SOCIAL/PHYSICAL IMPACTS AND WATER CONSUMPTION CHARACTERISTICS OF SOUTH DAKOTA'S RURAL WATER SYSTEMS

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ABOUT THE Regional Water System Research Consortium

The Regional Water System Research Consortium (RWSRC) was formed to support research and development projects to develop management and operational tools to sustain the development and service life of regional rural water systems. RWSRC is supported by funds contributed by South Dakota regional rural water systems, the South Dakota Association of Rural Water Systems, and several water development districts in South Dakota. Administrative support and project management are provided through the Water and Environmental Engineering Research Center in the College of Engineering at South Dakota State University.

This report provides the results of two projects funded by RWSRC. The social/physical impacts project examined the impacts of regional water system development on domestic water quality and the physical water delivery infrastructure improvements in the State of South Dakota. The water use characterization study examined trends in water demands of customers served by regional rural water systems. The report also served to meet the Master of Science thesis requirements for Matt Pajl, graduate research assistant in the Civil and Environmental Engineering Department at South Dakota State University.
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ABSTRACT

SOCIAL/PHYSICAL IMPACTS AND WATER CONSUMPTION CHARACTERISTICS OF SOUTH DAKOTA'S RURAL WATER SYSTEMS

This study investigates the social and physical impacts that rural water systems have on South Dakota's population and the water consumption characteristics of city, country dwelling, and farm customer classifications. The physical characteristics of South Dakota's rural water systems along with the 2006 water production and sales information were used to determine and relate the unique distribution characteristics and water consumption demands of the rural water systems. The impact of improved water quality to the customers of the rural water systems was shown in improved livestock production and health, customer softening salt savings, and reduction of total dissolved solids entering South Dakota's water ways. To examine the unique distribution system characteristics and water consumption demands of regional rural water systems, the water consumption characteristics and trends of city, country dwelling, and farm customers of Big Sioux Community Water System, Clay Rural Water System, Mid-Dakota Rural Water, and TM Rural Water District were compared.

The results indicated that South Dakota's regional rural water systems generally average 1.5 water meters per square mile. As a result of lower water hardness distributed through rural water systems, customers that switch from a community water system to rural water and use an ion exchange system in their dwelling could annually save $31.91 per year due to lower salt use for regeneration. The lower regeneration frequency improved water quality by reduced dissolved solids discharged into the water environment by 800 pounds per year. Farmers that switched their water source from private wells to rural water experienced increased livestock production and health - one dairy farm located in the TM Rural Water District saw a daily milk yield increase of 8 to 10 pounds per cow.

Water use records of customers served by rural water system indicated cities with populations fewer than 100 used 71 gallons per person per person per day, customers of cities with populations ranging from 100 to 500 used 87 gallons per person per day, and customers in cities with populations over 500 used 119 gallons per person per day. The daily water demand for country dwelling customers ranged from 151 gallons per day to 335 gallons per day, and generally experienced an increase in customer numbers from 1999 to 2007. Farm customers had the highest averaged daily water demand at 456 gallons per day.

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LIST OF ABBREVIATIONS

ADG	Average Daily Gains
$CaCO_3$	Calcium Carbonate
Ca	Calcium
Cl	Chloride
CWS	Community Water System
DENR	Department of Environment and Natural Resources
DW	Dam Water
Eq.	Equation
Fe	Iron
kg	Kilograms
Mg	Magnesium
Mn	Manganese
MG	Midgrasses
MG	Million Gallons
mg/L	Milligrams per Liter
Na	Sodium
NaCl	Sodium Chloride
NO_3	Nitrate
PEM	Polioencephalomalacia
ppm	Parts per Million
RW	Rural Water
RWS	Rural Water System/Regional Water System
SDDENR	South Dakota Department of Environment and Natural Resources
SG	Shortgrasses
SO_4	Sulfate
TDS	Total Dissolved Solids
WW	Well Water

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CHAPTER 1

INTRODUCTION

1.1 Background

Rural water systems have been developed and have matured as reliable water supply systems that are vital to South Dakota's infrastructure and society. They have brought high quality water to the taps of water users in rural areas and, in many cases, have replaced or supplemented the water sources of municipal systems. Rural water systems have contributed to the betterment of society through improved health and welfare of people, improved health and production of livestock, increased reliability of the water supply, and more efficient use of water. In realizing those benefits to society, new systems are continually being proposed, even while existing systems continue to grow in response to demand. Additionally, small utilities considering system improvements are encouraged by the South Dakota Department of Environment of Natural Resource (SDDENR) to connect to a rural system as an alternative source.

Each new system, or expansion to an existing system, requires a planning effort that develops design criteria for the system. Ultimately, flow variations, such as the average and maximum day demand must be estimated. Typically these flow estimates are considered "system specific", reflecting the water needs of the users in the system. The estimated flows vary as a function of user type and density. These design criteria drive funding requests and design calculations for the system. Accurate flow estimates provide credibility to the planning and design process.

After the system is constructed, additional factors influence the flows experienced and delivered by a system. These factors include pipe size, system pressure, water leakage, changes in customer base (additional customers such as value-added industry, population shifts in municipal customers, shutoffs due to decreasing farm population), and unanticipated climate impacts (drought and associated potential water restrictions).

While engineers and managers working with individual rural water systems examine their system's impact on the physical environment, existing and potential water demand, and system physical characteristics, a current overview and analysis of these topics that considers all of the systems in South Dakota is not available in textbooks or published technical literature. Additionally, there are no published comparisons of trends in water use in South Dakota's rural water systems.

1.2 Objective

The purposes of this study were to assess the impacts rural water systems have on South Dakota's social/physical environment and examine the trends in rural water system water usage. Water quality data were examined to determine whether water quality from rural water systems contributed substantial improvements to the social/physical environment of South Dakota. Relationships between rural water system characteristics and water consumption by various use categories were developed to identify trends in water usage.

1.3 Scope

This project required the creation of two surveys that acquired data on both the physical characteristics and the quantity/quality of water produced by South Dakota's rural water systems during 2006. The project also required the collection of monthly water meter readings for each individual customer from 1999 to 2007 for Big Sioux Community Water System, Clay Rural Water System, Mid-Dakota Rural Water, and TM Rural Water District. Data from the physical characteristics survey was analyzed to identify infrastructure characteristics South Dakota's rural water systems.

Data collected on the quality and quantity of drinking water produced and sold by rural water systems during 2006 were evaluated to determine the percent of unaccounted-for water loss for each system, the social impacts of improved drinking water quality, and the demand characteristics of four main customer classifications. Social/environmental impacts of improved drinking water quality were evaluated based on customer savings on water softening salt, reduction of total dissolved solids entering wastewater flows, and improved livestock production and health.

Monthly water meter readings from the Big Sioux, Clay, Mid-Dakota, and TM water systems were examined to find water demand variations and trends for city customers, country dwelling customers, farm customers, and other customers (mostly commercial customers). The examination of the water demand variations and trends led to the discovery of water consumption characteristics for the four customer classifications. Important water consumption characteristics were daily water demands per customer, peaking factors, effect of precipitation on daily water demands, and yearly consumption trends.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Published literature was reviewed to gain information that could be used to understand impacts of water quality on various agricultural uses, mainly various aspects of livestock production. Literature regarding demand variations in rural water systems was sought, but not found. However, regionalization of water supply systems has been studied, a summary of which is included in this review.

Researchers proved that drinking water quality had many effects on both livestock production (i.e. weight gains and milk yields) and health. Higher (better) quality drinking water had positive effects on livestock. Researchers also discovered that regionalization of community water supplies was mostly beneficial for small cities and communities similar to the majority of South Dakota's cities.

2.2 Impacts of Water Quality on Beef Cattle

A case study conducted by Lardner et al. (2005) examined the effect of water quality on cattle performance on pasture in Saskatchewan, Canada. The drinking water quality was affected by four different treatments. The treatments were direct water access, untreated dugout water, aerated water (removed taste and odor), and coagulated/chlorinated water (aluminum sulfate, powdered activated carbon, and 1.0 mg/L of chlorine). This study compared the effects of the four water treatments on 44 Hereford yearling steers for five years and 40 Angus cow-calf pairs for three years. In both experiments the data were collected between the months of late May/early June and mid-September. The results showed the aerated and coagulated water had a positive effect on the cattle so they spent less time drinking and more time grazing and loafing. The results also demonstrated that the aerated and coagulated water causes improved weight gains by 9-10% over a 90-day grazing period.

Patterson et al. (2003) studied three different types of water and the effect on steers in South Dakota. The study was conducted on 81 crossbred yearling steers (700 lbs) during June 20th to September 12th. The types of water were rural water (1,019 ppm TDS; 404 ppm sulfates), well water (4,835 ppm TDS; 3,087 ppm sulfates), and dam water (6,191 ppm TDS; 3,947 ppm sulfates). The results showed the final weights of the steers receiving well water (WW) and dam water (DW) were 33 and 35 lb lighter, respectively, than steers receiving rural water (RW). Dry matter intake in WW and DW treatments was 6.2% and 5.0% less, respectively, than RW. There was no morbidity or mortality in the calves receiving RW, but calves on WW and DW experienced 25% and 15% morbidity, respectively, and one steer from WW and two steers from DW died of polioencephalomalacia (PEM). The results illustrate that increased TDS and/or sulfates in the water reduced performance and health of growing steers. This conclusion is supported by Patterson et al. (2004) and Tjardes et al. (2004) who also examined the effect of TDS and sulfate on growing steers.

Patterson et al. (2004) conducted a case study on the effects of sulfates in water on grazing steers in South Dakota. The study placed steers in both warm-season shortgrasses (SG) and cool-season midgrasses (MG) during May 22nd to September 6th. Steers in both grasses could be exposed to either low sulfate water (375–420 ppm in 2001 and 375–490 ppm in 2002) or high sulfate water (3,170–4,600 ppm in 2001 and 4,550–5,390 ppm in 2002). The results showed that for both SG and MG pastures with high sulfate water, the steers had lower average daily gains (ADG) than the pastures with low sulfate water. In 2001, the high sulfate treatment resulted in a 10.7% reduction in average daily gains compared to low sulfate treatment, and in 2002, the difference in ADG between the two sulfate treatments was 26.4%. Steers receiving the high sulfate water also had a high rate of PEM, a metabolic disorder induced by high sulfur ingestion.

Another case study investigated the effects of water sulfate concentrations on the performance of water intake and carcass characteristics of feedlot steers in Kansas (Loneragan et al., 2001). Two hundred and forty crossbred steers (304 kg) were used to test the effects of several different concentrations of sulfate in drinking water: 136.1 (±6.3), 291.2 (±15.3), 582.6 (±16.9), 1219.2 (±23.7), and 2,360.4 (±68.2) mg/L. The results were accumulated from July 14th to November 4th and exhibited similar trends to those of Johnson et al. (2004), where increased sulfate concentrations caused decreased ADG and decreased food intake. In addition, steers exposed to increased sulfate concentrations exhibited a linear decrease in final weight, hot carcass weight, and dressing percentage.

A brief summary of the impact of different quality drinking waters on beef cattle performance as indicated by these studies is given in Table 2.1. These studies indicate improved performance (weight gain) in beef drinking lower sulfate/TDS water. Since most rural water systems in South Dakota provide water containing lower sulfate concentrations than the source used by the customer prior to connecting with rural water, it can be said that rural water supplies provide the potential to increase weight gain in beef animals.

2.3 Impacts of Water Quality on Dairy Cattle

Jaster et al. (1978) examined the effects of saline drinking water on dairy cows in Arizona. Twelve Holstein dairy cows in two groups were studied for 28 days to compare daily milk production. One group drank tap water (196 ppm dissolved salts) and the other group drank saline water (tap water plus 2,500 ppm sodium chloride). The cows that drank tap water decreased their water intake by 9.3 liters/head per day and increased daily milk production by 1.9 kg/head per day as compared to cows that drank saline water.

Solomon et al. (1995) examined the performance of dairy cows offered drinking water with high and low concentrations of salinity in southern Israel. In the case study 82 Holsteins were divided into two groups - one group received desalinated drinking water (442 mg/L of TDS) and the other group received saline drinking water (1,480 mg/L of

TDS) for the duration of early May to late August. The results showed the group that was offered desalinated drinking water produced 35.2 kg of milk per day versus 33.1 kg of milk per day from the second group that was offered saline drinking water. The daily

Table 2.1. Literature Summary of Beef Cattle Benefits

Title of Paper	Author(s)	Important Points
The effect of water quality on cattle performance on pasture	Lardner, H. A., B. D. Kirychuk, L. Braul, W. D. Willms, and J. Yarotski (2005)	Over the time of five years it was discovered that 44 Hereford yearling steers saw 9-10% weight gains during 90-day grazing periods when exposed to aerated and coagulated drinking water instead of untreated dugout water and direct water access.
Effects of water quality on performance and health of growing steers	Patterson, H. H., P. S. Johnson, D. B. Young, and R. Haigh (2003)	Crossbred yearling steers in South Dakota that were given rural water had experienced 33 and 35 pound weight gains over yearling steers given well water and dam water, respectfully. Steers given rural water had also seen a 25% and 15% reduction in morbidity.
Effect of total dissolved solids and sulfates in drinking water for growing steers	Patterson, H. H., P. S. Johnson, W. B. Epperson, and R. Haigh (2004)	Steers given low sulfate water during the summer months of May through September had experienced a 10.7% increase in average daily gains than steers given high sulfate water.
Effects of water sulfate concentration on performance, water intake, and carcass characteristics of feedlot steers	Loneragan, G. H., J. J. Wagner, D. H. Gould, F. B. Garry, and M. A. Thoren (2001)	In 240 crossbred steers the increased sulfate concentrations had a linear decrease in final weight, hot carcass weight, and dressing percentage.

protein production was also higher for the desalinated water herd over the saline water herd, 1.01 kg versus 0.93 kg, respectfully.

2.3 Impacts of Water Quality on Dairy Cattle

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Pedersen (2008) provided a local case study of a dairy farm of 1,530 head that connected to TM Rural Water District in South Dakota during August 2004 and had a monthly water consumption of 1.3 to 1.5 million gallons. The 1,530 head of dairy cows experienced an increase in daily milk production of about 8 to 10 pounds per cow, which in 2004 was equivalent to about $1,800 per day additional income. The dairy farm also experienced a cull rate reduction of 6% of the total herd size and the disease rate decreased by half. It was discovered that the dairy cows receiving rural water in the calving facility had higher levels of vitamin E than the cows receiving non-rural water in the main dairy. The dairy cows with the higher levels of vitamin E were healthier than the rest of the cows. After the main dairy area was connected to the rural water, the vitamin E levels stabilized for all of the cows.

The references reviewed for the impact of water quality on dairy cattle performance is given in Table 2.2.

2.4 Impacts of Water Quality on Swine

A publication by Shannon (2007) “Water: The Essential Nutrient” tells how quality water plays an important role in weaning pigs’ weight. Water with high total dissolved solids (TDS) and salinity caused swine to drink less water, which hinders weight gains. These results are supported by the results from Leibbrandt et al. (2001), who proved ample amounts of drinking water are essential for sow and litter performance.

Leibbrandt et al. (2001) investigated the effect of water availability on the performance of lactating swine by controlled water flow rates through nipple drinkers. In Wisconsin, two hundred and thirty-six crossbred litters were studied with drinking water flows of 700 mL/min and 70 mL/min during both winter (November through February; 124 litters) and summer (June through August; 112 litters). Results indicated that the restricted water flow rate (70 mL/min) decreased sow feed intake (4.68 vs. 3.85 kg/d, respectively, for 700 and 70 mL/min) and increased sow weight loss (0.46 vs. 0.83 kg/d, respectively, for winter and summer), and decreased litter weight at 21 days of lactating (52.8 vs. 49.6 kg, respectively, for winter and summer) but did not affect litter size.

Table 2.2. Literature Summary of Dairy Cattle Benefits

Title of Paper	Author(s)	Important Points
Physiological effects of saline drinking water on high producing dairy cows	Jaster, E. H., J. D. Schuh, and T. N. Wegner (1978)	Holsteins that drank tap water with 196 ppm of dissolved salts experienced daily milk yields of 1.9 kg/head more than Holsteins that drank water with 2,500 ppm of dissolved salts.
Performance of high producing dairy cows offered drinking water of high and low salinity in the Arava Desert	Solomon, R., J. Minor, D. Ben-Ghedalia, Z. Zomberg (1995)	Holsteins that drank desalinated water had increase daily milk yields and increased daily protein production versus Holsteins that drank saline water.
TM Rural Water Affects Milk Output*	Pedersen, Ken (2008)	Dairy cattle that drank rural water had increased daily milk production of 8 to 10 pounds per head, increased vitamin E levels, a 6% lower cull rate, and a decreased disease rate compared to dairy cattle that drank well water.

* Testimonial not a published technical paper

Anderson (1978) examined an experiment in Manitoba, Canada on effects of saline drinking water on young weanling pigs. One hundred and sixty-two, four to six kg weanling pigs were divided into three groups and studied for 6 weeks and 3 weeks to compare weight gains. Group one was given tap water (125 ppm total solids), group two saline water (6,000 ppm total solids), and group three saline water plus nitrate nitrogen (6,000 ppm sodium chloride plus 300 ppm nitrate nitrogen) to drink. The results showed no significant difference in the weanling pig's average daily gains between the different drinking waters. However, weanling pigs drinking tap water exhibited increased feed intake, faster gains, and a better feed to gain ratio, than the weanling pigs on saline water.

A brief summary of the impact that different quality drinking waters had on swine performance was given in Table 2.3.

2.5 Impacts of Water Quality on Poultry

Studies were conducted to see if different concentrations of sodium chloride (NaCl) in water would affect the quality of the egg shell. Damron (1998) tested five different concentrations of NaCl on White Leghorn hens in Florida; the concentrations were 0, 200, 400, 600, and 800 ppm of NaCl in drinking water. The hens were studied for durations of 5 and 6 weeks starting in October and July, respectfully. The results showed the egg quality was insensitive to any of the NaCl concentrations. This result is supported by Chen and Balnave (2001). Chen and Balnave studied a sodium chloride concentration of 2 g NaCl/L mixed into the local drinking water, which contained

Table 2.3. Literature Summary of Swine Benefits

Title of Paper	Author(s)	Important Points
Effect of nipple drinker water flow rate and season on performance of lactating swine	Leibbrandt, V. D., L. J. Johnston, G. C. Shurson, J. D. Crenshaw, G. W. Libal, and R. D. Arthur (2001)	Sows that drank 70 mL/min of water had decreased feed intake, decreased litter weight, and increased sow weight loss when compared to sows that drank 700 mL/min of water.
Water: the essential nutrient	Shannon, M. (2007)	Weaning pigs that drank high TDS water had lower water intakes which equaled lower weight gains.
Effects of saline water high in sulfate, chlorides, and nitrates on the performance of young weanling pigs	Anderson, D. M., S. C. Stothers (1978)	Weanling pigs that drank tap water compared to weanling pigs that drank both saline water and saline water with nitrate nitrogen had experienced increased feed intake, faster weight gains, and better feed to weight gain ratios.

<1mmol Cl/L, and used IsaBrown hens as the test subjects.

Vodela et al. (1997) examined effects of drinking water contaminants on the general performance and immune function in broiler chickens in Alabama. The experiment lasted for 49 days and had both low concentrations (0.80, 1.3, 5.0, 6.7, and 0.65 ppm) and high concentrations (8.6, 13, 50, 67, and 6.5 ppm) of arsenic, benzene, cadmium, lead, and trichloroethylene, respectfully, mixed in the drinking water. At day 49, the mean water and feed consumption in control chickens was 1,320 mL per chicken per day and 1,328 g per chicken per day, respectively. This was compared to water and feed consumption of 336 mL per chicken per day and 367 g per chicken per day in chickens simultaneously exposed to the high contaminant concentration. The results exhibited a decrease in feed consumption, body weight, and immune function for both the low and high concentrations of contaminants.

Shlosberg et al. (1998) studied the effects of sodium chloride, ammonium chloride, and potassium bicarbonate in the drinking water of broilers on the development of the ascites syndrome. The case study was conducted in Israel and lasted for 47 days. The pertinent part of the case study was the addition of 1,000 mg/L of NaCl to tap water. This addition of NaCl increased the mortality of the broilers due to ascites in the cold environment. It was discovered that sodium chloride levels of about 1,000 mg/L would threaten the health of broilers.

The publication by the University of Missouri (2005) "Interpretation guide for poultry water analysis" illustrates how poor water quality can reduce performance, retard growth, produce lower egg quality, and cause illness and/or death. Drinking water with total dissolved solids (TDS) levels of 3,000 - 5,000 ppm could cause poultry to refuse to drink and cause watery feces. Those TDS levels could also increase mortality and decrease growth, especially for turkeys. Nitrate-N levels of 3 - 20 ppm have been suspected to affect the poultry's performance, and sulfate levels greater than 50 ppm can affect the body size performance when sodium, magnesium or chloride levels are high.

A brief summary of the impact that different quality drinking waters had on poultry performance was given in Table 2.4.

Table 2.4. Literature Summary of Poultry Benefits

Title of Paper	Author(s)	Important Points
Sodium chloride concentration in drinking water and eggshell quality	Damron, B. L. (1998)	Different concentrations of sodium chloride from 0 ppm to 800 ppm had no significant impact of egg shell quality.
Interaction of contaminants with nutritional status on general performance and immune function in broiler chickens	Vodela, J. K., J. A. Renden, S. D. Lenz, W. H. Mcelhenney, and B. W. Kemppainen (1997)	Boiler chickens exposed to both low and high concentrations of arsenic, benzene, cadmium, lead, and trichloroethylene in drinking water experienced decrease in feed consumption, body weight, and immune function. Chickens that drank the higher concentration of contaminants had lower feed consumption.
Comparative effects of added sodium chloride, ammonium chloride, or potassium bicarbonate in the drinking water of broilers, and feed restriction, on the development of the ascites syndrome	Shlosberg, A., M. Bellaiche, E. Berman, A. Ben David, N. Deeb, and A. Cahaner (1998)	Boiler chickens that drank water with 1,000 mg/L of sodium chloride saw increased mortality due to ascites during cold environments. Also, sodium chloride levels of about 1,100 mg/L would threaten the health of broiler chickens.
Interpretation guide for poultry water analysis	University of Missouri Extension (2005)	Poultry that drank water with TDS levels of 3,000 to 5,000 could have exhibited increase mortality and decrease growth

2.6 Impacts of Water Quality on Sheep

Several case studies were conducted by A. W. Peirce to determine the salt tolerance of sheep from drinking water in Australia. The first case study (Peirce, 1957) examined the impact of sodium chloride (NaCl). Those concentrations were 0, 1.0, 1.5, and 2.0 percent of NaCl in the drinking water, and were given to four groups of six sheep each for 15 months. Results show the health of all six sheep drinking water containing 2.0 percent NaCl had been affected to some degree. At the end of the experiment one of the sheep from the 2.0 percent NaCl group had a food consumption of only 10% of the control group. Other results showed a linear reduction in food consumption as the percent of NaCl increased, and wool production was not affected.

Other case studies (Peirce, 1959, 1961, and 1963) showed similar results to the case study above. In Peirce (1959) sheep were given different mixtures of sodium chloride and magnesium chloride in the drinking water for 16 months, the concentrations were 1.3 + 0.0, 1.27 + 0.02, 1.24 + 0.05, 1.18 + 0.10, 1.05 + 0.20, and 0.69 + 0.50 percent, respectively. Results indicated the higher concentrations of magnesium chloride, the sheep ate less food, which related to decreased body weight. However, the wool production was not affected by the different concentrations. The ingestion of waters with high saline concentrations appeared to depress the sheep's appetite.

The results of Peirce (1961 and 1963) showed high concentration of salinity in drinking water reduced food consumption and in turn decreased body weight. High concentrations of salinity also increased the water intake of the sheep, but the different concentrations did not have an effect on wool production or the general health of the sheep.

A brief summary of the impact that different quality drinking waters had on sheep performance was given in Table 2.5.

Table 2.5. Literature Summary of Sheep Benefits

Title of Paper	Author(s)	Important Points
Studies on salt tolerance of sheep. I. The tolerance of sheep for sodium chloride in the drinking water	Peirce, A. W. (1957)	There was a linear reduction in food consumption as the percent of sodium chloride in the drinking water increased, but the wool production was not affected.
Studies on salt tolerance of sheep. II. The tolerance of sheep for mixtures of sodium chloride and magnesium chloride in the drinking water	Peirce, A. W. (1959)	Sheep that drank the water with higher the concentration of magnesium chloride saw decreased body weight. The wool production was not affected by the different drinking waters.
Studies on salt tolerance of sheep. IV. The tolerance of sheep for mixtures of sodium chloride and calcium chloride in the drinking water	Peirce, A. W. (1961)	Sheep that drank saline water had decrease body weight and increased water intake. Also the wool production was not affected by the saline drinking water.

2.7 Benefits of Regionalization of Community Water Systems

Schulz and Austin (1976) conducted a case study to estimating the water demands placed on rural water systems by livestock in Iowa. The study isolated two sections of a rural water system. Section one (Tower D) had 10 water connections while section two (Tower C) had 30 water connections. Both Tower D and Tower C service areas were heavily populated with livestock. The results showed that two major peak water demands formed during the times of 7 a.m. to 9 a.m. and 6 p.m. to 7 p.m. Sixty percent of the peak daily flow occurred during the afternoon hours. The peak daily flows were attributed to the watering of livestock, which generally occurred around 7 a.m. and 6 p.m. The results also found that a rural water system with a large livestock population experienced longer duration of peak daily flows than community water systems with high density residential areas. It was also found that many of the farms and rural customers served by the rural water system had previously used wells for their water supply. The wells produced poor quality water, whereas the rural water system provided greater quantity and better quality water to the customers.

Rogers and Louis (2007) studied the economic benefits received by community water systems once they consolidated to a regional water system. The study was conducted on the performance assessment and evaluation methods of consolidated community water systems. It was stated that the external forces of increasing service demands, decreased financial stability, and decreasing resource availability encourage small community water systems to consolidate into regional water systems. The results of the study indicated that consolidated community water systems would better benefit in both decision making and financially when operated by one regional water system entity.

Holmes (2006) studied small community water systems in New Mexico faced with economic and water quality problems. Most small community water systems lacked qualified operators; in fact only 60% of the water systems had certified operators. Community water systems that consolidated into regional water systems realized benefits of water security (reliability) during times of emergencies, professional operators, higher quality water, and reduced operational costs from shared expenses.

A brief summary of the benefits that came from regionalizing community water systems was given in Table 2.6.

Table 2.6. Impact of Regionalization on Community Water Systems

Title of Paper	Author(s)	Important Points
Estimating stock water use in rural water systems	Schulz, R. S., T. Austin (1976)	Rural water systems that have a high livestock population would experience longer daily peak flows than community water systems that have high density residential areas. Also, a rural water system provides its customers with quality drinking water and a reliable water source.
Method for comparative performance assessment and evaluation of consolidating community water systems as a regional water system	Rogers, J. W., G. E. Louis (2007)	Because of increasing service demands, decreased financial stability, and decreasing resource availability, small community water systems need to consolidate into regional water systems.
Regionalization of rural water systems in New Mexico	Holmes, M. (2006)	Regionalization of small community water systems provided water security during times of emergencies, professional operators, higher quality water, and reduced operational costs.

CHAPTER 3

METHODS AND MATERIALS

3.1 Introduction

Two surveys were created and sent out to all thirty of South Dakota's rural water systems to collect regional water system's physical characteristics and their 2006 customer classification's water consumption characteristics. In addition to the two surveys, an additional focused effort gathered specific customer consumption data from Big Sioux Community Water System, Clay Rural Water System, Mid-Dakota Rural Water, and TM Rural Water District. Analysis of the data collected for this study ranged from simple comparisons of the number of water meters per square mile of distribution system to more complicated comparisons of water consumption trends for different customer classifications over a period of years.

3.2 Collection of Regional Water System Characteristics Data

In order to analyze each rural water system's physical characteristics, a survey was created to ask specific questions about the number of water meter hookups, number of cities served and how they were served (bulk or individually), type of water sources, water treatment facilities and the quality of water produced, pumping station pressures and flows, capacity of water storage tanks, and distribution pipe characteristics. A copy of the survey form is found in Appendix A. Data regarding the characteristics of treatment facilities, storage tanks, number of meter hookups, and pipe characteristics gave insight into the unique characteristics of each regional water system's distribution service areas and water supply capabilities. Other data collected about the water source, the number of cities and their service type, and the water quality questions were used to describe the scope, extent, and impact of the rural water systems on the water supply infrastructure in South Dakota. Data from the physical characteristic survey was also used in conjunction with data from the 2006 water production and sales survey to find a relationship between unaccounted-for water and distribution system age.

3.3 Estimating the Impact of Improved Water Quality

Most rural water systems have been created to provide a reliable supply of water that has better quality than the prior water supply used by the customer. To quantify this impact, water quality data before and after the customer connected to the rural water system were compared. This analysis was restricted to communities served by rural water systems, because historical water quality data for community water systems were available from SDDENR sanitary survey data.

Water quality data was reported in the physical characteristics survey for most of the water treatment plants that were operated by the rural water systems responding to the survey. For the water treatment plants not reporting water quality data in their survey response, the most recent SDDENR sanitary survey water quality test results were used. The constituents that were used to describe the quality of drinking water from a RWS were alkalinity, calcium, chloride, iron, manganese, magnesium, nitrate, pH, sodium, sulfate, and total dissolved solids.

The rural water system treated water quality reports from both the physical characteristic survey and the DENR tests were compared to the DENR water quality test results of treated water from water supplies that were used before the communities were served by rural water systems. Water quality tests from water treatment plant(s) from each individual RWS were compared to the water quality tests of communities served by that RWS. From those comparisons, analyses were performed that established how much each community's quality of drinking water improved (or worsened) once the community connected to a regional water system. The results from the analysis were also used to calculate how much water softening salt each city customer saved and the amount of total dissolved solids discharged to the wastewater system after the communities switched to rural water.

The method used for calculating the softening salt reduction for each person was based on water hardness and daily water consumption. First, water hardness values were obtained from SDDENR water quality surveys for each community before they connected to a rural water system. Next, the water hardness values for the rural water systems were obtained, either from the physical characteristic survey or from the DENR water quality tests. The communities' 2006 population estimates from the United States Census and the daily water demand estimates from Section 4.3.2 were collected to calculate the softening salt reduction. Daily water demand estimates were 71 gallons per person for communities with populations under 100, 87 gallons per person for communities with populations of 100 to 500, and 119 gallons per person for communities with populations over 500. A customer was assumed to soften 50% of their daily water demand. Additionally, the average home water softening device was assumed to use 0.4 pounds of softening salt per 1000 grains exchanged. These values were used in Equation 3.1 to calculate the daily softening salt reduction per community.

$$\begin{aligned}\text{Daily softening salt reduction} \\ &= (\text{2006 population} \times \text{Daily water demand per person} \times 0.5) \\ &\times [(\text{Water hardness before rural water} - \text{Rural water hardness}) \\ &\div 17.1] \times (0.4 \div 1000) \qquad \text{(Eq. 3.1)}\end{aligned}$$

Once the softening salt reductions were calculated for each community, the cost savings per person was calculated. To calculate these cost savings, a 40 pound bag of water softening salt was assumed to cost \$4.18, thus each pound of softening salt cost 10.5 cents. Equation 3.2 was used to calculate the average yearly cost savings per person. The results of the water softening salt savings are discussed in Section 4.2.1.

$$\text{Yearly cost savings per person} = [(\text{Daily softening salt reduction } \times 365 \text{ days}) \div 2006 \text{ population}] \times \$0.1045 \quad \text{(Eq. 3.2)}$$

The method used to calculate the amount of total dissolved solids reduction for each person was based on the amount of softening salt reduction, water TDS, and daily water consumption. An assumption was made that all of a community's reduction in softening salt reduced the total dissolved solids by an equivalent amount. The daily water demand estimates were the same values as those used to calculate the softening salt reductions. The TDS values for each community prior to connecting to the rural water system were obtained from SDDENR water quality records. Next, the TDS values for the rural water system were obtained from either the physical characteristic survey or from the DENR water quality tests. Lastly, the communities' 2006 population estimates were gathered and an assumption was made that eighty percent of a person's daily water demand would reach the community's wastewater stream. All of those values were entered into Equation 3.3 to calculate the daily reduction of total dissolved solids per community.

$$\text{Daily total dissolved solids reduction} = \{[(0.8 \times \text{Daily water demand per person } \times 2006 \text{ population}) \div 1{,}000{,}000 \text{ gallons}] \times 8.34 \times (\text{TDS before rural water} - \text{Rural water's TDS})\} + \text{Softening salt reduction} \quad \text{(Eq. 3.3)}$$

From the daily reduction of total dissolved solids per community, the annual reduction of total dissolved solids per person was calculated with Equation 3.4. The results of this work are discussed in Section 4.2.2.

$$\text{Annual total dissolved solids reduction per person} = [(\text{Daily TDS reduction } \times 365 \text{ days}) \div 2006 \text{ population}] \quad \text{(Eq. 3.4)}$$

3.4 2006 Water Production and Sales

Rural water system water production and sales data were used to derive general trends in system-wide water production and trends in sales to specific customer categories. The 2006 water production and sales data were obtained from a separate survey that also collected financial information from the rural water systems. System-wide water production data from the survey included the total amount of water pumped into the distribution systems, the peak day water demand, and the total amount of metered water sales. The 2006 water production and sales data included sales to bulk community customers, farm customers, industrial customers, and individual community and/or country dwelling customers. Two of the twenty survey respondents combined the bulk community customers and the individually served community customers and/or country dwelling customers into one customer category.

Several analysis were conducted on the water production and sales data to understand how each customer category influenced a regional water system's water consumption characteristics. The analysis also helped to demonstrate how each of South Dakota's rural water systems' consumption characteristics compared to data obtained from a more detailed evaluation of Big Sioux, Clay, Mid-Dakota, and TM water systems' consumption characteristics. The 2006 water production and sales data were also used to compare water treatment plant and storage capacities during average day demands and peak day demands.

3.5 Detailed Evaluation of Monthly Consumption by User Category

Monthly water meter consumption data were collected from the Big Sioux, Clay, Mid-Dakota, and TM water systems. Big Sioux, Clay, and TM provided monthly customer water meter data for the years of 1999 through 2007, whereas Mid-Dakota provided customer water meter data from the years of 2005 through 2007.

Each individual water meter's monthly consumption data was provided by Clay, Mid-Dakota, and TM water systems. Big Sioux provided the total amount of monthly water consumption for each customer category, rather than the specific meter reading data for each customer. Big Sioux also provided the number of water meters served by each customer category.

The water consumption data was grouped into four main customer categories, city customers, country dwelling customers, farm customers, and other customers. Water usage trends for each customer category were analyzed separately and then compared to the other three categories in that specific rural water system. The customer categories were also compared with the same category from the other three rural water systems. This analysis enabled an assessment how an individual customer category water use affected the total water use of rural water system, but also enabled comparison of customer categories between the four rural water systems.

Big Sioux, Clay, Mid-Dakota, and TM all had city, country dwelling, and farm customer categories in their water consumption data, but the regional water systems also had additional customer categories that were grouped into the four main categories. Those additional customer categories were not always the same in each rural water system. Sections 3.5.1 through 3.5.4 describe those unique situations that were faced when grouping the customer categories for each rural water system.

The city category, country dwelling category, and farm category were also subdivided into separate categories. Subdivisions in the city customer category were; cities served individually, cities served bulk, and city populations ranging from less than 100 people to 100 to 500 people to greater than 500 people. Country dwelling subdivisions included country dwelling customers and lake cabin customers. Lastly the farm subdivisions were farm customers and pasture taps. The subdivisions of the customer categories in this manner enabled examination of how certain customers had affected the overall main customer categories (city, country dwelling, and farm).

Analyses for each customer category were done by calculating several different consumption characteristics of the trended water data. Those characteristics for each customer category were the percent of the regional water system's yearly water demand that the customer category consumed, the percent of the regional water system's yearly water meter hookups that were used for the customer category, daily water demand per customer, the monthly peaking factor, and the daily water demand per customer per inch of precipitation.

3.5.1 Big Sioux Community Water System User Categories

Big Sioux's customer data provided the total water consumed for each customer category per month and the number of customers (hookups) in each category. Big Sioux's city customer category included data from five different cities that were all served as bulk city customers. The five cities were Colman, Egan, Flandreau, Wentworth, and Trent. The country dwelling customer category included country dwellings customers, monthly cabin customers, and annual cabin customers. Since, annual cabin meters were read twice a year, those customer's peaking factors were not included into the overall country dwelling category peaking factor. The annual cabin customers would have induced an uncommonly high peaking factor for the country dwelling category. The farming customer category incorporated water consumption data from annual pasture taps, farms, and rotational pasture taps. For the same reason that peaking factors for the annual cabin customers was not used in the country dwelling category, the annual and rotational pasture taps were not included in calculating the peaking factor for the farming category. Finally, the other customer category included commercial customers, an ethanol plant, Native American housing, apartment complexes, resorts, and a trailer park. The ethanol plant was the main water user in the other customer category and the plant's effect on the other category's characteristics was discussed in Appendix F of the report.

3.5.2 Clay Rural Water System User Categories

Clay RWS provided monthly water consumption data for each customer in all of its customer categories. The individual consumption data allowed detailed analysis of the city customer, country dwelling customer, and farming customer categories. Clay RWS had multiple customer categories for the same type of customer (i.e. two categories for annual cabins). Their reason for the multiple customer category names was to identify customers in different locations in the rural water system. These multiple category names were grouped together in a single category to simplify the analysis.

The city customers were Gayville and Wakonda, which were both served as bulk customers. The country dwelling customer category included country dwellings customers, annual cabin customers, and group cabin customers. Unlike Big Sioux, Clay's annual cabin customer's peaking factors were calculated in the overall country dwelling category because the annual cabin meters were read monthly. However, after the year 2003 the annual cabin water consumption was read sporadically throughout the years causing higher peaking factors. This was evident in Section 4.3.3, when the impact of cabins on the country dwelling's consumption characteristics was observed. The farming customer category consumption data included data from annual pasture taps, irrigation, and farming customers. Annual pasture taps were read monthly up to 2003 when readings became sporadic and caused the overall farming peaking factor to be slightly inflated after 2003. Finally, the other customer category incorporated commercial customers and small town customers served individually. The small town customers were not classified as a particular town or community which was why the customers were placed in the "other" category. The small town customers were a little less than a third of the "other" customer category and water consumption of the "other" category was small compared to the city, country dwelling, and farming customer categories.

3.5.3 Mid-Dakota Rural Water User Categories

Mid-Dakota provided individual water consumption data for each customer in all of its customer categories. However, Mid-Dakota provided three years of water consumption data instead of nine years like the other three rural water systems. Since there were three years of water consumption data, it was more difficult to develop trends in customer category water usage.

Mid-Dakota's city customer category included data from four cities that were served as bulk city customers, and eleven cities that were served as individual city customers. The bulk city customers were Huron, Gettysburg, Onida, and Wolsey. The individual city customers were Agar, Camelot, Del Acres, Harrold, Lane, Lebanon, Orient, Polo, St. Lawrence, Virgil, and Yale. Mid-Dakota provided water consumption data for six different country dwelling customer categories. The country dwelling category with the lowest water consumption range was titled the country dwelling customer category. Mid-Dakota did not provide a specific farming customer category, thus country dwelling customers that consumed more than 33,000 gallons per month, which included the five remaining country dwelling customer categories, were grouped in the farming customer category along with pasture taps. The other customer category included individual bulk customers and bulk municipal customers.

3.5.4 TM Rural Water District User Categories

Similar to Clay and Mid-Dakota, TM provided individual water consumption data for each customer in all of its customer categories. TM had a more in-depth breakup of customer categories than the other three rural water systems particularly in the area of farm related customers. An arbitrary decision was made to determine which farm-related customers would be classified in the farm category or the other category, a likely the reason why TM's water consumption for the other customer category was large when compared to the water consumption for the city, country dwelling, and farming customer categories.

The city customer category included data from one city that was served as a bulk city customer (Davis) and five cities that were served as individual customers (Canistota, Dolton, Hurley, Marion, and Viborg). The country dwelling customer category only included country dwelling customers. The farming customer category included water consumption data from farming customers and pasture taps. However, the other customer category incorporated consumption data from dairies, hog operations, commercial customers, seasonal parks, a DOT rest area, and Swan Lake customers. As discussed in the previous paragraph, the other customer category has a large portion of TM's yearly water consumption. The major consumers of water from the other category were dairies and hog operations.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Characteristics of Regional Water Systems

This summary of rural water system characteristics describes the significance of regional water systems on South Dakota's way of life and the unique challenges that the systems are faced with each day. These characteristics ranged from the amount of clean drinking water produced during 2006 to the age of the systems infrastructure. The analysis of the system characteristics also illustrated some of the differences between systems located east and west of the Missouri River.

The magnitude of impact each of the thirty rural water systems has on South Dakota is evident in Figure 4.1 which shows the geographical size of each system and Table 4.1 which details the number of water meters and communities serviced. Each of the thirty rural water systems were assigned a number in place of their name, the assigned numbers were located on the x-axis of the figures in Chapter 4.

The analysis of system characteristics was made possible by the data received from the physical characteristic survey. Nineteen of South Dakota's thirty rural water systems returned the survey; however, several RWS provided partially answered surveys. The incomplete or missing data for those RWS is evident by the inconsistency in the number of rural water systems listed on the x-axis of this chapter's figures.

During 2006, twenty-seven of South Dakota's thirty rural water systems provided 13.9 billion gallons of clean drinking water. Of the 13.9 billion gallons of clean drinking water, 7.5 billion gallons were produced by rural water systems that utilized surface source waters and the other 6.4 billion gallons were produced by ground water systems. The rural water systems that utilized surface water on average produced 252 million gallons more than the systems that utilized ground water. In 2006, regional water systems served 242 cities or towns (approximately 98,561 people) which were 67% of all cities or towns in South Dakota but only 13% of the population. Figure 4.2 shows the cities and towns served by South Dakota's thirty rural water systems. The average rural water system produced 535 million gallons of water in 2006. East River systems had a higher average water production of 613 million gallons versus 322 million gallons for West River systems. The 2006 average water production for a RWS is summarized in Table 4.2, which also shows that the 2006 average rural water system employed 9 full-time workers with one system employing 31 full-time workers.

