2
23 CHIPPEWA	0.0	0.0	13626.8	0.0	0.0	0.0	12.6	0.0	0.0	0.0	12.6	2634.0	0.0	7.4	0.0	15.3	16296.1
24 YELLOW MEDICINE	0.0	0.0	117.2	5.5	0.0	0.0	0.0	0.0	0.0	0.0	5.5	451.4	0.0	3.1	0.0	0.0	577.3
25 REDWOOD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	988.8	0.0	0.3	0.0	0.0	989.1
26 COTTONWOOD	0.0	0.0	1488.7	350.2	0.0	0.0	30.7	0.0	0.0	0.0	380.9	6451.4	224.0	9.2	0.0	0.0	8554.2
27 BLUE EARTH	0.0	0.0	1529.8	2140.5	0.0	0.0	0.0	0.0	21.2	0.0	2161.7	18122.4	0.0	131.7	0.0	15.7	21961.3
28 WINN-HAWK CR	30.7	0.0	128.9	339.7	0.0	0.0	30.7	0.0	0.0	0.0	370.4	5649.5	0.0	118.8	0.0	0.0	6298.3
29 LOWER MINNESOTA	299.5	0.0	1193.8	4685.9	0.0	49.1	911.8	64.1	711.1	324.4	6746.4	53859.9	53.1	1330.7	685.6	2313.0	66481.9
30 KETTLE	0.0	0.0	0.0	0.0	0.0	0.0	67.8	0.0	0.0	0.0	67.8	666.3	0.0	150.1	168.5	54.0	1106.6
31 SNAKE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	791.8	0.0	7.7	0.0	0.0	799.4
32 LOWER ST CROIX	498.7	0.0	371.9	102.5	0.0	976.5	0.0	0.0	0.0	0.0	1079.0	8464.6	138.4	1535.1	709.2	7.4	12804.3
33 METROPOLITAN	464.6	0.0	13505.0	12480.6	0.0	23236.1	8785.6	3751.7	1220.5	1764.6	51239.1	80099.5	677.3	15234.0	952.9	9405.5	171577.8
34 CANNON	0.0	0.0	6955.6	609.2	5.5	0.0	316.7	0.0	312.7	16.6	1260.7	10771.8	0.0	776.7	8.0	0.0	19772.8
35 ZUMBRO	4.3	0.0	37.7	2052.2	0.0	0.0	838.1	4.3	53.1	0.0	2947.7	16545.6	544.1	431.5	34.7	587.7	21133.3
36 ROOT	0.0	0.0	9.2	1529.2	189.7	0.0	352.9	445.0	89.0	0.0	2605.8	9787.9	0.3	260.9	0.6	11096.2	23760.9
37 CEDAR	0.0	0.0	2803.4	2447.1	0.0	0.0	0.6	0.0	0.0	0.0	2447.7	7900.9	0.0	15.3	24.2	139.0	12610.7
38 DES MOINES	0.0	0.0	822.5	16.3	15.3	0.0	0.0	0.0	0.0	0.0	31.6	2589.8	0.0	15.3	0.0	0.0	3459.2
39 ROCK	0.0	0.0	449.0	15.3	0.0	0.0	0.0	0.0	0.0	0.0	15.3	6874.3	0.0	12.3	0.6	0.0	7351.5
40 TOTAL	1678.4	0.0	110332.3	33279.3	210.5	26675.7	11581.1	4987.6	2742.1	2105.6	81581.9	290855.3	36068.6	21773.1	3799.9	24674.8	569964.2

TABLE 17. 1985 SURFACE WATER WITHDRAWALS BY WATERSHED
(Acre-feet)

