



Technical Memorandum

To: Marvin Hora, Minnesota Pollution Control Agency
Doug Hall, Minnesota Pollution Control Agency
Mark Tomasek, Minnesota Pollution Control Agency

From: Jamie Bankston and Patrick Hirl

Subject: Effluent Total Phosphorus Reduction Efforts by Wastewater Treatment Plants

Date: November 24, 2003

Project: 23/62-853 CMPL 001

c: Greg Wilson
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The purpose of this memorandum is to provide the Minnesota Pollution Control Agency (MPCA) with information on current practices of cities to reduce the phosphorus concentration in their wastewater treatment plant (WWTP) effluent through such approaches as reduction in the influent phosphorus loading, chemical phosphorus precipitation, and enhanced biological phosphorus removal (EBPR). Information was collected from six Minnesota cities and two Oregon cities on their programs to reduce their effluent phosphorus loading. A small sampling of Minnesota cities was used due to the limited number of cities that had data available on phosphorus reduction and its costs. The two Oregon cities were included because of their ability to meet a very stringent effluent phosphorus limit of 0.07 mg/L.

This memorandum provides a review of the efforts of each of the cities to reduce the phosphorus in their effluent. Where available, costs for the specific phosphorus reduction efforts are provided. Finally, conclusions are drawn on the effectiveness of effluent phosphorus reduction efforts based on the data provided.

Effluent Phosphorus Reduction Approaches

As mentioned above, three approaches were used either separately or in combination by the communities surveyed to reduce their effluent phosphorus concentrations: source reduction, chemical precipitation, and EBPR. Source reduction efforts varied significantly between cities in the survey.

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The simplest approach was a public education campaign to promote reductions in the use of household products with high concentrations of phosphorus. The more aggressive cities implemented fees based on the phosphorus content of the sewer discharge for their significant industrial users (SIU). Pretreatment was also required in one city if a SIU exceeded a pre-defined phosphorus loading threshold. The specifics of each effort are described below.

Chemical phosphorus precipitation is the use of metal salts to promote the precipitation of metal phosphates. Iron or aluminum are the most commonly used metals. The metal salt can be added at many different points in the WWTP treatment train. The most common point of application is immediately prior to secondary clarification. The chemical used and point of application are identified for each plant surveyed. The equipment required for chemical precipitation is minimal with systems adding metal salts prior to secondary clarification needing only a bulk storage tank and a chemical dosing pump. The largest cost for chemical precipitation phosphorus treatment is operations, which includes chemical cost and the cost of additional sludge disposal. The chemical costs are provided for all WWTPs surveyed using chemical precipitation.

EBPR is achieved in the activated sludge system by promoting the growth of bacteria that can hyper-accumulate phosphorus. This is achieved by creating an initial anaerobic zone in the activated sludge system followed by the traditional aerobic zone. In addition, low molecular weight organic acids must be present in the anaerobic zone to achieve EBPR. These acids can be produced in the sewer system, in the primary clarifier, or in a separate sludge fermenter. EBPR can be implemented using a wide range of approaches. The simplest approach can be to adjust air flow within the activated sludge basins to create the anaerobic zone. The more sophisticated approaches can require separate anaerobic basins and separate sludge digestion tanks. Phosphorus is ultimately removed from the EBPR system when the bacteria, which have hyper-accumulated phosphorus, are wasted from the activated sludge system.

It should be noted that reductions in the influent phosphorus concentrations to a WWTP may or may not reduce the effluent phosphorus concentration. The effect of influent phosphorus concentration reduction on effluent phosphorus concentration is dependent on the operation of the WWTP. WWTPs that have not implemented phosphorus treatment (i.e., either chemical phosphorus precipitation or EBPR) will likely see a reduction in the effluent phosphorus concentration proportional to the reduction in influent phosphorus concentration. WWTPs using chemical precipitation to meet effluent phosphorus limits will not likely experience a reduction in effluent phosphorus concentration

if the influent phosphorus concentration is reduced because chemical precipitation will continue to be required to meet the effluent phosphorus limit. A reduction in influent phosphorus (soluble) concentration will reduce the amount of chemical required to achieve the effluent phosphorus limit, which will ultimately result in a reduction in chemical cost for phosphorus treatment. However, if the influent phosphorus was not soluble, which is precipitated chemically, but was particulate phosphorus, which is precipitated by flocculation, there may not be a direct reduction in chemical costs. Finally, WWTPs using EBPR will not likely experience a reduction in effluent phosphorus concentration if the influent phosphorus concentration is reduced because of the limits of this technology. The cost for operating EBPR will not be affected by the reductions in the influent phosphorus concentration.

