Metropolitan Council Environmental Services

In Association with

Agricultural Utilization Research Institute

Reclaimed Water for Value-Added Agricultural Processing Project

FINAL REPORT

June 29, 2009

Craddock Consulting Engineers

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Executive Summary

The ethanol industry is a component of the Minnesota agricultural processing sector that has grown significantly over the past decade. Some ethanol facilities, and other industries, have experienced difficulty in obtaining an adequate water supply for operation. While water supply availability is not currently considered a limitation for industrial development in many Minnesota communities, there are areas in the state that have a limited supply of high quality water. Industries requiring abundant or high quality water may find it difficult to locate or expand in some areas unless other water supply options are made known and available to them. One potential water supply is effluent from municipal wastewater treatment plants (WWTPs), also known as reclaimed water, recycled wastewater, or recycled water.

Background

The Agricultural Utilization Research Institute (AURI) recognized the value of reclaimed water for the agricultural processing industry and initiated action to conduct a study on the feasibility of water reuse. AURI contacted the Metropolitan Council Environmental Services (MCES), St. Paul, Minnesota, to coordinate efforts for a water reuse study focused on the agricultural processing community. MCES recently completed a study on the feasibility of industrial water reuse in Minnesota [MCES, 2007]. Funding for this study was recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR) from the Environment and Natural Resources Trust Fund.

The MCES-AURI project builds on the work already completed by MCES with context and specific considerations for the agricultural processing industry. Two technical memoranda were developed and form this project's final report: *Reclaimed Water for Agricultural Processing* and *Ethanol Facility Water Reuse Case Study.* The first document provides an overview of water reuse in Minnesota with specific applications and considerations for agricultural processing facilities. The second document provides a planning level analysis of facilities and operation and maintenance (O&M) requirements to supply reclaimed water to an ethanol facility for cooling water use. The analysis identifies the basic project elements that need to be evaluated to technically implement a project.

Drivers

There are four main drivers for water reuse, in general, and industrial-related reuse in particular for Minnesota: water quality, water quantity, environmental stewardship, and sustainable economic growth. Table ES-1 summarizes the key concepts for these drivers.

Water Use

Water used for agricultural activities in Minnesota totaled 140,480 million gallons/year (mgy) in 2007. Agricultural water uses account for approximately 10% of the total water use in the state and nearly 40% of the state's groundwater withdrawals, based on 2007 records [Minnesota Department of Natural Resources, 2008]. As a point of perspective, total water use in Minnesota in 2007 was 1,430,000 mgy of which nearly 60% or 840,000 mgy was the use of surface water for once-through cooling at power generation facilities.

Table ES.1. Water Reuse Drivers in Minnesota

Driver	Key Concepts
Water Quality	Historic water reuse applications have been water quality driven. Agricultural irrigation of treated wastewater effluent has been practiced in Minnesota's rural areas in lieu of summer pond discharges for facilities a significant distance from an acceptable receiving stream.
	Water quality issues will drive future water reuse in Minnesota. As growing communities generate additional wastewater, there will be a need to provide higher levels of wastewater treatment to maintain or decrease the discharge loads to the state's waterways. Finding other uses for the treated wastewater, through partnerships with industry or other users, will decrease wastewater discharges. The development of Minnesota's Total Maximum Daily Load (TMDL) program will affect the discharge allocations for most communities.
Water Quantity	While discharge limitations will increasingly be a factor in Minnesota, it is anticipated that water supply limitations will be a driver in the near future given water supply shortages at regional and local levels.
	The water demands of the ethanol industry in Minnesota's water supply-limited southwest region have required investigating water supply options other than local groundwater and were the impetus for this study.
Environmental Stewardship	Minnesota's environmental stewardship ethic has promoted the conservation and protection of water resources.
	This stewardship ethic can drive reuse projects even when other drivers are not present and when economics would not point to reuse.
Sustainable Economic Growth	The Minnesota Legislature is interested in industrial water reuse as a means of fostering sustainable economic growth, as indicated in funding for a previous MCES study [MCES, 2007].
	Recent legislation (H.F. 1231) provides grants for water reuse capital projects specifically aimed at ethanol facilities and the conservation of groundwater resources for potable water uses.

The largest agricultural water use in the state is for major crop irrigation, accounting for around 75-85% of the water withdrawn for agricultural purposes (119,970 mgy), as shown in Figure ES.1. 2007 was a dry year and irrigation use is a higher percentage of the total use. The next largest use is for agricultural product processing (10,250 mgy), followed by aquaculture (6,730 mgy), noncrop irrigation where agricultural applications include sod farms, orchards, and nurseries (1,490 mgy), biofuels production (1,430 mgy), and livestock watering (790 mgy).

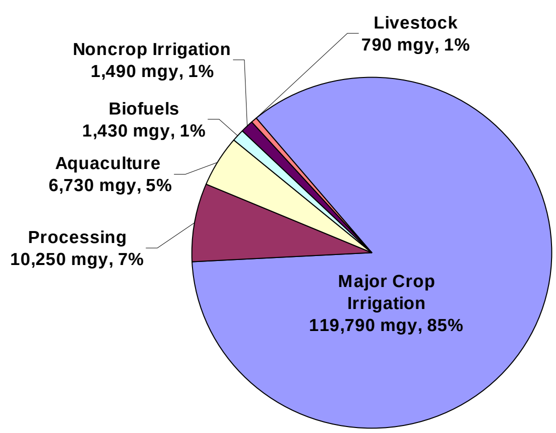


Figure ES.1. Agricultural Water Use in Minnesota, 2007 (Dry Year)
Source: MDNR, 2008

The majority of the agricultural water supply is from groundwater sources. Figure ES.2 provides a better perspective on the relationship of water uses without a comparison to major crop irrigation and also identifies the source as ground or surface water. While not shown, groundwater supplied nearly 90% of the major crop irrigation in 2007.

Other key findings related to agricultural processing water use include:

- Water use for the agricultural processing sector (including biofuel production facilities) over the last 20 years has fluctuated between 10,000 and 13,000 mgy. The largest water users are food processing facilities.

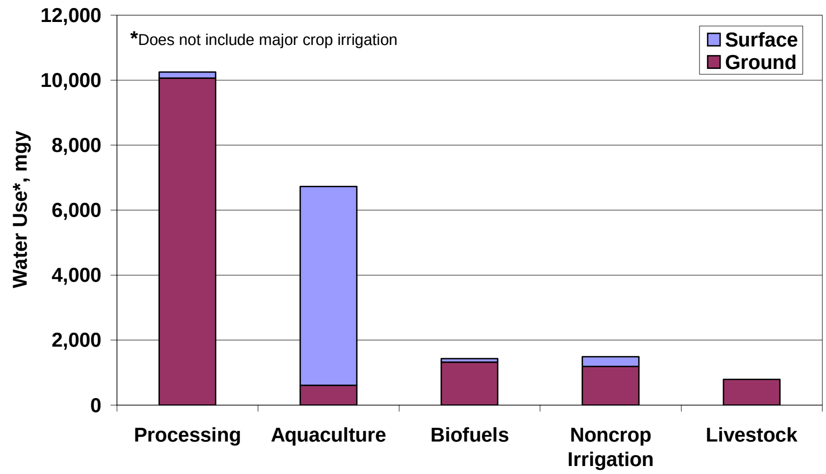


Figure ES.2. Agricultural Water Use by Source*, 2007
Source: MDNR, 2008

- The quantity of water used for the various agricultural processing practices is highly variable and facility-specific. Ethanol facilities, the example industry for this study, use between 3-6 gallons of water for every gallon of ethanol produced. Newer facilities typically have lower water use rates. The total water use reported for biofuels production in 2007 was 1,430 mgy, which accounts for 10 of the 16 facilities online in 2007. The other facilities use a community potable water supply and are not included in this analysis which is based on water users with a permitted water supply.

- Agricultural processing facility water use includes water used for processing and production, cooling, boiler feed, air conditioning, washing, stack scrubbing, transport of materials, sanitation, potable supply for personnel, and grounds irrigation. Cooling water is often one of the largest uses of water and one of the most common uses of water at an agricultural processing facility. Cooling water is also the most common application for industrial use of reclaimed water in the U.S.

Implementation Considerations

- Regulatory
  - Minnesota is one of several states that have not developed state water reuse criteria. Currently, Minnesota uses California's *Water Recycling Criteria* [State of California, 2000] to evaluate water reuse projects on a case-by-case basis. In Minnesota, water reuse requirements are included in NPDES permits administered by the MPCA.
  - A WWTP supplying reclaimed water will be required to monitor for total coliforms, meet total coliform limits, and modify their treatment process train to meet the regulations. For

cooling water uses, most WWTPs would be required at minimum to add disinfection facilities and filtration.

- The modifications for reclaimed water production must continue to meet existing NPDES and other permit requirements and consider future permit conditions. Some treatment technologies result in concentrated waste streams and there is concern that pollutant concentration discharge limits (i.e. TDS, chloride, sulfate, boron, and specific conductance) may exceed the water quality standards for some receiving streams.

- Some agricultural processing facilities may fall under other federal or state regulations that could affect how and if reclaimed water can be used. For example, the U. S. Food Safety Inspection Service (FSIS) has regulatory sanitation performance standards applicable to all official meat and poultry establishments (FSIS Docket 96-037F; 64 FR 56400). These regulations apply to in-facility recycling of water as well as to the use of reclaimed water from outside of a facility. Specific language restricts the use of reclaimed water at these facilities.

■ Technical/Economic

- The water quality of the WWTP treated effluent, the water quality required for the agricultural processing facility's use, the existing WWTP process train, and regulatory requirements all influence the processes selected for a water reuse treatment system. Most agricultural processing facility water uses require a higher quality water, as with cooling water. WWTPs with nutrient removal and in areas with moderate water hardness may require only treatment facilities to meet regulatory needs to supply cooling water. For WWTPs without nutrient removal, additional treatment is needed and if hardness or salts need to be removed, more extensive treatment is required.

- Removal of hardness and high salt levels significantly adds to the cost. Communities relying on home softening systems, which discharge salts in the wastewater, will likely require more treatment to meet reclaimed water quality goals for dissolved solids and salts. A reclaimed water supply with low dissolved solids and salts treated by a membrane softening process is around $2.50 per 1,000 gallons more than a reclaimed supply that does not require softening.

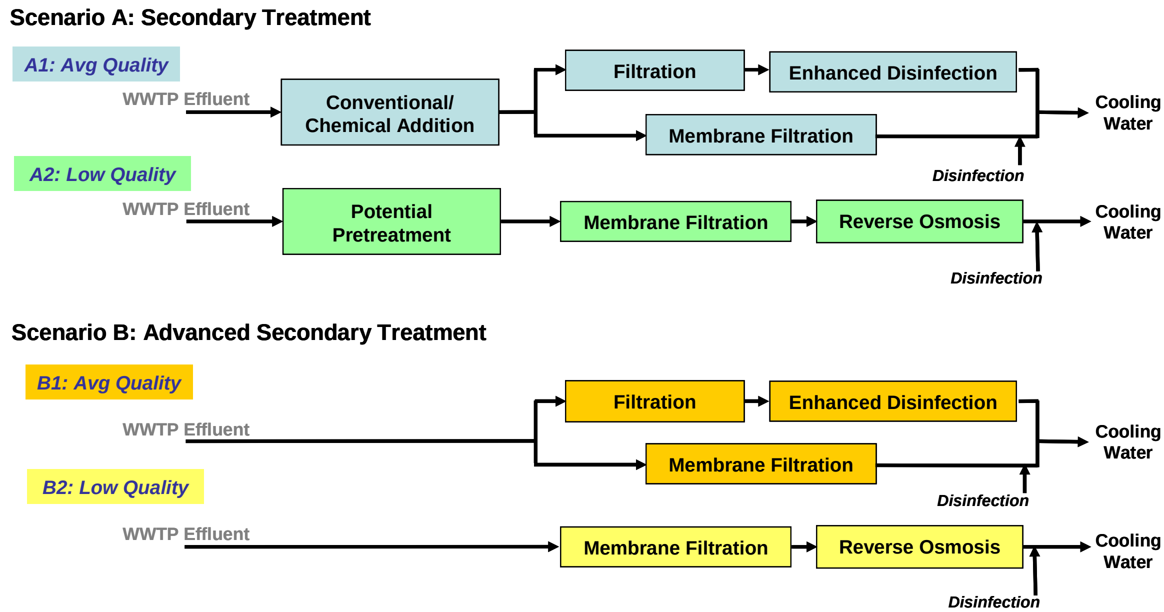
■ Institutional

- There are several institutional issues that need to be addressed for an agricultural processing facility to use reclaimed water such as: local planning ordinances, public involvement/education, legal agreements or contracts, agency jurisdictions, and fee structures.

- Experience from the one industrial project in Minnesota, cooling water for the Mankato Energy Center, and various irrigation reuse practices in Minnesota, and experience of other states can be used to frame the anticipated issues.

Ethanol Facility Case Study

Reclaimed water must meet regulatory requirements and be of suitable quality for use at an ethanol facility. Typical constituents of concern for cooling water applications are ammonia, chlorides, hardness, microorganisms, organic compounds, phosphorus, silica, sulfate, and TDS. The case study considered four alternative treatment scenarios to achieve reclaimed water that meets cooling water requirements. The scenarios, shown in Figure ES.3, cover differing levels of existing treatment at the WWTP as well as differing levels of hardness and salt concentrations in the WWTP effluent. Reclaimed water storage and transmission system requirements, generally significant cost components dependent on site-specific conditions, were assumed.



ES.3. Scenario Treatment Process Trains

The facilities to provide reclaimed water to ethanol plants is a significant investment. Overall capital costs to treat and transmit the water 5 miles were estimated to range from $7.4 million to $15 million. With annual costs considered, the cost of service for a 20-year life cycle period could range from $2.65 to $7.15/1,000 gallons. A reclaimed supply could be competitive with potable water supply system costs, which range from less than $1/1,000 gallons to over $5/1,000 gallons for communities in the vicinity of ethanol facilities. About one-third of the communities near ethanol facilities charge over $3/1,000 gallons for their potable water supply.

Capital costs for treatment were estimated to range from $2.9 million to $11 million and the annual treatment costs from $290,000 to $1,300,000. Areas with hard and high salt waters will have significantly higher costs to treat the water. However, ethanol facilities in these areas may have to treat their existing supply for cooling water and these costs could offset some of the treatment needs of the reclaimed water. The project components related to transmission were estimated to be $4.5 million and cost on average $75,000 a year to operate and maintain.

Other issues to consider include:

- The impact of reclaimed water use on the ethanol facility's NPDES permit and water appropriations permits.
- The impact of reclaimed water production on the WWTP's NPDES partnering opportunities that may arise as Minnesota's TMDL regulations are implemented.
- The potential to use reclaimed water for other ethanol facility water uses, such as process water.
- The potential for the WWTP to provide reclaimed water for other nonpotable water uses such as irrigation for golf courses, parks, residential areas; commercial/institutional building cooling; and other industrial water uses.

Reclaimed water is an emerging water supply for Minnesota industries and communities. Economic development, water supply limitations, and environmental regulations and stewardship will increasingly drive the need to find alternative water supplies. Communities with ethanol facilities and other industries with larger water demands provide conditions where water reuse can provide environmental benefits and economic advantages for both the community and industry.

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Reclaimed Water for Value-Added Agricultural Processing Project

TECHNICAL MEMORANDUM 1

Reclaimed Water for Agricultural Processing

June 29, 2009

Craddock Consulting Engineers

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Section 1
Introduction

1.1 Background

The ethanol industry is a component of the Minnesota agricultural processing sector that has grown significantly over the past decade. Some ethanol facilities, and other industries, have experienced issues in obtaining an adequate water supply for operation. While water supply availability is not currently considered a limitation for industrial development in many Minnesota communities, there are areas in the state that have a limited supply of high quality water. Industries requiring abundant or high quality water may find it difficult to locate or expand in some areas unless other water supply options are made known and available to them.

One potential water supply is effluent from municipal wastewater treatment plants (WWTPs), also known as reclaimed water, recycled wastewater, or recycled water. Communities can conserve their region's limited potable water supply by using treated wastewater effluent as an alternative nonpotable water source for an industry or other municipal nonpotable uses. The term, water reuse, is one typically used to define the use of treated wastewater plant effluent water for uses normally supplied by a water utility or another permitted water supply. The terms wastewater recycling, wastewater reuse, and water reclamation are also used and mean the same thing. For this study, the term "water reuse" pertains only to the use of treated municipal wastewater for nonpotable water supply use. Industries can also reuse water within their facility or a supply from another industry, but "water reuse" referenced in this study does not include these scenarios unless specifically stated.

The Agricultural Utilization Research Institute (AURI) recognized the potential value of reclaimed water for the agricultural processing industry and initiated action to conduct a study on the feasibility of water reuse. AURI contacted the Metropolitan Council Environmental Services (MCES), St .Paul, Minnesota, to coordinate efforts for a water reuse study focused on the agricultural processing community. MCES recently completed a study on the feasibility of industrial water reuse in Minnesota [MCES, 2007]. Funding for this previous study was recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR) from the Environment and Natural Resources Trust Fund.

The MCES water reuse study's guiding goal was to conserve Minnesota's water resources and provide the following benefits:

- Reduce groundwater depletion by providing an alternative supply for nonpotable water uses

- Provide a reliable and potentially lower cost water source for industries

The study results indicated that economic development, water supply limitations, and environmental regulations will increasingly drive the need to find alternative water supplies in

Minnesota. The analysis concluded that reclaimed water for industrial water use is feasible and, in some situations, cost competitive with other water supplies. Implementation issues exist, but are addressable. Water reuse can conserve water resources and support industries and economic development.

The MCES-AURI project builds on the work already completed by MCES with context and specific considerations for the agricultural processing industry. This technical memorandum summarizes the work efforts of Task 1 of the project and Task 2 will present a case study of water reuse at an ethanol plant. The third project task incorporates stakeholder involvement and further definition of implementation issues facing water reuse at agricultural processing facilities in Minnesota. MCES is responsible for Tasks 1 and 2 and AURI for Task 3.

1.2 Study Objective

The objective of this study is to assess the feasibility of utilizing reclaimed water in value-added agricultural processing. This study will provide the information needed for interested parties (agricultural processors, city leaders, and investors) to make sound economic and technical decisions.

1.3 Memorandum Content

Section 1 provides the setting for water reuse in Minnesota and specific applications and regulatory requirements for water reuse associated with agricultural processing facilities. The key drivers for water reuse and water use characteristics of the state are also identified. Section 2 presents historic water use for the agricultural sector of the state. The various water uses in typical agricultural processing facilities are summarized and evaluated for reuse. The ethanol production sector is highlighted as an example for potential water reuse applications for agricultural processing facilities. Implementation issues associated with water reuse, focusing on the regulatory requirements specific to this industry sector, are provided in Section 3.

1.4 Water Use in Minnesota

How much water do Minnesotans use and what is it used for? Major water use in Minnesota ranged from 1,270 – 1,430 billion gallons per year (bgy) during 2000-2007. This represents all permitted water users that withdraw more than 1 million gallons per year (mgy) and/or 100,000 gallons per day (gpd) of ground or surface water, and therefore, does not account for most domestic private well or surface withdrawals. The majority of the water use information reported in this document is based on the records maintained by the Minnesota Department of Natural Resources (MDNR) Appropriation Permits program (2008). While the water use information presented in this document does not include all uses since it excludes private, low volume users, it is based on a well-maintained data record that provides an accurate accounting of the users that are monitored.

Nearly 60% of the water used in Minnesota is for power generation facilities, mainly for once-through cooling, as depicted in Figure 1.1. As shown in Table 1.1 and Figure 1.2, cooling water is supplied mostly by surface waters. The MDNR tracks water use by nine categories. Several of these categories were combined to summarize water use. Irrigation is presented by both major and non-crop irrigation and the "Other" category combines air conditioning, special, temporary, and water level maintenance categories.

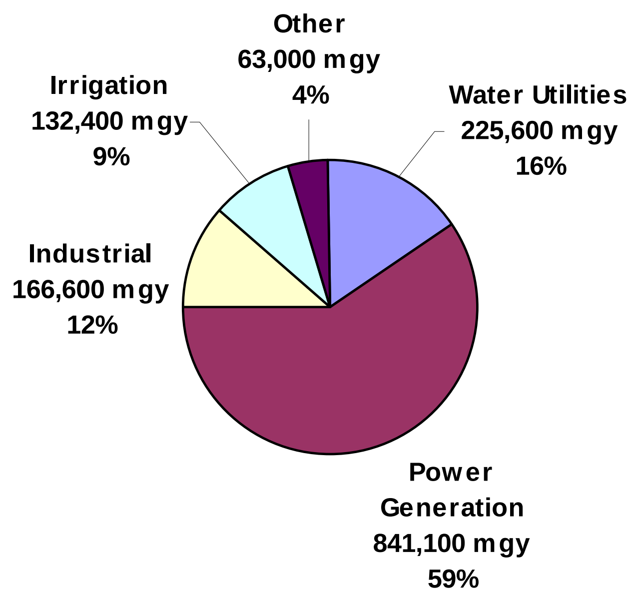

Figure 1.1. Water Use in Minnesota, 2007
Source: MDNR, 2008

Table 1.1. Water Use in Minnesota by Source, 2007

	Water Use, mgy		
Category	**Groundwater**	**Surface Water**	**Total**
Power	1,300	839,800	841,100
Water Utilities	149,100	76,500	225,600
Industrial	19,500	147,100	166,600
Irrigation	115,000	17,300	132,400
Other	16,700	46,300	63,000
Total	**301,600**	**1,127,100**	**1,428,700**

Source: MDNR, 2008
mgy=million gallons per year

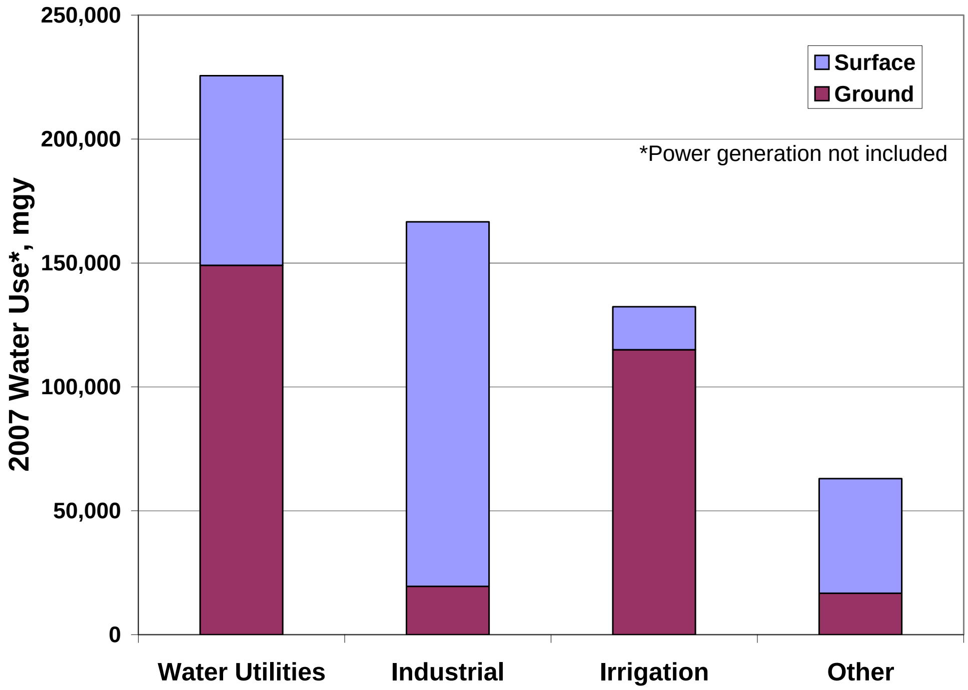

Figure 1.2. Water Use in Minnesota by Source*, 2007
Source: MNDR, 2008

The next largest use of water, over 15% of the total, is as a potable-quality water supply (water utilities), distributed by municipalities for domestic, commercial and industrial uses. Nearly two-thirds of the potable-quality water in Minnesota is supplied by groundwater. Water withdrawn by industries (those not served by water utilities) for various processing needs accounts for about 12% of the total water used in Minnesota. The majority of this is surface water used by the pulp and paper and mining industries. Irrigation accounts for about 9% of the water used and all other water uses comprise about 4% of the total water use.

In terms of daily average demands, 2,300 million gallons per day (mgd) of water was used by the state's power generation industry and 620 mgd served as a potable-quality supply by water utilities in 2007. Industries withdrew about 460 mgd for direct use in their business. Irrigation use was approximately 360 mgd, assuming an annual use as a daily rate over the entire year (total volume used in one year divided by 365 days), not just the seasonal application period. Water use is tabulated in Table 1.2 for annual and average daily rates. The unit rate of million gallons per year (mgy) will be the most common

Table 1.2. 2007 Minnesota Water Use, Unit Comparison

	Water Use	
	mgy	**mgd**
Power Generation	841,100	2,300
Water Utilities	225,600	620
Industrial	166,600	460
Irrigation	132,400	360
Other	63,000	170
Total	**1,428,700**	**3,910**

Source: MDNR, 2008

unit rate used, particularly in graphics, so that consistent comparisons can be made of small and large water users.

1.5 Water Reuse Background

Regulatory Environment

The use of reclaimed water in Minnesota requires a permit that includes routine monitoring of the water, conformance to water quality limits, treatment process requirements, and adherence to specific construction codes and possibly local ordinances. The overriding goal of regulations for reclaimed water is public health safety and conformance to treatment and disinfection practices that ensure destruction of pathogens.

There are no federal regulations governing water reuse in the United States; regulations are developed and implemented at the state government level. The lack of federal regulations has resulted in differing standards among states that have developed water reuse regulations. In the 1990s, several states adopted or revised their respective regulations, and it was common practice to base reuse criteria on those of states that had comprehensive regulations, guidelines, and background information to support them. The *Guidelines for Water Reuse* [U.S. Environmental Protection Agency, 1992, 2004], which were published in 1992 (revised in 2004), were also used as a resource by states that had limited or no regulations or guidelines. Since then, there has been increased interest in water reuse in several states that previously did not have water reuse regulations.

At present, no states have regulations that cover all potential uses of reclaimed water, but several states have extensive regulations that prescribe requirements for a wide range of end uses of the reclaimed water. Other states have regulations or guidelines that focus on land treatment of wastewater effluent, emphasizing additional treatment or effluent disposal rather than beneficial reuse, even though the effluent may be used for irrigation of agricultural sites or public access lands.

Minnesota is one of several states that have not developed state water reuse criteria. Currently, Minnesota uses California's *Water Recycling Criteria* [State of California, 2000], presented in Section 3, to evaluate water reuse projects on a case-by-case basis.

In Minnesota, water reuse requirements are included in National Pollutant Discharge Elimination System (NPDES) permits administered by the Minnesota Pollution Control Agency (MPCA). A change in the location of a wastewater treatment facility's discharge or any modifications to a facility to provide treatment and conveyance for a reuse application requires an NPDES permit modification. Any facility modifications to produce reclaimed water, either at the WWTP or the agricultural processing facility site, must also adhere to other NPDES permit discharge requirements. As discussed further in Section 3, the processes used to treat water to reclaimed water standards often result in waste streams with high concentrations of pollutants that upon discharge may exceed permit limits. Facility improvements and resulting changes in environmental discharges must meet all existing permit requirements and be planned with future permit limits in mind.

While there are no federal regulations governing water reuse in the United States, federal food and safety regulations govern the use of recycled and reclaimed water in many types of food processing facilities. These regulations apply to in-facility recycling of water as well as to the use of reclaimed water from outside of a facility. These regulations must be adhered to in addition to any state regulations and guidelines. In some cases, food safety regulations have a direct bearing on a facility's ability to use reclaimed water. Section 3.1 discusses this further.

Water Reuse Applications

While this project focuses on the beneficial reuse of treated wastewater effluent for agricultural processing facilities, other uses are briefly described to indicate the broad spectrum of water reuse as is commonly practiced around the globe. From the perspective of the municipality, investment in capital to provide reclaimed water will typically involve a review of all options; multiple users are commonly required for water reclamation to be a cost-effective practice for the municipal utility.

Many U.S. communities use reclaimed water for a variety of nonpotable purposes, typically categorized under the following major types:

- Industrial
- Urban
- Agricultural Irrigation
- Environmental and Recreational
- Groundwater Recharge
- Augmentation of Potable Supplies

Industrial

Industrial reuse applications in the U.S. have steadily increased over the past two decades, with an increasing diversity of industrial uses. The largest use of reclaimed water by industries in the U.S. has been for cooling water. The large water demands of power facilities for cooling water and other needs makes them an ideal facility for reuse. Given that the largest demands for many agricultural processing facilities is for cooling water, reclaimed water may also be an optimum supply for some locations. Reclaimed water is also used as process water for a variety of applications at petroleum refineries, chemical plants, metal working, pulp and paper mills, and other production facilities. Another large use of water in the industrial sector is for washing as part of a process or of facility work spaces and for dust control.

A limited literature review identified the only agricultural processing facilities using reclaimed municipal water to be ethanol facilities in the west and midwest, as discussed in Section 2.3. A review of California and Florida inventories on water reuse systems (California State Water Resources Control Board, 2002 and Florida Department of Environmental Protection, 2002) and the WateReuse Association's facility list (WateReuse Association, 2009) was inconclusive because the databases did not store enough detail about the type of industry.

In the agricultural processing industry, water reuse has focused on use of internal recycle streams or the treated waste effluent from their own facility. Internal facility water reuse has dropped water withdrawals significantly for many agricultural processing facilities. The lower water demands given internal water reuse, distance to a municipal WWTP with an adequate capacity, and requirement for potable quality water for many processes, particularly food processing, has limited municipal reclaimed water use by agricultural processing facilities. Section 2.2 develops this topic for Minnesota-based agricultural products.

Urban

The "urban" category is used to define water uses related to human activity and areas with concentrated people access. One common use, that is one of the few applications of reuse in Minnesota, is for golf course irrigation. Other typical irrigation reuse applications include: public lands such as parks, athletic fields, highway medians and shoulders, landscaped areas for commercial properties, and landscaping for residential areas. Other examples of urban reuse applications include vehicle washing facilities, laundry facilities, fire protection, toilet and urinal flushing in commercial buildings, decorative water features such as fountains and reflecting pools, street sweeping, and dust control and soil compaction for construction projects.

Agricultural Irrigation

In many states, agricultural irrigation is a significant percent of the total demand for freshwater and is estimated to represent 40% of the total water demand nationwide [Soley et al, 1998]. Reclaimed water has been used to irrigate a variety of agricultural applications including: pasture; orchards and vineyards; harvested feed, fiber and seed; food crops; processed food crops; and nursery and sod. Florida uses 19% of its reclaimed water supply for agricultural irrigation [Florida Department of Environmental Protection, 2002] and California uses approximately 48% [California State Water Resources Control Board, 2002].

Environmental and Recreational

Reclaimed water has been used for environmental improvements and recreational uses. Environmental reuse includes wetland enhancement and restoration, creation of wetlands for wildlife habitat, and stream augmentation. Wetland reuse projects often include dual goals: to enhance downstream surface water quality and create additional wildlife habitat. Recreational applications for reclaimed water include water impoundments restricted to boating and fishing or for full body contact activities such as swimming, smaller landscape impoundments, and golf course ponds. Lubbock, Texas uses 4 mgd of reclaimed water for recreational lakes (fishing and boating) in the Yellowhouse Canyon Lakes Park [Water Pollution Control Federation, 1989].

Groundwater Recharge

Groundwater recharge using reclaimed water has been used to reduce saltwater intrusion in coastal aquifers, augment potable or nonpotable aquifers, provide storage and/or further treatment of reclaimed water for later use, and prevent ground subsidence. In areas with extensive agricultural irrigation, groundwater recharge practices make use of aquifers for storage and withdrawal of stored reclaimed water from the aquifer when needed. This removes the need for constructed storage facilities to meet seasonal demands.

Augmentation of Potable Supplies

Potable water supplies can be supplemented with treated wastewater by surface water augmentation, groundwater recharge, and direct potable reuse. The first two applications are indirect potable reuse, which has been defined as the augmentation of a community's raw water supply with treated wastewater followed by an environmental buffer [Crook, 2001]. In this case, the treated wastewater is mixed with surface and/or groundwater and receives additional treatment prior to entering the potable water distribution system. Direct potable reuse is defined as the introduction of treated wastewater directly into a water distribution system without intervening storage (pipe-to-pipe) [Crook, 2001]. There are no direct potable reuse applications in the U.S..

1.6 Water Reuse in Minnesota

A review of current and potential reuse applications, as well as discussions with broad-base stakeholder groups [MCES, 2007], identified four main drivers for water reuse in general and industrial-related reuse in particular for Minnesota: water quality, water quantity, environmental stewardship, and sustainable economic growth. Current Minnesota reuse applications are shown in Table 1.3 with the primary driver identified.