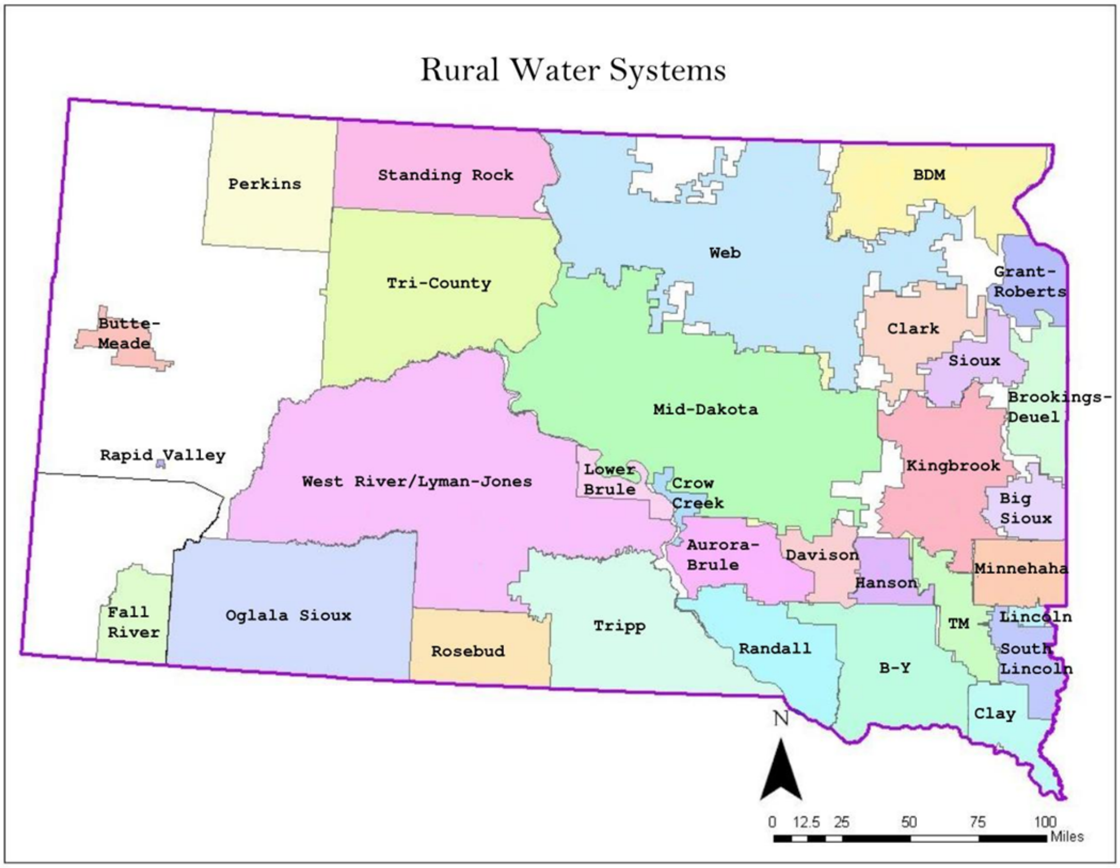

Figure 4.1. Map of South Dakota's Regional Water Systems (as of 2006)

Table 4.1. Summary of South Dakota's Regional Water Systems Service Information*

Rural Water System	Number of Customer Meters	Number of Cities Served	Type of Source Water
Aurora-Brule	Insufficient Data	8	Surface Water
Big Sioux	1970	6	Ground Water
Bon Homme-Yankton	Insufficient Data	16	Surface Water
Brookings-Deuel	2377	11	Surface & Ground Water
Brown-Day-Marshall	Insufficient Data	13	Ground Water
Butte-Meade	Insufficient Data	4	Ground Water
Clark	Insufficient Data	7	Ground Water
Clay	2010	4	Ground Water
Davison	1187	1	Surface Water
Fall River	300	2	Insufficient Data
Grant-Roberts	Insufficient Data	5	Ground Water
Hanson	Insufficient Data	8	Surface Water
Kingbrook	Insufficient Data	18	Surface & Ground Water
Lincoln County	2058	2	Surface & Ground Water
Lower Brule	Insufficient Data	1	Insufficient Data
Mid-Dakota	5090	26	Surface Water
Minnehaha	4500	11	Ground Water
Oglala Sioux	Insufficient Data	Insufficient Data	Insufficient Data
Perkins County	350	2	Surface Water
Randall	2600	12	Surface Water
Rapid Valley	3201	Insufficient Data	Insufficient Data
Rosebud	Insufficient Data	9	Surface & Ground Water
Sioux	1360	12	Ground Water
South Lincoln	Insufficient Data	4	Ground Water
TM	1360	5	Surface & Ground Water
Tri-County	Insufficient Data	4	Surface Water
Tripp County	2059	5	Ground Water
Web	7167	61	Surface Water
West River/Lyman-Jones	2807	17	Surface & Ground Water

*Data provided in 2006. Data not provided in the survey response by a rural water system was indicated as "Insufficient Data"

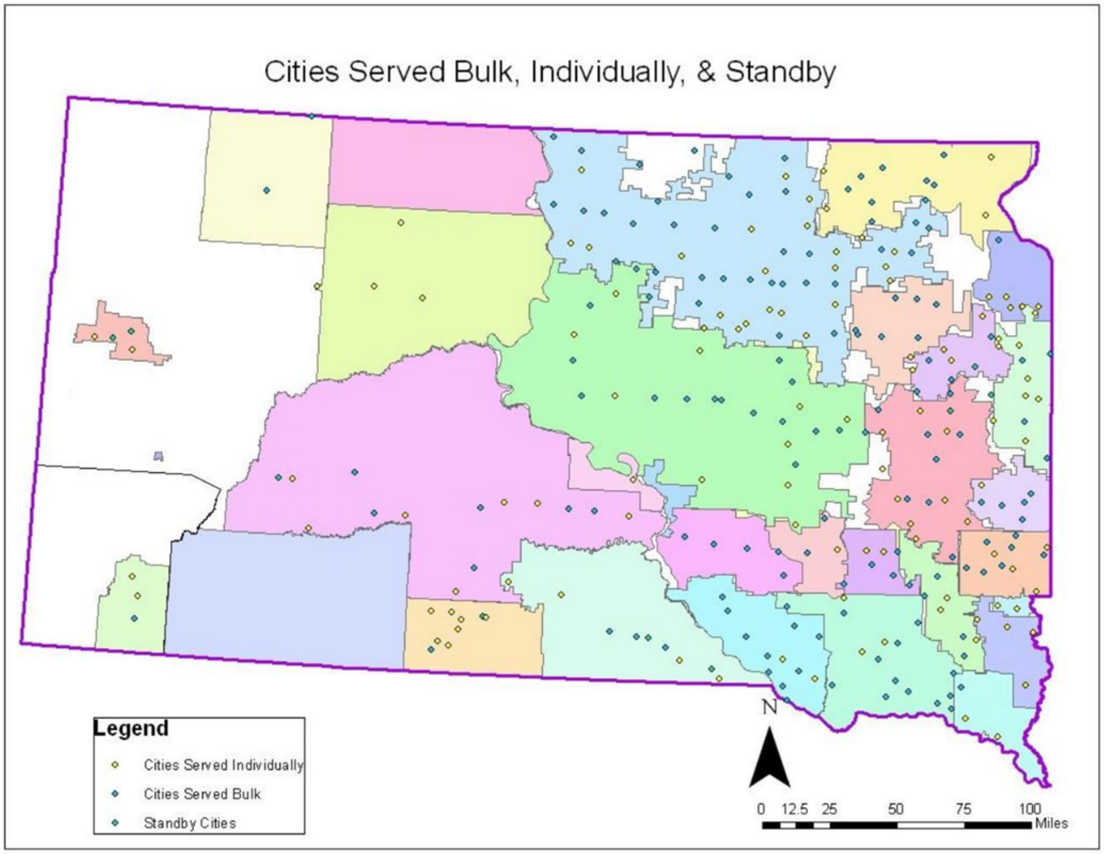

Figure 4.2. Map of South Dakota's Regional Water Systems
& the Cities & Towns They Served (as of 2006)

Table 4.2. Summary of Water Production and Sales During 2006

	Total Number of Full-time Employees	Total Number of Million Gallons Produced in 2006	Total Number of Million Gallons Sold in 2006
Total	221.5	13,899.89	9,223.12
Average	9	534.61	461.16
Maximum	31	2,005.40	1,517.34
Minimum	2.5	85.61	85.61
Number of Systems Reporting	24	26	21

4.1.1 Distribution Service Areas

The density of the water meters (customers) throughout the distribution area and the size of the system's distribution coverage area reveal the true nature of these systems. A system's water meter density was calculated by simply dividing the number of water meters served by the distribution's coverage area. The meter density for 15 rural water systems is shown in Figure 4.3. Most of the rural water systems across South Dakota had very low water meter densities relative to community systems. The average system had about 1.5 water meters per square mile, except for systems 22 and 24 which had approximately 457 meters per square mile and 34 meter per square mile, respectfully. System 22 exhibits a high meter density was because it provides drinking water to a section of a city where the customers lived within city blocks. System 24 exhibits a high water meter density because the system served six communities individually and only covered 40 square miles. Other than rural water systems 22 and 24 the water meter densities ranged from 0.14 meters per square mile to 5.6 meters per square mile. Generally, the larger a rural water system's distribution coverage, the smaller system's water density. The five West River rural water systems with the exception of system 22 had a smaller average meter density (0.3 meters per square mile) than the ten East River systems with the exception of system 24 (2.0 meters per square mile) represented in Figure 4.3.

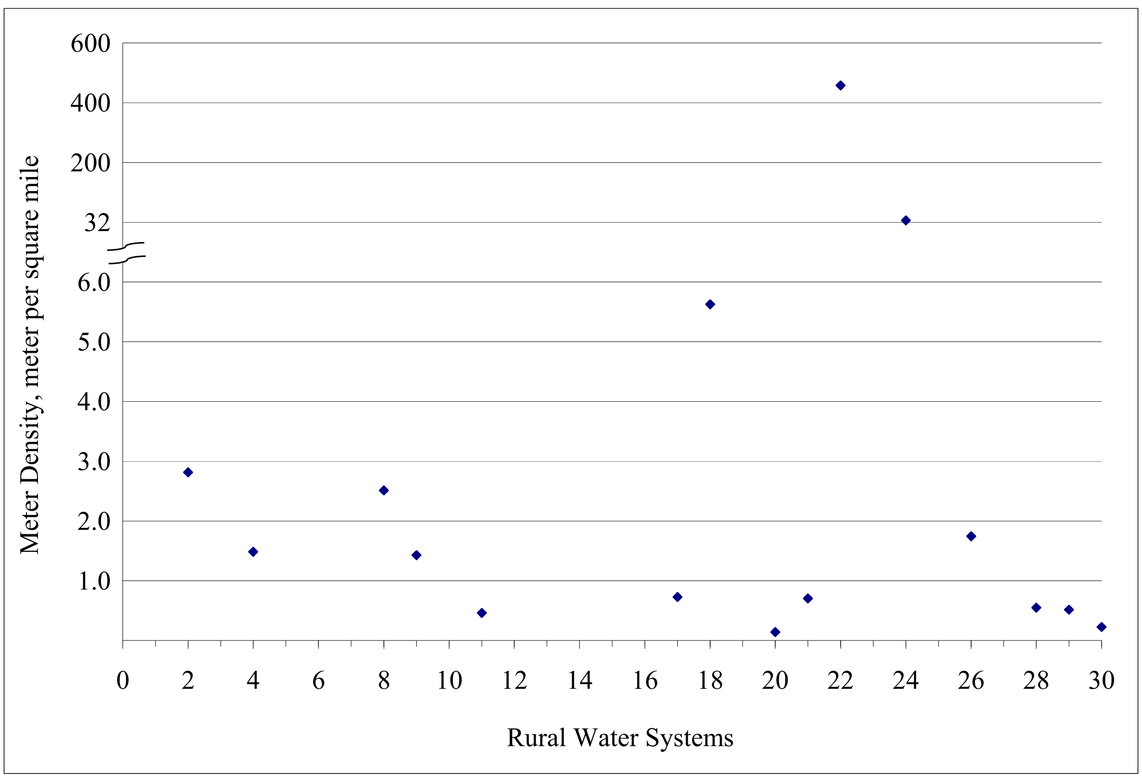

Figure 4.3. Comparisons of Water Meter Densities within Distribution Systems

The 15 rural water system's distribution coverage areas were given in Figure 4.4. The average system had a distribution coverage area of 3,810 square miles, not including systems 22 and 24 which had distribution areas of 7 square miles and 40 square miles. When systems 22 and 24 were excluded from the distribution sizes, the systems' distribution coverage areas ranged from 650 square miles up to 13,923 square miles. The average distribution size for the West River systems with the exception of system 22 was 4,850 square miles and the average distribution size for the East River systems with the exception of system 24 was 3,348 square miles. The total distribution area of seventeen rural water systems reporting their service areas covered 67% of South Dakota or 50,740 square miles.

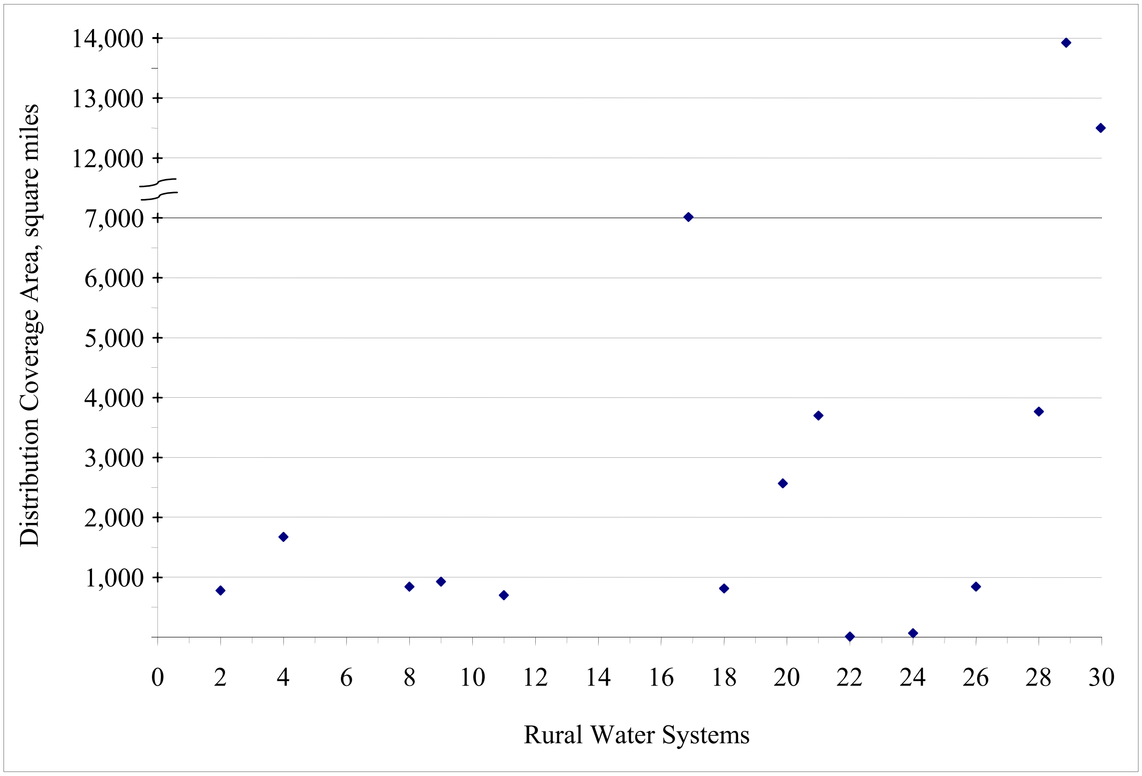

Figure 4.4. Comparisons of Rural Water System's Distribution Coverage Areas

Seventeen reporting systems maintain a total of 21,903 miles of pipeline with an average of 1,288 miles of pipe per distribution system. The average East River system had 1,338 miles of pipeline, while the average West River system had 1,168 miles of pipeline. Eighty-nine percent of the 21,903 miles of pipeline within seventeen of South Dakota's regional water systems was PVC and less than 1% was ductile iron. The most common size of pipe was 2-inch diameter and smaller, which was typically used to distribute water from a main pipeline to individual customers, followed by 3-inch and 4-inch pipe. Pipe size distributions were 47% or 8,934 miles for 2-inch and smaller, 12.5% or 2,348 miles for 3-inch, 12.4% or 2,342 miles for 4-inch, 11.2% or 2,119 miles for 2.5-inch, 8.4% or 1,580 miles for 6-inch, and the rest of the pipe sizes were 8.1% or 1,530 miles. Finally, it was discovered that the average water hookup required about 0.65 miles of pipe, which reaffirmed the fact that customers served by South Dakota's regional water systems were spread out over long distances.

4.1.2 2006 Water Sales, Production, and Capacities

The metered water sales from 2006 were tallied in four customer classifications - farm, bulk community, individual, and non-farm industry customers. The bulk community customers were supplied by a rural water system and would re-sell and distribute the water to each of its customers. Individual customers included country dwelling customers and communities served individually. Individual community customers were billed by the rural water system on an individual basis.

The water sales to each of the four categories are summarized in Figure 4.5. Forty-six percent (3.16 billion gallons) of the metered water sales in 2006 reported by fifteen rural water systems were sold to farm customers. On average, a rural water system sold 211 million gallons to its farm customer classification. Bulk community customers were sold 38% of the metered water sales or 2.54 billion gallons. On average, rural water system sold 169 million gallons to the bulk community classification. Individual customers and the non-farm industry customers received 15% and 1% of the metered water sales, respectively. The individual customers purchased 1.01 billion gallons and had an average system demand of 67 million gallons, while the non-farm industry customers purchased 54 million gallons of water with an average system demand of 3.6 million gallons.

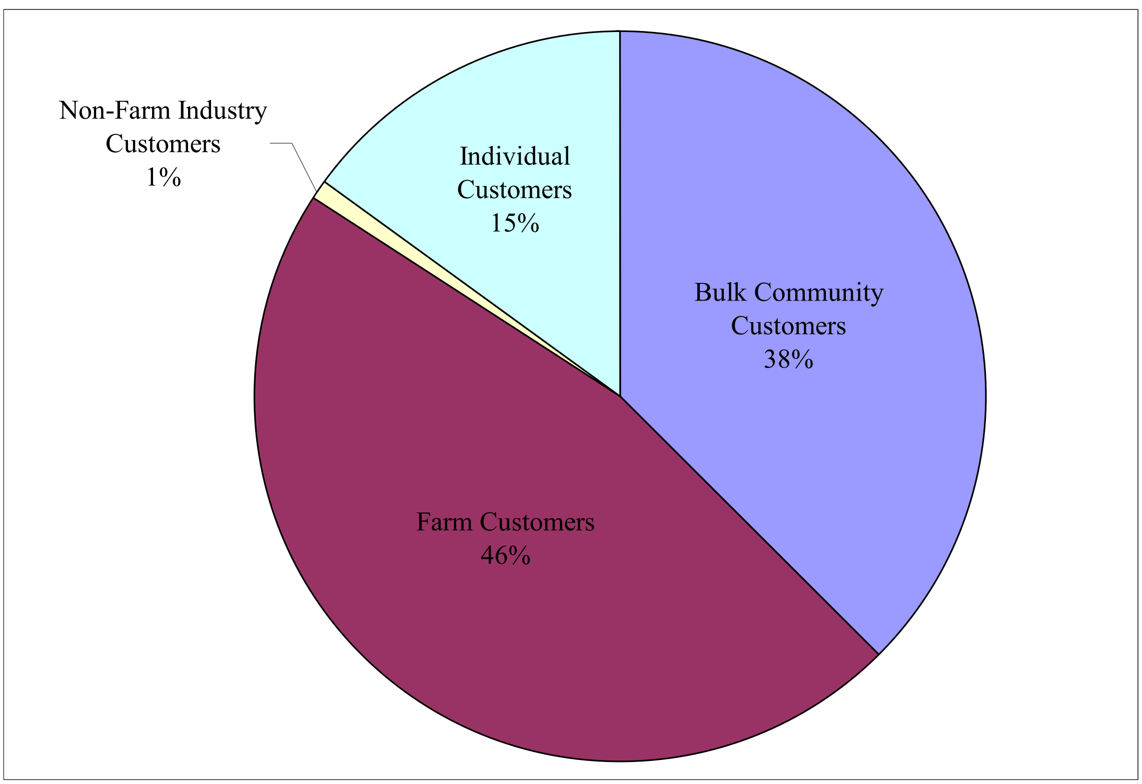

Figure 4.5. Distributions of Water Sales During 2006

A more detailed comparison of the rural water system's yearly water production in 2006 was accomplished by examining the system's daily demands and capacities. The daily water demands for South Dakota's rural water systems were based on the peak day demands directly reported by the systems in the water production and sales survey, and the average day demands were calculated by dividing the total yearly water sales by the number of days per year. The system treatment capacities were calculated by summing the daily treatment capacity of all the treatment plants in each rural water system. The total system storage capacities were calculated by summing the capacity of distribution system tanks and reservoirs reported by each of 13 rural water systems that responded with applicable data. Figure 4.6 shows the results of these calculations.

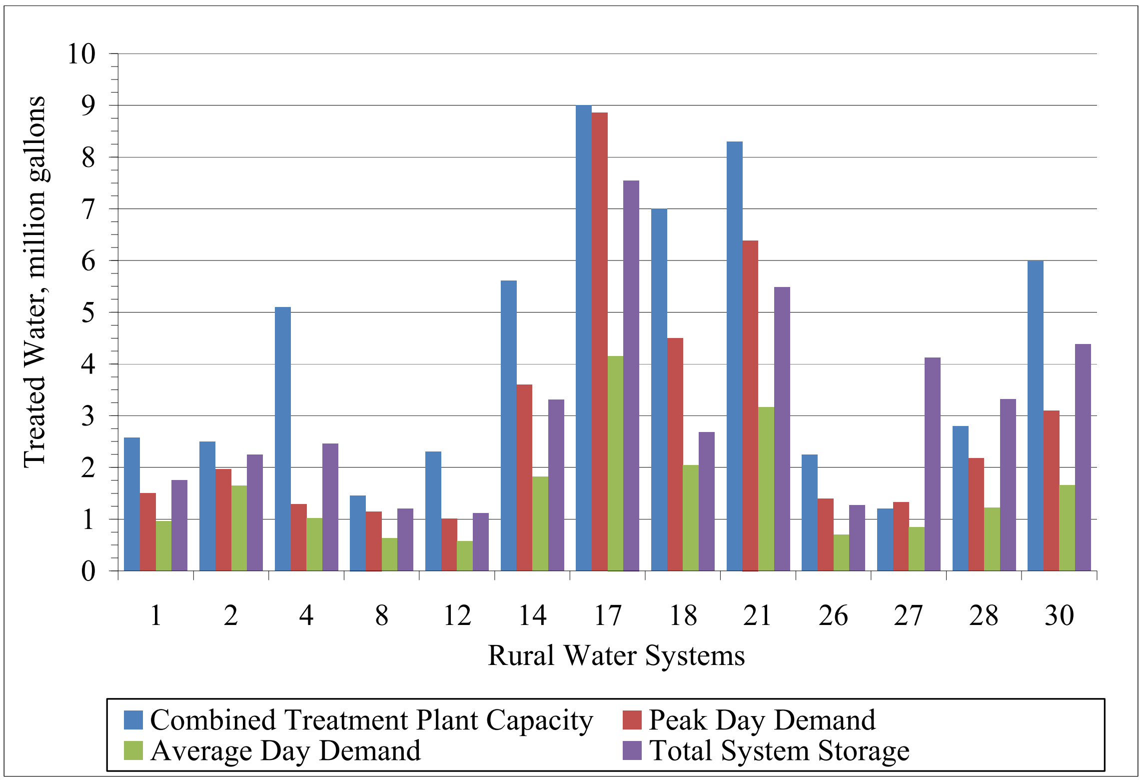

Figure 4.6. Comparisons of Rural Water Systems Daily Demands & Capacities

Comparing average and peak flows to treatment plant capacities and water storage capacities measures a system's capability to meet its demands and demands variations. Table 4.3 shows the percent of water treatment capacity used during the average day demands and the peak day demands during 2006 for the thirteen rural water systems. As illustrated in Figure 4.5, only two reporting rural water systems used more than 50% of their treatment plant capacity during the average day demands. Those systems were system 2 which used 66% of its total treatment capacity and system 27 which used 71% of its treatment capacity. With the exception of systems 2 and 27, the other eleven rural water systems only used an average of 34% of their total water treatment capacity during the average day demands or about 3.13 million gallons per day.

Table 4.3. Amount of Unused Treatment Plant Capacity

Rural Water System Number	Remaining Amount of Plant Capacity on Average Day	Percent of the Plant Capacity Used During Average Day	Remaining Amount of Plant Capacity on Peak Day	Percent of the Plant Capacity Used During Peak Day
1[a]	1,612,564	37.4%	1,076,000	58.2%
2	854,959	65.8%	536,000	78.6%
4	4,083,093	19.9%	3,811,671	25.3%
8	826,827	43.4%	310,000	78.8%
12	1,733,033	24.8%	1,293,000	43.9%
14	3,793,340	32.4%	2,012,000	64.1%
17	4,842,910	46.2%	142,000	98.4%
18	4,957,879	29.2%	2,500,000	64.3%
21[a]	5,130,137	38.2%	1,909,000	77.0%
26[a]	1,546,742	31.2%	849,000	62.2%
27	352,392	70.6%	-131,000	110.9%
28	1,577,444	43.7%	620,000	77.9%
30	4,324,934	27.7%	2,884,000	51.8%
Average	2,741,250	39.3%	1,370,129	68.6%
Max	5,130,137	70.6%	3,811,671	110.9%
Min	352,392	19.9%	-131,000	25.3%

[a] These rural water systems share treatment plant(s) with another rural water system.

Rural water system 4 had the lowest percent of treatment capacity used during the average day demands at just 20%. However, one of system 4's two water treatment plants was partly shared with system 14, so systems 4 and 14's total treatment capacity was actually less than that shown on Table 4.3. The actual percent of treatment capacity used during both average day demands and peak day demands for systems 4 and 14 could not be calculated from the information provided in the surveys.

The percent of treatment capacity used during the peak day demands were much higher than those of the average day demands. In fact, the average rural water system experienced almost double the percent capacity use from 39% on average day to 69% on peak day. Even when systems 2 and 27 were not included in the average, the percent capacity increased from 34% to 64%. Of the thirteen rural water systems, six systems (46%) experienced peak day demands of at least 75% of their total water treatment plant capacity. System 27 again had the highest use of its treatment plant capacity; in fact, the system experienced a peak day demands greater than its treatment plant production capacity.

Eight of the thirteen rural water systems had more water storage capacity than the peak day demands, enabling the system to provide water from storage to meet its peak day demand if the treatment plant was not at full capacity. The other five systems provide system storage between the average and peak day demand values. Given that the functions of storage are also to equalize pressures in the system, provide opportunities to break the hydraulic grade line and meet demand variations, additional information regarding the storage location, water user and storage elevations, and diurnal demand characteristics would be needed in order to understand the relationship between these factors and storage adequacy.

The 2006 survey data provided a means to calculate a system daily peaking factor. Each rural water system's peaking factors were calculated using equation 4.1.

$$\text{Daily Peaking Factor} = \text{2006 peak day demand} \div (\text{2006 metered water sales} \div \text{365 days}) \qquad \text{(Eq. 4.1)}$$

When calculated using equation 4.1, the peaking factor will be slightly over-estimated since the average water sales calculated in the denominator does not include un-accounted for water. Nonetheless, this peaking factor is useful to estimate future demands based on trends of metered water sales and also provides a measure of demand variations in a system.

The calculated peaking factors displayed in Figure 4.7 range from 1.19 to 2.20 and averaged 1.8. While there are no values for daily peaking factors specific to rural water systems found in the literature, the range of daily peaking factors for municipal systems is typically 1.2 to 2.5 (Walski, 2003), with an average peaking factor ranging from 1.5 to 2.2. Thus, when compared to municipal peaking factors, the rural water system peaking factors for the South Dakota systems fall into the typical range of peaking factors for municipal water supply systems.

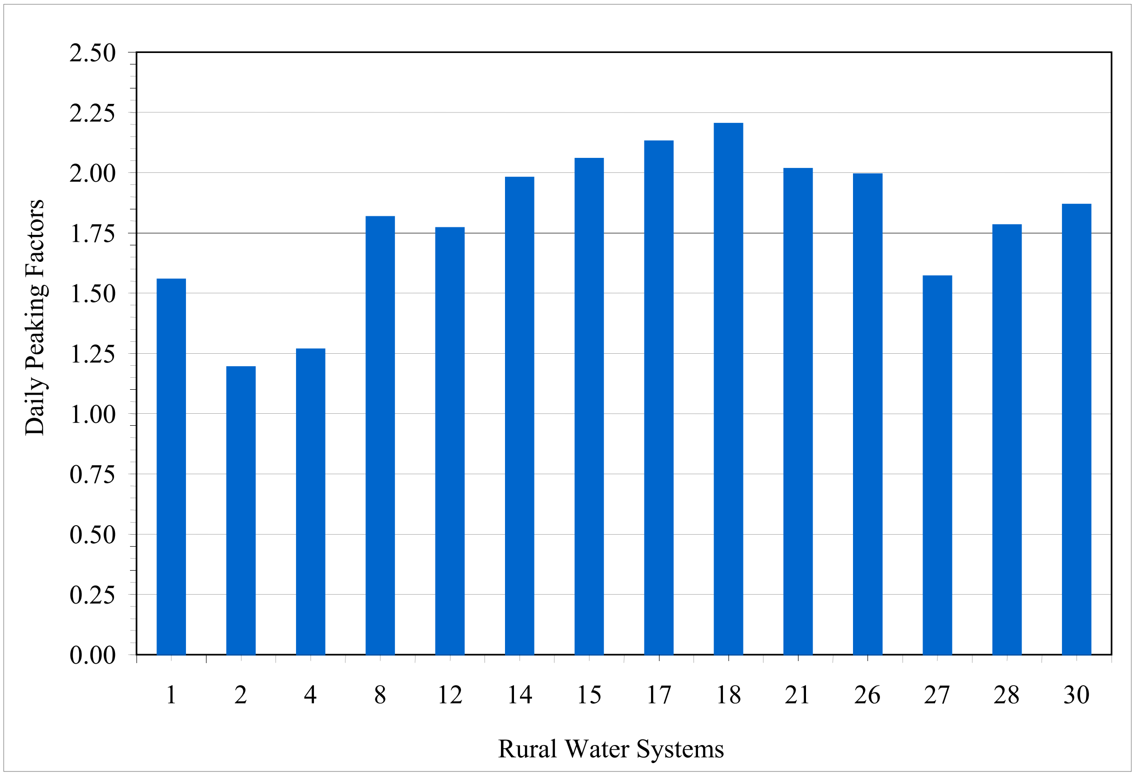

Figure 4.7. Peaking Factors for South Dakota Rural Water Systems in 2006

The 2006 metered water sales from each of the rural water systems were reported in the survey in four customer classifications; bulk community customers, farm customers, individual customers (cities served individually and country dwellings), and nonfarm industrial customers. The volume of water sold to these customer classifications for each of fifteen reporting systems is displayed in Figure 4.8.

Figure 4.8 illustrates the diversity of customer demands served by South Dakota rural water systems. Metered water demands ranged from 86 to 1,517 million gallons per year, depending on the size of service area and number of customers of each classification. The proportion of the total demand served to the four customer classification varies system by system. Table 4.4 provides a summary of the percentage of demand by customer classification.

Depending on the customer base, either the farm demand or the bulk community demand was typically the major demand of a system. Farm customers exerted the dominant demand in ten of fifteen systems. In these ten systems, the average farm demand was 67% percent of the total demand. Bulk community customers exerted the dominant demand in three of the fifteen reporting systems. In these three systems, the average bulk community demand was 57% percent of the total demand. Since farm customers and bulk community customers are likely to exert different demand

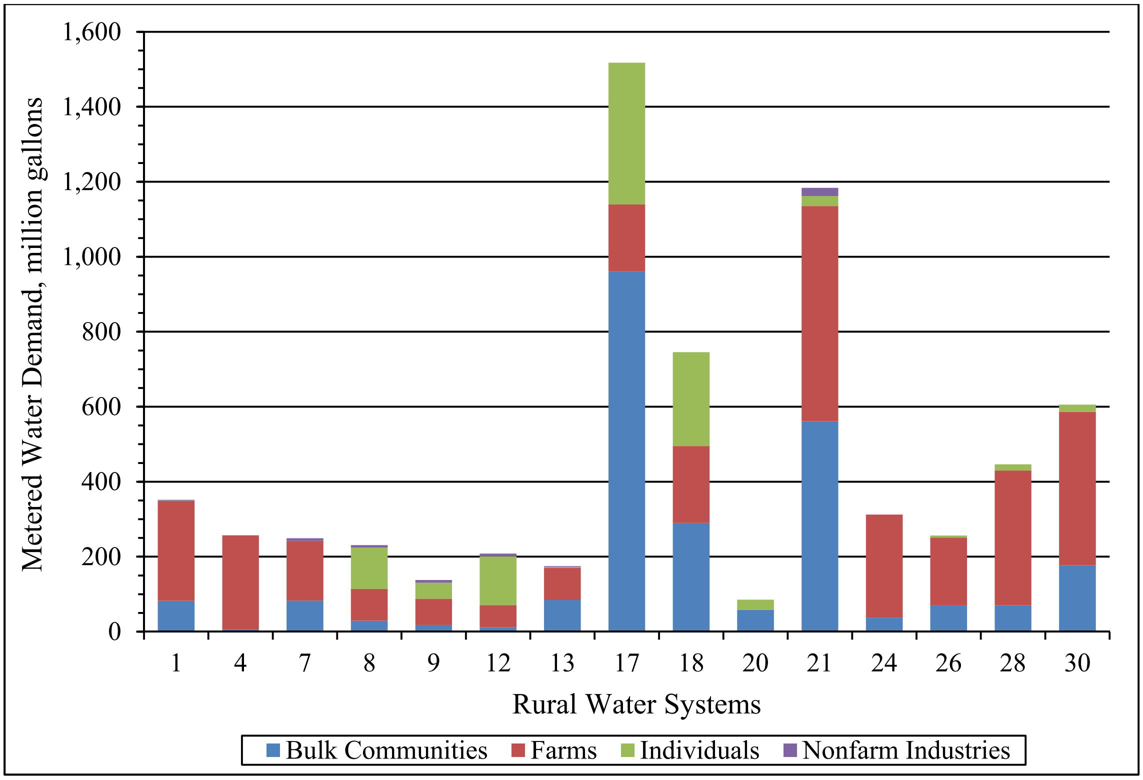

Figure 4.8. 2006 Annual Metered Water Demand for Four Customer Classifications

Table 4.4. Percent of Total Demand by Customer Classification

Rural Water System Number	Annual Metered Water Demand (MG)	Percent of Annual Metered Water Demand			
		Bulk Communities	Farms	Individuals	Nonfarm Industries
1	352	23%	76%	0%	1%
4	371	2%	68%	0%	0%
7	249	33%	64%	0%	3%
8	231	13%	37%	48%	3%
9	138	13%	51%	31%	5%
12	208	6%	28%	62%	4%
13	175	48%	49%	1%	1%
17	1,517	63%	12%	25%	0%
18	745	39%	27%	34%	0%
20	86	68%	0%	32%	0%
21	1,157	49%	50%	2%	2%
24	313	12%	88%	0%	0%
26	256	27%	71%	2%	0%
28	446	16%	81%	4%	0%
30	606	29%	68%	3%	0%

<u>4.1.3 Unaccounted-For Water & Aging Infrastructure</u>

The percent of unaccounted-for water for each system was calculated by using equation 4.2, the results of which are presented in Figure 4.9.

$$\text{Percent of unaccounted for water} = [(\text{Water pumped into the distribution system} - \text{Metered water sales}) \div \text{Water pumped into the distribution system}] \times 100\% \quad \text{(Eq. 4.2)}$$

Of the systems represented in Figure 4.9, the average percent of unaccounted-for water for the three highest systems was 21.6% and the largest percent was 23.4% for system 12. Eight of the seventeen rural water systems providing data exhibited unaccounted-for water of less than 10%. In fact, the average percent of unaccounted-for water for those eight systems was 5.8% and two systems reported percentages as low as 3.3% and 3.1%. The overall average percent of unaccounted-for water was about 11.1%. Given that there were six rural water systems with unaccounted-for water less than 6%, a goal of less than 10% unaccounted for water is not unreasonable.

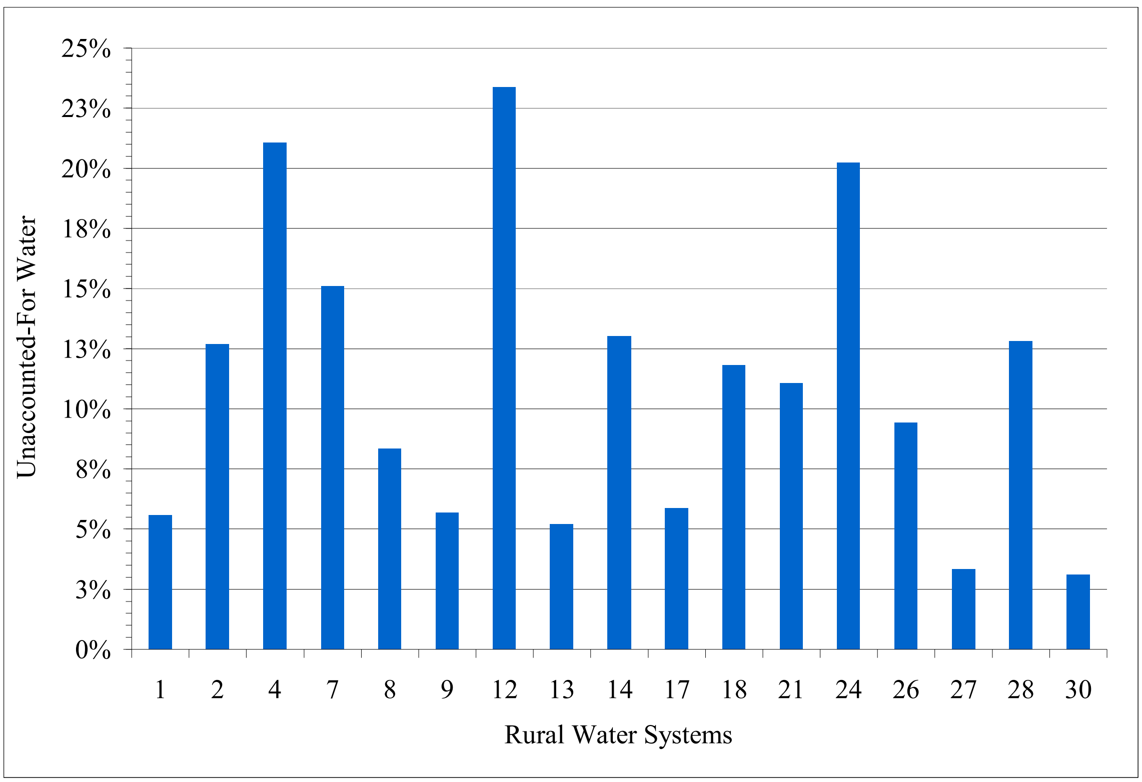

Figure 4.9. Percentage of System-wide Unaccounted-For Water in 2006

As a distribution system and associated water meters age, its pipes can leak more water and its water meters would not be as precise. Leaking pipes and inaccurate metering are major causes of unaccounted-for water in a distribution system. Since no data was collected on the age of the rural water systems' pipes and water meters, the ages of the water treatment plants were used to explore a relationship between infrastructure age and unaccounted-for water. The age distribution of 34 water treatment plants from 19 rural water systems (as of 2006) is shown in Figure 4.10.

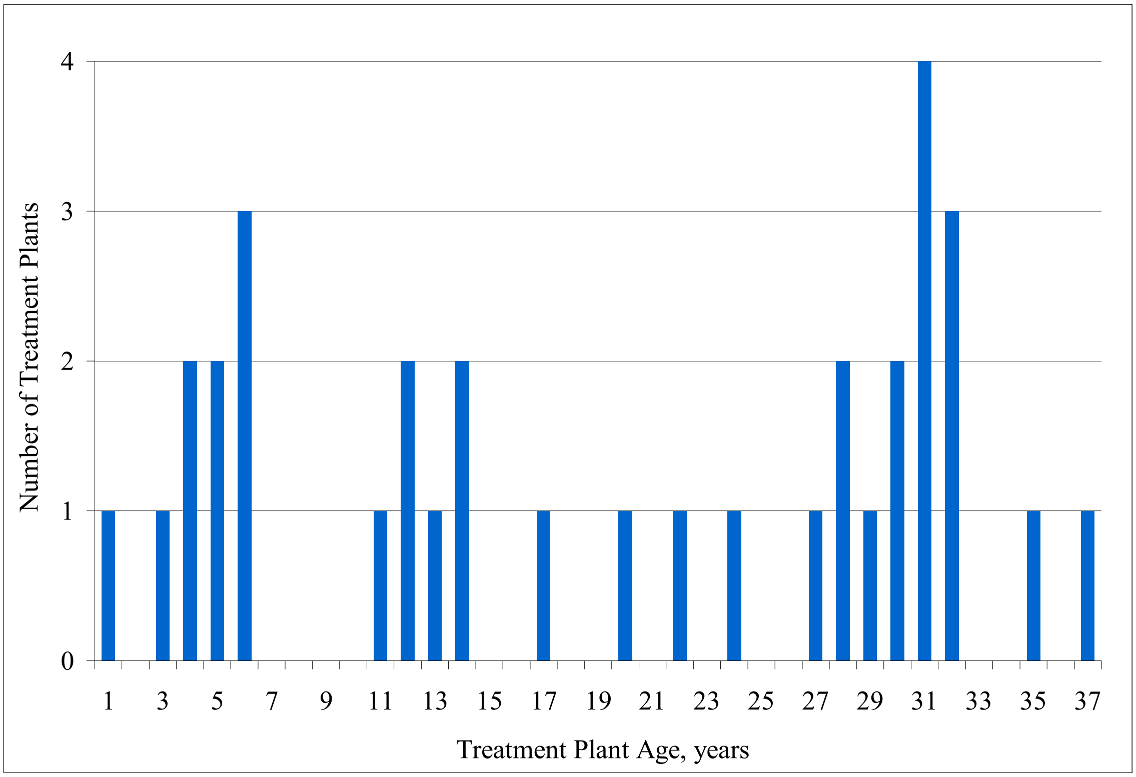

Figure 4.10. Age Distribution of Water Treatment Plants

The average water treatment plant age was 19 years and approximately 44% of the treatment plants were older than 25 years. However, 4 of the 11 rural water systems operating treatment plants older than 25 years also had newer treatment plants whose ages ranged from 3 years to 5 years.

Assuming that the age of the water treatment plants would be a fair predictor of the age of the actual distribution systems (infrastructure), the age of the treatment plant was plotted against the unaccounted-for water for each rural water system in Figure 4.11. Although the data exhibit much scatter, the plot demonstrates a general relationship between increased unaccounted-for water with increased treatment plant age. Since the coefficient of correlation (R) was 0.58, there was a fair relationship between unaccounted-for water and treatment plant age. The following factors could have negatively impacted the coefficient of correlation; RWS with older treatment plants could have rehabilitated portions of their aging distribution system piping and/or replaced aging customer water meters, which would have decreased their percent of unaccounted-for water.

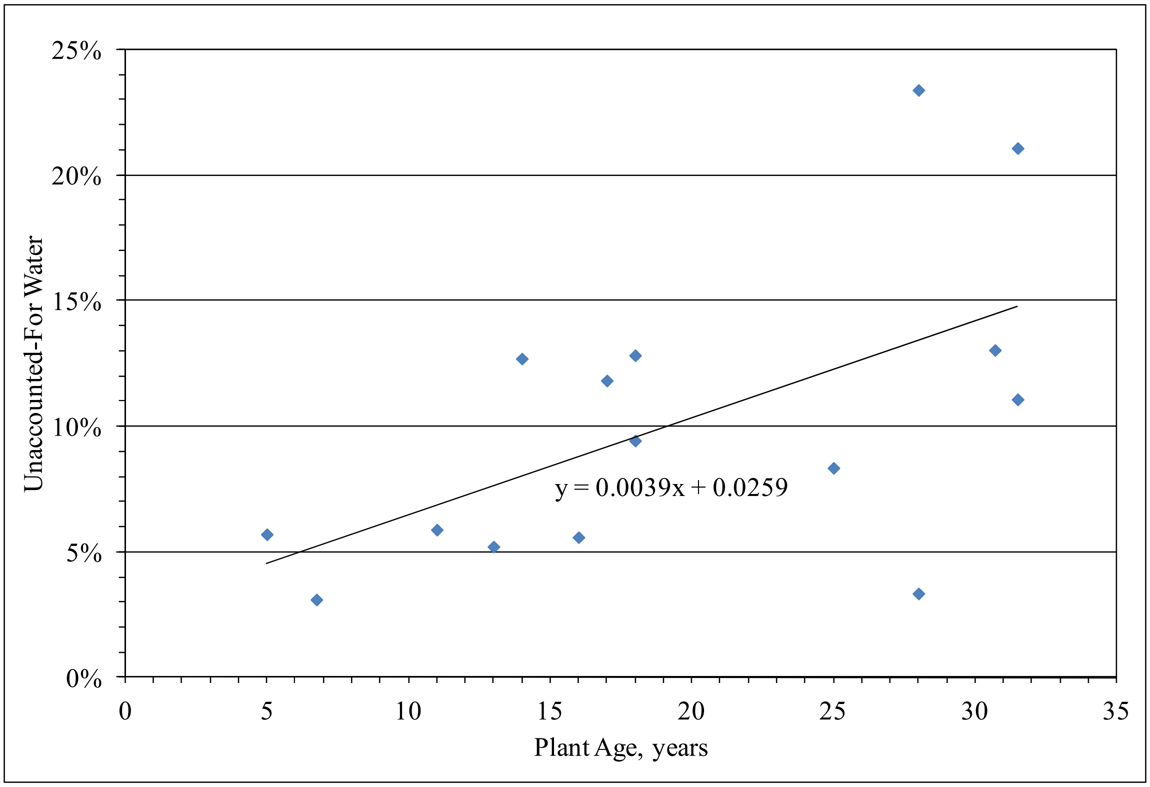

Figure 4.11. Percent Unaccounted-For Water versus Treatment Plant Age

Based on the slope of the trend line, the average percent of unaccounted-for water increased by 0.39% per year. This relationship suggests the potential value of replacing or rehabilitating older sections of pipe and/or water meters.

4.2 Social and Economic Impacts from Improved Drinking Water Quality

The primary impetus for developing South Dakota rural water systems is improved drinking water quality. Improved water quality is expected to improve human health, improve livestock health and production, extend infrastructure life, reduce softener salt usage, and lower the mass of total dissolved solids released by wastewater discharges.

Water quality data for communities served by a rural water system were examined to show the difference between water quality before and after the community switched from their prior source to rural water. The water quality data from 113 communities that connected to a rural water system utilizing a surface water source were averaged and compared to the average water quality of the 11 rural water systems serving these communities. The water quality data from 58 communities that connected to a rural water system utilizing a ground water source were averaged and compared to the average water quality of the 13 rural water systems serving these communities. The compiled data are shown in Table 4.5.

Table 4.5. Summary of Drinking Water Quality Improvement

	TDS mg/L	Alkalinity mg/L as $CaCO_3$	Na mg/L	Ca mg/L	Mg mg/L	Fe mg/L	Mn mg/L	Cl mg/L	SO_4 mg/L	NO_3 mg/L
Rural Water Systems Served By Surface Water										
Average Community Values Before Rural Water	1562	292	270	162	44.5	1.35	0.36	92.4	737	0.3
Average Rural Water System Values	448	130	70.3	48.1	19.5	0.03	0.02	15.5	186	0.2
Average Community Improvements	1114	162	200	114	25	1.32	0.34	76.9	551	0.1
Percent Reduction	71%	55%	74%	70%	56%	98%	94%	83%	75%	33%
Rural Water Systems Served By Ground Water										
Average Community Values Before Rural Water	1165	303	162	135	46.3	0.54	0.48	55.0	491	2.4
Average Rural Water System Values	596	211	58.3	76.4	28.4	0.07	0.02	23.3	201	0.5
Average Community Improvements	569	92	104	58.6	17.9	0.47	0.46	31.7	290	1.9
Percent Reduction	49%	30%	64%	43%	39%	87%	96%	58%	59%	79%

The magnitude of water quality improvement was affected by the type of source water that the rural water system used. The quality of drinking water from the surface water treatment plants and the ground water treatment plants was shown in Table 4.5. When a rural water system used surface water (mainly the Missouri River) as its source water, it typically received better quality drinking water than a rural water system that used ground water as its source water. The surface water treatment plants produced water with lower concentrations of all constituents except for sodium (Na), which on average was 12.0 mg/L higher per treatment plant, and manganese (Mn) which was equal to that of the ground water treatment plants. The reason that the surface water treatment plant treated water provided lower levels of the constituents was that the source surface water contained lower concentrations of the constituents before treatment than the source ground water. Although the ground water rural water systems exhibited poorer quality treated water (averaged) than the average surface water rural water systems, the water quality improvement by communities converting to rural water systems as the source of supply was still very substantial. The communities served by ground water rural water systems experienced at least 50% reduction in concentrations of sodium, iron (Fe), manganese, chloride (Cl), sulfate (SO_4), and nitrate (NO_3). Communities served by surface water systems experienced (on average) substantially greater than 50% reduction in all of the constituents except nitrate which was a 33% reduction. Averaged over all the systems, the total dissolved solids (TDS) of communities connecting to a ground water supplied rural water system was approximately one-half the TDS of the community's water supply prior to using rural water. The TDS of communities connecting to a surface water supplied rural water system was one third of the TDS of the community's water supply prior to using rural water. Appendix E contains figures that illustrate the improvement in water quality for each rural water system and the communities they serve.