Survey of Wastewater Treatment Plants for Phosphorus Removal

Several WWTPs were contacted by Barr Engineering regarding phosphorus treatment methods at their plant. The WWTPs were asked to identify the total flow into the plant, unit operations at the plant, phosphorus treatment method, influent and effluent phosphorus concentrations, estimated costs for phosphorus treatment, and methods used for limiting phosphorus input to the WWTPs. The WWTPs ranged in size (0.7 to 24 million gallons per day), treatment methods (chemical and/or biological), and phosphorus discharge requirements (0.07 mg/L to 2.41 mg/L). All of the WWTPs surveyed were activated sludge plants. This section summarizes the findings of the WWTP surveys, for a more detailed description of each WWTP see Attachment A. Phosphorus removal performance data for each of the WWTPs surveyed are presented in Table 1. Average wet weather design flow (AWWDF) and additional information concerning significant industrial users (SIUs) are included in Table 1 and Attachment A, respectively.

Wastewater Treatment Plants that Chemically Treat for Phosphorus

Four of the eight WWTPs that responded to our survey used chemical treatment only for phosphorus removal. The chemicals used were either alum or ferric chloride. Listed below is a brief description of the WWTPs that used chemical phosphorus removal. The WWTPs are described below in order from the lowest total phosphorus discharge requirement (0.3 mg/L, Bemidji, MN) to the highest (2.41 mg/L, Mankato, MN). Pond systems were not evaluated for this study, but it should be noted that pond systems are capable of removing phosphorus by batch chemical treatment prior to their controlled discharges.

Bemidji, Minnesota

This WWTP is the first WWTP discharge into the Mississippi River, just upstream of Lake Bemidji. A phosphorus discharge requirement of 0.3 mg/L total phosphorus or less is required as part of the NPDES permit. To meet the NPDES requirements, the WWTP uses alum for phosphorus precipitation and polymer for suspended solids precipitation. The alum and polymer are added after the activated sludge aeration basin but before the secondary clarifier. The average total phosphorus concentration entering the plant is 7 mg/L and the average total phosphorus concentration discharging from the plant is 0.15 mg/L. Bemidji does not have any significant industrial users, so the phosphorus entering the plant is primarily from domestic sources. This system has an average flow of 1.15 MGD. Costs for chemical treatment were based solely on alum costs. A treatment cost of \$3.25 per pound of total phosphorus removed was calculated using the average influent and effluent total phosphorus concentrations, the average flow, and alum costs for a year.

St. Croix Valley, Minnesota

This WWTP discharges into the St. Croix River/Lake St. Croix at Oak Park Heights, Minnesota and is one of the WWTPs operated by the Metropolitan Council. A phosphorus discharge requirement of 0.8 mg/L total phosphorus or less is required as part of the NPDES permit. To reach the NPDES requirements, the WWTP uses alum for phosphorus precipitation. The alum is added at the inlet to the primary clarifier. The average total phosphorus concentration entering the plant is 4.8 mg/L and the average total phosphorus concentration discharging from the plant is 0.45 mg/L. This system has an average flow of 3.4 MGD. Costs for chemical treatment were based solely on alum costs. A treatment cost of \$0.96 per pound of total phosphorus removed was calculated using the average influent and effluent total phosphorus concentrations, the average flow, and alum costs for a year.

Rochester, Minnesota

This WWTP discharges into the Zumbro River upstream of Lake Zumbro. A phosphorus discharge requirement of 1 mg/L total phosphorus or less is required as part of the NPDES permit. To reach the NPDES requirements, the WWTP uses ferric chloride and alum for phosphorus precipitation and polymer for suspended solids precipitation. The ferric chloride is added to the primary clarifier and alum and polymer are added to the secondary clarifier. The average total phosphorus concentration entering the plant is 7.5 mg/L and the average total phosphorus concentration discharging from the plant is 0.7 mg/L. Rochester has several significant industrial users that discharge to the WWTP. Daily maximum and monthly average total phosphorus limits are set for significant industrial users to

limit the phosphorus discharged to the WWTP by industry. This system has an average flow of 14 MGD. A treatment cost of \$1.76 per pound of phosphorus removed was given by the Rochester Environmental Coordinator. It should be noted that no further description of the treatment costs was given, so it was assumed that treatment costs were based solely on chemical costs.

Mankato, Minnesota

This WWTP discharges into the Minnesota River. A phosphorus discharge cap of 20,000 kg/yr (2.41 mg/L at 6 MGD) of total phosphorus is required as part of the NPDES permit, with a phosphorus discharge goal of 15,700 kg/yr (1.89 mg/L at 6 MGD). To reach the NPDES requirements, the WWTP uses ferric chloride for phosphorus precipitation and polymer for suspended solids precipitation. The ferric chloride is added at the influent of the WWTP and is settled out in the primary clarifier. Polymer is added to the secondary clarifier for solids precipitation. The average total phosphorus concentration entering the plant is 8.0 mg/L and the average total phosphorus concentration discharging from the plant is 1.88 mg/L. This system has an average flow of 6 MGD.

