Rochester Water Reclamation Plant

2019 Facilities Plan

Technical Memorandum 9: Disinfection and Outfall Evaluation

TM 9 of 13 | J4325

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Technical Memorandum

Prepared for: City of Rochester

Project Title: Water Reclamation Plant Facilities Plan

Project No.: 150811

City No.: J4325

Technical Memorandum No. 9

Subject: Disinfection and Outfall Evaluation

Date: September 27, 2019

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List of Abbreviations

°C	degree(s) Celsius
AA	annual average
AACEI	Association for the Advancement of Cost Engineering International
A/O	anaerobic/oxic
BC	Brown and Caldwell
CCT	chlorine contact tank
CFD	computational fluid dynamics
City	City of Rochester
Cl_2	chlorine
DO	dissolved oxygen
FRP	fiberglass reinforced plastic
hp	horsepower
HPO	high purity oxygen
HPOAS	high purity oxygen activated sludge
kW	kilowatt(s)
L	liter(s)
MDI	Morril Dispersion Index
mgd	million gallons per day
mg/L	milligrams per liter
MPCA	Minnesota Pollution Control Agency
MPN	most probable number
$NaHSO_3$	sodium bisulfite
NPDES	National Pollutant Discharge Elimination System
PHWWF	peak hour wet weather flow
PVC	polyvinyl chloride
RO	reverse osmosis
SCFM	standard cubic foot (feet) per minute
T_d	contact time
TCT	theoretical contact time
Title 22	Title 22 California Code of Regulations
TM	Technical Memorandum
WRP	Water Reclamation Plant
WSE	water surface elevation

Executive Summary

The existing Water Reclamation Plant (WRP) disinfection system has historically provided adequate disinfection, but opportunities exist to improve the system's performance. The following near-term disinfection improvements are proposed:

- **Chlorination**. This system will be converted to a chlorine solution delivery by installing chlorinators in the chlorine building. A perforated pipe diffuser will provide adequate dispersion and will eliminate the electrical energy consumption of the existing pumped ejector system.
- **Dechlorination**. Laboratory testing by the WRP has suggested that sodium bisulfite ($NaHSO_3$) consumption can be reduced with improved mixing. Sodium bisulfite will be added via a perforated pipe diffuser upstream of a new flow metering flume. A new sodium bisulfite pump will provide additional head to alleviate the current limitation on carrier water, improving the ability of the perforated pipe diffuser to disperse the solution and the flume will provide the intense mixing for efficient dechlorination.

In addition, the following outfall improvements are proposed:

- **Effluent flow measurement**. Reported effluent flow is currently calculated using several upstream flow meters. A new Parshall flume will provide improved accuracy for use in more stringent nutrient reporting. The Parshall flume will be installed within the existing chlorine contact tanks, located in the reconfigured middle bay of the middle chlorine contact tank (CCT).
- **Effluent aeration**. Conversion from high purity oxygen (HPO) to Anaerobic/Oxic (A/O) liquids stream treatment is expected to lower the dissolved oxygen (DO) concentration in the plant effluent. A cascade step system will provide most of the low-energy reaeration of the effluent to meet the National Pollutant Discharge Elimination System (NPDES) permit requirement of 5 milligrams per liter (mg/L). The cascade aeration structure will be located immediately downstream of the new Parshall flume within the footprint of the existing CCT. Due to limitations in the head available in this location, the cascade aeration is expected to require supplemental aeration via a small diffused air system.

The proposed location of the flume and cascade aeration in the existing CCT was chosen over an alternative location on east side of the adjacent roadway. The CCT configuration takes advantage of surplus CCT volume to minimize construction costs and disruption of the existing outfall pipe. The proposed CCT arrangement also provides an opportunity to reconfigure the tank with a serpentine baffle to reduce short-circuiting.

Treated effluent can be reused for irrigation, industrial cooling, and other uses, depending on effluent quality. The WRP's location near residential and commercial spaces does not provide an obvious potential reuse site without costly, long distribution systems. Reuse opportunities should be monitored to support City of Rochester (City) goals for managing raw water supplies but, at this time, no additional reuse beyond the WRP internal uses is recommended.

The outfall is also a potential source of micro-hydropower. However, the estimated energy output is relatively small (22 kW at current average plant flow rates), and the cost per kW is greater than other renewable energy opportunities such as co-digestion and solar. The micro-hydropower system would also bypass the cascade aeration system possibly resulting in a lower overall DO than if all the flow passed through the reaeration.

The recommended disinfection and outfall improvements are estimated to cost $1,000,000. The accuracy of this preliminary estimate ranges from -50 to +100 percent.

Section 1: Introduction

As part of the overall facilities planning effort, this Technical Memorandum (TM) addresses improvements to the disinfection system and plant outfall. This TM discusses the following improvements to the disinfection system and outfall:

- Chlorine addition
- Disinfection contact time
- Sodium bisulfite addition
- Reuse of plant effluent
- Effluent flow measurement
- Cascade aeration on plant effluent
- Evaluate potential of hydropower on plant effluent

1.1 Existing Facilities

Figure 1-1 shows the existing disinfection and outfall facilities at the WRP.

Figure 1-1. WRP disinfection and outfall site layout

Image source: Google Earth

Figure 1-2 shows the existing WRP hydraulic profile through the chlorine contact tanks and outfall to the South Fork of the Zumbro River. Flooding from the river is not typically an issue given the average river level is 962 or below and the invert of the outfall pipe leaving the chlorine contact tanks is 965.33. Recent wet weather events in 2019, however, have submerged the outfall and backed up flow into the collection channel to a water surface elevation (WSE) of 966.5. In addition, the 100-year flood river level is set at 972.00, which will cause the chlorine contact weirs to flood.

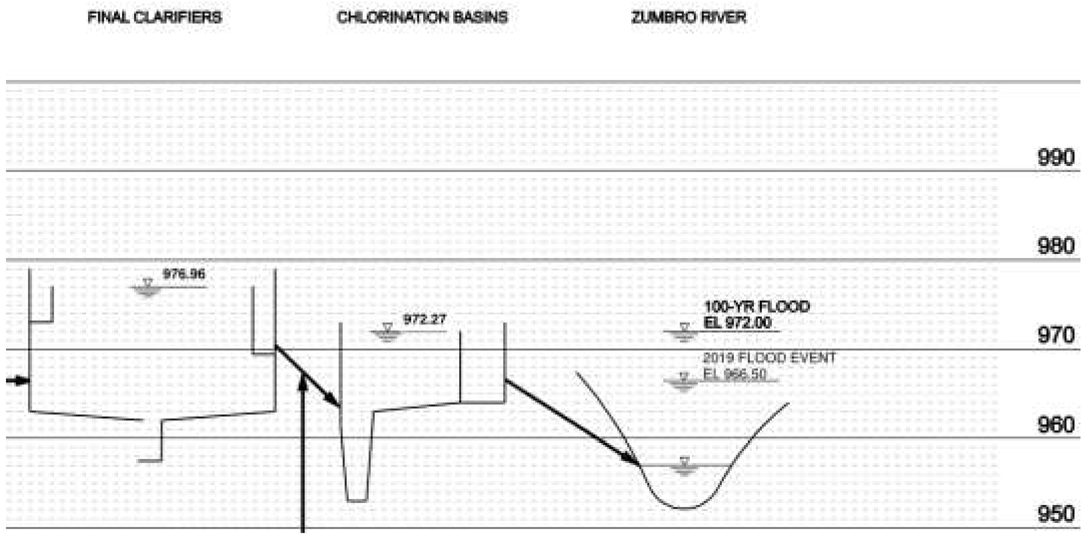


Figure 1-2. WRP existing hydraulic profile (51 mgd)

The WRP uses chlorine-based disinfection. Chlorine gas is added to the chlorine contact tank (CCT)influent via mechanical mixers (ejectors), and then further mixed as it discharges via a mixing nozzle. Figure 1-3 shows a section through a CCT with the mixing ejector and mixing nozzle called out. To dechlorinate, $NaHSO_3$ is pumped from a storage tank in the Chemical Building, diluted with process water, and then discharged via a submerged pipe upstream of the outlet structure of the CCT. Table 1-1 summarizes the design information for the disinfection and outfall facilities.