Typical treatment process schematics for plants utilized by South Dakota's rural water systems are illustrated in Figure 4.12. Softening plants use lime and soda ash to remove the source water hardness (calcium and magnesium). Chlorine is added as a disinfectant and fluoride is added to help protect the customer's teeth. Iron and manganese removal plants use aeration, potassium permanganate oxidation and granular media filters to accomplish iron and manganese removal. The lime and soda ash softening is an effective method of removing water hardness, which was one reason why some water treatment plants exhibit lower drinking water hardness than others. Not included in Figure 4.12 is the schematic of conventional coagulation plants used to remove turbidity and organic matter from surface water supplies (Baruth, 2005).

Drastic improvements in water quality achieved by connecting to a rural water system created positive social effects on the populations of the communities. It could be assumed that once the communities connected to rural water, the customers would have experienced improvement in taste and appearance of the water, especially since water distributed by the rural water systems is substantially free of iron and manganese. The decreased hardness of the rural water would be directly noticed in the cost of salt used in ion exchange softeners.

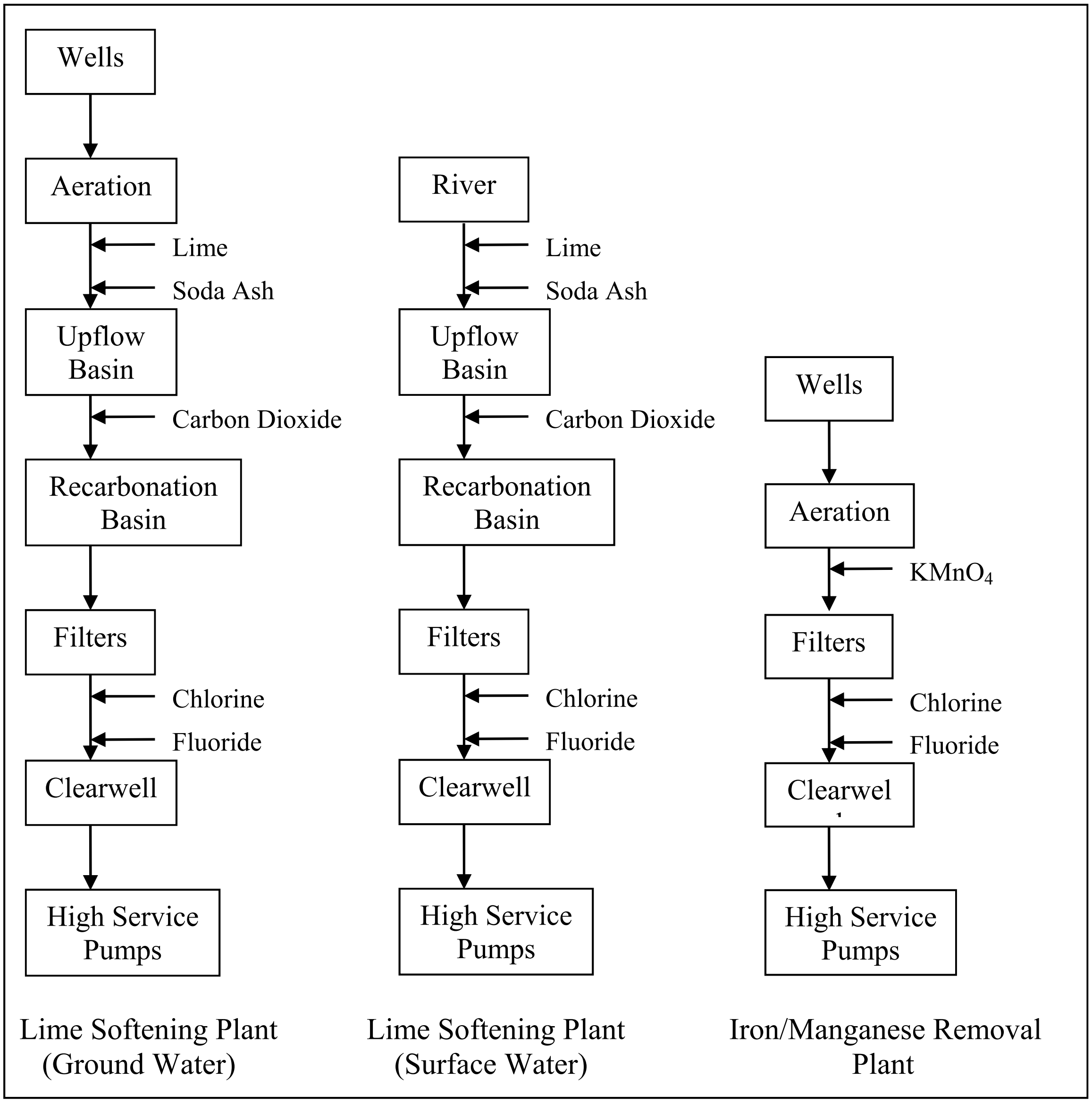

Figure 4.12. Typical Water Treatment Plant Schematics

4.2.1 Salt Savings from Softer Drinking Water

From an economic point of view a significant improvement in drinking water quality was the reduction of hardness (calcium and magnesium) concentrations. The reduction of water hardness allows individual customers to experience less encrustation in water heaters and enables customers to use less water softening salt to regenerate their ion exchange softeners. As stated in Section 4.2, the hardness of the drinking water provided by the rural water systems was lower for surface water systems than ground water systems.

The salt reductions and cost savings resulting from communities switching to a rural water system were estimated as described in Chapter 3. Data from 108 communities switching to 11 surface water supplied rural water systems and 58 communities connecting to 14 ground water supplied rural water systems were used in the estimates. The estimate is considered conservative because not all 171 communities connecting to a rural water system (based on survey responses) were included in the estimate. Table 4.6 summarizes the estimated softening salt reductions and cost savings.

As shown in Table 4.6, persons in communities served by surface water rural water systems could save (on average) $13.61 per year from a reduction of 130 pounds of softening salt. Persons in communities served by ground water rural water systems could experience average yearly cost savings of $11.21 per person from a reduction of 107 pounds of softening salt. Assuming that the average family size in South Dakota during 2006 was 2.5 people (per the 2000 census); a typical South Dakota family living in a community that switched to rural water would have experienced a yearly cost savings of $31.91. The 111,526 people served by rural water systems included in this calculation in 2006 could potentially save $1.4 million in the costs of softener salt, and use 13.6 million fewer pounds softening salt. It is noted that additional salt savings would be experienced by non-community customers (farms, country dwellings, etc.) that were not included in this estimate. Additional implications of lowered salt usage are further explored in Section 4.2.2.

Table 4.6. Summary of Estimated Softening Salt Reductions & Cost Savings

Rural Water Systems	Daily Salt Reduction (lbs/day)	Yearly Salt Reduction (lbs/year)	Population	Yearly Salt Reduction (lbs/person-year)	Yearly Cost Savings (dollar/person-year)	Cost Savings (dollar/year)
Surface Water Systems	25,696	9,379,086	71,991	130.3	$13.61	$980,115
Ground Water Systems	11,620	4,241,180	39,535	107.3	$11.21	$443,203
All Rural Water Systems	37,316	13,620,266	111,526	122.1	$12.76	$1,423,318

4.2.2 Reduction of Total Dissolved Solids in Wastewater Flows

The lower total dissolved solids (TDS) concentrations in water that the rural water systems provide to communities and the reduced use of water softening salts have beneficial impacts on streams and rivers receiving the community wastewater discharges. Dissolved solids in the water supply carry through into the wastewater collection system and are minimally removed in wastewater treatment system. Thus, TDS in the treated wastewater effluent passes into the aquatic environment of the receiving stream. High TDS concentrations in water bodies could have negative impacts on aquatic life according to Goodfellow et al. (2000). Therefore, the decrease of total dissolved solids in the water supply potentially improves aquatic life and habitat.

TDS reductions resulting from communities connecting to rural water systems were estimated according the assumptions and methods described in Chapter 3. The values of TDS reduction are tabulated in Table 4.7 and in Figure 4.13.

For the communities served by surface water rural water systems, the average estimated daily TDS reduction per person was 0.99 pounds, which is equivalent to nearly 363 pounds per year. Communities served by ground water systems exhibited an estimated average daily TDS reduction of 0.66 pounds per person, or about 243 pounds per year. Assuming an average family size in South Dakota during 2006 was 2.5 people, the average South Dakota family that switched to rural water prevented 800 pounds of TDS from entering the wastewater systems of their communities. Since wastewater systems discharge to some location in South Dakota's hydrologic system, the 111,526 people living in communities served by rural water in 2006 removed at least 35.7 million pounds or 17,850 tons of total dissolved solids from South Dakota's water environment.

Table 4.7. Summary of the Removal of Total Dissolved Solids from Wastewater Flows

TDS Reduction From 2006 Population Estimates					
Rural Water Systems	Daily TDS Reduction (lbs/day)	Yearly TDS Reduction (lbs/year)	Population	Daily TDS Reduction (lbs/person-day)	Yearly TDS Reduction (lbs/person-year)
Surface Water Systems	71,528	26,107,618	71,991	0.99	363
Ground Water Systems	26,280	9,592,220	39,535	0.66	243
All Rural Water Systems	97,808	35,699,838	111,526	0.88	320

The system-by-system reduction of water softening salt and total dissolved solids for communities that had connected to rural water systems is illustrated in Figure 4.13. It is noted that rural water systems 4, 5, 20, and 21 provided their customers with water containing hardness higher than that supplied by the communities' sources prior to connection to rural water. Even while these communities' drinking water exhibited higher hardness values than before connecting to rural water, the community was still receiving higher quality drinking water with lower values of other parameters, such as alkalinity, sodium, iron, manganese, chloride, sulfate, and nitrate.

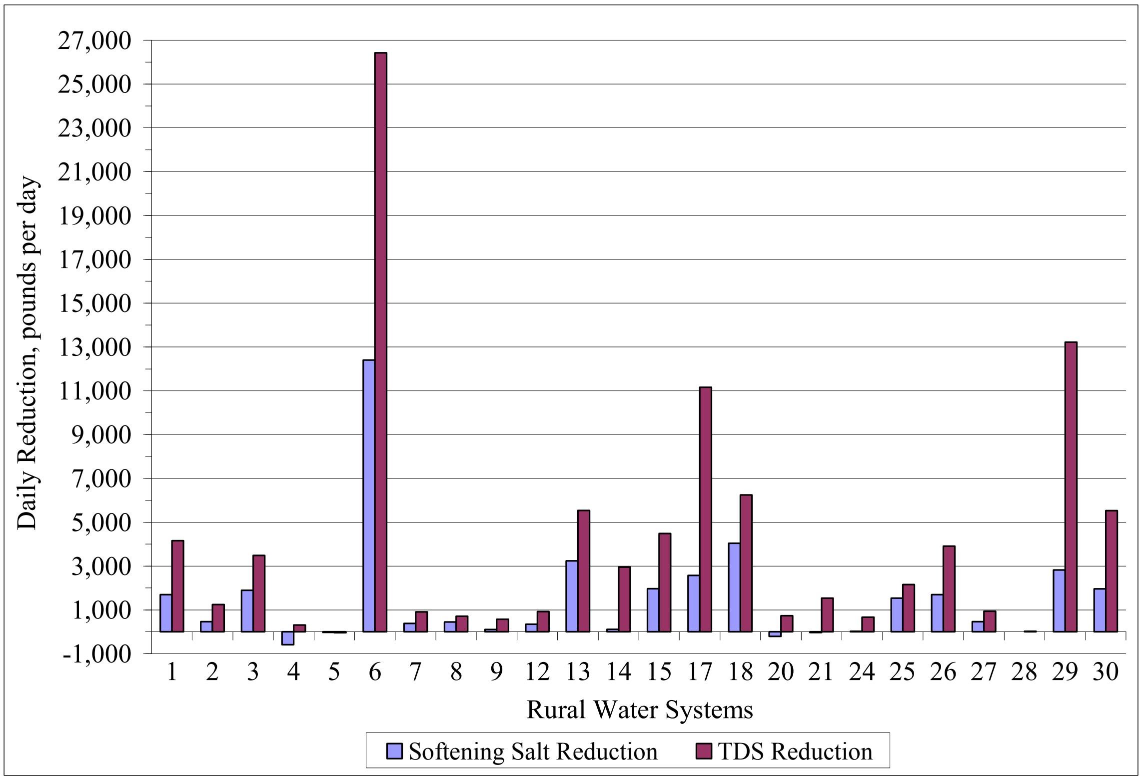

Figure 4.13. Individual Rural Water System Reduction of Water Softening Salt and Total Dissolved Solids

4.2.3 Improved Livestock Production & Health

Another important social impact was the improvement of livestock production and health from improved drinking water quality. The literature reviewed in Sections 2.2 through 2.6 showed that livestock ranging from beef cattle, dairy cattle, sheep, swine, and poultry exhibit improved production values and experience better health when exposed to high quality drinking water. The main drinking water constituents that were examined in both poor quality drinking water and high quality drinking water were total dissolved solids, sulfate, and sodium chloride. Studies indicated lower concentrations of those three constituents contributed to better livestock health and production.

Since the improvement in water quality when farms switched from individual farm wells to rural water service was not documented in this study, the improvement of water quality relative to sulfate, total dissolved and chloride is not quantified. However, if the improvement in community water supply quality (illustrated in Table 4.5) is an indicator, substantial improvements in farm water quality are very likely. The testimonial of a dairy farmer in the TM rural water system summarized in the literature confirmed that a dairy farm had experienced increased milk yields and improved cow health. Other testimonials of similar improvements are very likely but are not documented in this study.

4.3 Water Demand Variations & Trends of Customer Classifications

The water consumption characteristics of different customer classifications (city customers, country dwelling customers, and farm customers) served by Big Sioux, Clay, Mid-Dakota, and TM rural water systems from 1999 to 2007 established customer demands throughout the year. Sections 4.3.1 through 4.3.4 focus on the city, country dwelling, and farm customer classifications of these four systems, specifically examining demand variations within sub-customer classifications. (As discussed in Section 3.5, the city customer classification included two sub-customer classifications - bulk city customers and individual city customers. Both sub-customer classifications exhibited different water consumption characteristics and different degrees of influence on the overall city classification. The country dwelling and farm customer classifications also had sub-customer classifications.)

Section 4.3.5 and Appendix F examines the water consumption characteristics of city, country dwelling, and farm customer classifications, and determines how the consumption characteristics affect Big Sioux, Clay, Mid-Dakota, and TM rural water systems' overall water consumption.

4.3.1 Comparison of Individual Cities & Bulk Cities

Bulk cities receive water in bulk and distribute the water to each of their city customers. Customers in an "individual" city are supplied individually by Big Sioux, Clay, Mid-Dakota, and TM rural water systems. Since the two city customer classifications were serviced by different means (perhaps with different billing rates affected by system operations and maintenance procedures), one may expect the respective customers to have different water consumption characteristics. When comparing the consumption characteristics for each year, it is noted that the individual community classification contained data for one city (Davis) from 1999 to 2002 and no communities in 2003 and 2004. For that reason perhaps a better example of the individual communities' water consumption characteristics was obtained by examining data during 2005 through 2007, when data from ten to eleven cities were represented.

Data for the four rural water systems are tabulated in Appendix C. The total numbers of bulk and individual cities for the four systems are tabulated in Table 4.8. It is noted that the majority of cities served by the four systems are served on a bulk basis rather than an individual basis.

Table 4.8. Numbers of Bulk & Individual Cities Served by the Four RWS

Year	Cities Served Bulk	Cities Served Individually
1999	9	1
2000	9	1
2001	10	1
2002	11	1
2003	11	None
2004	11	None
2005	16	10
2006	16	11
2007	16	11

One characteristic that might distinguish the water consumption characteristics between bulk and individually served cities is the peaking factor. Water use data from these cities were used to calculate a monthly peaking factor, found by dividing the peak month use by the average month use for each year. The peaking factors for the communities are tabulated in Appendix C. The peaking factors for the bulk and individually served communities were averaged, and the results are plotted in Figure 4.14.

As shown in Figure 4.14, individual cities exhibit a slightly higher peaking factor than bulk cities, but both classifications are fairly similar. Even the individually served city of Davis (for which data are displayed for the years 1999 through 2002) followed the trend of having a higher peaking factor than the bulk communities. Based on the 2005 to 2007 data, the peaking factors for individually served cities ranged from 1.72 to 1.90 which was similar to the 1999 to 2007 bulk communities' peaking factors of 1.34 to 1.68. From 2005 to 2007 the average individual communities had a 12% higher peaking factor than the bulk communities.

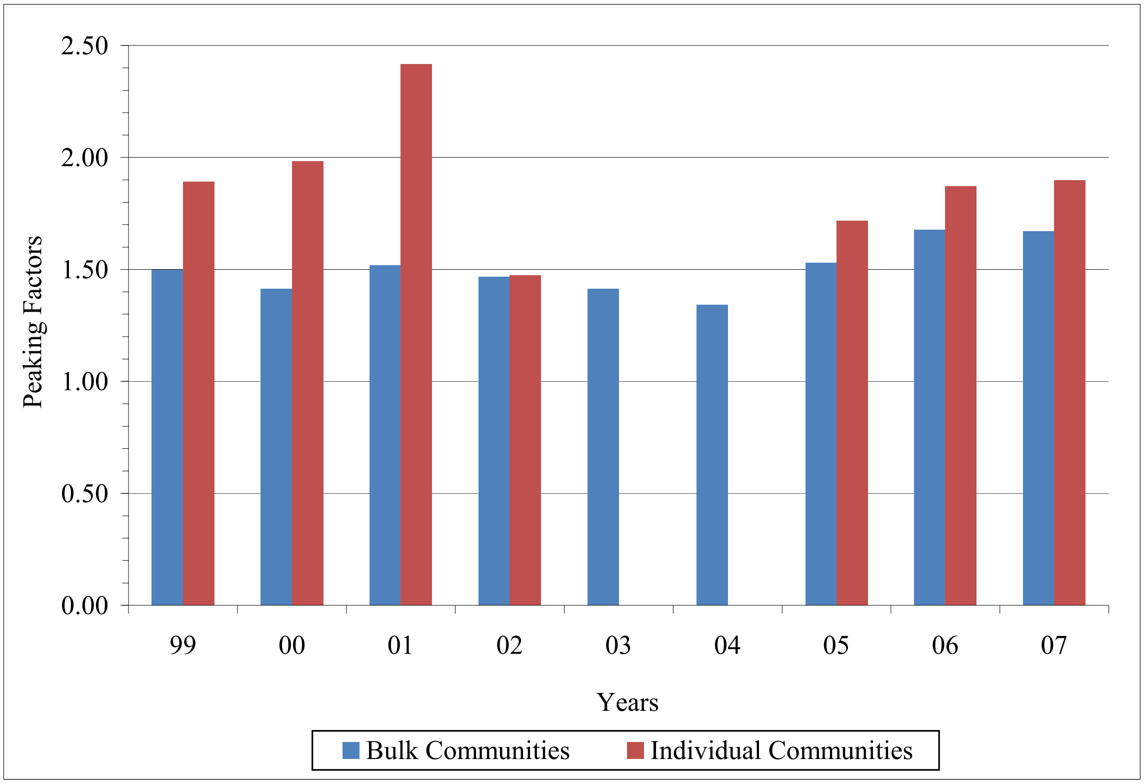

Figure 4.14. Monthly Peaking Factors for the City Classification

Although the individual cities exhibited higher peaking factors, the same was not true for the daily amount of water used per person, depicted in Figure 4.15. From the years 2005-2007, the bulk communities averaged about 30 gallons per person per day more water used than the individual communities (bulk 103 gppd vs. individual 73 gppd). Year to year trends in per person demand from year to year were likely a reflection of rainfall amounts. These data indicate that bulk community customers consumed more water per day than individual community customers, and that a community converted from bulk to individual service may realize a decrease in per person water consumption.

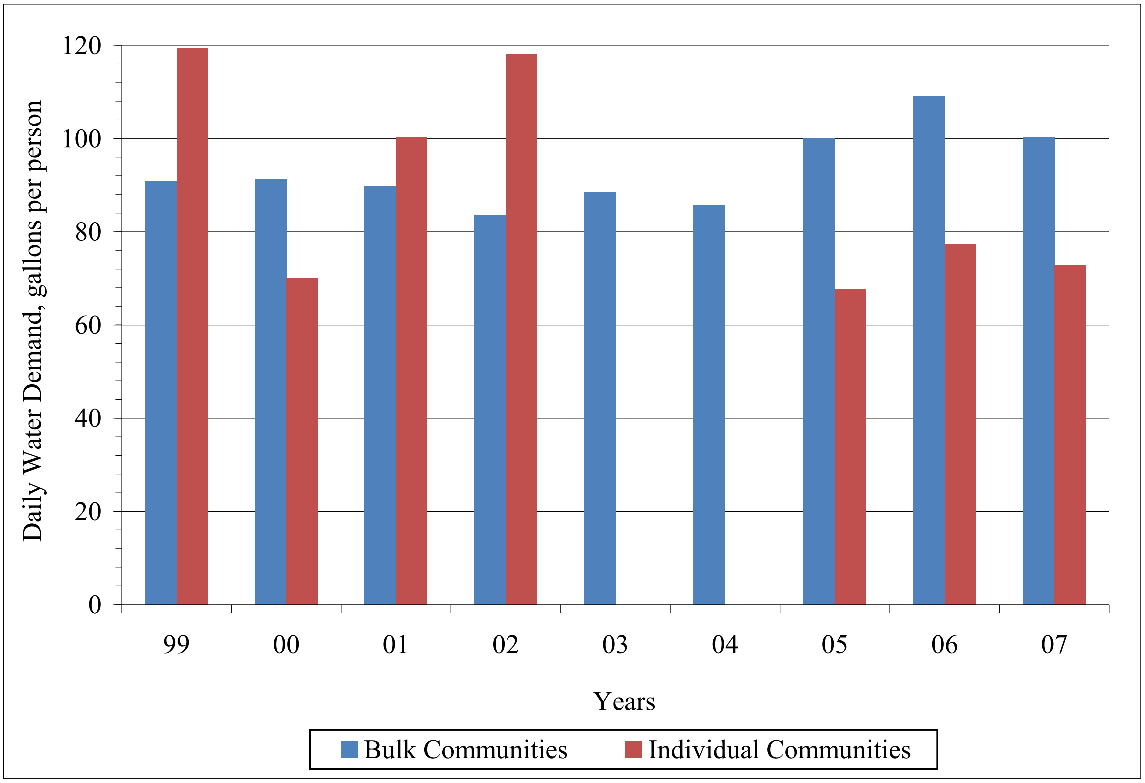

Figure 4.15. Daily Water Demand per Person for the City Classification

Whereas Figure 4.15 showed trends in per person water demand, Figure 4.16 is a plot of daily water consumption per customer. Per customer consumption was determined either from a calculation based on US Census housing unit data (for bulk cities) or from individual city hookup data. (An example of calculations for determining the number of water meter hookups for a bulk community is shown in Appendix D.) The average per customer consumption for bulk and individual communities are plotted in Figure 4.16. The per customer data followed the same trends as the per person data shown in Figure 4.15 except the daily water consumption per customer was a little more than twice that of the daily water consumption per person. For the years 2005-2007, the per customer daily water demand for bulk communities averaged 224 gpd as compared with an average of 150 gpd for individual communities, a difference of 74 gpd.

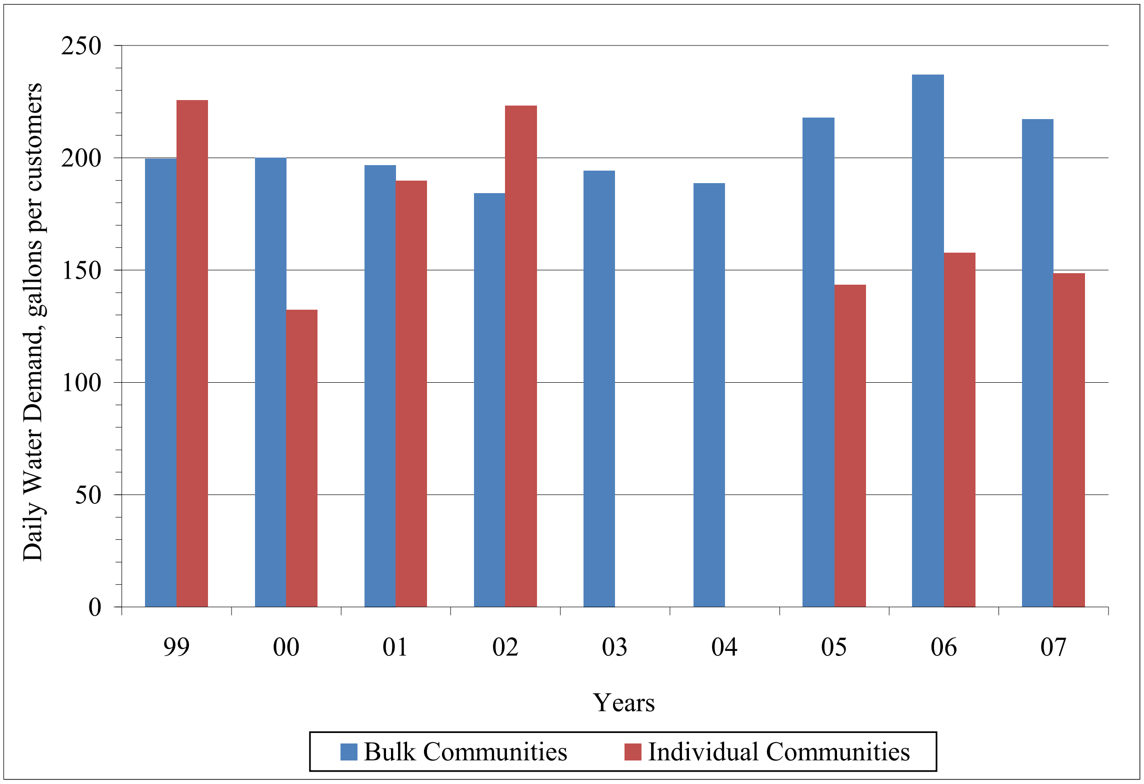

Figure 4.16. Daily Water Demand per Customer for the City Classification

4.3.2 Impact of City Size on Water Consumption

The consumption characteristics of the cities served by Big Sioux, Clay, Mid-Dakota, and TM rural water systems were compared as a function of city population. Cities served by the four systems were divided into three groups: 1) communities with a population fewer than 100, 2) communities with a population between 100 and 500, and 3) communities with a population greater than 500. The consumption characteristics that were compared were the peaking factors, the daily water consumption per customer, and the average monthly water demand per customer. Data were available for only one community with a population of fewer than 100 for the years 1999 to 2004, so the best illustration of water consumption characteristics for communities less than 100 population would be based on data during the years 2005 through 2007. However, the single city that represented the communities with a population of fewer than 100 from 1999 to 2004 did follow the same trends that were revealed when more cities were added to the classification. Table 4.9 shows the number of communities in each of the three categories for the years that city water data were available from the four systems. Data from Mid-Dakota RWS contributed to the increase in the number of cities (5, 3, and 3 for population categories from the least population category to the most population category) displaying consumption data for 2005-2007.

Table 4.9. Number of Communities for which Water Consumption was Available by Population Category

Year	< 100 people	100 to 500 people	> 500 people
1999	1	6	3
2000	1	6	3
2001	1	6	4
2002	1	6	5
2003	1	5	5
2004	1	5	5
2005	6	9	8
2006	6	9	8
2007	6	9	8

The maximum month to average month peaking factors for each year by population category are shown in Figure 4.17. All three groups exhibited similar peaking factors from year to year, and each group's peaking factors did not vary much from year to year. Cities with fewer people generally exhibited a slightly higher peaking factor than those cities with more people. The small community peaking factors ranged from 1.42 to 2.04 (average 1.65) and the peaking factors for the middle sized communities ranged from 1.44 to 1.74 (average 1.57). Finally the peaking factors for the larger communities ranged from 1.37 to 1.65 (average 1.48).

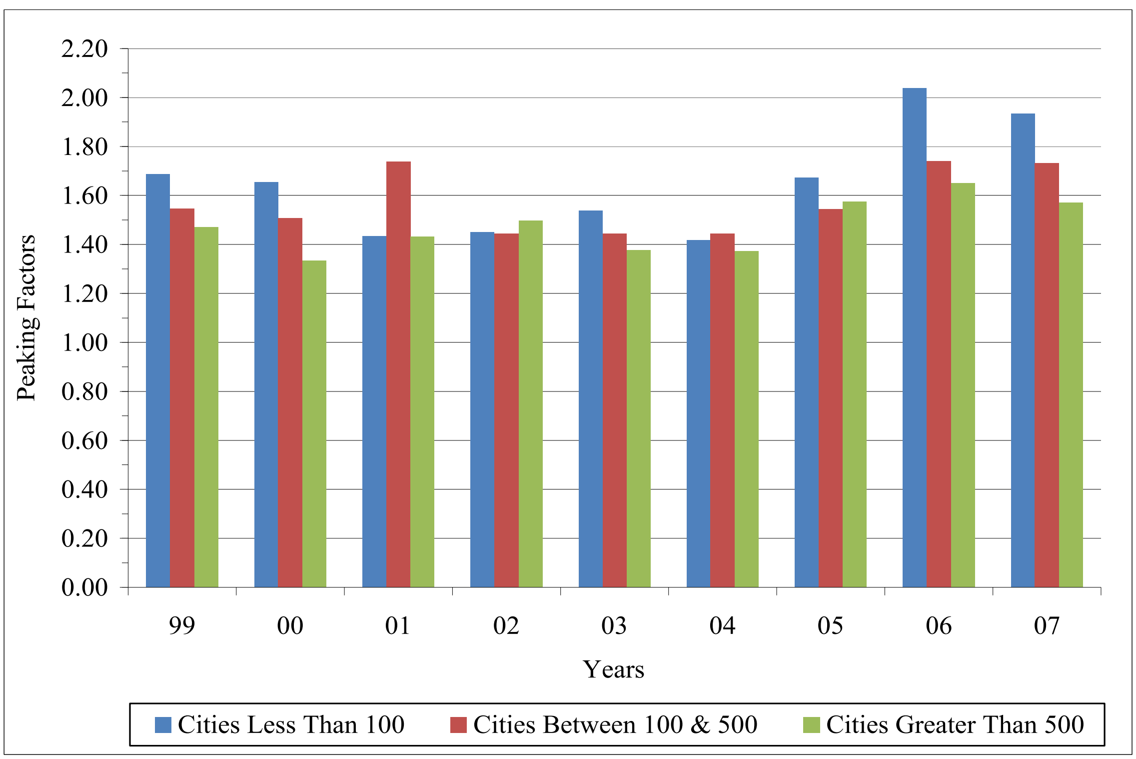

Figure 4.17. Monthly Peaking Factors for the Different Sized Communities

Although smaller communities exhibited higher peaking factors, larger communities exhibited greater per person and per customer (hookup) average water consumption. Figure 4.18 shows the daily per person water consumption for the communities with 100 to 500 people was similar to that of communities with greater than 500 people from 1999 through 2004. From 2004 to 2005 the daily water consumption for the communities with greater than 500 people jumped from an average daily demand of 94 gallons per person to 119 gallons per person. The 26 % increase in daily water demand was primarily due to the addition of Huron, Gettysburg, and Onida data to the category. The city of Gettysburg exhibited the highest daily water demand of 201 gallons per person in 2006. During 2005 to 2007 daily water demand for cities with fewer than 100 people was only 16 gallons per person less than the middle category of cities. The range of daily water demands for the smaller communities was 46 gallons per person to 77 gallons per person (average = 62 gallons per person). The range for the middle sized communities was 83 gallons per person to 102 gallons per person (average = 92 gallons per person), whereas range for the larger communities was 86 gallons per person to 123 gallons per person (average = 103 gallons per person).

Figure 4.19 shows the daily water consumption per customer (hookup) delineated by population category. Figure 4.19 showed the same trend exhibited in Figure 4.18, except the daily water demand per customer was double the daily water demand per person because each hookup serves approximately 2.5 people. From 2005 to 2007 the cities with fewer than 100 people exhibited an average daily water demand of 82 gallons per customer less than the middle sized cities and 144 gallons per customer less than the

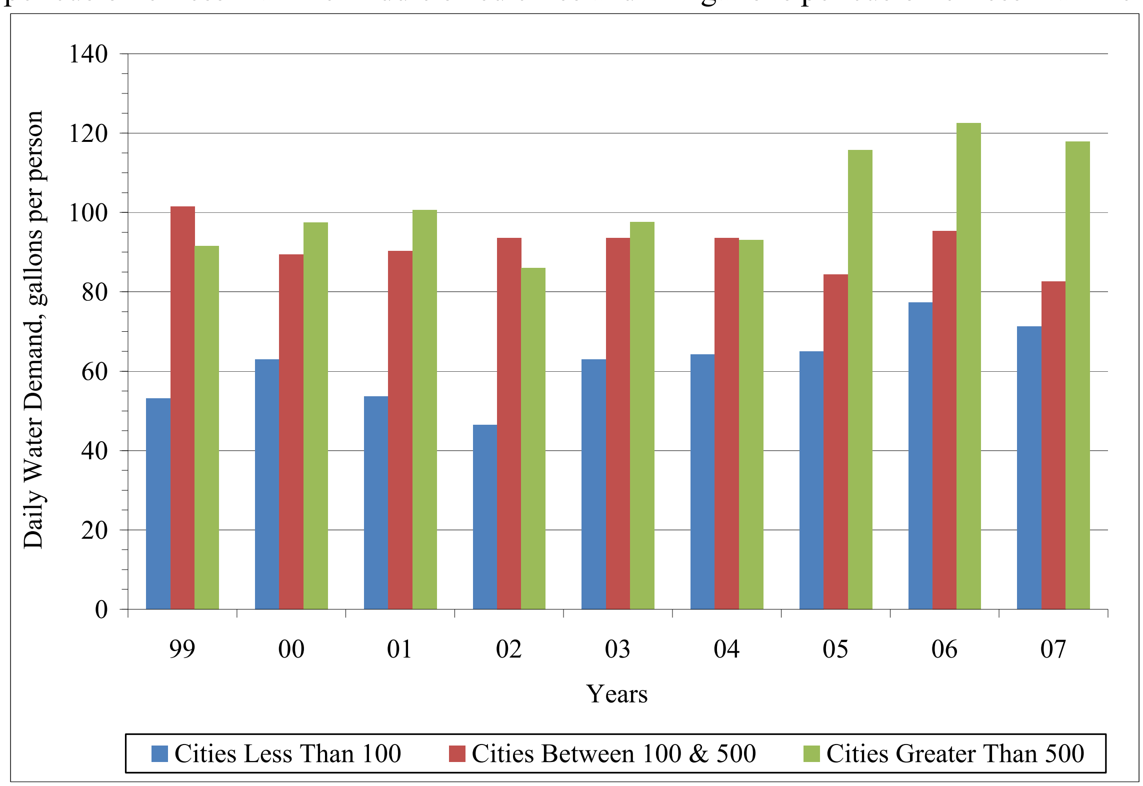

Figure 4.18. Daily Water Demand per Person for the Different Sized Communities

larger cities. In other words, the small city customers consumed 56% less water per day than customers in cities with population greater than 500. Even from 1999 to 2004 when Dolton was the only city with fewer than 100 people, the daily water consumption was 57% less than the cities with greater than 500 people. The average daily water demand of cities serving 100 to 500 people during 2005 through 2007 was 62 gallons per customer less than the cities serving greater than 500 people. Figure 4.19 illustrated that generally the customers in a larger populated city would consume substantially more water per day than the customers in a smaller populated city.

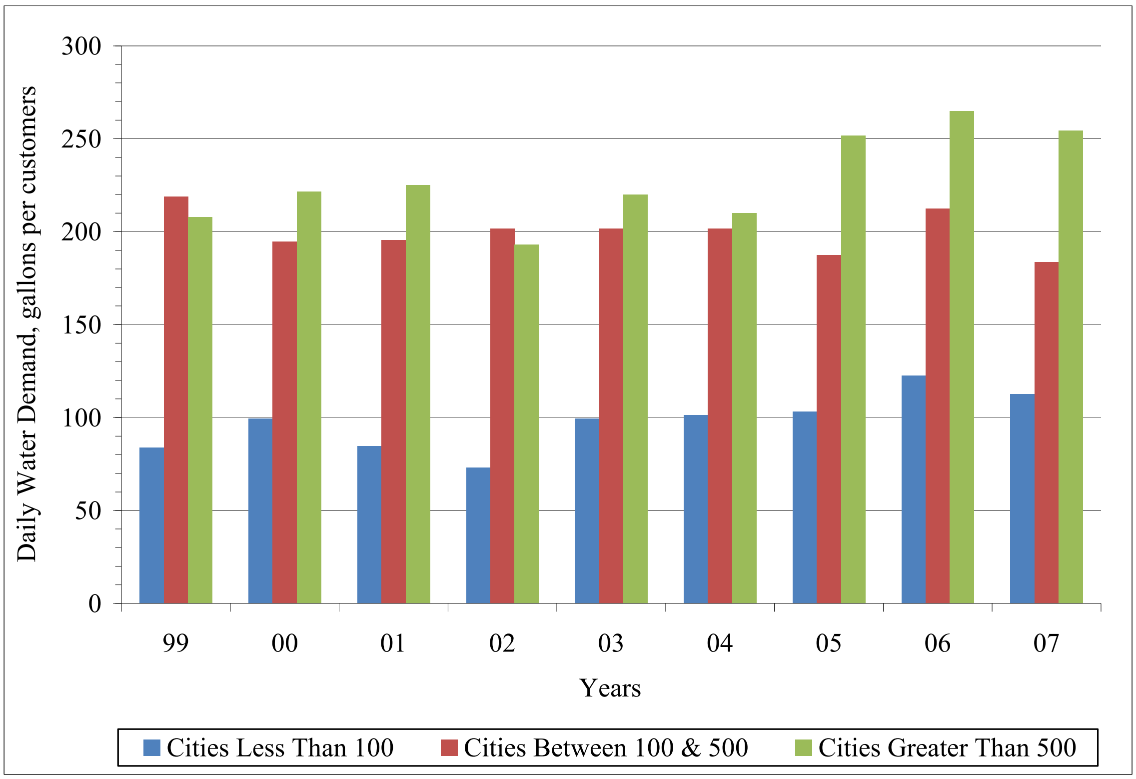

Figure 4.19. Daily Water Demand per Customer for the Different Sized Communities

The last water consumption characteristic that was compared among the population categories was the average monthly water demand per customer. Plots of average monthly water demand per customer were prepared and are shown in Figures 4.20 through 4.25.

Figures 4.20 and 4.21 contain trends of monthly water consumption for the cities less than 100 people. The data were split into two plots to avoid confusion among the data. The city of Dolton was the only community with fewer than 100 people from 1999 through 2004. Five more cities were added to the group in the year 2005. Each city exhibited the same trend of peak water demands during the summer months of May

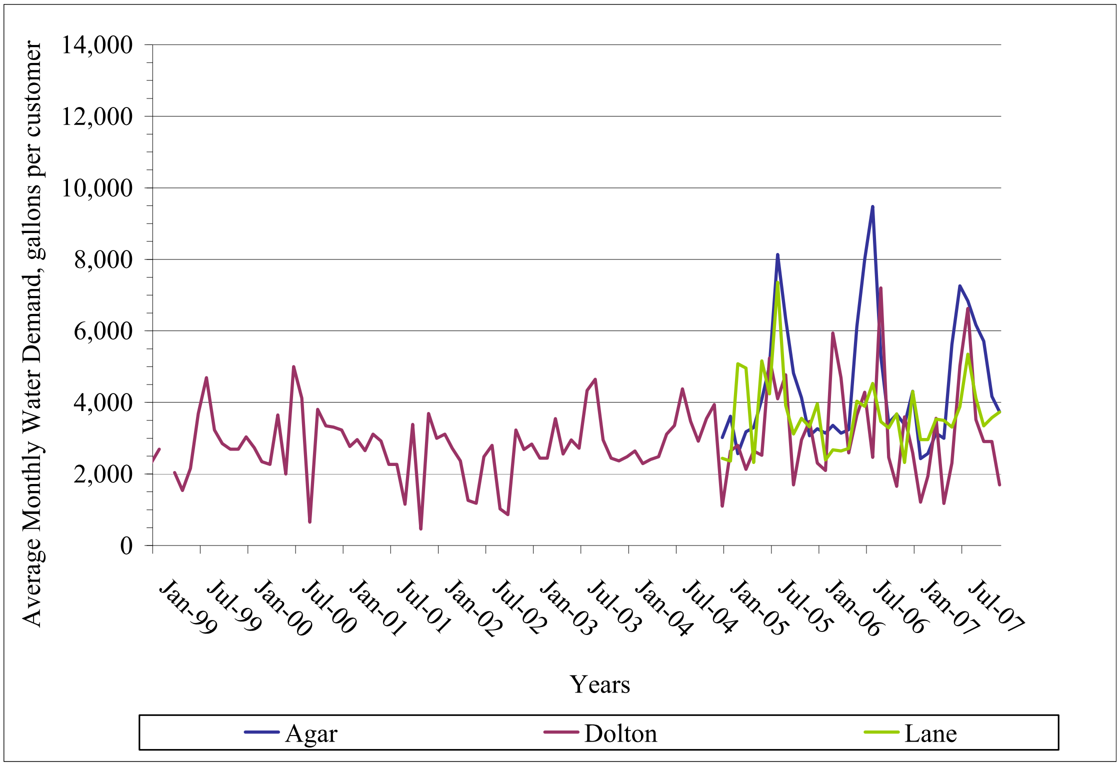

Figure 4.20. Average Monthly Water Demand per Customer for the Communities with fewer than 100 people, Part 1

through September. The average monthly water demand during the summer months (May through September) for the six cities was 5,451 gallons per customer, whereas the average monthly water demand for the remaining months was 3,465 gallons per customer. The overall average monthly water demand from 1999 to 2007 was 3,919 gallons per customer. As the years progressed from 1999 to 2005 the city of Dolton's average monthly water demand per customer remained fairly constant. However, the average monthly water demands per customer increased by 8% from 2005 to 2007.

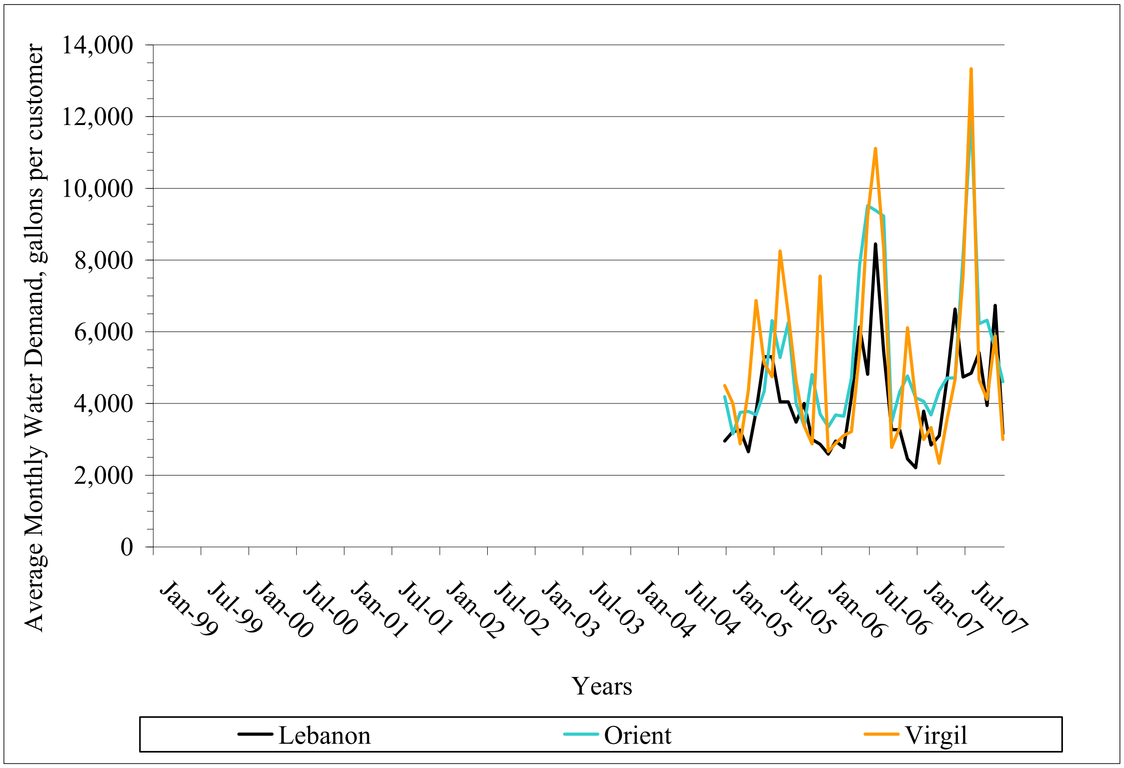

Figure 4.21. Average Monthly Water Demand per Customer for the Communities with fewer than 100 people, Part 2

The average monthly per customer water demands for the ten cities with populations between 100 and 500 are illustrated in Figures 4.22 and 4.23. While each "middle sized" city exhibited its own characteristic monthly water demand per customer, they also exhibited elevated demands through the summer months. The average monthly water demand during the summer months for the ten cities was 7,199 gallons per customer, whereas the average monthly water demand during the remaining months was 5,303 gallons per customer. The overall average monthly water demand from 1999 to 2007 was 6,135 gallons per customer, which was 36% larger than the average monthly water demand for the smaller cities. There was not a recognizable trend of increasing or decreasing average demands over this period of years.