	WATERSHED	MINING	MINE DEWATERING	IRRIGATION	MANUFACTURING							MUNICIPAL	ELECTRIC	COMMERCIAL	GOVERNMENT	OTHERS	TOTAL
					FOOD	TEXTILES	WOOD	CHEMICAL	METAL	MACHINERY	OTHER	TOTAL						
1	ST LOUIS	80888.5	38387.2	54.4	0.0	0.0	11827.5	1081.8	696.6	0.0	0.0	13605.9	17208.8	48331.9	152.2	2.1	0.0	198631.0
2	LAKE SUPERIOR	106313.6	0.0	4.0	0.0	0.0	0.0	15.3	0.0	0.0	0.0	15.3	19941.3	0.0	24.9	396.5	871.3	127566.9
3	RAINY LAKE	140.2	11084.8	0.0	0.0	0.0	45597.5	71.2	0.0	0.0	0.0	45668.7	1228.8	0.0	45.7	0.0	0.9	58169.2
4	LITTLE FORK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	4.6
5	BIG FORK	0.0	0.0	66.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.9
6	LAKE DE WOODS	0.0	0.0	426.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	426.9
7	MUSTINKA -SIOUX	0.0	0.0	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.1
8	OTTER TAIL	0.0	0.0	179.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1771.4	42262.6	0.0	0.0	0.0	44213.8
9	BUFFALO	45.1	0.0	344.9	2.1	0.0	0.0	139.6	0.0	0.0	0.0	141.7	2877.1	1.2	0.0	0.0	0.0	3410.1
10	WILD RICE	245.5	0.0	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	315.5
11	RED LAKE	1040.4	0.0	24696.2	32.8	0.0	0.0	56.5	0.0	0.0	0.0	89.3	6582.1	0.0	0.0	0.0	0.0	32328.0
12	MIDDLE	0.0	0.0	105.6	2145.2	0.0	0.0	0.0	0.0	0.0	0.0	2145.2	375.6	0.0	0.0	0.0	0.0	2626.4
13	TWO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	ROSEAU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	MISS HEADWATERS	36.5	3428.9	8906.9	0.0	0.0	27976.3	7.1	46423.4	0.0	0.0	74406.8	0.0	112253.5	1054.2	23.3	0.0	200109.9
16	CROW WING	0.0	0.0	2866.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2866.3
17	CROW	93.0	36.8	450.8	240.6	0.0	0.0	0.0	0.0	0.0	0.0	240.6	0.0	0.0	1.5	0.0	1340.2	2163.0
18	RUM	27.3	0.0	83.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	253.8	0.0	364.9
19	MISS -SAUK	109.9	0.0	2638.6	0.0	0.0	11172.0	3171.7	0.0	0.0	0.0	14343.7	5472.7	389834.0	238.8	2358.1	8.3	414996.1
20	BIG STONE	0.0	0.0	46.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2903.8	0.0	0.0	0.0	2949.8
21	POMME DE TERRE	0.0	0.0	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	8.9	0.0	30.1
22	LAC QUI PARLE	42.4	0.0	162.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	205.0
23	CHIPPEWA	0.0	0.0	427.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	433.3
24	YELLOW MEDICINE	0.0	0.0	83.8	21.8	0.0	0.0	0.0	0.0	0.0	0.0	21.8	364.9	806.8	0.0	0.0	0.0	1277.3
25	REDWOOD	99.1	0.0	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	138.7
26	COTTONWOOD	78.6	0.0	365.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	444.4
27	BLUE EARTH	144.5	0.0	316.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32317.2	0.0	0.0	0.0	32778.2
28	MINN-HAWK CR	0.0	0.0	260.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	260.2
29	LOWER MINNESOTA	2336.7	8306.3	152.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74370.8	0.0	603.3	0.0	85769.6
30	KETTLE	0.0	1643.7	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1647.4
31	SNAKE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	LOWER ST CROIX	0.0	0.0	101.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	258317.1	0.0	1528.0	0.0	259947.0
33	METROPOLITAN	69.0	17722.8	326.8	0.0	0.0	0.0	64.4	0.0	0.0	96.4	160.8	177085.2	594099.1	0.0	41.1	0.0	789385.0
34	CANNON	0.0	2344.6	221.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	327.5	8.6	2901.6
35	ZUMBRO	91.1	0.0	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	168.5	0.0	0.0	0.0	268.8
36	ROOT	73.0	0.0	194.3	0.0	0.0	0.0	0.0	296.1	0.0	0.0	296.1	0.0	0.0	0.0	0.0	0.0	563.4
37	CEDAR	0.0	0.0	320.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	320.1
38	DES MOINES	26.4	0.0	71.2	4.0	0.0	0.0	4.3	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	91.8	197.6
39	ROCK	15.3	0.0	452.3	0.0	0.0	0.0	7.4	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0	0.0	475.1
40	TOTAL	191916.2	82955.1	44474.9	2446.5	0.0	96573.3	4619.3	47416.2	0.0	96.4	151151.7	232827.9	1555666.5	1526.5	5550.4	2313.0	2268382.2