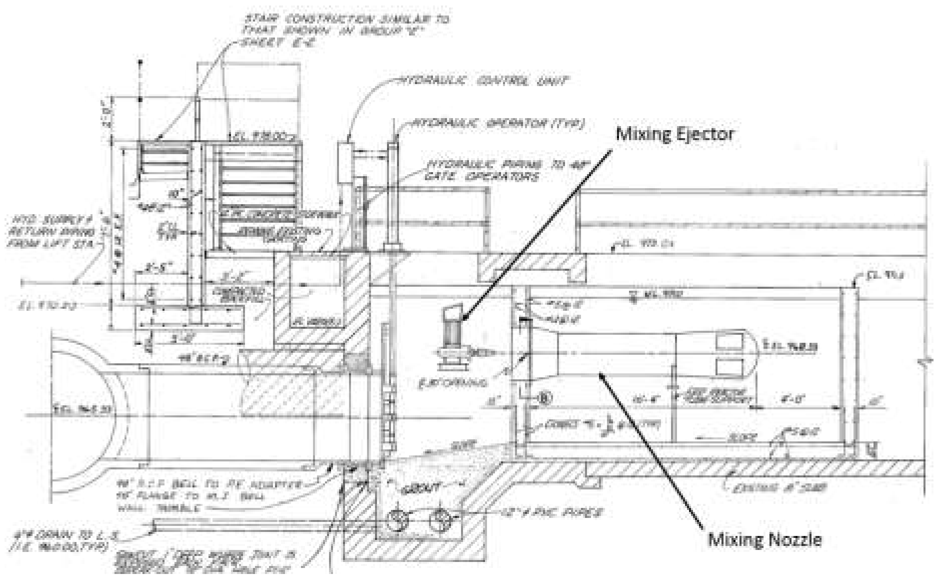


Figure 1-3. Chlorine contact tank section

Image source: Kirkham Michael Associates, et al., 1979.

Table 1-1. Disinfection and Outfall Facility Characteristics		
Item	**Units**	**Value**
Chlorine contact tanks		
Number	--	3
Tank width	feet	50
Tank length	feet	100
Tank sidewater depth	feet	7
Nominal volume	gallons	262,000
Chlorine storage		
Cylinder size	1	ton
Number	--	12 (3 online, 3 standby, 6 reserve)
Chlorine mixers		
Number	--	3
Motor	horsepower	5
Sodium bisulfite storage tank		
Number	--	1
Nominal volume	gallons	9545
Sodium bisulfite pumps		
Number	--	2
Type	--	Watson Marlow Peristaltic
Motor	horsepower	1/4
Outfall pipe		
Number	--	1
Diameter	inches	72
Length (approximate)	feet	400
Material	--	reinforced concrete
Invert elevation at basin	--	965.33
Invert elevation at river	--	953.60

Annual disinfection costs and purchased quantities are summarized in Table 1-2.

Table 1-2. WRP Disinfection 2018 Operating Costs		
Item	Quantity	Cost
Chlorine [c]	66,000 pounds [a]	$18,000 [b]
Sodium bisulfite [a]	12,800 gallons	$28,400
Chlorine mixer energy (esti-mate)	3 motors at 5 horsepower	$6,900

a. 2018 Chemical Inventory summary provided by City

b. WRP staff estimate

c. Includes chlorine for odor control (approximately 50 percent)

Section 2: Disinfection

The disinfection system is composed of the three CCTs and disinfection chemical feed systems. The tanks were originally commissioned as final clarifiers and later repurposed for chlorine contact which has resulted in some performance challenges. The disinfection evaluation is based on examining several specific items and locations rather than a comprehensive evaluation of the entire system. The sections below describe potential improvements to the chlorine (Cl_2) and $NaHSO_3$ chemical delivery systems and modifications to reduce short-circuiting in the CCTs.

2.1 Chlorine Addition

Chlorine is added before the CCTs via the mixing ejector shown in Figure 1-3. Plant staff have indicated that Cl_2 gas would continue to be used as the primary disinfectant for the foreseeable future.

One of the City's goals is to reduce power consumption where possible. One option to reduce power is to replace the mixing ejectors, each powered by a 5-horsepower (hp) motor. Currently, the ejectors are fed chlorine gas conveyed from the chlorine building creating an aqueous solution in the ejector.

The suggested low-power alternative includes removing the mixing ejectors and installing submerged perforated polyvinyl chloride (PVC) pipe at the inlet of the mixing chamber, using the velocity and turbulence of the flow to disperse the chlorine solution. The recommended configuration is one or two perforated PVC pipes mounted within the cross-sectional area of the entrance pipe. The pipe would be mounted using rigid supports on either side of the mixing chamber. It is recommended that the chlorine carrier pipe connect to both sides of the diffuser pipe in order to get even distribution throughout a recommended 12 to 16 holes. Figures 2-1 and 2-2 show the configuration.

The submerged chemical diffuser would be fed by an inductor system similar to the one installed for the scrubber systems. The piping from the chlorine building to the contact tanks would be replaced with PVC double containment pipe. The change would reduce the quantity of chlorine gas piping subject to failure and create higher velocity flows coming out of the chlorine diffusers in order to promote better mixing. The chlorine dilution water could be provided by the GBT washwater system because it has a strainer, with city water available as a backup. As an energy reduction alternative, the use of lower pressure sample water could be examined during a detailed design phase.

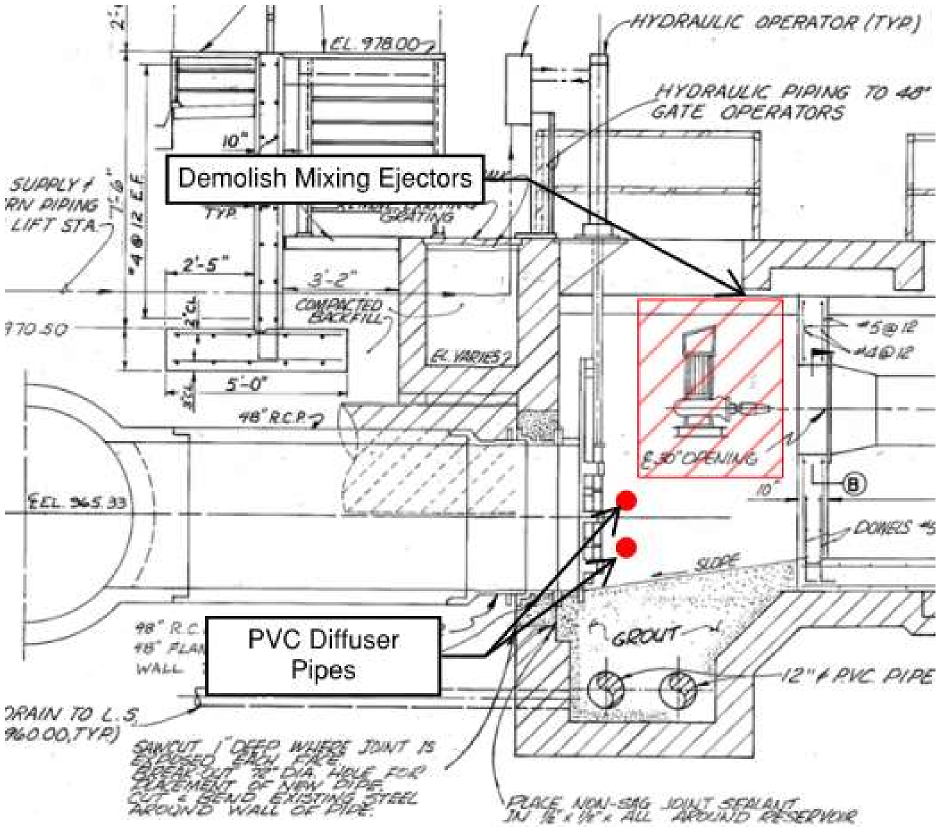


Figure 2-1. Example submerged chemical diffuser configuration

Image source: Kirkham Michael Associates, et al., 1979.

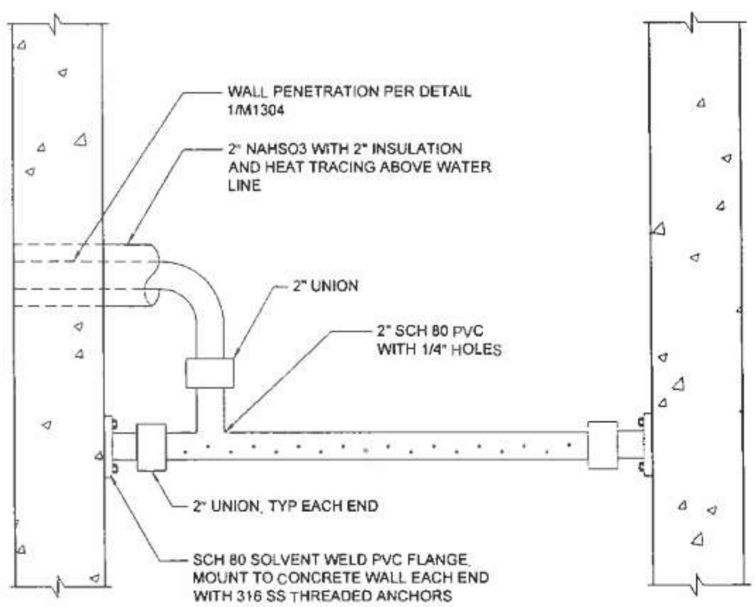


Figure 2-2. Cross section PVC chlorine diffuser

2.2 Chlorine Contact Time

Disinfection performance is a function of chlorine dose and contact time. Three existing CCTs serve to provide the contact time for disinfection. However, since the contact tank configuration does not exhibit good plug flow characteristics (e.g., length to width ratio appears very low), the tanks were evaluated to assess their performance in terms of contact time. The theoretical contact times for current and future annual average (AA) and peak hour wet weather flow (PHWWF) conditions for each of the tanks are shown in Table 2-1.