Table 1.3. Water Reuse Facilities in Minnesota

Facility	Driver[1]	Type of Reuse	Capacity mgd[2]
Hennepin County Public Works	Quality	Toilet flush water	0.0056
Lake Allie	Quality	Golf course irrigation	0.0056
Turtle Run South	Quality	Golf course irrigation	0.0168
Izaty's Golf and Yacht Club	Quality	Golf course and alfalfa field irrigation	0.086
City of Nisswa	Quality	Golf course irrigation and other uses	0.038
City of Montgomery[3]	Quality	Golf course irrigation and other uses	0.038
Minnesota National Golf Course (McGregor) [4]	Quality	Golf course irrigation	0.059
Multiple Municipalities (32)	Quality	Agricultural irrigation	5.24[5]
Shakopee Mdewakanton Sioux Community	Environ.	Wetland enhancement/golf course irrigation	0.96
City of Mankato	Quantity	Industrial – cooling water for power plant	6.2

[1] Driver: Quality=water quality or receiving stream discharge limitations; Quantity=water quantity limitations; Environ.=environmental stewardship and conservation.
[2] The permitted capacity of the WWTP in million gallons per day (mgd) producing reclaimed water, which can be significantly greater than the actual volume/flow, particularly for the pond systems associated with agricultural irrigation.
[3] WWTP expansion in 2003 discontinued water reuse practices.
[4] Golf course is permitted for reuse but reuse facilities have not been built yet.
[5] The combined permitted capacity for 32 facilities is 5.24 mgd.

Water Quality

Minnesota, the "Land of 10,000 Lakes," is known for its abundance of water. A safe, cost-effective, and adequate water supply generally has been readily attained for Minnesota industries and communities. But there are regions of the state where water quality is impaired or declining and where there are increased quality concerns from various pollution sources.

Historic water reuse applications have been water quality driven. Agricultural irrigation of treated wastewater effluent has been practiced in Minnesota's rural areas in lieu of summer pond discharges for facilities a significant distance from an acceptable receiving stream. More recent water reuse applications driven by discharge limitations include golf course irrigation in urban and resort areas and toilet flush water for a Hennepin County Public Works building. Looking to the future in the Twin Cities metro region, MCES' existing and new wastewater treatment facility planning incorporates plans for future reuse processes and applications.

Water quality issues will drive future water reuse in Minnesota. As growing communities generate additional wastewater, there will be a need to provide higher levels of wastewater treatment to maintain or decrease the discharge loads to the state's waterways. Finding other uses for the treated wastewater, through partnerships with industry or other users, will decrease wastewater discharges. The development of Minnesota's Total Maximum Daily Load (TMDL) program will affect the discharge allocations for most communities. For example, the Lake Pepin TMDL will affect nearly two-thirds of the state as shown in Figure 1.3. With a potential reduction requirement of one-half the phosphorus and solids loads to Lake Pepin, and non-point source reduction practices still untested, it is likely that point source reductions will be part of the solution. Water reuse may be a cost-effective solution for some communities, particularly when tertiary treatment processes are required to meet receiving stream discharge limits. If these communities are experiencing or forecasting water supply limitations, the benefits of a water reuse option could be even more pronounced.

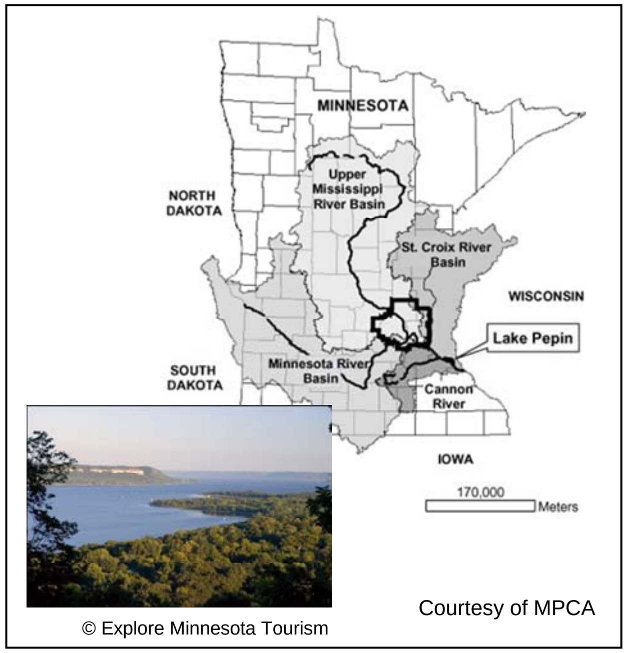

Figure 1.3. Areas Included in the Lake Pepin TMDL

Water Quantity

While discharge limitations will increasingly be a factor in Minnesota, it is anticipated that water supply limitations will be a driver in the near future. The southwestern part of the state has areas with low-production aquifers. The northwestern part of the state has regions of interspersed aquifer limitations, and localized aquifer limitations are also observed across the state. Withdrawals from Twin Cities aquifers serving some communities are being restricted.

Figure 1.4. Mankato Water Reclamation Facility

Limited water supply was the driver for the one existing industrial reuse application (of municipally treated wastewater) in Minnesota. The City of Mankato expanded its WWTP in 2006, shown in Figure 1.4, to provide the Mankato Energy Center (MEC), a 365 megawatt facility (ultimate capacity of 630 megawatts) with cooling water. The City provides 6.2 mgd of treated wastewater to the MEC, which returns its cooling water discharge to the WWTP (approximately 25% of the volume supplied) as a permitted industrial discharger. The cooling water is commingled with the WWTP process stream prior to dechlorination.

The water demands of the ethanol industry in Minnesota's water supply-limited southwest region have required investigating water supply options other than local groundwater. State agencies reviewing various permits for new and expanded ethanol plants formed a team to integrate the process and support the economic growth of ethanol in Minnesota. A key issue for some facility reviews was the lack of water in some southwestern communities and the inability to obtain a water appropriations permit. Reclaimed water was an option identified and discussed with ethanol industry stakeholders at various workshops and specific facility reviews.

Tharaldson Ethanol recognized the opportunity provided with reclaimed water in planning for a 120 million gallon ethanol facility in Casselton, North Dakota. A 1.4 mgd tertiary membrane facility was constructed to treat City of Fargo WWTP effluent and transport it 26 miles to the ethanol facility. Waste streams from the ethanol facility are conveyed back to the Fargo WWTP and treated as part of the discharge to the Red River. The Cass Rural Water District is responsible for the distribution of the reclaimed water and contracted the design and construction services for the new water reclamation and conveyance facilities.

As the quantity of water supply in the Twin Cities receives more attention, MCES is preparing for future reuse. MCES is designing its proposed East Bethel WWTP with a long-term goal of providing reclaimed water for irrigation and industrial reuse. The projected average daily flow from the facility in 2015 is 0.36 mgd and 1.22 mgd in 2030.

Environmental Stewardship

Minnesota's environmental stewardship ethic has promoted the conservation and protection of water resources. Conservation has gone hand-in-hand with improved water protection programs and more stringent regulations for surface water dischargers. This stewardship ethic can drive reuse projects even when other drivers are not present and when economics would not point to reuse.

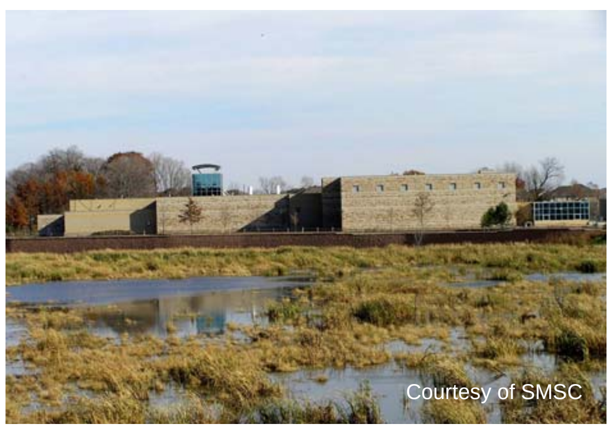

Figure 1.5. SMSC WRF and Wetlands

For example, the Shakopee Mdewakanton Sioux (Dakota) Community's (SMSC) 0.96 mgd Water Reclamation Facility (WRF), constructed in 2006, was initiated as part of SMSC's ongoing activities toward self-sufficiency and natural resources protection. "The Dakota way is to plan for the Seventh Generation, to make sure that resources will be available in the future to sustain life for seven generations to come" [SMSC, 2008]. The facility is permitted to discharge to one of two wetlands, shown in Figure 1.5, with downstream ponded areas that provide water for SMSC's golf course irrigation system. State agencies are working with the SMSC to explore aquifer recharge to be used primarily in the winter when irrigation is not needed.

Related legislative activity indicates Minnesota's increasing awareness that the state's water resources need protection. The 2009 legislative session appropriated grant funds for capital projects using reclaimed water instead of groundwater sources. H.F. 1231 provides $1.3 million the first year and $3.17 million the second year to cover 50% of the capital costs. A first year provision of $1 million was allotted to ethanol facilities within 1.5 miles of a municipal WWTP using more than 300,000 gallons of water per day. H.F. 1812 passed in 2008, amends Minnesota Statutes, Section 103G.291, and strengthens the requirement for water conservation practices. Public water suppliers serving more than 1,000 people (85% of Twin Cities metro suppliers) must implement a water conservation rate structure. The rate structures must be in use by Twin Cities metro area suppliers by 2010, and all remaining water suppliers by 2013.

Sustainable Economic Growth

The Minnesota Legislature is interested in industrial water reuse as a means of fostering sustainable economic growth. The Legislature's desire to explore the technical, cost, and implementation issues related to water reuse prompted the funding for an industrial water reuse study [MCES, 2007]. Legislation introduced in 2008 directed grant funds for pilot projects for water reuse with ethanol facilities as target candidates. This bill did not make it to the floor for a vote. However, H.F. 1231 introduced in 2009, modified to include other water reuse applications and the funding mechanism, was passed. As discussed above, it provides grants for capital projects with specific funds targeting ethanol facilities in the first year. These actions indicate that the state recognizes the value of its water resources and the integral role water plays in the state's economic vitality.

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Section 2
Agricultural Water Use

This section characterizes agricultural water uses in Minnesota by providing historic water use data, summarizing the different types of water uses and providing a review of the ethanol production sector.

2.1 Historical State Agricultural Water Use

Historic water use for Minnesota's agricultural sector was characterized for activities from the farm to final product distribution. The same database [MDNR, 2008] that defined the total water use for the state in Section 1 was analyzed for various agricultural water uses. The largest agricultural water use in the state is for major crop irrigation, accounting for 75-85% of the water withdrawn. The next largest use is for agricultural product processing, followed by aquaculture, biofuels production, noncrop irrigation (agricultural applications include sod farms, orchards, and nurseries) and livestock watering.

Figures 2.1 and 2.2 show the relationship of each type of water use to overall agricultural water use. Major crop irrigation in 2007 was nearly double that of 2002, a wetter year. Both years are presented to show the variations that occur each year because of the climatic influence on water uses such as irrigation. Figure 2.3 provides a better perspective on the relationship of water uses without a comparison to major crop irrigation and also identifies the source as ground or surface water.

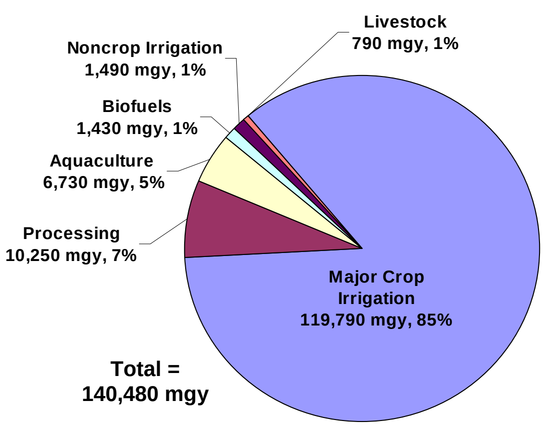

Figure 2.1. Agricultural Water Use in Minnesota, 2007 (Dry Year)
Source: MDNR, 2008

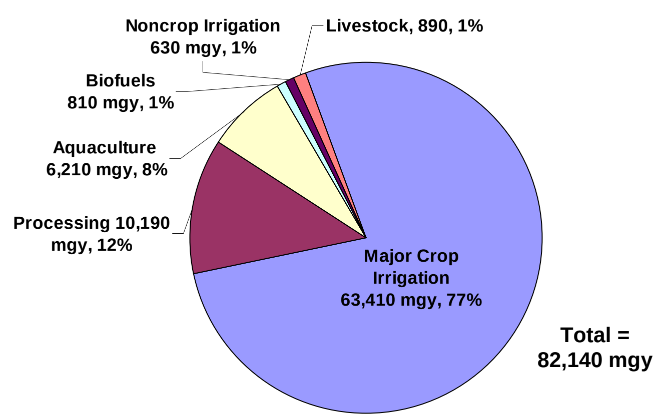

Figure 2.2. Agricultural Water Use in Minnesota, 2002 (Wet Year)
Source: MDNR, 2008

Figure 2.4 identifies the relationship of agricultural water uses to the total water use of the state for 2007. The Section 1 summary of the state's water use organized the major water uses into five categories, as shown in the pie chart in Figure 2.4. Agricultural uses are accounted for in three of the categories: aquaculture and livestock fall under the "Other" category; major crop, non-crop, and other irrigation (urban irrigation of golf courses and other greenways) fall under the "Irrigation" category; and agricultural processing and biofuels production fall under the "Industrial" category. Water use for all the sub-categories are shown in the bar charts in Figure 2.4.

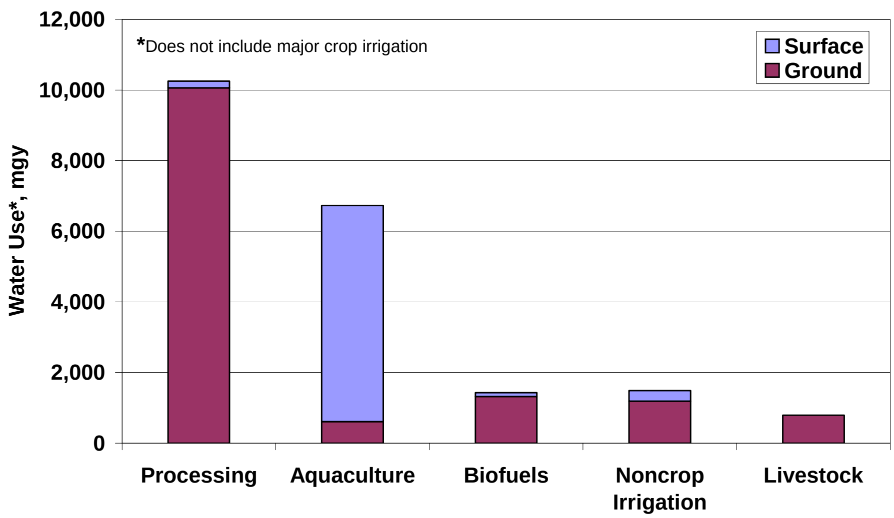

Figure 2.3. Agricultural Water Use by Source*, 2007
Source: MDNR, 2008

The 12,000 mgy of water used for agricultural processing and biofuels production is a small portion of the overall industrial water use (167,000 mgy). However, it does use a larger amount of groundwater than the other industrial water uses. Irrigation of major crops is the largest use of irrigation water, which is mainly supplied by groundwater. The 'Other' major category, with water use of approximately 63,000 mgy, includes an assortment of water use types, of which about a fifth are used for aquaculture (mainly surface water) and livestock watering (mainly groundwater).

This study focuses on agricultural processing applications for water reuse. Water use for the agricultural processing sector over the last 20 years has fluctuated between 10,000 and 13,000 mgy. Figure 2.5 displays the water use for biofuels facilities separately from other agricultural processing facilities. Keeping in mind that these data include only facilities with a water supply permit, the emergence of the biofuels industry in 1995 is not representative of all facilities, just those with their own water supply. Ethanol facilities were operating prior to this, but were using a municipal water supply. As the use of water for biofuels production increased from 13 mgy in 1994 to over 1,400 mgy in 2007, shown in Figure 2.6, the water use of other agricultural processing facilities was decreasing. One reason for this decrease is hypothesized to be improvements in cooling water systems. The MDNR has been working with industries over the last decade to reduce the amount of water used as once-through cooling water and industries are continually improving their processes to reduce water and energy use.

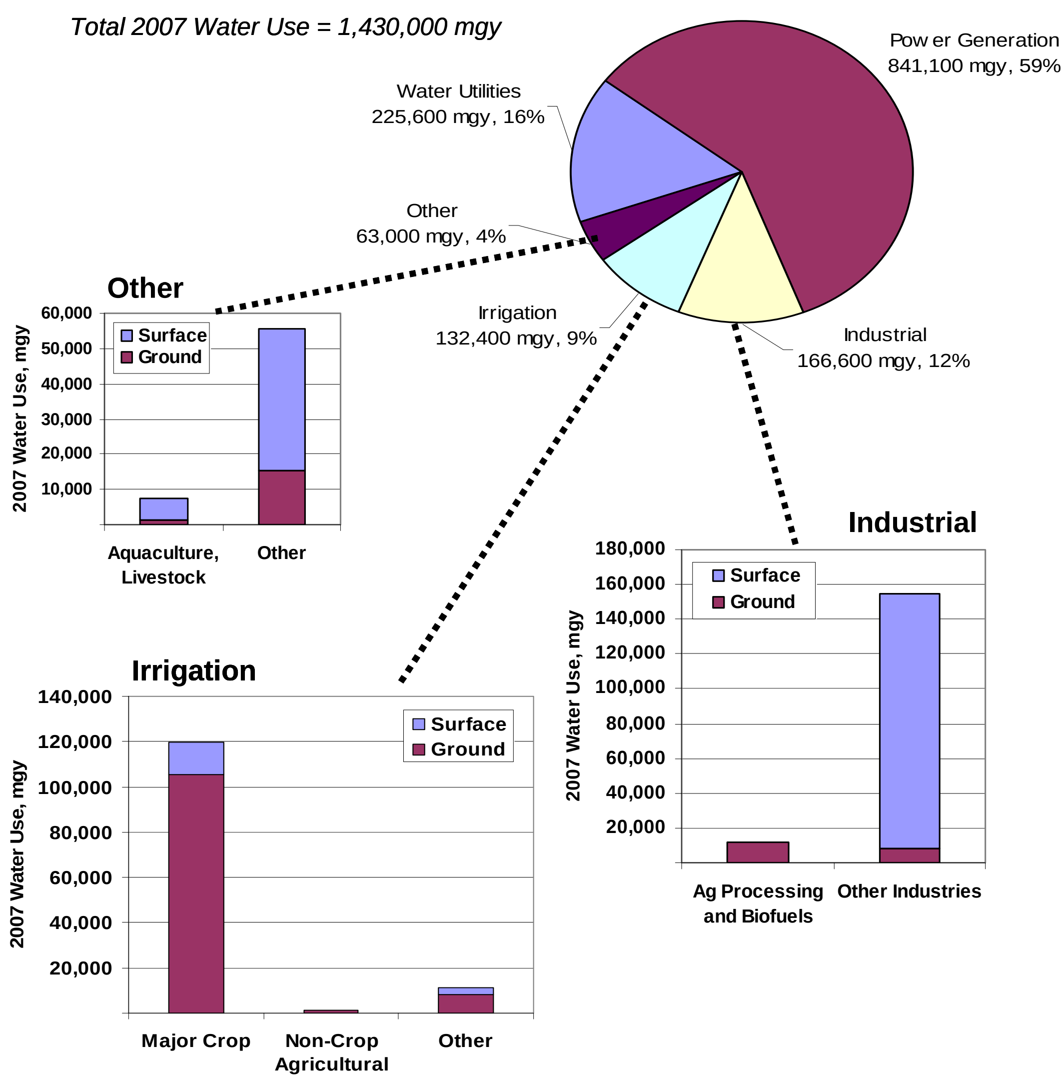

Figure 2.4. The Relationship of Agricultural Water Use to Total Water Use in Minnesota, 2007

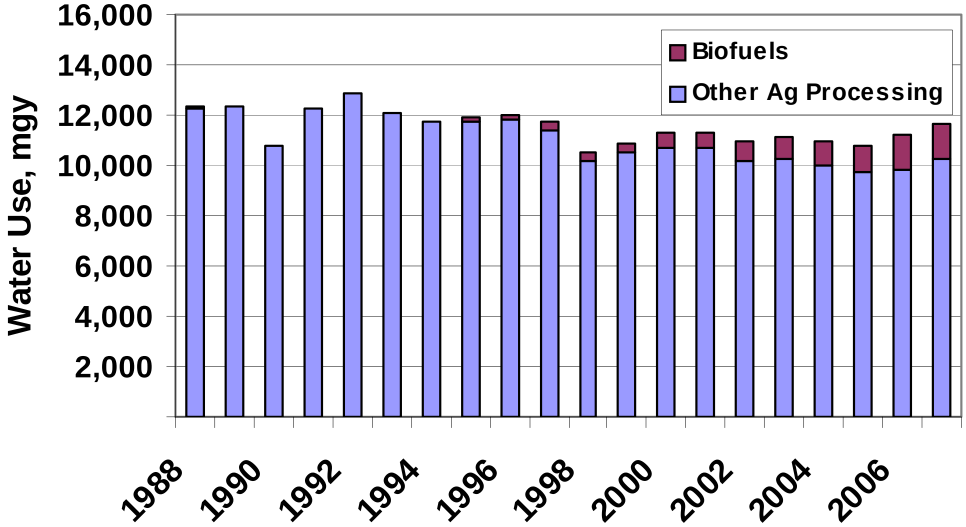

Figure 2.5. Agricultural Processing Water Use*, 1988-2007
Source: MDNR, 2008

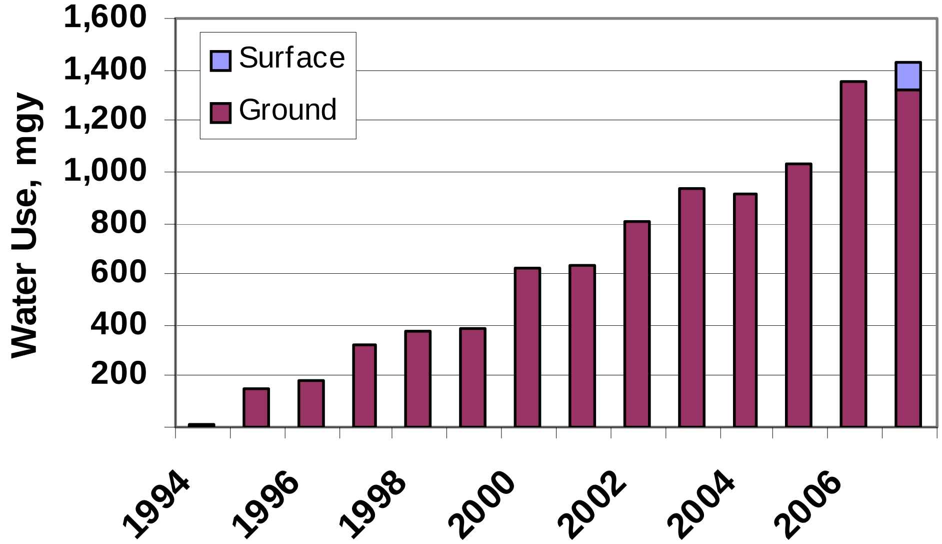

Figure 2.6. Biofuels Production Water Use*, 1994-2007
Source: MDNR. 2008

**Based only on facilities with water appropriations permits and does not include facilities using water supplied by local utilities. Total water volumes listed here provide relative comparisons, but do not reflect total water use for a specific industry. For example, in the Biofuels category, there were facilities online in 1998, but they were using a public water supply. Also in 2007, of the 17 operating facilities, 10 are represented by the data above.*

The largest water users in Minnesota's agricultural processing sector are related to the food processing industry. The top ten largest withdrawals of water for agricultural processing in 2007 included companies with facilities for oilseed production, meat processing, beverage production, fruit and vegetable canning and freezing, and dairy product processing.

2.2 Agricultural Processing Water Use

Overview

The agricultural processing industry, like many industries, has continually improved its practices and technologies to reduce water consumption. Reuse of water within a facility is commonly practiced at most industrial facilities. In the 1970s, as wastewater discharge allocations and pretreatment programs for municipal wastewater treatment facilities were developing, it was clear that reducing the waste discharge water volume and strength provided cost savings to industries as well as environmental benefits. Competition for high quality water sources was also becoming an issue for some regions not typically concerned with water scarcity and water reduction measures were implemented to conserve the local water supplies.

The majority of Minnesota's agricultural processing facilities include reuse of water in their facilities. As facilities age or process modifications are made, improvements are often included to reuse water. New facilities are built to optimize water and energy use. Water is reused within an agricultural processing facility through recycle of a process stream or the treated effluent from the facility's wastewater treatment system, if the facility has one. In most cases, treatment of a process stream is required before it is used in another process. For facilities with their own wastewater treatment system with a permitted discharge, treatment processes in addition to those required for discharge to the receiving stream are typically required.

Product safety and quality are foremost in the operations of an agricultural processing facility. Water reused in the facility must meet all public health standards and cannot degrade the quality of the product or reduce efficiencies in processing. While maintaining safety and quality, reductions in water use have been significant over the past 40 years. Some non-food related processing facilities have gone beyond in-plant water reuse to use of municipally reclaimed water for non-potable quality uses, as in the ethanol industry. Food processing industries must adhere to food safety regulations that limit the use of reused water to applications where the water does not contact the finished product. Some food safety regulations strictly forbid the use of municipally reclaimed water for specific uses.

The purpose of this subsection is to identify the potential uses of municipally reclaimed water in an agricultural processing facility. A literature review and personal communications with facilities provided information on how much water is used in general sector facilities and the applicability of using municipally reclaimed water for these uses. Most facilities are already practicing internal facility reuse, which is the most economic choice, unless the municipally reclaimed water is of significantly higher quality. However, as technologies advance, and costs to treat water for discharge increase, the incentive to use municipally reclaimed water will increase.

Types of Water Use

Agricultural processing facility water use includes water used for processing and production, cooling, boiler feed, air conditioning, washing, stack scrubbing, transport of materials, sanitation, potable supply for personnel, and grounds irrigation. Cooling and boiler feed water are common uses at most industrial facilities. These use types are independent of the product being processed and the issues to consider in using a reclaimed supply are applicable to all facilities. Cooling water, in particular, is often one of the largest uses of water at a processing facility. For these reasons, Section 3 provides a more in-depth review of issues to consider for use of reclaimed water as a supply for cooling and boiler feed water. Reclaimed water can also be used for grounds irrigation and toilet flush water. Though they are not considered in this study, these are uses that an overall facility plan should consider when looking to a reclaimed water supply.

Agricultural Processing Sector Water Use

The agricultural processing market can be generally classified under the major sectors of food and non-food products. Further classification for Minnesota-based products, as shown in Table 2.1, includes crop and livestock-based products and various subcategories. Water use for facilities processing these different commodities obviously vary, however there are some uses of water that are common in the operation of any process and overall building use.

A literature review identified the most comprehensive evaluations of water use in the agricultural processing industry from studies done 30 years ago [U.S. Dept of Interior, Bureau of Reclamation, 1983; Minnesota Water Planning Board, 1978]. This was when pretreatment and industrial wastewater treatment were rapidly being implemented, and also when an awareness of water conservation was ramping up in the Midwest. Though dated, these studies provide an indication of water use: the type of use and the relative quantity of water required for each specific use in proportion to the total water use. Total water use data presented in much of this section is likely higher than found at facilities today given in-plant water conservation practices that have been implemented by most industries.

Water use information in this subsection focuses on the food processing industry, while Section 2.3 highlights water use in a non-food processing industry - ethanol production. Other non-food processing facilities have similar types of water uses, such as cooling water, but the literature search did not yield specific quantitative information. Water use in the food processing industry is presented by the categories of the industry codes system (SIC, NAIC). Table 2.2 lists the main industry categories and provides a summary of water use characteristics.

Table 2.1 Agricultural Commodity Sectors in Minnesota

Food

- Processing Crops
  - Grains and Oilseeds
    - Grain elevators and feed mills
    - Food products
  - Row Crops
    - Food products
- Livestock
  - Meat
    - Processing
      - Beef
      - Pork
      - Chicken
      - Turkey
    - Livestock raising
    - Preparation
  - Dairy
    - Milk production
    - Dairy products
  - Eggs
  - Aquaculture

Non-Food

- Processing Crops
  - Biofuels
  - Animal Feed
  - Other Crop Products/ByProducts
- Livestock
  - Animal Feed
  - Other Animal Products/ByProducts
- Chemicals
- Soil/Nurseries/Trees

Table 2.2. Food Processing Water Use

Food Processing Industry	Relative Water Use	Relative Water Consumption[1]	Water Use (variable units)	Ref No.[2]	Areas for Water Reuse: Cooling Water	General Cleanup	Other
Meat							
Beef	High	Low	700 gal/1,000 lbs LW	a	x*	x	flush of products to rendering; internal recycles in processing
			13 gal/1 lb consumable product	b			
Swine	High	Low	800 gal/1,000 lbs LW	a	x*	x	flush of products to rendering; internal recycles in processing
Poultry	High	Low	2,500 gal/1,000 lbs LW	a	x*	x	flush of products to rendering; internal recycles in processing
			8 gal/bird	c			
Dairy Milk	High	Low	3,000 gal/ 1 lb milk processed	a	x*	x	minimal other non-potable uses
Other products			0.5 gallons/ 1 lb of product	a			
Fruit & Vegetables[3]	High	Low	1.5-10 gallons/ton	a	x*	x	barometric condensers cooling
Corn Mill; Cereals	Moderate	Moderate	no data	a	x*	x*	scrubber water; rail car washing
Grain Mill Products	Low	Low	no data	a	x*	x*	scrubber water
Sugar (Beet)	High	Low	5-8,000 gal/ton-condenser	a	x*	x	flume/transport water*; barometric condenser cooling
			10,000 gal/ton-flume transport	a			
Fat & Oils	High	Moderate	0.2-0.6 gal/1b oil produced	a	x*	x	barometric condensers cooling; soapstock washing
Beverage (malt liquor)	High	Moderate	10 gal/gal beer produced	a	x*	x	

Footnotes and Acronymns

*Major water use

[1]General process without any recycle; where low means little is used in the product

[2]Reference List

a - U.S. Department of the Interior, Bureau of Reclamation, 1983

b - Ross, 2000

c - Personal communications with Minnesota poultry processing engineer; based on 7 gallons water per bird for processing, 0. 5 gallons/bird in the bird chillers, and 0.25 gallons/bird in the scalder.

[3]Canned, Frozen, & Preserved Fruit & Vegetables

LW=live weight

Cooling water is the most common, significant requirement for water in food processing facilities. While there are different types of cooling systems, the majority are acceptable for uses of internally reused water (and likely for municipal reclaimed water unless specific food safety regulations do not permit its use). Table 2.2 identifies separate columns for cooling water and water for general cleanup, another use common to most facilities. Those with an " * " indicate a major water use for that food sector. In the far column, any other potential uses of reclaimed water are listed or the specific cooling or cleaning practice is defined. All cooling water uses are shown as major water uses. Some processing facilities, such as corn and grain mills also have large water uses related to facility and equipment cleaning.

Water use for two industries is presented in more detail to show the different types of water uses that occur in agricultural processing facilities. Table 2.3 presents the typical water uses for beef and pork processing and Table 2.4 presents the various milk processing operations for different dairy products and the amount of water that different processes use. In the case of meat processing, the different processes require fairly similar volumes of water, the exception is cooling water for beef processing and the process water for pork. For milk processing, the evaporation and condensing stages account for over half of the water use or more, depending on how the milk is processed.

Table 2.3. Water Usage in Meat Processing (gallons/1,000 lbs of live weight)

	Beef		Pork	
Operation	Process	Cleanup	Process	Cleanup
Holding Pens or Area	15	5	15	3
Killing	20	15	20	10
Hide Removal-Dehairing	15	10	80	30
Eviscerating, Trimming	85	50	85	50
Cooling	120	2	80	2
Cutting, Deboning	50	25	5	15
Processing	--	--	140	80
Blood Processing	0	2	0	1
Hide Processing	40	11	--	--
Viscera Handling	40	10	20	5
Edible Rendering	80	30	80	30
Inedible Rendering	45	30	30	9
Total	510	190	555	235
Process & Cleanup Total	700		790	

Source: U.S. Dept of the Interior, Bureau of Reclamation, 1983.

Table 2.4. Water Usage for Milk and Product Processing

Operation	Gallons of Water Used Per Pound of Milk Processed/Used
Can washing	0.1
Truck washing	8.4
Cooling milk in storage	24
Pasteurization	43
Bottle washer	60
Boilers and evaporators	30
Cleaning	30
Spray cleaning tanks	
Prerinse	0.6
Cleaning	1.2
Post-rinse	9.6
Sanitizing	0.6
Lines	
Prerinse	0.06
Cleaning	0.1
Post-rinse	0.06
Sanitizing	3
Evaporating, Calender condenser	1,079
Condensing, Plate condenser	1,439
Cottage cheese wash water	144
Cooling	
Receiving, bottling, ice cream and cream cheese	144
Receiving, pasteurization, separa-ting, condensing, spray drying	132-180
Receiving, condensing, canning, and sterilizing	3-48

Source: U.S. Dept of the Interior, Bureau of Reclamation, 1983.

2.3 Sector Focus: Ethanol Production

The expansion of the ethanol industry in Minnesota has stimulated the exploration of water reuse for this industry. Ethanol production requires on average 3-6 gallons of water to produce 1 gallon of ethanol (gallons water/gallon ethanol) and varies with a host of factors [Institute for Agriculture and Trade Policy, 2006; Aden, 2007; Wu, 2008; MnTAP, 2008]. In Minnesota, the lowest water use rate in 2005 was 3.6 gallons water/gallon ethanol at the Chippewa Valley Ethanol Company [Institute for Agriculture and Trade Policy, 2006] and rates were greater than 7 gallons water/gallon ethanol for some facilities pre-2002.