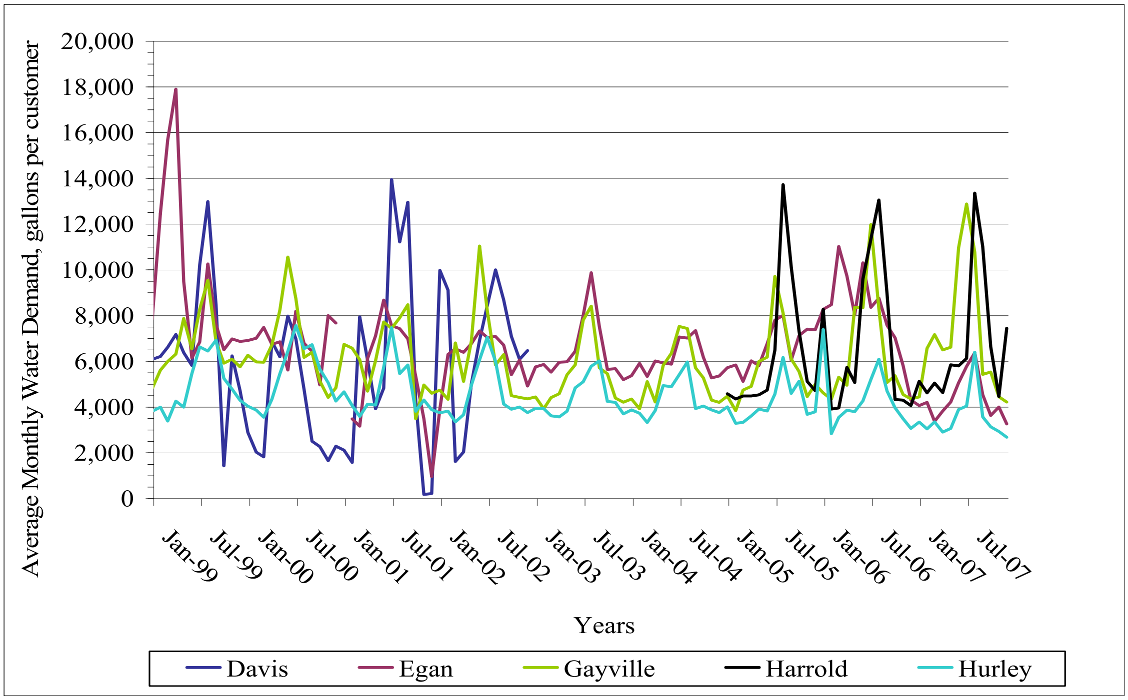

Figure 4.22. Average Monthly Water Demand per Customer for the Communities with 100 to 500 people, Part 1

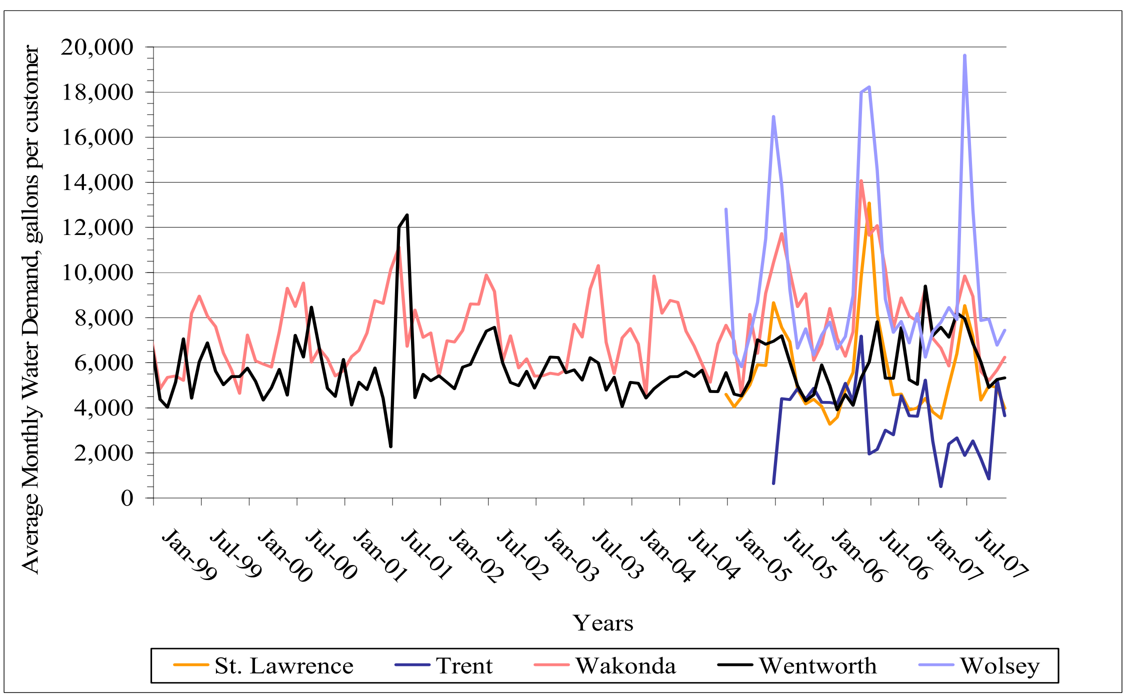

Figure 4.23. Average Monthly Water Demand per Customer for the Communities with 100 to 500 people, Part 2

The average monthly per customer water demands for the eight cities with populations greater than 500 were illustrated in Figures 4.24 and 4.25. The seasonal water demand variations exhibited by the other two population categories were also apparent in the greater than 500 people category. The average monthly water demand during the summer months for the eight cities was 8,463 gallons per customer, whereas the average monthly water demand during the remaining months was 6,086 gallons per customer. The overall average monthly water demand from 1999 to 2007 was 7,260 gallons per customer, which was 16% greater than the average monthly water demand for the middle sized cities.

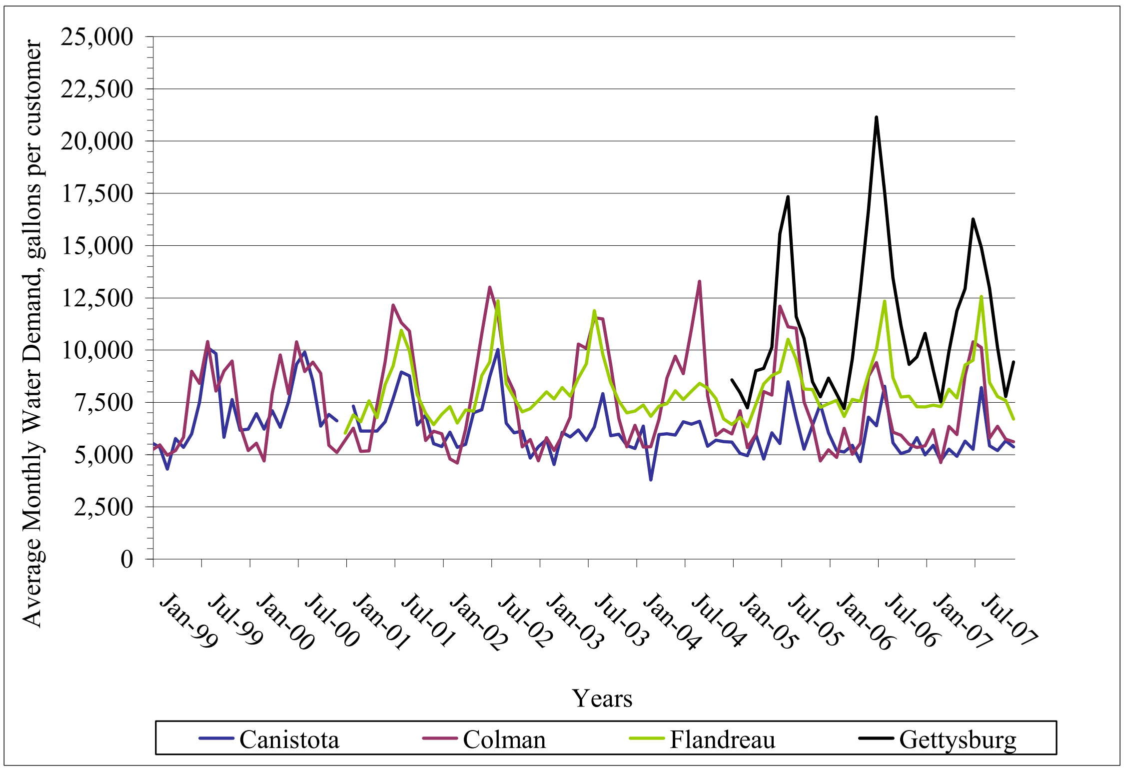

Figure 4.24. Average Monthly Water Demand per Customer for the Communities with greater than 500 people, Part 1

It was noted that Onida and Virgil exhibited very large summer month demands relative to the rest of the months. The summer month demand for Onida was 114% higher than the rest of the year and Virgil was 78% higher, the rest of the communities averaged 42% higher demand during summer months. The peak demands in Onida and Virgil may be due to lawn watering or swimming pool operations since these communities are located in central South Dakota, in a region of lower rainfall. The relationship between rainfall and water demand will be examined in subsequent sections.

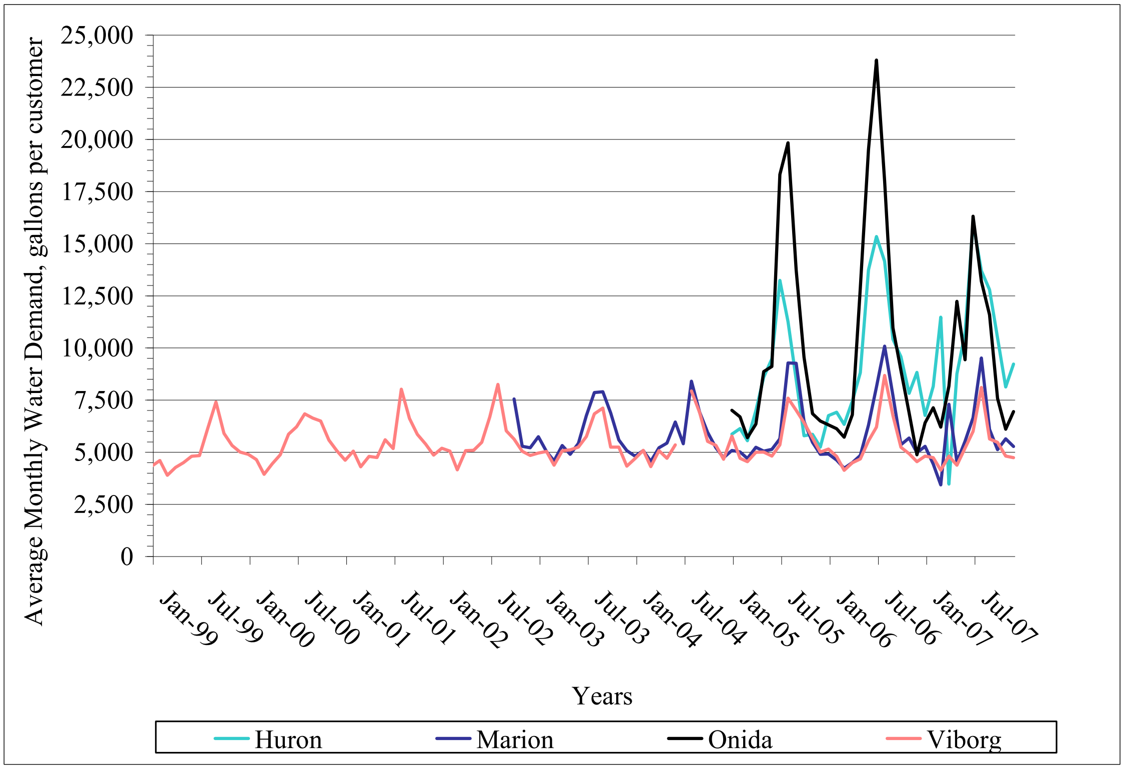

Figure 4.25. Average Monthly Water Demand per Customer for the Communities with greater than 500 people, Part 2

Table 4.10 provides a summary of per customer demands for the three categories of communities. The table provides numbers that could be used for demand estimates as well as showing trends of increased demands with the size of community.

Table 4.10. Summary of Community per Customer Demands by Population Size

Demand Characteristic	< 100 people	100 to 500 people	> 500 people
Average month, gallons	3,919	6,135	7,260
Average during summer months (May – Sep.), gallons	5,451	7,199	8,463
Average during remaining months (Oct. – Apr.), gallons	3,465	5,303	6,086

<u>4.3.3 Water Use Characteristics of Country Dwellings and Cabins</u>

Big Sioux and Clay RWS subdivided the country dwelling category to country dwellings and cabins. The two customer classifications exhibited dissimilar water consumption characteristics that varied for each rural water system. Both Mid-Dakota and TM RWS did not delineate cabins in their country dwelling category. The data from Big Sioux and Clay RWS were examined to compare the demands of country dwellings with the demands of cabins.

The Big Sioux RWS raw country dwelling customer data were subdivided into country dwellings, monthly cabins, and annual cabins, but for the purpose of this study, the monthly cabins and annual cabins data were consolidated into a single "cabins" category. The demand characteristics of these customers are tabulated in Table 4.11.

Table 4.11. Comparison of Big Sioux CWS Country Dwelling Classification

Country Dwellings				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	11,053,000	1.26	163	186
2000	12,458,000	1.39	174	196
2001	13,236,000	1.47	179	202
2002	14,069,000	1.42	190	203
2003	15,077,000	1.35	204	203
2004	15,313,000	1.20	218	192
2005	17,376,000	1.28	234	203
2006	18,184,000	1.70	255	195
2007	18,840,000	1.67	273	189
Average	Peaking Factor of 1.42		196 Gallons per Customer per Day	
Cabins				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	17,083,000	6.67	574	81
2000	21,074,000	6.79	599	95
2001	23,797,000	6.64	619	104
2002	24,266,000	6.71	641	104
2003	24,965,000	6.12	675	106
2004	22,895,000	5.43	699	89
2005	25,027,000	5.78	714	95
2006	28,998,000	3.15	739	98
2007	27,698,000	2.35	759	100
Average	Peaking Factor of 5.52		97 Gallons per Customer per Day	

[a] The gallons per customer per day were calculated from an annual average.

As seen in Table 4.11 the consumption characteristics of the Big Sioux country dwelling subcategory substantially differed from the consumption characteristics of cabin subcategory. The water consumption from the cabin customers constituted about 60% of the overall country dwelling classification's yearly water demand. Country dwelling customers consumed about 197 gallons a day per customer (the average over the years that data were provided) whereas cabin customers consumed about 97 gallons a day per customer. The maximum month to average month peaking factors for the country dwelling customers ranged from 1.20 to 1.70. The peaking factor for the cabin customers from 1999 through 2005 was artificially high because the water meters of the annual cabins in the sub customer classification were read one or two months of the year. In 2006, the annual cabin's water meters were read every month starting in June, so the cabins peaking factors dropped substantially. The peaking factor for the cabin customers was more accurately represented by data from years 2006 and 2007, which were 3.15 and 2.35 (average = 2.75), respectfully.

The numbers of country dwelling customers and cabin customers increased as the years progressed. Country dwelling customers increased at about 6 to 7 percent each year where as cabin customers increased at about 3 to 4 percent each year.

The Clay RWS raw country dwelling customer data were subdivided into country dwellings, cabins, and group cabins. For this study, the cabins and group cabins data were lumped together into the single "cabins" classification. The data are presented in Table 4.12.

Table 4.12. Comparison of Clay RWS Country Dwelling Classification

Country Dwellings				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	35,060,000	2.57	634	151
2000	42,390,000	2.35	666	174
2001	39,743,000	2.50	703	155
2002	44,272,000	2.53	737	164
2003	42,136,000	2.36	725	159
2004	41,811,000	2.35	758	151
2005	48,315,000	2.39	868	152
2006	89,013,000	2.68	1023	238
2007	112,965,000	2.67	1124	275
Average	Peaking Factor of 2.49		180 Gallons per Customer per Day	
Cabins				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	418,000	4.84	14	82
2000	479,000	4.91	12	109
2001	498,000	5.06	13	105
2002	523,000	5.54	13	110
2003	470,000	5.26	7	184
2004	567,000	5.65	9	173
2005	598,000	5.91	11	149
2006	525,000	5.53	9	160
2007	963,000	5.43	11	240
Average	Peaking Factor of 5.35		146 Gallons per Customer per Day	

[a] The gallons per customer per day were calculated from an annual average.

As compared to the Big Sioux RWS, the Clay RWS country dwelling customers dominated the overall country dwelling classification. The water consumption from the cabin customers comprised about 1% of the overall country dwelling classification's yearly water demand. The average day demand of the country dwelling customers ranged between 151 and 174 gallons per day through 2005, and then increased substantially as the system acquired the water system of an up-scale development near North Sioux City, as reflected in the increased customer numbers in 2006 and 2007. The peaking factor for the country dwelling customers ranged from 2.35 to 2.68 and the peaking factor for the cabin customers ranged from 4.84 to 5.91.

When the data from Big Sioux and Clay RWS are compared, the Big Sioux cabin data are likely more representative of cabin water use because of the larger sample size of cabin customers in the Big Sioux RWS data base. Generally the average daily demand of the cabin customers was approximately one half of the average daily demand of the country dwelling customers in the Big Sioux system and the peaking factor of the cabin customers was approximately double that of the country dwelling customers. The demand characteristics of country dwelling customers for all four systems are more generally compared in Section 4.3.5.

4.3.4 Comparison of Farm and Pasture Tap Water Demands

The raw farm customer data for the four rural water systems was sub-categorized into "farm" customers and "pasture taps". A farm customer would typically use water for household use, lawn irrigation, dilution of pesticides/herbicides for spray application and livestock watering, whereas the pasture taps are primarily used for livestock watering. The subdivided data for the four systems are tabulated in Tables 4.13 through 4.16 in order to examine the water usages of farms and pasture taps. For purposes of direct comparison, the average and ranges for each system are tabulated in Table 4.17.

Table 4.13. Water Demands of Big Sioux CWS Farm & Pasture Tap Customers

Farms				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	121,561,000	1.23	804	415
2000	126,787,000	1.21	803	431
2001	123,911,000	1.23	809	420
2002	132,033,000	1.36	799	453
2003	133,715,000	1.26	800	458
2004	124,363,000	1.14	799	425
2005	128,047,000	1.26	795	442
2006	124,840,000	1.36	796	430
2007	123,159,000	1.32	797	423
Average	Peaking Factor of 1.26		433 Gallons per Customer per Day	
Pasture Taps				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	1,830,000	12.00	37	133
2000	1,877,000	11.94	39	129
2001	2,864,000	11.21	35	220
2002	2,697,000	12.00	37	181
2003	3,405,000	11.77	35	221
2004	3,367,000	10.77	34	218
2005	3,585,000	11.99	27	270
2006	3,610,000	4.49	25	274
2007	3,124,000	2.09	27	228
Average	Peaking Factor of 3.3[b]		208 Gallons per Customer per Day	

[a] The gallons per customer per day were calculated from an annual average.
[b] Average of Peaking Factor for 2006 and 2007.

Table 4.14. Water Demands of Clay RWS Farm & Pasture Tap Customers

Farms				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	77,098,011	2.34	633	334
2000	80,176,015	2.34	631	347
2001	73,576,000	2.43	617	327
2002	77,263,005	2.40	656	323
2003	76,329,000	2.38	692	302
2004	74,612,000	2.32	674	302
2005	75,591,000	2.45	665	311
2006	82,780,000	2.54	662	342
2007	82,452,000	2.53	654	345
Average	Peaking Factor of 2.41		326 Gallons per Customer per Day	
Pasture Taps				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	2,882,000	5.74	42	188
2000	4,007,000	5.90	53	207
2001	3,507,000	6.16	50	192
2002	3,926,000	6.51	54	199
2003	2,690,000	6.75	49	150
2004	2,789,000	6.53	42	182
2005	4,511,000	5.01	62	199
2006	23,768,000	5.28	82	794
2007	27,966,000	5.33	86	891
Average	Peaking Factor of 5.91		188[b] Gallons per Customer per Day	

[a] The gallons per customer per day were calculated from an annual average.
[b] Average of 1999 through 2005.

Table 4.15. Water Demands of Mid-Dakota RW Farm & Pasture Tap Customers

Farms				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
2005	87,896,000	1.14	326	739
2006	108,050,000	1.40	340	866
2007	102,422,000	1.17	357	787
Average	Peaking Factor of 1.24		797 Gallons per Customer per Day	
Pasture Taps				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
2005	70,621,000	12.0	555	349
2006	102,975,000	12.0	683	413
2007	87,810,000	12.0	706	341
Average	Peaking Factor of 12		368 Gallons per Customer per Day	

[a] The gallons per customer per day were calculated from an annual average.

Table 4.16. Water Demands of TM RWD Farm & Pasture Tap Customers

Farms				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
1999	63,257,000	2.03	330	525
2000	67,804,000	2.06	328	566
2001	59,001,000	2.11	317	510
2002	63,900,000	2.35	356	492
2003	63,664,000	2.11	355	491
2004	58,118,000	2.40	347	459
2005	56,758,000	2.25	339	459
2006	57,135,100	2.35	325	482
2007	53,389,000	2.19	325	450
Average	Peaking Factor of 2.21		493 Gallons per Customer per Day	
Pasture Taps				
Year	Total Yearly Demand	Peaking Factor	Total Customers	Gallons per Customer per Day[a]
2004	2,714,000	1.93	3	2479
2005	825,000	1.63	2	1130
2006	883,000	2.60	3	806
2007	1,201,000	2.06	4	823
Average	Peaking Factor of 2.05		1,309 Gallons per Customer per Day	

[a] The gallons per customer per day were calculated from an annual average.

Table 4.17. Water Demands of Big Sioux CWS, Clay RWS, Mid-Dakota RW, & TM RWD Farm & Pasture Tap Customers

	Big Sioux		Clay		Mid-Dakota		TM	
	Farms	Pasture Taps	Farms	Pasture Taps	Farms	Pasture Taps	Farms	Pasture Taps
Average Total Yearly Demand (MG)	126.491	2.929	77.764	8.450	99.456	87.135	60.336	1.406
Range of Total Yearly Demand (MG)	121.561 - 133.715	1.830 - 3.610	73.576 - 82.780	2.690 - 27.966	87.896 - 108.050	70.621 - 102.975	53.389 - 67.804	0.825 - 1.201
Average Peaking Factor	1.26	9.81	2.41	5.91	1.24	12.00	2.21	2.06
Range of Peaking Factor	1.14 - 1.36	2.09 - 12.00	2.32 - 2.54	5.01 - 6.75	1.14 - 1.40	12.00	2.03 - 2.40	1.63 - 2.60
Average Total Customers	800	33	654	58	341	648	336	3
Range of Total Customers	795 - 809	25 - 39	617 - 692	42 - 86	326 - 357	555 - 706	317 - 356	2 - 4
Average Gallons per Customer per Day[a]	433	208	326	334	797	368	493	1,310
Range of Gallons per Customer per Day[a]	415 - 458	129 - 274	302 - 347	150 - 891	739 - 866	341 - 413	450 - 566	806 - 2,479

[a] The gallons per customer per day were calculated from an annual average.

Comparing the data from these four systems reveals several trends and conclusions that are summarized below.

- Whereas Big Sioux, Clay and TM have relatively few pasture taps compared to farm customers, (less that 10 % are pasture taps), Mid-Dakota has approximately twice as many pasture taps as farm customers. The relative proportions are a function of the service areas – Mid-Dakota serves customers that have higher acreages of rangeland for stock cattle production, whereas Big Sioux, Clay and TM have greater acreages in crop production and more confined animal operations with watering facilities on farms.
- Big Sioux and Mid-Dakota predominantly read their pasture taps once or twice per year. This artificially inflates the peaking factor for these systems – in some of these cases the peaking factor was 12, meaning the peak month is 12 times the average month. This inflates the peaking factor because the demand is actually used during the months when the stock cattle are using the pasture tap. Big Sioux RWS began monthly reads in 2006 and the peaking factor decreased substantially to the range of those experienced by Clay RWS. During those two years, approximately 80 % of the pasture tap demand occurred during the months of May through September, and the remaining 20% of demand occurred during the remainder of the year. Monthly meter readings are needed in order to fully characterize the demand characteristics of pasture taps.
- Based on a calculated average day demand, the annual water use for each farm customer in the Big Sioux, Clay, and Mid-Dakota rural water systems is approximately twice the water use for each pasture tap.
- The water use of pasture taps in the TM rural water system is extremely high relative to the other three systems. These pasture taps are view as atypical, and are likely serving confined animal feeding operations.
- Clay RWS pasture tap demands increased substantially in 2006 and 2007 when customers with meters designated for irrigation were incorporated into the pasture tap data. The data from these two years are not considered representative of pasture tap demands. Clay RWS pasture taps exhibited peaking factors that were more than twice the peaking factors of the farm customers (5.9 vs. 2.4).

4.3.5 Comparison of Water Demands for Big Sioux, Clay, Mid-Dakota, & TM Rural Water System Customer Classifications

The demand trends of each customer classification for the Big Sioux, Clay, Mid-Dakota and TM RWS were closely examined to see how the water use impacted the overall water consumption of each system. A summary of the detailed examination for each system is found in Appendix F. It was important to see how each of the four customer classifications affected Big Sioux, Clay, Mid-Dakota, and TM rural water systems' overall demand characteristics because the customer base of each system was different. The comparison of a single customer classification would help to determine if a customer classification had a common trend between the four rural water systems and to provide a general range of values for the consumption characteristics of each customer classification. The consumption characteristics that were compared in this section of the report were daily water demand per customer, peaking factors, and the effect of precipitation on daily water demand.

The percent distribution of customer classifications for each rural water system is displayed in Figure 4.26. Each system's distribution of customers is displayed for each year from right to left reading Big Sioux, Clay, Mid-Dakota, and TM.

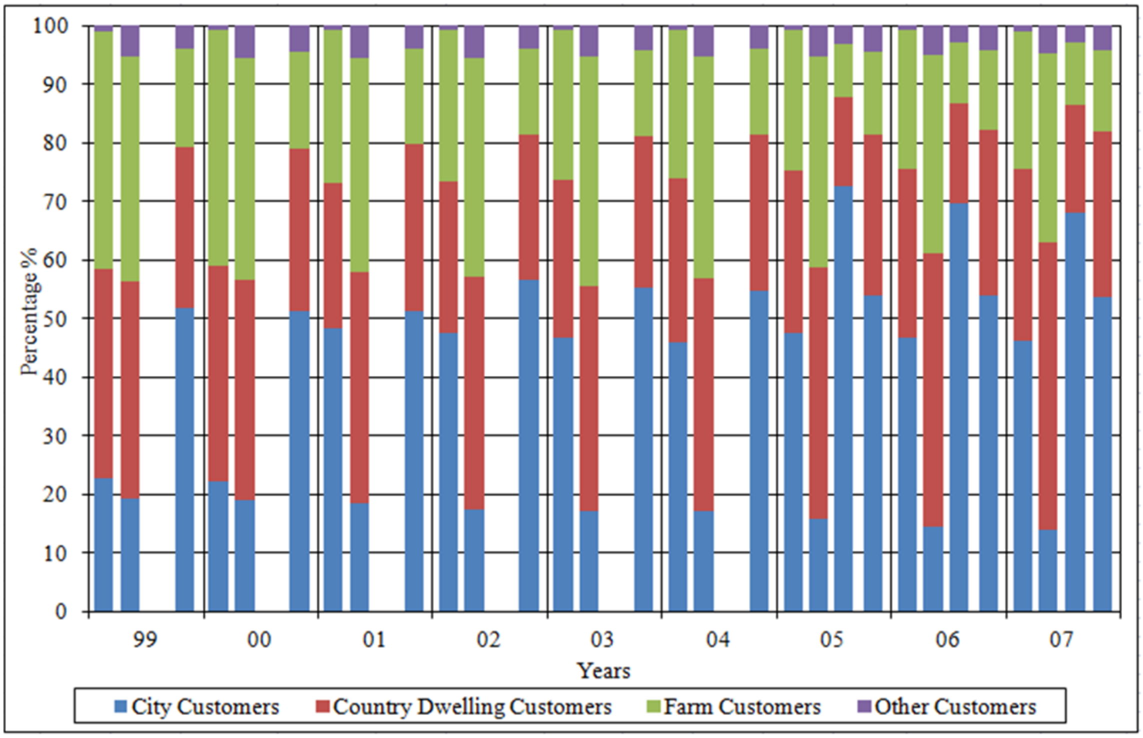

Figure 4.26. Percentage of Yearly Water Meter Customers

The daily water demand per customer is a key consumption characteristic because it can be used to predict the yearly water demand of a customer classification. Figures 4.27, 4.28, and 4.29 compare the daily water demand of the customer classifications for the four systems and Figure 4.30 summarizes the system-wide daily water demand.

The daily water demand trends for the city customers in each system are illustrated in Figure 4.27. City customers served both as bulk city and individual city customers are represented in the daily water demand trends. The daily water demand per customer for the city classification was fairly similar between each rural water system but TM RWS city customers consumed approximately 50 gpd less than those in the other three systems. Over the 9 years of data represented in Figure 4.27, the average daily water demand for Big Sioux, Clay, and Mid-Dakota was 220 gallons per customer but when TM was included the average daily water demand dropped to 202 gallons per customer. One factor that may have contributed to the lower demand in the TM RWS is that the average rainfall in the TM service area was approximately 4 inches greater than that in the other three systems' service areas.

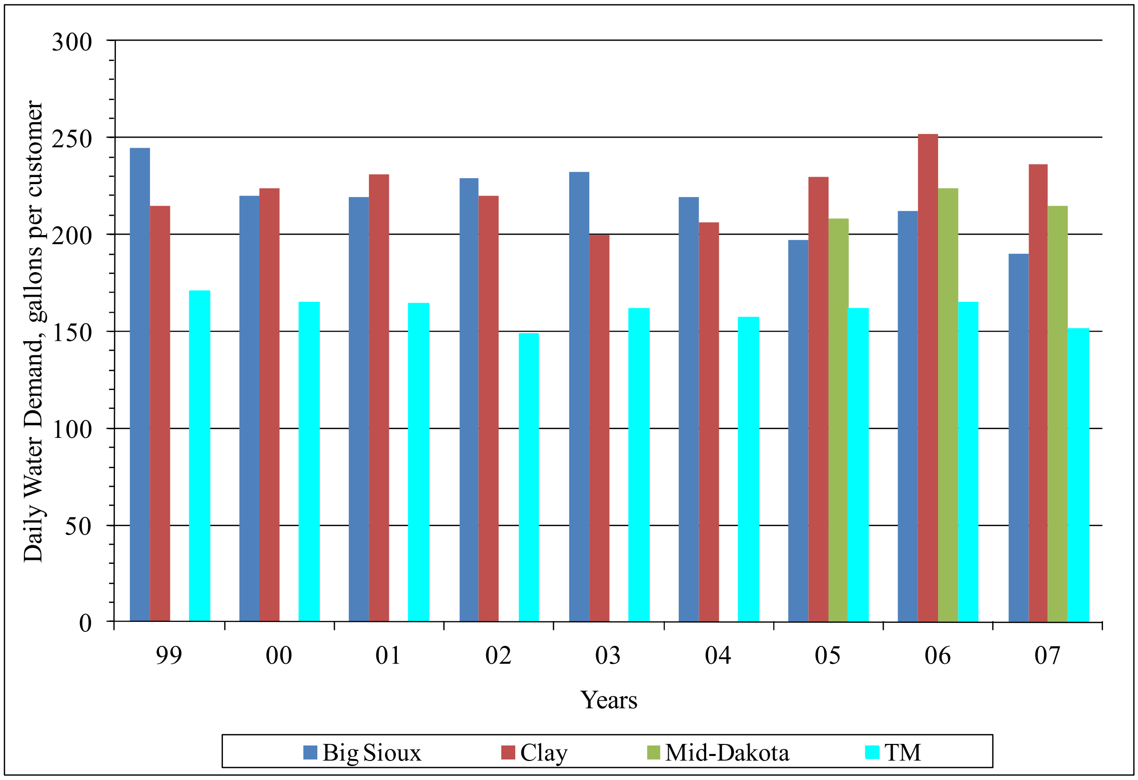

Figure 4.27. Daily Water Demand per Customer for the City Classifications

The range of the daily water demand for Big Sioux, Clay, and Mid-Dakota city customer demand was 190 gallons per customer to 252 gallons per customer. Due to the geographical diversity of these four systems, it would be fair to expect the daily water demand for customers in cities served by rural water systems across South Dakota to exhibit a similar range of consumption.

The daily water demands for country dwelling customers including cabin customers are shown in Figure 4.28. The daily water demand of the TM, Big Sioux and Clay country dwelling customers averaged 151 gallons per customer and ranged from 104 gallons per customer to 182 gallons per customer from 1999 through 2005. The customer demand did not seem to vary substantially from year to year. However, in 2006 and 2007, the average daily demand of Clay country dwelling customers increased substantially into the range of daily demand of the Mid-Dakota country dwelling customers. In 2006 and 2007, the Mid-Dakota and Clay RWS country dwelling customers' average daily water demand was 278 gallons per customer and ranged from 238 to 335 gallons per customer. Although there are variances between systems, the country dwelling demands were largely less than the city customer demands (150 to 252 gpd). With the exception of the Clay water demand trend in 2006 and 2007, the demands of the country dwelling customers were consistent from year to year.

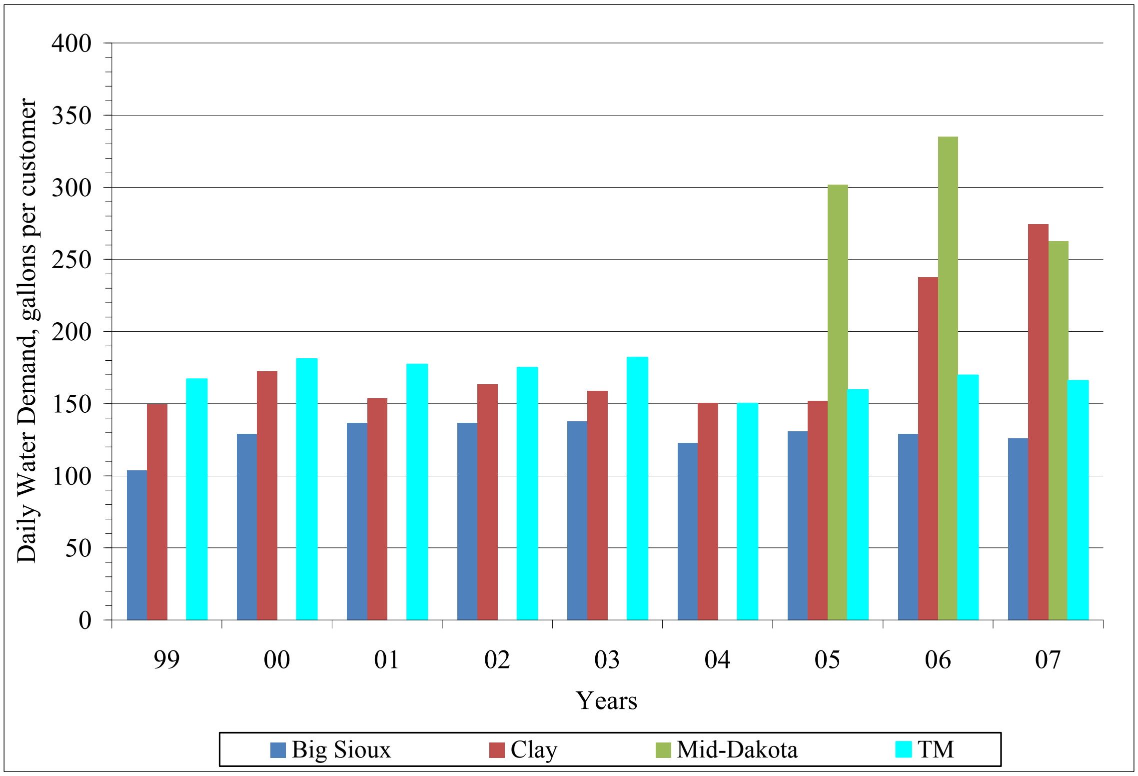

Figure 4.28. Daily Water Demand per Customer for the Country Dwelling Classifications

The daily water demands for the farm customers are illustrated in Figure 4.29. When the farm demands of the four systems are compared, the daily water demands exhibited a range of 100 gpd or more from 1999 to 2005, but the range narrowed during 2006 and 2007. During 2006 through 2007, the average daily water demand (of the four systems) was 455 gallons per customer and the range was 392 to 565 gallons per customer. These data indicate the farm customer daily demand could likely be two times the city customer or the country dwelling customer demand.

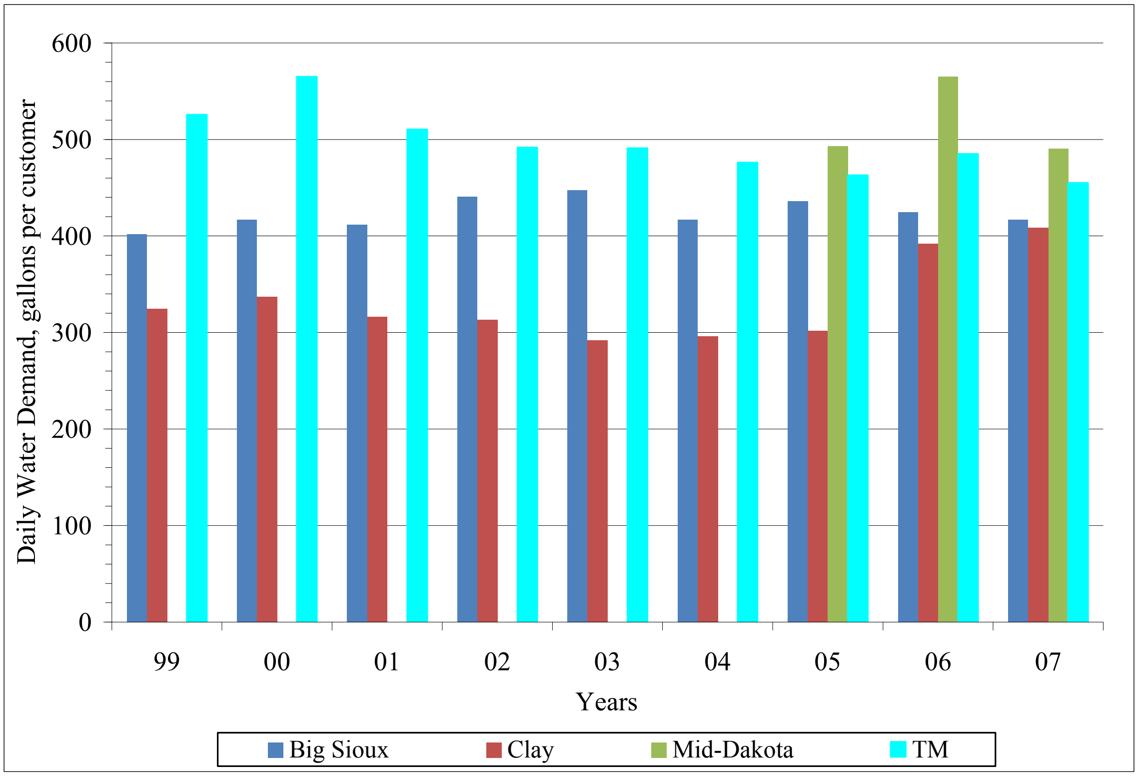

Figure 4.29. Daily Water Demand per Customer for the Farm Classifications

The system-wide daily water demands of the four rural water systems are plotted in Figure 4.30. The system-wide daily water demand was calculated by the use of a weighted average (Equation 4.3), which took into consideration the number of customers for each of the three customer classifications.

$$\text{Weighted Average} = [(\text{City customers} \times \text{gpd}) + (\text{Country dwelling customers} \times \text{gpd}) + (\text{Farm customers} \times \text{gpd})] \div (\text{City customers} + \text{Country dwelling customers} + \text{Farm customers}) \qquad \text{(Eq. 4.3)}$$

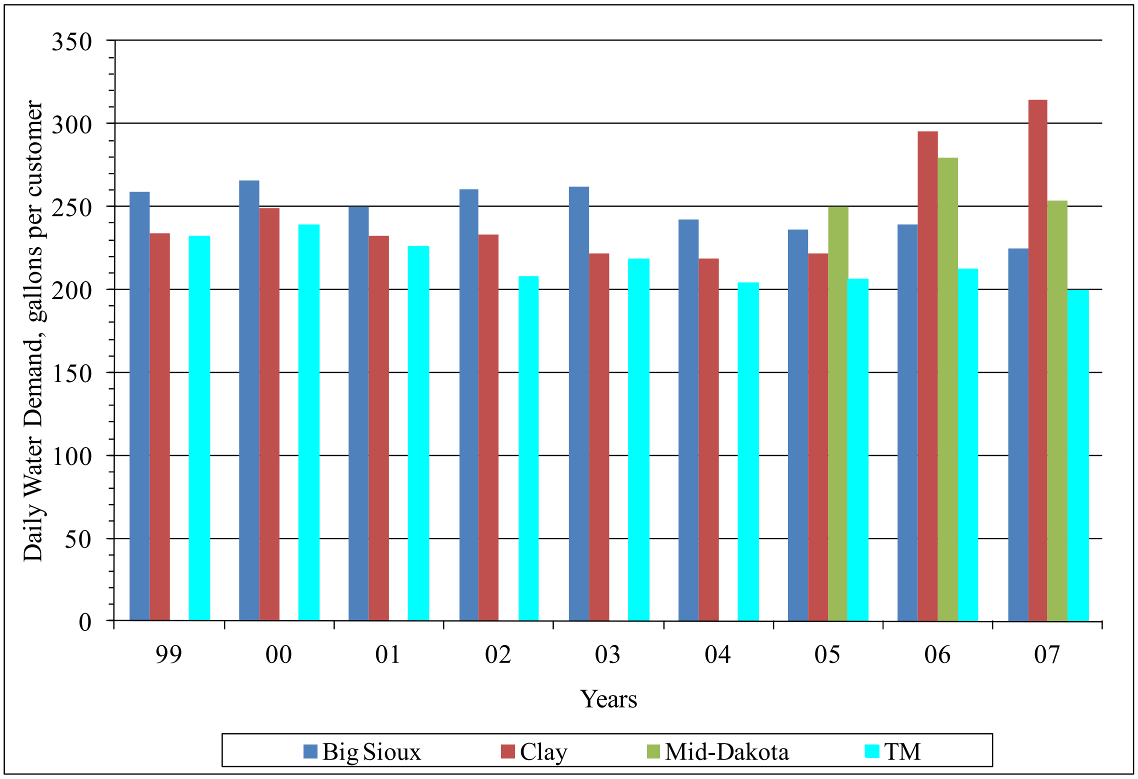

Figure 4.30. System-wide Daily Water Demand per Customer

As expected each rural water system's overall daily water demand resembled that of its largest customer classification. For example:

- Big Sioux's largest customer classification was the city classification which made up roughly 47% of the total number of customers. However, the country dwelling and farm classifications each made up 27% and 25% of the total customers, respectfully. Since 74 % of the customer data base was country dwelling and city customers, the system-wide daily water demand was dominated by the daily demand of those classifications and averaged 249 gallons per day per customer.
- Clay's largest customer classifications were both the country dwelling and farm classifications which each made up roughly 38% of the total number of customers until 2005 when the country dwelling customers increased faster than the farm customers. In 2007 the country dwelling customers made up about 49% of the total customers and the farm customers dropped to 32% of the total customers. Both the country dwelling customers and the farm customers started to consume more water per day than previously in 1999 to 2005. Clay's average daily water demand from 1999 to 2005 was 230 gallons per customer and from 2006 to 2007 was 305 gallons per customer.
- Mid-Dakota's largest customer classification was the city classification which made up roughly 70% of the total number of customers. The country dwelling classification made up about 17% of the total customers while the farm classification made up approximately 10% of the total customers. Since the city

classification had the majority of Mid-Dakota's customers, the system-wide daily water demand had a higher average water consumption of 261 gallons per customer.

- TM's largest customer classification was also the city classification which made up roughly 54% of the total number of customers. The country dwelling classification had roughly 27% of the total customers and farm classifications had about 15% of the total customer. Both the city customers and the country dwelling customers had about the same daily water demand, so TM had a smaller average daily water demand of 216 gallons per customer.

Knowledge of the peaking factors for each customer classification is equally important as knowing the daily water demand because the peaking factors help rural water systems determine the maximum month demand from a specific customer classification and establish the seasonal variations in demands. Figures 4.31, 4.32, and 4.33 are plots of the peaking factors for each customer classification of the four systems and Figure 4.34 is a plot of the system-wide peaking factors for each system.

The city customer classification's peaking factors (Figure 4.31) for each of the four rural water systems were all very similar to each other. The average peaking factor for the four rural water systems was 1.54 and the peaking factors ranged from 1.28 to 1.90.