Table 2-1. Theoretical Contact Time

Flow	2 CCT In Service (minutes)	3 CCT In Service (minutes)
2019 AA	55	84
2019 PWW	21	32
2045 AA	36	54
2045 PWW	14	21

Note: Please refer to Table 3-3 for theoretical contact time of proposed future configurations

One of the ways used to characterize contact tank performance is using tracers. In place of actual field measurements of tracer performance, computational fluid dynamics (CFD) computer modeling was employed to evaluate the existing tanks and potential modifications to improve plug flow characteristics. One parameter used for assessing performance is T_{10}. The T_{10} parameter indicates the contact time it takes for 10 percent of a tracer (chemical) to reach the outlet of the tank. The ratio between the T_{10} and theoretical contact time (T_d) provide a measure of short-circuiting in the contact tank. Table 2-2 summarizes generalized performance characterizations based on the T_{10}/T_d ratio. A perfectly performing contact tank results in a T_{10}/T_d ratio of 1.0.

Table 2-2. Typical T_{10}/T_d Ratios and Generalized Performance

Performance	T_{10}/T_d
Poor	0.1 – 0.3
Moderate	0.3 – 0.5
Average	0.5 – 0.7
Good	0.7+
Theoretical ideal	1.0

Another measure of contact tank performance uses the ratio between the time it takes for 90 percent of the flow to pass through the tanks (T_{90}) and T_{10}. This ratio is commonly referred to as the Morril Dispersion Index (MDI). For effective CCT performance, designers target an MDI (T_{90}/T_{10}) of less than 2.0.

To estimate the T_{10} and T_{90} of the existing CCT system, the CFD models were used to simulate a chemical tracer and then determine these parameters to assess performance.

2.2.1 Model Existing Conditions

The CFD models included the mixing nozzle inlet to the effluent weirs as boundary conditions. At a flow rate of 10 million gallons per day (mgd) (per tank), the model predicted considerable short-circuiting as shown in Figure 2-3. The model predicted heavily concentrated flow streams toward the outside walls with less flow in the center of the tank. The existing configuration of the mixing nozzle chamber with side openings results in flow jetting to the outer walls of the tank, as indicated by the high-velocity red colored flow lines. The model results at 4.5 mgd per tank predicted very similar flow patterns.

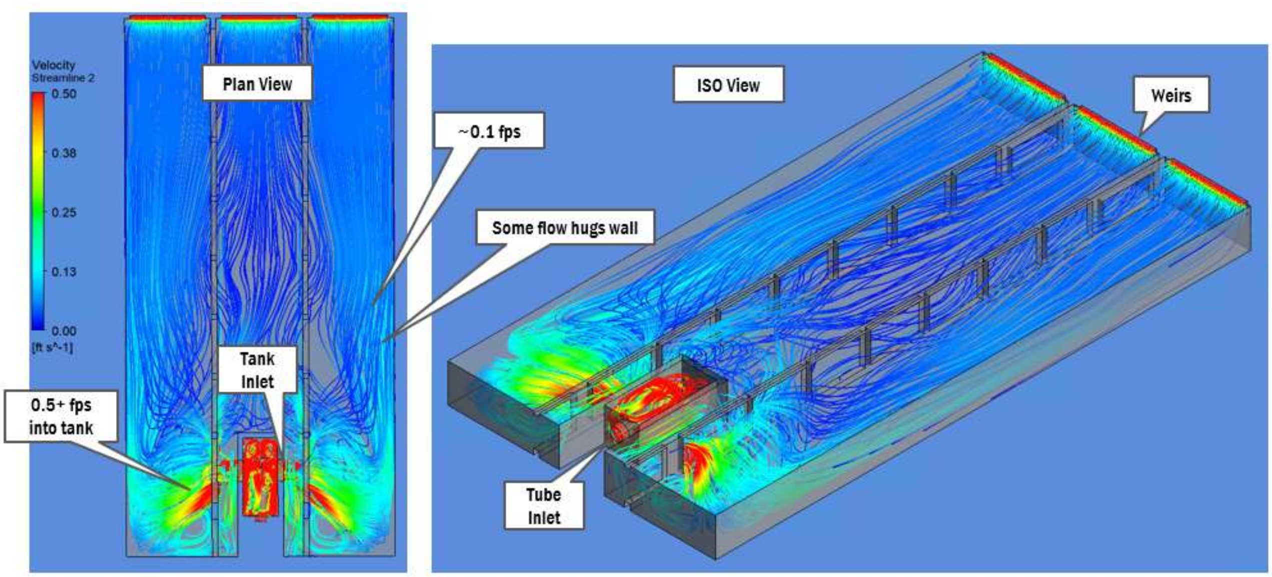


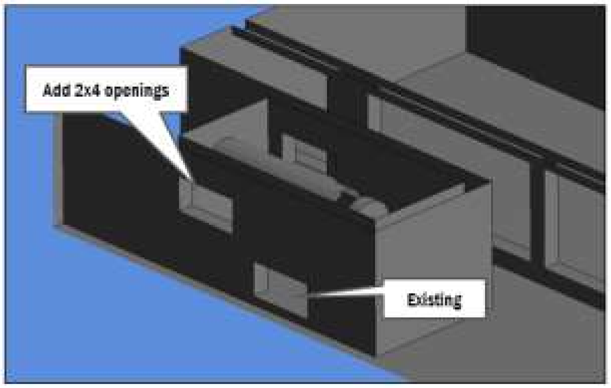
Figure 2-3. Predicted flow streams and velocities of existing chlorine contact tank at 10 mgd

At 10 mgd, the predicted T_{10} and T_d values were 23 and 38 minutes, respectively. This translates to a T_{10}/T_d of 0.6. The predicted T_{90} value came in at 53 minutes, so the MDI roughly equals 2.3. Based on these results, alternative configurations were evaluated to improve the tank's plug flow characteristics.

2.2.2 Contact Tank Modification Evaluation

Two modified tank configurations were modeled to identify preliminary improved tank performance, however these modifications were ultimately superseded by the recommended CCT configuration presented in Figure 3-4. Modifications focused on additional openings in the chlorinator chamber and stub baffles added to the exterior walls to modify the flow patterns in the tank. The initial configuration allowed for additional openings in the front of the chlorination chamber and along the sides. This resulted in an unacceptable short-circuiting of flow down the center of the tank.

The second configuration focused on only providing additional openings on the sides of the chamber and stub baffles along the tank walls and did not include a front opening. Figure 2-4 illustrates the modifications for this configuration.



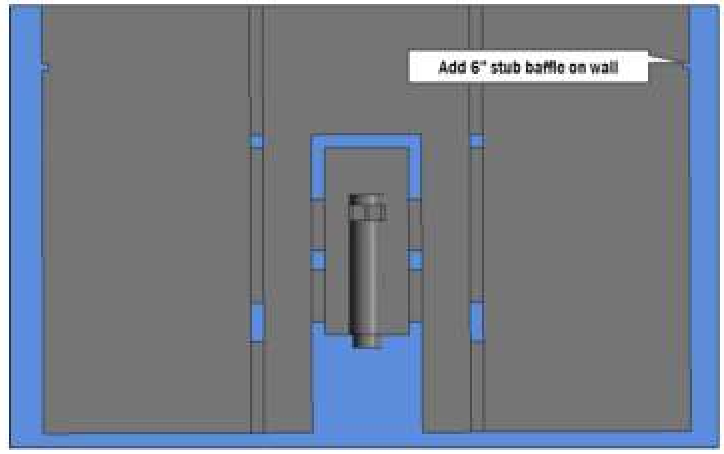


Figure 2-4. Configuration 2 - chlorine contact tank modifications

Figures 2-5 and 2-6 show the model results for the existing condition and configuration 2 models both at 10 mgd. The configuration 2 outcomes show a more evenly distributed flow pattern in the tank, resulting in improved plug flow characteristics. The resulting flow patterns were nearly the same at 4.5 mgd (not shown).