A Minnesota Technical Assistance Program (MnTAP) benchmarking study of Minnesota ethanol plants included evaluation of water efficiency supported by site visits to several facilities [MnTAP, 2008]. Of the 14 dry mill facilities evaluated, those starting up in 2005-06 (four new plants) used on average 3.4 gallon water/gallon of ethanol produced, and those going online between 1991-1994 (ten old plants) averaged 4.6 gallon water/gallon ethanol. In looking to the future, more efficient water use can be expected because more attention is being placed on evaluation of available water supplies at site selection and the process design integrates water and energy efficiencies [Wu, 2008].

The introduction of cellulosic ethanol technology will also present changes in the water requirements for production. Research with modeled estimates of water usage indicate that for the variety of feedstocks, water usage could range from 6 gallons water/gallon ethanol or more in an unoptimized process to 1.9 gallons water/gallon ethanol in an optimized thermochemical process converting wood chips to ethanol [Aden et al, 2002 and Aden, 2008].

While improved practices have reduced water use in ethanol production, ethanol production still requires a significant allocation of water resources. In addition, many ethanol facilities are located in areas with limited water supplies and water discharge quality may limit how much water can be recycled. The MnTAP study [2008] concluded that reductions in water use through recycling will be limited unless the high salt concentrations in the discharge water are managed. To properly address the water appropriations permitting and other permitting requirements for the ethanol industry, state agencies have formed teams to work specifically on the environmental issues of this industry sector. One action developed from these teams is to investigate reclaimed water as a water supply for ethanol facilities.

Facilities within the state have the capacity to produce over 850 million gallons of ethanol a year from nineteen locations across the middle and south part of the state [MDA, 2008]. Another five facilities are under or have just completed construction, which when operational will add another 420 mgy of ethanol capacity. Minnesota's ethanol facilities and water demands for facilities with their own permitted supply are listed in Table 2.5. Figure 2.7 shows their location. Based on a water use rate of 4 gallons water/gallon ethanol, a conservative estimate of the water demand for the state's ethanol production is 14 mgd, assuming 1,270 mgy of ethanol is produced a year. With continued efficiencies at existing facilities and new facilities built for lower water use rates, the total water requirement for all ethanol facilities (as listed in Table 2.5) will likely be lower.

The proximity of several ethanol plants to a WWTP was investigated. As shown in Table 2.6 there are several ethanol plants within ten miles of a WWTP that may have an adequate supply to meet at least the cooling water demands for the facility, estimated at 60-70% of the total facility water use. Additional information is needed on the diurnal variation of the WWTP flow and water quality to determine if these WWTPs could feasibly provide the water supply for these ethanol plants.

Table 2.5. Ethanol Plant Capacity and Water Use

City (plant name)	Ethanol Capacity mgy	Corn Production Required million bushels/yr	Start-up Year	2007 Water Use (MDNR Permit Only) mgy/mgd[1]
Marshall (ADM)	40	14.8	1988	--
Morris (DENCO)	24	9	1991	159/0.34
Winnebago (Corn Plus)	47	17.4	1994	180/0.49
Winthrop (Heartland)	37	13.7	1995	202/0.55
Benson (CVEC)	45	16.7	1996	163/0.45
Claremont (Al-Corn)	34	12.6	1996	154/0.42
Bingham Lake (Ethanol2000; POET)	31	11.5	1997	--
Buffalo Lake (MN Energy)	19	7	1997	84/0.23
Preston (Pro-Corn; POET)	42	15.6	1998	--
Luverne (Corn-er Stone)	21	7.8	1998	--
Little Falls (CMEC)	22	8.1	1999	--
Albert Lea (Exol/Agra Resources; POET)	41	15.2	1999	187/0.51
Lake Crystal (POET Biorefinig)	50	18	2005	--
Granite Falls (Granite Falls Energy)	50	18	2005	124/0.40
Atwater (Bushmills Ethanol)	45	16.6	2005	175/0.48
Heron Lake (Heron Lake Bioenergy)	50	18	2007	175/0.48
Fergus Falls (Otter Tail Ag Enterprises)	55	20	2008	0
Fairmont (Buffalo Lake Energy)	110	40	2008	0
OPERATING TOTAL (19 Plants)	**850**	**200**		
Plants Under/Completed Construction by Jan 2009				
Janesville (Verasun; prev. US BioEnergy)	110			
Welcome (Verasun)	110			
Lamberton (Highwater Ethanol)	50			
Alberta (APEC, LLC)	100			
TOTAL (24 Plants)	**1,270**			

Sources: Adapted from MDA, 2008 and MDNR, 2008.
[1] Water use data only available for those with MDNR permits on record in Aug 2008.

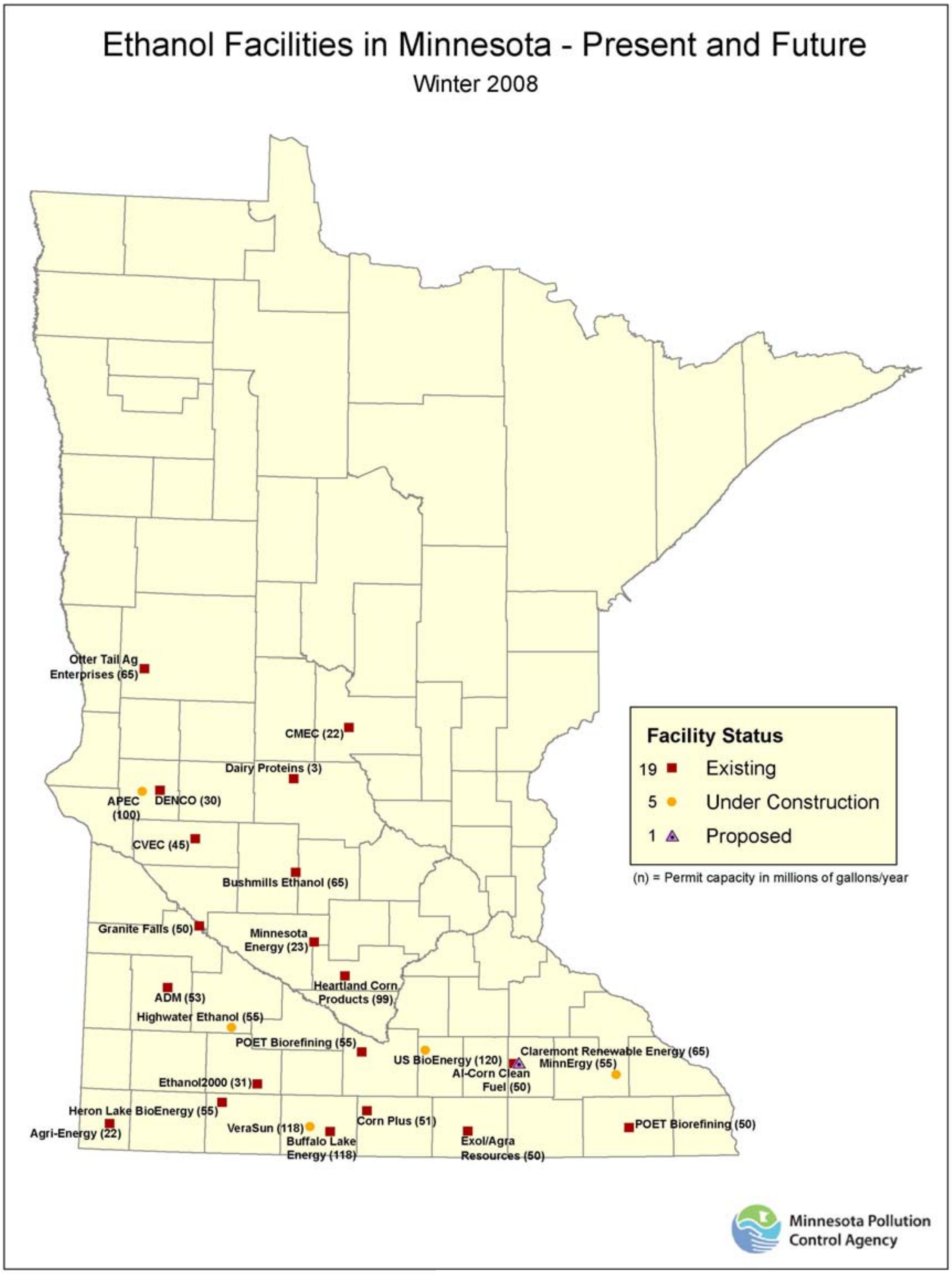

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Figure 2.7. Ethanol Facilities in Minnesota

Table 2.6. Select Ethanol Plants in Relation to Reclaimed Water Supply

Ethanol Plant[1]	Closest WWTP[2]	Distance to the WWTP (miles)	WWTP Permitted Capacity (mgd)	WWTP 2005 Flow (mgd)[3]	2007 Water Use (mgd)	Assumed Cooling Water Demand (mgd)[4]
Diversified Energy Co (DENCO)	Morris	1.7	0.964	0.60	0.37	0.22
Chippewa Valley Ethanol Co (CVEC)	Benson	1.7	0.985	0.43	0.40	0.24
Granite Falls Energy	Granite Falls	3	0.80	0.48	0.40	0.24
Minnesota Energy	Hector	3.4	0.66	0.21	0.24	0.14
Heartland Corn Products	Gaylord	3.2	0.55	0.36	0.28	0.17
Al-Corn Clean Fuel	Blooming Prairie	8	0.899	0.51	0.39	0.23
Corn Plus	Winnebago	2	1.7	0.59	0.27	0.16
Exol/Agra Resources Corp	Albert Lea	10	18.38	4.23	0.56	0.34

[1] Ethanol plants with MDNR water appropriations permits in 2007; 2007 water use is the reported use to the MDNR Water Appropriations Permit program [MDNR, 2008] – it is possible that some facilities used other sources of water and total water use is more than listed in this table.

[2] Selection criteria: closest WWTP with sufficient flow (based on 2005 flow data) for water use at the ethanol plants.

[3] Source: MPCA, 2005

[4] Assumed 60% of total water use is for cooling water requirements.

The Corn Plus plant in Winnebago is evaluating the use of the local WWTP effluent to furnish reclaimed water [Fischenich, 2009 and Winona Daily News, 2009]. The distance, approximately 2 miles, and WWTP size and process train, are favorable features with which to begin the evaluation.

Other ethanol plants across the county have used reclaimed water for cooling and/or process water. The Casselton, North Dakota plant highlighted in Section 1 uses Fargo WWTP water with new tertiary treatment facilities for process and cooling water. An ethanol facility in Madera, California is the first to use reclaimed water and includes processes that allow it to be a zero discharge facility. Green Plains Renewable Energy, in Shenedoa, Iowa was constructed with reclaimed water for cooling applications. Design teams involved with ethanol facilities are considering use of reclaimed water more in their projects and as seen with the Corn Plus plant, water reuse is being considered an option for retrofit of existing facilities.

The second technical memorandum for this study will present a case study of water reuse at an ethanol facility. The technical and institutional issues and costs to implement use of a reclaimed water supply for various uses at an ethanol facility will be evaluated. Section 3 elaborates on the regulatory and water treatment requirements applicable to ethanol and other biofuel production facilities.

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Section 3
Implementation Considerations

The decision to use a reclaimed water supply depends heavily on site-specific and area-specific conditions. For an industry such as an agricultural processing facility to partner with a wastewater treatment provider usually requires one or more economic and/or non-economic drivers as discussed in Section 1.

Even with the proper incentives, implementation of a water reuse system is contingent on successfully addressing a number of implementation challenges, such as:

- Negotiating a case-specific permit to meet regulatory requirements
- Technical considerations such as agricultural processing facility water quality requirements, wastewater treatment needs to achieve the users' (possibly multiple) water quality requirements, and effects on other facility permits
- Institutional considerations such as local ordinances, public perception, legal agreements, and fee structures

3.1 Regulatory Background and Requirements

Current Water Reuse Practice in Minnesota

Minnesota is one of several states that have not developed state water reuse criteria. Currently, Minnesota uses California's *Water Recycling Criteria* [State of California, 2000], as summarized in Table 3.1, to evaluate water reuse projects on a case-by-case basis. In Minnesota, water reuse requirements are included in NPDES permits administered by the MPCA. MPCA consults with MDNR staff on water appropriations issues, the Minnesota Department of Health (MDH) if there are water source protection concerns, and other entities in preparation and approval of permits for water reuse. The Department of Labor is responsible for administering the plumbing code for water reuse distribution systems and their relationship to other water systems.

The water recycling criteria applied to agricultural processing facilities would fall under the type of use categories of industrial process water, cooling water with and without a mist created, boiler feed water, dust control, and cleaning outdoor areas. The process water and cooling water where a mist is created use categories assume potential for human contact and have the most stringent requirements, noted by the fourth row of Table 3.1. The other applications require less stringent pathogen and treatment process requirements, as listed in the second row of Table 3.1.

There are no specific regulations in the California Water Recycling Criteria related to the use of reclaimed water for agricultural processing. California addresses specific industrial uses on a case-by-case basis. However, Florida regulations specifically prohibit the use of reclaimed water in the manufacture or processing of food or beverages for human consumption where the reclaimed water will be incorporated into or come in contact with the food or beverage product.

Table 3.1. 2000 California Water Recycling Criteria

Type of Use	Total Coliform Limits[a]	Treatment Required
Irrigation of fodder, fiber, and seed crops, orchards[b] and vineyards[b], processed food crops[c], nonfood-bearing trees, ornamental nursery stock[d], and sod farms[d]; flushing sanitary sewers	▪ None required	▪ Oxidation
Irrigation of pasture for milking animals, landscape areas[e], ornamental nursery stock and sod farms where public access is not restricted; landscape impoundments; industrial or commercial cooling water where no mist is created; nonstructural fire fighting; industrial boiler feed; soil compaction; dust control; cleaning roads, sidewalks, and outdoor areas	▪ ≤23/100 ml[a] ▪ ≤240/100 ml in more than one sample in any 30-day	▪ Oxidation ▪ Disinfection
Irrigation of food crops[b]; restricted recreational impoundments; fish hatcheries	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period	▪ Oxidation ▪ Disinfection
Irrigation of food crops[f] and open access landscape areas[g]; toilet and urinal flushing; industrial process water; decorative fountains; commercial laundries and car washes; snow-making; structural fire fighting; industrial or commercial cooling where mist is created	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation[h] ▪ Filtration[i] ▪ Disinfection
Nonrestricted recreational impoundments	▪ ≤2.2/100 ml[a] ▪ ≤23/100 ml in more than one sample in any 30-day period ▪ 240/100 ml (maximum)	▪ Oxidation ▪ Coagulation ▪ Clarification[j] ▪ Filtration[i] ▪ Disinfection
Groundwater recharge by spreading	▪ Case-by-case evaluation	▪ Case-by-case evaluation

Source: Adapted from State of California [2000].
[a] Based on running 7-day median; daily sampling is required.
[b] No contact between reclaimed water and edible portion of crop.
[c] Food crops that undergo commercial pathogen-destroying prior to human consumption.
[d] No irrigation for at least 14 days prior to harvesting, sale, or allowing public access.
[e] Cemeteries, freeway landscaping, restricted access golf courses, and other controlled access areas.
[f] Contact between reclaimed water and edible portion of crop; includes edible root crops.
[g] Parks, playgrounds, schoolyards, residential landscaping, unrestricted access golf courses, and other uncontrolled access irrigation areas.
[h] Not required if the turbidity of influent to the filters is continuously measured, does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert wastewater if the filter influent turbidity exceeds 5 NTU for more than 15 minutes.
[i] The turbidity after filtration through filter media cannot exceed an average of 2 nephelometric turbidity units (NTU) within any 24-hour period, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU at any time. The turbidity after filtration through a membrane process cannot exceed 0.2 NTU more than 5 percent of the time within any 24-hour period and 0.5 NTU at any time.
[j] Not required if reclaimed water is monitored for enteric viruses, *Giardia*, and *Cryptosporidium*.

Similarly, Washington standards do not allow the use of reclaimed water for food preparation and prohibit its use in food or drink for humans. Since Minnesota does not have any agricultural processing facilities using reclaimed water, it is unknown how Minnesota regulators will interpret California's or other state's criteria for agricultural processing facilities.

Other regulations governing operation and design of agricultural processing facilities may also determine if reclaimed water can be used for a specific application and if so prescribe treatment requirements and quality criteria. For example, water reuse requirements are prescribed in federally inspected meat and poultry processing facilities and do not allow reuse of treated water from municipal wastewater systems, as further discussed at the end of this subsection.

Other State Regulatory Practices

The regulatory background of other states is provided as a perspective on the requirements that MPCA may administer for an agricultural processing facility water reuse permit, given that there are none yet permitted in the state. While Minnesota applies California's criteria, the regulators also look to other state rules and guidelines for case-specific features.

The status and summary of water reuse regulations and guidelines in the United States as of 2004 have been documented in the EPA *Guidelines for Water Reuse* [U.S. Environmental Protection Agency, 2004] and are provided in Table 3.2. The absence of state regulations and guidelines for specific reuse applications does not necessarily prohibit those applications; many states like Minnesota evaluate specific types of water reuse on a case-by-case basis. Based on the data in Table 3.2, 25 states have adopted regulations regarding the use of reclaimed water, 16 states have guidelines or design standards, and 9 states have no regulations or guidelines. These data are somewhat misleading, as they include regulations and guidelines directed at land disposal of effluent or land application of wastewater intended primarily as a disposal mechanism rather than beneficial reuse.

Table 3.3 lists the number of states with regulations or guidelines for agricultural types of water reuse. As indicated in Tables 3.2 and 3.3, agricultural and landscape irrigation represent the reclaimed water uses most commonly regulated, and many states have implemented regulations that apply only to those types of use. As noted above, these data include state regulations that pertain to land disposal of effluent or land application of wastewater intended primarily as a disposal mechanism rather than beneficial reuse. Only nine states have regulations or guidelines for industrial uses, which is the category that agricultural processing facilities fall under.

The standards in states having the most reuse experience tend to be more stringent than those in states with fewer reuse projects. States that have water reuse regulations or guidelines typically set standards for reclaimed water quality and specify minimum treatment requirements, although a few states, such as Texas and New Mexico, do not prescribe treatment processes and rely solely on water quality limits.

General Regulatory Requirements for Nonpotable Uses of Reclaimed Water

In the past, most state water reuse regulations were developed in response to a need to regulate a growing number of water reuse projects in the particular state. Recently, some states with few reuse projects have taken a proactive approach and have adopted criteria, which tend to encourage implementation of projects. Arizona, California, Florida, and Texas, which have had comprehensive criteria for a number of years, have revised their water reuse regulations within the last ten years to reflect additional reclaimed water uses, advances in wastewater treatment technology, and increased knowledge in the areas of microbiology and public health protection.

Table 3.2. Summary of State Reuse Regulations and Guidelines for Nonpotable Reuse Applications*

State	Regulations	Guidelines	No Regulations or Guidelines	Unrestricted Nonpotable Urban Uses	Restricted Nonpotable Urban Uses	Agricultural Irrigation of Food Crops	Agricultural Irrigation of Non-Food Crops	Unrestricted Recreational Impoundments	Restricted Recreational Impoundments	Environmental Uses	Industrial Uses
Alabama		●			●		●				
Alaska	●						●				
Arizona	●			●	●	●	●		●		
Arkansas		●		●	●	●	●				
California	●			●	●	●	●	●	●		●
Colorado	●			●	●						●
Connecticut			●								
Delaware	●			●	●		●				
Florida	●			●	●	●	●			●	●
Georgia		●		●	●		●				
Hawaii		●		●	●	●	●		●		●
Idaho	●			●	●	●	●				
Illinois	●			●	●		●				
Indiana	●			●	●	●	●				
Iowa	●				●		●				
Kansas		●		●	●	●	●				
Kentucky			●								
Louisiana			●								
Maine			●								
Maryland		●			●		●				
Massachusetts		●		●	●		●				
Michigan	●					●	●				
Minnesota			●								
Mississippi			●								
Missouri	●				●		●				
Montana		●		●	●	●	●				
Nebraska	●				●		●				
Nevada	●			●	●	●	●	●	●		
New Hampshire			●								
New Jersey		●		●	●	●	●				●
New Mexico		●		●	●	●	●				
New York		●					●				
North Carolina	●			●	●						●
North Dakota		●		●	●		●				
Ohio		●		●	●		●				
Oklahoma	●				●	●	●				
Oregon	●			●	●	●	●	●	●		●
Pennsylvania		●					●				
Rhode Island			●								
South Carolina	●			●	●		●				
South Dakota		●		●	●		●			●	
Tennessee	●			●	●		●				
Texas	●			●	●	●	●	●	●		●
Utah	●			●	●	●	●	●	●		●
Vermont	●						●				
Virginia			●								
Washington		●		●	●	●	●	●	●	●	●
West Virginia	●					●	●				
Wisconsin	●						●				
Wyoming	●			●	●	●	●				

*Adapted from U.S. Environmental Protection Agency [2004] in 2006 update [MCES, 2007].

Table 3.3. Number of States with Water Reuse Regulations or Guidelines for Agricultural Uses

Type of Use	Number of States with Regulations or Guidelines	Description
Agricultural irrigation of food crops	21	Irrigation of food crops which are intended for human consumption; food crop is to be processed or food crop is consumed uncooked.
Agricultural irrigation of nonfood crops	40	Irrigation of fodder, fiber, and seed crops, pasture land, commercial nurseries, and sod farms.
Industrial water reuse	9	Reclaimed water used in industrial facilities primarily for cooling system makeup water, boiler-feed water, process water, and general washdown and cleansing.

Adapted from U.S. Environmental Protection Agency [2004].

State water reuse regulations typically include one or more of the following elements:

- Treatment Process Requirements
- Biochemical Oxygen Demand (BOD)/Total Suspended Solids (TSS), and Turbidity Requirements
- Coliform Bacteria Limits
- Limits and Monitoring for Pathogenic Organisms
- Disinfection Requirements
- Treatment Reliability
- Storage Requirements
- Cross Connection Control
- Irrigation-Specific Requirements

The variations among state regulations are illustrated in Table 3.4, which includes examples of several states' reclaimed water standards for agricultural water uses. Cooling water (last column) represents regulations that would be required for an agricultural processing facility that uses cooling water where there is a potential for human contact from the mist created.

Water reuse regulations focus on public health implications of using the water. Water quality criteria not related to health protection usually are not included in water reuse regulations. Most states with extensive water reuse experience have comparable, conservatively-based water quality criteria or guidelines.

Table 3.4. Examples of State Water Reuse Criteria for Nonpotable Agricultural Applications

State	Fodder Crop Irrigation[1]		Processed Food Crop Irrigation[2]		Food Crop Irrigation[3]		Industrial Cooling Water[4]	
	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required	Quality Limits	Treatment Required
Arizona	▪ 1,000 fecal coli/100 ml	▪ Secondary	Not covered	Not covered	▪ No detect. fecal coli/100 ml ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	Not covered	Not covered
California	Not specified	▪ Oxidation	Not specified	▪ Oxidation	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[5] ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation[4] ▪ Filtration ▪ Disinfection
Colorado	Not covered	Not covered	Not covered	Not covered	Not covered	Not covered	▪ 126 *E.coli*/100 ml ▪ 30 mg/L TSS	▪ Secondary ▪ Disinfection
Florida	▪ 200 fecal coli/100 ml ▪ 20 mg/L CBOD[6] ▪ 20 mg/l TSS[7]	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection	Use prohibited	Use prohibited	▪ No detect. fecal coli/100 ml ▪ 20 mg/L CBOD ▪ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection
New Mexico (Policy)	▪ 1,000 fecal coli/100 ml ▪ 75 mg/L TSS ▪ 30 mg/L BOD	Not specified	Not covered	Not covered	Use Prohibited	Use Prohibited	Not covered	Not covered
Utah	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/L TSS	▪ Secondary ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ No detect. fecal coli/100 ml ▪ 10 mg/L BOD ▪ 2 NTU	▪ Secondary ▪ Filtration ▪ Disinfection	▪ 200 fecal coli/100 ml ▪ 25 mg/L BOD ▪ 25 mg/TSS	▪ Secondary ▪ Disinfection
Texas	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified	Use prohibited	Use prohibited	▪ 200 fecal coli/100 ml ▪ 20 mg/L BOD ▪ 15 mg/L CBOD	Not specified
Washington	▪ 240 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 240 total coli/100 ml	▪ Oxidation ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection	▪ 2.2 total coli/100 ml ▪ 2 NTU	▪ Oxidation ▪ Coagulation ▪ Filtration ▪ Disinfection

1 In some states more restrictive requirements apply where milking animals are allowed to graze on pasture irrigated with reclaimed water.
2 Physical or chemical processing sufficient to destroy pathogenic microorganisms. Less restrictive requirements may apply where there is no direct contact between reclaimed water and the edible portion of the crop.
3 Food crops eaten raw where there is direct contact between reclaimed water and the edible portion of the crop.
4 Cooling towers where a mist is created that may reach populated areas.
5 Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.
6 CBOD – Carbonaceous biochemical oxygen demand; where BOD is the same as Total BOD
7 TSS – total suspended solids

Arguments for less restrictive standards are most often predicated upon a lack of documented health hazards rather than upon any certainty that hazards are small or nonexistent. In the absence of definitive epidemiological data and a unified interpretation of scientific and technical data on pathogen exposures, selection of water quality limits will continue to be somewhat subjective and inconsistent among the states.

Regulatory Water Reuse Criteria for Industrial Uses

Regulatory agencies generally prescribe water reuse requirements for industrial applications other than cooling on an individual case basis. In many cases, the specific industrial reuse customer will have additional criteria (or more stringent criteria) than those imposed by the regulatory agency. Some states have specified criteria for some general industrial use categories. The California and Florida reclaimed water quality requirements for industrial water uses applicable to agricultural processing industries are provided in Tables 3.5 and 3.6, respectively. Agricultural processing facilities in Minnesota must adhere to the requirements in Table 3.5, plus case-specific limits and/or treatment practices for water uses not listed or listed as a general category, such as "process water".

Table 3.5. California Water Recycling Criteria (Industrial Uses Applicable to Agricultural Processing Facilities)

Type of Use	Total Coliform Limits	Treatment Required
▪ Cooling water where no mist created ▪ Process water where no worker contact ▪ Boiler feed	▪ ≤ 23/100 ml	▪ Secondary ▪ Disinfection
▪ Cooling water where mist created[1] ▪ Process water where worker contact likely	▪ ≤ 2.2/100 ml	▪ Secondary ▪ Coagulation[2] ▪ Filtration ▪ Disinfection

[1] Drift eliminator required; chlorine or other biocide required to treat cooling water to control *Legionella* and other microorganisms.
[2] Not required under certain conditions.
Source: Adapted from State of California [2000].

Table 3.6. Florida Reuse Rule (Industrial Uses Applicable to Agricultural Processing Facilities)

Type of Use	Total Coliform Limits	Treatment Required
▪ Wash water[1] ▪ Process water[1]	▪ ≤ 200 fecal coli/100 ml ▪ ≤ 30 mg/L BOD ▪ ≤ 30 mg/L TSS	▪ Secondary ▪ Disinfection
▪ Once through cooling in closed system	▪ ≤ 30 mg/L BOD ▪ ≤ 30 mg/L TSS	▪ Secondary
▪ Once through cooling where mist created (alternative requirements acceptable if certain conditions met)	▪ No detectable fecal coli/100 ml ▪ ≤ 20 mg/L BOD ▪ ≤ 5 mg/L TSS	▪ Secondary ▪ Filtration ▪ Disinfection [2]

[1] Manufacture or processing of food or beverage where the water will be incorporated into or come in contact with the product is prohibited.
[2] Reclaimed water must be sampled at least once every two years for *Giardia* and *Cryptosporidium*.
Source: Adapted from Florida Department of Environmental Protection [1999].

Agricultural Processing Industry-Specific Regulations

Many of Minnesota's agricultural processing industries are recycling water within their facility. This practice must meet regulations pertinent to the particular industry. For example, the U. S. Food Safety Inspection Service (FSIS) established regulatory sanitation performance standards applicable to all official meat and poultry establishments (FSIS Docket 96-037F; 64 FR 56400). The regulations require that any recycled water must be accounted for in the standard operating procedures of the facility and meet specified guidelines, principally a reduction in the pathogens of a reused water supply that meets established testing procedures. In addition, the regulatory requirements for water reuse in these establishments restrict the use of reclaimed water, as listed in 9 CFR 416.2(g):

> "Any water that has never contained human waste and that is free of pathogenic organisms may be used in edible and inedible product areas, provided it does not contact edible product. For example, such reuse water may be used to move heavy solids, flush the bottom of open evisceration troughs, or to wash antemortem areas, livestock pens, trucks, poultry cages, picker aprons, picking room floors, and similar areas within the establishment."

For food and safety regulations related to other food processing, see www.fsis.usda.gov.

3.2 Technical Considerations

The main technical issues that must be addressed with water reuse involve water quality and conveyance of water from the WWTP to the agricultural processing facility. The most cost-effective source would be one where the wastewater effluent water quality meets all the processing facility water quality criteria and conveyance requirements are minor. In most cases, some additional treatment is required to meet the facility process requirements or health-related criteria. This section will provide some general water quality requirements and issues with reclaimed water use, which are broadly applicable to agricultural processing facilities. Treatment requirements and technologies are summarized for some common agricultural processing facility water uses.

Water quantity is also an important consideration for agricultural processing facilities. Many industries are often located near populated areas that generate large volumes of wastewater. This is not the case for most agricultural processing facilities, which are located in rural areas with small population centers, and hence, may not have the reclaimed supply available in a reasonable proximity to meet all their needs. In some instances storage facilities may be required to match the daily fluctuations of a WWTP supply to the industrial facility's demand. Storage and other conveyance considerations are site-specific and are not emphasized in this document.

Water Quality Concerns

Reclaimed water from conventional wastewater treatment processes is of adequate quality for many applications that can tolerate water of less than potable quality. The quality required depends upon the use of the water. Potential uses of reclaimed water for agricultural processing facilities include cooling, process water, stack scrubbing, boiler feed, washing, transport of material, and as an ingredient in a product such as ethanol.

Cooling is the predominant industrial reuse application, accounting for more than 90 percent of the total volume of reclaimed water used for industrial purposes in the U.S. [U.S. Environmental Protection Agency, 2004]. Water surveys and personal communications with agricultural processing facility staff for this study and previous studies [MCES, 2007] indicate that cooling water is a significant water use for some of Minnesota's agricultural processing sectors. Boiler feed water, while not a large water use at most facilities, is a water use common at most facilities.

Cooling Water

Pathogenic microorganisms in water used in cooling towers present potential hazards to workers and to the public in the vicinity of cooling towers from aerosols and windblown spray. In practice, biocides are usually added to all cooling waters onsite to prevent slimes and otherwise inhibit microbiological activity, which has the secondary effect of eliminating or greatly diminishing the potential health hazard associated with aerosols or windblown spray. States regulating cooling water have established pathogen limits and most have treatment requirements to ensure public safety.

Aerosols produced in the workplace or from cooling towers also may present hazards from the inhalation of VOCs, and although little definitive research has been done in this area, there has been no indication that VOCs have created health problems at any existing water reuse site. Closed-loop cooling systems using reclaimed water present minimal health concerns unless there is inadvertent or intentional misuse of the water.

There is no indication that reclaimed water is more likely to contain *Legionella pneumophila* bacteria than waters of non-sewage origin. All cooling water systems should be operated and maintained to reduce the *Legionella* threat, regardless of the origin of the source water.

In general, the major problems related to the use of municipal effluents as makeup water for cooling are scale formation, corrosion, foaming, and biological fouling due to high residual organic substrate and nutrient concentrations in the wastewater. These problems are caused by contaminants in potable water as well as reclaimed water, but the concentrations of some contaminants in reclaimed water may be higher, depending on the level of treatment at the WWTP.

Cooling water should not lead to the formation of scale, i.e. hard deposits in the cooling system. Such deposits reduce the efficiency of the heat exchange. The principal causes of scaling are calcium (as carbonate, sulfate, and phosphate) and magnesium (as carbonate and phosphate) deposits. Scale control for reclaimed water is achieved through chemical means and sedimentation. Acidification or addition of scale inhibitors can control scaling. Acids (sulfuric, hydrochloric, and citric acids and acid gases such as carbon dioxide and sulfur dioxide) and other chemicals (chelants such as EDTA and polymeric inorganic phosphates) are often added for pH and alkalinity control to increase the water solubility of scale-forming constituents, such as calcium and magnesium. Lime softening removes carbonate hardness and soda ash removes noncarbonate hardness. Other methods used to control scaling are alum treatment and sodium ion exchange.

Reclaimed water with high levels of total dissolved solids (TDS), ammonia, and heavy metals can cause serious increased corrosion rates [Puckorius and Hess, 1991]. The concentrations of TDS can increase electrical conductivity and promote corrosion. Ammonia can induce corrosion in copper-based alloys. Dissolved gases and certain metals with high oxidation states also promote corrosion. For example, heavy metals, particularly copper, can plate out on mild steel, causing severe pitting. Corrosion also may occur when acidic conditions develop in the cooling water. Corrosion inhibitors such as chromates, polyphosphates, zinc, and polysilicates can be used to reduce the corrosion potential of the cooling water. These substances may have to be removed from the blowdown prior to discharge. An alternative to chemical addition is ion exchange or reverse osmosis. Reclaimed water may have higher or lower corrosion-causing pollutant concentrations than other water supply sources.

The moist environment in a cooling tower is conducive to biological growth. Nutrient and organic matter in cooling water must be minimized to prevent the growth of slime-forming organisms. Removal of BOD and nutrients in the wastewater treatment process train reduces the potential of the reclaimed water to sustain microorganisms.

