Water Use in Minnesota

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Table of Contents

Figures & Tables

This paper characterizes water use in Minnesota in the context of various categorization schemes. Most broadly, water use can be broken into instream uses, in which water remains in the source, and offstream uses, in which water is removed from its source by pumping or diversion (Australian National Government 2005). Offstream uses are often divided according to consumption (consumptive vs. nonconsumptive), supplier (public vs. self-supplied), source (surface vs. ground), and use category (aquaculture, domestic, etc.).

A. Instream Uses

Instream uses typically refer to surface water rather than groundwater. They fall into three broad categories: recreational use, hydroelectric use, and ecological/ecosystem services.

1. Recreational Use

Recreational use includes primary and secondary contact uses and recreational fishing. Primary contact uses include swimming, wading, and waterskiing. Secondary contact uses include boating, canoeing, hunting, education, and spiritual and aesthetic appreciation. All have water supply and quality requirements; many also have impacts on water (Perlman 2009).

2. Hydroelectric Use

Hydroelectric use refers to the instream use of falling water to drive electricity-generating turbines. Minnesota's hydroelectric use was approximately 7,232 billion gallons in 1995, the last year for which an estimate is available (Solley et al. 1998).

3. Ecological/Ecosystem Services

Ecosystem services are the benefits provided by ecosystems. These benefits accrue to aquatic and riparian communities as well as to humans, and include provisioning services, such as food, water, habitat, timber, fiber, and genetic resources; regulating services, such as the regulation of climate, floods, disease, and water quality as well as waste treatment; cultural services, such as recreation, aesthetic enjoyment, and spiritual fulfillment; and supporting services, such as soil formation, pollination, and nutrient cycling (Millennium Ecosystem Assessment 2005).

Requirements for instream uses can be difficult to quantify (Australian National Government 2005).When assessing whether offstream uses are interfering with instream needs, the spatial and temporal scales of assessment become important due to regional, seasonal, and daily variations in instream flow. For example, O'Shea (2000) noted that an analysis of permitted offstream allocations versus estimated available water (for offstream and instream uses) in Minnesota from 1985 to 1995 yielded different results depending on geographic and temporal scale. Statewide, permitted allocation of estimated total available water ranged from 2% to 7% when analyzed by year; permitted allocation of each watershed's estimated total available water ranged from 1% to 28% when analyzed by year;

permitted allocation of each watershed's total available water ranged from 0% to 660% when analyzed by month.

B. Offstream Uses

Offstream use can be described in terms of consumption (consumptive vs. nonconsumptive), supplier (public vs. self), source (surface water vs. groundwater), and use category (aquaculture, domestic, irrigation, etc.).

Most of the information presented here was gathered from *Water Year Data Summary* reports published by the Minnesota Department of Natural Resources (DNR; Hunt 1999, 2001, 2003, 2005, 2007, 2009) and *Estimated Use of Water in the United States* reports published by the U.S. Geological Survey (USGS; Hutson 2004, Kenny et al. 2009; Solley et al. 1988; Solley et al. 1993; Solley et al. 1998). The DNR reports provide data regarding Minnesota's water use at county and statewide scales, and are published every other year. The USGS reports are published every five years and contain water use data by state and for the entire country. The DNR reports contain estimates of annual water "appropriations." These are uses that require a permit due to withdrawal of more than 10,000 gallons per day or 1 million gallons per year. The USGS reports contain estimates of total use (permitted or not) based on estimates from state agencies and USGS estimates of nonreported uses such as those of rural households that have self-supplied wells Both series of reports break down water use by use category and source.

1. Consumption

Definitions vary, but consumptive use can be conceived of as the portion of water that is removed from a source and not returned directly to that same source (Hunt 2009; Kenny et al. 2009). Return flows from different use categories have different reuse potentials due to alterations during use. For example, irrigation return flow may be contaminated with pesticides or fertilizers and have a relatively high mineral content, while thermoelectric return flow may have elevated temperature (Solley 1998). Most groundwater withdrawals are considered to be consumptive because groundwater is rarely directly returned to the source aquifer (Hunt 2009).

Because of the amount of uncertainty involved, consumptive use estimates have not been included in USGS reports since 1995 (Hutson 2004). In 1995, nationwide consumptive use averaged about 29%of total offstream freshwater use (37 trillion gallons of 125 trillion gallons, Solley 1998). In the same year, Minnesota's consumptive use was estimated to be about 12%of its total offstream use (152 billion gallons of 1,238 billion gallons). Use-category breakdowns of Minnesota's total consumptive use in 1995 (Solley 1998) were: irrigation 34% (51 billion gallons), domestic 26% (40 billion gallons), livestock 15% (23 billion gallons), thermoelectric 12% (18 billion gallons), industrial 6% (9 billion gallons), and commercial 4% (7 billion gallons).

2. Supplier

Water is either delivered by a public supplier or self-supplied. A public water supply supplies water to at least 25 people or 15 connections. Any supply that does not meet this public supply definition is considered self-supplied.

Public suppliers include municipal water works, commercial or institutional water works, fire departments, and privately owned suppliers such as mobile home parks (Kenny et al. 2009). Self-supplied uses include rural domestic wells, dewatering of mines, agricultural irrigation, and livestock watering from a private well. Self-supplied uses that are categorically reported in USGS and/or DNR reports include domestic, industrial, thermoelectric, irrigation, livestock, aquaculture, mining, and "other" (Hunt 1999, 2001, 2003, 2005, 2007, 2009; Hutson 2004; Kenny et al. 2009; Solley et al. 1988; Solley et al. 1993; Solley et al. 1998).

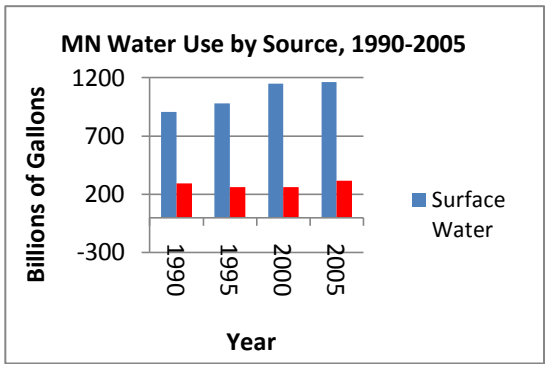
Publicly supplied water comprised approximately 13%of total Minnesota use in 2005 (196 billion gallons of 1,476 billion gallons, Kenny et al. 2009). Pre-2000 USGS reports also included estimates of self-supplied commercial and hydroelectric uses; of public supply deliveries for industrial, commercial, and thermoelectric uses; and of the consumptively used portion of each category (Solley et al. 1988, 1993, 1998). Such estimates are no longer a part of the reports (Hutson 2004, Kenny 2009), but the previous estimates may be useful as a starting point in assessing present consumptive usage.

3. Source

Offstream uses may also be categorized according to source. Most offstream water use in Minnesota uses surface water—about 78%, or 1,161 billion gallons of 1,476 billion total gallons, in 2005 (Kenny et al. 2009). However, when the primarily nonconsumptive thermoelectric use is removed from estimates, as it often is (Hunt 2009, Metropolitan Council 2007a, 2007b), the source proportions become more equal: 46% surface water (270 billion gallons) and 54% groundwater (314 billion gallons) out of 584 billion gallons in 2005 (Kenny et al. 2009, figures 1 and 2). In Minnesota, uses that are supplied primarily (>80%) by surface water sources include mining and thermoelectric; uses that are supplied primarily by groundwater sources include self-supplied domestic, livestock, and irrigation. Uses that tend to draw from both are aquaculture, industrial, and public supply (figure 3, table 1).

Figure 1. Minnesota source withdrawals, 1990–2005.