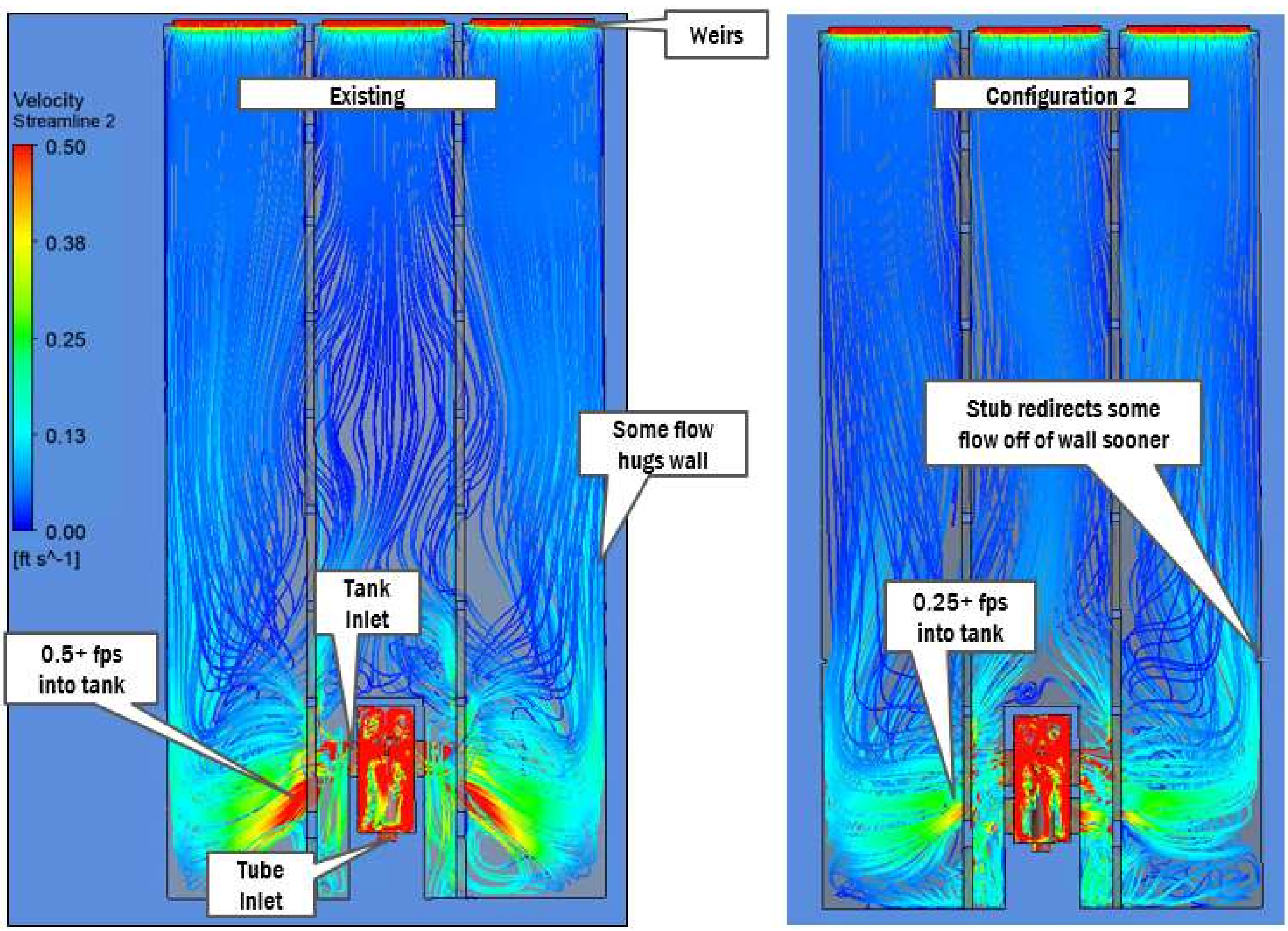


Figure 2-5. Existing versus Configuration 2 predicted flow streams and velocities at 10 mgd – plan view

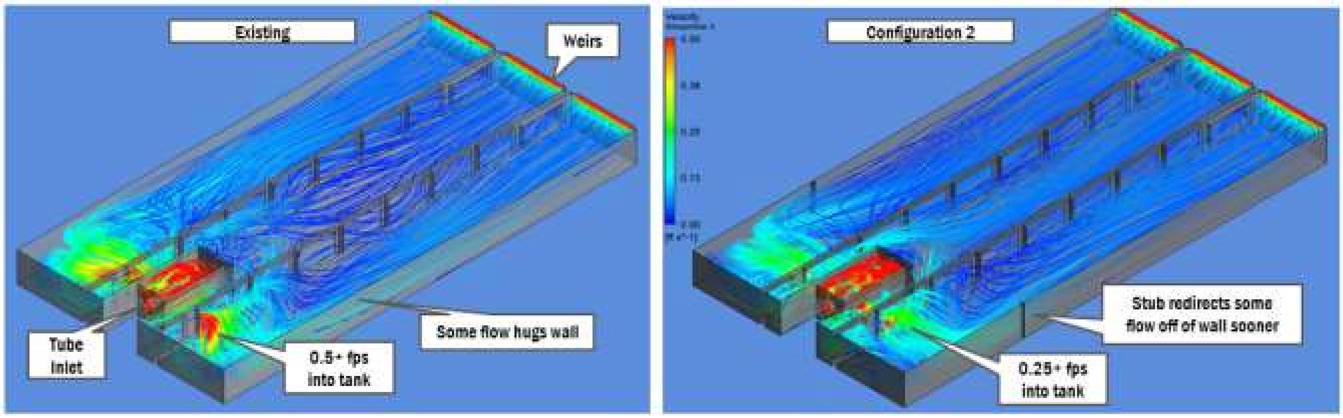


Figure 2-6. Existing versus Configuration 2 predicted flow streams and velocities at 10 mgd – isometric view

Table 2-3 summarizes the changes in contact time performance. The relatively minor modifications for Configuration 2 provided an improvement in the CCT performance. Additional modifications could be evaluated during final design of disinfection and effluent modifications. Refer to Section 3.3 for other proposed modifications to the CCTs that will supersede these improvements if implemented.

Table 2-3. Improvement in CCT Performance with Inlet Modifications at 10 mgd per CCT

Parameter	T_d (minutes)	T_{10+} (minutes)	T_{10} / T_d	Performance	T_{90} (minutes)	MDI
Current value	23	38	0.6	Average	53	2.3
Modified inlet	27	38	0.7	Good	48	1.8
Improvement	17 percent		17 percent			22 percent

Note: Additional stub on tank walls included for results in this table.

2.2.3 Bench-Scale Chlorine Dose Testing

The City conducted several disinfection bench-scale trials to investigate dose-kill performance. The intent was to estimate how much impact chlorine dose and contact time have on log reductions in bacteria.

City staff collected samples of effluent from the Final Clarifier 2 (HPO facility), Final Clarifier 5 (ABC facility), and combined effluent from both facilities. Each sample was treated with different doses of Cl_2 bracketing the current dose of approximately 1.5 mg/L. City staff also obtained samples from each location to measure the residual chlorine concentration. The results from the single test of Final Clarifier 5 effluent was influenced by an industrial spill that likely impacted the disinfection test results, so this test was disregarded.

Figure 2-7 shows the disinfection performance of the three effluents sampled at different chlorine doses. Because of the limited data, it is difficult to draw too many conclusions; however, the Final Clarifier 2 and combined effluents both show significant log reduction of bacteria in less than 10 minutes, achieving levels below the permit limit of 200 most probable number (MPN) for fecal coliform. Higher doses result in greater bacteria reductions in shorter times. It is important to note that additional reductions continue but at a slower rate. Additional testing at lower doses may provide insight into lower potential doses of chlorine to achieve reductions in bacteria.