Mankato has several significant industrial users (SIUs) that discharge to the WWTP. SIUs are allowed to discharge 1 kg/day of total phosphorus, which is averaged on an annual basis. Any discharge above this loading is charged a fee. The fee is based on the treatment costs and phosphorus treatment efficiency for the year and includes chemical costs, biosolids disposal, maintenance, utilities, and lab analysis. The all inclusive treatment cost, which does not include capital costs, is approximately \$1.70 per pound of phosphorus removed (\$3.75 per kg). In comparison, the cost for phosphorus removal using chemical costs alone was \$0.70 per pound of phosphorus removed. The all-inclusive costs are 2.3 times greater than the chemical only costs. This was the only facility in the survey that provided all-inclusive costs for chemical phosphorus removal.

Wastewater Treatment Plants that use Enhanced Biological Phosphorus Removal

Four of the eight WWTPs that responded to our survey used enhanced biological phosphorus removal (EBPR). In addition to EBPR, three of the four plants surveyed also use chemical treatment to meet total phosphorus discharge requirements below 1 mg/L. Listed below is a brief description of the WWTPs that used EBPR. The WWTPs are described in order from the lowest total phosphorus discharge requirement (0.07 mg/L, Durham and Rock Creek WWTPs, Oregon) to the greatest (monitoring only, St. Cloud).

Rock Creek and Durham WWTPs – Portland, Oregon

The Rock Creek and Durham WWTPs are located just west of Portland, Oregon in the Tualatin Watershed and have one of the lowest phosphorus discharge requirements in the United States of approximately 0.07 mg/L total phosphorus. These WWTPs are two of four WWTPs operated by Clean Water Services in urban Washington County, who serves approximately 455,000 customers with an average daily flow rate of 72 million gallons. The average flow for the Durham WWTP is approximately 20 MGD and the Rock Creek WWTP is 24 MGD. The average total phosphorus influent concentration is 7 mg/L for both plants. The WWTPs discharge to the Tualatin River and their combined flow comprises approximately one-third of the flow in the Tualatin River. These WWTPs are located in the Tualatin Watershed Sub-basin of the Willamette Watershed Basin. Each WWTP has a mass-based monthly median total phosphorus discharge of 9 lb/day (0.07 mg/L total phosphorus based on the average flow rate for each plant) during the summer (May – October). The total phosphorus discharge concentration is based on a TMDL for the Tualatin Watershed Sub-basin. The total phosphorus discharge requirements are subject to change when the TMDLs are re-evaluated for this watershed (effluent levels may be increased).

The Rock Creek and Durham WWTPs use EBPR and two-point alum addition to meet the stringent 0.07 mg/L total phosphorus discharge requirement. Pilot testing and full scale system modifications were required to reach the high level of phosphorus removal achieved by these plants. Alum is added to the primary clarifier prior to EBPR, total phosphorus concentrations after alum treatment in the primary clarifier and EBPR are approximately 0.5 mg/L. After the first alum treatment and EBPR, alum is added to the secondary clarifier; the effluent from the secondary clarifier is then filtered for an average total phosphorus effluent concentration of 0.05 mg/L. Prior to implementing EBPR, the Durham facility only used chemical treatment (alum) for phosphorus removal. Significant cost savings were observed once enhanced biological phosphorus removal was implemented at the Durham facility (i.e., the chemical costs for alum were cut by one third). Chemical costs for the facility are now approximately \$0.47 per pound of total phosphorus removed. The pilot test and plant modifications to achieve EBPR at the Durham facility cost approximately \$900,000.

The city of Portland implemented a phosphorus ban for non-industrial dischargers, which was soon followed by a state-wide ban. A 22% reduction in total phosphorus was observed in the influent to the WWTPs after the ban (9 mg/L pre-ban to 7 mg/L post-ban). Industrial users are not required to

limit phosphorus discharge. Because of the public awareness of phosphorus discharge into this sensitive watershed, industries have voluntarily reduced phosphorus discharges.

Ely, Minnesota

The Ely WWTP discharges into Shagawa Lake. The NPDES discharge requirement is 0.3 mg/L total phosphorus. EBPR and chemical addition of alum are used to meet the NPDES discharge requirements. The average annual flow into the WWTP is approximately 0.7 MGD. Lime had originally been used at the Ely plant for chemical precipitation, but because of the high cost associated with lime treatment, the plant switched to alum.