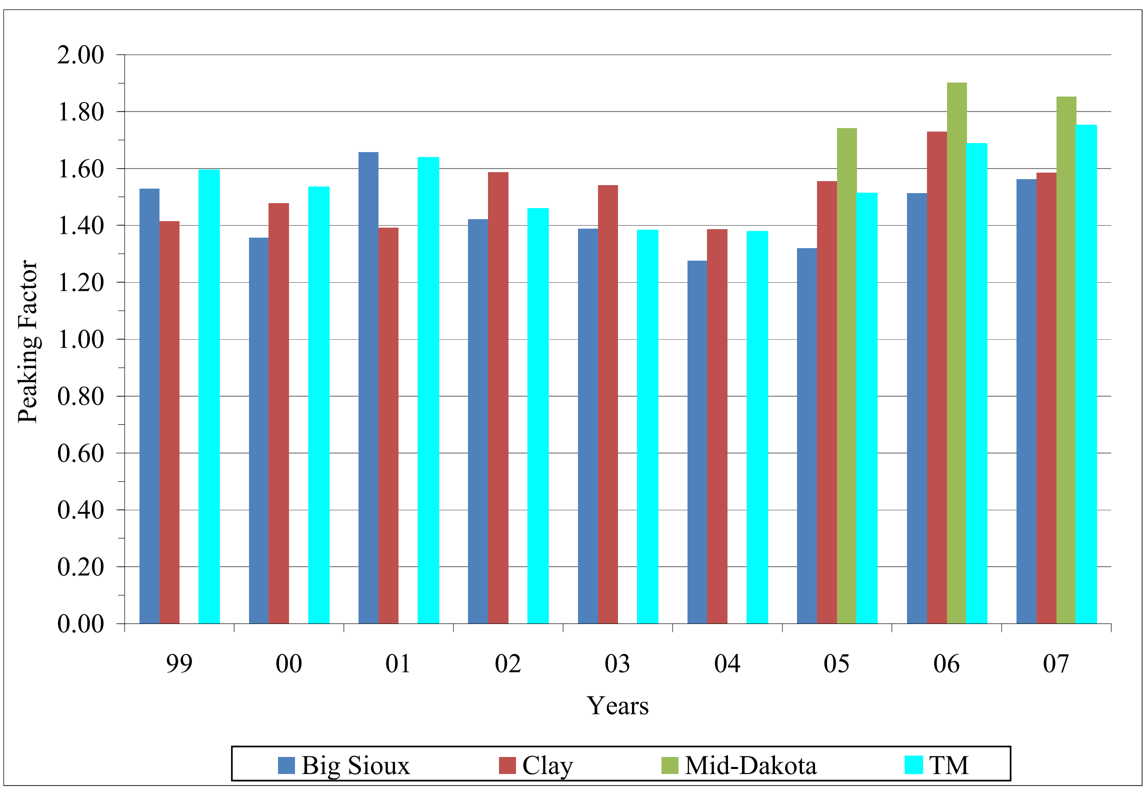

Figure 4.31. Monthly Peaking Factors for the City Classifications

The country dwelling customer classification's peaking factors are plotted in Figure 4.32. Peaking factors of Big Sioux and Mid-Dakota country dwellings were similar to each other, averaging 1.52 and ranging from 1.28 to 1.80. The average peaking factor for the Clay and TM country dwelling customers averaged 2.47 and ranged from 2.28 to 2.68. The reason for this cluster of upper and lower peaking factor ranges is not known. However, the value of the peaking factor can certainly have an impact on the peak month demand, especially if the rural water system had a large percentage of country dwelling customers.

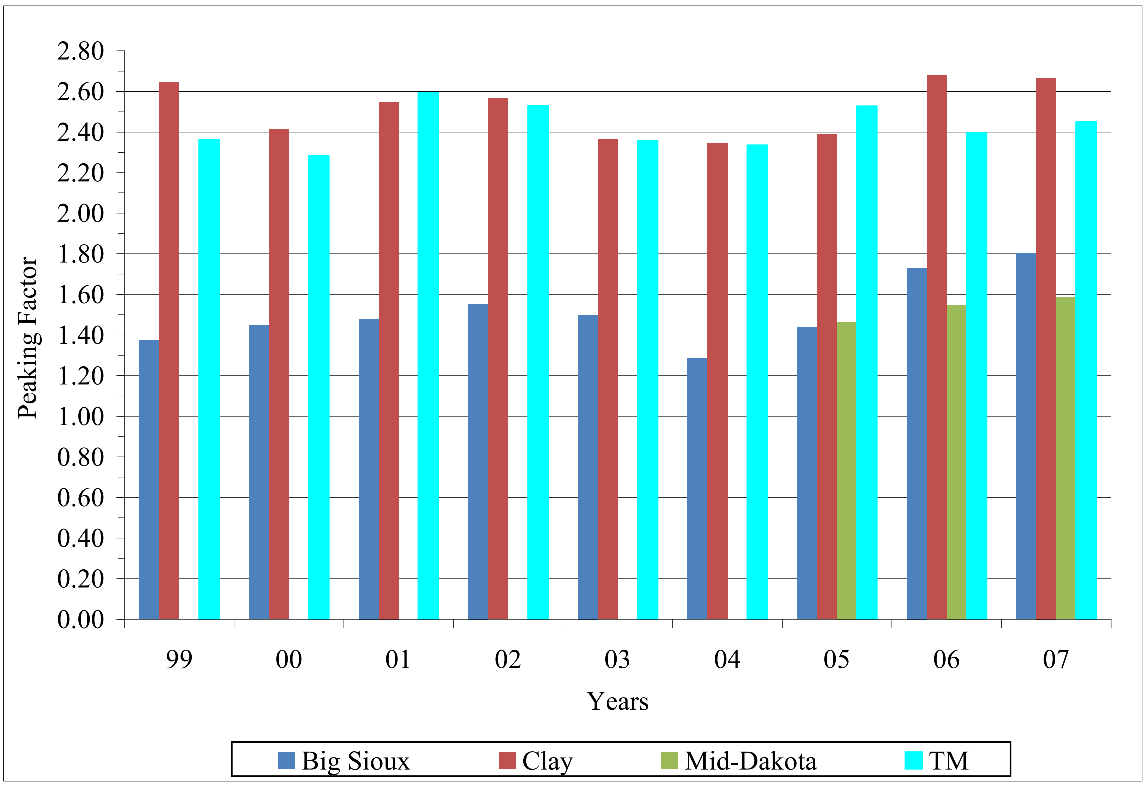

Figure 4.32. Monthly Peaking Factors for the Country Dwelling Classifications

The farm customer classification's peaking factors are plotted in Figure 4.33. Again, the Big Sioux and Mid-Dakota's monthly peaking factors were in a similar range, and the Clay and TM peaking factors were 96% higher. The average monthly peaking factor for Big Sioux and Mid-Dakota was 1.26 and ranged from 1.14 to 1.40, whereas average peaking factor for Clay was 2.70 (ranged from 2.55 to 2.95) and the average peaking factor for TM was 2.21 (ranged from 2.03 to 2.40).

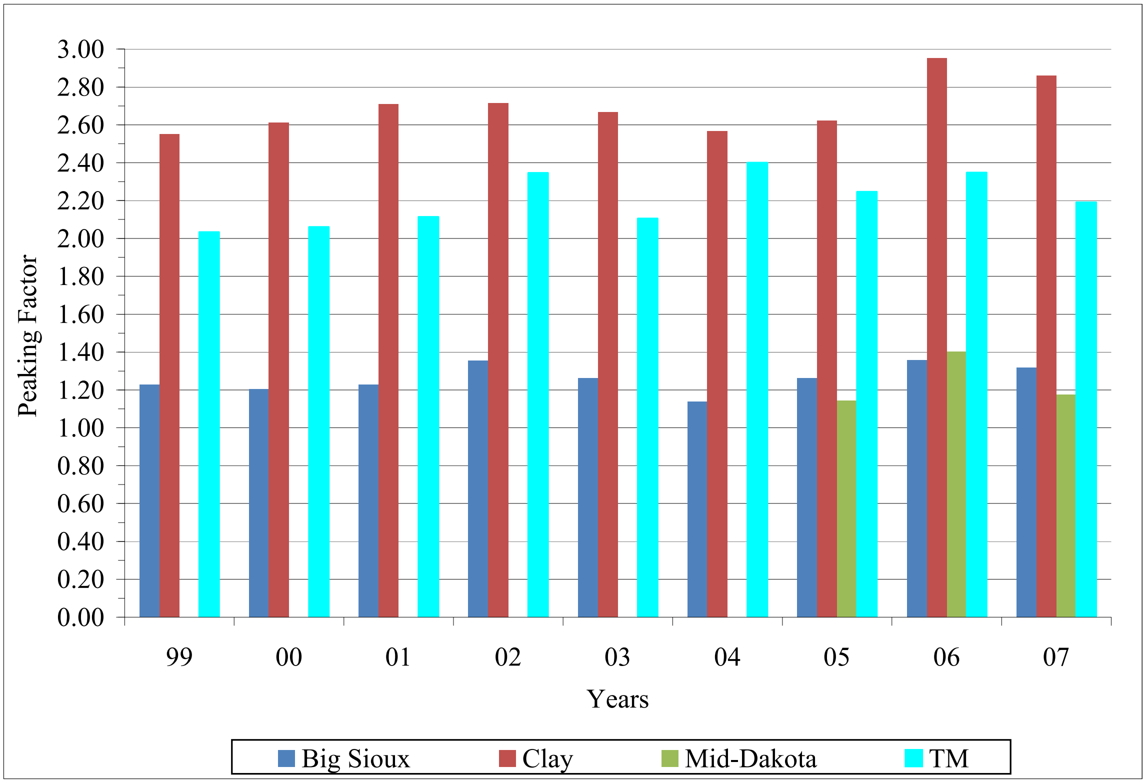

Figure 4.33. Monthly Peaking Factors for the Farm Classifications

The system-wide peaking factors were calculated by the use of the weighted average detailed in Equation 4.3, which took into consideration the amount of customers for each of the three customer classifications. As expected each rural water system's overall peaking factors resembled that of its largest customer classification. The impacts of customer classifications on the peaking factor are explained as follows.

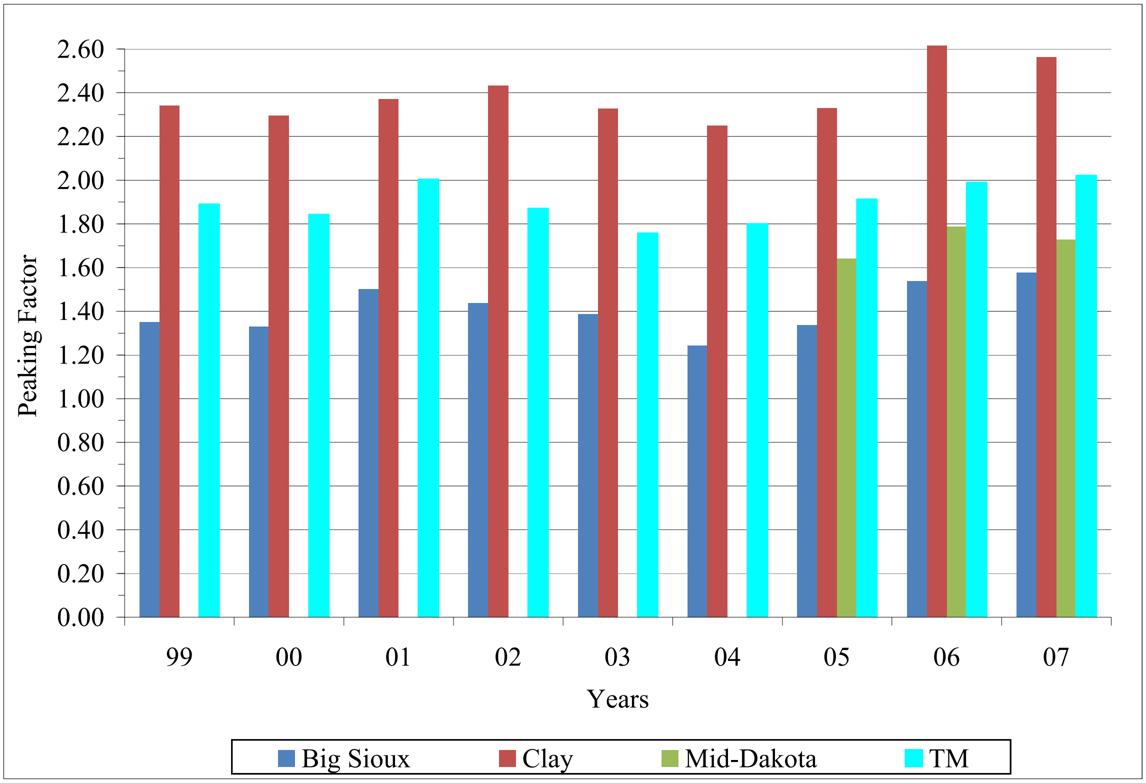

Figure 4.34. System-wide Monthly Peaking Factors

- Big Sioux's largest customer classification was the city classification which made up roughly 47% of the total number of customers. However, the country dwelling and farm classifications each made up about 25% of the total customers, which was why Big Sioux's system-wide peaking factor was the smallest with an average 1.41.
- Clay's largest customer classifications were both the country dwelling and farm classifications which each made up roughly 37% of the total number of customers until 2005. In 2007 the country dwelling customers made up about 49% of the total customers and the farm customers dropped to 32% of the total customers. Even though the percentage of farm customers dropped from 2005 to 2007, there was enough influence from the farm classification to cause Clay's system-wide peaking factors to increase from 2005 to 2006. Clay's average peaking factor from 1999 to 2005 was 2.34 and during 2006 to 2007 the average peaking factor had changed to 2.59.
- Mid-Dakota's distribution of customer classifications was 70% city customers, 17% country dwelling customers and 10% farm customers. Since the city classification had the majority of Mid-Dakota's customers, the system-wide peaking factor of 1.72 was nearly the same as the city classification peaking factor.

- TM's distribution of customer classifications was 54% city customers, 27% country dwelling customers and 14% farm customers. The largest customer classification was city classification which made up roughly 54% of the total number of customers. TM's average system-wide peaking factor was 1.90, well in the range of a city classification.

Rainfall is known to have an impact on water demand. Water demand is typically greater during times of low rainfall. The system-wide consumption per inch of precipitation was calculated by the use of a weighted average (Equation 4.3), which considered the amount of water consumed per inch of precipitation for each of the three customer classifications. The relationships between precipitation and water consumption for each customer classification of the four systems are presented in Appendix F. The general trends between water demand and precipitation are shown in Figure 4.35. The Big Sioux rural water system demand was affected the most by the amount of yearly precipitation which saw a 50% increase in daily water demand from 38.0 inches of precipitation to 21.0 inches of precipitation, whereas TM's demand was the least affected by the amount of yearly precipitation. TM only exhibited an increase in daily water demand of 30% from 35.4 inches of precipitation to 24.5 inches of precipitation. The average percent increase of the daily water demand per less inch of precipitation from all four rural water systems was 3.5%.

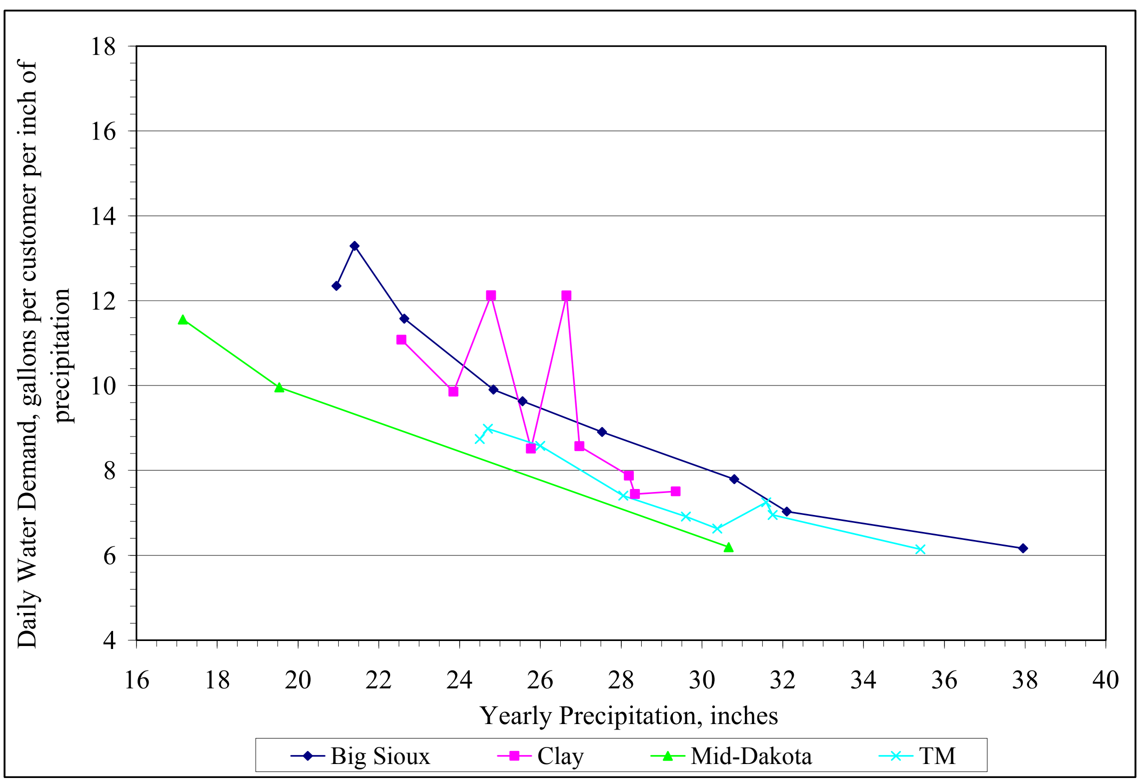

Figure 4.35. System-wide Daily Customer Water Demand for Yearly Precipitation

The coefficient of correlation (R) from tread lines for Big Sioux (0.95), Mid-Dakota (0.99), and TM (0.93) RWS depicted a strong correlation between the relationships of increased water consumption during years of low precipitation. Clay RWS was the only system that did not exhibit a coefficient of correlation near 1.0, due to 2006 (24.78 inches of precipitation) and 2007 (26.65 inches of precipitation) when the consumption of water defied the trend. Refer to Appendix F for the explanation of the trend reversal. Big Sioux, Mid-Dakota, and TM's best fit trend lines indicated that the increase in water consumption per less precipitation was not completely linear but rather water consumption per inch of precipitation leveled off as the yearly precipitation increased. The trend line slopes produced an approximation of the increase in water consumption (gallons per customer per inch of precipitation) per one inch reduction of yearly precipitation for each RWS, which could be used to estimate future system-wide water consumptions based on precipitation. Big Sioux had a trend line slope of 0.411, Clay was 0.580, Mid-Dakota was 0.379, and TM was 0.259.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results of this study demonstrated that South Dakota's regional water systems exhibited unique distribution characteristics and provided their customers with many positive social benefits. The water consumption characteristics examined in this study (i.e. daily water demand per customer, peaking factors, and affect of precipitation on customer's daily water demand) were conducted only for city, country dwelling, and farm customers. The following is a summary of the analysis performed on South Dakota's regional water systems.

- Low water meter densities and large distribution service areas were typical of regional water systems. The average water meter density for a regional water system was 1.5 water meters per mile with the exception of two systems that had meter densities of 457 water meters per mile and 34 water meters per mile. West River (west of the Missouri River in South Dakota) regional water systems averaged a lower meter density than East River systems by 1.7 water meters per mile. The average distribution service area of all regional water systems was 3,810 miles. When compared to East River RWS, West River systems displayed larger distribution service areas.
- All regional water systems except for one system had the treatment plant capacity sufficient to meet each system's 2006 yearly water demands. Six of the thirteen systems experienced peak day water demands of more than 75% of their treatment plant capacity. During the average day demands, the average RWS used 39.3% of its treatment plant capacity and 68.6% of the treatment plant capacity during peak day demands.
- The average percent of unaccounted-for water for the three regional water systems that had the highest percent of unaccounted-for water were 21.6%. This high percent of unaccounted-for water was not typical of South Dakota's RWS, as the statewide average for unaccounted-for water was 11.1%. Six out of the seventeen systems experienced less than 6% unaccounted-for water, with one system at 3.1% unaccounted-for water. The regional water systems could reduce their percent of unaccounted-for water by repairing or replacing aging infrastructure (i.e. water mains & water meters).
- On average, regional water systems that utilized surface water as their source water supply produced higher quality drinking water (i.e. lower concentrations of TDS, alkalinity, sulfate, etc.) than systems that utilized ground water as a source water supply. Thus, communities served by surface water treatment systems displayed larger improvements in drinking water quality than the communities served by ground water treatment systems. The average city person served by a surface water treatment system during 2006 saved a total of $13.61 on softening

salt and reduced the amount of total dissolved solids from entering the water environment by 363 pounds. That was compared to a savings of $11.21 on softening salt and a reduction of 243 pounds of total dissolved solids for the average city person served by a ground water treatment system. Statewide, the average city family (2.5 people) saved $31.91 on softening salt and prevented 800 pounds of total dissolved solids from entering the environment.

- Increased livestock health and production was an additional benefit to farm customers that switched to regional water systems. From beef cattle to poultry the health and production of livestock increased when livestock drank water with lower amounts of TDS, sulfate, and sodium. A testimonial from a dairy farm on one of South Dakota's RWS told how the milk yields and dairy cattle health had increased when the dairy farm switched to rural water.
- Cities served as bulk customers had peaking factors of about 12% less than the cities that were served as individual customers. Average peaking factors for the bulk city customers and the individual city customers were 1.63 and 1.83, respectfully. Daily water demand of bulk city customers was 30 gallons per person and 74 gallons per customer more than individually served city customers. On average bulk city customers consumed 93 gallons per person per day and averaged 204 gallons per customer per day compared to the average daily water demand per person of 73 gallons for individually served city customers and an average daily water demand per customer of 150 gallons. Ninety-five percent of all the city customers served by Big Sioux, Clay, Mid-Dakota, and TM RWS were bulk city customers which indicated that regional water systems would normally experience daily water demands per city customer of 204 gallons.
- Typically cities with smaller populations exhibited slightly higher seasonal water demands than cities with larger populations. This was illustrated by the average peaking factor of 1.88 for cities with fewer than 100 people, 1.57 for cities with 100 to 500 people, and 1.48 for cities with greater than 500 people. The summer months of May through September had the highest monthly water demands out of the whole year. It was also discovered that cities with smaller populations displayed considerably lower daily water demands per customer than cities with larger populations. From 2005 to 2007 the average daily water demand per customer for cities with fewer than 100 people was 113 gallons, while the average daily water demand for cities with 100 to 500 people was 195 gallons and for cities with greater than 500 people, the average day demand was 257 gallons.
- A trend of increasing country dwelling customers and country dwelling yearly water consumption was discovered for Big Sioux, Clay, Mid-Dakota, and TM RWS from the years of 1999 through 2007. Clay rural water displayed rapid increases in both country dwelling customers and water demand from 2005 through 2007. Country dwelling customers had two distinct ranges of daily water demands. One range was made-up of lower consumption values (Big Sioux & TM) and the other range made-up of higher consumption values (Clay & Mid-Dakota). The daily water demand for the lower range country dwelling customers ranged from 104 to 182 gallons per customer and averaged 151 gallons per

customer. The higher range country dwelling customers consumed 51% more water per day than the lower range customers for 2006 and 2007 with an average of 278 gallons per customer per day. The same phenomenon was true with the country dwelling peaking factors. The lower range (Big Sioux and Mid-Dakota) customer's peaking factors averaged 1.52 and ranged from 1.28 to 1.80 whereas the higher range (Clay and TM) customer's peaking factors were 63% larger. The average peaking factor for the higher range country dwelling customers was 2.47 and ranged from 2.28 to 2.68.

- The farm customer classification had the highest daily water demand per customer of all three classifications and exhibited similar ranges of peaking factors as the country dwelling customers. The average daily water demand per farm customer during 2006 and 2007 was 455 gallons, which was more than double that of the city and lower ranged country dwelling customer's daily water demands. The farm customer's peaking factors were represented in three ranges, low, middle, and high ranges. The low range peaking factors ranged from 1.14 to 1.40 and averaged 1.26. While the middle range peaking factors averaged 2.21 and the high range peaking factors averaged 2.70, which was the highest average peaking factor of any customer classification.
- Section 4.3.5 illustrated that the annual amount of precipitation affected the overall daily water demand of the customer classifications. Daily water demands of Clay and Mid-Dakota RWS were affected the most by the amount of yearly precipitation. Clay's customers displayed a 4.8% reduction in daily water demand per additional inch of yearly precipitation, and Mid-Dakota's customers displayed a 3.4% reduction in daily water demand. Big Sioux and TM's customers also experienced sizable reduction in daily water demand per additional inch of precipitation. The average reduction in daily water demand per inch of precipitation for all four regional water systems was 3.5%.
- Peaking factors of the four regional water systems ranged from 1.19 to 2.20 and averaged 1.80. The average peaking factor of 1.80 indicated that all four systems experienced relatively substantial seasonal water demands with the higher demands in the summer months of May through September. The high system-wide peaking factors were heavily influenced by the farm and country dwelling customers since the majority of metered water sales came from those customers. Both farm and country dwelling customer classifications exhibited higher peaking factors.

5.2 Recommendations

After the study was conducted it was apparent that several additional data collections and additional analysis would have improved the results of the study. The recommendations for the additional data collections and analysis are listed below.

- Gather additional physical characteristics data from the regional water systems that did not provide complete surveys and additional data on the age of system's infrastructure. Full survey results from each system would provide increased accuracy of the results presented in this study. The additional infrastructure data would allow for in-depth analysis to correlate infrastructure age to percent of unaccounted-for water and overall system capacity.

- Chapter 2 of the report addressed the fact that high quality drinking water improved livestock health and production. Additional testimonials of local case studies would allow for the examination of specific improvements in livestock health and production for farms connected to South Dakota RWS. Further analysis should be conducted to examine the relationship between the use of South Dakota RWS water to increases in monetary value from improved livestock health and production.
- Collect individual monthly customer water consumption data from Big Sioux rural water system to enable an apples to apples comparison with Clay, Mid-Dakota, and TM's monthly customer water consumption data.
- Collect Mid-Dakota's monthly customer water consumption data from 1999 to 2004. The additional data would improve trending results and comparisons of consumption data between Big Sioux, Clay, and TM. The data would also improve the analysis results of the cities served as bulk and individual customers, since Mid-Dakota served a large amount of the cities studied.
- Additional analysis should be conducted to compare customer and system characteristics between East River and West River regional water systems. The analysis should determine the similarities and differences of customer and system characteristics in reference to the differing terrain and population densities.
- Further analysis should be conducted to determine the effects of precipitation on South Dakota's regional water systems. The analysis should establish changes in percent of unaccounted-for water and peaking factors for customer classification with relationships to inches of precipitation. The analysis should also compare each regional water system's treatment capacity and the ability to meet customer water demands during low precipitation years.

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APPENDIX A:

Survey of South Dakota's Regional Water Systems' Physical Characteristics

System Name:

Contact:

E-mail:

Phone:

Customer Characteristics and Service Area

Counties Served (incl. partial counties):

Towns Served Bulk (include year service began):

Towns Served Individually (include year service began):

Towns Served Standby:

Other Significant Customers: (include industries, housing developments or districts, other rural water systems)

Customers for who contract operations are provided:

Total Hookups (all metered customers including the above categories):

Water Sources and Characteristics

Surface Water Source(s)

Source Name	Year Placed in Service	Permitted Withdrawal (MG)	2006 Total Withdrawal (MG)

Ground Water Source(s)

Well (name/number)	Year Placed in Service	Aquifer	Depth (ft)	2006 Annual Production (MG)

Treatment Facility Characteristics and Treated Water Quality

(Please submit a treatment process schematic diagram for each facility)

Facility Name	Year Placed in Service	Water Source(s) (from Source List)	Current Production Capacity, MGD

Treated Water Quality (mg/L, alkalinity in mg/L as $CaCO_3$, pH in pH units):

Cations

Facility Name	Date	Calcium	Magnesium	Iron	Manganese	Sodium

Anions

Facility Name	Date	Alkalinity	Sulfate	Chloride	Nitrate	pH	TDS

Water Pumping/Distribution System Characteristics

High Service (treated water) Pump Characteristics:

Plant Name	Typ. Discharge Pressure (psi)	Max. Flow (gpm)	Number of Pumps	Constant Speed or VFD?

Distribution System Pumping (Booster Stations):

Booster Name	Typ. Discharge Pressure (psi)	Max. Flow (gpm)	Number of Pumps	Constant Speed or VFD?

System Storage Reservoirs and Tanks:
(Type = Clearwell, Elevated Tank, Standpipe, Ground Tank)
(Tank Material = Steel, Glass-lined, Concrete)

Tank Name	Type	Material	Capacity (gals)	Size or Diameter (ft)	Full Water Height (ft above base)

Pipe Characteristics:
(include mains and pipe up to customer meters)
(categorize by size – Include 2-inch or smaller as one category)

Diameter (inches)	Material (Steel, Ductile, PVC, Polyethylene)	Length (miles)

APPENDIX B:

2006 Water Production & Sales Data for South Dakota's Regional Water Systems

Table B.1. 2006 Water Production and Sales Survey of Regional Water Systems

Regional Water System Number	
Category	Annual Volume
Water pumped to the distribution system	gallons
Metered Sales	
- Metered sales to bulk communities	gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	gallons
Total Metered Sales	gallons
2006 Maximum Day Demand	gallons per day

System Number 01	
Category	Annual Volume
Water pumped to the distribution system	372,436,000 gallons
Metered Sales	
- Metered sales to bulk communities	82,334,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	266,527,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	2,002,000 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	791,000 gallons
Total Metered Sales	351,654,000 gallons
2006 Maximum Day Demand	1,500,000 gallons per day

System Number 02	
Category	Annual Volume
Water pumped to the distribution system	447,116,000 gallons
Metered Sales	
- Metered sales to bulk communities	gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	gallons
Total Metered Sales	367,825,000 gallons
2006 Maximum Day Demand	gallons per day

System Number 04	
Category	Annual Volume
Water pumped to the distribution system	687,719,000 gallons
Metered Sales	
- Metered sales to cities, towns and communities (include individually served and bulk)	142,649,000 gallons
- Metered sales to farms and farmsteads (including pasture taps, production farms, and no-production farmsteads)	179,441,000 gallons
- Other metered sales	278,350,000 gallons
Total Metered Sales	600,440,000 gallons
2006 Maximum Day Demand	1,964,000 gallons per day

System Number 05	
Category	Annual Volume
Water pumped to the distribution system	470,240,000 gallons
Metered Sales	
- Metered sales to bulk communities	5,780,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	251,290,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	0 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	114,101 gallons
Total Metered Sales	371,171,000 gallons
2006 Maximum Day Demand	1,288,329 gallons per day

System Number 07	
Category	Annual Volume
Water pumped to the distribution system	293,816,340 gallons
Metered Sales	
- Metered sales to bulk communities	83,040,700 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	159,543,660 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	6,853,300 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	0 gallons
Total Metered Sales	249,437,660 gallons
2006 Maximum Day Demand	1,300,000 gallons per day

System Number 08	
Category	Annual Volume
Water pumped to the distribution system	252,140,000 gallons
Metered Sales	
- Metered sales to bulk communities	29,202,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	84,798,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	6,630,000 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	110,478,000 gallons
Total Metered Sales	231,108,000 gallons
2006 Maximum Day Demand	1,150,000 gallons per day

System Number 09	
Category	Annual Volume
Water pumped to the distribution system	146,070,000 gallons
Metered Sales	
- Metered sales to bulk communities	17,889,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	70,235,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	7,308,000 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	42,315,000 gallons
Total Metered Sales	137,747,000 gallons
2006 Maximum Day Demand	gallons per day

System Number 12	
Category	Annual Volume
Water pumped to the distribution system	272,000,000 gallons
Metered Sales	
- Metered sales to bulk communities	11,988,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	59,058,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	7,523,000 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	129,834,000 gallons
Total Metered Sales	208,403,000 gallons
2006 Maximum Day Demand	1,011,000 gallons per day

System Number 13	
Category	Annual Volume
Water pumped to the distribution system	184,557,000 gallons
Metered Sales	
- Metered sales to bulk communities	84,451,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	86,424,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	2,111,000 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	1,958,000 gallons
Total Metered Sales	174,944,000 gallons
2006 Maximum Day Demand	gallons per day

System Number 14	
Category	Annual Volume
Water pumped to the distribution system	763,277,000 gallons
Metered Sales	
- Metered sales to cities, towns and communities (include individually served and bulk)	126,636,000 gallons
- Metered sales to farms and farmsteads (including pasture taps, production farms, and no-production farmsteads)	537,175,000 gallons
- Other metered sales	gallons
Total Metered Sales	663,811,000 gallons
2006 Maximum Day Demand	3,600,000 gallons per day

System Number 15	
Category	Annual Volume
Water pumped to the distribution system	327,834,000 gallons
Metered Sales	
- Metered sales to bulk communities	145,625,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	8,847,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	0 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	145,254,000 gallons
Total Metered Sales	299,726,000 gallons
2006 Maximum Day Demand	1,690,000 gallons per day

System Number 17	
Category	Annual Volume
Water pumped to the distribution system	1,612,150,000 gallons
Metered Sales	
- Metered sales to bulk communities	960,962,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	178,552,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	0 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	377,824,000 gallons
Total Metered Sales	1,517,338,000 gallons
2006 Maximum Day Demand	8,858,000 gallons per day

System Number 18	
Category	Annual Volume
Water pumped to the distribution system	845,277,000 gallons
Metered Sales	
- Metered sales to bulk communities	290,222,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	204,819,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	0 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	250,333,000 gallons
Total Metered Sales	745,374,000 gallons
2006 Maximum Day Demand	4,500,000 gallons per day

System Number 20	
Category	Annual Volume
Water pumped to the distribution system	85,605,000 gallons
Metered Sales	
- Metered sales to bulk communities	58,318,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	27,287,000 gallons
Total Metered Sales	85,605,000 gallons
2006 Maximum Day Demand	gallons per day

System Number 21	
Category	Annual Volume
Water pumped to the distribution system	1,301,000,000 gallons
Metered Sales	
- Metered sales to bulk communities	561,376,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	573,725,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	21,719,000 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	27,000,000 gallons
Total Metered Sales	1,157,000,000 gallons
2006 Maximum Day Demand	6,391,000 gallons per day

System Number 24	
Category	Annual Volume
Water pumped to the distribution system	391,880,500 gallons
Metered Sales	
- Metered sales to bulk communities	37,563,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	275,077,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	0 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	0 gallons
Total Metered Sales	312,640,000 gallons
2006 Maximum Day Demand	1,000,000 gallons per day

System Number 26	
Category	Annual Volume
Water pumped to the distribution system	283,000,000 gallons
Metered Sales	
- Metered sales to bulk communities	69,983,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	180,926,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	5,415,000 gallons
Total Metered Sales	256,324,000 gallons
2006 Maximum Day Demand	1,400,000 gallons per day

System Number 27	
Category	Annual Volume
Water pumped to the distribution system	320,075,000 gallons
Metered Sales	
- Metered sales to bulk communities	gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	gallons
Total Metered Sales	309,377,000 gallons
2006 Maximum Day Demand	1,331,000 gallons per day

System Number 28	
Category	Annual Volume
Water pumped to the distribution system	511,857,500 gallons
Metered Sales	
- Metered sales to bulk communities	70,423,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	359,278,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	0 gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	16,532,000 gallons
Total Metered Sales	446,223,000 gallons
2006 Maximum Day Demand	2,180,000 gallons per day

System Number 30	
Category	Annual Volume
Water pumped to the distribution system	624,937,000 gallons
Metered Sales	
- Metered sales to bulk communities	177,041,000 gallons
- Metered sales to farms (including pasture taps, production farms, etc.)	409,345,000 gallons
- Metered sales to non-farm industries (ethanol plants, etc.)	gallons
- Metered sales to individual customers other than the above categories (individual customers in communities, country dwellings, non-farm homes, etc.)	19,173,000 gallons
Total Metered Sales	605,559,000 gallons
2006 Maximum Day Demand	3,100,000 gallons per day

APPENDIX C:

Analysis of Big Sioux, Clay, Mid-Dakota, & TM's Water Demand Trends from 1999 Through 2007

	Big Sioux ‘s Customer Water Demands from 1999					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	22,539,000	1,878,250	1.43	570	258	108*
City of Egan	13,737,000	1,144,750	1.87	267	120	141*
City of Flandreau						
Town of Trent						
City of Wentworth	5,921,000	493,417	1.28	187	90	87*
Country Dwellings	11,053,000	921,083	1.26		163	186
Monthly Cabins	11,566,000	963,833	1.49		275	115
Annual Cabins	5,517,000	459,750	11.44		299	50
Farms	121,561,000	10,130,083	1.23		804	415
Pasture Taps	1,830,000	152,500	12.00		37	133
Other Customers	7,418,000	209,306	2.28		19	4,367

*Represents gallons per person-day, only for cities with population data

	Big Sioux 's Customer Water Demands from 2000					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	23,039,000	1,919,917	1.40	570	258	111*
City of Egan	9,917,000	826,417	1.19	267	120	102*
City of Flandreau						
Town of Trent						
City of Wentworth	6,124,000	510,333	1.49	187	90	90*
Country Dwellings	12,458,000	1,038,167	1.39		174	196
Monthly Cabins	13,601,000	1,133,417	1.51		292	127
Annual Cabins	7,473,000	622,750	11.82		307	65
Farms	126,787,000	10,565,583	1.21		803	431
Pasture Taps	1,877,000	156,417	11.94		39	129
Other Customers	7,314,000	203,167	2.19		19	3,245

*Represents gallons per person-day, only for cities with population data

Big Sioux ‘s Customer Water Demands from 2001

	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	24,215,000	2,017,917	1.56	572	259	116*
City of Egan	7,260,000	660,000	1.58	268	120	74*
City of Flandreau	102,038,000	8,503,167	1.40	2,376	1,090	118*
Town of Trent						
City of Wentworth	6,410,000	534,167	2.08	185	89	95*
Country Dwellings	13,236,000	1,103,000	1.47		179	202
Monthly Cabins	14,152,000	1,179,333	1.50		304	127
Annual Cabins	9,645,000	803,750	11.60		315	82
Farms	123,911,000	10,325,917	1.23		809	420
Pasture Taps	2,864,000	238,667	11.21		35	220
Other Customers	44,948,000	2,525,083	1.56		21	88,587

*Represents gallons per person-day, only for cities with population data

	Big Sioux 's Customer Water Demands from 2002					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	23,889,000	1,990,750	1.67	565	256	116*
City of Egan	8,831,000	735,917	1.18	264	119	92*
City of Flandreau	102,963,000	8,580,250	1.55	2,341	1,074	120*
Town of Trent						
City of Wentworth	6,213,000	517,750	1.29	184	88	93*
Country Dwellings	14,069,000	1,172,417	1.42		190	203
Monthly Cabins	16,066,000	1,338,833	1.69		319	138
Annual Cabins	8,200,000	683,333	11.68		322	71
Farms	132,033,000	11,002,750	1.36		799	453
Pasture Taps	2,413,000	201,083	12.00		37	181
Other Customers	202,239,000	4,213,313	1.32		21	514,124

*Represents gallons per person-day, only for cities with population data

	Big Sioux ‘s Customer Water Demands from 2003					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	23,606,000	1,967,167	1.49	559	253	116*
City of Egan	9,082,000	756,833	1.53	261	117	95*
City of Flandreau	108,452,000	9,037,667	1.40	2,319	1,064	128*
Town of Trent						
City of Wentworth	5,676,000	473,000	1.14	180	86	86*
Country Dwellings	15,077,000	1,256,417	1.35		204	203
Monthly Cabins	16,428,000	1,340,000	1.65		333	138
Annual Cabins	8,537,000	713,417	10.48		342	74
Farms	133,715,000	11,142,917	1.26		800	458
Pasture Taps	2,873,000	239,417	11.53		35	221
Other Customers	209,813,000	4,371,104	1.33		24	537,395

*Represents gallons per person-day, only for cities with population data

	Big Sioux 's Customer Water Demands from 2004					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	24,125,000	2,010,417	1.67	559	253	118*
City of Egan	8,488,000	707,333	1.21	260	117	89*
City of Flandreau	96,282,000	8,023,500	1.11	2,313	1,061	114*
Town of Trent						
City of Wentworth	5,241,000	436,750	1.11	178	85	81*
Country Dwellings	15,313,000	1,276,083	1.20		218	192
Monthly Cabins	15,054,000	1,254,500	1.37		351	117
Annual Cabins	7,841,000	653,417	9.52		348	61
Farms	124,363,000	10,363,583	1.14		799	425
Pasture Taps	2,757,000	229,750	12.00		34	218
Other Customers	244,555,000	5,094,896	1.21		27	619,696

*Represents gallons per person-day, only for cities with population data

Big Sioux ‘s Customer Water Demands from 2005

	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	23,497,000	1,958,083	1.56	557	252	116*
City of Egan	9,268,000	772,333	1.22	261	117	97*
City of Flandreau	102,952,000	8,579,333	1.31	2,321	1,065	122*
Town of Trent	2,568,000	428,000	1.24	250	109	28*
City of Wentworth	5,811,000	484,250	1.27	179	86	89*
Country Dwellings	17,376,000	1,448,000	1.28		234	203
Monthly Cabins	16,101,000	1,341,750	1.60		378	117
Annual Cabins	8,926,000	743,833	10.48		336	72
Farms	128,047,000	10,670,583	1.26		795	442
Pasture Taps	2,710,000	225,833	11.98		27	270
Other Customers	263,862,000	5,497,125	1.21		29	651,573

*Represents gallons per person-day, only for cities with population data

	Big Sioux 's Customer Water Demands from 2006					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	19,040,000	1,586,667	1.49	555	251	94*
City of Egan	11,366,000	947,167	1.35	259	116	120*
City of Flandreau	105,935,000	8,827,917	1.48	2,314	1,062	125*
Town of Trent	5,129,000	427,417	1.82	248	108	57*
City of Wentworth	5,697,000	474,750	1.42	180	86	87*
Country Dwellings	18,184,000	1,515,333	1.70		255	195
Monthly Cabins	17,106,000	1,503,333	1.76		416	119
Annual Cabins	11,892,000	708,500	4.93		323	72
Farms	124,840,000	10,403,333	1.36		796	430
Pasture Taps	2,499,000	208,250	5.28		25	274
Other Customers	264,922,000	5,519,208	1.28		31	644,428

*Represents gallons per person-day, only for cities with population data

Big Sioux 's Customer Water Demands from 2007

	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Colman	20,438,000	1,703,167	1.53	555	251	101*
City of Egan	6,089,000	507,417	1.46	259	116	64*
City of Flandreau	105,798,000	8,816,500	1.51	2,314	1,062	125*
Town of Trent	3,566,000	297,167	1.91	248	108	39*
City of Wentworth	6,969,000	580,750	1.39	180	86	106*
Country Dwellings	18,840,000	1,570,000	1.67		273	189
Monthly Cabins	19,861,000	1,655,083	1.94		447	121
Annual Cabins	7,837,000	653,083	2.94		312	68
Farms	123,159,000	10,263,250	1.32		797	423
Pasture Taps	2,263,000	205,727	2.19		27	228
Other Customers	268,049,000	630,546	1.17		33	5,584,354

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 1999					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	14,701,000	1,225,083	1.44	424	185	95*
City of Wakonda	12,005,000	1,000,417	1.39	372	155	88*
Country Dwellings	35,060,000	2,921,667	2.57		634	151
Monthly Cabins	418,000	34,833	4.84		14	82
Farms	77,098,011	6,424,834	2.34		633	334
Pasture Taps	2,882,000	240,167	5.74		42	188
Farm Irrigations						
Other Customers	9,924,000	827,000	3.02		93	292

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 2000					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	14,662,000	1,221,833	1.60	424	185	95*
City of Wakonda	13,034,000	1,086,167	1.36	372	155	96*
Country Dwellings	42,390,000	3,532,500	2.35		666	174
Monthly Cabins	479,000	39,917	4.91		12	109
Farms	80,176,015	6,681,335	2.34		631	347
Pasture Taps	4,007,000	333,917	5.90		53	207
Farm Irrigations						
Other Customers	9,533,000	794,417	2.73		98	267

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 2001					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	13,570,000	1,130,833	1.36	417	182	89*
City of Wakonda	14,537,000	1,211,417	1.42	371	155	107*
Country Dwellings	39,743,000	3,311,917	2.50		703	155
Monthly Cabins	498,000	41,500	5.06		13	105
Farms	73,576,000	6,131,333	2.43		617	327
Pasture Taps	3,507,000	292,250	6.16		50	192
Farm Irrigations						
Other Customers	8,466,004	705,500	2.78		100	232

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 2002					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	12,990,000	1,082,500	1.83	411	179	87*
City of Wakonda	13,314,000	1,109,500	1.35	362	151	101*
Country Dwellings	44,272,000	3,689,333	2.53		737	164
Monthly Cabins	523,000	43,583	5.54	13	110	
Farms	77,263,005	6,438,584	2.40		656	323
Pasture Taps	3,926,000	327,167	6.51		54	199
Farm Irrigations						
Other Customers	9,058,000	754,833	3.04		104	239

*Represents gallons per person-day, only for cities with population data

	Clay‘s Customer Water Demands from 2003					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	11,483,000	956,917	1.56	408	178	77*
City of Wakonda	12,165,000	1,013,750	1.52	358	149	93*
Country Dwellings	42,136,000	3,511,333	2.36		725	159
Monthly Cabins	470,000	39,167	5.26		7	184
Farms	76,329,000	6,360,750	2.38		692	302
Pasture Taps	2,690,000	224,167	6.75		49	150
Farm Irrigations						
Other Customers	9,347,000	778,917	2.91		101	254

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 2004					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	11,387,000	948,917	1.41	407	177	77*
City of Wakonda	12,657,000	1,054,750	1.37	351	146	99*
Country Dwellings	41,811,000	3,484,250	2.35		758	151
Monthly Cabins	567,000	47,250	5.65		9	173
Farms	74,612,000	6,217,667	2.32		674	302
Pasture Taps	2,789,000	232,417	6.53		42	182
Farm Irrigations						
Other Customers	9,078,000	756,500	2.75		102	244

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 2005					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	12,064,000	1,005,333	1.69	401	175	82*
City of Wakonda	14,167,000	1,180,583	1.42	344	143	113*
Country Dwellings	48,315,000	4,026,250	2.39		868	152
Monthly Cabins	598,000	49,833	5.91		11	149
Farms	75,591,000	6,299,250	2.45		665	311
Pasture Taps	3,433,000	286,083	6.35		44	214
Farm Irrigations	1,078,000	89,833	1.71		18	651
Other Customers	8,644,000	720,333	2.30		105	226