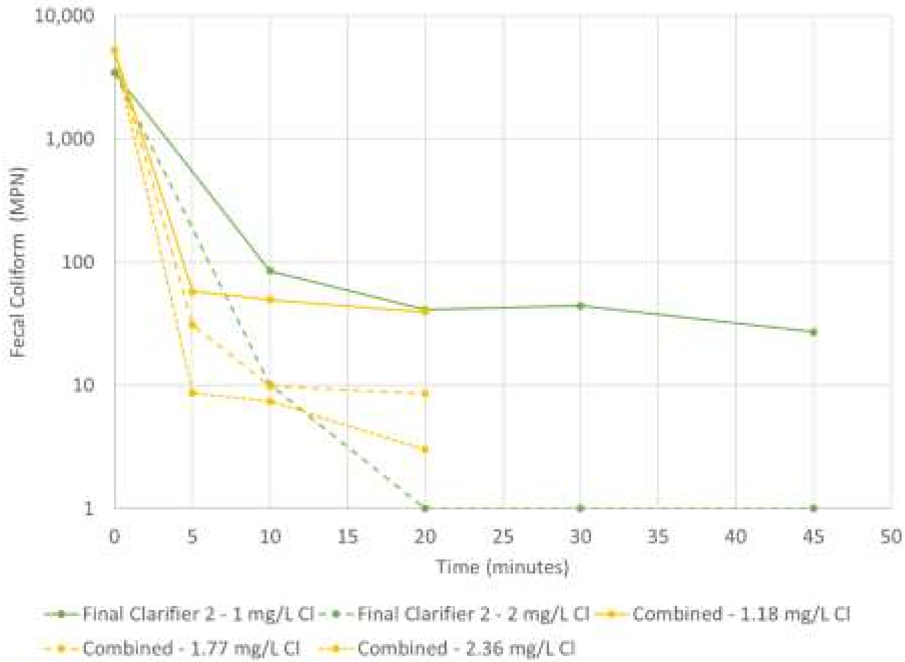


Figure 2-7. Disinfection bench-scale testing performance for different effluent locations and Cl_2 doses

2.3 Dechlorination

Dechlorination is currently accomplished by the injection of $NaHSO_3$ to the discharge from the CCTs. Sodium bisulfite is currently added approximately 10 feet upstream of the entrance to the outfall pipe. Figure 2-8 shows the discharge of the CCTs and the approximate location where the $NaHSO_3$ is added. The current delivery system includes pumping $NaHSO_3$ mixed with carrier water to a submerged pipe at the end of the CCT launders near the invert of the launder.

Figure 2-8. Sodium bisulfite addition

The operations staff have indicated that they currently use more $NaHSO_3$ than would be expected based on the stoichiometric relationship with residual Cl_2 would suggest. For example, the theoretical stochiometric ratio of $NaHSO_3$ to Cl_2 residual is approximately 1.5. The actual $NaHSO_3$dosing has been several factors larger than this. This suggests the mixing of $NaHSO_3$ is not adequate, requiring an overdose to overcome the lack of mixing.

Modifications to the $NaHSO_3$ system are recommended to improve efficiency of the dechlorination system. BC recommends placing a $NaHSO_3$ diffuser upstream of the new Parshall flume (Section 3.1). Extending the diffuser across the channel prior to the flume will facilitate even distribution of $NaHSO_3$ while using the turbulence through the flume to passively mix the effluent and $NaHSO_3$. The new chemical diffuser will be a submerged, perforated PVC pipe. .

A supply of adequate carrier water is important to achieve even distribution across the length of the diffuser. Because the sodium bisulfite flow rate is low, the dilution ratio can be 20 to 50 times the chemical flow rate, depending on the diffuser and orifice diameters. The current sodium bisulfite pump and piping system does not have enough head to accommodate this level of dilution. During final design the sodium bisulfite pump and dechlorination piping configuration will need to be evaluated to determine the future head requirements and appropriate pump design criteria.

2.4 Modifications to Accommodate Future Effluent Filtration

Tightening effluent limits may require filtering the effluent prior to disinfection in the future. Single-stage, deep-bed, continuous backwash filters would conservatively require approximately 4 feet of head between the secondary clarifiers and disinfection system under average 2045 flow conditions. The existing system, under 39.5 mgd of flow (current peak instantaneous flow) provides about 4.7 feet of static head between water surface levels of the HPO final clarifiers and the CCT. A preliminary hydraulics investigation, including dynamic losses in the conveyance piping, has determined the available head for future filter installation is inadequate. As a result, one or more modifications will be required.

At the City's desired 60 mgd hydraulic capacity the chlorine mixing tubes, shown in Figure 2-9, need to be removed. Removing the tubes eliminates about 1.5-feet of headloss. This modification would be done in conjunction with the revised CCT inlet configuration presented in Section 3.3.

Figure 2-9. Chlorine mixing tube at chlorine contact inlet

At 60 mgd the future filter system would have to be bypassed as well.

Section 3: CCT and Outfall Modifications

The existing outfall pipe directly conveys treated effluent from the CCTs to the discharge at the river. The existing permit requirement of DO at 5 mg/L rarely poses challenges for the WRP because of the HPO high DO effluent. However, with future modifications to the liquid stream treatment, meeting the DO permit requirement will almost certainly require additional aeration mechanisms at the outfall.

The City also desires an effluent flow measurement device to more reliably calculate discharge loads for permit purposes. This evaluation looks at incorporating a Parshall flume for flow measurement.

3.1 Outfall Flume

The WRP currently does not measure the flow discharged through the outfall to the river. The City relies on upstream flow meters to calculate the effluent flow. By relying on several upstream flow meters, the calculated effluent flow is susceptible to errors from multiple instruments. With the expected tightening effluent limits on phosphorus, the City requires a more reliable, direct effluent flow measurement.

Parshall flumes offer a simple and effective way to measure the effluent flow. Figure 3-1 displays the typical design dimensions of a Parshall flume. Table 3-1 lists the design dimensions for a 5-foot-wide Parshall flume.

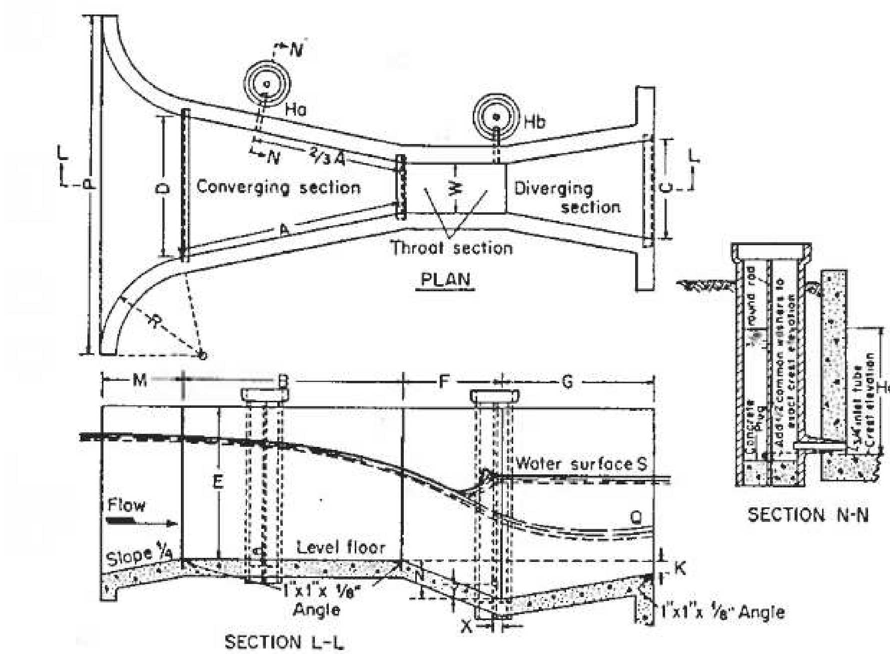


Figure 3-1. Parshall flume dimensions

Source: Chow, 1959

Table 3-1. Parshall Flume Design Dimensions		
Dimension	Units	Value
Throat width	ft	5
Outlet width	ft	6
Flume height	ft	3
Flow measurement range	mgd	1.0 – 55.3

3.2 Reaeration

Currently, the plant has little difficulty meeting the DO effluent requirement set at 5 mg/L. When operators notice effluent DO is trending downwards, usually in the summer, they increase the oxygen used for HPO treatment. However, it is likely that the HPO portion of the plant will be retired in favor of A/O treatment, which will eliminate the operator's ability to increase DO. Therefore, an aeration system at the outfall is recommended to meet the permit requirements in the future. Table 3-2 summarizes current and future DO parameters.

Table 3-2. Dissolved Oxygen Parameters		
Parameter	Units	Value
Current average effluent DO (2014-2017)	mg/L	7.0
Projected average effluent DO following A/O modifications	mg/L	1.0
Effluent DO requirement (NPDES permit)	mg/L	5.0

Cascade aeration is often recommended over a diffused air system because adequate head is available to provide aeration without blower energy use. There are two different design approaches to cascade aeration: typical step aeration and Nakasone cascade mixing. Typical step aeration involves simply having the wastewater cascade down a set of short steps, entraining air along the way. In contrast, Hideo Nakasone published an article titled "Story of Aeration at Weirs and Cascades" in 1987 empirically demonstrating that creating a series of cascades and pools is more effective at entraining air and increasing effluent DO than using steps. Because the Nakasone steps require less height, the alternatives presented below are based on this method. Refer to Section 3.6 for an evaluation of cascade aeration and diffused aeration alternatives for use with the chosen CCT and outfall configuration.