When EBPR does not meet the discharge requirement alum is added to the mixing zone of the secondary clarifier. The secondary clarifier effluent is then passed through sand filters; the final total phosphorus average effluent discharge concentration is 0.2 mg/L. For short periods of time, the WWTP has been able to achieve 0.05 mg/L total phosphorus discharge concentrations. It was estimated by the WWTP superintendent that the costs associated with phosphorus removal are approximately 25% of the annual operating budget. Therefore, the estimated cost for phosphorus treatment is approximately \$20 per pound of phosphorus removed. It should be noted that raw cost data was not immediately available for this WWTP and that the phosphorus treatment costs were based on verbal estimates given by the WWTP superintendent, therefore, the estimated costs presented here may be greater than the actual treatment costs.

This WWTP does not have any significant industrial users discharging to the WWTP; therefore, the phosphorus source is primarily from domestic dischargers. Phosphorus influent to the plant was significantly reduced in the early 1980's by educating the public on limiting the use of phosphorus in detergents. As estimated by the WWTP superintendent, the total phosphorus influent to the WWTP was reduced from 12 to 15 mg/L prior to public education to approximately 5 mg/L after public education.

St. Cloud, Minnesota

The St. Cloud WWTP uses EBPR for phosphorus removal. The discharge from this WWTP is into the Upper Mississippi River. This WWTP was not initially designed for EBPR. In 1996 the City of St. Cloud modified the existing wastewater treatment plant to improve energy efficiency by replacing the coarse air diffusers in the aeration basin with fine air diffusers. In addition to the energy

efficiency improvements, the WWTP was modified for EBPR by installing an anaerobic zone in the first pass of each aeration tank. The average flow into the WWTP in 2002 was 10.6 MGD and the average total phosphorus influent in 2002 was 5.03 mg/L; after EBPR the average effluent total phosphorus is 0.93 mg/L. The St. Cloud WWTP NPDES discharge permit requires monitoring of effluent total phosphorus and development and implementation of a phosphorus management plan.

The City of St. Cloud has a Phosphorus Management Plan (PMP) that was implemented in 2001, the major goal of this PMP is to limit the amount of phosphorus coming into the facility by means of pretreatment and public outreach. The goal of the pretreatment program is to assist non-domestic nutrient contributors (NDNC) in developing phosphorus reduction strategies that will reduce the amount of phosphorus that enters the wastewater collection system and eliminate phosphorus slug loads. The city works with industrial users to keep phosphorus discharges to the WWTP below 6 mg/L. This method is effective at reducing spike loads and the average influent phosphorus concentrations. Comparing the 95% confidence limits of the average influent phosphorus concentrations prior to implementation of the PMP ($7.72 \text{ mg/L} \pm 1.22 \text{ mg/L}$, 2000) to the 95% confidence limits of the average influent phosphorus concentrations after implementation of the PMP ($5.03 \text{ mg/L} \pm 0.14 \text{ mg/L}$, 2002), there has been a significant reduction and less variability in the average phosphorus influent concentration. The lowering and stabilization of the influent total phosphorus concentration has also resulted in a decreased average total phosphorus effluent concentration from $2.01 \text{ mg/L} \pm 0.64 \text{ mg/L}$ in 2000 to $0.93 \text{ mg/L} \pm 0.11 \text{ mg/L}$ in 2002.

Conclusions

Phosphorus Reduction Methods

- The cities implementing source reduction programs all achieved significant reduction in phosphorus loading on their WWTPs using a variety of methods: public outreach, phosphorus bans, surcharges for phosphorus treatment, and maximum limits on SIU phosphorus discharges.
- The St. Cloud WWTP showed that a reduction in influent phosphorus loading and phosphorus slug loads lead to a reduction in effluent phosphorus concentration.

Chemical Treatment of Phosphorus

- Chemical treatment is capable of reaching the lowest phosphorus effluent concentrations.

- The cost per unit of total phosphorus removed varied from \$0.96 to \$20.00 per pound of total phosphorus removed. The cost of treating phosphorus chemically appeared to show an economy of scale.
- The cost for chemical treatment was lower for those WWTPs that used a combination of EBPR and chemical treatment.

Biological Treatment of Phosphorus

- EBPR alone is generally effective at achieving 0.5 mg/L to 1 mg/L effluent phosphorus concentrations. Chemical addition is necessary to achieve effluent phosphorus concentrations less than 0.5 mg/L. One of the best available bio/chemical treatment facilities (Durham WWTP, OR) was able to achieve an average effluent phosphorus concentration of 0.05 mg/L. To reach this low effluent concentration, significant pilot testing was required and phosphorus removal efficiency was dependent upon wastewater characteristics.
- Once the initial capital improvements are made there are no additional costs associated with phosphorus removal using EBPR.
- EBPR can be implemented with simple process modifications (e.g., St Cloud aeration modifications) that achieve reductions in effluent phosphorus concentrations. St Cloud was able to achieve an effluent phosphorus concentration of 2 mg/L with this approach.