Microorganisms can significantly reduce the heat transfer efficiency, reduce water flow, and in some cases generate corrosive by-products [California State Water Resources Control Board, 1980]. Sulfide-producing bacteria and sulfate-reducing bacteria are the most common corrosion-causing organisms in cooling systems using reclaimed water. These anaerobic sulfide producers occur beneath deposits and cause pitting corrosion that is most severe on mild and stainless steels. Serious corrosion is caused by thiobaccillus bacteria, an acid-producer that converts sulfides to sulfuric acid. Similarly, nitrifying bacteria can convert ammonia to nitric acid, thus causing pH depression, which increases corrosion on most metals.

Chlorine is the most common biocide used to control biological growth because of its low cost, availability, and ease of operation. Chlorination is also used as a disinfectant to reduce potential pathogens in the reclaimed water. Frequent chlorination and shock treatment are generally adequate.

Non-oxidizing microbiocides are generally required in addition to chlorine for reclaimed water with a higher nutrient content. Since most scale inhibitors and dispersants are anionic, either anionic or nonionic biocides are usually used. Low-foaming, nonionic surfactants enhance microbiological control by allowing the microbiocides to penetrate the biological slimes. Wastewater facilities with chemical coagulation and filtration for phosphorus removal significantly reduce the contaminants that can lead to fouling. Chemical dispersants are also used as required.

Additional treatment of any water supply is often needed for recirculating cooling systems. Treatment may include lime or alum treatment, filtration, ferric chloride precipitation, ion exchange, and reverse osmosis. For reclaimed water, the treatment required for cooling water is dependent on the existing municipal WWTP process train and other variables, as discussed later in this section. In some cases, only additional chemical treatment is necessary, which may include many of the chemicals mentioned above and others, such as phosphonates or calcium phosphate for destabilization, polyacrylates for suspended solids dispersion, and anti-foaming agents for dispersion of foam caused by phosphates and some organic compounds.

Boiler Feed Water

The use of reclaimed water for boiler feed water typically requires extensive treatment. Quality requirements for boiler-feed makeup water are dependent upon the pressure at which the boiler is operated. Generally, the higher the pressure, the higher the quality of water required.

Reclaimed water must be treated to remove hardness. Calcium and magnesium salts are the principal contributors to scale formation and deposits in boilers. Excessive alkalinity contributes to foaming and results in deposits in heater, reheater, and turbine units. Bicarbonate alkalinity, under the influence of boiler heat, may lead to the release of carbon dioxide, which is a source of corrosion in steam-using equipment. Silica and aluminum form a hard scale on heat-exchanger surfaces, while high concentrations of potassium and sodium can cause excessive foaming in the boiler. Depending on the characteristics of the reclaimed water, lime treatment (including flocculation, sedimentation, and recarbonation) may be required, possibly followed by multi-media filtration, carbon adsorption, and nitrogen removal. High-purity boiler-feed water for high-pressure boilers might also require treatment by reverse osmosis or ion exchange [Meyer, 1991]. The considerable treatment and the relatively small amounts of makeup required make boiler-feed a poor candidate for reclaimed water as the sole water use at a facility.

Process Water

The wide spectrum of processes used in the agricultural processing of food and non-food products requires a facility-specific inquiry. Some general issues for process water include: impurities found in water, particularly certain metal ions and color bodies, cause reactions that affect product quality; biological growth can cause clogging of equipment and odors and can affect process performance; corrosion and scaling of equipment may result from the presence of silica, aluminum, and hardness; and presence of pathogens for food and beverage products.

Recommended Water Quality Criteria for Select Uses

The water quality requirements for each agricultural processing facility are unique and typically require different levels of quality for the various uses of water within a facility. The common use of water for cooling and boiler feed, as discussed above, follow the general quality guidelines listed in Tables 3.7 and 3.8.

Treatment Requirements and Technologies

The treatment requirements for water reuse applications are typically based on the quality of the source water used by a community, industries discharging to the wastewater treatment facility, the wastewater treatment processes, and the intended use of the reclaimed water. The type of technology selected will depend on whether treatment is incorporated into the wastewater treatment facility's process train, at the agricultural processing facility site, or at a municipal satellite facility along the distribution line that could benefit multiple customers. If storage is required for a constant flow, additional treatment may be required. With all these variables, the treatment process and conveyance system selected is certainly a site and case-specific one. This subsection presents an overview of treatment processes used to provide reclaimed water to any customers with a focus on those most applicable to agricultural processing facilities.

Table 3.7. Recommended Cooling Water Quality (Makeup for Recirculating Systems)

Parameter	Recommended Limit (mg/L)
Alkalinity	350
Aluminum	0.1
Ammonia	24
Bicarbonate	200
Calcium	50
Chloride	500
Hardness	650
Iron	0.5
Manganese	0.5
Phosphorous	1.0
Silica	50
Total Suspended Solids	100
Sulfate	200
Total Dissolved Solids	500

Source: Adapted from Water Pollution Control Federation [1989] and Goldstein *et al.* [1979].

Table 3.8. Recommended Industrial Boiler Feed Water Quality

Parameter	Recommended Limit (mg/L)		
	Low Pressure (<150 psig)	Medium Pressure (150-700 psig)	High Pressure (>700 psig)
Alkalinity	350	100	40
Aluminum	5	0.1	0.01
Ammonia	0.1	0.1	0.1
Bicarbonate	170	120	48
Calcium	*	0.4	0.01
Chemical Oxygen Demand	5	5	1
Copper	0.5	0.05	0.05
Dissolved Oxygen	2.5	0.007	0.007
Hardness	350	1.0	0.07
Iron	1.0	0.3	0.05
Magnesium	*	0.25	0.01
Manganese	0.3	0.1	0.01
Silica	30	10	0.7
Suspended Solids	10	5	0.5
TDS	700	500	200
Zinc	*	0.01	0.01

Source: Adapted from U.S. EPA [2004] and Metcalf & Eddy [2007].

Wastewater Plant Effluent Quality

The constituent concentrations in municipal wastewater plant effluent are different for every facility. However, given common permit limits, some constituent concentrations are universal to most facilities based on the general treatment trains presented in Table 3.9. In Minnesota, all municipal wastewater treatment facilities have secondary treatment and many have nutrient removal processes, particularly for nitrogen. Many plant upgrades will likely include the requirement for phosphorus removal. There are few facilities in Minnesota that have filtration processes, but this practice may become increasingly common as receiving streams reach their maximum load capacity and additional pollutant removal is necessary.

Table 3.9. Typical Wastewater Treatment Plant Effluent Quality

	Constituent Concentration, mg/L		
Constituent	**Secondary Treatment**	**Secondary Treatment with Nutrient Removal***	**Tertiary Treatment with Filtration**
BOD	5-20	5-10	≤5
TSS	5-20	5-10	≤2
Fecal Coliform	< 200/100 ml	< 200/100 ml	< 200/100 ml
pH	6-9	6-9	6-9
Total Phosphorus	4-15	≤1	≤0.4
Ammonia	10-30	≤3	≤1

*Ammonia limit of 3 mg/L and total phosphorus limit of 1 mg/L

Agricultural processing facilities are typically located in smaller communities, many of which use pond systems for their wastewater treatment. The water quality from these systems would fall under the secondary treatment column of Table 3.9. Most water uses at an agricultural processing facility would require treatment to remove nutrients and possibly more organics and solids. If the main water supply of an agricultural community is hard and has iron and manganese problems, it is likely that the wastewater effluent will require softening and be high in salts, which requires further treatment. The basic and potential additional treatment processes to produce a reclaimed supply for various uses are described below.

Treatment Processes

Cooling and Process Water. When chemical treatment options for cooling water cannot provide the necessary water quality, other treatment processes must be used. The treatment processes commonly used for larger industrial cooling water systems are shown in Figure 3.1. Nitrification is usually used to remove ammonia that causes stress in copper based alloy pipes. Ferric chloride or alum is used to precipitate phosphorus to levels less than 0.6 mg/L, to avoid precipitation and scale formation.

Many Minnesota WWTP process trains include nitrification, clarification and disinfection. Additional processes needed to provide the quality required for cooling water include chemical addition/mixing (flocculation) and filtration. Membrane softening is also used at some facilities for cooling water.

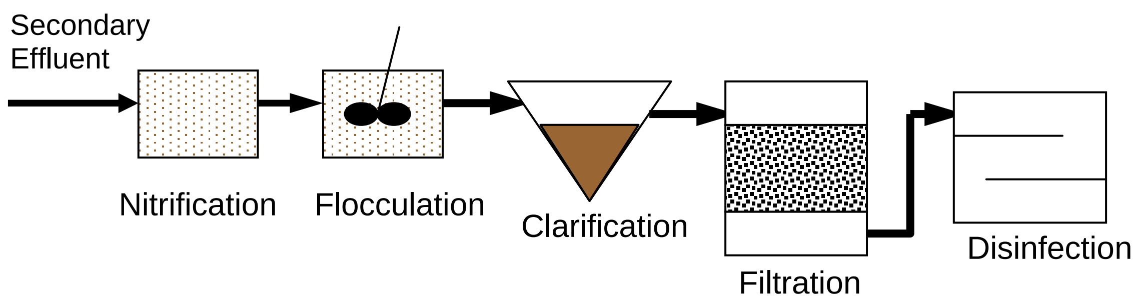

Figure 3.1. Typical Treatment Train of Reclaimed Water for Cooling Water

Disinfection. Disinfection is required for all uses of reclaimed water to meet the pathogen standards and protect public health. While Minnesota's municipal wastewater treatment facilities have disinfection requirements, the level of treatment typically needs to be modified to meet the lower pathogen requirements for some agricultural processing facility uses. Chlorine disinfection is the most commonly used practice in Minnesota. Higher chlorine dosages and contact time (requiring additional contact tanks) or modification to UV system operation will likely be required for reclaimed water uses.

UV disinfection is used at many wastewater treatment facilities and is becoming more common at Minnesota facilities. Its application is dependent on the wastewater effluent characteristics and site-specific economics. While there are several factors to evaluate to determine if UV is the optimum disinfection practice, better performance is typically achieved with lower suspended solids and smaller particle sizes. Hence, for plants with process trains with filters, UV may be the cost-effective technology to achieve the higher levels of disinfection required for most reuse applications. UV disinfection has been successfully used for reclamation water production to achieve fecal coliforms of less than 20/100 ml [Smith and Brown, 2002], a limit that provides the pathogen protection required for many reuse practices. In addition to meeting pathogen limits prior to leaving a facility, a disinfectant residual is typically maintained in the transmission lines to the reuse customer. Chlorine residuals of 0.5 mg/L or greater in the conveyance system are typically recommended to reduce odors, slime and bacterial growth.

Other Processes. Process water and other applications, particularly for agricultural processing facilities, will likely require advanced wastewater treatment processes. Processes not discussed previously include:

- Membrane Processes
- Carbon Adsportion
- Advanced Oxidation Processes

Figure 3.2. Membrane System Used as a Tertiary Treatment Process

Membrane processes are moving into the wastewater treatment arena. They have been used for water reclamation in much the same capacity as for potable water supply treatment. Figure 3.2 shows a typical membrane system for tertiary treatment. New technologies are providing the ability to use membranes in the secondary process train of WWTPs. This advancement provides flexibility and/or simplification of the process train to meet wastewater process performance goals and produce the higher quality effluent required for many reuse applications.

The type of membrane used is dependent on the various quality goals. Membranes are typically characterized by the pathogen requirements as shown in Figure 3.3. For agricultural processing facilities, other constituents are targeted to select the proper membrane system. For example, a boiler feed water application could include microfiltration followed by a two-pass reverse osmosis system. Reverse osmosis systems are already used at most facilities with boilers to treat the existing water supply.

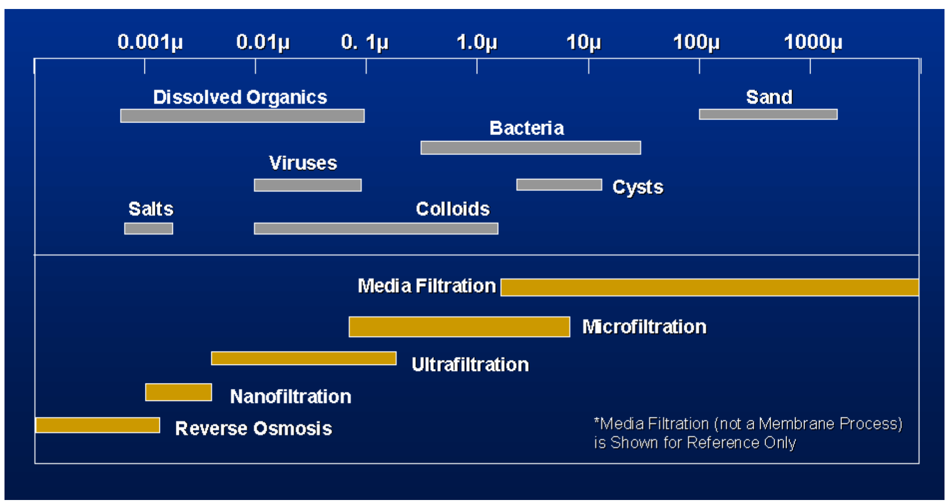

Figure 3.3. Constituent Rejection by Membranes

Carbon adsorption and advanced oxidation processes are used to address specific organic contaminant removal. Carbon adsorption, a process used by potable water supply systems for taste and odor control or removal of organic contaminants, can be used to reduce the biodegradable and refractory organic constituents in wastewater effluent. Carbon adsorption following a secondary treatment and filtration treatment train can produce an effluent with a BOD of 0.1-5 mg/L, a COD of 3-25 mg/L and a TOC of 1-6 mg/L. It can also be used to remove several metal ions, particularly cadmium, hexavalent chromium, silver, and selenium. Activated carbon has also been used to remove uncharged elements such as arsenic and antimony from an acidic stream. Endocrine disrupting compounds have also been successfully removed with activated carbon [Hunter and Long, 2002]. The use of activated carbon for reclaimed water would be a very industry specific requirement. Given that filtration is typically required prior to the carbon adsportion process, and that most municipal plants in Minnesota do not have filters, a different technology, notably membranes, might be selected to meet organic and metal removal goals, as well as serve other process needs.

Organics present in very small concentrations, noted as trace organics can potentially be removed with advanced oxidation processes. Trace organics include pharmaceuticals, endocrine disruptors, personal care product compounds, and other potential carcinogens. There are combinations of treatment processes under study now and used to remove trace organics at some facilities. The commercially available processes in the U.S. include: UV and hydrogen peroxide, ozone and hydrogen peroxide, and ozone and UV. These processes are applied to highly treated waters and typically follow a reverse osmosis process.

Reliability in Treatment. The treatment technologies selected must also incorporate redundancy or other reliability features. In Minnesota, the MPCA has regulations and guidelines for redundancy in wastewater treatment systems. If reclaimed water is the primary source for the agricultural processing facility, then the reliability features will likely need to meet higher standards. If the facility is able to maintain a backup source, then this can be factored into the design. Reliability requirements are another element of a reuse project that will be subject to regulatory review, as well as the user agreements between the industry and municipal supplier of the reclaimed water.

Waste Stream Disposal/Treatment. Many of the treatment technologies used in water reclamation result in waste streams with high concentrations of pollutants (e.g. TDS, chloride, sodium, sulfate, boron, and specific conductance) which are evaluated for discharge to Minnesota receiving waters. This is currently a concern with the cooling water blowdown for several existing industrial facilities, including ethanol plants, and may present similar water quality issues for municipal WWTPs recycling water.

3.3 Economic Considerations

Feasibility will depend on the specific match of WWTP effluent quality to an agricultural processing facility's water quality requirements, the system capacity, transmission distance, and the availability of traditional water supplies in the area. The major conclusions from the cost analysis performed in a previous MCES study [MCES, 2007], summarized in Figure 3.4, include the following:

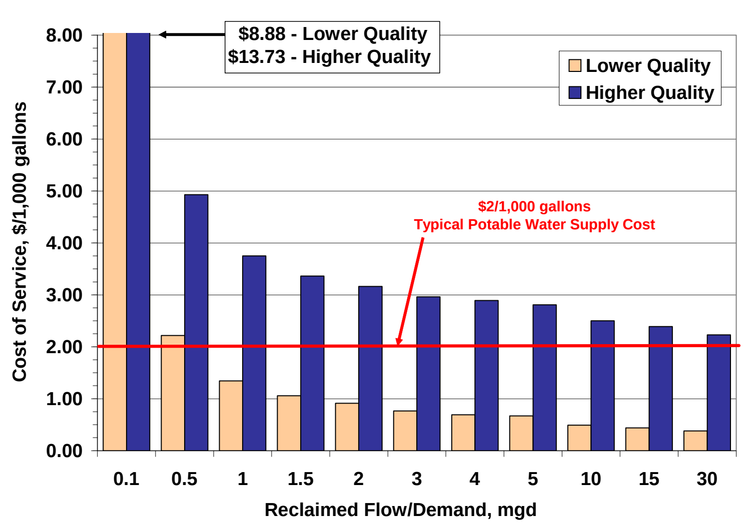

Figure 3.4. Treatment and 5-Mile Transmission System Costs

- Reclaimed water can be competitive with traditional water supplies in some cases. Potable water supplies average around $2 per 1,000 gallons in Minnesota and can be as high as $5 per 1,000 gallons in rural areas. A reclaimed supply from a secondary treatment system with nutrient removal (lower quality in Figure 3.4) could be less than $2 per 1,000 gallons.

- Removal of hardness and high salt levels significantly adds to the cost. Communities relying on home softening systems, which discharge salts in the wastewater, will likely require more treatment to meet reclaimed water quality goals for dissolved solids and salts. A reclaimed water supply with low dissolved solids and salts treated by a membrane softening process (higher quality in Figure 3.4) is around $2.50 per 1,000 gallons more than a secondary effluent supply. This equates to approximately $3.75/1,000 gallons for a 1 mgd supply. For a 0.5 mgd supply, costs rise to $5.00/1,000 gallons, assuming a 5-mile transmission distance.

- Cost efficiency improves as reclaimed water usage increases and favors systems delivering more than 1 mgd.

Other factors affecting the economic feasibility of water reuse include:

- The presence of microconstituents, a collective term for contaminants of concern found in trace amounts, notably pharmaceuticals, endocrine disruptors, and personal care product compounds, will likely be a future issue for water reuse applications, as it will for all water supplies. Advanced tertiary processes are available to remove microconstituents and can add significantly to the cost.

- Historical records of important constituents of concern for reclaimed water uses are not usually available for WWTP effluent and are needed to fully evaluate alternative water supplies. Limited data on wastewater effluent chlorides, total dissolved solids, and hardness characteristics can lead to estimating average values without considering seasonal or other cycles of variability. Additional water quality monitoring will provide the data to more accurately estimate costs and better evaluate the feasibility of water reuse.

3.4 Institutional Considerations

There are several institutional issues that need to be addressed for an agricultural processing facility to use reclaimed water. Laws, policies, rules, and regulations that affect the planning and implementation of water reuse projects include: water rights, conflicting laws and regulations, permitting, local planning ordinances, environmental assessment and impact, public involvement/education, legal agreements or contracts, agency jurisdictions, and fee structures.

Currently, no agricultural processor in Minnesota uses reclaimed water as a nonpotable water supply. However, agricultural processors are beginning to investigate its use, such as the Corn Plus ethanol facility in Winnebago, Minnesota. Institutional issues will arise as these projects unfold. Experience from the one industrial example, cooling water for the Mankato Energy Center, and various irrigation reuse practices in Minnesota, and experience of other states can be used to frame the anticipated issues. Some issues are explored in a companion document to this study, a case study of water reuse in an ethanol facility.

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Section 4
Summary and Conclusions

This memorandum provides an overview of water reuse in Minnesota with specific applications and considerations for agricultural processing facilities as summarized in this section.

4.1 Drivers

There are four main drivers for water reuse, in general, and industrial-related reuse in particular for Minnesota: water quality, water quantity, environmental stewardship, and sustainable economic growth.

- Water Quality
  - Historic water reuse applications have been water quality driven. Agricultural irrigation of treated wastewater effluent has been practiced in Minnesota's rural areas in lieu of summer pond discharges for facilities a significant distance from an acceptable receiving stream.
  - Water quality issues will drive future water reuse in Minnesota. As growing communities generate additional wastewater, there will be a need to provide higher levels of wastewater treatment to maintain or decrease the discharge loads to the state's waterways. Finding other uses for the treated wastewater, through partnerships with industry or other users, will decrease wastewater discharges. The development of Minnesota's Total Maximum Daily Load (TMDL) program will affect the discharge allocations for most communities.
- Water Quantity
  - While discharge limitations will increasingly be a factor in Minnesota, it is anticipated that water supply limitations will be a driver in the near future given water supply shortages at regional and local levels.
  - The water demands of the ethanol industry in Minnesota's water supply-limited southwest region have required investigating water supply options other than local groundwater and were the impetus for this study.
- Environmental Stewardship
  - Minnesota's environmental stewardship ethic has promoted the conservation and protection of water resources.
  - This stewardship ethic can drive reuse projects even when other drivers are not present and when economics would not point to reuse.

- Sustainable Economic Growth
  - The Minnesota Legislature is interested in industrial water reuse as a means of fostering sustainable economic growth, as indicated in funding for a previous MCES study [MCES, 2007].
  - Recent legislation (H.F. 1231) provides grants for water reuse capital projects specifically aimed at ethanol facilities and the conservation of groundwater resources for potable water uses.

4.2 Water Use

Historic water use for Minnesota's agricultural sector was characterized for activities from the farm to final product distribution. The Minnesota DNR water appropriations permit database was analyzed for various agricultural water uses. The data presented reflect water use under a state permit and do not include facility use of community potable water supplies.

- The largest agricultural water use in the state is for major crop irrigation, accounting for around 75-85% of the water withdrawn for agricultural purpose (119,970 mgy in 2007). Based on 2007 records, the next largest use is for agricultural product processing (10,250 mgy), followed by aquaculture (6,730 mgy), noncrop irrigation where agricultural applications include sod farms, orchards, and nurseries (1,490 mgy), biofuels production (1,430 mgy), and livestock watering (790 mgy). As a point of perspective, total water use in Minnesota in 2007 was 1,430,000 mgy of which nearly 60% or 840,000 mgy was the use of surface water for once-through cooling at power generation facilities.
- Water use for the agricultural processing sector over the last 20 years has fluctuated between 10,000 and 13,000 mgy. The largest water users are food processing facilities.
- The quantity of water used for the various agricultural processing practices is highly variable and facility-specific. Ethanol facilities, the example industry for this study, use between 3-6 gallons of water for every gallon of ethanol produced. Newer facilities typically have lower water use rates.
- Agricultural processing facility water use includes water used for processing and production, cooling, boiler feed, air conditioning, washing, stack scrubbing, transport of materials, sanitation, potable supply for personnel, and grounds irrigation. Cooling water is often one of the largest uses of water and one of the most common uses of water at an agricultural processing facility. Cooling water is also the most common application for industrial use of reclaimed water in the U.S.

4.3 Implementation Considerations

- Regulatory

  – Minnesota is one of several states that have not developed state water reuse criteria. Currently, Minnesota uses California's *Water Recycling Criteria* [State of California, 2000] to evaluate water reuse projects on a case-by-case basis. In Minnesota, water reuse requirements are included in NPDES permits administered by the MPCA.

  – A WWTP supplying reclaimed water will be required to monitor for total coliforms, meet total coliform limits, and modify their treatment process train to meet the regulations. For cooling water uses, most WWTPs would be required at minimum to add disinfection facilities and filtration.

  – The modifications for reclaimed water production must continue to meet existing NPDES and other permit requirements and consider future permit conditions. Some treatment technologies result in concentrated waste streams and there is concern that pollutant concentration discharge limits (i.e. TDS, chloride, sulfate, boron, and specific conductance) may exceed the water quality standards for some receiving streams.

  – Some agricultural processing facilities may fall under other federal or state regulations that could affect how and if reclaimed water can be used. For example, the U. S. Food Safety Inspection Service (FSIS) has regulatory sanitation performance standards applicable to all official meat and poultry establishments (FSIS Docket 96-037F; 64 FR 56400). These regulations apply to in-facility recycling of water as well as to the use of reclaimed water from outside of a facility. Specific language restricts the use of reclaimed water at these facilities.

- Technical/Economic

  – The water quality of the WWTP treated effluent, the water quality required for the agricultural processing facility's use, the existing WWTP process train, and regulatory requirements all influence the processes selected for a water reuse treatment system. Most agricultural processing facility water uses require a higher quality water, as with cooling water. WWTPs with nutrient removal and in areas with moderate water hardness may require only treatment facilities to meet regulatory needs to supply cooling water. For WWTPs without nutrient removal, additional treatment is needed and if hardness or salts need to be removed, more extensive treatment is required.

  – Removal of hardness and high salt levels significantly adds to the cost. Communities relying on home softening systems, which discharge salts in the wastewater, will likely require more treatment to meet reclaimed water quality goals for dissolved solids and salts. A reclaimed water supply with low dissolved solids and salts treated by a membrane softening process is around $2.50 per 1,000 gallons more than a reclaimed supply that does not require softening.

- Institutional
  - There are several institutional issues that need to be addressed for an agricultural processing facility to use reclaimed water such as: local planning ordinances, public involvement/education, legal agreements or contracts, agency jurisdictions, and fee structures.
  - Experience from the one industrial project in Minnesota, cooling water for the Mankato Energy Center, and various irrigation reuse practices in Minnesota, and experience of other states can be used to frame the anticipated issues.

Metropolitan Council Environmental Services

In Association with

Agricultural Utilization Research Institute

Reclaimed Water for Value-Added Agricultural Processing Project

TECHNICAL MEMORANDUM 2

Ethanol Facility Water Reuse Case Study

June 29, 2009

Craddock Consulting Engineers

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Section 1
Introduction

The ethanol industry is a component of the Minnesota agricultural processing sector that has grown significantly over the past decade. Some ethanol facilities, and other industries, have experienced difficulty in obtaining an adequate water supply for operation. While water supply availability is not currently considered a limitation for industrial development in many Minnesota communities, there are areas in the state that have a limited supply of high quality water. Industries requiring abundant or high quality water may find it difficult to locate or expand in some areas unless other water supply options are made known and available to them. One potential water supply is effluent from municipal wastewater treatment plants (WWTPs), also known as reclaimed water, recycled wastewater, or recycled water.

The Agricultural Utilization Research Institute (AURI) recognized the value of reclaimed water for the agricultural processing industry and initiated action to conduct a study on the feasibility of water reuse. AURI contacted the Metropolitan Council Environmental Services (MCES), St. Paul, Minnesota, to coordinate efforts for a water reuse study focused on the agricultural processing community. MCES recently completed a study on the feasibility of industrial water reuse in Minnesota [MCES, 2007]. Funding for this study was recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR) from the Environment and Natural Resources Trust Fund.

The MCES-AURI project builds on the work already completed by MCES with context and specific considerations for the agricultural processing industry. This technical memorandum documents the work efforts of Task 2 of the project, a case study of water reuse in the ethanol industry. Technical Memorandum 1, *Reclaimed Water for Agricultural Processing*, provides background information relevant to this document. The third project task incorporates stakeholder involvement and further definition of implementation issues facing water reuse at agricultural processing facilities in Minnesota. MCES is responsible for Tasks 1 and 2 and AURI for Task 3.

This memorandum provides a planning level analysis of facilities and operation and maintenance (O&M) requirements to supply reclaimed water to an ethanol facility for cooling water use. The purpose is to identify the basic project elements that need to be evaluated to technically implement a project. The emphasis is on the treatment requirements and costs. This memorandum details the following information:

- Facilities to provide reclaimed water to an ethanol facility for cooling water use
  - Treatment requirements to achieve regulatory and ethanol facility goals
  - Alternative treatment processes
  - Transmission system requirements
- Planning level system costs
- Implementation considerations
- Checklist of information to perform a water reuse assessment

Section 2
Case Study Description

This case study evaluates the project components and the related implementation issues associated with supplying reclaimed water to a hypothetical ethanol facility in Minnesota. The case study's assumed project elements were selected to illustrate, in a generic manner, the process by which an ethanol facility or, potentially, other agricultural processing facilities would evaluate the use of reclaimed water as a non-potable water supply. The case study as a whole is not specific to a particular WWTP, ethanol facility, or geographic location. However, information from specific facilities and locations was used in order to represent realistic data and circumstances.

The system elements that strongly influence the design and related costs to supply reclaimed water to an ethanol facility include the following:

- Municipal WWTP effluent quality and existing process train
- Water quality of local water supplies
- Location of water reuse treatment facilities
- Distance between the municipal WWTP and ethanol facility

This case study incorporates different characteristics for these elements based on the conceptual model described below.

2.1 General Characteristics and Conceptual Model

This case study assumes a dry mill process ethanol facility that requires a non-potable water supply of 1 mgd. A 1 mgd water supply would be the requirement for a 70 million gallon per year (mgy) ethanol facility that uses on average 4 gallons of water to produce 1 gallon of ethanol (gallons water/gallons ethanol). Excess water system capacity is assumed to provide for seasonal fluctuations in usage and system performance and for expansion, potentially to 100 mgy of ethanol production. The source of the reclaimed water is assumed to be the treated effluent from the local municipal WWTP.

Although the WWTPs closest to most existing ethanol facilities in Minnesota generate less than 1 mgd of effluent, 1 mgd was selected because it is relatively straightforward to scale up or down from this value. Reclaimed water from smaller WWTPs can be blended with an ethanol facility's other water supplies, providing flexibility. A 1 mgd supply would also be a typical requirement for a new ethanol facility, which may choose to locate near a larger community with an adequate wastewater supply.

Water reuse systems can be configured in many ways. Commonly used components are shown in Figure 2.1. This study's assumptions about the system components are summarized below and described further in this section.

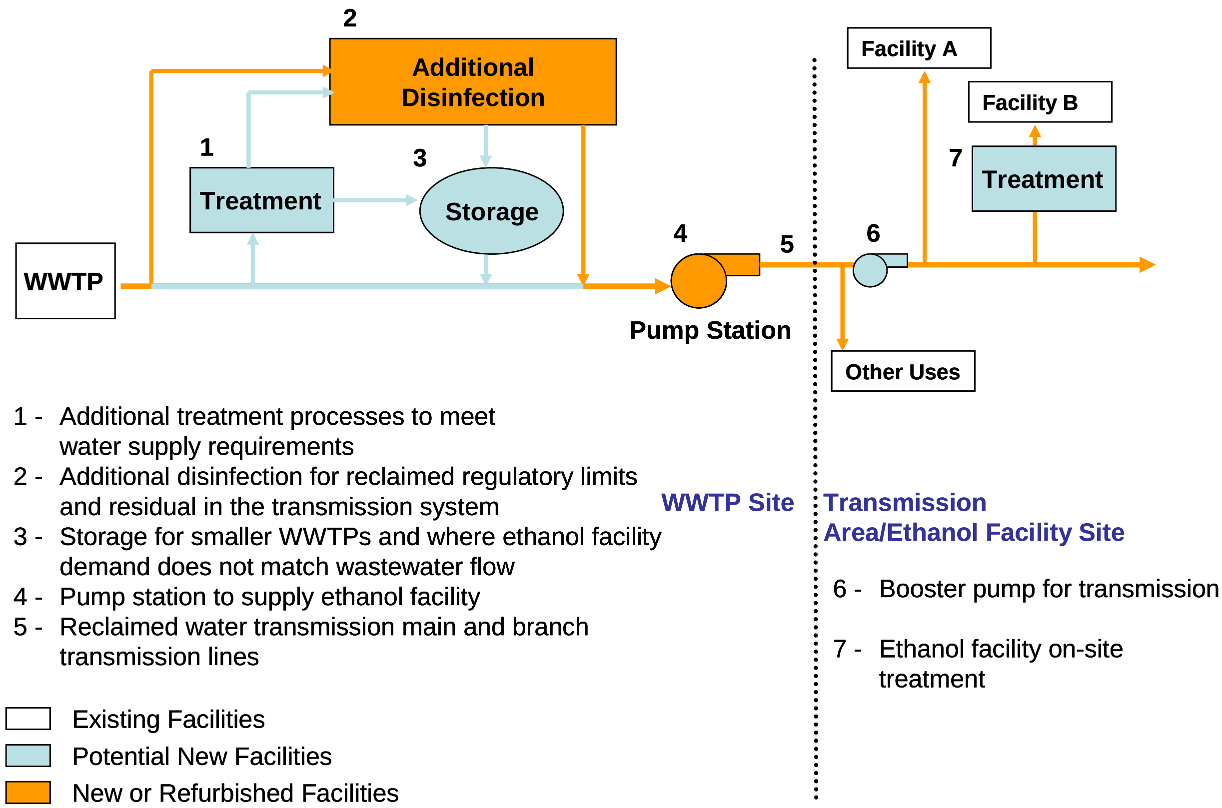

Figure 2.1. Water Reuse System Conceptual Model

- Treatment of WWTP Effluent (1)
  - Additional processes to those currently used by an existing WWTP, if needed.
  - New WWTP processes to replace existing processes during a plant upgrade.
- Additional Disinfection (2)
  - A residual disinfectant is often used in the transmission system to minimize bacterial growth. Liquid chlorine (sodium hypochlorite) is assumed for this study.
  - Additional disinfection is required for year-round disinfection and more stringent pathogen limits. The existing facilities may be able to achieve this, but it is assumed new equipment is required.
- Storage (3)
  - In some instances, storage will be required to balance the diurnal or other WWTP flow variations with the requirements of a specific industrial demand for different peak hour, weekly or other dominant demand patterns.
  - Storage will likely be required for WWTPs that reclaim over 50 percent of their flow. Most WWTPs supplying an existing ethanol facility will require storage. This study assumed storage is required.
- Pump Station (4)
  - A pump station located onsite at the WWTP.
  - For cost development purposes, this study assumes delivery of 1 mgd of reclaimed water to the ethanol facility at a pressure of 40 pounds per square inch (psi) and the same elevation as the WWTP.