3.3 CCT and Outfall Configuration Alternatives

The following sections present three potential configurations that incorporate a Parshall flume and cascade aeration system into the existing CCT area.

3.3.1 Alternative 1: Flume and Cascade Aeration in Existing CCT

The first alternative incorporates the outfall modifications into the existing CCT area by reconfiguring the center tank to accommodate the Parshall flume and cascade aeration steps. Figure 3-2 illustrates this configuration and flow paths. The inlet to the center tank would be eliminated and fiberglass reinforced plastic (FRP) partitions would be used to create two channels to convey flow from the east end of the outer tanks to the entrance of the flume channel. There are two options to create an end channel to convey flow to the reconfigured center tank: construct a baffle wall and new end channel or lower the invert of the existing end lauders. In the first option, a perforated FRP baffle wall would create an end channel to convey flow to the reconfigured center tank and still control flow distribution in the CCTs. The second option would be to keep the existing CCT weirs and excavate to make the end launders deeper to handle design flows. The launders would need to be as deep as the tank in order to avoid creating a hydraulic pinch point.

Revised channels would direct flow to the center channel where slide gates would be installed so that either side of the system can be taken out of service while continuing to operate the other side. A set of slide gates will also be installed just downstream of the Parshall flume to bypass the flume in case it needs to be accessed.

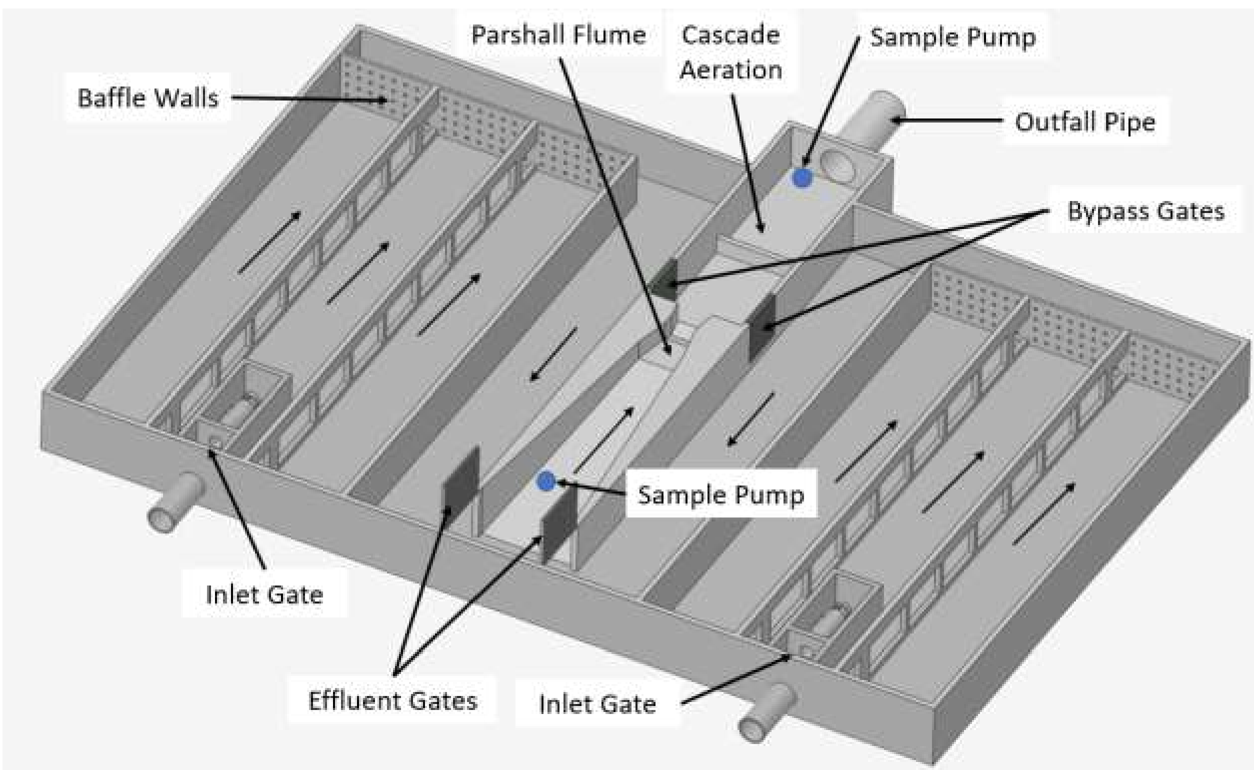


Figure 3-2. Center channel flume and cascade aeration configuration

A Parshall flume with a throat width of 5 feet and an invert of 969.00 would control the WSE in the CCT, with WSE varying from 970.0 to 971.8 under current average and 2045 PHWWF flows. Hydraulic modeling has shown that this alternative is viable; however, details would need to be refined during detailed design.

A single cascade aeration baffle is shown in Figure 3-2, with additional re-aeration options discussed in Section 3.6. Data sheets for both corrugated and flat panel FRP baffle walls are located in Attachment A.

3.3.2 Alternative 2: Flume and Cascade Aeration in Serpentine CCT

This alternative is similar to the first, but replaces the perforated baffles on the east end of the tank with a serpentine flow configuration by filling the existing partitions with FRP panels to improve the plug flow characteristics of the CCT. Figure 3-3 shows these modifications.

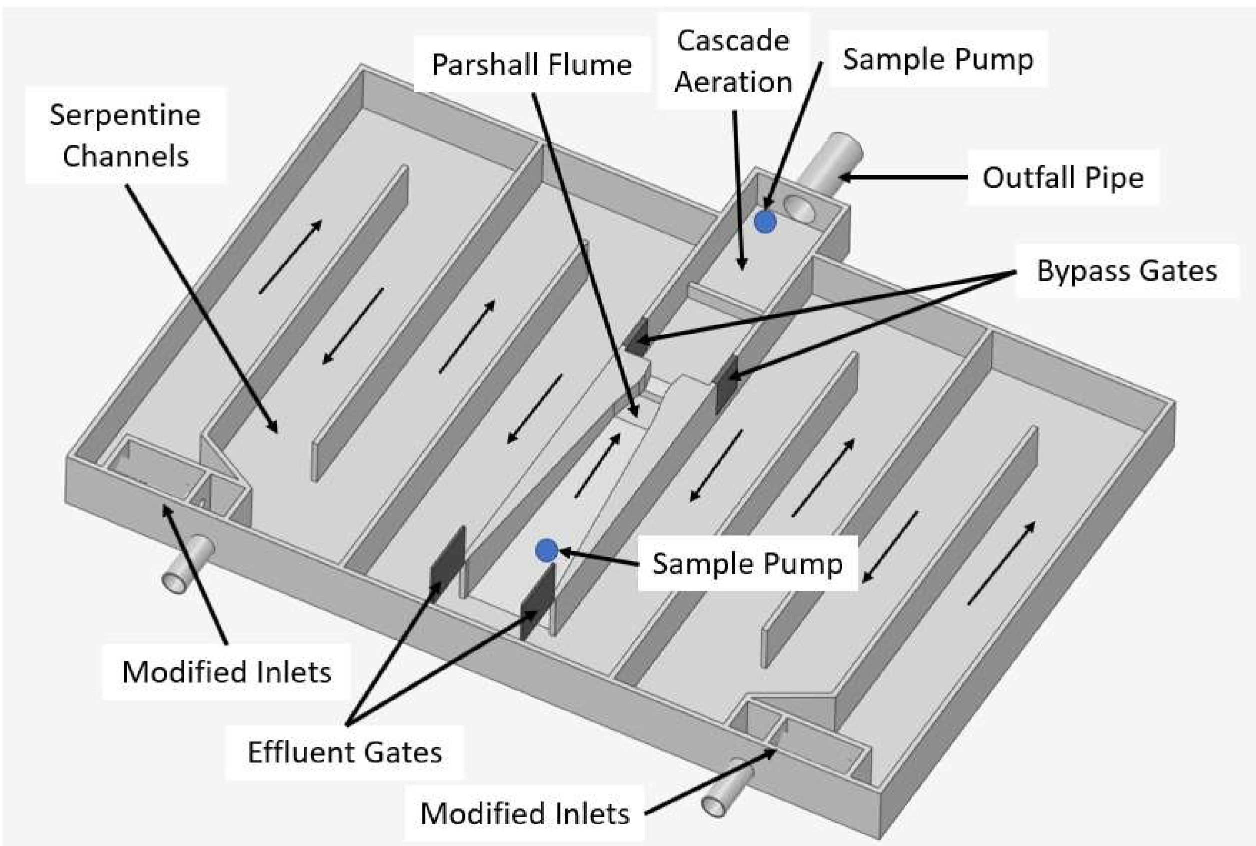


Figure 3-3. Serpentine CCT configuration

Table 3-3 displays the theoretical chlorine contact times for outfall alternatives 1 and 2. The contact times are The serpentine configuration does not change the theoretical contact time but is expected to improve the CCT performance.