Conclusions and Recommendations

In this analysis, the total volumes of water withdrawn and consumed in each economic region in Minnesota were evaluated. These volumes were broken down among seventy-four economic sectors and household demand. The results of the analysis were used as inputs to IPASS, a computer simulation model of the state economy. In addition, a more general evaluation of water use in each region and watershed in the state was conducted. The results of this phase of the project were used in the water balance analysis of the main report to the Legislative Commission on Minnesota Resources, entitled The Value of Water to Minnesota.

In addition to their value in providing information for use in the IPASS computer simulations, the methods of analysis used and the results obtained by this project have intrinsic value to water resource managers. For instance, knowledge of the average volume of water used per employee in each economic sector can be used to estimate total water requirements for a proposed industrial facility. An understanding of the breakdown of end uses of water supplied by municipal utilities is useful in allocating water resources during periods of short supply. Estimates of consumptive water use are helpful in determining the net volumes of water withdrawn by a surface water appropriator.

The results of any analysis are only as good as the data used in their derivation. Future analyses of this type would benefit from improved data sources. The largest source of uncertainty in determining the volumes of water used in the state is the unknown number of users who appropriate water without a DNR permit. Two options are available which might improve compliance with Minnesota statutes regulating the use of water. First, a public education program could be used to notify citizens of the requirements under the law and to stress the importance of timely and accurate reporting of water use. This program could also improve the quality of the information provided by existing permit holders. Second, the DNR should expand its enforcement efforts in order to bring non-permitted water users into compliance with State statutes.

While Minnesota is far ahead of most other states in collecting and analyzing water use data, there are some useful water measures which are not collected but could improve the evaluation of individual permit applications and utilization of computer simulation models such as IPASS. The DNR should obtain information regarding the actual costs of water withdrawal from a variety of ground and surface water sources, and the withdrawal and consumptive water requirements for various industrial processes in terms of engineering efficiency. This would enable the DNR to more realistically develop standards for reasonable use and water conservation.

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Appendix

Cover letter and forms used in
DNR Water Allocation Survey

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

BOX 32, 500 LAFAYETTE ROAD • ST. PAUL MINNESOTA • 55146

DNR INFORMATION
(612) 296-6157

January 17, 1986

Dear Minnesota Water User:

The Department of Natural Resources would like to enlist your cooperation in a special study of water use in Minnesota. The Water Allocation Project, funded by a grant from the Legislative Commission on Minnesota Resources, is examining the value of water to the state's economy. Among the questions we wish to answer are:

1. How much water is available for use in Minnesota?
2. How much water is currently being used?
3. How important is water to Minnesota industry? commerce? recreation? agriculture? private use?
4. How much water will we need in future years?
5. What would happen if we had a repeat of the drought of the 1930's?

A number of issues and events prompted us to begin this study. First, water has become a major concern of the 1980's - much like energy was in the 1970's. Second, despite the abundance of clean water in the state, there are areas, particularly in western Minnesota, where available supplies do not meet demand. Third, every year, more communities are discovering that their water supplies have become contaminated and are unfit for use. Fourth, potentially severe water shortages in some western states have spawned discussions of large-scale diversions from water-rich states such as Minnesota. Fifth, thanks to the information and processing fees we have received from water appropriation permit holders, we now have ready access to water use data on our computerized storage files.

One of the goals for this project is to gain a better understanding of the ways in which water is used in the state. Therefore, we would appreciate your taking the time to complete the survey form on the reverse of this page.

Participation in this survey is optional; it is not required under the provisions of your permit. Furthermore, the information you provide is confidential; the data we collect will only be released to the public in aggregated form. If you have any questions, comments, or suggestions regarding the survey or the project, please enclose them with the form or call me at 612/297-3899. You may submit the form along with your annual report of water use.