- Reclaimed Water Transmission System (5)
  - Transmission main and branch transmission lines supplying reclaimed water to the ethanol facility.
  - This study assumes transporting 1 mgd of reclaimed water a distance of 5 miles.
- Booster Pumps (6)
  - Some ethanol facilities may require booster pumps depending on their location and delivery pressure requirements.
  - Booster pumps are not assumed to be necessary in this analysis.
- Ethanol Facility Site Treatment (7)
  - Some ethanol facilities already treat their existing water supply. These same processes or modifications may be required with a reclaimed supply.
  - Some ethanol facilities may require new treatment processes to use a reclaimed supply. It may be cost-effective to locate this treatment at the ethanol facility site.
  - For this study, it is assumed that all new treatment processes are located at the WWTP site.

2.2 Municipal WWTP Effluent Quality

The majority of the ethanol facilities in Minnesota are located in greater Minnesota in communities with small population centers. WWTPs for these communities are often pond or mechanical systems meeting secondary treatment performance standards. Some communities have or will have discharge permits that require removal of the nutrients phosphorus and/or ammonia. Future regulations may require removal of total nitrogen (not just ammonia nitrogen). For purposes of this case study, a WWTP that removes nutrients, specifically phosphorus and ammonia, is considered an advanced secondary treatment (AST) system. While some WWTPs are equipped with tertiary treatment processes, such as filtration, this study focuses on those without tertiary processes. In general, WWTPs that have or will have tertiary processes will require less investment in facilities to provide reclaimed water.

Effluent water quality characteristics by treatment level are shown in Table 2.1. In general, advanced secondary treatment produces lower concentrations of most regulated constituents than secondary treatment alone. Most noticeable are the lower phosphorus and ammonia concentrations, but on average the biochemical oxygen demand (BOD) and total suspended solids (TSS) concentrations are also typically lower.

The effluent quality for WWTPs with processes following advanced secondary treatment or in place of some secondary processes are also listed in Table 2.1. Additional processes could include filtration, chemical addition followed by coagulation, flocculation, and sedimentation processes, a membrane bioreactor, or chemical/physical and ion exchange softening processes to remove residual dissolved solids and trace constituents.

This study assumes the WWTP supplying reclaimed water has either a secondary or advanced secondary treatment system. Municipal effluent treated to these levels will require additional treatment for use as cooling and process water at an ethanol facility. The regulatory requirements, discussed in Section 3, require at minimum a filtration process and additional disinfection to meet pathogen limits.

Table 2.1. Typical WWTP Effluent Quality[1]

Constituent	Effluent Constituent Concentration by Treatment Level					
	Secondary Treatment	**Advanced Secondary Treatment[2]**	**AST with Filtration[3]**	**AST with Chemical Addition & Filtration[4]**	**Membrane Bioreactor[5]**	**Advanced Tertiary Processes[6]**
BOD, mg/L	5-20	5-10	≤5	≤5	<1-5	≤1
TSS, mg/L	5-20	5-10	≤3	≤3	≤2	≤1
TOC, mg/L	8-30	8-20	1-5	*1-5*	0.5-5	0.1-1
Total Phosphorus, mg/L	3-10	≤1	≤0.8	≤0.4	0.5-2	≤0.5
Ammonia, mg/L	10-40	≤3	≤3	≤2	<1-5	≤0.1
Nitrate, mg/L	trace	10-30	10-30	10-30	<10	≤1
Total Nitrogen, mg/L	15-45	15-35	15-35	15-35	<10	≤1
Turbidity, NTU	2-15	2-8	0.3-2	0.3-2	≤1	0.01-1
TDS[7], mg/L	750/1500	750/1500	750/1500	<500/800	750/1500	≤5-40
Hardness[7], mg/L as $CaCO_3$	250/400	250/400	250/400	100/200[8]	250/400	<30
Fecal Coliform[9]	>10^4/< 200	>10^4/< 200	>10^4/< 200	---	---	Approx. 0
Total Coliform[9]	>10^4/< 23	>10^4/< 23	>10^4/< 2.2	>10^4/< 2.2	<100/<2.2	Approx. 0

[1] Adapted in part from Metcalf & Eddy, 2007.
[2] Conventional activated sludge treatment with nutrient removal based on meeting a discharge permit ammonia limit of 3 mg/L and total phosphorus limit of 1 mg/L. It does not include total nitrogen removal (denitrification); AST=advanced secondary treatment.
[3] Filtered advanced secondary treatment effluent using depth filtration, surface filtration, or dissolved air flotation.
[4] Same as filtered advanced secondary treatment effluent, but it includes a chemical addition/coagulation/flocculation/sedimentation process typically using ferric chloride (or alum) and lime for softening (additional unit processes required for softening)
[5] Secondary treatment comprised of aeration with membranes configured as external pressure-driven, integrated submerged, or external submerged rotating bioreactors with biological nutrient removal (for total nitrogen).
[6] Treatment processes to remove residual dissolved solids and specific trace constituents, including chemical/physical and ion exchange softening. These processes follow or include a filtration process.
[7] Concentrations are highly variable and are represented by average concentrations for two different supplies: Average Quality and Low Quality (average/low), where low quality waters are considered to be hard and/or have high salt concentrations.
[8] Chemical addition treatment process assumes use of lime.
[9] Values are presented as most probable number /100 ml for estimated fecal and total coliform concentrations without disinfection and with disinfection (without/with). The second concentration is also the reclaimed water quality standard that the disinfection process is designed to meet.
Acronyms: AST=advanced secondary treatment; BOD=biochemical oxygen demand; TSS=total suspended solids; TOC=total organic carbon; TDS=total dissolved solids; NTU=nephelometric turbidity unit

WWTP effluent data for permitted constituents is well documented as part of the WWTP's permit requirements. These constituents include carbonaceous or total BOD (CBOD, BOD), TSS, ammonia (NH3), total phosphorus (TP), and fecal coliform. Many WWTPs with industrial dischargers also have a historic record of heavy metals and priority pollutant compounds collected on a less frequent basis. These parameters are important in characterizing the effluent quality and applicability as a reclaimed supply. However, there are many other constituents of concern for cooling, process and other water uses and the majority of these are not commonly characterized in municipal WWTP effluent.

Sampling should be performed to characterize the specific WWTP effluent quality to determine general applicability. An understanding of the intended uses of the water and any water quality concerns with existing supplies should be determined. In the case of the ethanol industry, and generally most industries, a significant factor affecting the economic selection of a water supply is the water quality ion balance affecting hardness and dissolved ions (solids, metals, and salts).

2.3 Water Quality of Local Water Supplies

Recognizing that water quality varies over the state, a broad assumption was made for this study that Minnesota's waters tend to be either hard with high concentrations of dissolved ions or of average quality. Given that wastewater originates from the local water supplies, reclaimed water is likely to have some water quality characteristics similar to the local water supply.

WWTPs are designed to remove organics, solids, and possibly nutrients. The constituents associated with hardness and dissolved salts generally are not removed by advanced secondary treatment processes. Additional treatment is required to provide a water quality suitable for cooling water use. Hence, the local water quality characteristics are an important factor in determining the treatment required and the associated costs.

2.4 Location of Water Reuse Treatment Facilities

This case study assumes the treatment facilities to produce reclaimed water for cooling water use at an ethanol facility are located at the WWTP. There are situations where the treatment processes would be better located at the ethanol facility site. Reasons to locate the treatment facilities at the ethanol facility include:

- Site constraints at the WWTP preclude the addition of new facilities at the WWTP.
- The new treatment processes may require reclassification of the WWTP and a change in operator certification which may not be practical for a small community.
- The ethanol facility may already have treatment facilities that can be used to achieve the water quality goals and reduce the capital expenditure of new equipment.
- The ethanol facility operations staff would prefer to have control and optimize the treatment to meet their various process requirements.

The advantages to locating the water reuse treatment facilities at the WWTP include:

- The ability to provide reclaimed water for multiple uses such as to irrigate golf courses, parks, or residential areas, and use the infrastructure to further conserve water resources or to attract more industries and promote growth in water limited areas.
- Capital and operation and maintenance cost savings realized by integrating planned improvements for the WWTP with treatment processes to meet reclaimed water quality goals.

- Flexibility in operating the WWTP to meet other discharge requirements and provision of redundant unit processes (e.g. additional chemical addition facilities to handle phosphorus removal).
- The regulatory requirements are the responsibility of one entity, in this case the municipality.
- The ability to accept the ethanol facility discharge streams back at the WWTP, which might be of benefit to those ethanol facilities already near their maximum discharge permit flow, loads and/or concentration limits.
- Potential cost savings and long-term aquifer conservation through coordinated planning of the wastewater system with the water supply systems for the community, surrounding communities and industries.

The location of water reuse treatment facilities will be a case-specific solution given the variability in existing WWTP processes, local water supply quantity and quality, existing ethanol facility water treatment processes, distance and pumping requirements for transmission of the reclaimed water, and other considerations. It is beyond the scope of this study to address all the variables and associated costs; rather, the potential issues and site conditions that should be considered in location of treatment facilities are highlighted.

2.6 Case Study Scenarios

This case study evaluates four scenarios comprising the basic treatment requirements for a secondary and advanced secondary treatment facility with and without treatment for hardness and salt removal. It is assumed that the water reuse facilities are located at the WWTP and reclaimed water is transmitted five miles to an ethanol facility for use as cooling water. The scenarios are identified as follows:

- A1- Secondary WWTP effluent with average quality
- A2 - Secondary WWTP effluent with low quality (hard/high salt water)
- B1 - Advanced Secondary WWTP effluent with average quality
- B2 - Advanced Secondary WWTP effluent with low quality (hard/high salt water)

Section 3
Treatment Requirements

This section identifies the treatment processes required to provide a suitable reclaimed supply to an ethanol facility. This case study evaluates the treatment process trains for four scenarios to produce reclaimed water suitable for use as cooling water. Reclaimed water could be treated and used for other uses within an ethanol facility such as process water or boiler feed water. However, because cooling water accounts for approximately 60-70% of the water use in ethanol processing, this case study focuses on analyzing reclaimed water for cooling water purposes. A similar evaluation process would be used to evaluate the potential for reclaimed water to fill other water use requirements.

The treatment required is dependent on the WWTP effluent quality, the regulatory requirements, and the intended use of the water. Sections 3.1 and 3.2 summarize the regulatory requirements and water quality characteristics assumed for cooling water that serve as the basis for the treatment process alternatives presented in Section 3.3. Technical Memorandum 1 provides background information on the regulatory requirements that reclaimed water must meet and the water quality characteristics required for various water uses at an ethanol facility. Appendix A provides alternative treatment process information.

3.1 Treatment to Meet Regulatory Requirements

Regulatory Requirements to Supply Reclaimed Water

The reclaimed water must meet the regulatory requirements administered by the Minnesota Pollution Control Agency (MPCA), based on the California Water Recycling Criteria [State of California, 2000]. Table 3.1 lists the regulatory requirements which include specific pathogen limits and treatment requirements.

The regulatory requirements impose two basic treatment process modifications or additions for all Minnesota WWTPs providing reclaimed water:

- Disinfection – higher levels of disinfection, year-round disinfection (currently required only from April – October in Minnesota), and for transmission system residual

- Filtration and possibly coagulation processes (or membrane processes) for water uses where worker contact is likely. In the case of ethanol facilities, cooling towers produce a mist and therefore fall under this requirement.

Other Regulatory Requirements

In addition to meeting the regulatory requirements of the California Water Recycling Criteria, the municipality and ethanol facility must still meet other facility permit requirements. Any process changes made to treat and transmit the reclaimed water will fall under the regulatory review process and must comply with the existing (or future) National Pollutant Discharge Elimination System/State Disposal System (NPDES) permit limits. Use of a reclaimed supply will affect both the municipal WWTP and ethanol facility NPDES permits.

Table 3.1. California Water Recycling Criteria (Applicable to Ethanol Facilities)

Type of Use	Total Coliform Limits	Treatment Required
■ Cooling water where no mist created ■ Process water with no worker contact ■ Boiler feed	■ ≤ 23/100 ml[1] ■ ≤ 240/100 ml (max in any 30-day period)	■ Secondary ■ Disinfection
■ Cooling water where mist created[2] ■ Process water where worker contact likely	■ ≤ 2.2/100 ml[1] ■ ≤ 23/100 ml (max in any 30-day period)	■ Secondary ■ Coagulation[3] ■ Filtration ■ Disinfection

Source: Adapted from State of California [2000].

[1] Based on running 7-day median; daily sampling is required.
[2] Drift eliminator required; chlorine or other biocide required to treat cooling water to control *Legionella* and other microorganisms.
[3] Not required under certain conditions.

For some water reuse treatment systems, the waste streams generated from some unit processes present disposal problems. While this case study focuses on treatment to meet the intended uses of the water, the treatment train design must also consider waste stream management that meets discharge limits. This issue is discussed further in Section 3.3.

3.2 Treatment for End Use Requirements

The reclaimed water must also be of suitable quality for use at an ethanol facility. Most uses of water for cooling purposes require constituent concentrations below certain thresholds to avoid corrosion, scaling, and biological growth in the cooling water system. Typical constituents of concern for cooling water and the associated problems are summarized in Table 3.1. Technical Memorandum 1 provides related background information.

Table 3.1. Typical Constituents of Concern for Cooling Water Applications

Constituent	Potential Problems
Ammonia	Biological fouling, corrosion
Chlorides	Corrosion
Hardness (Related ions: calcium, magnesium, carbonate, bicarbonate)	Scaling (corrosion potential for some ions)
Microorganisms	Biological fouling
Organic compounds	Biological fouling
Phosphorus	Scaling, biological fouling
Silica	Scaling
Sulfate	Corrosion
TDS	Corrosion, scaling

Table 3.2 lists recommended water quality concentrations for the main non-potable water uses at an ethanol facility and compares them to potential water supply characteristics. As seen in the cooling water column, the target concentrations for some constituents vary widely, given the different cooling water applications and the overall water chemistry. While this case study

is based on cooling water applications, there is a strong potential to use reclaimed water for other non-potable uses and specific projects should consider non-cooling water uses. Values presented for ethanol process water are based on personal communications supplemented with literature values for boiler feed water. Boiler feed water is typically supplied by water treated with reverse osmosis (RO) or ion exchange even for most potable water supplies. The water quality limits shown in the process/boiler water column represent a very high quality water for boilers, not necessarily required for every process in ethanol production.

Table 3.2. Water Quality Recommended for Ethanol Facilities Compared to Different Supplies

Parameter	Cooling Water[1]	Process/ Boiler Water[2]	WWTP Effluent[3]	Ground Water[4]	River Water[5]
Temperature, min (deg C)	--	--	8	12	0
Temperature, max (deg C)	--	--	22	14	25
Temperature, avg (deg C)	--	--	19	--	--
Alkalinity (mg/L as $CaCO_3$)	20-350	*20-40	274	260	213
Aluminum (mg/L)	0.1	0.01	0.034	ND	ND
Ammonia (mg/L)	24	0.1-0.5	<1	0.7	0.39
Bicarbonate (mg/L)	25-200	50	367	ND	260
Calcium (mg/L)	15-50	0.01	88	105	76
CBOD (mg/L)	<20	--	4.0	ND	<2-8**
COD (mg/L)	--	1	42	ND	ND
Chloride (mg/L)	50-500	2	419	35	35
Fluoride (mg/L)	--	--	ND	0.22	0.32
Hardness (mg/L as $CaCO_3$)	130-650	0.07-20	306	ND	250-350**
Iron (mg/L)	0.5	0.05	0.13	1.99	0.13
Magnesium (mg/L)	--	0.01	28	36	31
Manganese (mg/L)	0.5	0.01	0.097	0.07	0.074
Nitrate (mg/L)	--	--	19.1	23.7	5.0
Phosphorus, total (mg/L)	1	1	<1	ND	0.29
pH	6.5 – 9	6.5 - 8.5	7.3	8.1	8.5
Silica[3] (mg/L)	15-50	0.7-3	20	17	17
Sulfate (mg/L)	50-200	--	45.9	44.3	127
Total dissolved solids (mg/L)	100-500	*6-200	1160	ND	370-750**
Total suspended solids (mg/L)	20-100	0.5	8	ND	37-950**
Turbidity (ntu)	--	--	5	2.2	26

[1] Cooling Water (USEPA, 2004); variable range related to amount of recycling and materials of construction; high range is typically maximum in blowdown/final water; low range is more typical for Minnesota industries

[2] Ethanol process requirements are noted with an asterisk (*), for parameters supplied by ethanol industry; otherwise values are for Industrial Boiler Feed Water (high pressure). Values in ranges typically refer to boiler feed water requirements for the lower value except where noted with an asterisk (*).

[3] The wastewater treatment effluent is characterized by a limited sampling program conducted in 2006-2007 for the MCES Empire WWTP plant [MCES, 2007].

[4] The ground water supply is represented by the average of several well samples in the proximity of the Empire WWTP obtained from county records.

[5] The river water quality is based on the MCES and USGS sampling of the Mississippi River in a reach close to the Empire WWTP. Values are the 95th percentile unless noted by **, where ** =range from average to maximum reported values in available data.

ND = no data available

Table 3.2 also lists constituent concentrations for treated wastewater effluent, ground water, and river water. Data from a wastewater treatment plant in the southeast metro area (an advanced secondary treatment system with UV radiation for disinfection) and nearby ground and surface water supplies are provided as an example. Table 3.2 illustrates the variability in the water quality that an ethanol facility must address when selecting a water supply.

This case study evaluates four treatment scenarios defined by different water quality characteristics of the WWTP effluent. The target constituents used for this case study and defining thresholds are listed in Table 3.3. The primary classification is based on the level of the nutrients, ammonia and phosphorus, in the WWTP effluent and the following definitions:

- Secondary treatment systems (A) do not remove phosphorus and may or may not remove ammonia.
- Advanced secondary treatment systems (B) remove both ammonia and phosphorus, defined by the maximum concentration limits of 3 mg/L and 1 mg/L, respectively.

Table 3.3. Target Constituent Levels in WWTP Effluent by Scenario

Constituent	*Scenario A Secondary Treatment*		*Scenario B Advanced Secondary Treatment*	
	A1: Average Quality	*A2: Low Quality*	*B1: Average Quality*	*B2: Low Quality*
Ammonia, mg/L	variable	variable	< 3	< 3
Phosphorus, mg/L	> 1	> 1	$\leq$ 1	$\leq$ 1
Chlorides, mg/L	< 250-500	> 250-500	< 250-500	> 250-500
Hardness[2], mg/L as $CaCO_3$	< 250-400	> 250-400	< 250-400	> 250-400
TDS, mg/L	< 750-1,000	> 750-1,000	< 750-1,000	> 750-1,000

[1] Variable range reflects multiple site factors, including the number of cooling system cycles of concentration.
[2] Hardness is used to represent the scaling potential of the water. Complete characterization of the related ions (calcium, magnesium, carbonate, and bicarbonate), other ions and indices is required.

The second classification is based on water quality characteristics of concern not typically removed in a WWTP. Average quality (1) water is defined to be suitable for cooling water without additional treatment to prevent scaling or corrosion. Low quality (2) water is considered to be hard (tendency to scale) and/or have high salt concentrations (potential for corrosion). The scaling and corrosion issues are represented by the following constituents: chlorides, hardness, and TDS. The target levels are presented as a range to indicate the variability associated with a specific effluent water quality and the type of cooling system.

A comparison of the target water quality constituents listed in Table 3.3 with the example water supplies in Table 3.2 and recommended levels in cooling water, indicates that for the wastewater effluent, chlorides and TDS are near or above thresholds for cooling water and the scaling potential related to water hardness species should be evaluated further. The ground and surface water supplies have much lower chloride levels than the WWTP effluent. Insufficient data exists to evaluate TDS and hardness in ground water, but given the alkalinity, bicarbonate and calcium concentrations, the river water and ground water could have scaling issues. Other issues of concern for the river water are TSS and sulfate, while high iron levels may be a problem for the ground water supply. A comparison of WWTP effluent to ground and surface water supplies related to treatment requirements is addressed in Section 6.

3.3 Alternative Treatment Processes

The evaluation of treatment processes is based on the following assumptions:

- The existing municipal WWTP effluent quality listed in Table 2.1 and Table 3.3.
- The reclaimed water delivered to the ethanol facility:
  - Meets the total coliform levels and process requirements listed in Table 3.1.
  - Provides a water supply without scaling, corrosion, or biological fouling issues, as represented by constituent concentrations recommended for cooling water in Table 3.2.

An overview of the potential treatment processes is followed by a description of the process trains selected for each scenario that form the basis of the costs presented in Section 5.

Scenario Overview

Regulatory requirements to use reclaimed water for cooling applications dictate at minimum a higher level of disinfection and filtration, and possibly a coagulation process prior to filtration. It is assumed for this study that a coagulation/clarification process is required for WWTPs without advanced secondary treatment (Scenario A), while it is not needed to treat advanced secondary effluent (Scenario B). Facility-specific and certain types of technology may impose the regulatory requirement for a coagulation process.

A secondary WWTP will typically require more treatment processes than an advanced secondary WWTP. If the secondary WWTP has ammonia removal, then a chemical system with coagulation and flocculation, followed by filtration and disinfection may be all that is needed to provide cooling water, assuming average water quality. If ammonia is not removed at the WWTP, then one option could be to implement a new secondary treatment process to incorporate nutrient removal. This process could be one of the many activated sludge based systems with biological nutrient removal (chemical phosphorus removal is also an option). Another alternative is to incorporate a membrane bioreactor (MBR) system with nutrient removal.

For purposes of this case study it is assumed that the secondary WWTP has ammonia removal and phosphorus will be removed by chemical addition, as shown for the Scenario A1 process train in Figure 3.1. With ammonia and phosphorus at levels suitable for cooling water, advanced secondary WWTPs with average water quality, represented as Scenario B1 in Figure 3.1, require only filtration and disinfection. Two options for the filtration and disinfection steps are considered for Scenarios A1 and B1, as shown by the split stream on the process schematics.

One option is filtration followed by enhanced disinfection and the other option is a membrane filtration process.

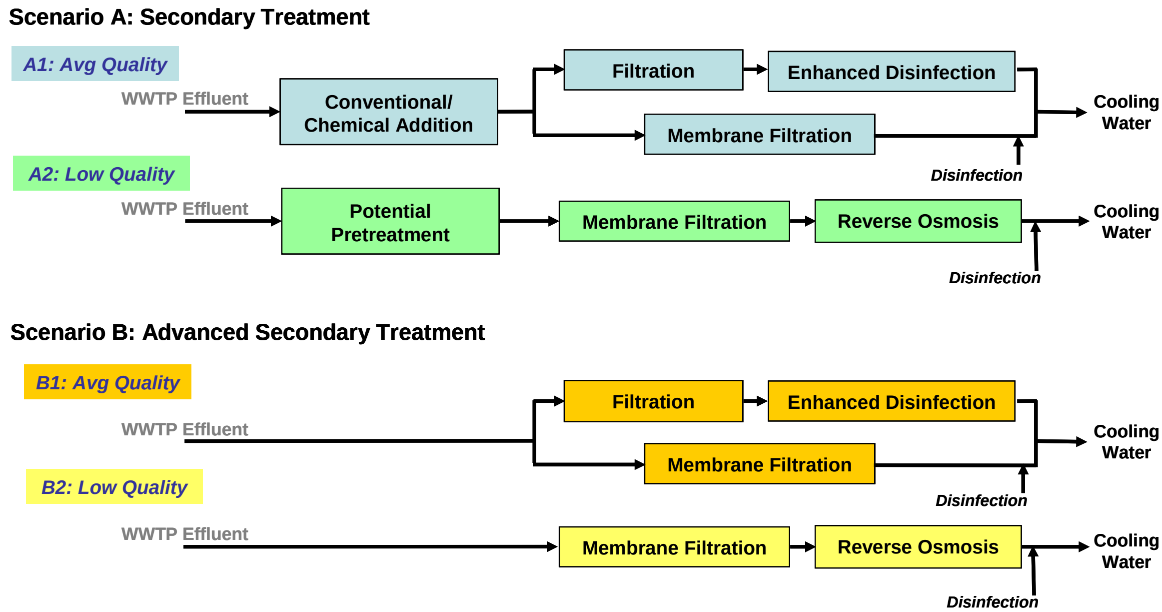

Figure 3.1. Scenario Treatment Process Trains

For hard and high salt water typified by Scenarios A2 and B2, the most likely treatment is RO. RO is a membrane softening process that provides both hardness and dissolved solids removal, where other technologies provide only partial softening or limited dissolved solids removal. Membrane filtration is required prior to RO, as shown in the process schematics for Scenarios A2 and B2 in Figure 3.1. Conventional lime softening is also a potential treatment option for hard waters without high salt concentrations, where the process train would be more similar to Scenario A1.

The proposed process trains for the four scenarios have similar unit processes, as illustrated in Figure 3.1 and discussed below.

Scenarios A1 and B1: Average Quality

Scenarios A1 and B1 are assumed to have the same unit process options for filtration and disinfection. The secondary treatment system, Scenario A1, requires a process to remove phosphorus to produce a quality that would be similar to an advanced secondary treatment system (B1) prior to filtration.

Conventional/Chemical Addition

A conventional, chemical addition process with ferric chloride is assumed for phosphorus removal and increased suspended solids and pathogen removal in Scenario A1. The process train consists of facilities for chemical addition, flocculation, sedimentation, and filtration, as depicted in Figure 3.2. The costs presented in this study assume the use of traditional concrete basins for coagulation, flocculation, and sedimentation. Two options are assumed for the filtration and disinfection processes as shown by the split stream after the sedimentation process in Figure 3.2 and described below.

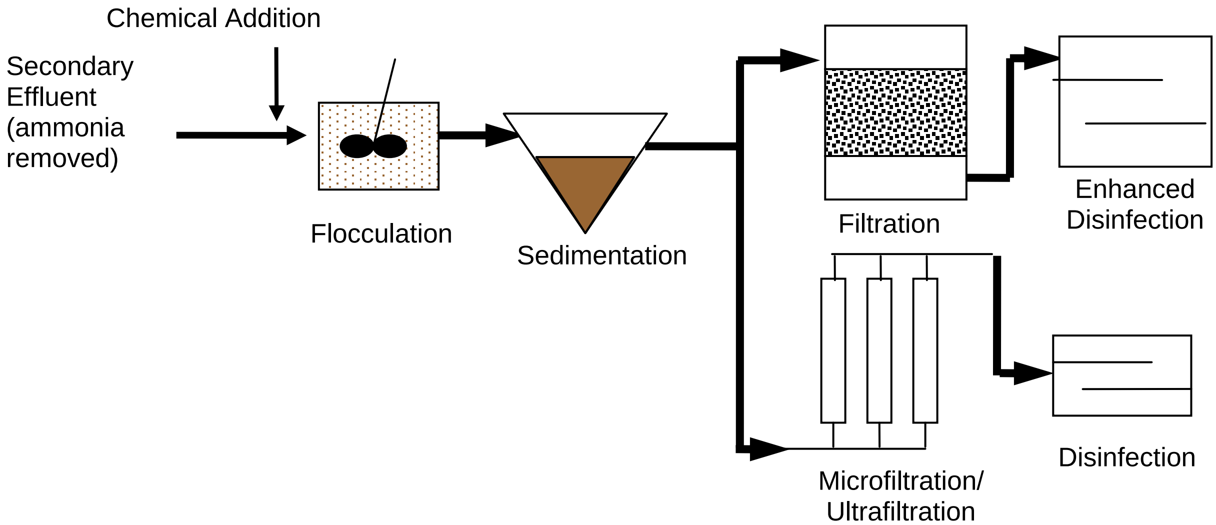

Figure 3.2. Scenario A1: Conventional/Chemical Addition Process Train

Filtration and Disinfection

Filtration and disinfection processes are required to achieve the regulatory total coliform limit of 2.2/100 ml (refer to Table 3.1 for the basis of the limit). This is a health-based limit given the potential human contact from cooling water mist. This limit also ensures treatment of the water to minimize or inhibit biological fouling in cooling water systems. The regulations also prescribe process requirements that must be achieved for both filtration and disinfection unit processes. In general, a filtration process using specified filtration rates and/or demonstrated effluent turbidities must be used in conjunction with prescribed disinfection processes that must be either:

1. A chlorine disinfection process that provides a CT (the product of total chlorine residual and modal contact time measured at the same point) value of 450 mg-min/l with a modal contact time of not less than 90 minutes based on peak dry weather flow, or

2. A disinfection process that, when combined with filtration, has been demonstrated to achieve 5-log inactivation of virus.

The California Water Recycling Criteria sections specifically calling out requirements for filtration and disinfection are provided in Appendix B.

Filtration can be accomplished by conventional methods such as gravity filtration or cloth disk filters. A gravity filtration process with sand and anthracite is assumed for conventional filtration. There are a variety of process enhancements and fabricated systems available that can be used for removal of particulate and dissolved solids, as indicated in Appendix A. The costs for these systems will vary with the specific site conditions but generally will be of the same magnitude or less than concrete basins and gravity filters.

Membrane filtration can be used instead of conventional filtration and will provide increased pathogen removal, possibly decreasing the disinfection system requirements. Membrane filtration typically removes total coliforms to values below 100/100 ml. In contrast, total coliform concentrations of conventionally filtered advanced secondary effluent are often greater than 10,000/100 ml. The process train for membrane filtration consists of microfiltration or ultrafiltration (MF/UF) membrane modules and the related piping for waste streams and appurtenances for chemical treatment.

Membrane filtration produces a rejection stream or concentrate that must be recycled o r processed for disposal. The assumptions made on management of these waste streams and the required flows to produce a final 1 mgd reclaimed supply are presented under the Scenario A2 and B2 process train description.

Disinfection in this case study is assumed to be chlorination with sodium hypochlorite. Sodium hypochlorite feed systems provide a unit process that can meet the three disinfection system improvement requirements: to meet a year-round disinfectant, provide a higher level of disinfection, and maintain a residual in the transmission system. A conservative assumption is made that all WWTPs will require new equipment for application of sodium hypochlorite at levels higher than any existing chlorination systems.

Disinfection requirements are assumed to be different for the two types of filtration processes considered. Conventional filtration will require chlorination equipment and new contact basins to meet regulatory requirements, the facilities needed for enhanced disinfection. For membrane filtration, it is assumed that the municipality will look to demonstrate virus removals with MF/UF followed by chlorination. It is assumed that new chlorination equipment is required and there will be continuous chlorination, but that new chlorine contact basins are not necessary. Chlorination will be required to achieve a total coliform limit of 2.2/100 ml, and chlorine will also be required to provide a residual for transmission.

For enhanced disinfection, it is assumed that additional contact basins are below grade concrete tanks sized to provide at least 75 minutes of extra contact time at peak dry weather flow. This is based on existing chlorine basins sized for 15 minutes of contact time at peak flows, thereby providing the total 90 minute contact time required by the regulations.

Chlorine doses were assumed as follows for the two annual operating practices and residual disinfection:

- April-October months with disinfection practiced by Minnesota WWTPs, where chlorination provides incremental disinfection from the NPDES pathogen limit to the reclaimed water pathogen limit.

- November-March months with no disinfection practiced by Minnesota WWTPs to provide disinfection to the reclaimed water pathogen limit.
- A chlorine dose of 2.5 mg/L was selected to achieve adequate residual through the transmission system. This is a dose commonly used by reclaimed systems across the country.

Chlorination practices at MCES facilities and facilities with reuse systems were reviewed to identify chlorine doses for existing systems to meet NPDES permit limits and to meet a variety of state reclaimed water criteria. For MCES facilities, average chlorine doses to meet NPDES discharge limits range from 2-4 mg/L with peak demands requiring 6 mg/L of chlorine. A reclaimed system in Cary, North Carolina reported the use of an 8 mg/L dose to meet pathogen kill and residual disinfection requirements. Use of the Refined Collins-Selleck Model to estimate chlorine dosages for disinfection of a nitrified secondary effluent [White, 1999] indicates that a dose of 4-15 mg/L is required depending on the nitrification process (ammonia at concentrations from 0.5 – 2 mg/L).

It is assumed that a chlorine dose of 6.5 mg/L applied to an advanced secondary treatment system effluent with a contact time of 90 minutes is required to meet a total coliform limit of 2.2/100 ml. For the disinfection season months of April through October it is assumed that WWTPs have a disinfection process equivalent to a chlorination system with an average dose of 3 mg/L. Therefore, an additional 3.5 mg/L chlorine is required to meet the more stringent reclaimed water pathogen limit from April to October. When the 2.5 mg/L chlorine dose for disinfection residual is included, the chlorine doses are as follows:

- April-October (7 months): 3.5 mg/L + 2.5 mg/L = 6 mg/L
- November-March (5 months): 6.5 mg/L + 2.5 mg/L = 9 mg/L
- Average Annual (based on weighted average, rounded) = 7 mg/L

Scenarios A2 and B2: Low Quality

RO was selected as the treatment process to remove both hardness and salts. RO requires a pre-filtered water supply. The cost analysis assumes use of MF/UF and cartridge filtration, as shown in Figure 3.3. The disinfection requirements are assumed to be similar to the requirements following membrane filtration under Scenarios A1 and B1. Total coliform concentrations in waters processed by RO are typically non-detectable.