(Data from Hutson 2004, Kenny et al. 2009, Solleet al. 1993, Solley et al. 1998.)



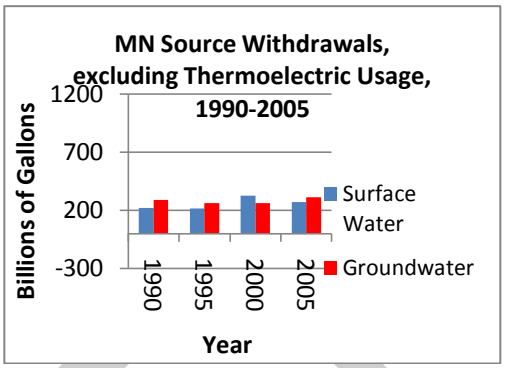


Figure 2. Minnesota source withdrawals, excluding thermoelectric, 1990–2005.

(Data from Hutson, 2004; Kenny et al. 2009; Solleyet al. 1993, Solley et al. 1998.)

Figure 3. Minnesota water use by source and use category, 2005.

(Data from Kenny et al. 2009.)

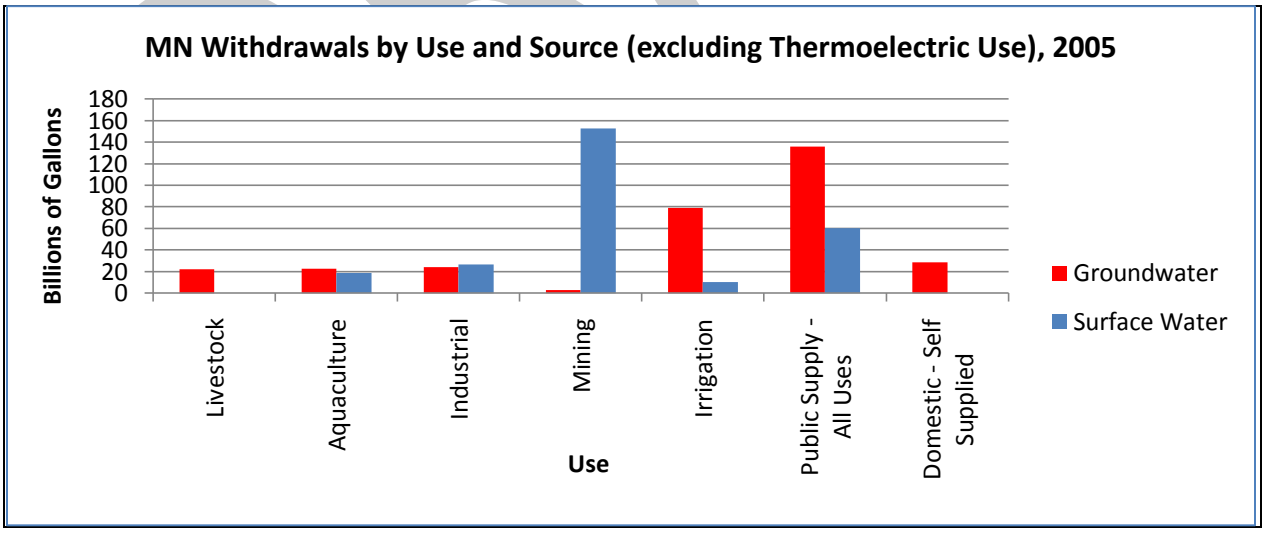


Table 1. Minnesota's water use in 2005

Use Category	GW (billion gal/yr)	SW (billion gal/yr)	SW and GW Total (billion gal/yr)	% of Total GW Use	% of Total SW Use	% of Total SW and GW Use
Livestock	22.1	0.0	22.1	7.0	0.0	1.5
Aquaculture	22.6	18.6	41.1	7.2	1.6	2.8
Industrial	23.9	26.7	50.6	7.6	2.3	3.4
Mining	2.9	152.7	155.6	0.9	13.1	10.5
Thermoelectric	0.9	891.2	892.1	0.3	76.7	60.4
Irrigation	78.9	10.4	89.3	25.0	0.9	6.0
Public Supply (All Uses)	135.9	60.3	196.1	43.1	5.2	13.3
Domestic (Self-Supplied)	28.4	0.0	28.4	9.0	0.0	1.9
Total	315.2	1161.5	1476.7	100.1	**99.8**	99.8

Data from Kenny et al. 2009. GW = groundwater, SW = surface water. Numbers may not add to 100% due to independent rounding.

4. Use Category

The USGS breaks offstream water uses into eight use categories: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power. Different categories of uses tend to have different proportions with respect to **consumptive vs. nonconsumptive use, self-supplied vs. publicly supplied, and surface water vs. groundwater source.

a. **Aquaculture Use.** Aquaculture in Minnesota consists of production of food fish, fingerlings for stocking, and baitfish (Ji, 2008). The 2005 USGS report is the first to contain estimates for the aquaculture category as a whole. Withdrawals now included under this category previously fell into a) fish hatchery activities under the commercial category and b) fish farming activities under the former "animal subspecialties" subcategory of the livestock category (Kenny et al. 2009). All withdrawals are considered self-supplied. Aquaculture accounted for about 2.8%of Minnesota's total 2005 estimated use (41.3 billion gallons of 1,476 billion gallons). Surface water accounted for 45% (18.6 billion gallons), and groundwater for 55% (22.6 billion gallons) of Minnesota's total estimated aquaculture use (Kenny et al. 2009).

b. **Domestic Use.** In Minnesota, domestic use (publicly supplied and self-supplied) accounted for approximately 8.7%of total estimated use (128 billion gallons of 1,476 billion gallons) in 2005. About 78% (99.7 billion gallons) of this domestic use was publicly supplied to 4.02 million people (78% of state population), and 22% (28.4 billion gallons) was self-supplied to 1.11 million people (22% of state

population, Kenny et al. 2009). All self-supplied domestic water in Minnesota is presumed to be from groundwater sources. USGS estimated that about 34% of Minnesota's domestic use in 1995 was consumptive (Solley et al. 1998).

c. Other Public Supply Use. Since 2000, USGS has divided public supply deliveries into "domestic" and "all other uses and system losses" (Hutson 2004, Kenny et al. 2009); previously, subcategories had also included industrial, commercial, and thermoelectric uses (Solley 1988, 1993, 1998). For 2005, public supply deliveries for domestic use in Minnesota were estimated to be 50.8% (99.7 billion gallons) of total public supply deliveries (196.1 billion gallons), while other uses and system losses were 49.2 % (96.4 billion gallons, Kenny et al. 2009). Current statewide estimates of publicly supplied deliveries subdivided by industrial, commercial, and institutional use categories are difficult to obtain (Hunt 2009). Solley et al. (1998) estimated Minnesota's total public supply use in 1995 (177 billion gallons) to be apportioned as 49.3% domestic (87 billion gallons), 21.2% commercial/institutional (38 billion gallons), 8.5% industrial (15 billion gallons), and 21.2% other uses and system loss (38 billion gallons).

d. Industrial Use. Although industrial water is both self-supplied and publicly supplied, recent (2000 to present) USGS and DNR reports include only self-supplied withdrawals. In 1995, an estimated 77% (51 billion gallons) of Minnesota's industrial use (66 billion gallons) was self-supplied, and 23% (15 billion gallons) was publicly supplied. Nationally, 82% of water for industrial uses was self-supplied (surface and groundwater), while 18% came from public supplies (Solley et al. 1998). The USGS estimates that in 2005 about 53% (26.7 billion gallons) of Minnesota's total self-supplied industrial use (50.8 billion gallons) was drawn from surface water, and 47% (23.9 billion gallons) was drawn from groundwater (Kenny et al. 2009). Note that the USGS separates industrial and mining uses into two distinct categories, whereas DNR includes mining usage in its "industrial processing" category. USGS estimated that industrial use (self-supplied) accounted for about 3.4% (50.8 billion gallons) of Minnesota's total estimated 2005 use (1,476 billion gallons). In 1995, USGS estimated that about 18% of Minnesota's industrial use was consumptive (Solley et al. 1998).