Table 1
MPCA Phosphorus Study
Wastewater Treatment Plant Summary
Phosphorus Removal

Treatment Plant	Treatment Method	Average WWDF (MGD)	Average Flow (MGD)	TP Influent (mg/L)	Average TP Effluent (mg/L)	Treatment Cost	Total Phosphorus NPDES Requirement
Ely	EBPR and alum after activated sludge and before secondary clarifier when necessary and sand filtration	3	0.7	5	0.2	\$20/lb All inclusive	0.3 mg/L
Bemidji	Alum & polymer after activated sludge and before secondary clarifier	2.5	1.15	7	0.15	\$3.25/lb TP Chemical only	0.3 mg/L
St. Croix Valley	Alum in primary clarifier inlet	5.8	3.4	4.8	0.45	\$0.96/lb TP Chemical only	0.8 mg/L
Mankato	Ferric chloride at influent and polymer at belt filter for sludge dewatering	11.25	6	8	1.88	\$1.70/lb TP all inclusive \$0.74/lb Chemical only	20,000 kg/yr (cap) = 2.41 mg/L TP at 6 MGD and 15,700 kg/yr (goal) = 1.89 mg/L at 6 MGD
St. Cloud	EBPR	26	10.6	5.03	0.93	NA	ND
Rochester	Ferric chloride in primary; alum & polymer in secondary	19.1	14	7.5	0.7	\$1.76/lb TP Chemical only	1 mg/L
Durham WWTP (Tigard, OR)	Alum in primary, EBPR, alum in tertiary, and filtration	NA	20	7	0.05	\$0.47/lb TP Chemical only	9 lb/day monthly median = approx. 0.07 mg/L at current flow
Rock Creek (Hillsboro, OR)	Alum in primary, EBPR, alum in tertiary, and filtration	NA	24	7	0.05	\$0.47/lb TP Chemical only	9 lb/day monthly median = approx. 0.07 mg/L at current flow

Key:

EBPR = Enhanced Biological Phosphorus Removal

NA = Not Available

MGD = Million Gallons per Day

TP = Total Phosphorus

ND = Not Determined

Bemidji WWTP

Contacts: Brian Freeberg (218) 759-3590 and Tim Whiting (WWTP Superintendent – (218) 751-2894)

Unit Operations: Bar racks → Screens → Primary Clarification → Activated Sludge → Alum/Polymer Addition → Secondary Clarification → Gravity Sand Filter → UV disinfection and an anaerobic digester for sludge. Note that the system was originally designed for dissolved air flotation thickening (DAF) but did not work well. Sends sludge from clarifiers directly to digester.

Phosphorus Treatment: Chemical treatment: Alum and polymer added after activated sludge and before secondary clarifier.

SIUs: None

Phosphorus Input: Because there are no significant industrial users and the phosphorus input is primarily from domestic sources, there is no phosphorus reduction plan or phosphorus bans in the city of Bemidji.

Additional Notes: Annual phosphorus treatment budget is \$78,000. Annual laboratory and O&M costs are approximately \$10,000. The plant was constructed in 1985, the capital costs for chemical holding tanks and pumps was \$80,000 in 1985. Alum is wasted with sludge. The actual alum concentrations added to the system were derived from alum dosing/alum costs given by Tim Whiting and ranged from 220 mg/L to 400 mg/L.

Treatment Summary:

Q_{in} (MGD)	AWWDF (MGD)	Treatment Method	TP_{in} (mg/L)	TP_{out} (mg/L)	Chemical Conc.	Treatment Cost (chem.)	NPDES TP Effluent Limit
1.15	2.5	Alum & Polymer	7	0.15	400 mg/L Alum (estimated by cost)	\$3.25/lb TP	0.3 mg/L

Ely WWTP

Contacts: Micky Schusta (WWTP Operator (218) 365-3247) and Terry Jackson (WWTP Superintendent (218) 365-2695)

Unit Operations: Screens → Degritter → Activated Sludge (for both BOD and P by tweaking aeration zones) → Alum/Polymer Addition → Secondary Clarification → Overflow Basin → Continuous Flow Sand Filter → Chlorine disinfection with sulfur dioxide for chlorine residual removal. Dissolved air flotation (DAF) for sludge thickening.

Phosphorus Treatment: Biological phosphorus removal with chemical addition when necessary; Alum and polymer added after activated sludge and before secondary clarifier. Acetic acid is added to the activated sludge for volatile fatty acids (VFAs).

SIUs: None

Phosphorus Input: There was a public education outreach (early 1980s) on using non-phosphate/low-phosphate containing detergents. Prior to public education total phosphorus influent was estimated by Terry Jackson to be 12-15 mg/L, after education total phosphorus influent was 5 mg/L.