Specific Process Configuration

The specific process train for RO and the water flows assumed for the study are shown in Figure 3.4. Preliminary modeling was performed using the example WWTP effluent data presented in Table 3.2. Models were run using the Hydranautics modeling software, and those results are presented in Table 3.4, along with the assumed concentrations of WWTP secondary or advanced secondary effluent (Feed). The production of 1 mgd of water treated with RO requires a total of 1.4 mgd of WWTP effluent; about a 70% recovery. The MF/UF process has about an 80% recovery and if used without a RO process (as in Scenarios A1 and B1) would require about 1.2 mgd to produce 1 mgd.

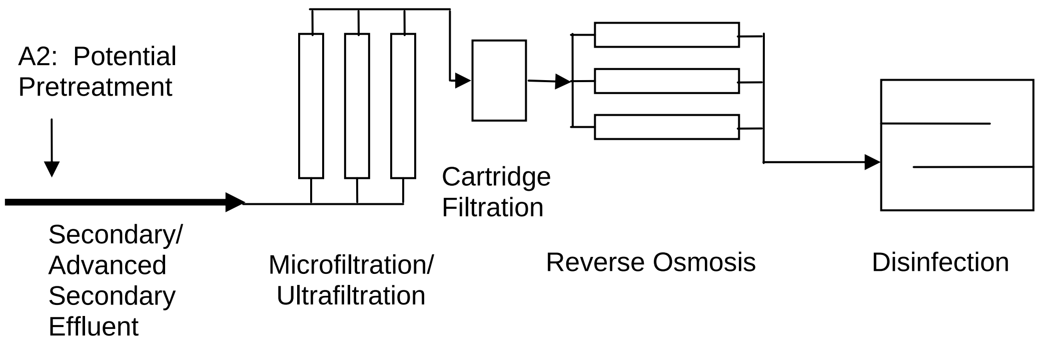

Figure 3.3. Scenarios A2 & B2: Reverse Osmosis Process Train

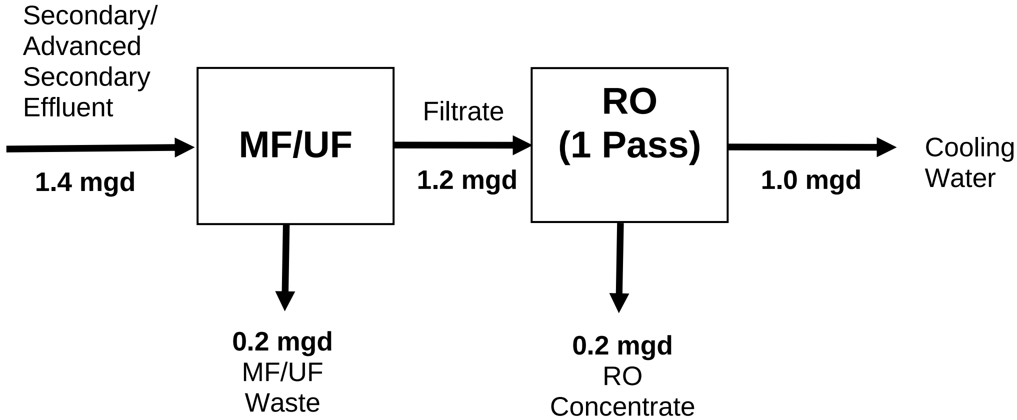

Figure 3.4. Process Flow Diagram for Reverse Osmosis

Technical Considerations

For the cooling tower application, the RO system modeled shows the membranes can treat the WWTP effluent to a greater degree than is actually required for the make-up water. This allows room for blending of advanced secondary effluent and RO permeate to reduce the size of the RO system required for this application. With the concentrations presented in Table 3.4, it was estimated that the size of the RO system could be reduced by approximately 20%, and with blending of permeate and effluent, water of acceptable quality would be produced. This provides one potential avenue for both capital and operation and maintenance cost savings.

Table 3.4. RO Membrane Treatment of WWTP Effluent (One Pass)

Parameter	Feed	Permeate	Concentrate
Ca	90	0.75	580
Mg	30	0.24	185
Na	250	10.0	1610
K	35	1.75	220
NH_4	2	0.1	13
Ba[1]	--	0	0
Sr[1]	--	0	0
CO_3	0.6	0	0.4
HCO_3	370	10.7	1545
SO_4	46	0.92	970
Cl	420	10.5	2736
F	--	0	0
NO_3	20	3.3	110
B	--	0	0
SiO_2	20	0.46	130
TDS[2]	1270	39	8100
pH[2]	7.3	5.2	7.3
LSI[2]	0.11	-5.5	1.44

[1] Barium and strontium are assumed at zero concentration (no data available). These elements form insoluble salts with sulfate and can be limiting factors Even at low levels. Further evaluation of membrane treatment should include analysis of these constituents.

[2] Values calculated by IMSDesign

Another important consideration for any membrane system is the fate of the waste streams produced by it. The RO systems are typically comprised of the following subsystems:

- Feed water strainers
- MF/UF
- Fine screen strainers
- Cartridge filters
- RO filtration

These systems will each produce waste streams that will either be able to be recycled back to the WWTP or directly blended with the remaining effluent discharge, depending on final concentrations and flows. The membrane systems typically generate wastes as described below:

- Strainer backwash waste comprised primarily of suspended solids
- MF/UF backwash waste comprised primarily of suspended solids
- MF/UF chemical cleaning waste comprised of suspended solids and cleaning solutions such as mineral acids and bases, citric acid, or hypochlorite
- RO concentrate (see Table 3.4 for estimated composition).

- RO chemical cleaning waste compromised of cleaning solution solutions such as citric acid or mineral acids or bases, organics and/or dissolved salts removed from the membranes.

The MF/UF backwash and chemical cleaning waste streams would, in most cases, be recycled to the head of the WWTP for treatment, as they contain suspended solids and biochemical oxygen demand. For this memo, it is assumed that the RO concentrate is discharged to a receiving body without further treatment at the WWTP. For this disposal option, the loads to the discharge receiving water body do not increase, but the concentrations of the discharge streams do. This may be an issue for some municipal WWTPs, but the constituents of concern such as chlorides, TDS, and sulfate are typically not parameters permitted in a municipal WWTP effluent. However, the high constituent concentrations are a significant issue for many ethanol facilities already near the thresholds of various NPDES permit limits.

Section 4
Transmission Requirements

4.1 Overview

An integral part of the planning, operation, and maintenance of water reuse systems is for the transmission of the reclaimed water to the customer. Most states with regulations and guidelines include standards for the design, installation, operation, and maintenance of the transmission systems. There are very specific guidelines for prevention of cross-connections to other systems, including use of backflow preventions devices and other plumbing features. The Minnesota Department of Labor regulates the design and installation of reclamation systems through the plumbing code.

4.2 Storage

This study assumes only storage for diurnal, daily or weekly industrial demand patterns that the WWTP cannot meet with their continuous supply. The conceptual water reuse system presented in Figure 2.1 provides for storage facilities on the WWTP site to meet a range of storage volumes. Given the size of most WWTPs near ethanol facilities, this study assumes storage is required for all scenarios characterized. The majority of WWTPs will only be able to supply a portion of an existing ethanol facility's demand.

Reclaimed water storage for this study is defined as the difference in the demand and diurnal wastewater flow. While most WWTPs have a consistent diurnal pattern that varies during the weekdays and weekend, reclaimed water demand will vary with the customer or set of customers. This case study is based on a 1 mgd supply of WWTP effluent and assumes a storage tank of 250,000 gallons to provide a consistent 1 mgd supply. The storage requirement is based on the following assumptions that can be applied to different size WWTPs: 50% of the water volume produced per day will be stored for annual average flows less than 0.5 mgd, 33% of a daily volume is stored for flows between 0.5 and 1.0 mgd and for 25% storage is provided for flows greater than or equal to 1 mgd. Additional storage that may be required by the ethanol facility was not considered in this analysis.

4.3 Pumping

The model for this study assumes a pump station is located on the WWTP site and is owned by the municipality. The pump station will include redundancy and reliability features consistent with state design standards and plumbing code requirements. The pump station is sized for peak flow and a residual pressure at the end of the pipe line of 40 psi, assuming delivery at the same elevation as the WWTP.

4.4 Transmission Pipelines

The majority of reclaimed transmission piping is polyvinyl chloride pipe (PVC) or ductile iron pipe (DIP) meeting specific industry standards. For this study, the transmission system is assumed to be PVC, DR 18, Class 150 forcemain with a diameter of 24 inches or less. Pipelines are sized to carry the peak hour demand (peaking factor of 3) of a given industry at a target velocity of 5 to 7 fps.

Section 5
Planning Level System Costs

The system costs presented in this study are planning level costs for a complete system to provide reclaimed water to an ethanol facility for cooling water use. This analysis does not differentiate which costs are to be supported by the supplier (municipality/owner of the WWTP) or the customer (ethanol facility). The variability in the WWTP process and flow, ethanol facility water requirements, facility site constraints/advantages, facility discharge requirements and other variables require individual supplier/customer agreements to be developed to provide a system that meets the water resource and business needs for all involved stakeholders.

5.1 Cost Basis and Assumptions

The estimated capital and O&M costs and the cost of service ($/1,000 gallons supplied) are based on cost information obtained from equipment manufacturers, constructed projects, peer-reviewed publications, as well as the financial analysis guidance set by MCES. Redundancy and reliability criteria follow the MCES's recommendations for WWTPs (which incorporates MPCA guidelines) and documented reuse system practices. Construction is assumed to be the responsibility of the municipality. Projects carried out by an industry may have lower costs. Costs do not include non-capital and O&M costs related to project implementation, such as legal costs associated with developing legal agreements between a WWTP and an ethanol facility. The major criteria and assumptions are listed in Table 5.1.

Table 5.1. Cost Criteria and Assumptions

Description	Value
Rates & Planning Information	
Discount Rate	5.0%
Planning Period	20 years
Present Year	Apr 2009 (ENR CCI*=8528)
Debt Financing Issuance Costs	1% capital cost
Useful Lives	
Force mains	40 years
Process Piping	30 years
Equipment	20 years
Redundancy & Reliability	
Equipment	1 unit out of service at peak hour flow
Piping	Single force main
Capital Cost Assumptions	
Undeveloped Design Details	50% of Construction Cost
Engineering, Admin & Legal	20% of Construction Cost
Operations & Maintenance Assumptions	
Electricity	$0.045/kwh
Sodium Hypochlorite, 12.5%	$0.70/gallon
Pump System Equipment	1% capital cost/yr
Treatment System Equipment	5% capital cost/yr
Transmission System	$5,500/mile/yr
Sampling & Laboratory Analysis	$20,000/yr
Administrative/Engineering	$38,500/yr (1mgd); $40,000/yr (1.4mgd)

* ENR CCI = Engineering News Record Construction Cost Index

5.2 Cost Model

Total system costs are based on the conceptual system model assumptions and unit process treatment assumptions identified in Section 3 and the transmission assumptions presented in Section 4. There are three major facility components in this case study cost model, as depicted in Figure 5.1.

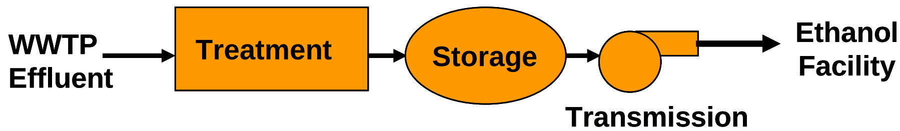

Figure 5.1. Major System Components

The cost model is predicated on all treatment being provided on the WWTP site with available land (land purchase is not included). Water is delivered with the prescribed water quality at a delivery pressure of 40 psi. The water quality delivered will depend on the treatment processes used. The model does not include costs for treatment facilities at the industry site or booster pumps to meet industry specific requirements.

Capital costs are annualized based on a 20-year debt service and presented as a cost of service, in $/1000 gallons, in conjunction with all major O&M costs. The cost of service provides a unit of measure that can be compared to existing water supply costs.

5.3 System Costs

Total system costs to provide cooling water to an ethanol facility are presented for the four scenarios in Table 5.2. While treatment facilities are the only variable component for the system, storage and transmission costs are included to show the relationship of the components. Appendix C provides more detailed cost information.

Treatment Facilities and Total System

The costs presented in Table 5.2 define scenarios with treatment processes summarized in Table 5.3. The treatment facility costs account for 40 to 70% of the total water reuse system capital costs and 70 to 92% of the annual O&M costs. WWTPs with advanced secondary treatment systems and average water quality will require the least investment and lowest operating costs with a potential cost of service of $2.67 to $3.24 per 1,000 gallons. The cost to remove nutrients (in this case only phosphorus), adds another $1/1,000 gallons to the cost of service. This cost will be highly variable with each WWTP given the multiple treatment options related to nutrient removal. The estimated costs shown here are on the low end, given the assumption that only phosphorus removal is required. The most significant costs are related to membrane treatment to soften and remove salts from the water. Costs are estimated to require between $5.92 to $7.17/1,000 gallons.

Table 5.2. Planning Level Costs for Different Water Reuse Scenarios (Cost, $1,000)

Alternative	Scenario A Secondary WWTP		Scenario B Advanced Secondary WWTP	
	A1 Avg Quality[1]	A2 Low Quality[2]	B1 Avg Quality[1]	B2 Low Quality[2]
Capital Costs, $1,000s				
Treatment	$5,090/$6,355	$11,025	$2,895/$3,955	$8,165
Storage	$470	$470	$470	$470
Pump Station	$535	$535	$535	$535
Transmission	$3,515	$3,515	$3,515	$3,515
Total Capital Costs	$9,605/$10,870	$15,540	$7,410/$8,470	$12,685
Annualized Capital Costs	$740/$840	$1,200	$570/$655	$980
O&M Costs, $1,000s				
Treatment	$475/$620	$1,295	$290/$410	$1,060
Transmission	$75	$75	$75	$75
Other	$45	$45	$45	$45
Total Annual Costs	$595/$740	$1,415	$409/$530	$1,180
Total Annualized Cost, $1,000/year	$1,335/$1,580	$2,615	$980/$1,185	$2,160
Cost of Service, $/1,000 gallon	**$3.65/$4.35**	**$7.15**	**$2.65/$3.25**	**$5.90**

[1] Two costs are presented for treatment of average quality water: first is the process train with conventional filtration followed by enhanced disinfection; second is for membrane filtration followed by disinfection. Refer to Figure 3.1.
[2] Low quality water requires treatment for either (or both) hardness and high salt concentrations.

Table 5.3. Treatment Processes by Scenario

Constituent	*Scenario A Secondary Treatment*		*Scenario B Advanced Secondary Treatment*	
	A1: Average Quality	*A2: Low Quality*	*B1: Average Quality*	*B2: Low Quality*
Chem Addition/Flocculation/ Sedimentation or Other	X	X		
Conventional Filtration/ Enhanced Disinfection	X*		X*	
Membrane Filtration/ Disinfection	X*		X*	
Membrane Filtration/ Reverse Osmosis/Disinfection		X		X

* Option for either conventional filtration followed by enhanced disinfection or membrane filtration and disinfection.

Storage

Table 5.4. Storage System Cost

WWTP Annual Average Flow, mgd	$/gallon of WWTP flow
≤ 0.5	0.94
0.5 to <1.0	0.62
1 to 7	0.47

Storage is assumed to be provided in an underground concrete tank, for which the unit cost of construction is estimated to be $1.87/gallon of concrete storage. Costs per gallon are listed in Table 5.4, based on the assumed storage volumes presented in Section 4 for a range of WWTP flows. For this case study the WWTP is assumed to supply 1 mgd, requiring a storage of

250,000 gallons. This equates to $0.47/gallon of WWTP flow or a capital cost of $470,000. Storage costs are approximately 4% of the total capital cost of a 1 mgd supply.

Pump Station

The cost model uses a flow-based cost equation developed for an MCES study [MCES, 2007]. A cost of $0.53/gpd of annual average capacity was the basis to estimate the $530,000 pump station.

Transmission Piping

The transmission system is assumed to be a force main from the WWTP to the ethanol plant with pipe materials defined in Section 4. The unit cost for materials and labor to install reclaimed water piping are based on undeveloped site conditions as summarized and documented in Appendix C

Transmission system operations costs characterized for this cost model include electrical power costs and a unit cost per mile for equipment and labor to maintain the distribution system. The cost to maintain the transmission pipe system is based on the length of the pipe at $5,500 per mile per year. This compares reasonably to MCES records and literature references [Gumerman et al, 1992].

The transmission infrastructure represents a significant cost of the water reuse system for the 5-mile transmission systems characterized for this case study. The capital costs are approximately $3.5 million and the operating costs are nearly $75,000 per year. The overall infrastructure costs including storage account for as much as 60% of the capital costs for the lower cost treatment options to 35% of the highest cost treatment scenario. An extensive evaluation of transmission system costs can be found in a previous MCES study [MCES, 2007].

5.4 Cost Summary

The cost analysis was performed to achieve two primary objectives:

- To understand overall project and annual costs associated with systems for municipal WWTPs to provide cooling water to ethanol facilities
- To identify the relative differences in system costs to upgrade existing WWTPs with variable water quality.

The facilities to provide reclaimed water to ethanol plants is a significant investment. Overall capital costs to treat and transmit the water 5 miles were estimated to range from $7.4 million to $15 million. With annual costs considered, the cost of service for a 20-year life cycle period, could range from $2.70 to $7.20/1,000 gallons. Capital costs for treatment ranged from $2.9 million to $11 million and the annual treatment costs ranged from $290,000 to $1,300,000. Areas with hard and high salt waters will have significantly higher costs to treat the water. The project components related to transmission were estimated to be $4.5 million and cost on average $75,000 a year to operate and maintain.

Items to consider related to costs of a water reuse system include the following:

- Many ethanol facilities in regions with hard/high salt waters or that use a surface water supply already have to treat their existing supply for cooling water. The annual savings related to the existing supply water treatment system costs would offset (at least partially) the treatment costs of the reclaimed water.

- New ethanol facilities and several existing facilities are closer than 5 miles to a WWTP and would have lower transmission capital and operating costs. Some facilities may also have sufficient wastewater flow to not require storage, which would decrease capital costs.

- Additional costs are required to achieve a quality for process and/or boiler feed water. Site specific studies need to incorporate the costs for process water or the decision may be to design a system only for cooling water.

- Ethanol facilities that continue to discharge under their NPDES permit and currently are near discharge permit limits may require solutions that are not reflected in the costs. There may be advantages to sending the ethanol facility cooling water blow down and other waste streams back to the WWTP to blend with the WWTP effluent prior to discharge. Another possibility is to provide waste stream treatment (e.g. evaporation), which is expected to be a high energy option. This is not desirable given the extra annual cost (with an uncertain future cost) and because it is not aligned with sustainability practices of some ethanol facilities. Regardless of the solution, there are significant capital and O&M costs associated with handling of the recycle streams for ethanol facilities with existing concentration pollutant limit issues.

- The infrastructure investment, catalyzed by a partnership between the ethanol producer and the community, can be leveraged to support other water reuse applications. Any community looking to this significant investment in a reclaimed water supply for an ethanol facility should also consider the additional benefits to their water resources, both in reduction of water withdrawals and improved discharges to their watershed.

- Total costs and availability of other water supply options. These planning level costs need to be placed in the perspective of other water source options and the costs to treat water to similar levels. When compared to a potable water supply, the cost of service estimates for reclaimed water are in a comparable range. Potable water supply system costs range from less than $1/1,000 gallons to over $5/1,000 gallons for communities in the vicinity of ethanol facilities and about one-third charge over $3/1,000 gallons for their potable water supply. Twin Cities metro area communities have billing rates between $1.80 and $3.50/1,000 gallons. This case study estimated reclaimed water supply costs to range from $2.65 to $7.15/1,000 gallons. As ground water supply availability decreases, the value placed on water will increase and the costs for reclaimed water will fall in a range of costs that are competitive to alternative supplies.

Section 6
Implementation Considerations

Implementation of a water reuse system is contingent on successfully addressing a number of implementation challenges, such as:

- Negotiating a case-specific permit to meet regulatory requirements
- Balancing technical considerations such as agricultural processing facility water quality requirements, wastewater treatment needs to achieve the users' (possibly multiple) water quality requirements, and effects on other facility permits
- Working at institutional considerations such as local ordinances, public perception, legal agreements, and fee structures

The case study presented in Sections 2-5 of this technical memorandum provides the basis for technical considerations. Technical Memorandum 1, the companion document to this one, provided background on the regulatory requirements and an overview of issues to address in the implementation of a water reuse system. This section focuses on implementation issues related to water reuse for ethanol facilities, although they have applicability for other applications as well.

6.1 Minnesota Industry Perspective

To provide a perspective on the range of implementation issues facing a municipality and ethanol facility considering water reuse, this subsection presents a summary of issues identified in stakeholder meetings with industries, regulatory agencies, municipal wastewater utilities and other groups as part of a previous MCES water reuse study [MCES, 2007] that addressed reuse for many different Minnesota industry categories, not just agricultural processing or ethanol production. Table 6.1 summarizes the implementation issues identified initially by industries and discussed with various other stakeholders.

6.2 Topics Identified in Ethanol Facility Case Study

The key implementation issues that surfaced in review of water reuse for ethanol facilities were related to regulatory permits. Other considerations are also identified below.

Regulatory Considerations

The regulatory topics of concern include those related to the NPDES permits for the ethanol facility and the WWTP, the coordination of total maximum daily load (TMDL) assessments with water reuse activities, and water appropriations permits.

- **NPDES Permit for Ethanol Facility**
  - Many of the constituents of concern for cooling water and other ethanol facility water uses are also of concern from an NPDES permit perspective. Key constituents include: chloride, TDS, sulfate, sodium, boron, and specific conductance.

Table 6.1. Diverse Stakeholder Group Implementation Issue Summary*

Environmental Need & Stewardship	
Minnesota's commitment to natural resources protection can serve as a catalyst for water reuse practices.	**Need** ■ Water supply shortages and watershed water quality issues occur in Minnesota and have been the driver for water reuse applications in areas where thresholds were reached with few options. The state needs to be prepared for an increase in water issues that can be solved with water reuse applications. ■ A vision for wastewater and water supply systems in Minnesota beyond the typical 20-year planning cycle is needed – looking to Minnesota's long-term economic vitality and quality of life. **Stewardship** ■ Water conservation awareness in Minnesota is increasing and many industries are adopting water protection measures. Industries recognize that water reuse can be of benefit to their business and the community. Water reuse practices can build on this awareness. ■ A positive image for water reuse needs to be established: it protects Minnesota's water resources and it is a safe supply. Customers and suppliers will be less likely to engage in water reuse projects if there will be resistance from the community. Water reuse needs to move from an unknown to a positive image.
Regulations	
The regulatory requirements and permitting process should encourage industries and municipalities to pursue water reuse.	■ Current regulations: MN handles water reuse applications on a case-by-case basis using the California Water Recycling Criteria. This approach matches the demand. ■ Municipalities and industries identified several permit-related issues that without resolution early in the planning process would deter them from water reuse. ■ Existing regulatory requirements for wastewater facility planning to include water reuse alternatives needs to be enforced and linked to water supply studies. ■ There currently is not a demand for reclaimed water that requires investment in water regulation development. However, without resolution of some issues, it may inhibit the planning for water reuse practices that should be occurring for long-term sustainability of Minnesota's water resources.
Economic Incentives and Risk Assessment	
Economic incentives and assessment/ resolution of risks will attract industries to use reclaimed water and municipalities to incorporate recycling in their WWTP practices.	■ There are unresolved industrial concerns with risk and liability. Establishing partnerships to foster recycling of treated municipal wastewater will provide examples to evaluate reuse practices in Minnesota and the information to develop potential, future regulatory infrastructure, address concerns with risk and legal language for user agreements, and other institutional elements. ■ To gain acceptance and to recognize the benefits of water reuse, particularly when economics are perceived to be in favor of current practices, economic incentives will attract suppliers and customers – and can jumpstart a broader water reuse practice in Minnesota. (Minnesota legislature passed H.F. 1231.4 appropriating grant money for ethanol plant water reuse. See Appendix D). ■ The cost of water currently does not factor in the benefits of conservation and reclaimed water competes against a low cost supply in many areas.
Data Collection and Research	
Information on-hand related to treatment requirements for reclaimed water would expedite the planning process for water reuse projects.	■ Information related to the treatment and distribution of reclaimed water for Minnesota-specific applications is lacking, specifically for cold weather and hard, high salt concentration waters. ■ Site-specific water quality and customer-specific uses require water sampling and analysis. Many of the parameters of interest in planning treatment of a water supply are not analyzed by WWTPs discharging to receiving streams. If water quality data were readily available, water reuse may be evaluated more in the planning stages for new or expansions/improvements or existing industries and WWTPs.

*Based on input from a diverse stakeholder group considering water reuse for all of Minnesota's industries [MCES, 2007].

- When these constituents are removed through treatment processes to make the water suitable for the intended use, the residual waste streams, with highly elevated constituent levels, present problems for disposal.

- Several ethanol facilities already operate near the discharge limits for some constituents. Some facilities have to limit their internal water recycling to meet concentration limits (which address aquatic toxicity concerns in the receiving water). In some cases, volume discharge limits impose the need for recycling, which is also encouraged as a water conservation measure. However, with more recycling, concentrations increase and the ethanol facility is required to find a balance between water conservation and meeting discharge concentration and volume limits.

- The use of a reclaimed supply with higher constituent levels will create challenges for ethanol facility discharge compliance. However, if the reclaimed water contains lower constituent levels than the current supply, it would provide more flexibility in ethanol facility operations to meet NPDES permit limits.

- Ethanol facilities could consider (and some may already have in place) discharges to the municipal WWTP, rather than to a receiving stream. This presents another set of issues to resolve that will be very site-specific. For existing ethanol facilities already near their permitted limits for some constituents, it is likely that the municipal WWTP discharge will have permit issues similar to the ethanol facility to address, assuming discharge to the same receiving water.

– A reclaimed supply may introduce new constituents and require more monitoring, reporting, and possibly additional permitted parameters to a modified permit.

– Discharge volume and loading considerations if the facility continues to discharge according to their existing NPDES permit or decide to discharge back to the WWTP.

■ **NPDES Permit for WWTP**

– The incorporation of water reuse facilities will require a modification of the existing NPDES permit. At a minimum, additional monitoring, reporting, and new pollutant limits for total coliform will be required.

– Discharge volume, loading, and concentration limits will require review, particularly if an ethanol facility decides to discharge the cooling water blowdown and other ethanol facility waste streams to the WWTP.

– New waste stream management issues similar to those identified for the ethanol facility.

– For facilities under review to implement nutrient removal to meet future regulations, there is the potential to coordinate and provide overall reductions from the WWTP and the ethanol facility. The question is how the permits will handle the 'exchange' of wastewater effluent from a WWTP to an ethanol facility and the resultant volume and loads to the permitted receiving water locations.

- If complete treatment of secondary effluent to reclaimed water standards does not occur at the WWTP site, but at the ethanol facility, regulatory decisions and municipal/ethanol facility agreements are required to address:
  - The level of treatment required for transmission to the ethanol facility.
  - The sampling location at which the permitted limits would be applied.
  - The regulatory responsibility for sampling, reporting, and compliance and incorporation into user agreements.

- **TMDL Development**
  - The partnering opportunities with water reuse applications could provide economic advantages to meet phosphorus and related pollutant reductions, as well as provide water conservation and secondary water sources for the ethanol facilities.
  - Of particular interest is the phosphorus trading in practice on the Minnesota River as part of permit and TMDL development for that watershed. Several ethanol facilities and communities on the Minnesota River are involved in the General Phosphorus Permit.
  - As TMDL development progresses, the coordination of discharges and reductions could be integrated and provide guidance and incentives for water reuse applications.

- **Water Appropriations Permits**
  - While communities and ethanol facilities understand the need for water conservation, it is not desirable to reduce the appropriations of existing permits, particularly if there are some peaking needs that need to be met and there are not alternative supplies. Discussion needs to address how the DNR will handle permit renewals for systems engaging in water reuse.
  - Use of incentives or other permit features will promote water reuse. Given the current permit structure and community planning requirements encouraging water conservation, water reuse should be emphasized as a potential supply source. This would bring attention to the concept of water reuse and encourage its consideration for targeted uses and longer range planning of communities.

Other Considerations

Implementation considerations falling outside of a purely regulatory role that have an impact on costs and long-term benefits are discussed below and include:

- Treatment for non-potable water uses at an ethanol plant, other than for cooling water

- Alternative source selection
- Assessment of a water reuse system for multiple community uses

Treatment for Process and Other Water Uses

The treatment requirements to produce water of quality for non-potable water use at an ethanol plant in addition to cooling water were explored for the reverse osmosis (RO) treatment train because minor modifications can be made to accommodate additional removals to higher quality levels. A model that evaluated system needs for cooling water was also used to configure a system to meet process and boiler feed water quality requirements. A preliminary analysis indicated that the effluent requirements of the process water (presented in Table 3.2) are able to be met using a 2-pass RO system. In such a configuration, the permeate from the first pass is treated again by a second pass RO system. Additionally, to maintain recoveries, the first pass can be arranged in a two stage array to achieve 83% recovery and the second pass in a three stage array to achieve 90% recovery. This proposed system configuration is presented in Figure 6.1.

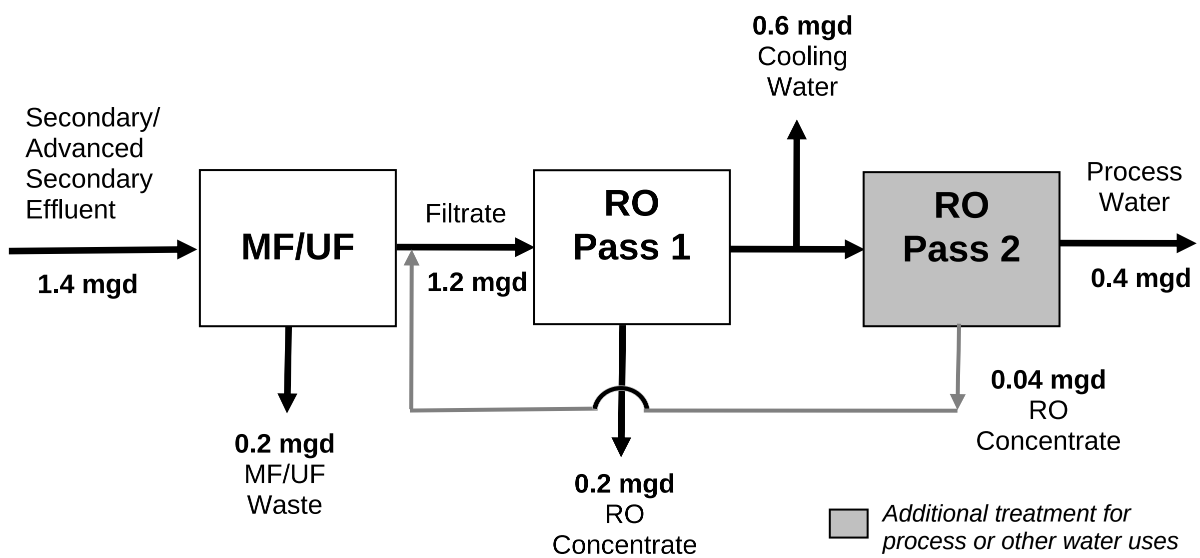

Figure 6.1. Process Flow Diagram for 2-Pass Reverse Osmosis

For water reuse systems requiring RO for cooling water, the cost to provide the additional supply for other ethanol facility water uses is less than 20% the total system cost for 30-40% of the total supply.

Alternative Source Selection

The hypothetical case study presented in this document was based on a treated wastewater effluent as the only supply option for the ethanol facility. A facility-specific case study would likely evaluate a reclaimed supply in relationship to other water supply sources. To provide a perspective on treatment considerations to use other water supply sources as cooling water, the example data presented in Table 3.2 is used to compare treatment requirements of an advanced secondary wastewater effluent, ground water, and river water supply. While cost comparisons are not made, this analysis indicates that other water supply options carry treatment and conveyance costs that could be in the range of reclaimed water system costs.

For purposes of this example, it is assumed that hardness is an issue for all three supplies and dissolved salt concentrations in the ground and river water need to be reduced for process water. The treated wastewater effluent salt concentrations require treatment for both cooling and process water. The treatment train to produce reclaimed water for cooling and process water would be similar to the one shown in Figure 6.1, and applicable to all three water sources with the exceptions noted below.

The groundwater supply is of reasonable quality, but would need some treatment to meet the requirements for cooling water to reduce the scaling potential with the given hardness. It is possible that ground water could be of sufficient quality, that with chemical addition, the scaling concerns can be abated. If softening is required, processes other than RO can be considered for treatment. Preliminary modeling indicated that nanofiltration (NF) would likely treat the water to the levels required. The cost of NF is typically about 25% less than RO. The bicarbonate levels in the aquifer were estimated for modeling, and it is recommended that sampling and analysis be undertaken to confirm assumptions. Like RO, NF also requires filtration upstream. The lower turbidity of the groundwater (versus WWTP effluent) allows for other filtration techniques such as sand filtration, which are cheaper than microfiltration/ultrafiltration (MF/UF) systems. In order to use groundwater for process water, more advanced treatment, such as RO, would be required to achieve the low chloride levels necessary.

The Mississippi River is a dynamic and highly variable source water. While the primary chemical constituents of concern for cooling water applications are only alkalinity, hardness, calcium, bicarbonate, and sulfate, the physical parameters of temperature and turbidity present their own challenges. Lime softening is a candidate technology to remove hardness and turbidity and handles fluctuations in quality well.