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 2006					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	13,197,000	1,099,750	1.90	401	175	90*
City of Wakonda	15,419,000	1,284,917	1.56	341	142	124*
Country Dwellings	89,013,000	7,417,750	2.68		1,023	238
Monthly Cabins	525,000	43,750	5.53		9	160
Farms	82,780,000	6,898,333	2.54		662	342
Pasture Taps	3,995,000	332,917	6.25		46	238
Farm Irrigations	19,773,000	1,647,750	4.03		36	1,505
Other Customers	9,695,000	807,917	2.83		108	246

*Represents gallons per person-day, only for cities with population data

	Clay's Customer Water Demands from 2007					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Gayville	14,939,000	1,244,917	1.81	401	175	102*
City of Wakonda	12,334,000	1,027,833	1.36	341	142	99*
Country Dwellings	112,965,000	9,413,750	2.67		1,124	275
Monthly Cabins	963,000	80,250	5.43		11	240
Farms	82,452,000	6,871,000	2.53		654	345
Pasture Taps	3,914,000	326,167	6.47		47	228
Farm Irrigations	24,052,000	2,004,333	3.96		39	1,690
Other Customers	9,027,000	752,250	2.69		109	227

*Represents gallons per person-day, only for cities with population data

	Mid-Dakota's Customer Water Demands from 2005					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Agar	2,257,000	188,083	1.90	75	49	82*
City of Camelot	6,832,000	621,091	2.29		60	
City of Del Acres	843,000	70,250	1.22		18	
City of Gettysburg	73,396,000	6,116,333	1.69	1,178	595	171*
City of Harrold	5,006,000	417,167	2.21	206	89	67*
City of Huron	505,420,000	42,118,333	1.72	11,063	5,462	125*
City of Lane	1,196,000	99,667	1.85	55	32	60*
City of Lebanon	1,036,000	86,333	1.41	76	48	37*
City of Onida	35,098,000	2,924,833	2.01	666	296	144*
City of Orient	1,694,000	141,167	1.43	50	33	93*
City of Polo	579,000	48,250	1.60		10	
City of St. Lawrence	5,314,000	442,833	1.56	183	91	80*
City of Virgil	465,000	38,750	1.70	23	14	55*
City of Wolsey	19,403,000	1,616,917	1.80	388	172	137*
City of Yale						
Country Dwellings	163,895,000	13,657,917	1.47		1,467	302
Farms	87,896,000	7,324,667	1.14		326	739
Pasture Taps	70,621,000	5,885,674	12.00		555	349
Other Customers	296,571,000	24,714,250	1.57		291	2,792

*Represents gallons per person-day, only for cities with population data

	Mid-Dakota's Customer Water Demands from 2006					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Agar	2,331,000	194,250	2.05	75	49	85*
City of Camelot	8,508,000	709,000	2.31		61	
City of Del Acres	723,000	60,250	1.13		18	
City of Gettysburg	84,678,000	7,056,500	1.75	1,154	583	201*
City of Harrold	5,701,000	475,083	1.90	205	88	76*
City of Huron	625,720,000	52,143,333	1.59	10,909	5,386	157*
City of Lane	1,109,000	92,417	1.37	53	31	57*
City of Lebanon	1,083,000	90,250	2.06	75	47	40*
City of Onida	38,620,000	3,218,333	2.18	664	295	159*
City of Orient	2,098,000	174,833	1.69	49	33	117*
City of Polo	530,000	44,167	1.54		11	
City of St. Lawrence	6,026,000	502,167	2.19	182	90	91*
City of Virgil	720,000	49,333	2.03	22	13	90*
City of Wolsey	20,135,000	1,677,917	1.83	381	169	145*
City of Yale	2,461,000	223,727	1.31	108	50	62*
Country Dwellings	208,627,000	17,385,583	1.55		1,686	335
Farms	108,050,000	9,004,167	1.40		340	866
Pasture Taps	102,975,000	8,582,220	12.00		683	413
Other Customers	348,916,000	29,075,667	1.82		294	3,251

*Represents gallons per person-day, only for cities with population data

Mid-Dakota's Customer Water Demands from 2007

	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Agar	2,308,000	192,333	1.59	75	49	84*
City of Camelot	6,449,000	537,417	2.66		59	
City of Del Acres	786,000	65,500	1.27		18	
City of Gettysburg	77,874,000	6,489,500	1.46	1,154	583	185*
City of Harrold	4,969,000	414,083	2.00	205	88	66*
City of Huron	644,680,000	53,723,333	1.60	10,909	5,386	162*
City of Lane	1,159,000	96,583	1.44	53	31	60*
City of Lebanon	990,000	82,500	1.55	75	47	36*
City of Onida	32,868,000	2,739,000	1.76	664	295	136*
City of Orient	2,122,000	176,833	2.10	49	33	119*
City of Polo	625,000	52,083	1.96		10	
City of St. Lawrence	5,253,000	437,750	1.68	182	90	79*
City of Virgil	536,000	44,667	2.69	22	13	67*
City of Wolsey	18,279,000	1,523,250	2.17	381	169	131*
City of Yale	2,800,000	233,333	1.96	108	50	71*
Country Dwellings	181,778,000	15,148,167	1.58		1,885	263
Farms	102,422,000	8,535,167	1.17		357	787
Pasture Taps	87,810,000	7,316,077	12.00		706	341
Other Customers	316,792,000	26,397,250	1.62		298	2,912

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 1999					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	21,925,000	1,827,083	1.53	703	276	85*
City of Davis	4,531,000	377,583	1.89	104	55	119*
City of Dolton	795,000	72,273	1.69	41	26	53*
City of Hurley	12,213,000	1,017,750	1.40	426	206	79*
City of Marion						
City of Viborg	24,682,000	2,056,833	1.46	835	404	81*
Country Dwellings	32,718,000	2,726,500	2.36		537	167
Farms	63,257,000	5,271,417	2.03		330	525
Pasture Taps						
Other Customers	75,640,000	6,303,333	2.66		69	3,003

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 2000					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	24,297,000	2,024,750	1.35	703	276	95*
City of Davis	2,656,000	221,333	1.98	104	55	70*
City of Dolton	943,000	78,583	1.65	41	26	63*
City of Hurley	13,091,000	1,090,917	1.43	426	206	84*
City of Marion						
City of Viborg	26,504,000	2,208,667	1.25	835	404	87*
Country Dwellings	36,384,000	3,032,000	2.28		549	181
Farms	67,804,000	5,650,333	2.06		328	566
Pasture Taps						
Other Customers	39,408,000	3,284,000	2.66		60	1,799

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 2001					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	21,210,000	1,928,182	1.29	706	277	82*
City of Davis	3,774,000	314,500	2.42	103	54	100*
City of Dolton	803,000	66,917	1.43	41	26	54*
City of Hurley	11,596,000	966,333	1.57	420	203	76*
City of Marion						
City of Viborg	26,418,000	2,201,500	1.48	838	406	86*
Country Dwellings	36,541,000	3,045,083	2.59		565	177
Farms	59,001,000	4,916,750	2.11		317	510
Pasture Taps						
Other Customers	47,068,000	3,922,333	2.91		55	2,345

*Represents gallons per person-day, only for cities with population data

	TM‘s Customer Water Demands from 2002					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	21,919,000	1,826,583	1.53	709	279	85*
City of Davis	4,309,000	359,083	1.47	100	53	118*
City of Dolton	678,000	56,500	1.45	40	25	46*
City of Hurley	10,747,000	895,583	1.55	408	197	72*
City of Marion	6,557,000	2,185,667	1.25	859	363	21*
City of Viborg	26,365,000	2,197,083	1.49	818	396	88*
Country Dwellings	38,709,000	3,225,750	2.53		606	175
Farms	63,900,000	5,325,000	2.35		356	492
Pasture Taps						
Other Customers	40,131,000	3,344,250	2.36		62	1,773

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 2003					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	19,536,000	1,628,000	1.34	701	275	76*
City of Davis						
City of Dolton	920,000	76,667	1.54	40	25	63*
City of Hurley	10,448,000	870,667	1.37	409	198	70*
City of Marion	25,661,000	2,138,417	1.33	854	361	82*
City of Viborg	25,407,000	2,117,250	1.33	815	395	85*
Country Dwellings	41,087,000	3,423,917	2.36		619	182
Farms	63,664,000	5,305,333	2.11		355	491
Pasture Taps						
Other Customers	35,317,000	2,943,083	2.31		56	1,728

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 2004					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	19,129,000	1,594,083	1.14	699	275	75*
City of Davis						
City of Dolton	939,000	78,250	1.42	40	25	64*
City of Hurley	10,136,000	844,667	1.39	406	196	68*
City of Marion	24,421,000	2,035,083	1.48	847	358	79*
City of Viborg	23,411,000	2,128,273	1.46	811	393	79*
Country Dwellings	35,386,000	2,948,833	2.33		644	150
Farms	58,118,000	4,843,167		2.40	347	459
Pasture Taps	2,714,000	226,167	1.93		3	2,479
Other Customers	53,727,000	4,477,250	2.44		69	2,133

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 2005					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	19,780,000	1,648,333	1.41	800	388	89*
City of Davis						
City of Dolton	915,000	76,250	1.74	40	25	63*
City of Hurley	9,657,000	804,750	1.48	400	193	66*
City of Marion	25,137,000	2,094,750	1.56	834	352	83*
City of Viborg	25,943,000	2,161,917	1.36	800	388	89*
Country Dwellings	38,355,000	3,196,250	2.53		659	160
Farms	56,758,000	4,729,833	2.25		339	459
Pasture Taps	825,000	68,750	1.63		2	1,130
Other Customers	58,785,000	4,898,750	2.21		68	2,368

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 2006					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	18,651,000	1,554,250	1.43	683	268	75*
City of Davis						
City of Dolton	1,062,000	88,500	2.01	39	25	75*
City of Hurley	10,056,000	838,000	1.70	398	192	69*
City of Marion	25,231,000	2,102,583	1.70	836	353	83*
City of Viborg	25,188,000	2,099,000	1.60	798	387	86*
Country Dwellings	41,510,000	3,459,167	2.40		670	170
Farms	57,135,100	4,761,258	2.35		325	482
Pasture Taps	883,000	73,583	2.60		3	806
Other Customers	63,634,000	5,302,833	2.41		64	2,724

*Represents gallons per person-day, only for cities with population data

	TM's Customer Water Demands from 2007					
	Yearly Demand, gallons	Average Month Demand, gallons	Peaking Factor	Population	Customers	Gallons per customer-day
City of Canistota	17,727,000	1,477,250	1.49	683	268	71*
City of Davis						
City of Dolton	877,000	73,083	2.24	39	25	62*
City of Hurley	8,160,000	680,000	1.81	398	192	56*
City of Marion	24,330,000	2,027,500	1.66	836	353	80*
City of Viborg	24,304,000	2,025,333	1.55	798	387	83*
Country Dwellings	41,199,000	3,433,250	2.45		680	166
Farms	53,389,000	4,449,083	2.19		325	450
Pasture Taps	1,201,000	100,083	2.06		4	823
Other Customers	61,236,000	5,103,000	2.42		68	2,467

*Represents gallons per person-day, only for cities with population data

APPENDIX D:

Method for Calculating City Customers

Example:

According to the United States Census the city of Egan had a population of 265 and had 119 housing units in the year 2000. The method of calculating the number of customers the city of Egan had from 1999 to 2007 was as follows. First a ratio of population to housing units was calculated for the year 2000. Next the city population for each year from 1999 to 2007 was divided by the ratio to calculate how many customers or housing units were in the city for that year. Below are the actual calculations for the number of customers that were in the city of Egan.

Solution:

Population for year 2000 = 265, Housing Units for year 2000 = 119

Population to Housing Unit Ratio => (265/119) => 2.23

Results:

Population for year 1999 = 267, Customers for year 1999 => (267/2.23) => 120

Population for year 2000 = 265, Customers for year 2000 => (265/2.23) => 119

Population for year 2001 = 268, Customers for year 2001 => (268/2.23) => 120

Population for year 2002 = 264, Customers for year 2002 => (264/2.23) => 119

Population for year 2003 = 261, Customers for year 2003 => (261/2.23) => 117

Population for year 2004 = 260, Customers for year 2004 => (260/2.23) => 117

Population for year 2005 = 261, Customers for year 2005 => (261/2.23) => 117

Population for year 2006 = 259, Customers for year 2006 => (259/2.23) => 116

Population for year 2007 = 259, Customers for year 2007 => (259/2.23) => 116

APPENDIX E:

Water Quality Graphs for Regional Water System & Their Communities

Figure E.1. Hardness of Surface Water Sources from Missouri River

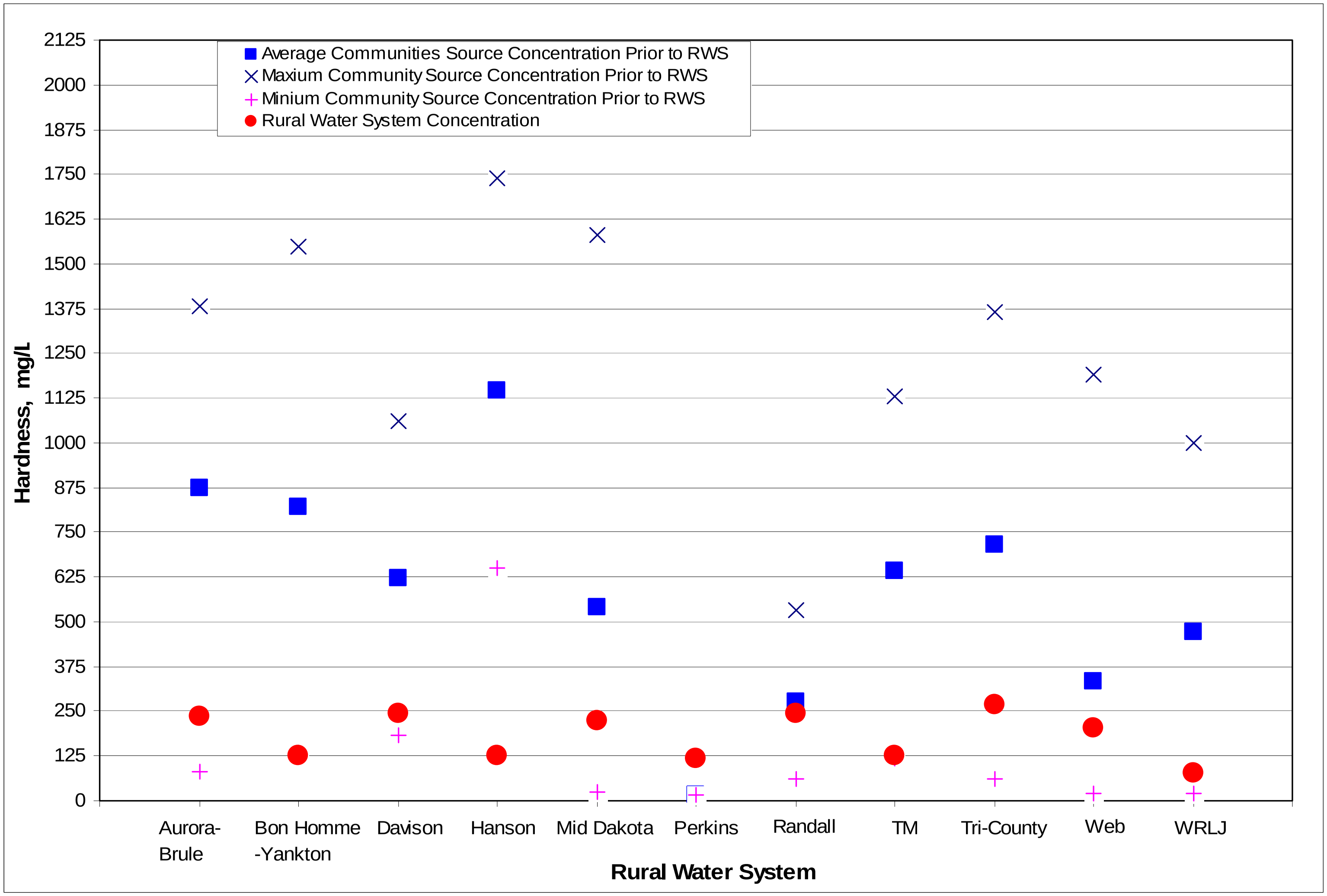


Figure E.2. Hardness of Ground Water Sources

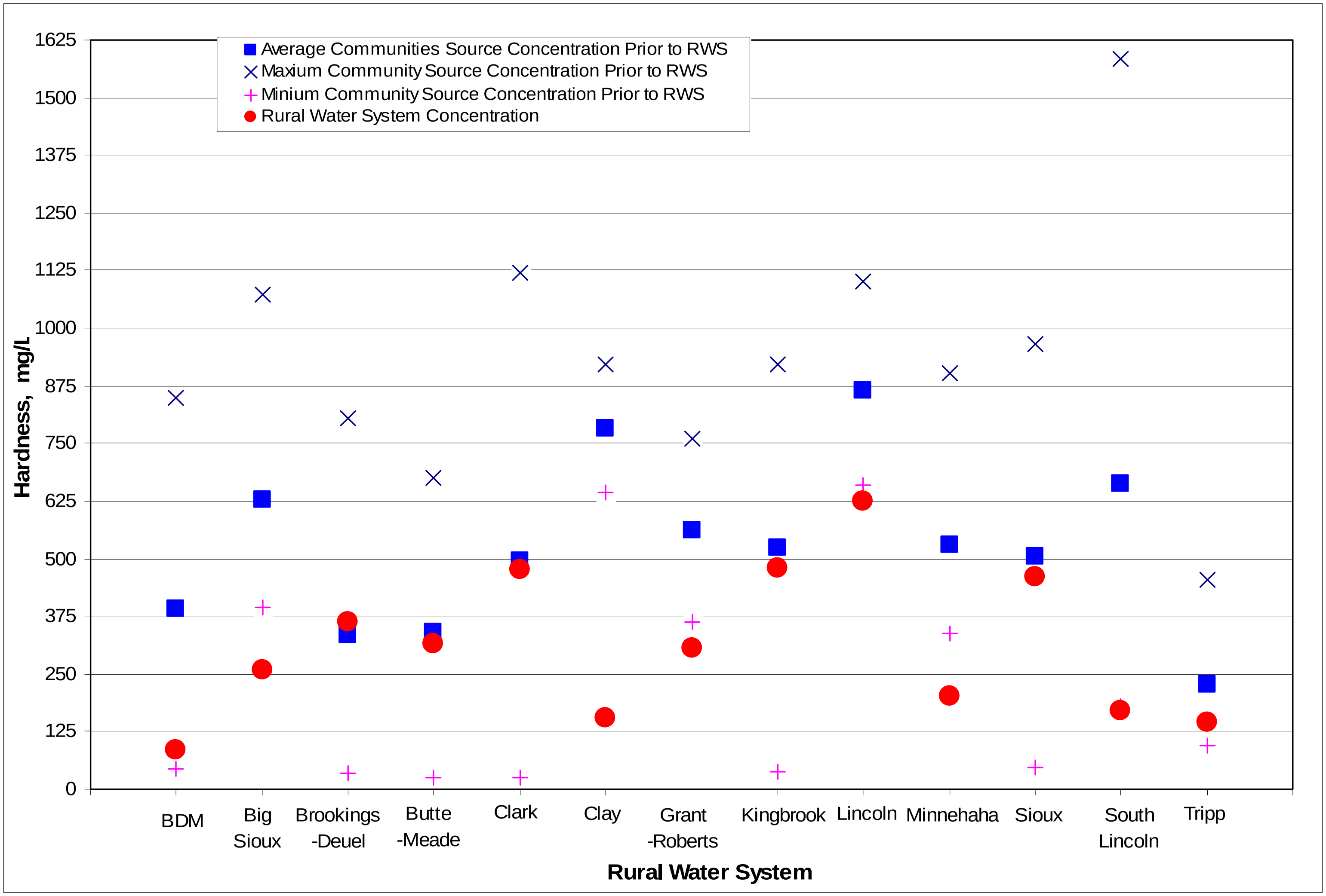


Figure E.3. Sulfate of Surface Water Sources from Missouri River

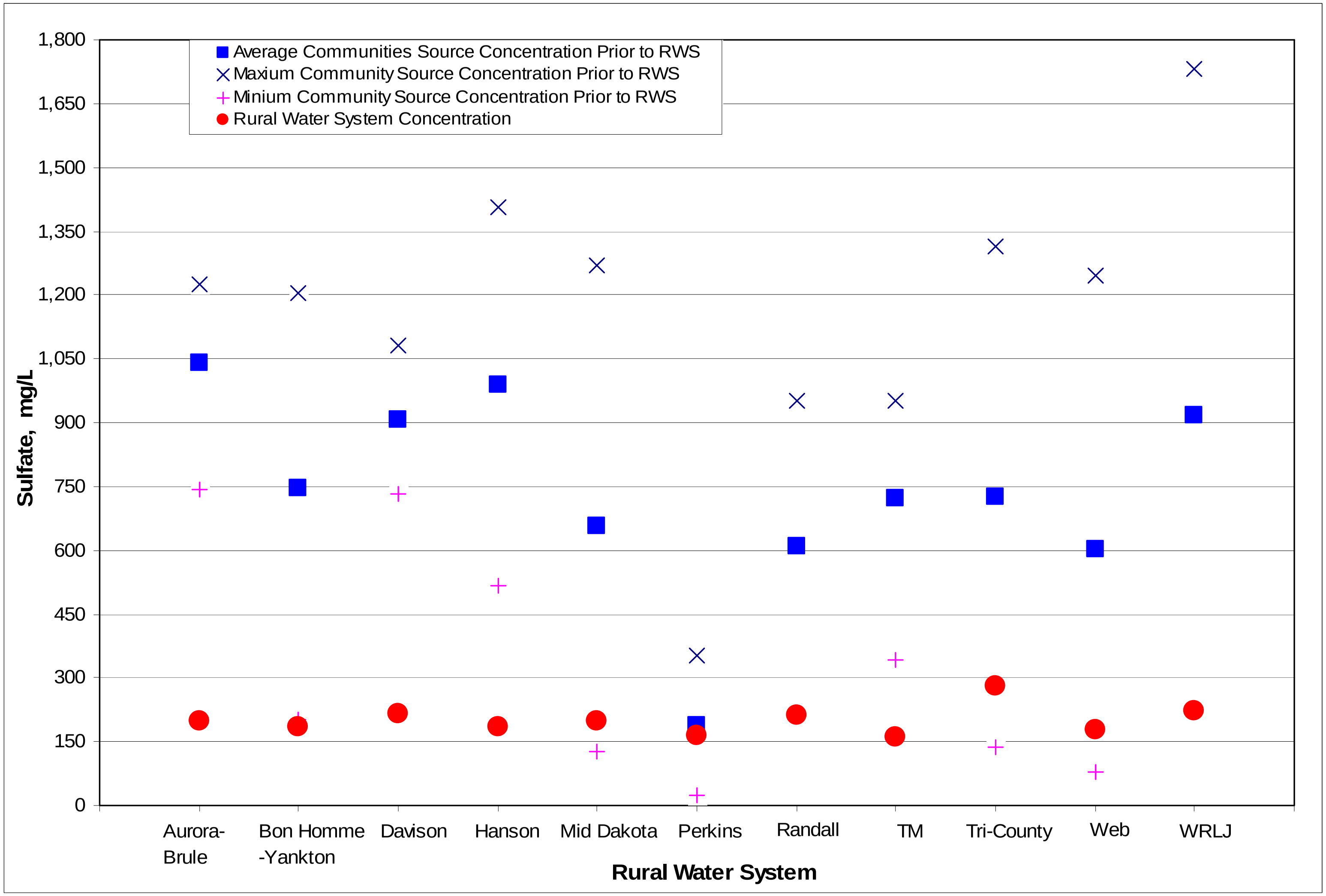


Figure E.4. Sulfate of Ground Water Sources

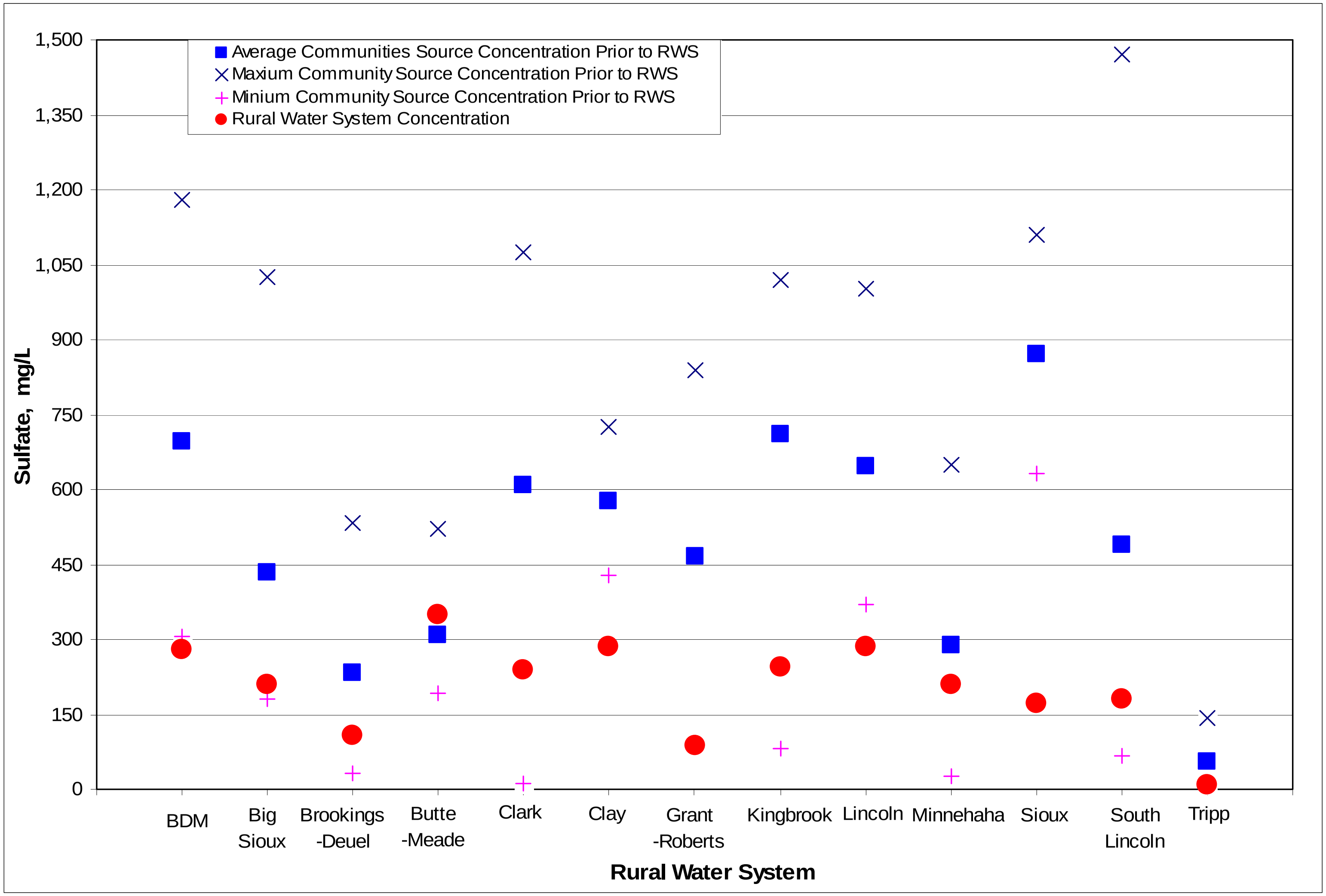


Figure E.5. Total Dissolved Solids of Surface Water Sources from Missouri River

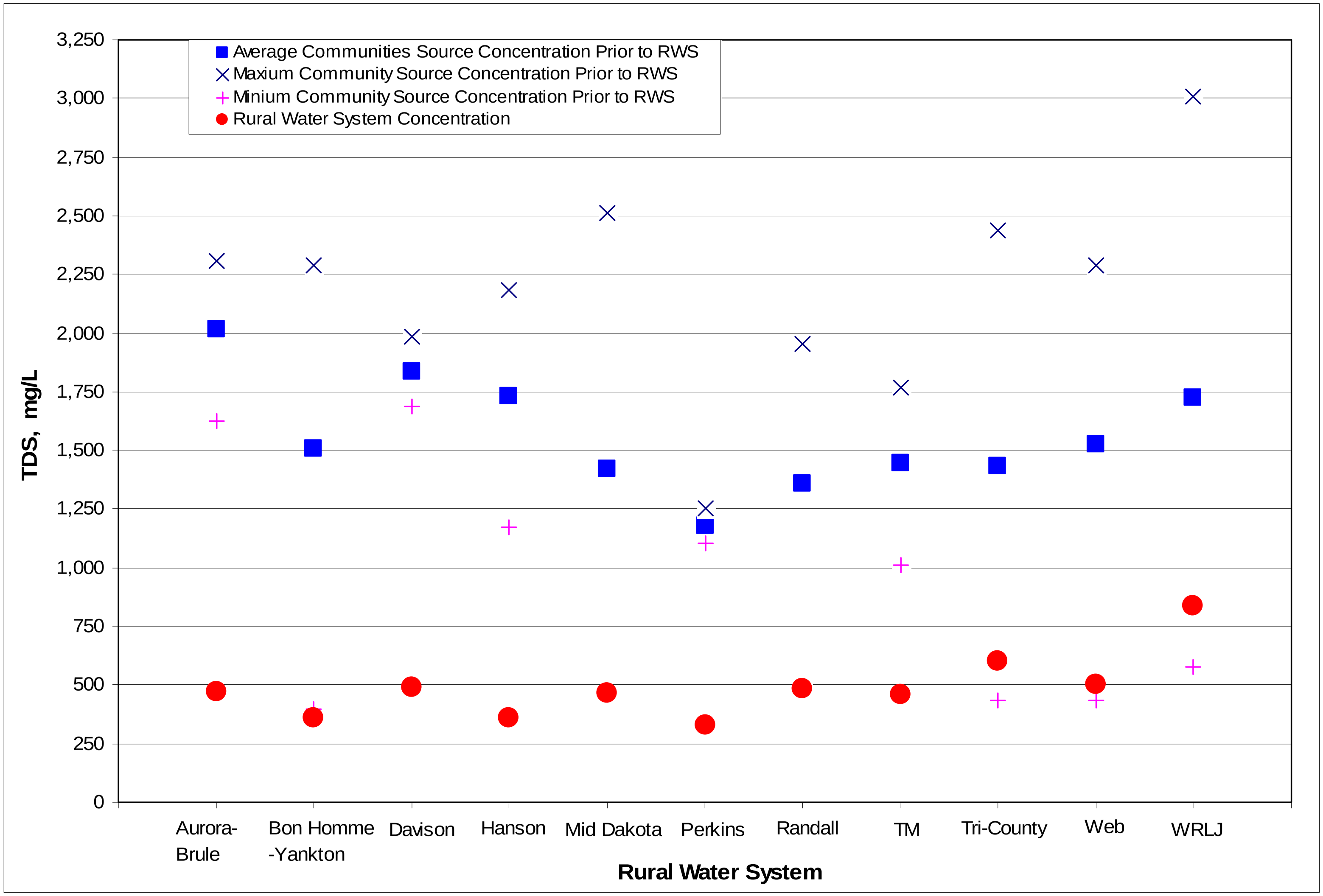
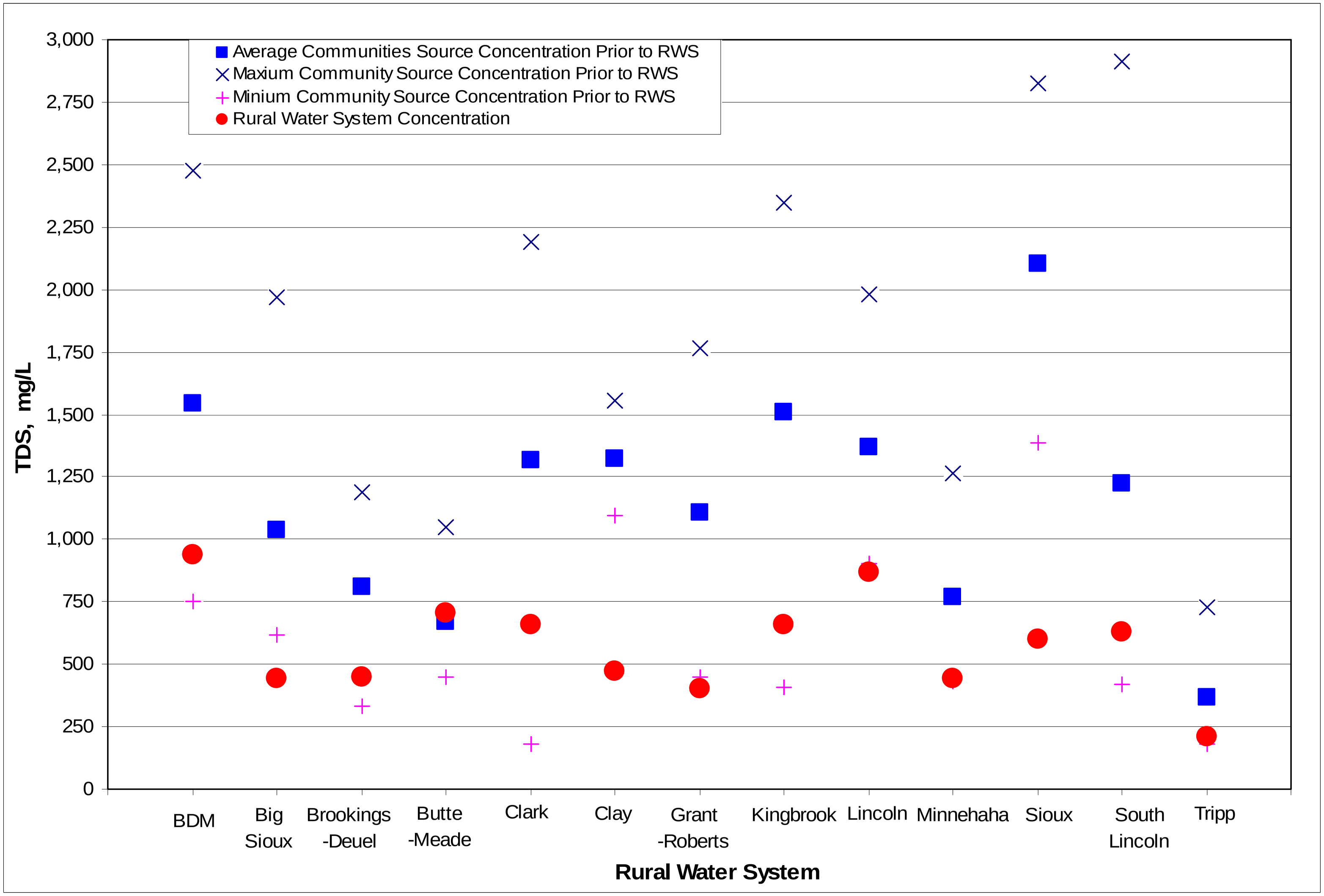


Figure E.6: Total Dissolved Solids of Ground Water Sources



APPENDIX F

Discussion of Demand Variations & Trends for Big Sioux, Clay, Mid-Dakota & TM Rural Water Systems

F.1 Big Sioux Rural Water System Water Demand Variations & Trends

Demand variations and trends for the Big Sioux RWS represent those of a system with industrial, rural, farm, and municipal customers. Figures F.1 and F.2 represent the percent of total water consumption and annual demands for Big Sioux's city customers, country dwelling customers, farm customers, and other customers. The major consumption of water during 1999 and 2000 came from the farming classification. This classification consumed 61% of the total water consumption. The City of Flandreau connected to the RWS in 2001 causing the city consumption to surpass farming consumption. On average Flandreau consumed 72% of the city classification's

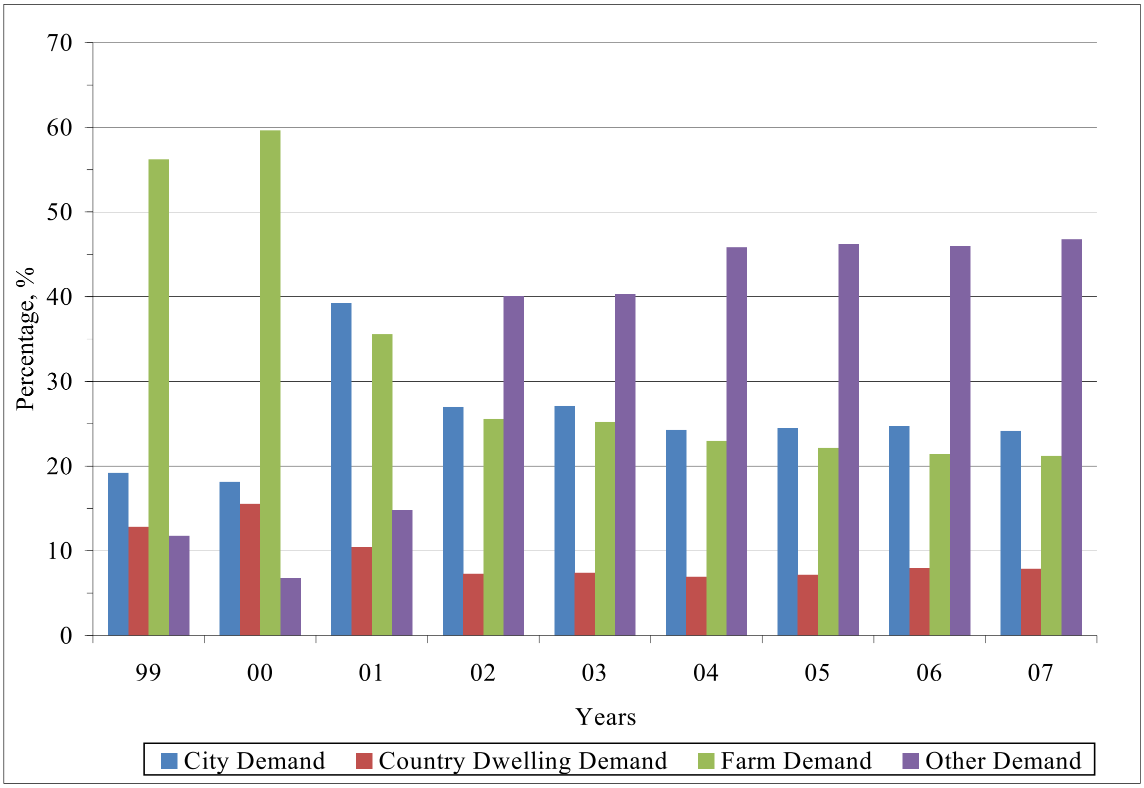


Figure F.1. Percentages of Yearly Water Demand for Big Sioux's Customer Classifications

consumption. In 2002 Dakota Ethanol was added to the other customer classification and contributed 93% to the other classification's yearly water consumption. This is illustrated by the sudden spike in demand of the others classification in 2002. Big Sioux's overall water consumption characteristics will be highly influenced by demand characteristics of Dakota Ethanol, city, and farm customers. Demand characteristics of the country dwelling customers (8% of total demand) will have a minimal affect on the system's consumption characteristics. The distribution of water consumption is outlined in Figure F.1.

The quantified demand of all four customer classifications is shown in Figure F.2. The total million gallons (MG) of water consumed by the country dwelling and farm classifications varied little from 1999 through 2007; however, the country dwelling classification demonstrated a steady 4% rise in yearly consumption while farm classification exhibited a decline of 2% in yearly consumption. The trend of rising water consumption for the country dwelling classification was common among all four water systems. Both the city and other classifications exhibited a 101 MG and 251 MG increases in total consumption from 1999 to 2007, respectively. Dakota Ethanol made-up approximately 43% of Big Sioux's yearly water demand after 2005 consuming 250 million gallons of water a year. When compared to Clay, Mid-Dakota, and TM; Big Sioux was the second largest provider of rural water by selling roughly 580 million gallons per year.

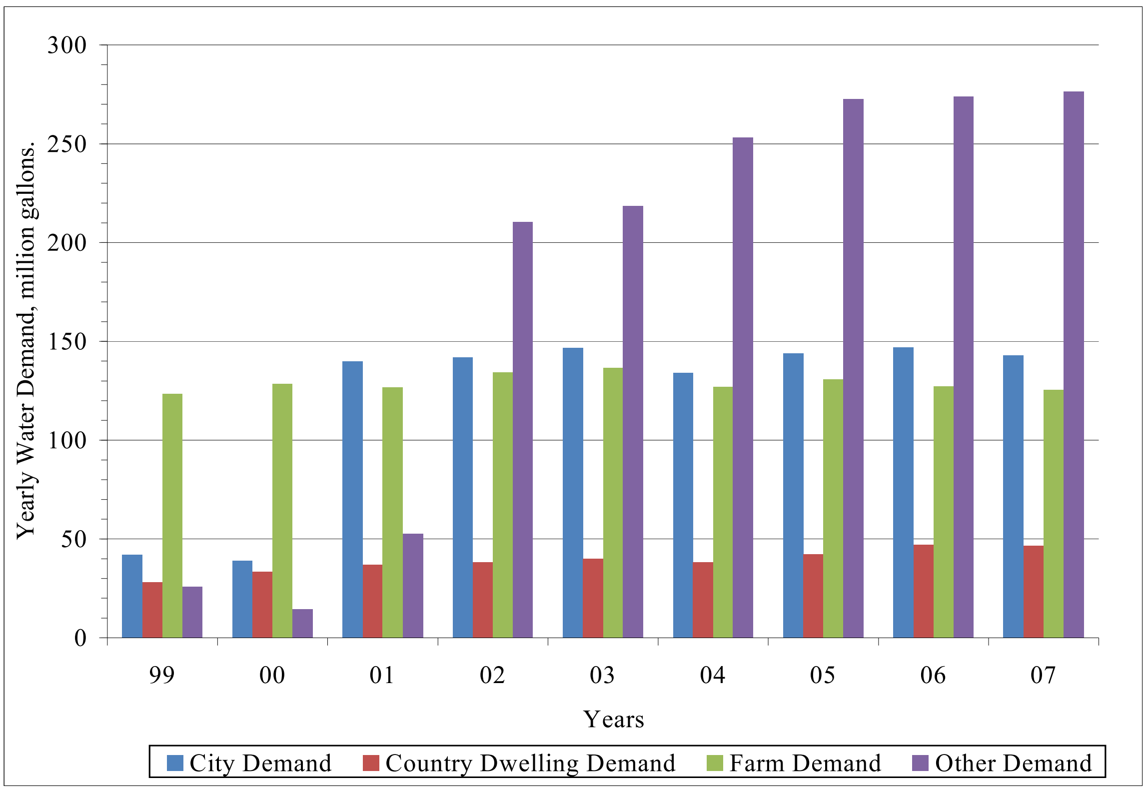


Figure F.2. Yearly Water Demand for Big Sioux's Customer Classifications

The country dwelling classification had the second highest percent of customers at 29%, behind the city classification (42%), and displayed a continual yearly rise. Big Sioux's other customer classification was made-up of mostly large commercial and industrial customers and represented about 0.8% of all Big Sioux's customers. The breakdowns of Big Sioux's customers are explained by Figure F.3 and Figure F.4.

The number of individual customer water meters for each city was not available, so a method of counting the individual water meters was created. That method was the same method discussed in Section 4.3.1 and also in Appendix D. The method of determining the amount of city customers was an approximation. The actual number of city customers could change the data represented in Figures F.3, F.4, F.5, and F.7.

Illustrated in Figure F.3 is a trend showing the percentage of country dwelling customers on a slight rise of 0.8% each year and the farm customers on a slight decline of 0.5% each year. The trend of increasing country dwelling customers will likely have an effect on the cost that Big Sioux associates with infrastructure and maintenance for each classification type for the following reasons.

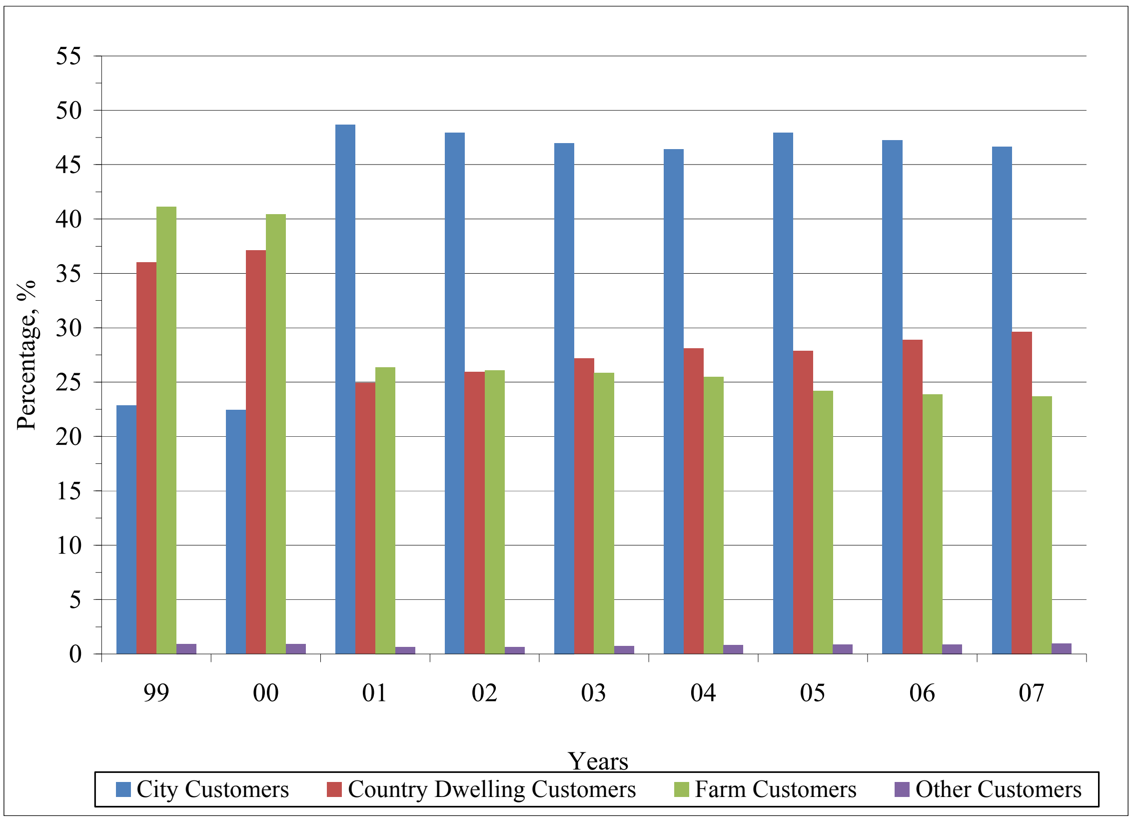


Figure F.3. Percentages of Yearly Water Meter Customers for Big Sioux

Typically, country dwelling customers were spread out over long distances. Those long distances required miles of infrastructure and routine maintenance to connect a single dwelling, whereas, city customers were served as bulk cities which meant, Big Sioux did not pay for the infrastructure or the routine maintenance of the distribution systems within each city. Similarly to country dwellings, the other and farm customers were typically spread out over long distances; however, unlike the country dwelling customers most of Big Sioux's other (commercial/industrial) customers and farm customers, to a lesser degree, were individually large consumers of water.