Additional Notes: Because there was not any itemized cost data available, Terry Jackson estimated that approximately 25% of annual operating budget goes toward phosphorus treatment, which includes: sampling, maintenance, labor, etc. The estimated annual costs are \$200,000. TPout average is approximately 0.2 mg/L, but the plant has achieved effluent concentrations of 0.05 mg/L TP.

Treatment Summary:

Qin (MGD)	AWWDF (MGD)	Treatment Method	TPin (mg/L)	TPout (mg/L)	Chemical Conc.	Treatment Cost (Total)	NPDES TP Effluent Limit
0.7	3	Bio P w/ Alum & Polymer	5	0.2	Not Available	\$20/lb TP	0.3 mg/L

Rochester WWTP

Contacts: David Lane (Environmental Coordinator (507) 281-6190 ext 3006)

Unit Operations: Bar Screens → Aerated Grit Tanks → Primary Clarification → Two-Stage High Purity Oxygen Activated Sludge → Intermediate/Secondary Clarification → Chlorine Disinfection → Sodium Bisulfite De-Chlorination.

Phosphorus Treatment: Chemical treatment with ferric chloride in the primary clarifiers and alum and polymer in the secondary clarifiers.

SIUs: Yes. AMPI, Marigold S., Marigold N., Pace, Quest, and Seneca are sampled 5 days a week. Crenlo has a significant phosphorus load, but is only sampled 3 times per year. Their phosphorus load was calculated from the concentration times the total flow for the month divided by 30. Their flow is also only measured monthly as opposed to daily for the other industries.

Phosphorus Input: Methods in place for limiting phosphorous input to WWTP include daily maximum and monthly average total phosphorus limits for large industrial users.

Additional Notes: None

Treatment Summary:

Qin (MGD)	AWWDF (MGD)	Treatment Method	TPin (mg/L)	TPout (mg/L)	Chemical Conc.	Treatment Cost (Chem.)	NPDES TP Effluent Limit
14	19.1	Ferric Chloride in Primary and Alum/polymer in Secondary	7.5	0.7	Not Available	\$1.76/lb TP	1 mg/L TP

St. Croix Valley WWTP (Metropolitan Council Plant)

Contacts: Kathy Larson (651) 602-1275 (Met Council point of contact for MPCA study) and Dennis Lindeke (Hastings WWTP (651) 437-4212)

Unit Operations: Bar screen → Grit Removal → Primary Clarification (Alum added to primary inlet) → Plug Flow Activated Sludge → Final Clarification → Effluent Ultraviolet Disinfection. Solids are co-thickened in a gravity thickener and hauled off site for disposal.

Phosphorus Treatment: Chemical treatment with alum addition to the primary clarifier inlet.

SIUs: Not Available.

Phosphorus Input: Not Available.

Additional Notes: Annual phosphorus treatment budget is \$43,000. The actual alum concentrations added to the system were derived from alum dosing/alum costs.

Treatment Summary:

Qin (MGD)	AWWDF (MGD)	Treatment Method	TPin (mg/L)	TPout (mg/L)	Chemical Conc.	Treatment Cost (Chem)	NPDES TP Effluent limit
3.4	5.8	Alum in primary	4.8	0.45	76 mg/l Alum (est. by cost)	\$0.96/lb TP	0.8 mg/L

St. Cloud WWTP

Contacts: Tracy Hodel (Water Quality Coordinator (320) 255-7226)

Unit Operations: Bar Screen → 2 Grit Tanks → Aerated Influent Channel to Primaries → 4 Primary Settling Tanks → 3 Aeration Tanks → 3 Final Clarifiers → 2 Chlorine Contact Tanks

2 Primary and 1 Secondary Anaerobic Digester and 5 MG Biosolids Holding Tanks

Phosphorus Treatment: Biological, modified the preexisting WWTP. The City of St. Cloud did an energy improvement project in 1996 where the diffusers were changed from coarse air to fine air and an anoxic zone was placed in the first pass of each aeration tank for phosphorus removal. The city has also changed the way decant from the biosolids storage cells returns to the plant to prevent foaming in the aeration tanks.

SIUs: Electrolux Home Products, Northern Wire Products, Precision Optics, AmeriPride Linen & Apparel Services, G&K Services, Grede Foundaries Landfill, International Paper Landfill, Dezurik Landfill, X-Cel Optical Company, Rapid Plating, DBL Labs, Essilor Coating Center, and New Flyer. SIUs do not get charged for phosphorus treatment, SIUs need to follow Phosphorus Management Plan (PMP).