e. Irrigation Use. Irrigation water use includes self-supplied withdrawals and deliveries from irrigation companies, irrigation districts, cooperatives, or governmental entities. The USGS estimated that irrigation accounted for about 6% (89.1 billion gallons) of Minnesota's total 2005 use (Kenny et al. 2009). Surface water accounted for about 12% (10.4 billion gallons) and groundwater for about 88% (78.9 billion gallons) of Minnesota's total irrigation water withdrawals (89.1 billion gallons) in 2005 (Kenny et al. 2009). Some 467,000 acres of Minnesota land were irrigated in 2005, at an average application rate of 0.59 acre-feet per acre. The national average application rate is 2.35 acre-feet per acre, although nearby states have lower average rates than the national rate (Wisconsin, 1.14 ac-ft/ac; Iowa, 0.30

ac-ft/ac; North Dakota, 0.65 ac-ft/ac; Illinois, 1.23 ac-ft/ac). The USGS estimated that Minnesota's irrigation use in 1995 was 90% consumptive (Solley et al. 1998).

f. Livestock Use. Kenny et al. (2009) estimated that Minnesota's livestock use in 2005 was 1.5% (22 billion gallons) of Minnesota's total estimated use (1,476 billion gallons). All withdrawals for livestock usage in Minnesota are considered to be self-supplied from groundwater sources, and to be 100% consumptive.

g. Mining Use. The DNR includes mining in its "industrial processing" category, while the USGS separates it (Hunt 2009, Kenny et al. 2009). All mining withdrawals are considered self-supplied. Mining accounted for about 11% of Minnesota's total use in 2005 (1,476 billion gallons); surface water withdrawals accounted for about 98% (152.7 billion gallons) of this total (Kenny et al. 2009). The USGS estimated that Minnesota's mining use in 1995 was about 26% consumptive (Solley et al. 1998).

h. Thermoelectric Use. In Minnesota, more than 99% of thermoelectric water is drawn from surface water. Most of the water withdrawn is used for condenser and reactor cooling (Kenny et al. 2009). Thermoelectric cooling systems can be once-through cooling systems or recirculation systems. Once-through cooling systems, or open-loop systems, have been estimated to consume less than 3% of the total usage (Solley et al. 1998). In recirculation (closed-loop cooling) systems, smaller amounts of water are withdrawn for cooling than for once-through cooling, but consumptive use (mostly through evaporation) is a larger proportion (often over 60%) of that which is withdrawn (Kenny et al. 2009). There is a trend toward using recirculation cooling systems in place of once-through cooling systems (EPA 2009). As more recirculation systems are used relative to once-through cooling systems, the consumptive fraction of thermoelectric use will likely increase, even though total thermoelectric use will decrease. Kenny et al. (2009) reported that in 2005 once-through cooling accounted for about 63% (563 billion gallons) of Minnesota's thermoelectric use, while recirculation cooling accounted for 37% (331 billion gallons). As a whole, thermoelectric power accounted for about 61% (894.8 billion gallons) of Minnesota's total 2005 water use (Kenny et al. 2009). The USGS estimated that in 1995 thermoelectric use in Minnesota was about 2.3% consumptive (Solley et al. 1998).

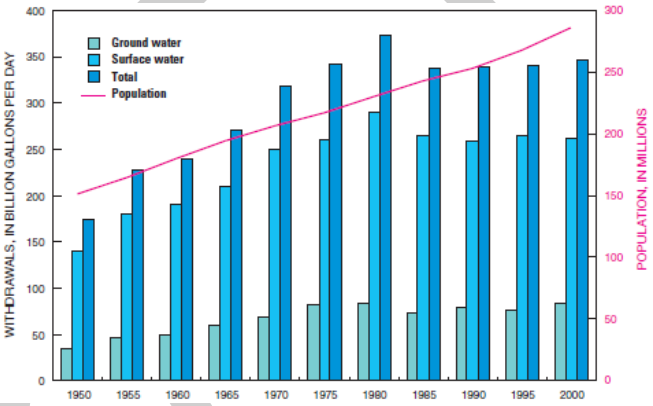
C. Total National, State, and Metro Withdrawals

1. National

Total U.S. water use and population over time are shown in figure 4. In 2005, total offstream water use was 150 trillion gallons. About 127 trillion gallons of this was freshwater. Of the freshwater usage, about 77% (99 trillion gallons) was surface water, and about 23% (29 trillion gallons) was groundwater. In 1995, about 29% (37 trillion gallons) of total U.S. freshwater use (125 trillion gallons) was consumptive (Solley et al. 1998). In 2005, nationwide per capita freshwater use (all uses) is estimated to have been 1,360 gallons per day; nationwide domestic use per capita is estimated to have been 98 gallons per day (Kenny et al. 2009).

Figure 4. Trends in population and freshwater withdrawals by source, 1950–2000.

(Data from Hutson 2004.)

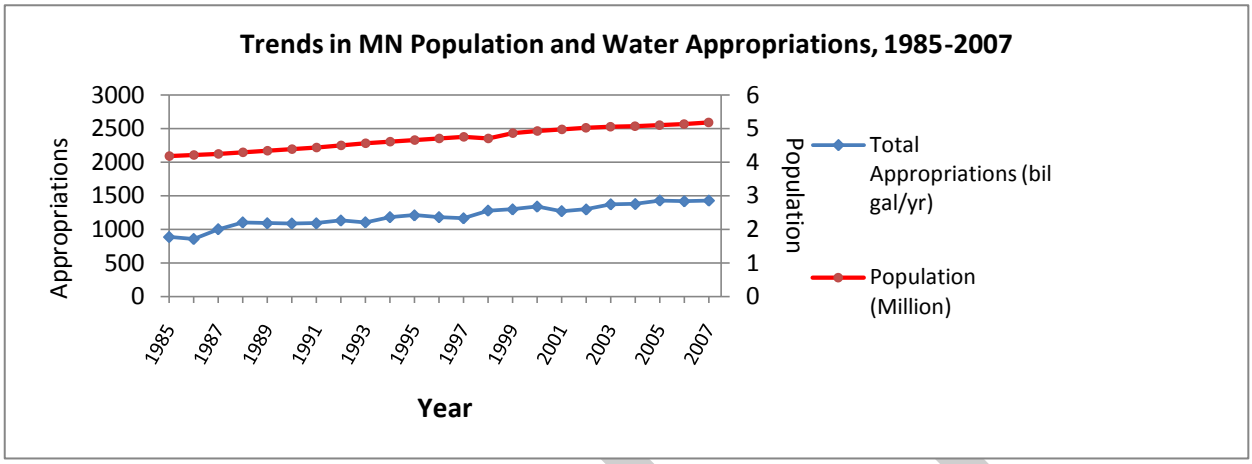


2. Minnesota

Trends in Minnesota's population and appropriated water use are shown in figure 5. From 2000 to 2007, annual DNR permitted water appropriations averaged 1.37 trillion gallons per year, with an average estimated state population of 5.06 million (Hunt 1999, 2001, 2003, 2005, 2007, 2009). USGS estimates for all offstream uses and population in Minnesota in 2000 and 2005 averaged 1.44 trillion gallons per year and 5.03 million residents (Kenny et al. 2009).