Figure F.4 demonstrates Big Sioux's increase in water customers throughout the years with 2,065 customers in 1999 to 3,513 customers in 2007. Big Sioux added 1,090 water customers in 2001 with the addition of the City of Flandreau and 109 customers in 2005 from the addition of the City of Trent, both were cities. From 2002 through 2007 Big Sioux averaged 36 additional water customers each year with an increase of 40 country dwelling customers and 2 commercial/industrial customers each year and a decline of 4 city customers and 2 farm customers each year.

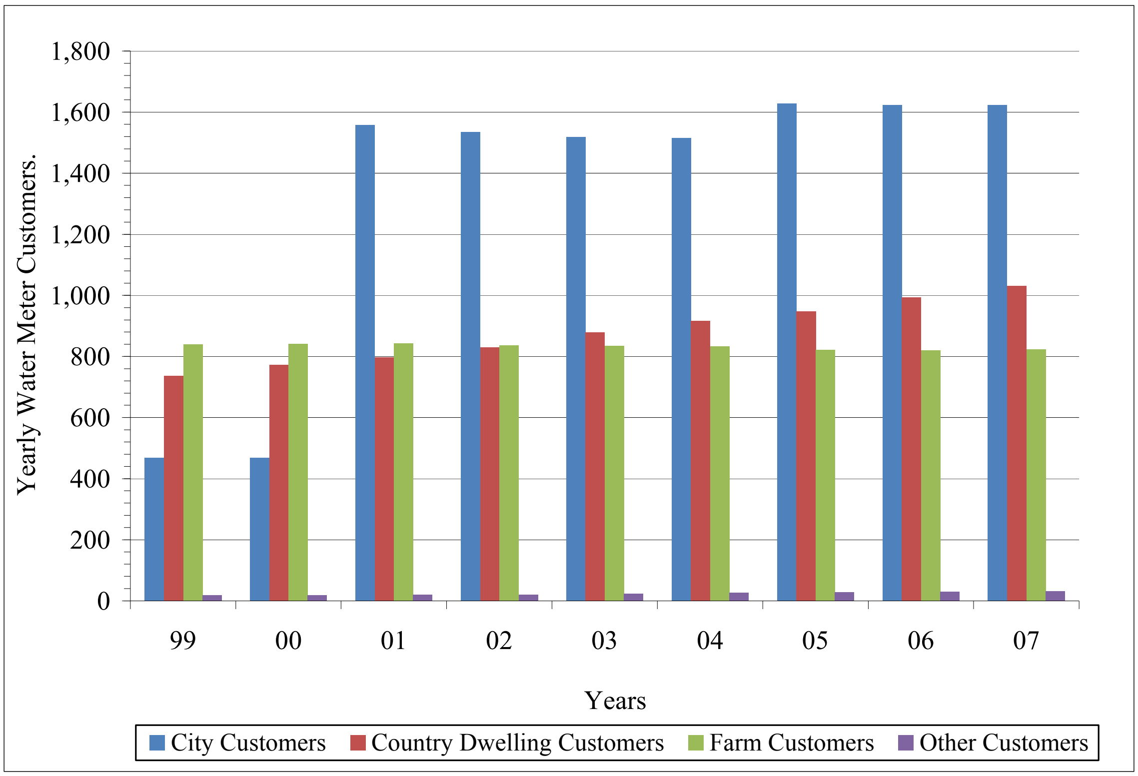


Figure F.4. Number of Yearly Water Meter Customers for Big Sioux

Another important water consumption characteristic was the daily water demand per customer because the characteristic could be used to predict the yearly water demand that each customer classification would place on the overall RWS. By coupling the daily water demand with the monthly peaking factors, Big Sioux could predict the maximum month water demand for future years. Figures F.5 and F.6 show the daily water demand per customer and the monthly peaking factors for each customer classification. The other customer classification was not included in the following figures because of skewed results. The three customer classification's had reasonably constant daily water demands from year to year. Of the three customer classifications, the farm customers had the highest daily water demand at 402 gallons per customer up to 448 gallons per customer; nearly twice the consumption of the city customers. Farm customers exhibited consistently low monthly peaking factors of 1.14 to 1.36. Since the peaking factors were

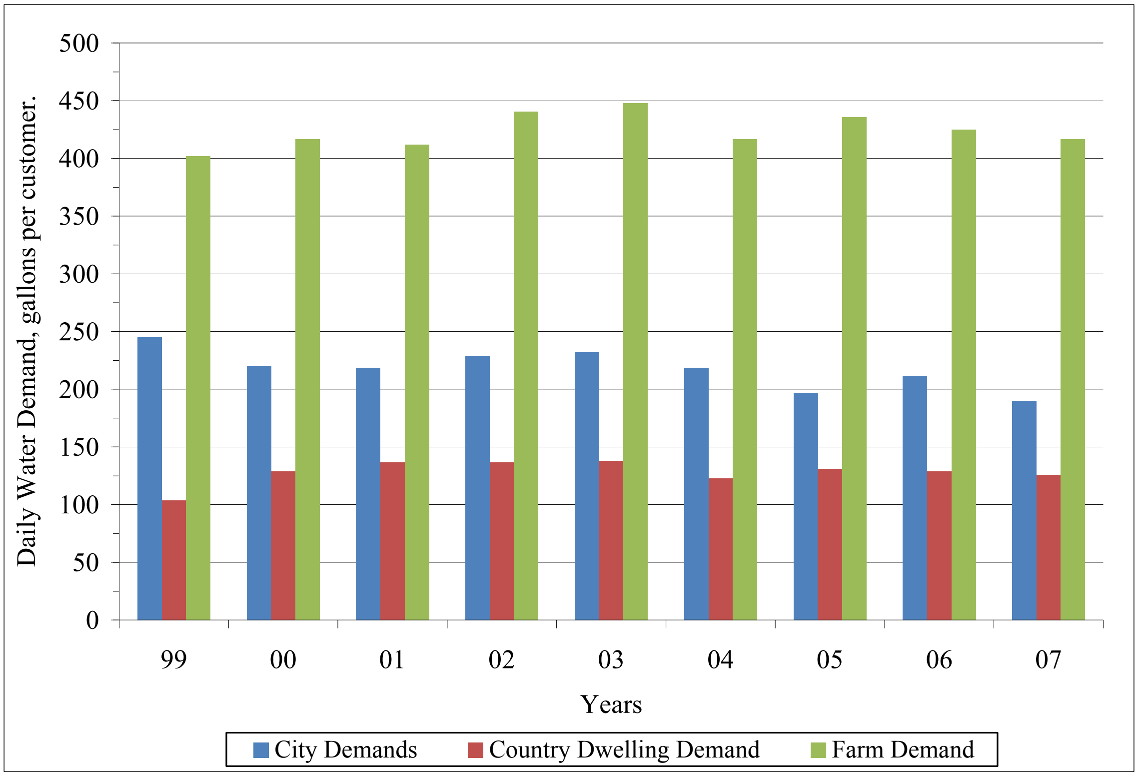


Figure F.5. Daily Water Demand per Customer for Big Sioux's Customer Classifications

so close to 1.0, it was evident that the farm customers placed a fairly constant monthly water demand on the overall RWS.

The daily water demand for the country dwelling customers was the lowest of the three classifications ranging from 104 gallons per customer to 138 gallons per customer. The monthly peaking factors ranged widely from 1.28 to 1.80 with the highest two years having been 2006 and 2007. From 1999 to 2007, the monthly peaking factors progressively increased each year with the exception of years 2003 to 2005. The increasing peaking factors indicated that the country dwelling customers were increasingly consuming more water during the summer months than the rest of the year. This phenomenon coupled with the increasing country dwelling customer base will gradually play a more significant role in shaping Big Sioux's demand characteristics. City customers' daily water demands trended downward from 1999 to 2007 ranging from 190 gallons per customer to 245 gallons per customer with peaking factors of 1.28 to 1.66.

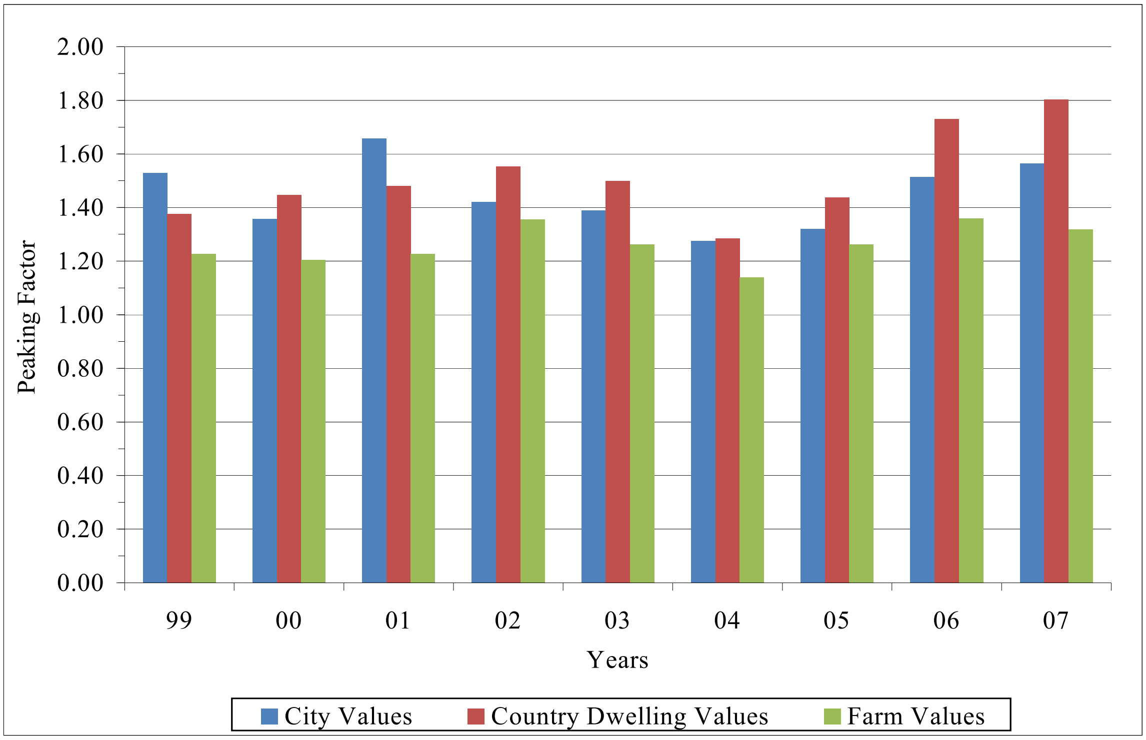


Figure F.6. Monthly Peaking Factors for Big Sioux's Customer Classification

Figure F.7 illustrates Big Sioux's last consumption characteristic that all customer classifications consumed less water per customer during wetter precipitation years. The city classification had the largest increase in daily water demand of 56% when precipitation ranged from 37.95 inches to 20.95 inches. Country dwelling customers and farm customers also exhibited large increases in daily water demands during low precipitation years with the largest increase during the year with 21.40 inches of precipitation. Country dwelling customers displayed an increase in daily water demand of 46% while farm customers had an increase of 45%. Precipitation played a significant role in Big Sioux's daily water demands and should always be considered when predicting future demands.

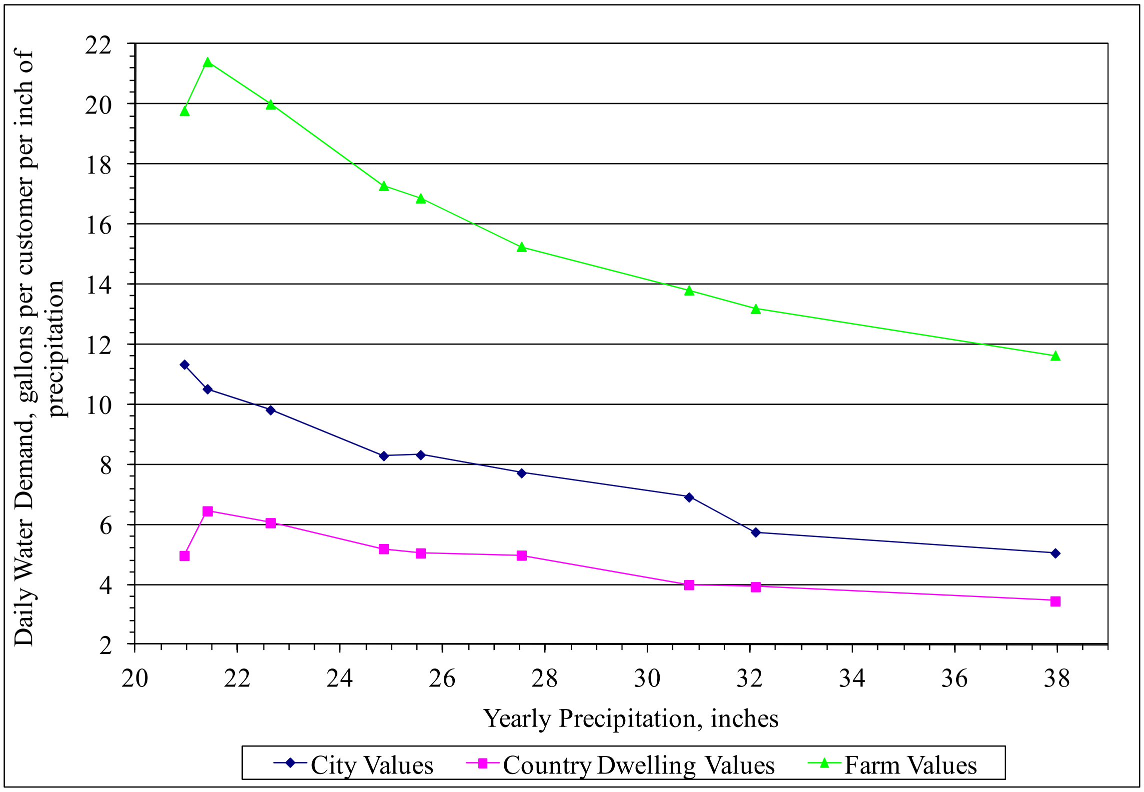


Figure F.7. Daily Customer Water Demand versus Yearly Precipitation for Big Sioux

F.2 Clay Rural Water System Water Demand Variations & Trends

Demand variations and trends of the Clay RWS represent those of a system with farm, rural, municipal, and commercial customers. Figures F.8 and F.9 represent the percent of total water consumption and annual demands for Clay's city customers, country dwelling customers, farm customers, and other customers. The major consumption of water from 1999 through 2004 came from the farming classification. This classification consumed 51% of the total water consumption. In 2005, 2006, and 2007 the farming classification experienced a gradual decrease in total percent consumption of 2% to 3% each year. The percent decrease for the farming classification came primarily from large increases in country dwelling consumption; 2% in 2005, 8.5% in 2006, and 5.5% in 2007. Prior to 2005, the country dwelling classification consumed 23% of the total water consumption. Clay's overall water consumption characteristics will be highly influenced by demand characteristics of farm, country dwelling, and city customers. Demand characteristics of the other customers (5% of total demand) will have a minimal affect on the system's consumption characteristics. The distribution of water consumption is outlined in Figure F.8.

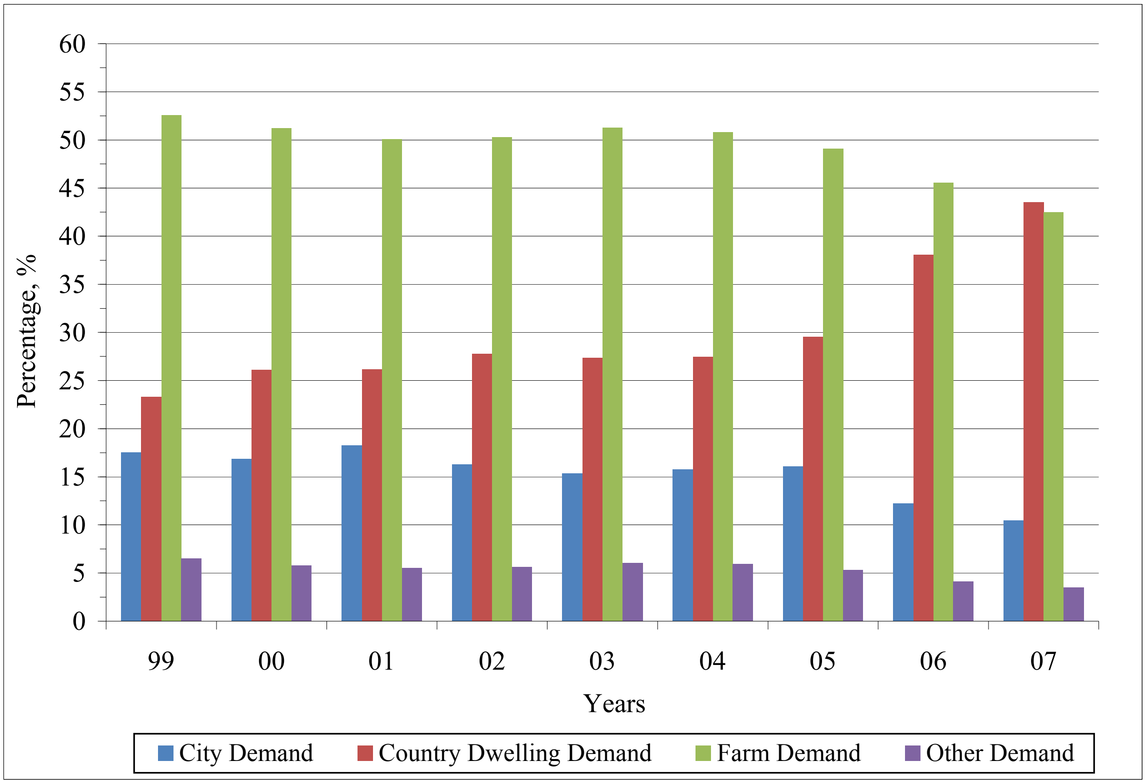


Figure F.8. Percentages of Yearly Water Demand for Clay's Customer Classifications

The quantified demand of all four customer classifications is shown in Figure F.9. The total million gallons (MG) of water consumed by the city and other classifications varied little from 1999 through 2007. Water consumption from the country dwelling and farm classifications varied little from 1999 through 2004 but increased 65 MG and 30 MG from 2005 to 2007, respectfully. The trend of rising water consumption for the country dwelling classification was common among all four water systems. When compared to Big Sioux, Mid-Dakota, and TM; Clay was the third largest provider of rural water by selling roughly 260 million gallons in 2007.

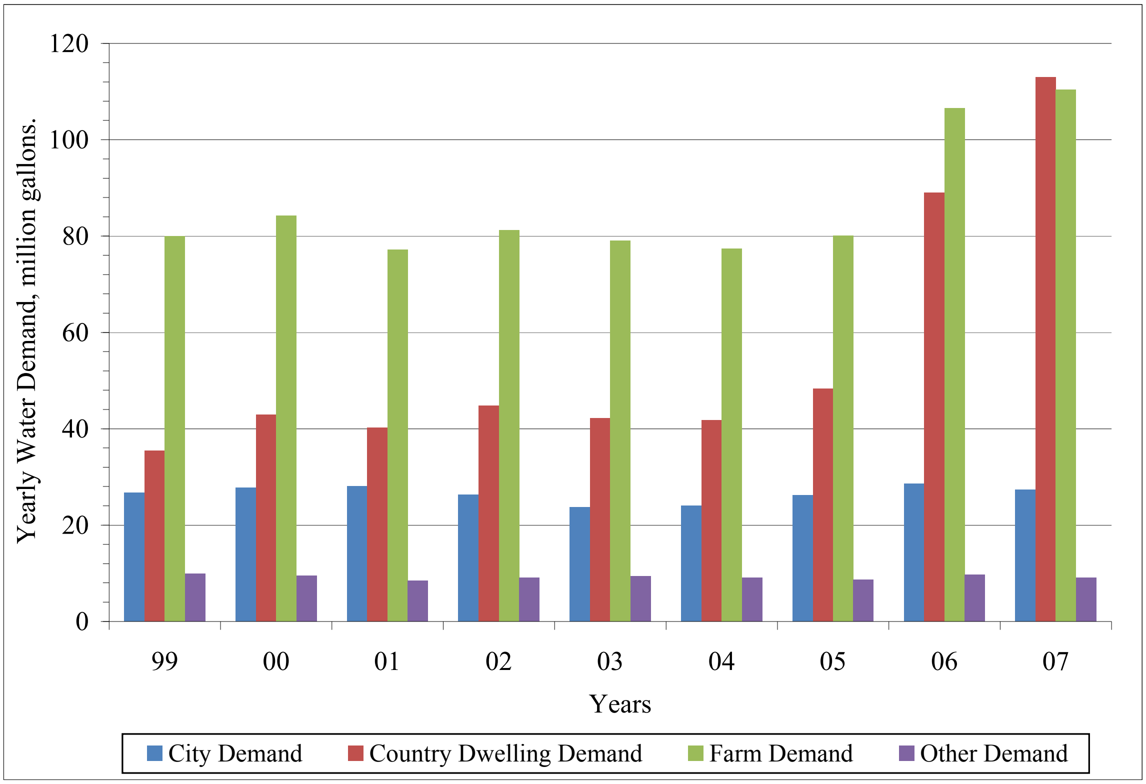


Figure F.9. Yearly Water Demand for Clay's Customer Classifications

The country dwelling classification had the highest percent of customer at 41%, slightly ahead of the farm classification (37%), and exhibited an increase of 3% each year after 2004. Clay's other customer classification was made-up of mainly commercial customers and represented about 5% of all Clay's customers. The breakdowns of Clay's customers are explained by Figure F.10 and Figure F.11.

The number of individual customer water meters for each city was not available, so a method of counting the individual water meters was created. That method was the same method discussed in Section 4.3.1 and also in Appendix D. The method of determining the amount of city customers was an approximation. The actual number of city customers could change the data represented in Figures F.10, F.11, F.12, and F.14.

Illustrated in Figure F.10 is a trend showing the percentage of country dwelling customers on a dramatic rise of 3% each year after 2003. The dramatic increase in country dwelling customers caused the percentages of the three remaining classifications to decrease, even though, the three classifications held about the same number of customers from 1999 to 2007. The trend of increasing country dwelling customers will likely have an effect on the cost that Clay associates with infrastructure and maintenance for each classification type for the following reasons.

Typically, country dwelling customers were spread out over long distances. Those long distances required miles of infrastructure and routine maintenance to connect a single dwelling, whereas, city customers were served as bulk cities which meant, Clay

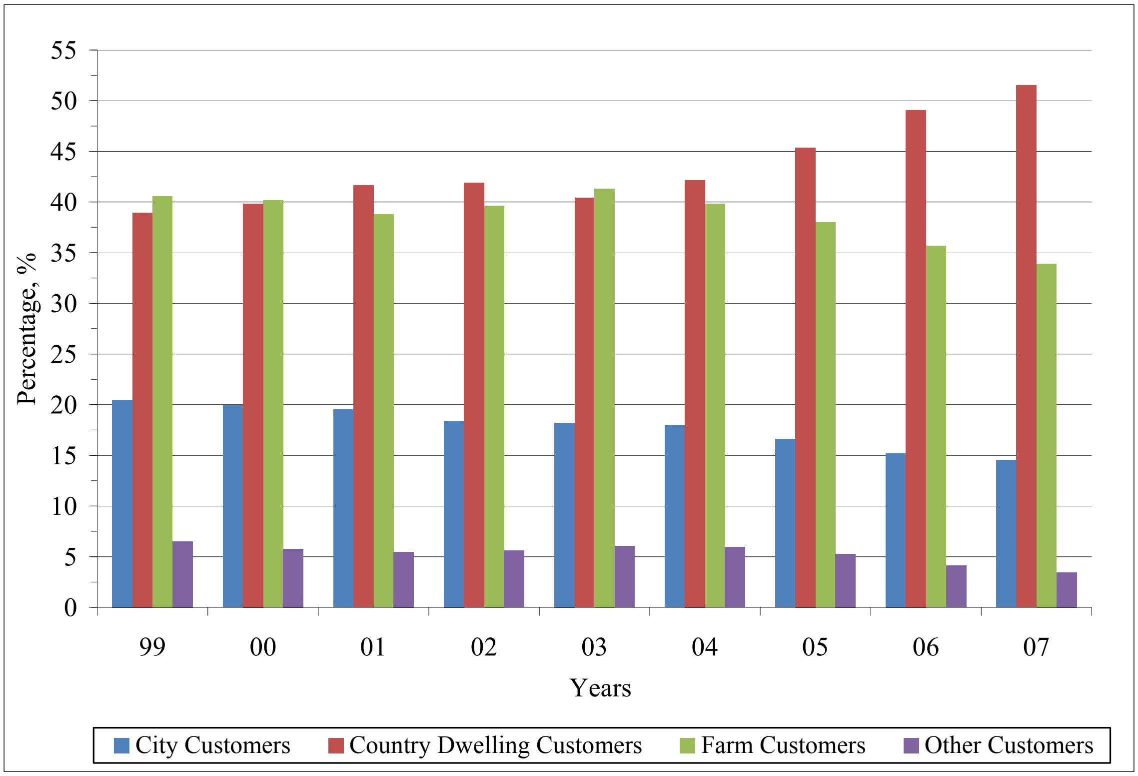


Figure F.10. Percentages of Yearly Water Meter Customers for Clay

did not pay for the infrastructure or the routine maintenance of the distribution systems within each city. Similarly to country dwellings, the farm customers were typically spread out over long distances; however, unlike the country dwelling customers most of Clay's farm customers were individually large consumers of water.

Figure F.11 demonstrates Clay's increase in water customers throughout the years with 1,756 customers in 1999 to 2,290 customers in 2007. Clay added 272 water customers from 2005 through 2007, an average of 130 customers per year. Prior to 2005, Clay averaged an addition of 29 water customers each year. Of those 534 new water customers, 476 were country dwelling customers, 65 were farm customers, 16 were commercial/industrial customers, and 23 city customers left the RWS.

Another important water consumption characteristic was the daily water demand per customer because the characteristic could be used to predict the yearly water demand that each customer classification would place on the overall RWS. By coupling the daily

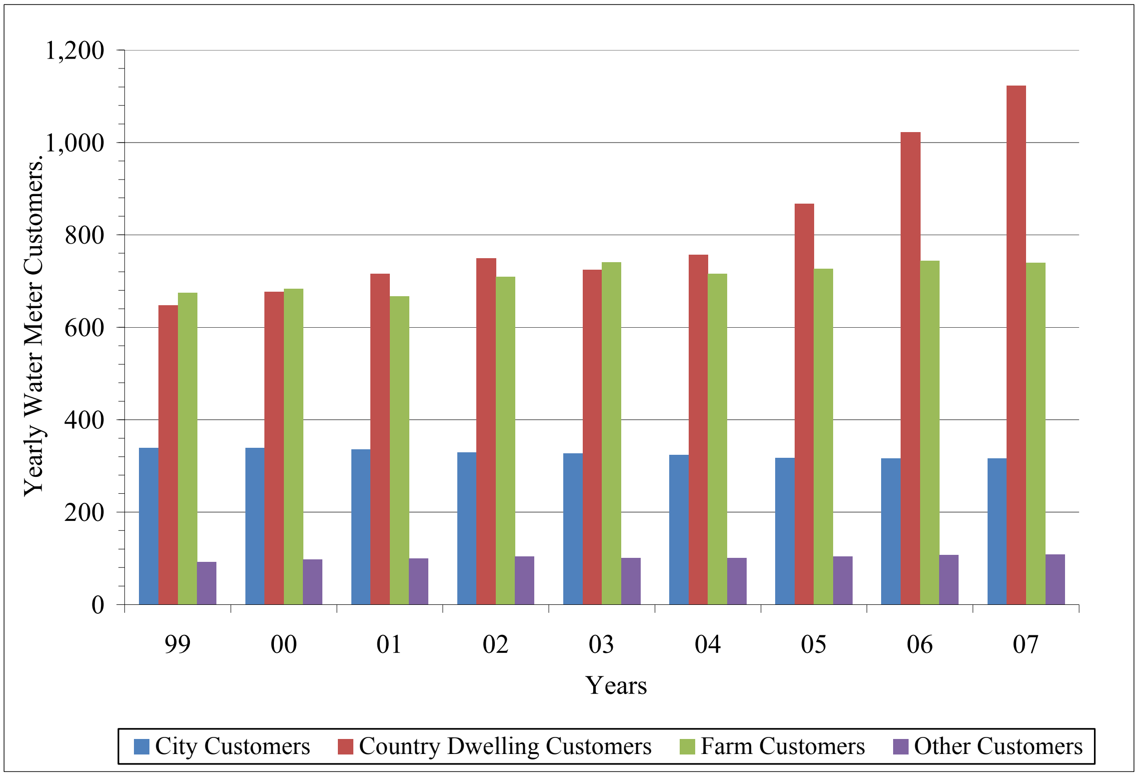


Figure F.11. Number of Yearly Water Meter Customers for Clay

water demand with the monthly peaking factors, Clay could predict the maximum month water demand for future years. Figure F.12 and F.13 show the daily water demand per customer and the monthly peaking factors for each customer classification. The other customer classification was not included in the following figures because of skewed results. Of the three customer classifications, the farm customers had the highest daily water demand at 292 gallons per customer up to 409 gallons per customer, nearly twice the consumption of the country dwelling customers with the exception of years 2006 and 2007. Farm customers exhibited consistently high monthly peaking factors of 2.55 to 2.95. Since the peaking factors were high, it was evident that the farm customers placed significantly higher monthly water demands on the overall RWS during certain months out of the year, mainly the summer months.

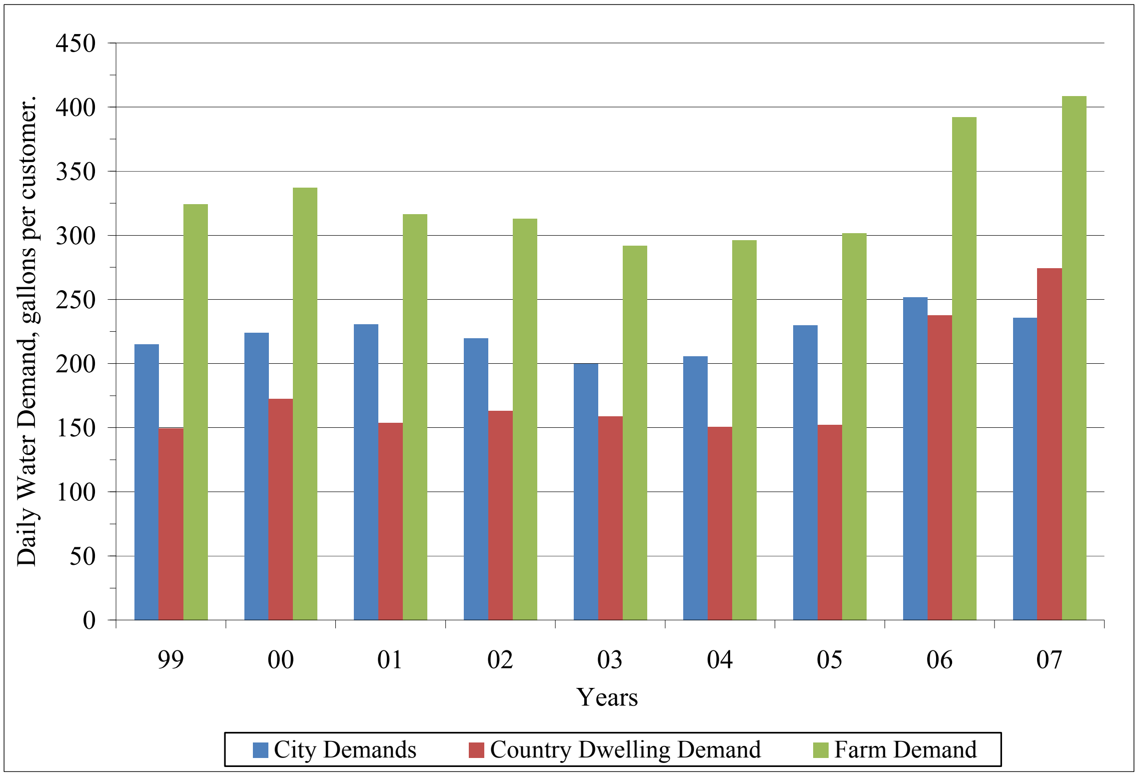


Figure F.12. Daily Water Demand per Customer for Clay's Customer Classifications

The daily water demand for the country dwelling customers was typically the lowest of the three classifications ranging from 150 gallons per customer to 173 gallons per customer and spiking up to 238 and 275 gallons per customer in 2006 and 2007. Like the farm customers, the country dwelling customers exhibited consistently high monthly peaking factors from 2.35 to 2.68. From 1999 to 2005, the country dwelling customers consumed on average 30% more water during the summer months and 60% more water during the summer months through the years of 2006 and 2007. This phenomenon coupled with the increasing country dwelling customer base will gradually play a more significant role in shaping Clay's demand characteristics. City customers' daily water demands displayed steady consumption from 1999 to 2007 ranging from 200 gallons per customer to 252 gallons per customer with peaking factors of 1.39 to 1.73.

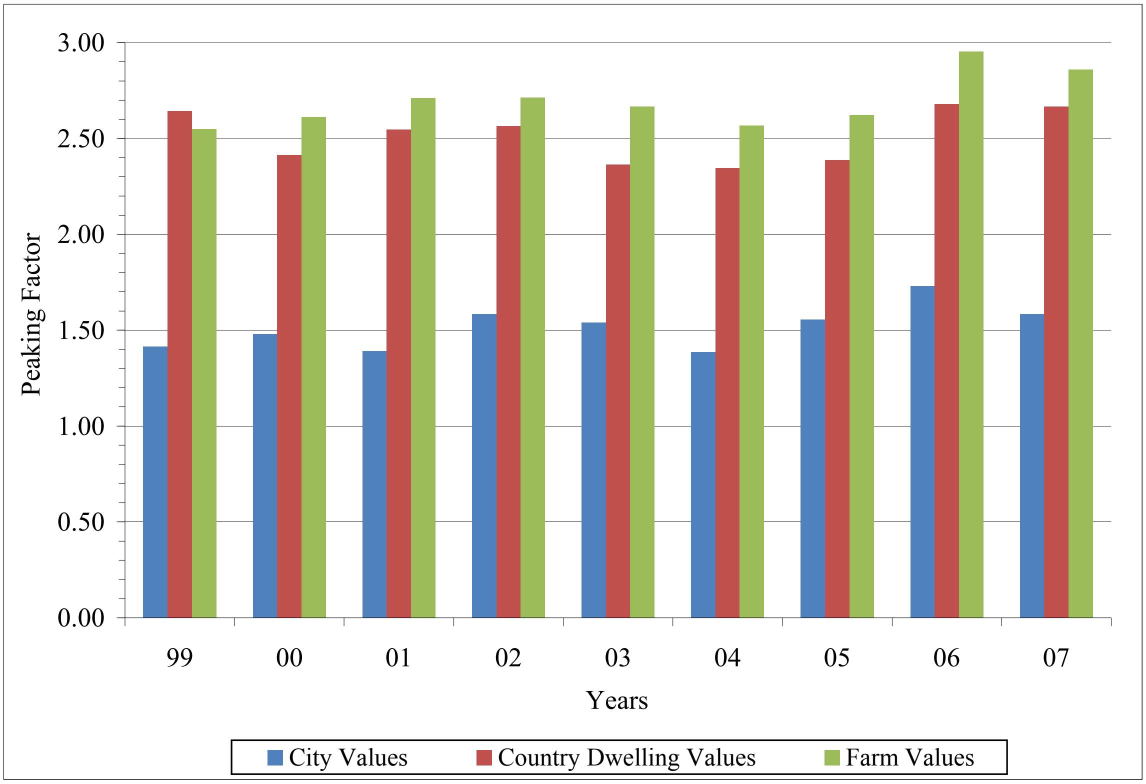


Figure F.13. Monthly Peaking Factors for Clay's Customer Classification

Figure F.14 illustrates Clay's last consumption characteristic that all customer classifications typically consumed less water per customer during wetter precipitation years. Two exceptions occurred with all three classifications at 24.78 inches of precipitation (year 2006) and 26.65 inches of precipitation (year 2007). Possible reasons for the irregularity in trending could be that the City of Vermillion (the location where the precipitation was recorded) received several additional inches of precipitation throughout the year that the majority of Clay's RWS did not experience. Or possible the precipitation gauge was calibrated or replaced at the end of 2005 providing increased accuracy in 2006 and 2007. The country dwelling classification had the largest increase in daily water demand of 32% when precipitation ranged from 29.35 inches to 22.56 inches. City and farm customers also exhibited modest increases in daily water demands during low precipitation years with the largest increase during the year with 24.78 inches of precipitation. Farm customers displayed an increase in daily water demand of 28% while city customers had an increase of 21%. Precipitation played a moderate role in Clay's daily water demands and should always be considered when predicting future demands.

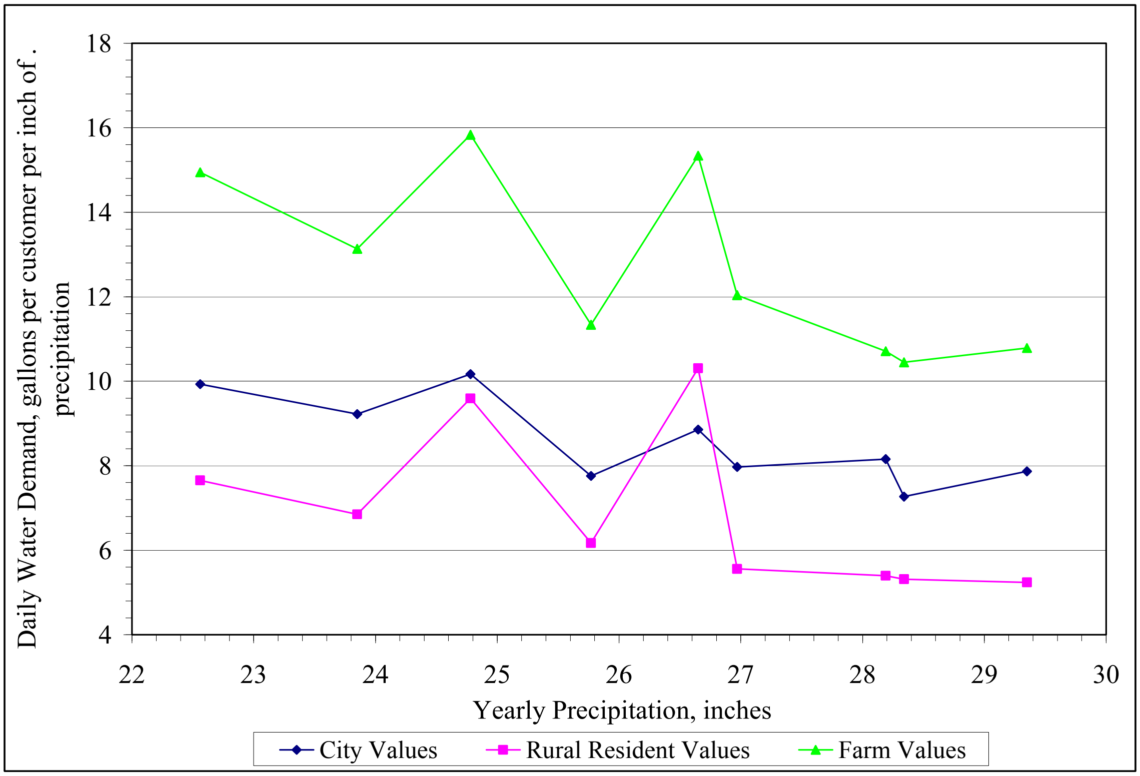


Figure F.14. Daily Customer Water Demand versus Yearly Precipitation for Clay

F.3 Mid-Dakota Rural Water System Water Demand Variations & Trends

Demand variations and trends for the Mid-Dakota RWS represent those of a system with commercial, rural, farm, and municipal customers. Figures F.15 and F.16 represent the percent of total water consumption and annual demands for Mid-Dakota's city customers, country dwelling customers, farm customers, and other customers. The major consumption of water during 2005 to 2007 came from the city classification, mainly the City of Huron. This classification consumed 52% of the total water consumption with the City of Huron making up 78% of the classification's consumption. The other customer classification, made-up of large to small commercial users, consumed 22% of Mid-Dakota's total water demand. Mid-Dakota's overall water consumption characteristics will be highly influenced by demand characteristics of the City of Huron and commercial customers. Demand characteristics of the country dwelling (13% of total demand) and farm customers (13% of total demand) will have a minimal affect on the system's consumption characteristics. The distribution of water consumption is outlined in Figure F.15.

The quantified demand of all four customer classifications is shown in Figure F.16. The total million gallons (MG) of water consumed by the city, country dwelling, farm, and other classifications all varied little from 2005 through 2007. City customer's consumption increased by 2.2% or 143 MG, farm consumption increased by 0.4% or 32 MG, country dwelling consumption decreased by 0.6% or an increase of 18 MG, and other consumption decreased by 2.0% or an increase of 20 MG. The City of Huron

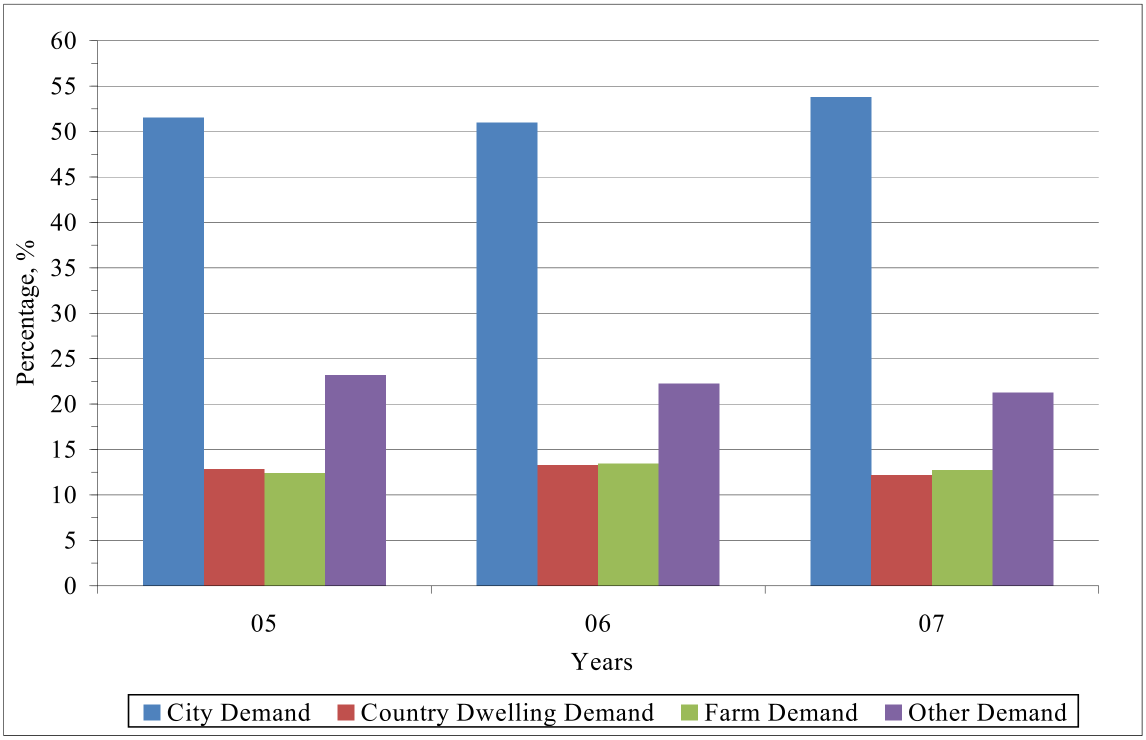


Figure F.15. Percentages of Yearly Water Demand for Mid-Dakota's Customer Classifications

made-up approximately 41% of Mid-Dakota's yearly water demand by consuming 592 million gallons of water a year. When compared to Big Sioux, Clay, and TM; Mid-Dakota was the largest provider of rural water by selling roughly 1.45 billion gallons per year.

The country dwelling classification had the second highest percent of customers at 17%, behind the city classification (70%), and displayed a continual yearly rise. The farm classification also presented a continual yearly rise and made-up 10% of the total number of customers. Mid-Dakota's other customer classification was made-up of large to small commercial customers and represented about 3% of all Mid-Dakota's customers. The breakdown of Mid-Dakota's customers are explained by Figure F. 17 and F.18.