Phosphorus Input: The City of St. Cloud has an extensive Phosphorus Management Plan (PMP), the major goal of this PMP is to limit the amount of phosphorus coming into the facility by means of pretreatment and education outreach. The Phosphorus Management Plan sets operational guidelines for the following: slug loads, laboratory testing, phosphorus reporting, chlorine practices, and plant improvements, etc. The goal of the pretreatment program is to assist non-domestic nutrient contributors (NDNC) in developing phosphorus reduction strategies that will reduce the amount of phosphorus that enters the wastewater collection system and eliminate phosphorus slug loads.

1. Permitted Industries:

All permitted industries are required to test for phosphorus in their discharge. Industrial discharges that exceed 6.0 mg/L require daily testing for three months or a specified time period as determined by the Director. If any sample exceeds 6.0 mg/L a phosphorus reduction strategy (PRS) is required.

- Commercial Laundry:

PRS: Requires daily testing for phosphorus to develop loading information. Any test result greater than 6.0 mg/L will require elimination of phosphorus-based chemicals, pretreatment, and/or other phosphorus reduction measures.

- Metal Finishers:

PRS: Requires daily testing for phosphorus to develop loading information. Any test result greater than 6.0 mg/L will require pretreatment, elimination of phosphorous-based chemicals, and/or other phosphorus reduction measures.

2. NDNC's Categories

- Car Washes:

PRS: The use of phosphorus-based chemicals is prohibited. All car washes must annually submit MSDS information to the POTW.

- Other Large Laundry Services:

PRS: The use of phosphorus-based chemicals is prohibited without written consent from the Director and adequate pretreatment and/or other phosphorus reduction methods to achieve phosphorus levels below the domestic level of 6.0 mg/L.

Additional Notes: The PMP went into effect in 2001. The PMP was effective at reducing spike loads and the average influent phosphorus concentrations. Comparing the 95% confidence limits of the average influent phosphorus concentrations prior to implementation of the PMP (7.72 mg/L \pm 1.22 mg/L, 2000) to the 95% confidence limits of the average influent phosphorus concentrations after implementation of the PMP (5.03 mg/L \pm 0.14 mg/L, 2002), there has been a significant reduction and less variability in the average phosphorus influent concentration. The lowering and stabilization of the influent total phosphorus concentration has also resulted in a decreased average total phosphorus effluent concentration from 2.01 mg/L \pm 0.64 mg/L in 2000 to 0.93 mg/L \pm 0.11 mg/L in 2002.

Treatment Summary:

Qin (MGD)	AWWDF (MGD)	Treatment Method	TPin 2002 Avg (mg/L)	TPout 2002 Avg (mg/L)	Chemical Conc.	Treatment Cost (Bio)	NPDES TP Effluent Limit
10.6	26	Biological	5.03 mg/L	0.93 mg/L	NA	NA	ND

Mankato WWTP

Contacts: Mary Fralish (Utility Supervisor Wastewater Treatment Plant (507) 387-8665)

Unit Operations: (Assuming Bar Racks and Screens even though not listed) → Equalization Basins (assuming here location not listed) → Primary Clarifiers → Aeration Basins → Secondary Clarifiers → Primary Digesters → Secondary Digesters → Disinfection Tank → Dechlorination Tank

Phosphorus Treatment: Ferric chloride is added to the influent and is settled out in the primary clarifier. Polymer is used in the operation of the belt filter press for biosolids dewatering. Polymer is added to the phosphorus removal costs, because phosphorus removal increases biosolids by 20%.

SIUs: Honeymead, ADM, WISPAK, Ameripride, Associated Finishing, Jones Metal, Viessman, Hiniker, and Coloplast. SIUs are allowed 1 kg/day TP discharge limit. TP above this limit are charged a fee which is based on the quantity of TP that exceeds the 1 kg/d of TP allowed for the year. Charges to these users are based on the treatment costs for TP treatment for the year; this includes chemical costs, biosolids, maintenance, utilities, and lab analyses. The final fee is based on the phosphorus removal efficiency for the plant (70%). The PMP went into effect when the plant upgrade was completed. Although several industries decreased their phosphorus output, there is one soybean processor who increased their phosphorus output considerably, overshadowing gains from the others. The amount of phosphorus in their effluent is directly related to the uptake of phosphorus in the bean during the growing season. The city of Mankato has told them that they have to reduce the amount of phosphorus in their effluent and we have entered into a joint study to determine whether it should be done at their facility or at the Mankato WWTP through EBPR.

Phosphorus Input: PMP plan and working with industries to reduce TP loading. Several SIUs have reduced TP loading, however a soybean processor has significantly increased TP loading. The city and industry are currently doing a joint study to determine if phosphorus pretreatment should occur at the facility or at the WWTP using biological phosphorus removal.

Additional Notes: The PMP plan went into effect in 2001 when the WWTP upgrade was completed.