Thank you,

DIVISION OF WATERS

Gil Young, Research Analyst
Water Allocation Unit

DEPARTMENT OF NATURAL RESOURCES
WATER ALLOCATION SURVEY FORM
MUNICIPAL WATER SUPPLY SYSTEMS

CITY NAME:_____ DNR PERMIT NUMBER:_____
CONTACT PERSON:_____

****

A. **WATER USE**

1. SOURCE OF WATER: _____
2. WHAT IS THE TOTAL AMOUNT OF WATER PRESENT IN THE SUPPLY SYSTEM AT ANY GIVEN TIME? Include the volume of water in the distribution system, in storage facilities or holding ponds, and treatment facilities:

_____

****

B. **DISTRIBUTION**

1. INDICATE THE NUMBER OF SERVICE CONNECTIONS AND THE PER CENT OF THE TOTAL WATER USED BY EACH SECTOR:

	NUMBER OF CONNECTIONS	PER CENT OF TOTAL WATER USED
Residential	_____	_____
Commercial	_____	_____
Industrial/Manufacturing	_____	_____
Parks/Recreation	_____	_____
Water Treatment	_____	_____
Other (Describe):		
_____	_____	_____
_____	_____	_____

2. POPULATION SERVED _____
3. DO YOU PROVIDE MORE THAN 25,000 GALLONS OF WATER PER DAY TO ANY USER? IF SO, PLEASE LIST: (enclose additional sheets if necessary)

NAME OF FIRM	USE OF WATER	AVG. GAL. PER YEAR
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

****

C. **DISCHARGE - SANITARY SEWER SYSTEM**

1. NAME OF DISCHARGE WATERBODY:_____
2. AVERAGE YEARLY VOLUME DISCHARGED: (gallons)_____
3. AVERAGE COST OF TREATMENT: ($/1000 gal.)_____
4. NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT NUMBER_____

****

Would you like us to keep you informed on the status of this project?

Yes _____ No _____

_____ _____

Signature Date

DEPARTMENT OF NATURAL RESOURCES
WATER ALLOCATION SURVEY FORM

FIRM NAME:_____ **DNR PERMIT NUMBER:**_____
FACILITY NAME:_____ **CONTACT PERSON:**_____
CITY OR TOWNSHIP:_____ **COUNTY:**_____
TYPE OF FIRM:_____
STANDARD INDUSTRIAL CLASSIFICATION(S) (IF KNOWN):_____
NAME OF PRODUCTS OR SERVICES: _____

_____

****

A. WATER USE

1. **SOURCE OF WATER:**_____

2. **USE OF WATER:** (Be specific. If water is used for cooling, indicate what is being cooled.)

_____

3. **WHAT IS THE TOTAL AMOUNT OF WATER PRESENT IN THE SYSTEM AT ANY GIVEN TIME?** Include the volume of water in the distribution system, in storage facilities or holding ponds, and processing equipment:_____

_____

4. **IS THE WATER RECYCLED OR REUSED FOR ANOTHER PURPOSE? PLEASE DESCRIBE:**

_____

****

B. OTHER WATER SUPPLIES

1. **LIST ANY OTHER SOURCES OF WATER FOR THIS FACILITY:**_____

_____

2. **AVERAGE VOLUME USED PER YEAR:**_____

3. **USE OF THIS WATER:**_____

4. **IF YOU PURCHASE THIS WATER (e.g., from a municipality) WHAT IS YOUR AVERAGE COST?** ($/1000 gal.)_____

****

C. CONSUMPTION

HOW MUCH OF THE TOTAL AMOUNT OF WATER WITHDRAWN FROM ALL SOURCES IS NOT DISCHARGED: (i.e., how much water is consumed by your operation?)

Per cent:_____ Average total volume per year (gallons):_____

****

D. TREATMENT AND DISPOSAL

1. **DESCRIBE ANY TREATMENT REQUIRED FOR YOUR WATER SUPPLIES:**

	Treatment	Cost
Before use:	_____	$_____/1000 gal.
After use:	_____	$_____/1000 gal.

2. **WHERE IS THE WATER DISCHARGED?** **PER CENT**

Municipal storm sewer system_____(city) _____
Holding pond to_____(name) _____
River, stream, lake, ditch_____(name) _____
Other_____(describe) _____
National Pollution Discharge Elimination System Number (NPDES):_____

****

Would you like us to inform you of the status of this project?
Yes_____ No_____

_____ _____
Signature Date