In order to size the membrane systems to treat river water, temperature is a critical variable, and the river water temperature varies from less than 1˚C to greater than 25 ˚C over the year. The MF/UF and RO processes are strongly influenced by temperature. As water temperature decreases and the viscosity of the water increases either the membrane area and/or the operating pressure of the membrane system must be increased to maintain a specified permeate flow. Since MF/UF membranes typically operate in a relatively narrow pressure range, some increase in membrane area will be required to adjust for large variations in water temperature. Similarly, RO membrane operating pressure and/or membrane area must increase as water temperature decreases to maintain a specified permeate flow. The RO membrane typically can be operated over a wider pressure range and typically temperature corrections are accommodated by pressure adjustments. However, when the temperature variation is large, additional membrane area must be included in the design to keep the maximum pressure within a desired upper limit.

In addition to temperature variations, the turbidity of the river water varies throughout the year from less than 5 ntu to greater than 25 ntu. Such a large variation in solids in the water will likely require that the water have some form of pretreatment prior to the MF/UF system, such as coagulation, flocculation, and sedimentation.

Multiple Community Uses

A water reuse system is a significant investment and can be used as the building block for sustainability of a community's water resources and economic vitality. The partnership of a community and ethanol facility to construct a water reuse system can be integrated with other non-potable water supply uses in the long-term planning of a region. Potential uses include irrigation of golf courses, parks, and residential areas, commercial/institutional building cooling, and other industrial uses. An analysis of potential reclaimed water uses in a community should be performed and these demands should be considered in the sizing of facilities and overall costs related to water supply and protection in a community or region. As costs per gallon decrease with the increasing capacity of the system, there are strong economic incentives to look for the maximum use of reclaimed water supplies.

Reclaimed water is an emerging water supply for Minnesota industries and communities. Economic development, water supply limitations, and environmental regulations and stewardship will increasingly drive the need to find alternative water supplies. Communities with ethanol facilities and other industries with larger water demands provide conditions where water reuse can provide environmental benefits and economic advantages for both the community and industry. As observed with the Mankato Energy Center, the first industrial water reuse system in the state, and the planning of the Corn Plus ethanol plant in Winnebago, communities and industries are recognizing the benefits of water reuse. Future applications should encourage the integration of the water reuse system beyond one industrial user to other applications to maximize the benefits.

Section 7
Summary and Conclusions

This memorandum provides a planning level analysis of facilities and operation and maintenance (O&M) requirements to supply reclaimed water to an ethanol facility for cooling water use. The analysis identifies the basic project elements that need to be evaluated to technically implement a project.

The reclaimed water must meet the regulatory requirements administered by the Minnesota Pollution Control Agency (MPCA), based on the California Water Recycling Criteria [State of California, 2000]. These regulations impose requirements for disinfection, filtration, and possibly coagulation or membrane processes that would result in new or modified processes at Minnesota WWTPs providing reclaimed water. In addition to the California Water Recycling Criteria, the municipality and ethanol facility must still meet other facility permit requirements, such as existing or future NPDES permit limits. For some water reuse treatment systems, the waste streams generated from some unit processes present disposal challenges.

The reclaimed water must be of suitable quality for use at an ethanol facility. Typical constituents of concern for cooling water applications are ammonia, chlorides, hardness, microorganisms, organic compounds, phosphorus, silica, sulfate, and TDS. The case study considered four alternative treatment scenarios to achieve reclaimed water that meets cooling water requirements. The scenarios cover differing levels of existing treatment at the WWTP as well as differing levels of hardness and salt concentrations in the WWTP effluent. Reclaimed water storage and transmission system requirements, generally significant cost components dependent on site-specific conditions, were assumed.

The facilities to provide reclaimed water to ethanol plants is a significant investment. Overall capital costs to treat and transmit the water 5 miles were estimated to range from $7.4 million to $15 million. With annual costs considered, the cost of service for a 20-year life cycle period could range from $2.65 to $7.15/1,000 gallons. A reclaimed supply could be competitive with potable water supply system costs, which range from less than $1/1,000 gallons to over $5/1,000 gallons for communities in the vicinity of ethanol facilities. About one-third of the communities near ethanol facilities charge over $3/1,000 gallons for their potable water supply.

Capital costs for treatment were estimated to range from $2.9 million to $11 million and the annual treatment costs from $290,000 to $1,300,000. Areas with hard and high salt waters will have significantly higher costs to treat the water. However, ethanol facilities in these areas may have to treat their existing supply for cooling water and these costs could offset some of the treatment needs of the reclaimed water. The project components related to transmission were estimated to be $4.5 million and cost on average $75,000 a year to operate and maintain.

Other issues to consider include:

- The impact of reclaimed water use on the ethanol facility's NPDES permit and water appropriations permits.

- The impact of reclaimed water production on the WWTP's NPDES partnering opportunities that may arise as Minnesota's TMDL regulations are implemented.

- The potential to use reclaimed water for other ethanol facility water uses, such as process water.

- The potential for the WWTP to provide reclaimed water for other nonpotable water uses such as irrigation for golf courses, parks, residential areas; commercial/institutional building cooling; and other industrial water uses. Future applications should encourage the integration of the water reuse system beyond one industrial user to other applications to maximize the benefits.

A checklist of information to perform an assessment of water reuse at an agricultural processing facility follows (Section 8).

Reclaimed water is an emerging water supply for Minnesota industries and communities. Economic development, water supply limitations, and environmental regulations and stewardship will increasingly drive the need to find alternative water supplies. Communities with ethanol facilities and other industries with larger water demands provide conditions where water reuse can provide environmental benefits and economic advantages for both the community and industry.

Section 8
Checklist for Water Reuse System Assessment

This section provides a list of information recommended for initiating an assessment of water reuse of treated municipal wastewater effluent at an ethanol facility. This list is applicable to most other industries looking to reclaimed water as a new water supply. The main categories of information include:

- WWTP
- Ethanol facility
- Community/local conditions

WWTP Information

- Process Schematic
- Plant layout on site
- Property boundary
- Capacity, mgd
- NPDES Permit
- Flow data to characterize (note: MPCA maintains all discharge monitoring report (DMR) data for NPDES permit discharges in the Data Access database available online, which includes flow and water quality data for permitted constituents and flow streams).
  - Annual average flow
  - Max/min monthly flow
  - Max/min daily flow
  - Max/min hourly flow
- Water Quality Data (note: data for most parameters are not permitted and included in the DMR reports – need to do specific sampling)
  - BOD
  - TSS
  - Total Phosphorus
  - Ammonia
  - TKN
  - Metals
  - TDS
  - Chlorides
  - Sulfate

- Hardness
- Anions/Cations, LSI
- Total coliforms/E. coli of disinfected supply
- Miscellaneous for membrane modeling (Ba, St, other)

- Most recent master or facility plan
  - Planned improvements based on recent permit discussions/forecasts
  - Future flow projections
- Drawings showing plant elevations for assessment of transmission system

Ethanol Facility Information

- Ethanol production capacity, existing and planned
- Site plan
- Process schematic
- Water balance schematic
- Water treatment process schematic (if available)
- Water use, historic records
- Water quality of existing supply
  - TSS
  - Total Phosphorus
  - Ammonia
  - TKN
  - Metals
  - TDS
  - Chlorides
  - Sulfate
  - Hardness
  - Anions/cations, LSI
  - Sulfate
  - Other available
- NPDES Permit
- NPDES permit water quality discharge data

Community/Local Conditions

- Contour map of WWTP and ethanol facility sites with elevations
- Potable water supply system
  - Treatment process
  - Use of home softening systems
  - Water quality data (same constituents as for ethanol facility)
  - Water use data
    - Volume, rate used for landscape irrigation
    - Other significant uses of water as candidate for reclaimed water
    - Appropriations permit limits/issues related to restrictions of existing supply
  - Most recent master or facility plan
- Other water supply sources, related water quality, availability of supply (any restrictions noted for appropriations permits)
- Existing utility alignments (for transmission system planning)

Section 9
References

Gumerman, R.C. B.E. Burris, and D.E. Burris, 1992. Standardized Costs for Water Supply Distribution Systems. EPA/600/R-92/009.

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State of California. 2000. *Water Recycling Criteria*. Title 22, Division 4, Chapter 3, California Code of Regulations. California Department of Health Services, Drinking Water Program, Sacramento, CA.

White, G.C. 1999. Handbook of Chlorination and Alternative Disinfectnts, 4th ed., John Wiley & Sons, New York.

Appendix A
Alternative Treatment Processes

Excerpt from Volume II – Appendix II-3

Metropolitan Council Environmental Services (MCES). 2007. *Recycling Treated Municipal Wastewater for Industrial Water Use.* Report prepared under funding recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR) from the Environment and Natural Resources Trust Fund.

3.2 Water Reuse Treatment Technologies

3.2.1 Overview

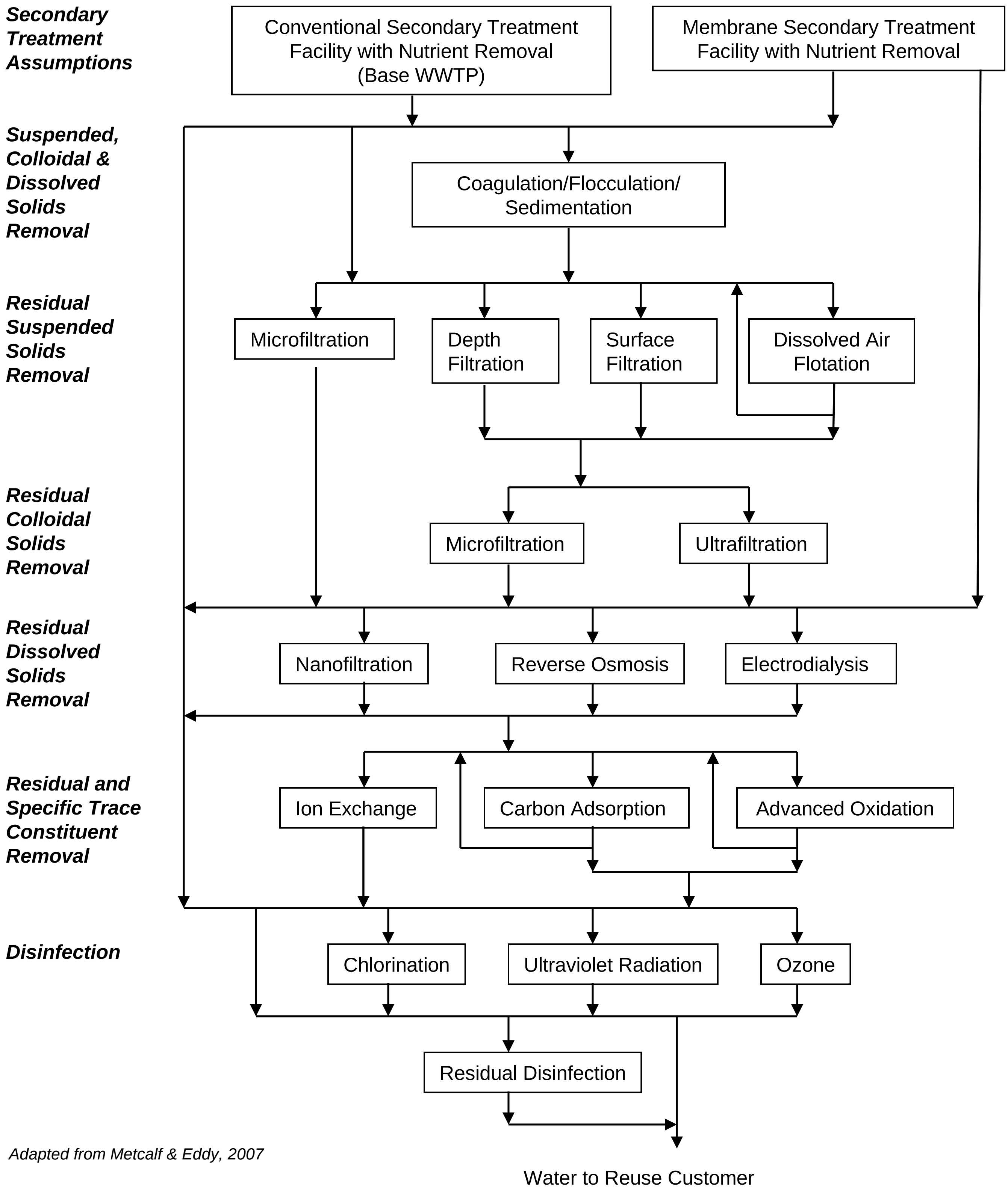
Treatment requirements for specific industrial reuse applications are based on multiple factors including: the quality of the source water used by a community, chemicals discharged to the WWTP, the WWTP's existing process train, water reuse regulations, the intended use of the water by the industry, and the quantity of water reclaimed at an individual facility. The treatment technology selected will depend in part on whether treatment is incorporated at the centralized WWTP, onsite at the industry, or at a satellite facility along the distribution line. If storage is required, additional treatment may be required for algae growth and by-products and for residual disinfection. With all these variables, the treatment process and transmission system selected is a site and case-specific one.

Treatment process requirements for reclaimed water beyond standard secondary treatment processes can be categorized by the target parameter (adapted from Metcalf & Eddy, 2007):

- Enhanced suspended and dissolved solids removal (chemical addition/softening)
- Residual suspended solids removal (filtration)
- Residual colloidal solids removal (membrane filtration)
- Residual dissolved solids removal (demineralization/softening)
- Residual and specific trace constituent removal (multiple processes)
- Disinfection (microorganim removal/inactivation)

The relationship of various treatment technologies that can be used to achieve a desired reclaimed water quality is depicted in Figure 3. The treatment process schematic assumes a WWTP secondary effluent as the beginning point of the treatment train. The schematic shows the **potential use** of one or more of the processes targeting a specific parameter. A treatment train would consist of several of the processes shown, but would not include all processes shown.

The effluent quality of various treatment trains is compared in Table 3 to provide a perspective on the additional removals obtained with different levels of treatment. Secondary effluent from an activated sludge facility with and without nutrient removal are listed in the first two columns of the table and represent a quality for non-contact industrial activities without concern for hardness and dissolved solids. An example industrial water use application for secondary treatment water is sand and gravel washing operations or site dust control. Advanced secondary treatment water, which has reduced levels of phosphorus and ammonia, could be used for cooling water purposes if the hardness and dissolved salt concentrations are not too high or an industry provides their own additional onsite treatment. For these process



Adapted from Metcalf & Eddy, 2007

Figure 3. Schematic of Available Treatment Technologies for Water Reuse

trains (referring to Figure 3) the only processes required would be the disinfection process to meet regulatory standards (for health effects) for micororgansims.

Table 3. Typical Wastewater Treatment Plant Effluent Quality[1]

	Effluent Constituent Concentration by Treatment Level					
Constituent	**Secondary Treatment**	**Advanced Secondary Treatment[2] (Base WWTP)**	**AST with Filtration[3]**	**AST with Chemical Addition & Filtration[4]**	**Membrane Bioreactor[5]**	**Advanced Tertiary Processes[6]**
BOD, mg/L	5-20	5-10	≤5	≤5	<1-5	≤1
TSS, mg/L	5-20	5-10	≤3	≤3	≤2	≤1
TOC, mg/L	8-30	8-20	1-5	*1-5*	0.5-5	0.1-1
Total Phosphorus, mg/L	3-10	≤1	≤0.8	≤0.4	0.5-2	≤0.5
Ammonia, mg/L	10-40	≤3	≤2	≤2	<1-5	≤0.1
Nitrate, mg/L	trace	10-30	10-30	*10-30*	<10	≤1
Total Nitrogen, mg/L	15-45	15-35	15-35	*15-35*	<10	≤1
Turbidity, NTU	2-15	2-8	0.3-2	*0.3-2*	≤1	0.01-1
TDS, mg/L	500-1500	500-1500	500-1500	<100-500	500-1500	≤5-40
Fecal Coliform[7]	>10^4/< 200	>10^4/< 200	>10^4/< 200	---	---	Approx. 0
Total Coliform[7]	>10^4/< 23	>10^4/< 23	>10^4/< 2.2	>10^4/< 2.2	<100/<2.2	Approx. 0

[1] Adapted in part from Metcalf & Eddy, 2007.
[2] Conventional activated sludge treatment with nutrient removal based on meeting a discharge permit ammonia limit of 3 mg/L and total phosphorus limit of 1 mg/L. It does not include total nitrogen removal (denitrification).
[3] Filtered advanced secondary treatment effluent using depth filtration, surface filtration, or dissolved air flotation.
[4] Same as filtered advanced secondary treatment effluent, but it includes a chemical addition/coagulation/flocculation/sedimentation process typically using ferric chloride (or alum) and lime for softening (additional unit processes required for softening)
[5] Secondary treatment comprised of aeration with membranes configured as external pressure-driven, integrated submerged, or external submerged rotating bioreactors with biological nutrient removal (for total nitrogen).
[6] Treatment processes to remove residual dissolved solids and specific trace constituents, including chemical/physical and ion exchange softening. These processes follow or include a filtration process.
[7] Values are presented as most probable number /100 ml for estimated fecal and total coliform concentrations without disinfection and with disinfection (without/with). The second concentration is also the reclaimed water quality standard hat the disinfection process is designed to meet.

If advanced secondary treatment effluent is to be used directly for cooling water, additional hardness and dissolved salts may need to be removed. For existing WWTPs, one option is chemical addition/ coagulation/flocculation/ sedimentation. This process system could be incorporated with chemical phosphorus removal to meet both water reuse requirements and NPDES permit limits, either as a polishing step or the principal point of chemical application. Lime softening will be required to remove excessive hardness, however, it does not remove a significant level of dissolved salts. The sedimentation process would be followed by filtration and disinfection. Another alternative is a microfiltration process followed by membrane softening, which could also serve industries that need nearly complete removal of dissolved salts, as with boiler feed water. Removal of dissolved salts can also be handled with an ion exchange unit process after a softening/filtration process.

A secondary membrane WWTP (membrane bioreactor) would be an option for a new or expanding WWTP that expects a significant reclaimed water use. Disinfection requirements would be less and the majority of other constituents are markedly lower than with conventional secondary treatment. Trace constituent removal can also be achieved with carbon adsoprtion and advanced oxidation processes, as discussed in subsequent sections.

If Minnesota continues to adhere to the Title 22 California Water Recycling Criteria and the reuse application requires a recycled tertiary water (for potential human contact uses such as recycle water in cooling towers), most existing WWTPs would need to add a filtration process to supply reclaimed water. The requirement for a chemical addition/flocculation/ sedimentation process will be site-specific and in some cases will depend on the types and size of particles in the secondary effluent and effectiveness of the disinfection process. Some facilities may include the chemical addition process system to meet phosphorus removal goals for both the NPDES permit and specific reclaimed water requirements for the industry served. The treatment technologies approved to meet the Title 22 criteria are listed in Appendix A, Exhibit 2.

The following subsections provide an introduction to unit processes to remove specific categorical constituents. The technologies presented are principally for applications onsite at WWTPs. However, the processes could be used alone or in combination with treatment facilities on the industrial site, particularly where a single user has a unique water quality. Package systems (multiple process units) supplied by manufacturers, applicable to industries with smaller demands and/or to target specific constituents, are not identified in this study. Some proprietary processes are identified for specific unit processes to present the variety of technologies available.

3.2.2 Enhanced Suspended and Dissolved Solids Removal (Chemical Addition/Softening)

With hard, high salt waters common in Minnesota, treatment may be required to lower hardness and dissolved solids in the reclaimed supply to an industry. Traditional chemical addition/coagulation/flocculation/sedimentation processes can be used to reduce dissolved solids, as well as remove suspended solids in the effluent. In addition, a coagulation process may be required to meet the Title 22 regulations for process requirements.

If the industrial water demand uses the majority of the municipal effluent generated, it may be cost-effective to locate the treatment process at the WWTP. Additional benefits can also be realized by the municipality if the planning for a reclaimed supply coincides with expansion and/or improvements planning to meet new discharge limits, notably for phosphorus. The WWTP can incorporate a unit process that optimizes chemical addition for phosphorus removal and achieves some other dissolved solids removal. While lime softening is what is needed for hardness removal; metal salts, the chemical of choice for phosphorus removal, can achieve some reduction in dissolved solids. In addition it provides a polishing step to ensure that phosphorus concentrations in the reclaimed supply are consistently below 1 mg/L.

The facilities for chemical addition through sedimentation can be package or proprietary systems or designed systems, typically with in-ground tanks. The proprietary systems are typically more compact and well suited for a reduced footprint. Two process systems commonly used for coagulation, flocculation and sedimentation are the Kruger Actiflo and Infilco Densadeg. For larger flows, it is likely that specifically designed facilities would be used. The sedimentation process would be followed by a filtration process, as described in Section 3.2.3.

3.2.3 Residual Suspended and Colloidal Solids Removal (Filtration)

The removal of suspended solids from WWTP secondary effluent is a physical process typically performed by one of the following technologies: depth filtration, surface filtration, membrane filtration, and dissolved air flotation (DAF). Membrane filtration is also used for colloidal solids removal.

Depth Filtration

Depth filtration is used in water reuse applications for a variety of purposes including: additional removal of particles for more effective disinfection; as part of the process train following lime softening or chemical precipitation of phosphorus; and as a pretreatment step for additional treatment processes such as membrane filtration, carbon adsorption or advanced oxidation.

Depth filtration has a long history of use in the treatment of potable water. The same principles and design features are used in the treatment of wastewater effluent. Particulate material is removed by passing the water through a filter bed of granular or compressible filter media. There are a variety of depth filters used for reclaimed water applications (Metcalf & Eddy, 2007; as adapted from Tchobanoglous et al, 2003) and include:

- Conventional downflow – consists of a single, dual or multimedia filter material (sand and anthracite are most common)
- Deep-bed downflow – a deeper bed filter than conventional downflow filters; allows for extended run lengths
- Pressure filters – operate as conventional gravity filters, but in a closed vessel under pressurized conditions achieved by pumping; achieve longer filter runs and are typically used for smaller systems
- Proprietary Filters
  - Deep-bed upflow continuous backwash
  - Pulsed-bed
  - Traveling bridge

- Synthetic medium
- Two-stage

Surface Filtration

Surface filtration has been used for the same purposes as depth filtration, with more specific application in the removal of algae and other suspended solids from stabilization pond effluents. In surface filtration, particulate matter is removed by passing water through a filter material, in a mechanical sieving process. Cloth fabrics, woven metal fabrics, and various synthetic materials have been used as the filter material. This subsection focuses on the cloth media filters. Membranes and cartridge filters are also surface filters and are discussed in subsequent subsections.

The cloth media surface filters used are known under the names of Cloth-Media Filter (CMF), Discfilter (DF), and the diamond cloth-media filter (DCMF). The CMF, by Aqua-Aerobic Systems under the trademark name AquaDisk, uses either a needle felt cloth of polyester or a synthetic pile fabric cloth. The cloth covers several disks mounted vertically in a tank. Water flows by gravity from the exterior of the disks through the filter media to an internal collection system. The DF, by Veolia Water Systems under the trademark name Hydrotech, brings water through the central feed tube and the effluent exits on the exterior of the disks. The cloth screen material is either polyester or Type 304 or 316 stainless steel. A more recent product on the market is the DCMF. The cloth filter elements, which have a diamond shaped cross pattern, are cleaned by a vacuum sweep moving along the length of the filter.

Membrane Filtration

Membrane filtration is a fast-growing sector of the filtration market for potable water treatment, wastewater treatment, and water reuse applications. The number of potable water systems in the upper Midwest has increased dramatically over the past decade. Full-scale membrane bioreactor (MBR) WWTPs are also in operation and are an integral part of the facility planning for new and expanding WWTPs in Minnesota. Factors influencing the use of membranes at WWTPs include: a smaller footprint is required, a reduction (or elimination) of chemicals or energy use for disinfection, and use of secondary effluent for water reuse applications.

Membrane filtration is a general term that encompasses a wide range of filtration types. The common feature is the use of a thin membrane for the purpose of removing constituents from water. Membrane processes include microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO), and electrodialysis (ED). This subsection focuses on MF and UF as unit processes in place of depth and surface filtration for removal of suspended particulates. NF, RO, and ED are processes that also remove dissolved solids, as depicted in Figure 4, and discussed in subsequent sections.

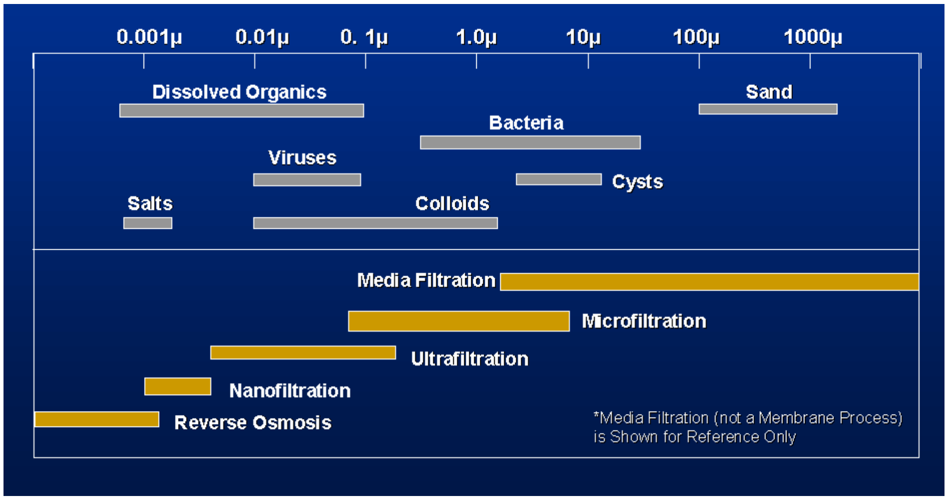


Figure 4. Constituent Rejection by Membranes

Membranes (MF or UF) are used at WWTPs for two primary purposes:

- As a replacement for the sedimentation process (MBR)
- As a filtration process in place of depth or surface filters following secondary treatment

While this section specifically addresses the use of MF and UF for filtration following secondary treatment, similar effluent quality can be obtained from MBRs, depending on the operation of the secondary system.

A significant advantage of MF/UF for production of reclaimed water is the additional barrier protection from microorganisms. As presented earlier in Table 3, total coliform counts following membrane filtration (without any disinfection) are typically below 100/100ml. Following conventional filtration, total coliform counts can be above 10,000/100ml. In addition, MF/UF removes protozoan, cysts, oocysts, and helminths ova. There are also disadvantages to MF/UF, as summarized in Table 4.

Dissolved Air Flotation

Dissolved air flotation (DAF) has traditionally been used in the wastewater treatment industry for removal of oil and grease, to thicken waste-activated sludge, and remove algae from pond water. High-rate DAF technology has made its way into the water treatment industry, where it is used to remove low density floc particles, difficult to remove in a gravity sedimentation process. DAF technology for water reuse systems had been used in place of a coagulation/flocculation/sedimentation process followed by filtration. In some of these applications, it was further treated for dissolved constituents and required a microfiltration followed by a RO process. It is also used to treat algae in systems with seasonal storage ponds and reservoirs.

Table 4. Comparison of Microfiltration/Ultrafiltration to Depth/Surface Filtration[1]

Advantages
Better microorganism removal: removes protozoans, cysts, oocysts, and helminthes; partial removal of bacteria and viruses; could result in lower costs for disinfection.
Smaller footprint for equipment; typically 50-80 percent less.
As an MBR, can be cost-competitive to conventional secondary treatment processes.
Disadvantages
Higher O&M costs associated with: ° Energy ° Membrane replacement (approximately every 5 yrs) ° Monitoring for performance (membrane integrity testing) ° Residuals handling and disposal of concentrate (for some facilities)
Pretreatment may be required to prevent fouling, adding to footprint and overall costs.
Scale formation can lead to problems.
Less flow variation capability.

[1]Adapted from Metcalf & Eddy, 2007

The DAF process relies on the formation of microbubbles released after air dissolved under pressure in the water is brought to standard conditions. The bubbles surround slow-settling particles and float them to the surface. The float layer accumulates solids and thickens and is removed by mechanical skimming systems. Clarified water is removed from below the surface.

3.2.4 Residual Dissolved Solids Removal (Demineralization/ Softening)

Reclaimed supplies from areas with traditionally hard source waters and high dissolved salts may require some type of softening or demineralization process to meet the requirements of certain industrial water uses. Most of Minnesota's water supplies are of medium to high hardness and are higher in dissolved salts. However, some waters may have an adequate balance of anions and cations and depending on the use of the water, could be of adequate quality without the need for additional treatment. A complete analysis of the secondary effluent is required to assess the additional treatment needs. The applicable technologies addressed in this study are limited to membrane processes and VRTX, a hydrodynamic cavitation process, since lime softening was summarized in Section 3.2.2. Reuse applications include recycled cooling water uses and electronics production.

There are two basic membrane separation processes: pressure driven and electrically driven. Nanofiltration (NF) and reverse osmosis (RO) are pressure driven processes and require hydrostatic pressure to overcome the osmotic pressure of the feed stream. Reverse osmosis provides the most complete removal of constituents of concern for industrial water use applications, such as TDS, hardness, nitrate, and dissolved organic compounds. The removal rate of these constituents is between 90-98 percent for osmosis and half that for nanofiltration (Wong, 2003). Electrodialysis has removal rates of 50-95 percent for multivalent ions and does not remove smaller organic compounds. Microorganism removal (bacteria, protozoa, viruses) is considered to be 4-7 log removal for RO and 3-6 log removal for NF. No log removal credit is given for

ED. Table 5 summarizes removal rates for the three membrane technologies, as well as other factors related to the process and application uses pertinent to reuse.

Table 5. Factors and Applications for Dissolved Solids Removal Membrane Processes[1]

Factor/Application	Nanofiltration	Reverse Osmosis	Electrodialysis
Factors			
Typical constituents removed	• small molecules • color • some hardness • bacteria, viruses • proteins	• very small molecules • color • hardness • sulfates • nitrate, sodium • other ions • bacteria, viruses	• charged ionic solutes
Molecular weight cutoff	300-1000	<300	na
Energy consumption[2]	0.6-1.2 kWh/m[3]	1.5-2.5 kWh/m[3]	1.1-2.6 kWh/m[3]
Constituent Removal			
TDS	40-60%	90-98%	50-94%
TOC	90-98%	90-98%	20-40%[3]
Hardness	80-85%	90-98%	?
Nitrate	10-30%	84-98%	55-95%[3]
Bacteria	3-6 log removal	4-7 log removal	No log credits
Product Recovery	70-90%	50-85%	80-90%
Applications			
Desalination	Not common	Remove dissolved constituents from brackish and sea water	Remove dissolved constituents from brackish water
Water Softening	Partial reduction of multivalent ion concentrations	Most complete removal of multivalent ions	Higher level of multivalent ion reduction than NF
Water Reuse	• TDS and hardness reduction for various applications • for groundwater injection (following MF or UF)	• same as NF, but where lower concentrations are required • with two-stage RO, used for high pressure boiler feed water	• TDS and hardness reduction for various applications • only for ionized compounds; dissolved organic compounds and microorganisms are not captured

[1]Adapted from Tchobanoglous et al, 2003; Stephenson et al, 2000, Wong, 2003; and Metcalf & Eddy, 2007.
[2] Based on treating reclaimed water with a TDS concentration in the range form 1000-2500 mg/L.
[3]Reahl, Eugene, 2006.

All three membrane processes require pretreatment of secondary effluent. In all cases, particulate matter must be removed to levels typical of the filtration technologies discussed previously. Cartridge filters, pressure-driven filters, are commonly installed ahead of RO membranes. Other pretreatment requirements depend on the secondary effluent quality and type of membrane selected. Pretreatment processes can be required for iron and manganese removal (to avoid scaling on the membranes), disinfection to avoid biofouling (some membranes are sensitive to chlorine), pH adjustment to avoid scale formation, and antiscalants. ED membranes have the least pretreatment requirements, with cartridge filtration recommended.

In addition to pretreatment considerations, there is the management and disposal of the waste streams. The amount of product water resulting from the treatment of the incoming water, also called recovery, can range from 50-85 percent for RO, 70-90 percent for NF facilities, and 80-90 percent for ED. Disposal options for the concentrated waste streams vary from energy intensive thermal evaporation processes to ocean discharge. As concern for trace constituents grows, surface water discharges may be less likely. Concentrate disposal and flexibility of options should be incorporated in the planning stages to assure it is the optimum choice for a specific site and application.

VRTX Technologies has a product that prevents scale and biofouling in cooling water systems without the use of chemicals. It relies on localized effects of hydrodynamic cavitation to create high temperatures and pressures that break the bonds between the dissolved mineral and water. Minerals (including calcium) are precipitated out of the water stream as solids for disposal. Most microbiological cells are also destroyed at these extreme temperatures and pressures and dissolved gases leading to corrosion are stripped away. This technology may be an appropriate application for reclaimed waters where hardness is an issue; but may not apply to high dissolved salt waters.

This unit process will likely be located on the industry site. A major benefit of the technology is the reduction in chemical use. If it is at the WWTP site, then disinfectant may need to be added for transmission to the industry, which may not be cost-effective or meet other industry goals.

3.2.5 Residual and Specific Trace Constituent Removal (Multiple Processes)

Residual amount of organic and inorganic constituents can still remain after reverse osmosis and may need to be removed for specific industrial applications. Other constituents occur in trace amount in conventionally treated secondary effluent. These trace constituents are of concern because of known or suspected toxicity. Of heightened interest, is the environmental impact of several emerging contaminants of concern, such as:

- pharmaceutically active chemicals (PhACs)
- endocrine disrupting compounds (EDCs)
- disinfection by products (DBPs) such as N-nitrosodimethylamine (NDMA)
- a host of groundwater supply contaminants such as 1,4-dioxane and methyl tertiary-butyl ether (MTBE)
- new and reemerging pathogenic microorganisms such as *Legionella pneumophila, Cryptosporidium,* and *Giardia*

These emerging contaminants of concern have been an issue for aquifer recharge and reuse applications that affect potable water supplies. They are likely not an issue for industrial water reuse except for applications with potential for human or animal consumption. They are mentioned because it is a concern for potable water treatment and water reuse in general and could affect future regulations and the direction for best management practices that would impact the entire water reuse industry.