Figure 5. Minnesota population and total water appropriations, 1985–2007.

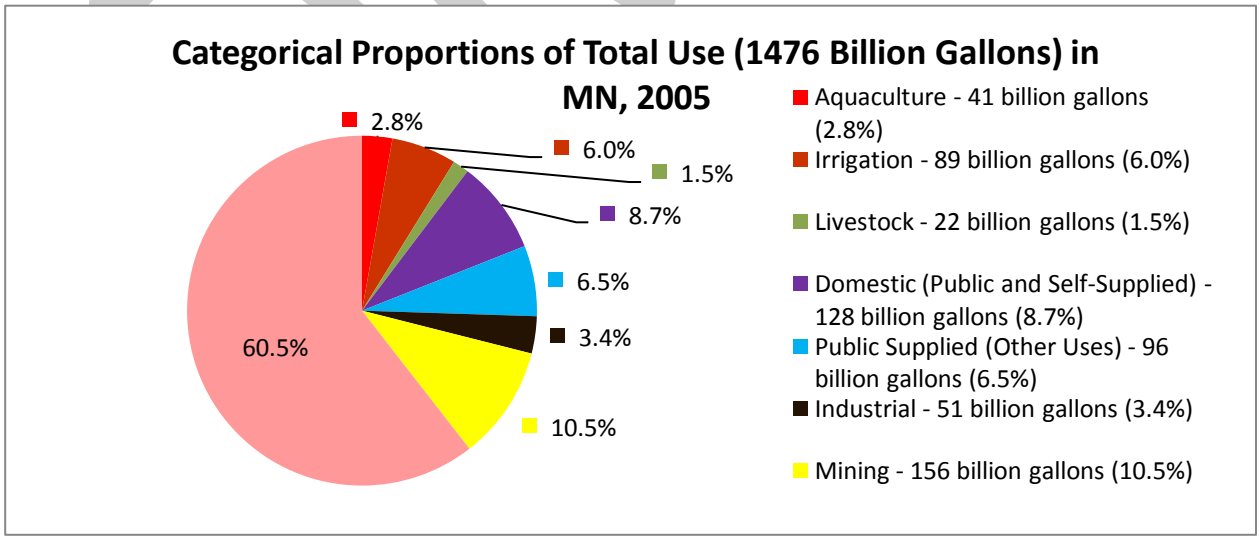
(Data from Hunt 1999, 2001, 2003, 2005, 2007, 2009.)



In Minnesota in 2005, total use per capita was an estimated 788 gallons per day; domestic per capita use was an estimated 68 gallons per day. In 2005, surface water accounted for about 79% (1,161 billion gallons) of total withdrawals (1,476 billion gallons), while groundwater accounted for 21% (315 billion gallons). If the "once-through cooling" subcategory (562 billion gallons)of thermoelectric use, a largely (97%–98%) nonconsumptive use primarily drawn from surface water (Solley et al. 1998), is removed, surface water and groundwater withdrawal are 66% (270 billion gallons) and 34% (314 billion gallons) of total use, respectively.

Figure 6. Minnesota water use by use category, 2005.

(Data from Kenny et al. 2009.)



In 2005, the USGS estimated that 1.11 million Minnesotans (22%) used self-supplied groundwater wells for their residential supply, with an estimated use of 28 billion gallons (22% of total domestic use). The remaining 4.02 million people (78% of MN population) received domestic water from public supply (approximately 100 billion gallons, or 78% of total domestic use), 69% of which came from groundwater and 31% of which came from surface water (Kenny et al. 2009). In 1995, Minnesota's consumptive use was estimated to be 12% (152 billion gallons) of total use (1,238 billion gallons, Solley et al. 1998). Minnesota's 2005 total (surface and groundwater) withdrawals are shown by use category in figure 6; 2005's groundwater and surface water withdrawals by use category are shown in figures 8 and 9, respectively. Figure 7 and table 2 express Minnesota's total use by use category over time (1985–2005).

Figure 7. Minnesota water use by use category, 1985–2005.

(Data from Hutson 2004; Kenny et al. 2009; Solley et al. 1988, 1993, 1998.)

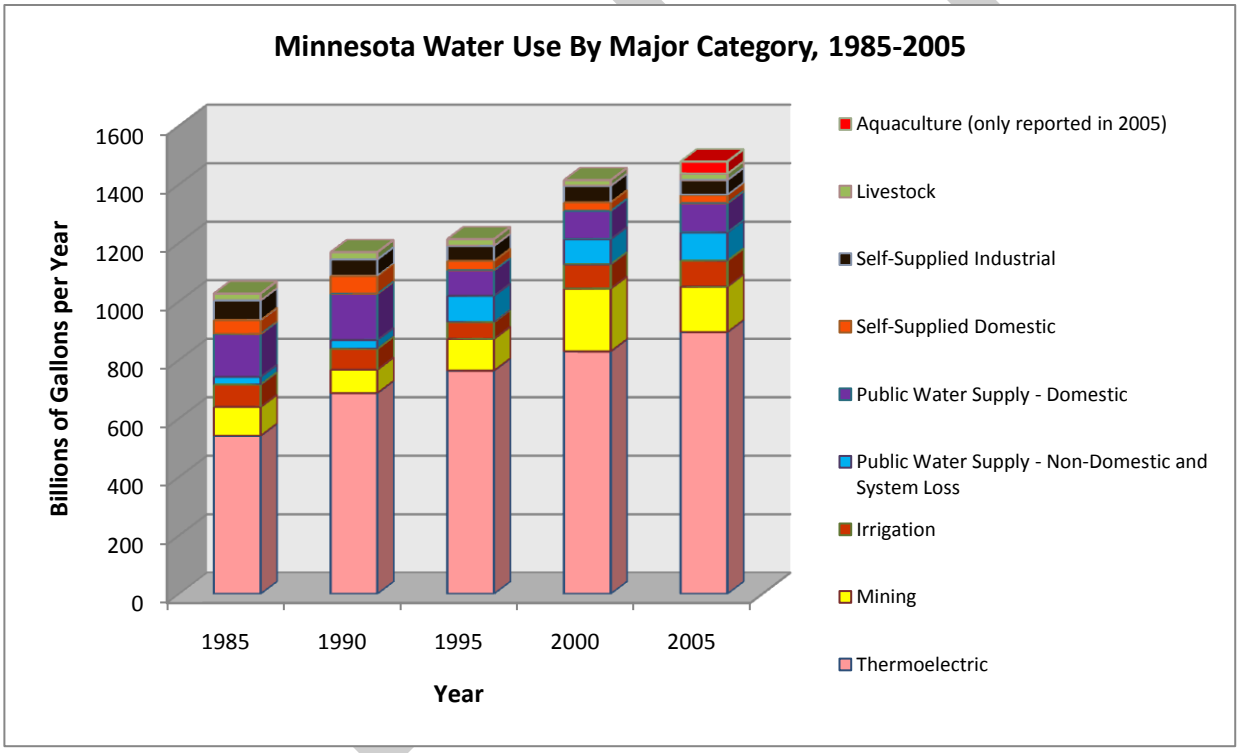


Table 2. Minnesota water use by use category, 1985–2005

Year / Use Category	1985	% of 1985	1990	% of 1990	1995	% of 1995	2000	% of 2000	2005	% of 2005
Public Water Supply (Domestic)	147	*14.2*	158	*13.2*	87	*7.0*	96	*6.8*	100	*6.8*
Public Water Supply (All Other Uses and System Loss)	26	*2.5*	30	*2.4*	90	*7.3*	86	*6.1*	96	*6.5*
Domestic (Self-Supplied)	48	*4.6*	61	*5.1*	32	*2.6*	30	*2.1*	28	*1.9*
Industrial (Self-Supplied)	67	*6.5*	56	*4.7*	51	*4.1*	56	*4.0*	51	*3.5*
Irrigation	76	*7.4*	71	*5.9*	57	*4.6*	83	*5.9*	89	*6.0*
Livestock	23	*2.2*	24	*2.0*	23	*1.9*	19	*.3*	22	*1.5*
Aquaculture									41	*2.8*
Mining	99	*9.6*	80	*6.7*	109	*8.8*	215	*15.2*	156	*10.6*
Commercial (Self-Supplied)	26	*2.5*	71	*5.9*						
Thermoelectric	541	*52.3*	687	*57.5*	763	*61.6*	829	*58.7*	895	*60.6*
Total Annual Use (billions of gallons)	1034	*101.8*	1194	*103.4*	1238	*97.9*	1413	*99.1*	1476	*100.2*

Data from Hutson 2004; Kenny et al. 2009; Solley 1988, 1993, 1998. Numbers may not add to 100% due to rounding.