Table 3-3. Theoretical Chlorine Contact Time for Proposed Configuration		
Flow	1 CCT In Service (minutes)	2 CCT In Service (minutes)
2019 AA	35	71
2019 PWW	13	27
2045 AA	23	46
2045 PWW	9	18

3.3.3 Alternative 3 Flume and Cascade Aeration on East Side of Road

The final alternative involves placing the Parshall flume and cascade aeration steps in the open area on the east side of the plant access road. Figure 3-4 shows a plan view of the outfall configuration for this alternative.

The effluent from the three existing CCTs would flow into the existing outfall pipe and discharge into a new 8-foot-diameter manhole on the east side of the road. There would be a transition channel from the manhole to the flume. Cascade aeration steps would be located after the flume.

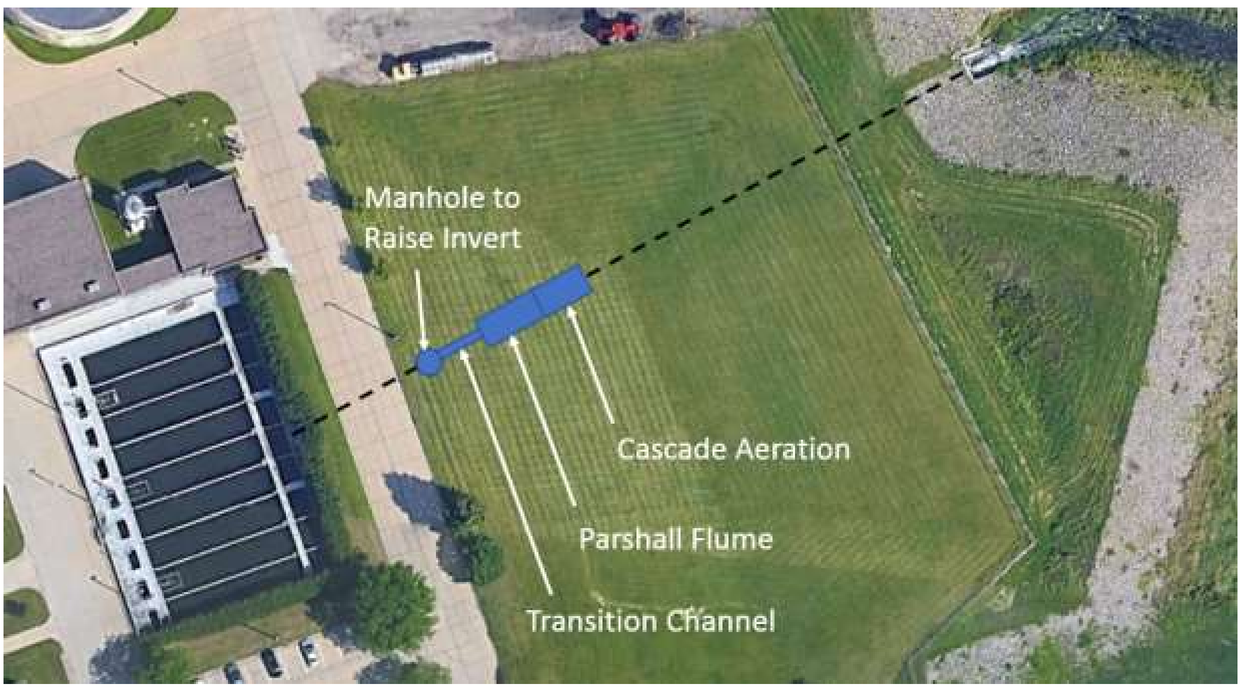


Figure 3-4. Outfall profile for east side configuration

This alternative is not ideal given that a future garage is to be built on the east side of the road in the vicinity of the proposed modifications. This will restrict access to the garage.

3.4 Effluent Sampling

Currently, effluent samples are taken from the end of the CCTs and at the entrance to the outfall pipe via a set of effluent sample pumps located inside the chlorine building. The CCT sample point supplies the residual chlorine analyzer to set the $NaHSO_3$ dosing. The outfall sample point supplies the sampler collecting final effluent samples. The suction piping for this pump is very long and has created sampling issues. Along with other modifications to the tanks, it is recommended that a new effluent sampling pump be installed. Assuming Alternative 1 or 2 is chosen, the new outfall sample pump would be a submersible type located just upstream of the outfall pipe, as shown in Figure 3-3. A submersible pump will provide a more representative effluent sample while eliminating the suction pipe.

The CCT sampling pump would be installed upstream of the $NaHSO_3$ diffuser and Parshall flume to measure chlorine residual prior to dechlorination.

3.5 Recommended Configuration

The recommended alternative is Alternative 2, flume and cascade aeration in serpentine CCT. The major advantage to this alternative, as well as Alternative 1, is being able to contain most of the outfall modifications to the existing CCT area. In comparison, Alternative 3 requires a large amount of costly excavation and new construction on the east side of the road where flume instrumentation and sampling equipment would be more difficult to access.

Additionally, Alternative 2 has an advantage over Alternative 1 in being able to reduce short-circuiting via the serpentine configuration. The cost of this option is expected to be comparable to Alternative 1.

3.6 Revised Reaeration Evaluation

After identifying Alternative 2 as the preferred outfall configuration, BC looked at the reaeration requirements in more detail. As is, Alternative 2 requires replacing some of the outfall pipe because the hydraulic profile of the CCTs limits the number of steps that can be installed for cascade aeration without excavating near the tank outlet. Alternative 2 requires a second “step” (counting flume outlet achieves three cascades) in the cascade system to achieve the 5.0 mg/L DO, which lowers the invert of the outfall pipe at the CCT outlet by 5.8 ft. To reduce costs, this section evaluates three reaeration options that would not alter the outfall pipe.

3.6.1 Option 1: Single Cascade

This option eliminates the second cascade in the Alternative 2 configuration to maintain the existing outfall invert of 965.33 at the CCT outlet. Figure 3-5 schematically depicts a cross section of the Parshall flume and cascade aeration channel.

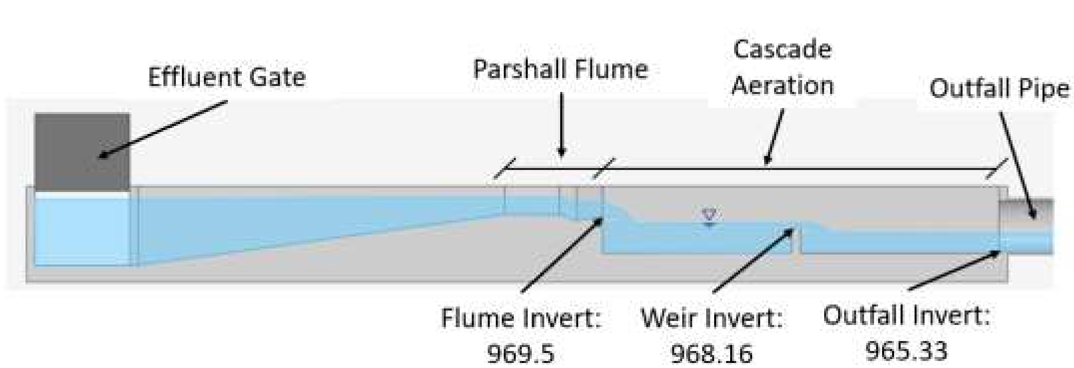


Figure 3-5. Single cascade aeration channel – section view

The predicted CCT outlet DO for this approach is 4.1 mg/L at 19.6 mgd (2045 AA) and 20-degree Celsius (°C) water temperature with a 1.0 mg/L DO inlet concentration. Even at Year 2019 AA conditions of 12.9 mgd and 16°C with a similar inlet DO concentration, the cascade system failed to achieve the 5.0 mg/L DO level, instead reaching 4.5 mg/L. To make up the remaining DO to achieve the 5.0 mg/L requirement BC considered the DO gain in the outfall pipe prior to discharging to the river.