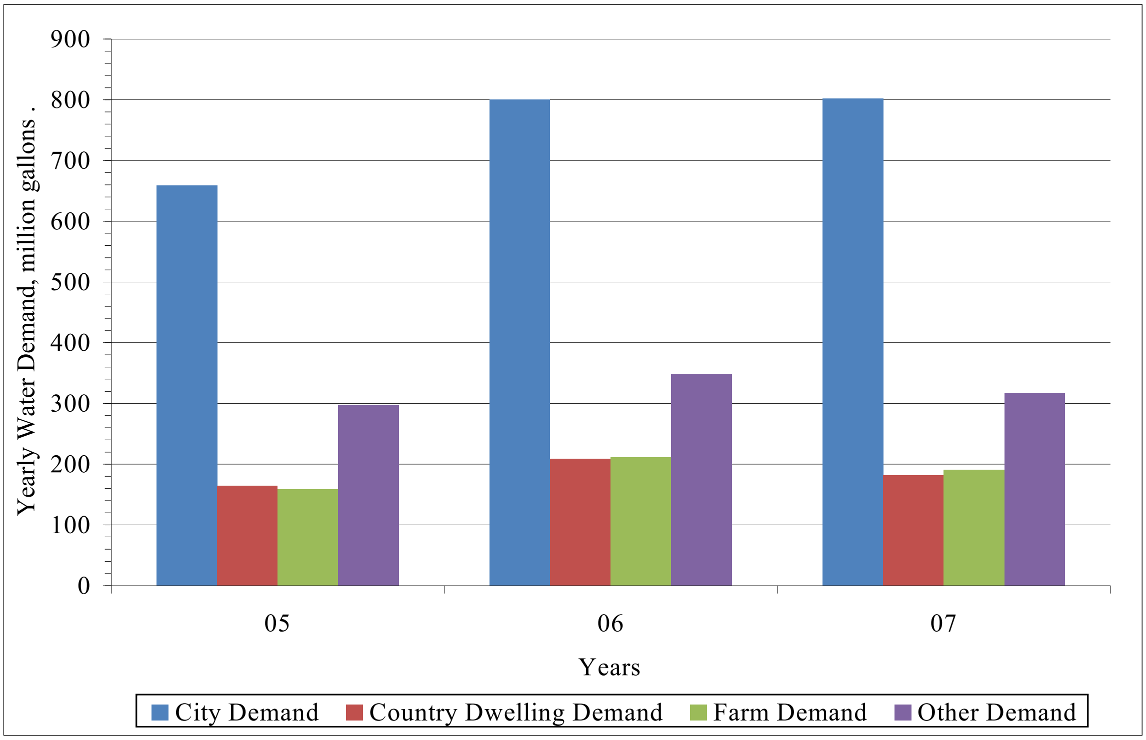


Figure F.16. Yearly Water Demand for Mid-Dakota's Customer Classifications

The number of individual customer water meters for each of the four cities served as bulk cities was not available, so a method of counting the individual water meters was created. That method was the same method discussed in Section 4.3.1 and also in Appendix D. The method of determining the amount of city customers was an approximation. The actual number of city customers could change the data represented in Figures F.17, F.18, F.19, and F.21. The ten other cities/communities that were served as individual cities/communities had their number of customer water meters, which was added to the calculated number of water meters from the bulk cities.

Illustrated in Figure F.17 is a trend showing the percentage of country dwelling customers on a slight rise of 1.6% each year and the city customers on a slight decline of 2.3% each year. The trend of increasing country dwelling customers will likely have an effect on the cost that Mid-Dakota associate with infrastructure and maintenance for each classification type for the following reasons.

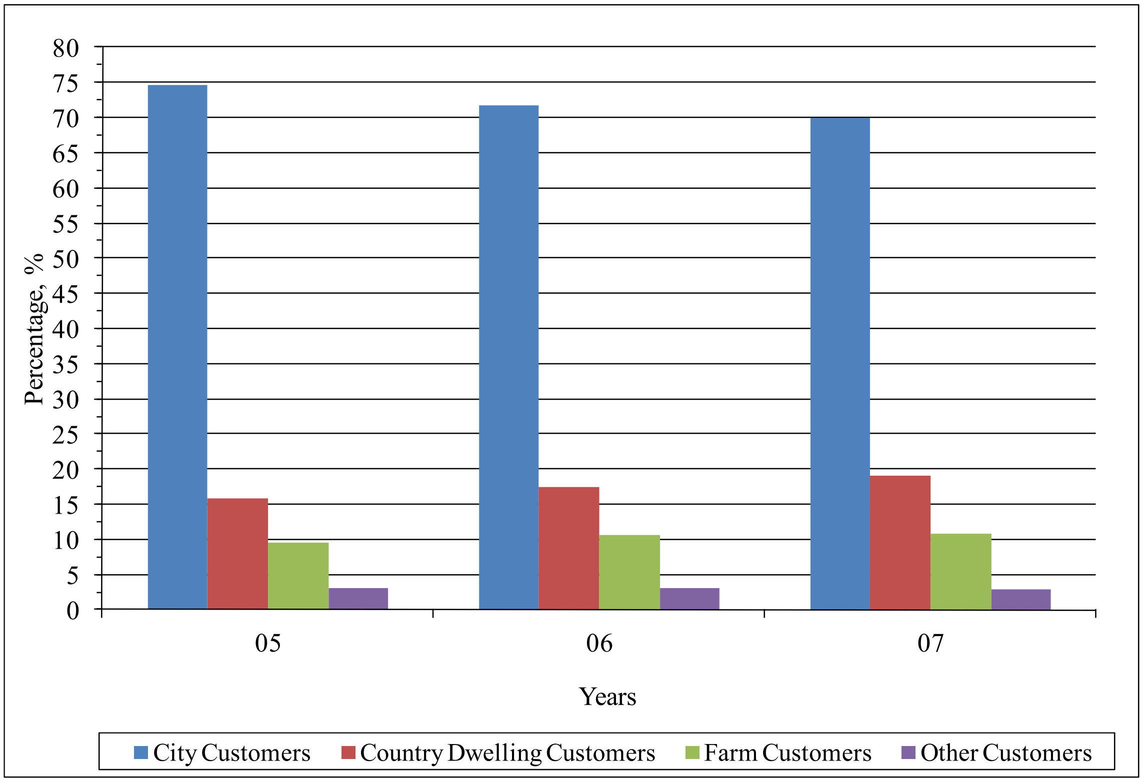


Figure F.17. Percentages of Yearly Water Meter Customers for Mid-Dakota

Typically, country dwelling customers were spread out over long distances. Those long distances required miles of infrastructure and routine maintenance to connect a single dwelling, whereas, city customers were served as bulk cities (95% of the city customers) which meant, Mid-Dakota did not pay for the infrastructure or the routine maintenance of the distribution systems within each city. Similarly to country dwellings, the farm customers were typically spread out over long distances; however, unlike the country dwelling customers most of Mid-Dakota's farm customers were individually large consumers of water.

Figure F.18 demonstrates Mid-Dakota's increase in water customers throughout the years with 9,531 customers in 2005 to 10,083 customers in 2007. Mid-Dakota added 324 water customers in 2006 and 228 water customers in 2007 but lost 55 city customers during the same period. Of those 552 new water customers, 418 were country dwelling customers, 182 were farm customers, 7 were commercial/industrial customers, and 55 city customers left the RWS.

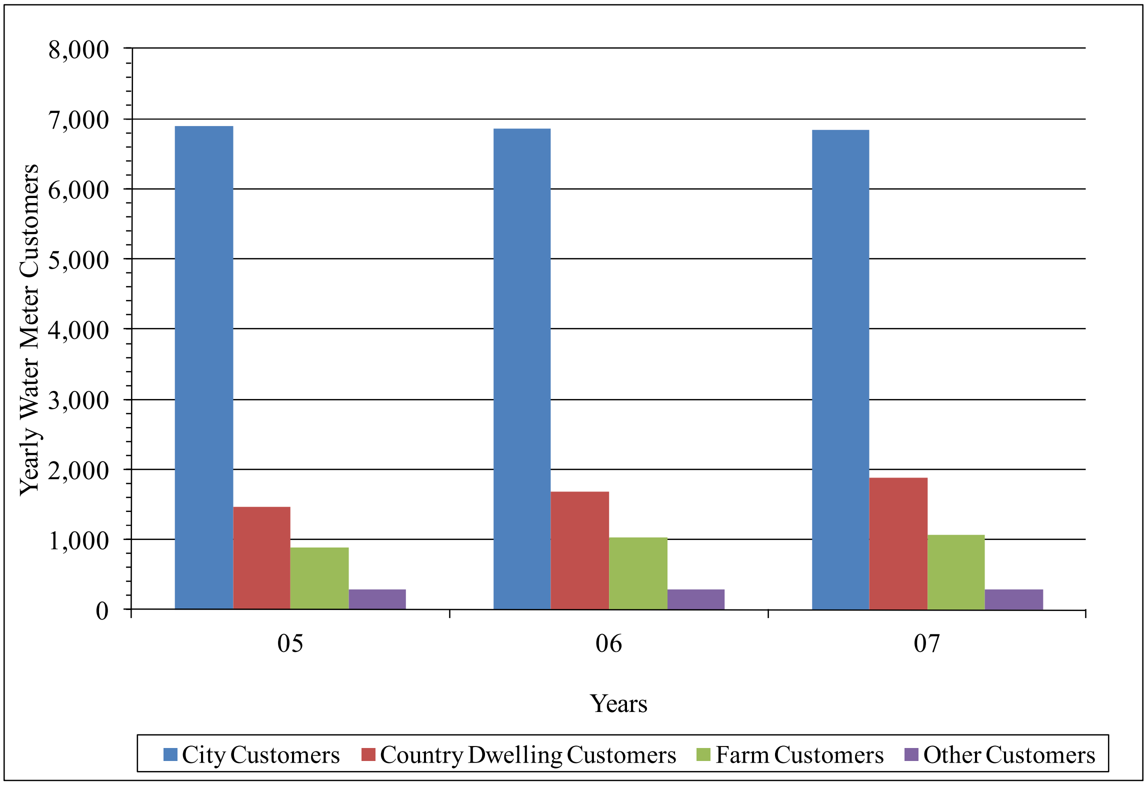


Figure F.18. Number of Yearly Water Meter Customers for Mid-Dakota

Another important water consumption characteristic was the daily water demand per customer because the characteristic could be used to predict the yearly water demand that each customer classification would place on the overall RWS. By coupling the daily water demand with the monthly peaking factors, Mid-Dakota could predict the maximum month water demand for future years. Figures F.19 and F.20 show the daily water demand per customer and the monthly peaking factors for each customer classification. The other customer classification was not included in the following figures because of skewed results. The city customer classification had a reasonably constant daily water demand from year to year while the other two customer classifications varied. Of the three customer classifications, the farm customers had the highest daily water demand at 490 gallons per customer up to 565 gallons per customer; more than twice the consumption of the city customers. Farm customers exhibited consistently low monthly peaking factors of 1.14 to 1.40. Since the peaking factors were so close to 1.0, it was evident that the farm customers placed a fairly constant monthly water demand on the overall RWS.

The daily water demand for the country dwelling customers was the second highest of the three classifications ranging from 263 gallons per customer to 335 gallons per customer. Like the farm customers, the country dwelling customers exhibited consistently low monthly peaking factors from 1.47 to 1.58; however, the monthly peaking factors progressively increase each year. The increasing peaking factors

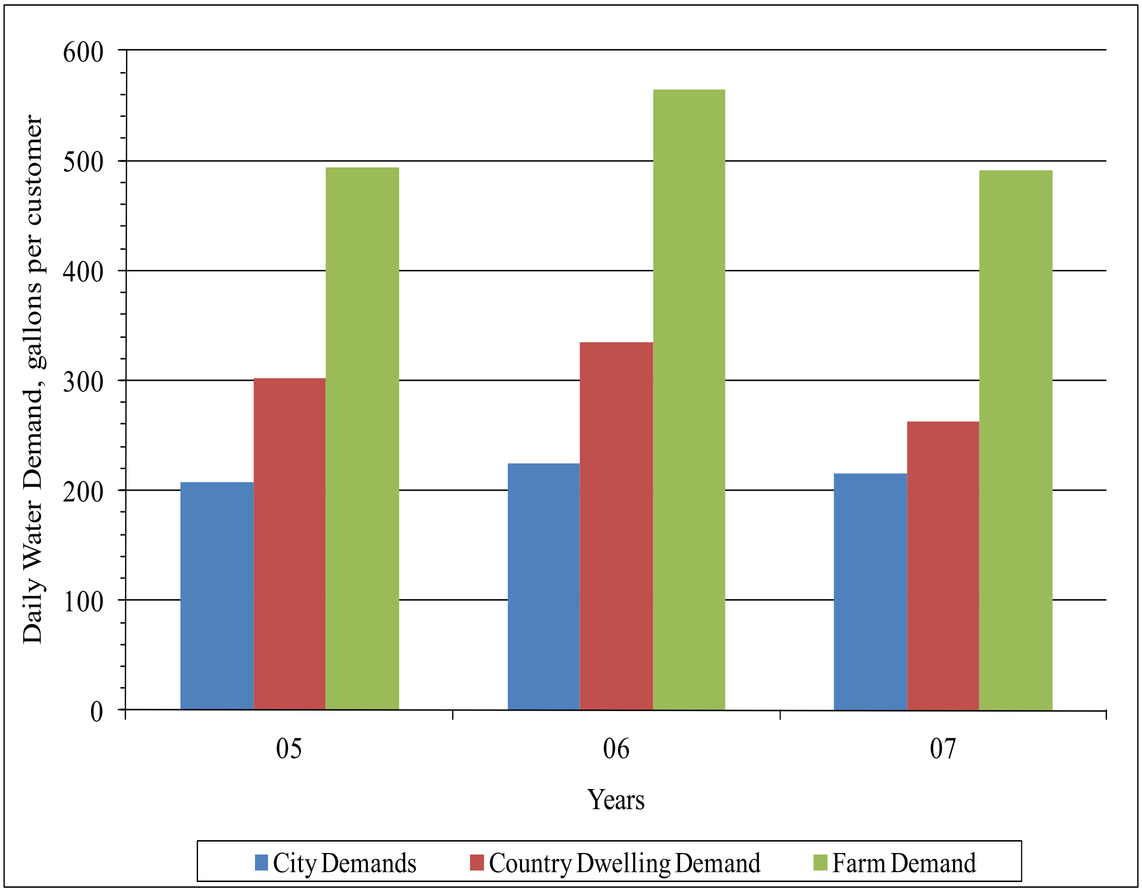


Figure F.19. Daily Water Demand per Customer for Mid-Dakota's Customer Classifications

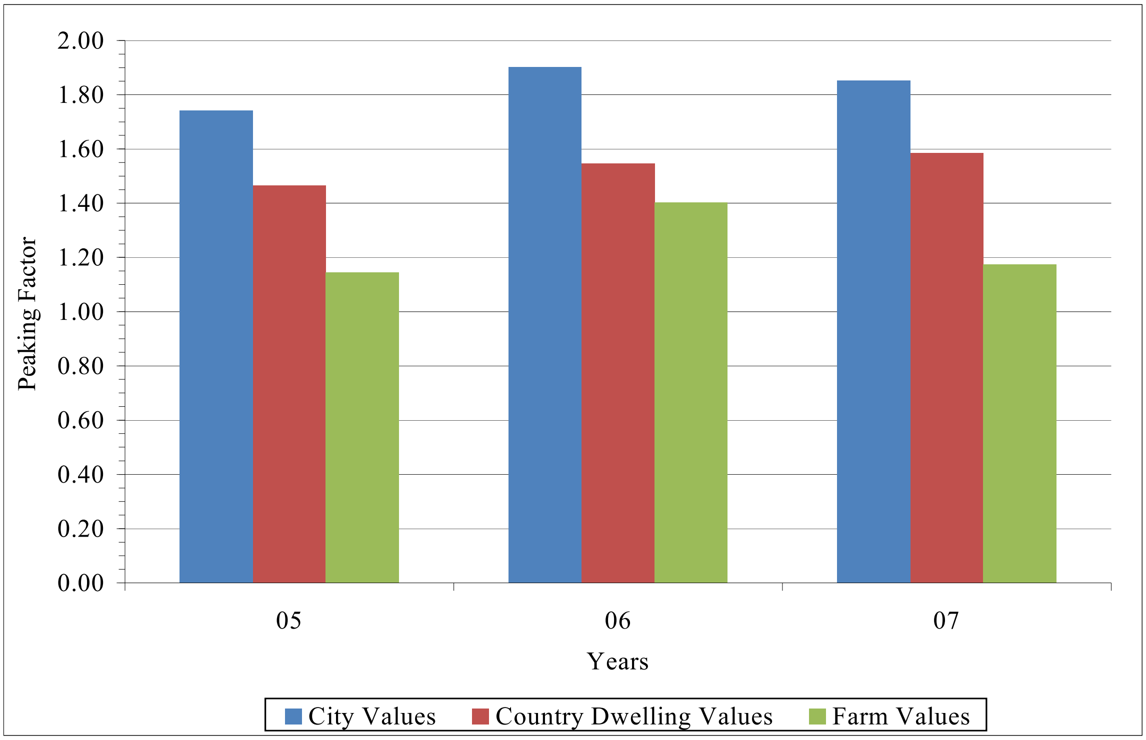


Figure F.20. Monthly Peaking Factors for Mid-Dakota's Customer Classification

indicated that the country dwelling customers were increasingly consuming more water during the summer months than the rest of the year. This phenomenon coupled with the increasing country dwelling customer base will gradually play a more significant role in shaping Mid-Dakota's demand characteristics. City customers' daily water demands stayed nearly the same from 2005 to 2007 ranging from 208 gallons per customer to 224 gallons per customer with moderate peaking factors of 1.74 to 1.90.

Figure F.21 illustrates Mid-Dakota's last consumption characteristic that all customer classifications consumed less water per customer during wetter precipitation years. The country dwelling classification had the largest increase in daily water demand of 56% when precipitation ranged from 30.66 inches to 17.15 inches. Farm customers and city customers also exhibited large increases in daily water demands during low precipitation years with the largest increase during the year with 17.15 inches of precipitation. Farm customers displayed an increase in daily water demand of 52% while city customers had an increase of 46%. Precipitation played a significant role in Mid-Dakota's daily water demands and should always be considered when predicting future demands.

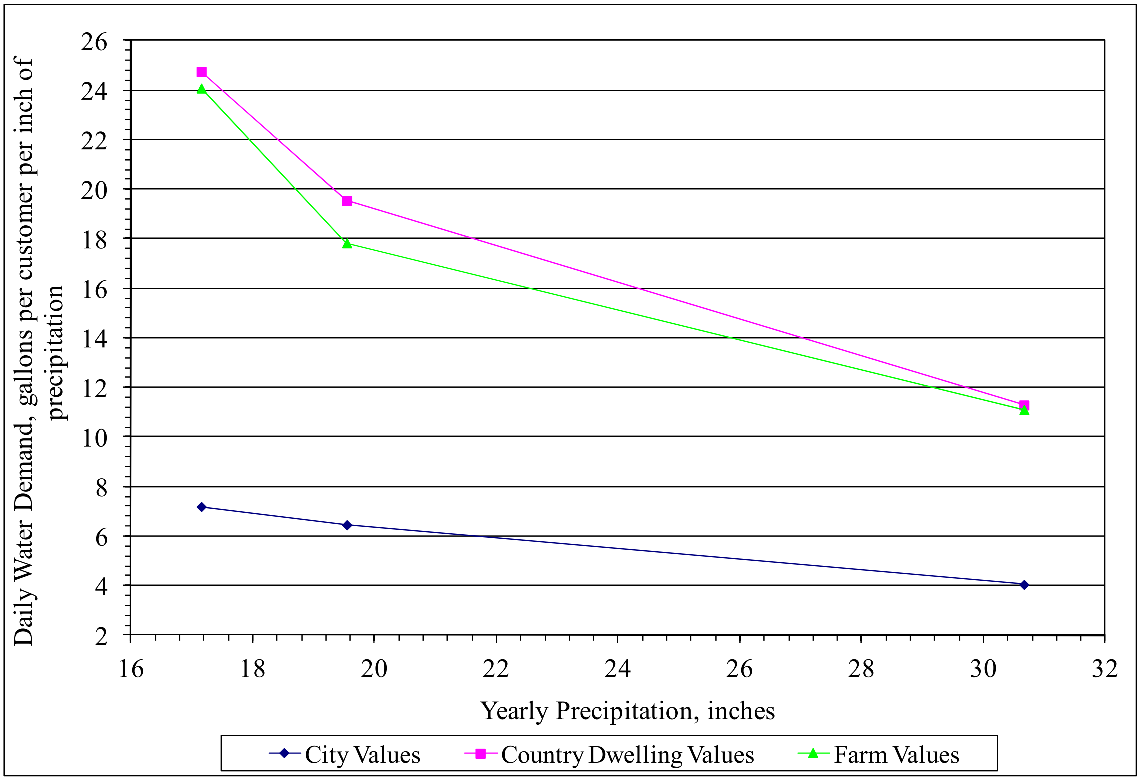


Figure F.21. Daily Customer Water Demand versus Yearly Precipitation for Mid-Dakota

F.4 TM Rural Water System Water Demand Variations & Trends

Demand variations and trends for the TM RWS represent those of a system with municipal, rural, farm, and commercial customers. Figures F.22 and F.23 represent the percent of total water consumption and annual demands for TM's city customers, country dwelling customers, farm customers, and other customers. The major consumer of water varied from year to year between the city and other classifications with the city classification topping the demand seven of the nine years. The city classification consumed 32% and the other classification consumed 25% of the total water consumption. From 1999 through 2007 the farming classification experienced a gentle decrease in total percent consumption of 0.7% each year. The percent decrease for the farming classification was mirror by the country dwelling classification's gradual increase in total percent consumption from 1999 to 2003 of 0.9% and again from 2005 to 2007 of 0.8%. Total water consumption of the farm classification and country dwelling classification was 26% and 16%, respectively. TM's overall water consumption characteristics will be highly influenced by demand characteristics of all four customer classifications. The distribution of water consumption is outlined in Figure F.22.

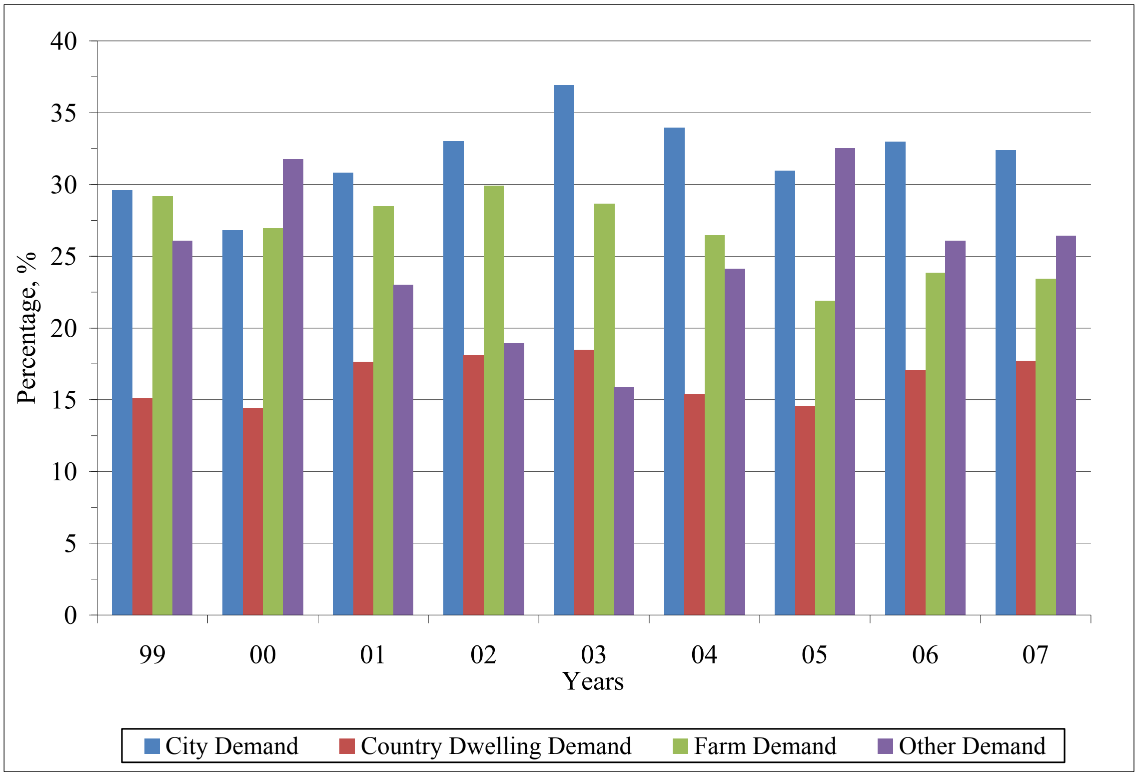


Figure F.22. Percentages of Yearly Water Demand for TM's Customer Classifications

The quantified demand of all four customer classifications is shown in Figure F.23. The total million gallons (MG) of water consumed by the country dwelling and farm classifications varied little from 1999 through 2007; however, the country dwelling classification demonstrated a steady 6% rise in yearly consumption until 2004 (14% decrease) than continued with a 5% rise in yearly consumption. From 1999 through 2007 the farm classification exhibited a decline of 2% in yearly consumption. The trend of rising water consumption for the country dwelling classification was common among all four water systems. The city classification exhibited a 16 MG increase in total consumption from 1999 to 2007 mainly due to the addition of the City of Marion in late 2002. When compared to Big Sioux, Clay, and Mid-Dakota; TM was the smallest provider of rural water by selling roughly 231 million gallons per year.

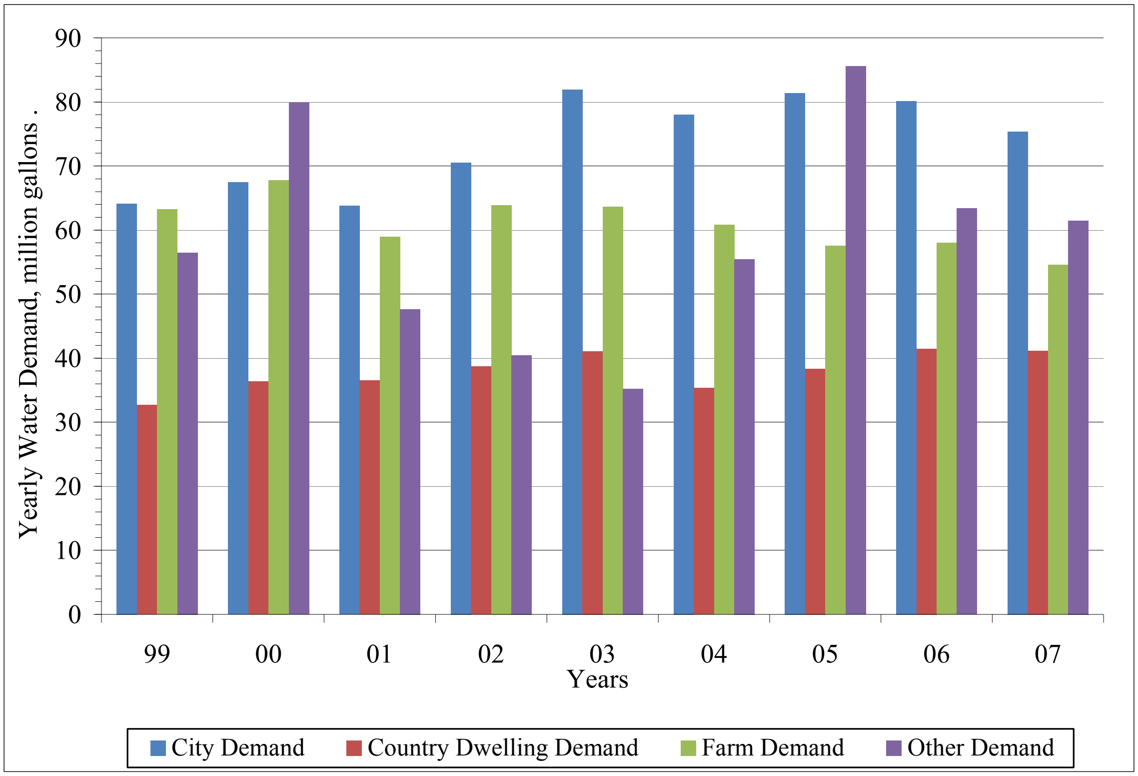


Figure F.23. Yearly Water Demand for TM's Customer Classifications

The country dwelling classification had the second highest percent of customers at 27%, behind the city classification (54%), and displayed a continual yearly rise. TM's other customer classification was made-up of mostly large dairy farms, hog operations, and commercial customers and represented about 4% of all TM's customers. The breakdowns of TM's customers are explained by Figure F.24 and Figure F.25.

The number of individual customer water meters for each city was not available, so a method of counting the individual water meters was created. That method was the same method discussed in Section 4.3.1 and also in Appendix D. The method of determining the amount of city customers was an approximation. The actual number of city customers could change the data represented in Figures F.24, F.25, F.26, and F.28.

Illustrated in Figure F.24 is a trend showing the percent of country dwelling customers on a slight rise of 0.7% each year, with the exception of 2002 when the City of Marion was added, and the farm customers on a slight decline of 0.4% each year. The trend of increasing country dwelling customers will likely have an effect on the cost that TM associates with infrastructure and maintenance for each classification type for the following reasons.

Typically, country dwelling customers were spread out over long distances. Those long distances required miles of infrastructure and routine maintenance to connect a single dwelling, whereas, city customers were served as bulk cities which meant, TM did not pay for the infrastructure or the routine maintenance of the distribution systems within each city. Similarly to country dwellings, the other and farm customers were typically spread out over long distances; however, unlike the country dwelling customers most of TM's other (dairy farms, hog operations, and commercial) customers and farm customers, to a lesser degree, were individually large consumers of water.

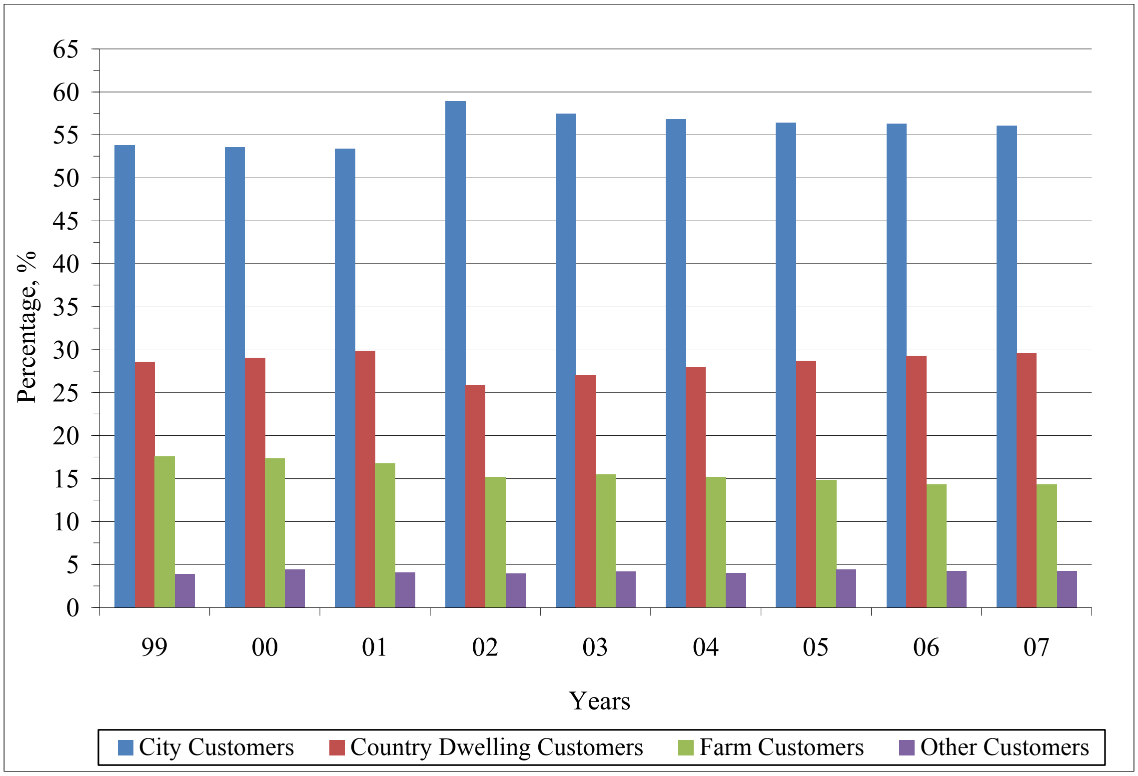


Figure F.24. Percentages of Yearly Water Meter Customers for TM

Figure F.25 demonstrates TM's increase in water customers throughout the years with 1,955 customers in 1999 to 2,399 customers in 2007. TM added 363 water customers in 2002 with the addition of the City of Marion. Prior to 2002, TM averaged an addition of 10 water customers each year and after 2003 the average declined to a reduction of 8 water customers each year. From 2003 to 2007 TM average an increase of 15 country dwelling customers and 1 other customer each year and a decline of 8 city customers and 7 farm customers each year.

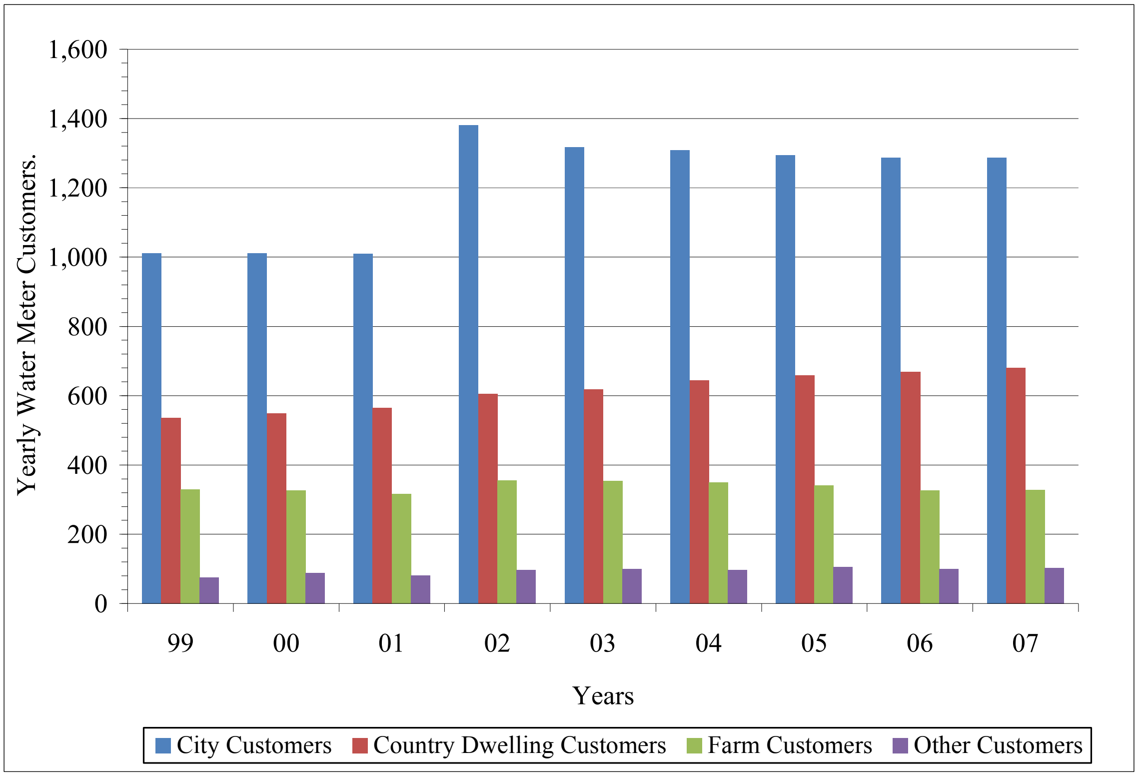


Figure F.25. Number of Yearly Water Meter Customers for TM

Another important water consumption characteristic was the daily water demand per customer because the characteristic could be used to predict the yearly water demand that each customer classification would place on the overall RWS. By coupling the daily water demand with the monthly peaking factors, TM could predict the maximum month water demand for future years. Figures F.26 and F.27 show the daily water demand per customer and the monthly peaking factors for each customer classification. The other customer classification was not included in the following figures because of skewed results. The three customer classification's had reasonably constant daily water demands from year to year. Of the three customer classifications, the farm customers had the highest daily water demand at 455 gallons per customer up to 565 gallons per customer; more than twice the consumption of the city and country dwelling customers. Farm customers exhibited consistently moderate peaking factors of 2.03 to 2.40. Since the peaking factors were moderate, it was evident that the farm customers placed reasonably higher monthly water demands on the overall RWS during certain months out of the year, mainly the summer months. The daily water demand for the country dwelling customers was the typically the second highest of the three classifications ranging from 150 gallons per customer to 182 gallons per customer. Like the farm customers, the country dwelling customers exhibited consistently high monthly peaking factors from 2.28 to 2.59. City customers' daily water demands displayed a steady consumption from 1999 to 2007 ranging from 149 gallons per customer to 165 gallons per customer with peaking factors of 1.38 to 1.75.

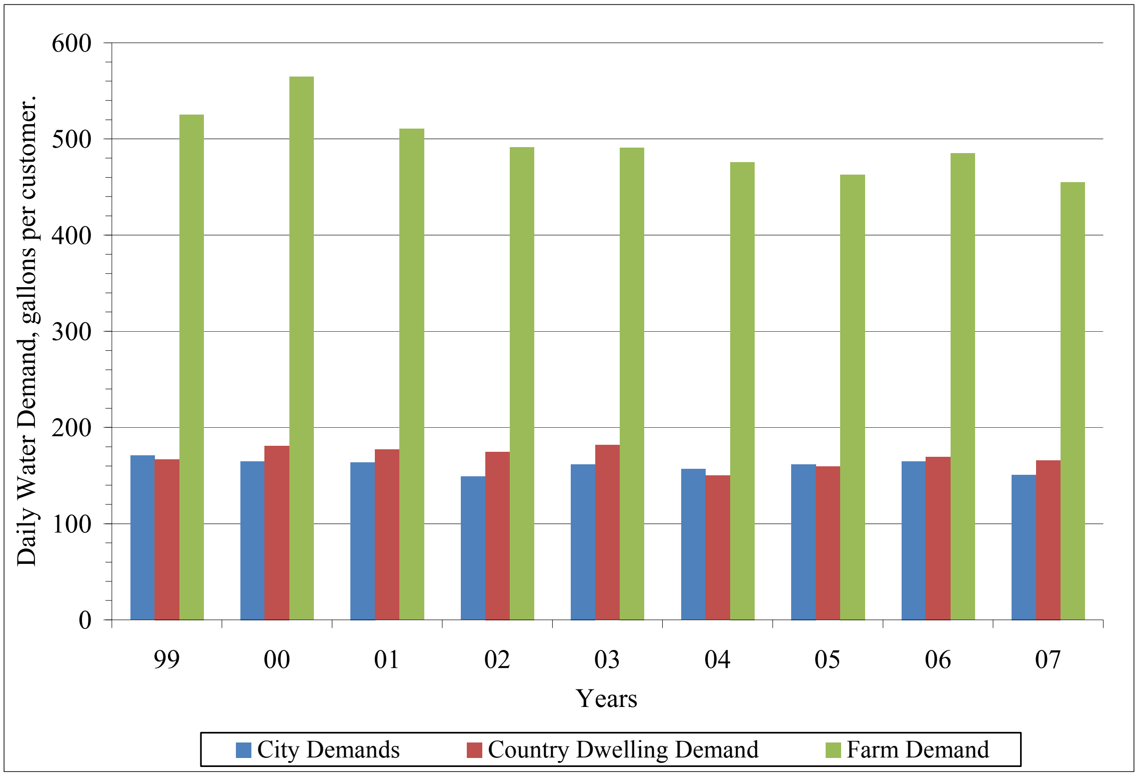


Figure F.26. Daily Water Demand per Customer for TM's Customer Classifications

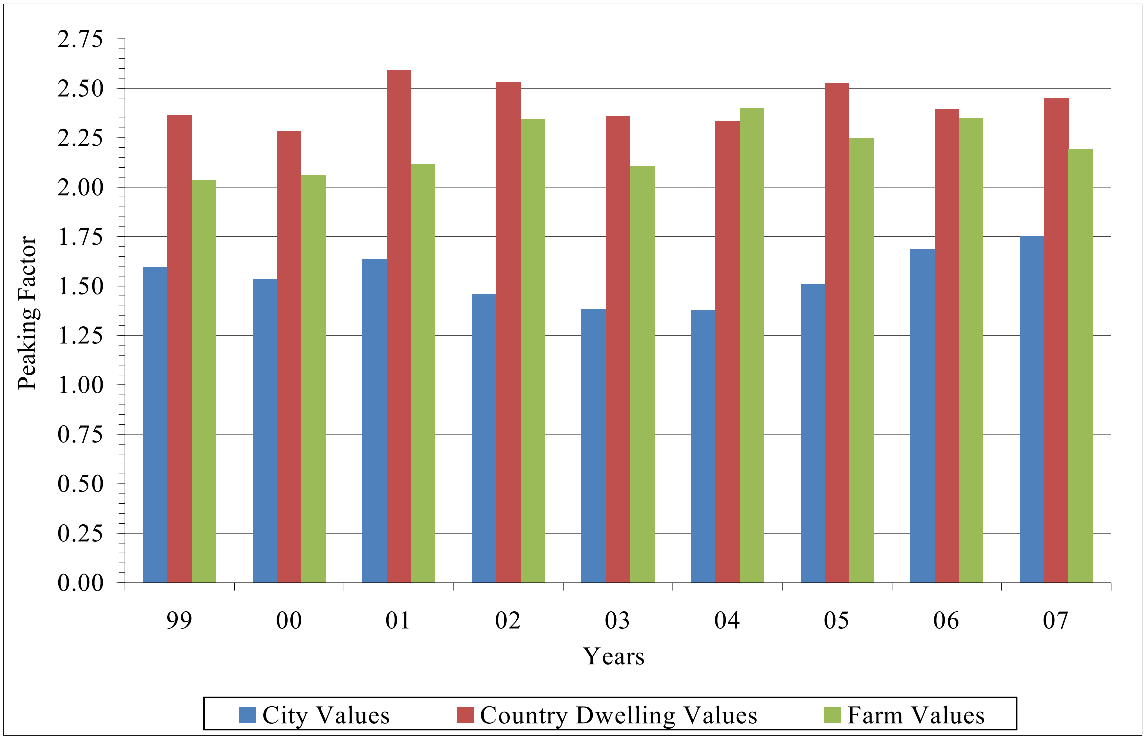


Figure F.27. Monthly Peaking Factors for TM's Customer Classification

Figure F.28 illustrates TM's last consumption characteristic that all customer classifications typically consumed less water per customer during wetter precipitation years. The city classification had the largest increase in daily water demand of 44% where precipitation ranged from 35.41 inches to 24.50 inches. Farm and country dwelling customers also exhibited modest increases in daily water demands during low precipitation years with the largest increase during the year with 24.70 inches of precipitation and 26.00 inches of precipitation, respectively. Farm customers displayed an increase in daily water demand of 31% while country dwelling customers had an increase of 30%. Precipitation played a moderate role in TM's daily water demands and should always be considered when predicting future demands.

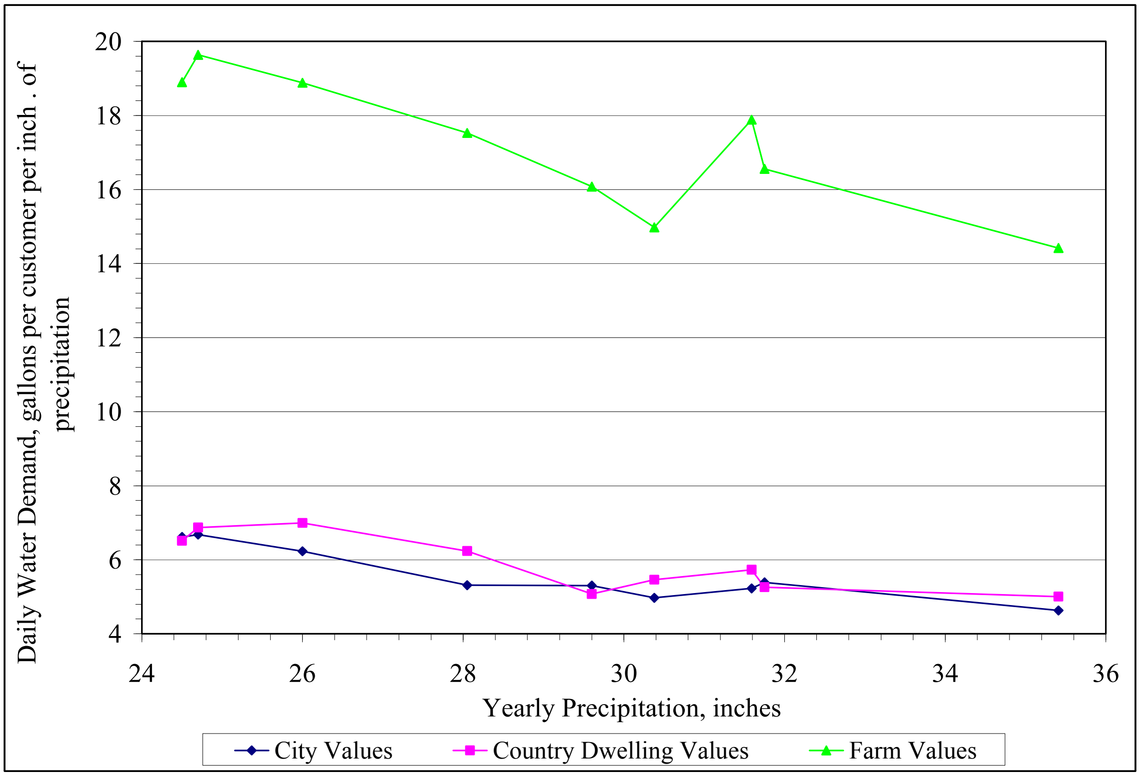


Figure F.28. Daily Customer Water Demand versus Yearly Precipitation for TM Rural Water.