Figure 8. Minnesota groundwater withdrawals by use category.

(Data from Kenny et al. 2009.)

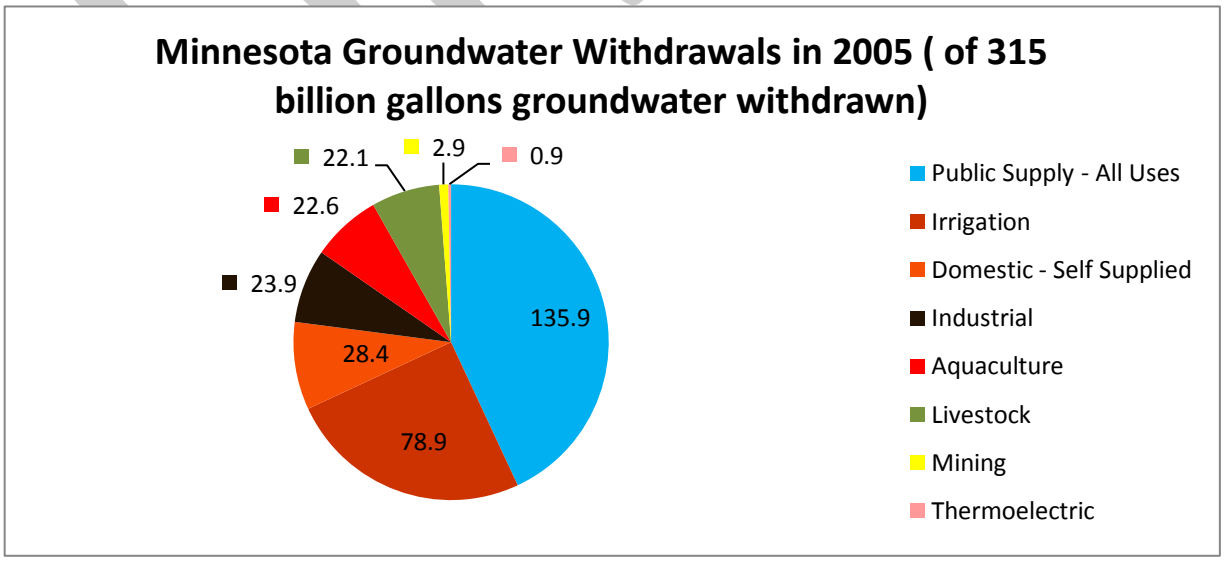
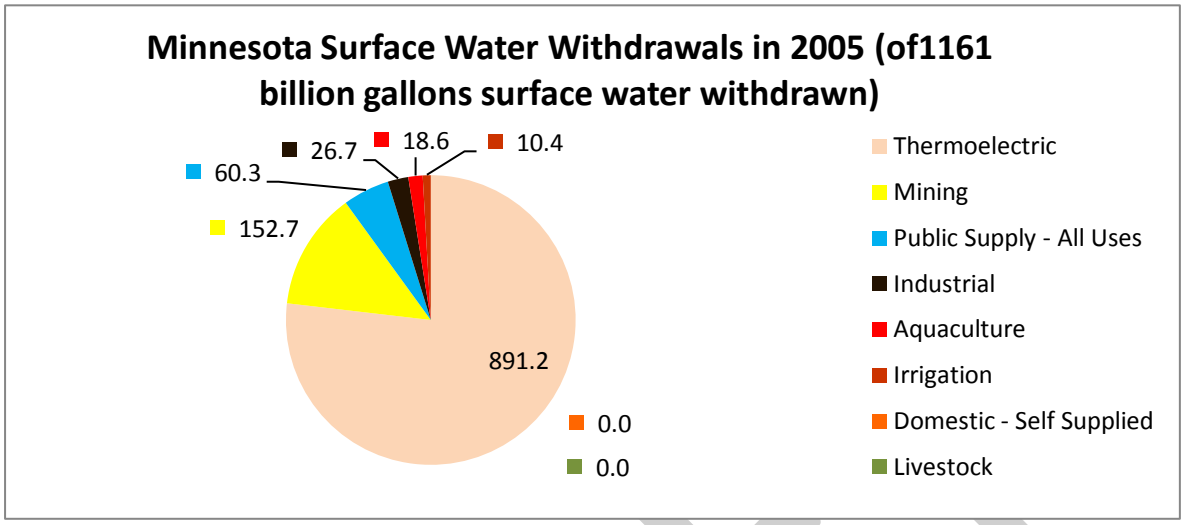


Figure 9. Minnesota surface water withdrawals by use category.

(Data from Kenny et al. 2009.)



a. Current Use vs. Estimated Supply. The Environmental Quality Board (EQB) estimated water supply availability in Minnesota by using four different methods to generate five renewable resource estimates for each of Minnesota's counties. Each county's median estimate was then compared with its estimated net (consumptive) usage (VanBuren 2007). The EQB found that 14 of 87 Minnesota counties reported net (consumptive) water usage that was more than 10% of their estimated available renewable water in 2005 (figure 10). When looking at permitted volume (not volume actually used) versus estimates of available renewable water, 29 of 87 counties had more than 10% of their available water allocated for consumptive use (figure 11).

b. Projected Use. The EQB projected that most Minnesota counties would be able to meet their water supply needs from their own renewable resources through 2030. Eighteen counties are projected to be using more than 10% of their renewable resource in 2030 (figure 12). However, if nonconsumptive portions of use are included in the estimates ("gross water use" in figure 13), 22 counties would be projected to be using more than 10%, and 16 counties to be using more than 20%, of their estimated renewable resource (see figure 13). The report acknowledges that water availability within aquifers and ecosystem water needs are not well understood. The EQB report calls for research to define and characterize groundwater resources; to assess how much of the resource is renewable; to develop supply quantification methods; to characterize groundwater–surface water interactions; to describe and quantify ecosystem needs; and to understand the impacts of climate change as well as drainage and other land uses on rates of recharge and water demand, in order to effectively and sustainably manage Minnesota's water resources (VanBuren 2007).

Figure 10. Net 2005 water use as a percentage of renewable resource.

(Map from VanBuren 2007.)