Treatment Summary:

Qin (MGD)	AWWDF (MGD)	Treatment Method	TPin- 2002 (mg/L)	TPout- 2002 (mg/L)	Chemical Conc.	Treatment Cost (2002)	NPDES TP Effluent Limit
6	11.25	Ferric Chloride and Polymer	8.0	1.88	Not Available	\$1.70/lb TP \$3.75/kg TP (all inclusive) \$0.74/lb TP \$1.62/kg TP (chem. only) 2.3 (all incl/chem.) ^a	20,000 kg/yr (cap) = 2.41 mg/L @ 6 MGD 15,700 kg/yr (goal) = 1.89 mg/L @ 6 MGD

a) all inclusive cost for phosphorus removal ÷ the cost for phosphorus precipitation chemicals only

Durham WWTP (Oregon – 0.07 mg/L TP discharge)

Contacts: Rob Baur (R&D for Cleanwater Services (503) 846-4617) and Mark Pohling (Director of WWTP)

Unit Operations: Not completely specified. Summary or partial description: Bar Screen → Primary Clarifier (30 mg/L alum addition) → Activated Sludge with Bio P → Secondary Clarifier → Filters (30 mg/L alum addition) → Tertiary Clarifier → Hypochlorite Disinfection with Persulfite for Dechlorination → Fermenter with VFA addition.

Phosphorus Treatment: Chemical (alum) and Biological. Alum addition to primary and bio P gets TP concentrations to approximately 0.5 mg/L. Alum addition at filter followed by tertiary clarification reduces TP to 0.05 mg/L. NPDES permit is based on a monthly median of 9 lbs TP/day (0.07 mg/L for current flows) for discharges from May to October. The plant was originally designed for lime treatment but was modified for alum treatment. Alum use was cut in 1/3 once EBPR was implemented.

SIUs: There are no TP discharge limits for industries. There have been voluntary reductions, the major reduction was by Intel who spent \$200,000 to not discharge from phosphate acid bath to WWTP. Instead waste was used for making fertilizer.

Phosphorus Input: Initially, the phosphorus ban in the city resulted in a 22% TP influent reduction. After city implementation, the phosphorus ban went to the entire state of Oregon. Currently TMDL is being re-evaluated, so TP discharge from WWTP may be increased after further study.

Additional Notes: First TMDL in nation of 0.07 mg/L TP discharge. Discharge is to the Tualatin River. The Durham and Rock Creek WWTP are required to discharge to river in the summer, because they provide approximately 1/3 of the rivers total flow. Rob Baur stated that 90% of the TP discharged from the WWTP is tied up with the alum and that only 10% is bioavailable.

Treatment Summary:

Qin (MGD)	AWWDF (MGD)	Treatment Method	TPin - 2002 (mg/L)	TPout -2002 (mg/L)	Chemical Conc.	Treatment Cost (2002)	NPDES TP Effluent Limit
20	NA	Alum and Bio P	7	0.05	60 mg/L Alum Total (30 mg/L in primary and 30 mg/L at filters)	\$0.47/lb TP Alum	9 lb TP per day (0.07 mg/L based on current flow – required May - October)

Rock Creek WWTP (Oregon – 0.07 mg/L TP discharge)

Contacts: Rob Baur (R&D for Cleanwater Services (503) 846-4617) and Mark Pohling (Director of WWTP)

Unit Operations: Not specified. Claricones are used for contact clarification of the wastewater; this is considered an innovative unit operation because it is generally used for drinking water clarification. The claricone process uses tangential flow and gravity precipitation to remove suspended solids.

Phosphorus Treatment: Chemical (alum) and Biological. Alum added to the primary (20 mg/L) and the tertiary clarifier (40 mg/L).

SIUs: See Durham WWTP

Phosphorus Input: Initially phosphorus ban in city resulted in 22% TP influent reduction. Then phosphorus ban went to entire state of Oregon. Currently TMDL is being evaluated, so TP discharge from WWTP may be increased.

Additional Notes: First TMDL in nation of 0.07 mg/L TP discharge. Discharge is to the Tualatin River. The Durham and Rock Creek WWTP are required to discharge to river in the summer, because they provide approximately 1/3 of the rivers total flow. Rob Baur stated that 90% of the TP discharged from the WWTP is tied up with the alum and that only 10% is bioavailable.

Treatment Summary:

Qin (MGD)	AWWDF (MGD)	Treatment Method	TPin -2002 (mg/L)	TPout - 2002 (mg/L)	Chemical Conc.	Treatment Cost (2002)	NPDES TP Effluent Limit
24	NA	Alum and Bio-P	7	0.05	60 mg/L Alum Total (20 mg/L in primary and 40 mg/L at tertiary)	\$0.47/lb TP Alum	9 lb TP per day (0.07 mg/L based on current flow – required May - October)