While NF and RO are able to remove or reduce most of these emerging contaminant compounds, there are some processes and groups of processes that may be more effective and/or economical. The treatment processes with the widest range of application include:

- Adsorption
- Ion Exchange
- Advanced Oxidation – hydrogen peroxide, ultraviolet radiation (UV), and ozone

Other processes used to destroy or remove trace constituents include: distillation, chemical oxidation, photolysis and advanced biological treatment.

Adsorption

Activated carbon is the most commonly used adsorbent in water reuse treatment systems and will serve as the general reference for adsorption technologies. Adsorption is used in water reuse treatment systems for either the continuous removal of compounds or as a barrier to protect against breakthrough from other unit processes. Organic compounds are the most commonly removed constituent with adsorption processes, but adsorption has been used to remove nitrogen, sulfides, heavy metals, and odor compounds.

A fixed-bed downflow reactor configuration is the most typical for activated carbon adsorption. This configuration is assumed for the cost information presented in Section 4.

Ion Exchange

Ion exchange involves the replacement of an ion in the aqueous phase for an ion in the solid phase. In the case of water reuse systems, the goal is to remove specific ions from the treated wastewater effluent to the solid material in the ion exchange column. The applications expected for water reuse systems supplying industries include:

- **Softening:** Industrial water uses such as recycled cooling water require removal of calcium and magnesium ions. Ion exchange units with a cationic exchange resin, exchange sodium for calcium and magnesium ions in the water. Several industries surveyed for this project used softening ion exchange units for various uses including cooling water.
- **Nitrogen Control:** Typically synthetic resins are used to remove ammonium and nitrate.

- **Heavy Metals Removal:** Industrial processes have historically used ion exchange to recover heavy metals. A variety of natural an synthetic resins are available with selectivity for specific metals.
- **Total Dissolved Solids Removal:** Anionic and cationic exchange units used in a series can be used to remove TDS or demineralize the water.
- **Reduction of Organics:** Ion exchange can be used to remove the highly ionized organics in the water. Specifically prepared resins have been used to reduce TOC levels by 50 percent.

Advanced Oxidation Processes (AOPs)

Advanced oxidation processes destroy trace constituents that are not completely oxidized by conventional oxidation processes. There are a host of processes and groupings of processes that have been used, principally in the drinking water industry and research stages, to handle specific contaminants and the emerging contaminants of concern. These processes are all applicable to treatment of water for reuse.

The primary AOPs that have application to water reuse systems include:

- Hydrogen Peroxide/Ultraviolet Light (H_2O_2/UV)
- Hydrogen Peroxide/Ozone (H_2O_2/Ozone)
- Ozone/Ultraviolet Light (Ozone/UV)

The UV processes are the most promising for Minnesota application, where UV radiation is becoming amore common form of disinfection. UV facilities could be retrofitted or planned for new construction to handle any specific removal of trace constituents.

The use of AOPs will be a very site-specific application or is a consideration for future management of trace constituents. The technology is identified in this study to emphasize that applications do exist and research is ongoing to prepare for handling the treatment of these constituents.

3.2.6 Disinfection (Microorganism Removal/Inactivation)

Most Minnesota WWTPs disinfect with chlorine or UV. The main compounds used for chlorination are gaseous chlorine (Cl_2) and liquid sodium hypochlorite (NaOCl). Because of safety concerns and regulatory requirements, many WWTPs have moved from chlorine gas to sodium hypochlorite. Other disinfectants (not emphasized in this study) include ozone, chlorine dioxide, and calcium hypochlorite (for smaller WWTPs). Membranes also provide a barrier to microorganisms and reduce or can potentially remove the need for chemical or UV disinfection.

Given the elevated potential for human contact, disinfection is an essential part of the process train in treating water for reuse. Disinfection requirements for reuse under the Title 22 criteria are greater than for discharge to the receiving stream under most Minnesota NPDES permits. Specific needs for Minnesota's wastewater treatment facilities to achieve microbial limits to protect public health are discussed under Section 3.3.

References

Metcalf & Eddy, Inc., 2007. *Water Reuse: Issues, Technologies, and Applications.* McGraw Hill. New York.

Tchobanoglous, G., F.L Burton, and H.D. Stensel. 2003. *Wastewater Engineering: Treatment and Reuse*, 4th ed. McGraw-Hill, New York.

Wong, J. 2003. "A Survey of Advanced Membrane Technologies and Their Applications in Water Reuse Projects." In: *Proceedings of the 76th Annual Technical Exhibition & Conference,* Water Environment Federation, Alexandria, Virginia.

Appendix B
California Water Recycling Criteria Excerpts

Refer to the following Article I definitions for specific process requirements:

- **Section 60301.160. Coagulated Wastewater.**
- **Section 60301.230. Disinfected Tertiary Recycled Water.**
- **Section 60301.320. Filtered Wastewater.**

Title 22

California Code of Regulations

INCLUDES REGULATIONS EFFECTIVE DECEMBER 2, 2000

March 20, 2001

DIVISION 4. ENVIRONMENTAL HEALTH

CHAPTER 3 WATER RECYCLING CRITERIA

ARTICLE 1 DEFINITIONS

Section 60301. Definitions

Section 60301.100. Approved Laboratory.

"Approved laboratory" means a laboratory that has been certified by the Department to perform microbiological analyses pursuant to section 116390, Health and Safety Code.

Section 60301.160. Coagulated Wastewater.

"Coagulated wastewater" means oxidized wastewater in which colloidal and finely divided suspended matter have been destabilized and agglomerated upstream from a filter by the addition of suitable floc-forming chemicals.

Section 60301.170. Conventional Treatment.

"Conventional treatment" means a treatment chain that utilizes a sedimentation unit process between the coagulation and filtration processes and produces an effluent that meets the definition for disinfected tertiary recycled water.

Section 60301.200. Direct Beneficial Use.

"Direct beneficial use" means the use of recycled water that has been transported from the point of treatment or production to the point of use without an intervening discharge to waters of the State.

Section 60301.220. Disinfected Secondary-2.2 Recycled Water.

"Disinfected secondary-2.2 recycled water" means recycled water that has been oxidized and disinfected so that the median concentration of total coliform bacteria in the disinfected effluent does not exceed a most probable number (MPN) of 2.2 per 100 milliliters utilizing the bacteriological results of the last seven days for which analyses have been completed, and the number of total coliform bacteria does not exceed an MPN of 23 per 100 milliliters in more than one sample in any 30 day period.

Section 60301.225. Disinfected Secondary-23 Recycled Water.

"Disinfected secondary-23 recycled water" means recycled water that has been oxidized and disinfected so that the median concentration of total coliform bacteria in the disinfected effluent does not exceed a most probable number (MPN) of 23 per 100 milliliters utilizing the bacteriological results of the last seven days for which analyses have been completed, and the number of total coliform bacteria does not exceed an MPN of 240 per 100 milliliters in more than one sample in any 30 day period.

Section 60301.230. Disinfected Tertiary Recycled Water.

"Disinfected tertiary recycled water" means a filtered and subsequently disinfected wastewater that meets the following criteria:

(a) The filtered wastewater has been disinfected by either:

(1) A chlorine disinfection process following filtration that provides a CT (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 milligram-minutes per liter at all times with a modal contact time of at least 90 minutes, based on peak dry weather design flow; or

(2) A disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999 percent of the plaque-forming units of F-specific bacteriophage MS2, or polio virus in the wastewater. A virus that is at least as resistant to disinfection as polio virus may be used for purposes of the demonstration.

(b) The median concentration of total coliform bacteria measured in the disinfected effluent does not exceed an MPN of 2.2 per 100 milliliters utilizing the bacteriological results of the last seven days for which analyses have been completed and the number of total coliform bacteria does not exceed an MPN of 23 per 100 milliliters in more than one sample in any 30 day period. No sample shall exceed an MPN of 240 total coliform bacteria per 100 milliliters.

Section 60301.240. Drift.

"Drift" means the water that escapes to the atmosphere as water droplets from a cooling system.

Section 60301.245. Drift Eliminator.

"Drift eliminator" means a feature of a cooling system that reduces to a minimum the generation of drift from the system.

Section 60301.250. Dual Plumbed System.

"Dual plumbed system" or "dual plumbed" means a system that utilizes separate piping systems for recycled water and potable water within a facility and where the recycled water is used for either of the following purposes:

(a) To serve plumbing outlets (excluding fire suppression systems) within a building or

(b) Outdoor landscape irrigation at individual residences.

Section 60301.300. F-Specific Bacteriophage MS-2.

"F-specific bacteriophage MS-2" means a strain of a specific type of virus that infects coliform bacteria that is traceable to the American Type Culture Collection (ATCC 15597B1) and is grown on lawns of E. coli (ATCC 15597).

Section 60301.310. Facility.

"Facility" means any type of building or structure, or a defined area of specific use that receives water for domestic use from a public water system as defined in section 116275 of the Health and Safety Code.

Section 60301.320. Filtered Wastewater.

"Filtered wastewater" means an oxidized wastewater that meets the criteria in subsection (a) or (b):

(a) Has been coagulated and passed through natural undisturbed soils or a bed of filter media pursuant to the following:

(1) At a rate that does not exceed 5 gallons per minute per square foot of surface area in mono, dual or mixed media gravity, upflow or pressure filtration systems, or does not exceed 2 gallons per minute per square foot of surface area in traveling bridge automatic backwash filters; and

(2) So that the turbidity of the filtered wastewater does not exceed any of the following:

(A) An average of 2 NTU within a 24-hour period;

(B) 5 NTU more than 5 percent of the time within a 24-hour period; and

(C) 10 NTU at any time.

(b) Has been passed through a microfiltration, ultrafiltration, nanofiltration, or reverse osmosis membrane so that the turbidity of the filtered wastewater does not exceed any of the following:

(1) 0.2 NTU more than 5 percent of the time within a 24-hour period; and

(2) 0.5 NTU at any time.

Section 60301.330. Food Crops.
"Food crops" means any crops intended for human consumption.

Section 60301.400. Hose Bibb.
"Hose bibb" means a faucet or similar device to which a common garden hose can be readily attached.

Section 60301.550. Landscape Impoundment.
"Landscape impoundment" means an impoundment in which recycled water is stored or used for aesthetic enjoyment or landscape irrigation, or which otherwise serves a similar function and is not intended to include public contact.

Section 60301.600. Modal Contact Time.
"Modal contact time" means the amount of time elapsed between the time that a tracer, such as salt or dye, is injected into the influent at the entrance to a chamber and the time that the highest concentration of the tracer is observed in the effluent from the chamber.

Section 60301.620. Nonrestricted Recreational Impoundment.
"Nonrestricted recreational impoundment" means an impoundment of recycled water, in which no limitations are imposed on body-contact water recreational activities.

Section 60301.630. NTU.
"NTU" (Nephelometric turbidity unit) means a measurement of turbidity as determined by the ratio of the intensity of light scattered by the sample to the intensity of incident light as measured by method 2130 B. in Standard Methods for the Examination of Water and Wastewater, 20th ed.; Eaton, A. D., Clesceri, L. S., and Greenberg, A. E., Eds; American Public Health Association: Washington, DC, 1995; p. 2-8.

Section 60301.650. Oxidized Wastewater.
"Oxidized wastewater" means wastewater in which the organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen.

Section 60301.660. Peak Dry Weather Design Flow.
"Peak Dry Weather Design Flow" means the arithmetic mean of the maximum peak flow rates sustained over some period of time (for example three hours) during the maximum 24-hour dry weather period. Dry weather period is defined as periods of little or no rainfall.

Section 60301.700. Recycled Water Agency.

"Recycled water agency" means the public water system, or a publicly or privately owned or operated recycled water system, that delivers or proposes to deliver recycled water to a facility.

Section 60301.710. Recycling Plant.

"Recycling plant" means an arrangement of devices, structures, equipment, processes and controls which produce recycled water.

Section 60301.740. Regulatory Agency.

"Regulatory agency" means the California Regional Water Quality Control Board(s) that have jurisdiction over the recycling plant and use areas.

Section 60301.750. Restricted Access Golf Course.

"Restricted access golf course" means a golf course where public access is controlled so that areas irrigated with recycled water cannot be used as if they were part of a park, playground, or school yard and where irrigation is conducted only in areas and during periods when the golf course is not being used by golfers.

Section 60301.760. Restricted Recreational Impoundment.

"Restricted recreational impoundment" means an impoundment of recycled water in which recreation is limited to fishing, boating, and other non-body-contact water recreational activities.

Section 60301.800. Spray Irrigation.

"Spray irrigation" means the application of recycled water to crops to maintain vegetation or support growth of vegetation by applying it from sprinklers.

Section 60301.830. Standby Unit Process.

"Standby unit process" means an alternate unit process or an equivalent alternative process which is maintained in operable condition and which is capable of providing comparable treatment of the actual flow through the unit for which it is a substitute.

Section 60301.900. Undisinfected Secondary Recycled Water.

"Undisinfected secondary recycled water" means oxidized wastewater.

Section 60301.920. Use Area.

"Use area" means an area of recycled water use with defined boundaries. A use area may contain one or more facilities.

Appendix C
Cost Information

Cost Summaries for Treatment Scenarios
Transmission System Unit Costs

Scenario A1 - Process Train 1a

CONVENTIONAL WITH GRAVITY FILTRATION - 5 MILE TRANSMISSION

WATER REUSE SYSTEM COST OF SERVICE ASSUMPTIONS AND SUMMARY RESULTS

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	$9,607,492
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

Summary of Capital Cost Estimates

Description	Total Cost	% of Total
Treatment Facilities	$5,091,078	53
Storage Facilities	$467,500	5
Pump Station	$534,193	6
Piping	$3,514,720	37
TOTAL CAPITAL	**$9,607,492**	

Annual Avg Flow/Demand (mgd)	**1.0**
Length of Distribution System (mi)	**5.0**

Operation and Maintenance Cost Items

Lab, Chemicals & Power		***Maintenance***	
Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Sodium Hypochlorite, $/gal of 12.5%	$0.70	Pump System Equip, % capital	1%
Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Electrical Power, $/kwhr	$0.045	Distribution System, $/mile	$5,500

FTE Annual Salary with Benefits, $

Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

	Cost Components	Basis/Methodology	Estimated Total Cost in Year 1 (2009)	Type of Cost: Fixed or Variable?	Estimated Cost per 1,000 Gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$741,561	Fixed	**$2.03**
OPERATION AND MAINTENANCE	Pumping System				
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	Combination	$0.02
	Equipment Maintenance	Based on % of capital cost input	$10,017	Combination	$0.03
	Electrical Power	Based on per Kwh rate input; see Note C	$27,388	Variable	$0.08
	Reuse Treatment at WWTP				
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$14,342	Variable	$0.04
	Other Chemicals/Misc	From Treatment Module	$186,366	Variable	$0.51
	Laboratory	Lab cost input	$20,000	Fixed	$0.05
	Electrical Power	From Treatment Module	$0	Variable	$0.00
	Equipment Maintenance	Based on % of capital cost input	$254,554	Combination	$0.70
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	Combination	$0.08
GENERAL AND ADMINISTRATIVE	General System Management				
	Engineering	0.15 FTE base; .05% increase per mgd >1	$18,000	Combination	$0.05
	Finance and Accounting	0.15 FTE	$14,400	Combination	$0.04
	Legal	0.05 FTE	$9,000	Combination	$0.02
	Customer Service	0.05 FTE	$4,800	Combination	$0.01
	Total Annual O&M and Management Costs		$595,200		
		TOTAL OF ALL COST COMPONENTS FOR SYSTEM:			**$3.66**

Total Treatment O&M	$475,262
Total Transmission O&M	$73,705
Total Other Annual Costs	$46,200
Total Check	$595,200

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-Oct when MN WWTPs disinfect and 9 mg/l for Nov-Apr to provide main disinfection and residual for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Scenario A1: Process Train 1b
CONVENTIONAL WITH MICROFILTRATION - 5 MILE TRANSMISSION
WATER REUSE SYSTEM COST OF SERVICE ASSUMPTIONS AND SUMMARY RESULTS

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	$10,870,250
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

Summary of Capital Cost Estimates

Description	Total Cost	% of Total
Treatment Facilities	$6,353,837	58
Storage Facilities	$467,500	4
Pump Station	$534,193	5
Piping	$3,514,720	32
TOTAL CAPITAL	**$10,870,250**	

Annual Avg Flow/Demand (mgd)	**1.0**
Length of Distribution System (mi)	**5.0**

Operation and Maintenance Cost Items

Lab, Chemicals & Power		***Maintenance***	
Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Sodium Hypochlorite, $/gal of 12.5%	$0.70	Pump System Equip, % capital	1%
Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Electrical Power, $/kwhr	$0.045	Distribution System, $/mile	$5,500

FTE Annual Salary with Benefits, $	
Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

	Cost Components	Basis/Methodology	Estimated Total Cost in Year 1 (2009)	Type of Cost: Fixed or Variable?	Estimated Cost per 1,000 Gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$839,028	Fixed	**$2.30**
OPERATION AND MAINTENANCE	Pumping System				
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	Combination	$0.02
	Equipment Maintenance	Based on % of capital cost input	$10,017	Combination	$0.03
	Electrical Power	Based on per Kwh rate input; see Note C	$27,388	Variable	$0.08
	Reuse Treatment at WWTP				
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$14,342	Variable	$0.04
	Other Chemicals/Misc	From Treatment Module	$270,317	Variable	$0.74
	Laboratory	Lab cost input	$20,000	Fixed	$0.05
	Electrical Power	From Treatment Module	$0	Variable	$0.00
	Equipment Maintenance	Based on % of capital cost input	$317,692	Combination	$0.87
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	Combination	$0.08
GENERAL AND ADMINISTRATIVE	General System Management				
	Engineering	0.15 FTE base; .05% increase per mgd >1	$18,000	Combination	$0.05
	Finance and Accounting	0.15 FTE	$14,400	Combination	$0.04
	Legal	0.05 FTE	$9,000	Combination	$0.02
	Customer Service	0.05 FTE	$4,800	Combination	$0.01
	Total Annual O&M and Management Costs		$742,300		
	TOTAL OF ALL COST COMPONENTS FOR SYSTEM:				**$4.33**

Total Treatment O&M	$622,351
Total Transmission O&M	$73,705
Total Other Annual Costs	$46,200
Total Check	$742,300

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-Oct when MN WWTPs disinfect and 9 mg/l for Nov-Apr to provide main disinfection and residual for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Scenario A2: Process Train 4

MICROFILTRATION AND REVERSE OSMOSIS* - 5 MILE TRANSMISSION

WATER REUSE SYSTEM COST OF SERVICE ASSUMPTIONS AND SUMMARY RESULTS

***Secondary treatment process without nutrient removal**

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	$15,540,647
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

Annual Avg Flow/Demand (mgd)	**1.0**
Length of Distribution System (mi)	**5.0**

Summary of Capital Cost Estimates

Description	Total Cost	% of Total
Treatment Facilities	$11,024,233	71
Storage Facilities	$467,500	3
Pump Station	$534,193	3
Piping	$3,514,720	23
TOTAL CAPITAL	**$15,540,647**	

Operation and Maintenance Cost Items

Lab, Chemicals & Power		***Maintenance***	
Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Sodium Hypochlorite, $/gal of 12.5%	$0.70	Pump System Equip, % capital	1%
Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Electrical Power, $/kwhr	$0.045	Distribution System, $/mile	$5,500

FTE Annual Salary with Benefits, $	
Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

	Cost Components	Basis/Methodology	Estimated Total Cost in Year 1 (2009)	Type of Cost: Fixed or Variable?	Estimated Cost per 1,000 Gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$1,199,516	Fixed	**$3.29**
OPERATION AND MAINTENANCE	Pumping System				
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	Combination	$0.02
	Equipment Maintenance	Based on % of capital cost input	$10,017	Combination	$0.03
	Electrical Power	Based on per Kwh rate input; see Note C	$27,388	Variable	$0.08
	Reuse Treatment at WWTP				
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$14,342	Variable	$0.04
	Other Chemicals/Misc	From Treatment Module	$711,039	Variable	$1.95
	Laboratory	Lab cost input	$20,000	Fixed	$0.05
	Electrical Power	From Treatment Module	$0	Variable	$0.00
	Equipment Maintenance	Based on % of capital cost input	$551,212	Combination	$1.51
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	Combination	$0.08
GENERAL AND ADMINISTRATIVE	General System Management				
	Engineering	0.15 FTE base; .05% increase per mgd >1	$18,000	Combination	$0.05
	Finance and Accounting	0.15 FTE	$14,400	Combination	$0.04
	Legal	0.05 FTE	$9,000	Combination	$0.02
	Customer Service	0.05 FTE	$4,800	Combination	$0.01
	Total Annual O&M and Management Costs		$1,416,500		
	TOTAL OF ALL COST COMPONENTS FOR SYSTEM:				**$7.17**

Total Treatment O&M	$1,296,593
Total Transmission O&M	$73,705
Total Other Annual Costs	$46,200
Total Check	$1,416,500

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-Oct when MN WWTPs disinfect and 9 mg/l for Nov-Apr to provide main disinfection and residual for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Scenario B1: Process Train 5a
GRAVITY FILTRATION - 5 MILE TRANSMISSION
WATER REUSE SYSTEM COST OF SERVICE ASSUMPTIONS AND SUMMARY RESULTS

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	$7,410,025
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

Summary of Capital Cost Estimates

Description	Total Cost	% of Total
Treatment Facilities	$2,893,611	39
Storage Facilities	$467,500	6
Pump Station	$534,193	7
Piping	$3,514,720	47
TOTAL CAPITAL	**$7,410,025**	

Annual Avg Flow/Demand (mgd)	**1.0**
Length of Distribution System (mi)	**5.0**

Operation and Maintenance Cost Items

Lab, Chemicals & Power		***Maintenance***	
Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Sodium Hypochlorite, $/gal of 12.5%	$0.70	Pump System Equip, % capital	1%
Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Electrical Power, $/kwhr	$0.045	Distribution System, $/mile	$5,500

FTE Annual Salary with Benefits, $	
Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

	Cost Components	Basis/Methodology	Estimated Total Cost in Year 1 (2009)	Type of Cost: Fixed or Variable?	Estimated Cost per 1,000 Gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$571,948	Fixed	**$1.57**
OPERATION AND MAINTENANCE	Pumping System				
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	Combination	$0.02
	Equipment Maintenance	Based on % of capital cost input	$10,017	Combination	$0.03
	Electrical Power	Based on per Kwh rate input; see Note C	$27,388	Variable	$0.08
	Reuse Treatment at WWTP				
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$14,342	Variable	$0.04
	Other Chemicals/Misc	From Treatment Module	$110,069	Variable	$0.30
	Laboratory	Lab cost input	$20,000	Fixed	$0.05
	Electrical Power	From Treatment Module	$0	Variable	$0.00
	Equipment Maintenance	Based on % of capital cost input	$144,681	Combination	$0.40
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	Combination	$0.08
GENERAL AND ADMINISTRATIVE	General System Management				
	Engineering	0.15 FTE base; .05% increase per mgd >1	$18,000	Combination	$0.05
	Finance and Accounting	0.15 FTE	$14,400	Combination	$0.04
	Legal	0.05 FTE	$9,000	Combination	$0.02
	Customer Service	0.05 FTE	$4,800	Combination	$0.01
	Total Annual O&M and Management Costs		$409,000		
		TOTAL OF ALL COST COMPONENTS FOR SYSTEM:			**$2.69**

Total Treatment O&M	$289,092
Total Transmission O&M	$73,705
Total Other Annual Costs	$46,200
Total Check	$409,000

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-Oct when MN WWTPs disinfect and 9 mg/l for Nov-Apr to provide main disinfection and residual for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Scenario B1: Process Train 5b
MICROFILTRATION - 5 MILE TRANSMISSION
WATER REUSE SYSTEM COST OF SERVICE ASSUMPTIONS AND SUMMARY RESULTS

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	$8,470,884
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

Summary of Capital Cost Estimates

Description	Total Cost	% of Total
Treatment Facilities	$3,954,471	47
Storage Facilities	$467,500	6
Pump Station	$534,193	6
Piping	$3,514,720	41
TOTAL CAPITAL	**$8,470,884**	

Annual Avg Flow/Demand (mgd)	**1.0**
Length of Distribution System (mi)	**5.0**

Operation and Maintenance Cost Items

Lab, Chemicals & Power		***Maintenance***	
Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Sodium Hypochlorite, $/gal of 12.5%	$0.70	Pump System Equip, % capital	1%
Chlorine Dose, mg/L (year-round, see Note A)	3	Treatment Facilities, % capital	5%
Electrical Power, $/kwhr	$0.045	Distribution System, $/mile	$5,500

FTE Annual Salary with Benefits, $	
Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

	Cost Components	Basis/Methodology	Estimated Total Cost in Year 1 (2009)	Type of Cost: Fixed or Variable?	Estimated Cost per 1,000 Gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$653,831	Fixed	**$1.79**
OPERATION AND MAINTENANCE	Pumping System				
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	Combination	$0.02
	Equipment Maintenance	Based on % of capital cost input	$10,017	Combination	$0.03
	Electrical Power	Based on per Kwh rate input; see Note C	$27,388	Variable	$0.08
	Reuse Treatment at WWTP				
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$6,147	Variable	$0.02
	Other Chemicals/Misc	From Treatment Module	$186,465	Variable	$0.51
	Laboratory	Lab cost input	$20,000	Fixed	$0.05
	Electrical Power	From Treatment Module	$0	Variable	$0.00
	Equipment Maintenance	Based on % of capital cost input	$197,724	Combination	$0.54
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	Combination	$0.08
GENERAL AND ADMINISTRATIVE	General System Management				
	Engineering	0.15 FTE base; .05% increase per mgd >1	$18,000	Combination	$0.05
	Finance and Accounting	0.15 FTE	$14,400	Combination	$0.04
	Legal	0.05 FTE	$9,000	Combination	$0.02
	Customer Service	0.05 FTE	$4,800	Combination	$0.01
TOTAL ANNUAL	Total Annual O&M and Management Costs		$530,200		
		TOTAL OF ALL COST COMPONENTS FOR SYSTEM:			**$3.24**

Total Treatment O&M	$410,335
Total Transmission O&M	$73,705
Total Other Annual Costs	$46,200
Total Check	$530,200

NOTES:

A - based on a dose of 3.0 mg/l for residual disinfection for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Scenario B2: Process Train 6
MICROFILTRATION AND REVERSE OSMOSIS - 5 MILE TRANSMISSION
WATER REUSE SYSTEM COST OF SERVICE ASSUMPTIONS AND SUMMARY RESULTS

Blue = Values to input

Capital Cost and Debt Financing Assumptions

Total Capital Cost	$12,682,512
Amount of Grant Funding	$0
Municipal % of Up-Front Capital	100%
Other % of Up-Front Capital	0%
Debt Term (Years)	20
Annual Interest Rate	5.00%
Issuance Costs, % of Capital	1%

Summary of Capital Cost Estimates

Description	Total Cost	% of Total
Treatment Facilities	$8,166,099	64
Storage Facilities	$467,500	4
Pump Station	$534,193	4
Piping	$3,514,720	28
TOTAL CAPITAL	**$12,682,512**	

Annual Avg Flow/Demand (mgd)	**1.0**
Length of Distribution System (mi)	**5.0**

Operation and Maintenance Cost Items

Lab, Chemicals & Power		***Maintenance***	
Lab Costs, $	$20,000	Pump System Labor, hrs/wk	4
Sodium Hypochlorite, $/gal of 12.5%	$0.70	Pump System Equip, % capital	1%
Chlorine Dose, mg/L (year-round, see Note A)	7	Treatment Facilities, % capital	5%
Electrical Power, $/kwhr	$0.045	Distribution System, $/mile	$5,500

FTE Annual Salary with Benefits, $	
Finance, Operations, Cust Service	$80,000
Legal	$150,000
Engineering	$100,000

	Cost Components	Basis/Methodology	Estimated Total Cost in Year 1 (2009)	Type of Cost: Fixed or Variable?	Estimated Cost per 1,000 Gallons
CAPITAL	Debt Service (Capital Cost)	Based on debt service payment	$978,909	Fixed	**$2.68**
OPERATION AND MAINTENANCE	Pumping System				
	Maintenance Labor	hours/week at operator rate input-see Note B	$8,800	Combination	$0.02
	Equipment Maintenance	Based on % of capital cost input	$10,017	Combination	$0.03
	Electrical Power	Based on per Kwh rate input; see Note C	$27,388	Variable	$0.08
	Reuse Treatment at WWTP				
	Chlorine Disinfection	$/gallon at %Conc input; see Note A	$14,342	Variable	$0.04
	Other Chemicals/Misc	From Treatment Module	$618,295	Variable	$1.69
	Laboratory	Lab cost input	$20,000	Fixed	$0.05
	Electrical Power	From Treatment Module	$0	Variable	$0.00
	Equipment Maintenance	Based on % of capital cost input	$408,305	Combination	$1.12
	Distribution System Maintenance	Equals water system cost/mile-see Note B	$27,500	Combination	$0.08
GENERAL AND ADMINISTRATIVE	General System Management				
	Engineering	0.15 FTE base; .05% increase per mgd >1	$18,000	Combination	$0.05
	Finance and Accounting	0.15 FTE	$14,400	Combination	$0.04
	Legal	0.05 FTE	$9,000	Combination	$0.02
	Customer Service	0.05 FTE	$4,800	Combination	$0.01
	Total Annual O&M and Management Costs		$1,180,800		
				TOTAL OF ALL COST COMPONENTS FOR SYSTEM:	**$5.92**

Total Treatment O&M	$1,060,942
Total Transmission O&M	$73,705
Total Other Annual Costs	$46,200
Total Check	$1,180,800

NOTES:

A - based on a dose of 6.0 mg/l for additional disinfection and residual disinfection during Apr-Oct when MN WWTPs disinfect and 9 mg/l for Nov-Apr to provide main disinfection and residual for transmission.

B - escalates 10% for flows from 1-10 mgd and 30% for flows greater than 10 mgd.

C - costs based on cost curves developed and included in separate worksheet

Unit Construction and Project Costs for Force Mains[1]

Diameter (inches)	Unit Construction Cost , $/lf		Unit Project Cost[2], $/lf	
	Developed Area	Undeveloped Area	Developed Area	Undeveloped Area
4	59	48	107	87
6	65	53	117	95
8	70	58	127	105
10	78	66	141	119
12	86	73	154	131
14	96	84	173	151
16	116	102	208	184
18	129	116	232	208
20	144	131	260	235
24	174	161	312	289
30	216	198	388	356
36	265	246	477	443
42	325	305	584	549
48	410	388	738	699
54	477	454	859	817
60	545	517	980	931

[1]Based on the following:

-Sept. 2006 dollars, ENR CCI = 7763 escalated to Apr 2009 dollars, ENR CCI=8528

-Mean Indices, 2006 and Cost Tool with detailed unit costs (App. B, Exhibit 1)

-Average depth of installation for force mains assumed to be 8 ft.

-4 to 24" pipe is PVC; >24" is DIP

[2]Project unit costs based on master planning level assumptions: 50% for undeveloped design detail (includes allowance for related appurtenances).

Appendix D
2009 Minnesota Legislation
Fund Appropriation for Water
Reuse Projects at Ethanol Facilities

2009 Legislative Session – Fund Appropriation for Water Reuse Projects at Ethanol Facilities

H.F. No. 1231, 4th Engrossment - 86th Legislative Session (2009-2010) Posted on May 19, 2009 [Article 2, Section 4(c).]

A bill for an act relating to state government; appropriating money from constitutionally dedicated funds and providing for policy and governance of outdoor heritage, clean water, parks and trails, and arts and cultural heritage purposes; establishing and modifying grants and funding programs; providing for advisory groups; providing appointments; requiring reports; requiring rulemaking; amending Minnesota Statutes 2008, sections 3.303, by adding a subdivision; 84.02, by adding subdivisions; 84.66, subdivision 2; 85.53; 97A.056, subdivisions 2, 3, 6, 7; 103F.505; 103F.511, subdivisions 5, 8a, by adding a subdivision; 103F.515, subdivisions 1, 2, 4, 5, 6; 103F.521, subdivision 1; 103F.525; 103F.526; 103F.531; 103F.535, subdivision 5; 114D.50; 116G.15; 129D.17; proposing coding for new law in Minnesota Statutes, chapters 3; 84; 85; 116; 129D; repealing Minnesota Statutes 2008, sections 103B.101, subdivision 11; 103F.511, subdivision 4; 103F.521, subdivision 2; Minnesota Rules, parts 8400.3130; 8400.3160; 8400.3200; 8400.3230; 8400.3330; 8400.3360; 8400.3390; 8400.3500; 8400.3530; 8400.3560.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF MINNESOTA:

ARTICLE 2

CLEAN WATER FUND

Section 1. CLEAN WATER FUND APPROPRIATIONS.

Sec. 4. POLLUTION CONTROL AGENCY

Article 2, Section 4(c).

(c) $1,500,000 the first year and $3,169,000 the second year are for grants under Minnesota Statutes, section 116.195, to political subdivisions for up to 50 percent of the costs to predesign, design, and implement capital projects that use treated municipal wastewater instead of groundwater from drinking water aquifers, in order to demonstrate the beneficial use of wastewater, including the conservation and protection of water resources. Of this amount, $1,000,000 the first year is for grants to ethanol plants that are within one and one-half miles of a city for improvements that reuse greater than 300,000 gallons of wastewater per day.