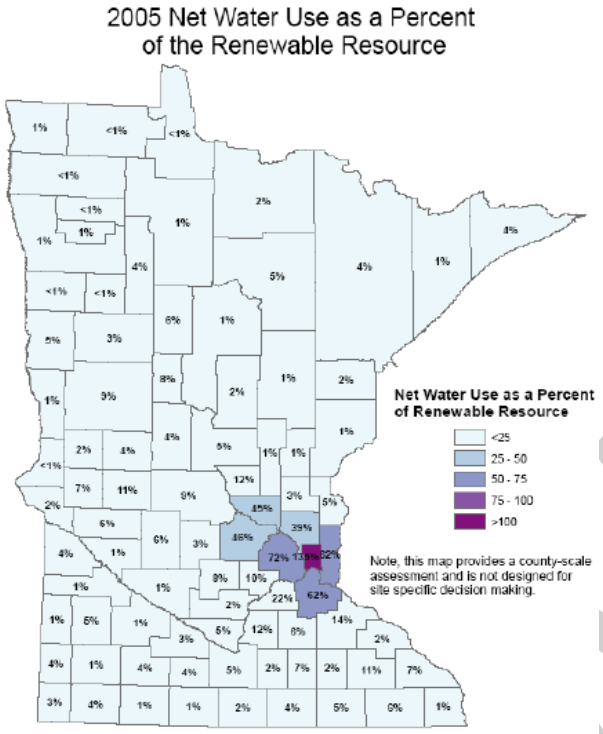


Figure 11. Net 2005 water allocations as a percentage of renewable resource.

(Map from VanBuren 2007.)

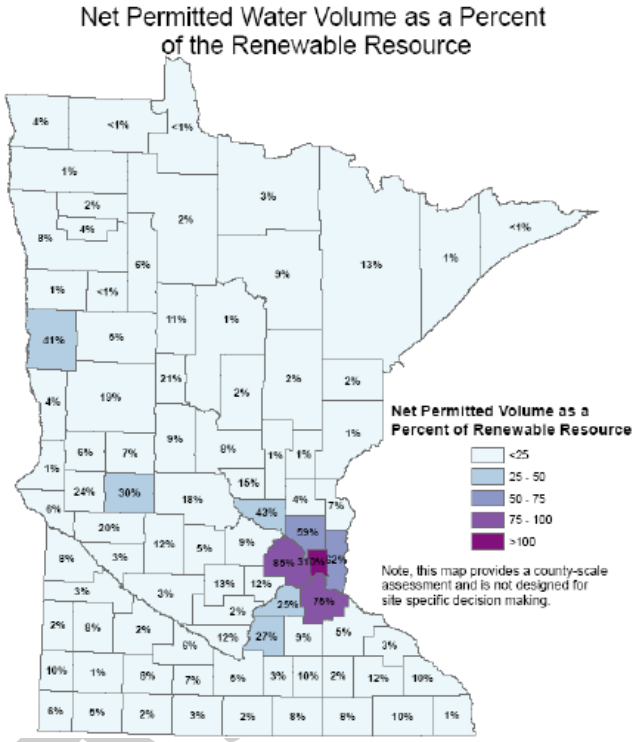


Figure 12. Projected net 2030 water use as a percentage of renewable resource.

(Map from VanBuren 2007.)

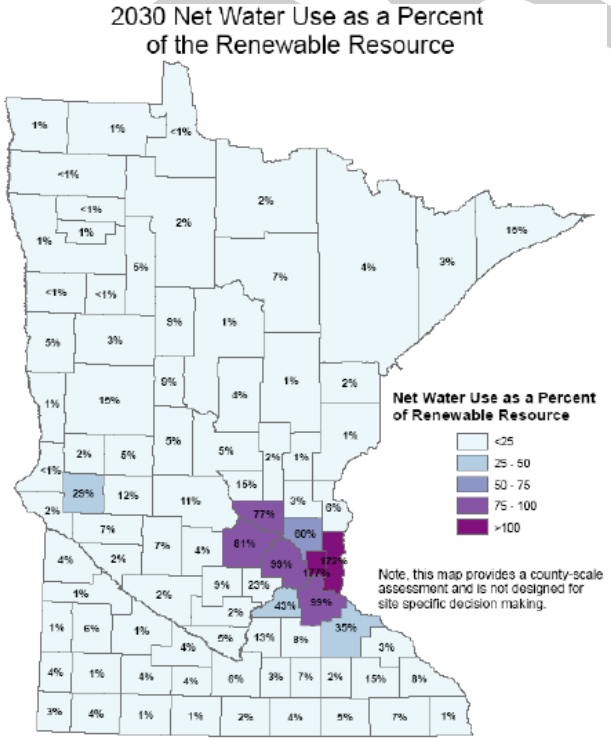
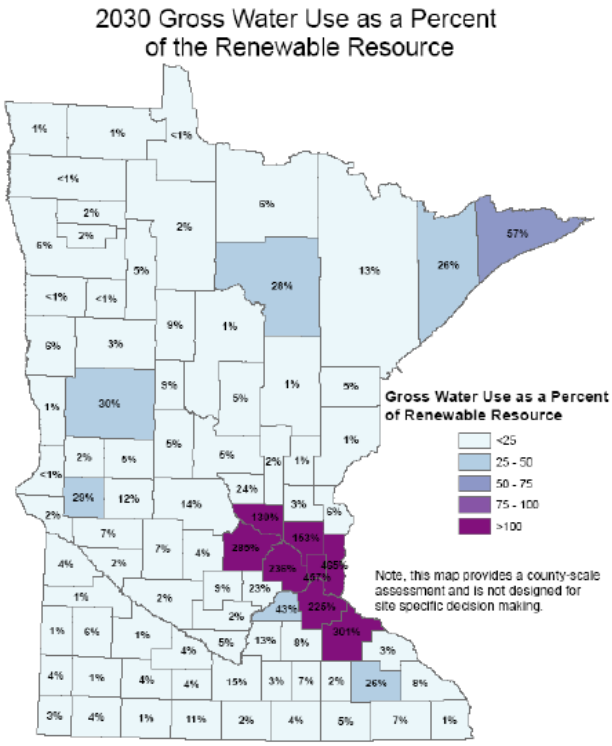


Figure 13. Projected gross 2030 water use as a percentage of renewable resource.

(Map from VanBuren 2007.)



3. Twin Cities Metropolitan Area

a. Recent. Twin Cities metropolitan area counties use a higher proportion of their assessed renewable resources than the rest of Minnesota (VanBuren 2007), as might be expected given the higher population density. Groundwater sources provide approximately two-thirds of the water consumed in the Twin Cities metro area, and serve about 1.6 million people through municipal water systems. An additional 290,000 people are estimated to be using self-supplied wells in the metro area. Approximately 880,000 people in the Twin Cities metro region rely, at least in part, on surface water as their drinking water source (Metropolitan Council 2007a, 2004).

Metro area water use in 2004 can be seen in figure 14. Metro counties' portions of annual total withdrawals (2000–2007) are shown in figure 15. Figures 16 and 17 show metro surface and groundwater use over time with and without thermoelectric use, respectively. The Twin Cities metro area used approximately 163 billion gallons of water in 2004(Metropolitan Council 2007a). Of this total, 46.3 billion gallons (9%) were self-supplied for nondomestic purposes. Another 116 billion gallons (22%) were delivered through municipal public supply. Of this municipal supply, 81.2 billion gallons (70%) were delivered for residential use by approximately 2.5 million people. These estimates do not include use for power generation. Power generation, although deemed nonconsumptive, accounted for approximately 345 billion gallons in the metro area for 2004, more than double all other reported uses combined (Hunt 2005, figure 14). As noted earlier, the movement toward the use of recirculation cooling in place of once-through cooling may call into question the presumption that power-generating use is nonconsumptive (Kenny et al. 2009, U.S. Environmental Protection Agency 2009). When including thermoelectric usage in state and metro use estimates, metro usage (508 billion gallons) accounts for approximately 37% of Minnesota's total 2004 usage (1,379 billion gallons); not including thermoelectric, metro usage (163 billion gallons) accounts for 32% of Minnesota's 2004 usage (506 billion gallons; Hunt 2005, Metropolitan Council 2007a, Metropolitan Council 2007b).

Figure 14. Water use in the Twin Cities metropolitan area, 2004.

(Data from Metropolitan Council 2007a, 2007b.)

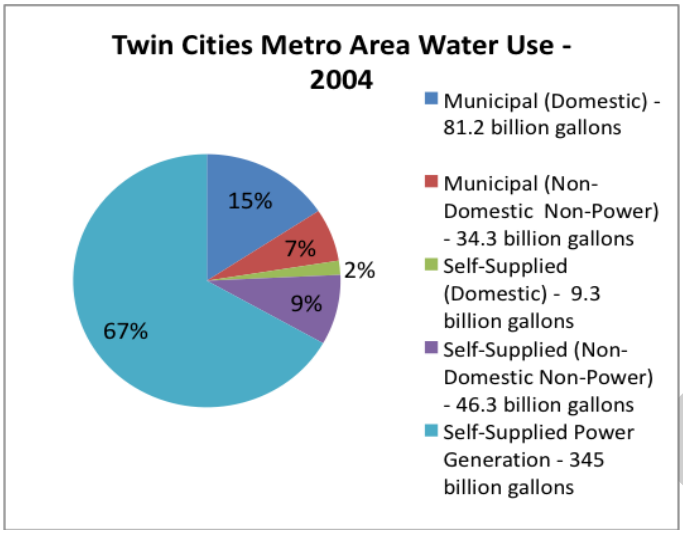


Figure 15. Annual metro water use by county.

(Data from Hunt, 1999, 2001, 2003, 2005, 2007, 2009.)

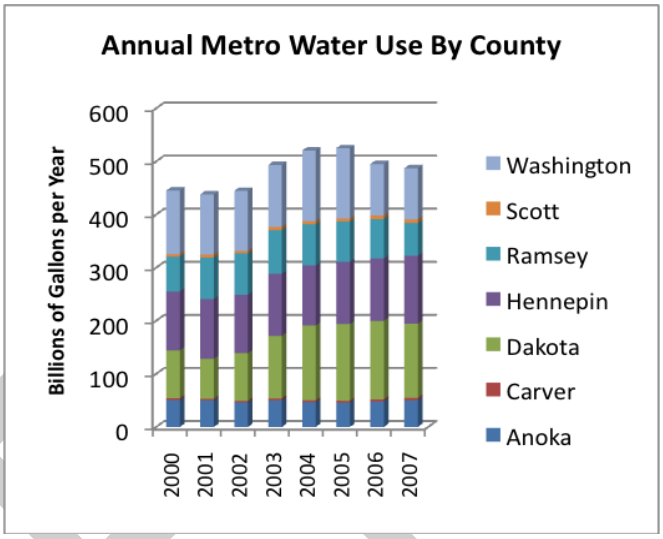


Figure 16. Metro area source withdrawals, 2001–2007.

(Data from Hunt 2003, 2005, 2007, 2009.)

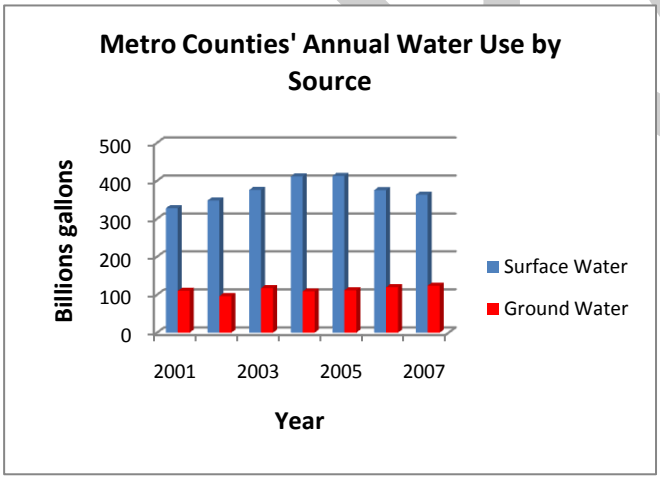
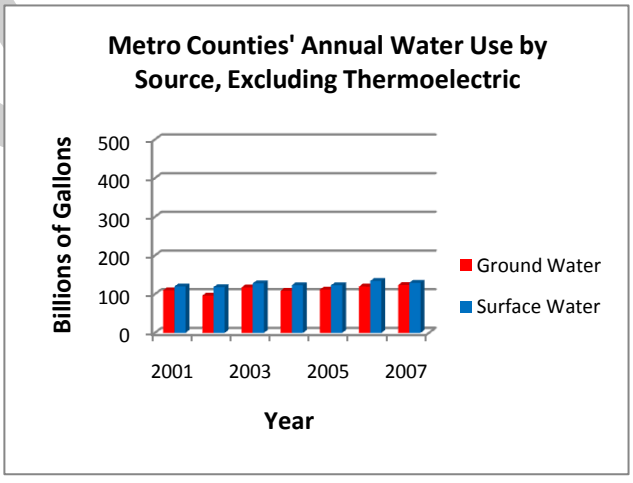


Figure 17. Metro area source withdrawals excluding thermoelectric 2001–2007.

(Data from Hunt 2003, 2005, 2007, 2009.)

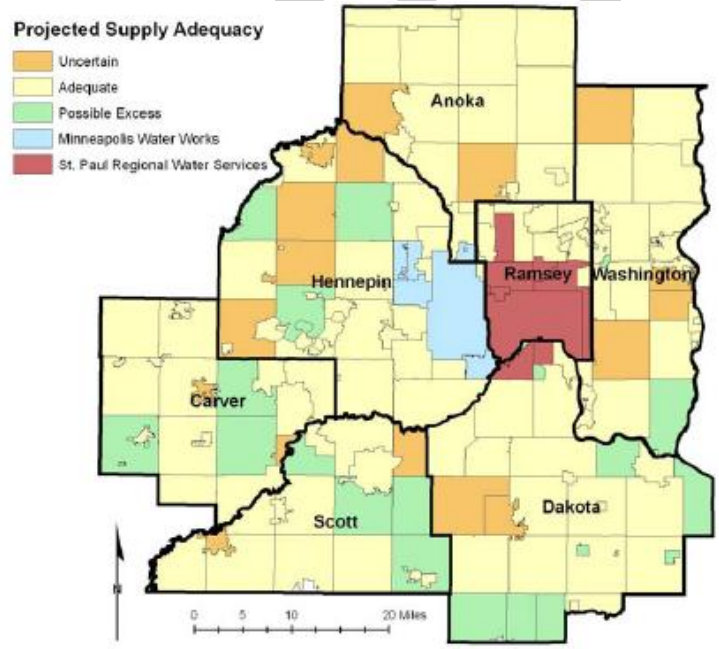


b. Projected. Compared to 2004, the Twin Cities metro area population is expected to increase about 33% by 2030, and about 60% by 2050 (Metropolitan Council 2007a, 2007b). The Metropolitan Council projected that related *municipal* water demands would increase about 27% by 2030, and about 52% by 2050. Projected municipal water use increases at a slightly lower rate than population growth based on the assumption that use of water-efficient appliances and general water conservation will increase in the future. *Total* water demand is projected to increase about 16% between 2004 and 2030, and 35% from 2004 to 2050. This projection incorporates expected increases in efficiency in domestic, commercial, and industrial uses, as well as reductions in withdrawals associated with once-through cooling, quarry dewatering, and agricultural uses during this period (Metropolitan Council 2007a, 2007b).

Based on these projections and estimates of available renewable supply, the Metropolitan Council found that 143 of 161 communities in the metro area are likely to have adequate supplies to meet their needs through 2030, with 23 of these communities likely having excess supply (figure 18). This is acknowledged to be a preliminary evaluation; further research is suggested in order to increase understanding of sustainability issues such as aquifer recharge and contamination, groundwater–surface water interactions, surface water contamination, low-flow impacts on availability, and well interference. Once again, thermoelectric use is not included in these estimates (Metropolitan Council 2007a, 2007b).

Figure 18. Projected adequacy of local supplies in 2050

(source: Metropolitan Council 2007a.)



VanBuren (2007) projected that metro counties will use a higher proportion of their renewable resources than will other Minnesota counties in 2030. Estimates of net (nonconsumptive) use as a percent of renewable supply for each metro county were: Anoka, 60%; Carver, 23%; Dakota, 99%; Hennepin, 99%; Ramsey, 177%; Scott, 43%; Washington, 172% (figure 12). When looking at gross (consumptive and nonconsumptive) use, the average metro county was projected to be using 229% of its renewable resource in 2030 (figure 13).

D. Uncertainties

The nature of the data makes a number of uncertainties inherent to this analysis. Among them:

- As has been stated above, consumptive use estimates are no longer provided in the USGS reports. Return flows from various uses may have altered composition or temperature. There is noted uncertainty related to consumptive use estimations when made on a category and statewide scale (Hutson 2004). As such, recent consumptive use estimates at such scales are difficult to obtain.

- Consumption related to thermoelectric use is often omitted from quantifications due to its being deemed largely nonconsumptive. However, given that recirculation cooling consumes a much higher proportion of the withdrawn water than does once-through cooling, and that recirculation cooling is becoming more common for new facilities, the nonconsumptive presumption regarding thermoelectric use should be examined. Note that the Metropolitan Council did not include thermoelectric use in its estimates (Metropolitan Council 2007b).

- Estimates of self-supplied domestic withdrawals are based on estimates of per capita use and total population not obtaining water from a public supplier, which could be subject to some error. This estimate amounts to about 2% of total Minnesota use (Kenny et al. 2009), however, so uncertainty in this category does not create as much overall uncertainty as does thermoelectric uncertainty.

- Different estimation methods used by different organizations also add uncertainty, especially when comparing information from different sources. As stated previously, the DNR includes mining withdrawals in the category of industrial processing, whereas the USGS lists mining as a separate category. The DNR does not include self-supplied domestic withdrawals or other withdrawals that do not require a permit in its reports, whereas the USGS does.

- Water needs for ecological services may need greater consideration to define flows necessary for maintenance of biological communities and the physical characteristics of water bodies.

- Estimates of future human demand for water entail uncertainty related to potential increases in efficiency and changes in use habits.

- Water supply estimation has acknowledged uncertainties. Increased understanding and characterization of Minnesota's glacial aquifers, aquifer recharge, and groundwater–surface water interactions would improve confidence in water supply estimations.

- Impacts of long-term climate change and of normal variations in precipitation and temperature on water use and water supply add to the uncertainty in estimating how much water we will have and how much we will need.

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Appendix A. Glossary

Aquaculture water use - water use associated with raising organisms that live in water (e.g., finfish and shellfish) for food, restoration, conservation, or sport. Aquaculture production occurs under controlled feeding, sanitation, and harvesting procedures primarily in ponds, flow-through raceways, and (to a lesser extent) cages, net pens, and closed-recirculation tanks.

Commercial water use - water use by motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from publicly supplied sources, such as a county water department, and self-supplied sources, such as local wells. Some commercial use estimates include public supply deliveries to golf courses.

Consumptive use - (1) the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment (USGS); (2) water withdrawn that is not directly returned to its original source. Under the second definition, all groundwater withdrawals are consumptive unless the water is returned to the aquifer from which it was obtained. Surface-water withdrawals are considered consumptive if the water is not directly returned to the source so that it is available for immediate further use (DNR).

Domestic water use - water used for indoor household purposes(e.g., drinking, food preparation, bathing, washing clothes and dishes, flushing toilets) or outdoor household purposes (e.g., watering lawns and gardens). This term can refer solely to self-supplied domestic water, or it may include both publicly supplied and self-supplied water used for domestic purposes.

Hydroelectric power water use - classified as an instream use, refers to the use of water in the generation of electricity at plants where the turbine generators are driven by falling water.

Industrial water use - water use for fabrication, processing, washing, and cooling, in such industries as steel, chemical, paper, and petroleum refining. The DNR includes mining in this category, whereas the USGS distinguishes mining as a separate category.

Instream use - the use of freshwater in situ (for example, within a river or stream). This can include recreation, tourism, scientific and cultural uses, ecosystem maintenance, hydroelectricity and commercial activities, and dilution of waste. The volume of water required for most instream uses cannot be quantified, with the exception of hydroelectricity generation.

Irrigation water use - water application on land to assist in plant growth in agriculture and horticulture or to maintain plant growth in land used for recreation or other purposes, such as parks, golf courses, and cemeteries. Irrigation also includes water applied for pre-irrigation, frost protection, application of chemicals, weed control, field preparation, crop cooling, harvesting, dust suppression, or leaching salts from the root zone, and water lost in conveyance. Irrigation water use includes self-supplied withdrawals and deliveries from irrigation companies, irrigation districts, cooperatives, or governmental entities.

Livestock water use - water use for livestock watering, feedlots, dairy operations, fish farming, and other on-farm needs. Livestock water uses include cooling of facilities for animals and animal products such as milk, dairy sanitation and wash-down of facilities, animal waste disposal, and incidental water losses. All withdrawals are considered self-supplied. The livestock category excludes on-farm domestic use, lawn and garden watering, and irrigation.

Mining water use - water use for the extraction of minerals in the form of solids, such as coal, iron, sand, and gravel; liquids, such as crude petroleum; and gases, such as natural gas. The category includes quarrying, milling (crushing, screening, washing, and flotation of mined materials), reinjecting extracted water for secondary oil recovery, and other operations associated with mining. Dewatering is not reported as a mining withdrawal unless the water was used beneficially, such as dampening roads for dust control.

Offstream uses - uses in which water is removed from its source by pumping or diversion.

Other uses - includes water withdrawn for activities including air conditioning, construction dewatering, water level maintenance, and pollution confinement

Public supply - surface water and groundwater distributed by community suppliers for domestic, commercial, industrial, and public users. Depending on context, this term connotes either a source (e.g., publicly supplied domestic vs. self-supplied domestic) or a use (e.g. water appropriated for public suppliers vs. that appropriated for self-supplied industrial use).

Public-supply delivery - delivery of water from a public supplier to users for domestic, commercial, industrial, thermoelectric power, or public use.

Public-supply water -water withdrawn by public and private suppliers that furnish water to at least 25 people at least 60 days per year or have a minimum of 15 connections. Public suppliers provide water for a variety of uses, such as domestic, commercial, industrial, thermoelectric power, and public water use.

Public water use - use of water from a public supplier for purposes such as firefighting, street washing, flushing of water lines, and maintaining municipal parks and swimming pools. Generally, public water use is not billed by the public supplier.

Thermoelectric power water use - use of water in thermoelectric power generation. Power plants that burn coal and oil are examples of thermoelectric power facilities. Most water withdrawn by thermoelectric plants is used for condenser and reactor cooling. Thermoelectric cooling systems can be "once-through cooling" or "recirculation" systems. In **once-through cooling systems,** also known as open-loop systems, water is withdrawn from a source, circulated through heat exchangers, and then returned to a body of water at a higher temperature. The USGS has estimated that less than 3% of water used in these systems is consumed. In **recirculation (closed-loop cooling) systems,** water is withdrawn from a source, circulated through heat exchangers, cooled, and then recycled. Subsequent water withdrawals for a closed-loop system are used to replace water lost to evaporation, blow-down, drift, and leakage.