BC estimated the likely DO gain over the outfall pipe based on data collected by the City. Table 3-4 summarizes the three data points collected in late June 2019. The outfall roughly provided a 2.0 mg/L DO increase at flows and water temperatures in the range of 17 mgd and 18°C.

Table 3-4. Parshall Flume Design Dimensions

Date	Units	Outfall Inlet[a]	Outfall Outlet[b]
June 20, 2019 10:00 AM	mg/L	6.0	7.9
June 20, 2019 3:00 PM	mg/L	6.1	8.0
June 24, 2019 10:15 AM	mg/L	6.4	8.3

a. *Location of effluent sampler.*

b. *Outfall discharge prior to drop onto riprap of river bank.*

Although the sampling indicated that DO will increase through the outfall pipe, adverse conditions such as the following could affect the system's ability to achieve the desired 5.0 mg/L DO at the river discharge:

- Cascade aeration system provides lower than expected DO at the outfall pipe inlet
- Water temperature warmer than that measured on the sampling day
- Pipe turbulence less than that measured on the sampling day
- Outfall pipe surcharged due to high river levels

With the limited data available BC cannot determine whether this option will reliably provide adequate DO under all the design conditions. If the City selects this option for further evaluation BC, recommends repeating the sampling during warm water temperatures and at various flow rates. In addition, this option would require routine sampling at the outfall, increasing the time required to obtain the DO sample.

3.6.2 Option 2: Single Cascade with Diffused Air

The second option BC considered is similar to the first option depicted in Figure 3.6, but this option adds a diffused air system ahead of the Parshall flume, which would work in conjunction with the single cascade downstream of the Parshall flume and the DO provided by it. The membrane diffuser system would be installed into the roughly 15-ft by 17-ft area leading into the Parshall flume. Table 3-5 summarizes the conditions analyzed and resulting DO if the maximum diffuser density (about 22 percent) were installed and a maximum airflow of 3.5 standard cubic feet per minute (SCFM) per diffuser.

Table 3-5. Effluent Aeration – Diffused Air Summary			
Parameter	Units	Annual Average	Maximum Month
Effluent flow (average wet weather)			
2030	mgd	15.9	19.0
2045	mgd	19.9	23.8
Water temperature	°C	16	20
Diffuser system inlet DO	mg/L	1.0	0.0
Diffuser system outlet DO			
2030	mg/L	3.0	3.0
2045	mg/L	3.0	3.0
Cascade outlet DO			
2030	mg/L	5.2	5.2
2045	mg/L	5.2	5.2
Power requirements			
2030	hp	3.0	6.0
2045	hp	3.5	8.0

The diffuser system only needs to boost the DO to roughly 3 mg/L and then the cascade aeration system provides the additional 2 mg/L required. The power requirements range from 3 to 8 hp.

This option requires the following equipment:

- 135 membrane diffusers, 9-inch diameter.
- 3 blowers at 5 hp each, which leaves one standby

3.6.3 Option 3: Dual Cascade with Elevated Flume

The final option considered elevates the Parshall flume to provide the vertical drop required to include the second cascade and entrain enough DO to meet the permit limits. Figure 3-6 provides a schematic depiction of the channel section showing the Parshall flume elevated to a 970 invert and the two cascades downstream.

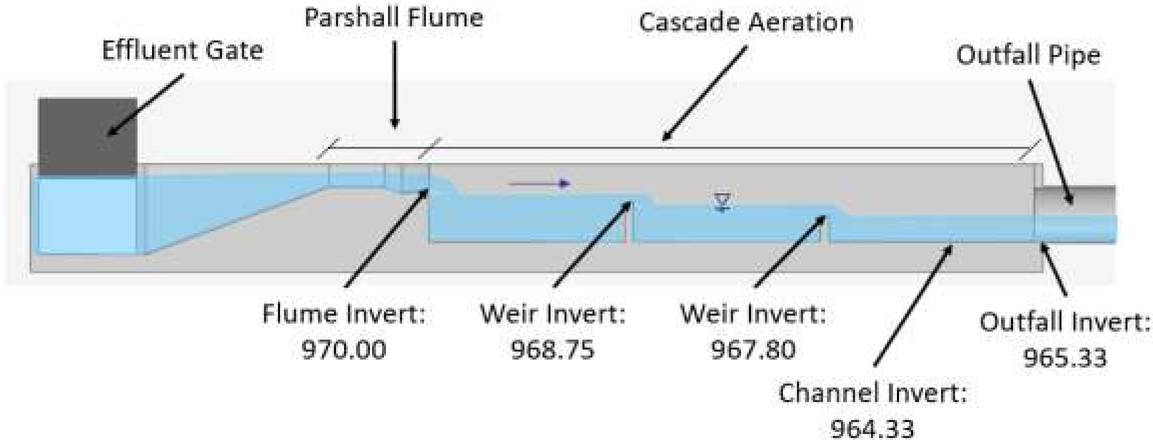


Figure 3-6. Dual cascade aeration channel with elevated Parshall flume – section view

The performance of this configuration is not significantly better than the Option 1 configuration. The Option 3 approach cannot provide the 5.0 mg/L DO under maximum month conditions assuming an inlet DO of 1.0 mg/L and the outfall pipe is not surcharged. At the maximum month 20° C temperature preliminary calculations predict 4.3 mg/L of DO. The low drop heights over the weirs limits the DO gain, so even under average conditions the outfall DO is expected to be less than 5.0 mg/L. Similar to Option 1, this configuration would require either measurement of DO at the outfall or the addition of a small diffused air reaeration system to supplement the cascade. Further investigation may identify an approach to reliably meet the permit DO requirements.

The elevated Parshall flume does affect the upstream hydraulic profile and requires further evaluation to confirm the selected elevation works with the final design. Given the hydraulic impacts, the Parshall flume will have a false bottom so that it can be lowered more readily in the future if additional head is needed to incorporate new or modified upstream processes such as filtration. The hydraulic evaluation technical memorandum (BC, 2019) presents the overall WRP hydraulic profile incorporating this option.

Section 4: Reuse

With the expected population increases in the greater Rochester area, the existing drinking water supply requires expansion. Rochester Public Utilities commissioned a preliminary study (Barr 2017) to identify potential alternative drinking water sources to the existing groundwater well system. This report concluded that the groundwater resources accessible to the City likely have the capacity to meet anticipated future demand. The study also considered treated wastewater effluent for some sort of reuse to offset some potable water demand. This TM focuses on non-potable reuse potential since that would be the most likely approach for the City.

The use of treated municipal wastewater in Minnesota is currently regulated by limits based on the California Water Recycling Criteria, Title 22 California Code of Regulations (Title 22). The Minnesota Pollution Control Agency (MPCA) includes permitting of water reuse systems as part of the NPDES permit process. The MPCA establishes water quality criteria for water reuse systems on a case-by-case basis and bases its assessment on the Title 22 criteria. MPCA's summary of the Title 22 criteria for Minnesota is provided in a fact sheet included as Attachment B with references to California's regulations.

The regulatory requirements are based on the intended use of the water. The higher the potential for exposure to humans, the more treatment is required to reduce the risk of pathogen-related health issues. The MPCA summary in Attachment B identifies three levels of water quality defined by pathogen limit and treatment process requirements as listed in Table 4-1. From January 1, 2014 through December 31, 2017, the WRP averaged 36 MPN with 4 days exceeding 200 MPN. This would place the WRP treated effluent in the Disinfected Secondary 200 classification for reuse.

Table 4-1. Water Reuse Regulatory Criteria

Classification	Limits	Treatment Processes	General Use
Disinfected Tertiary	2.2 MPN/100 mL Total Coliform 2 NTU daily average; 10 NTU daily maximum turbidity	secondary, filtration, disinfection	Highest potential for human exposure (e.g., Irrigation of residential parks, playgrounds; cooling water with towers creating a mist)
Disinfected Secondary 23	23 MPN/100 mL Total Coliform	secondary, disinfection	Limited potential for human exposure (e.g., roadway landscape irrigation, closed loop cooling systems)
Disinfected Secondary 200	200 MPN/100 mL Fecal Coliform	secondary, disinfection	Lowest potential for human exposure (e.g., irrigation of food crops not for human consumption)

The Disinfected Secondary 200 classification allows for reuse in low potential for human exposure activities. These types of uses include irrigation of food crops not directly consumed by humans, such as animal feed crops, plant nurseries, and sod farms. In order to keep distribution costs low, reuse customers would need to be relatively close to the WRP. Figure 4-1 shows the land uses around the WRP. To the south and west, the land use is mainly residential, with low potential for reuse. There may be limited irrigation opportunities to the north and east in agriculture and industrial plots but pumping energy would be required to reach these sites.

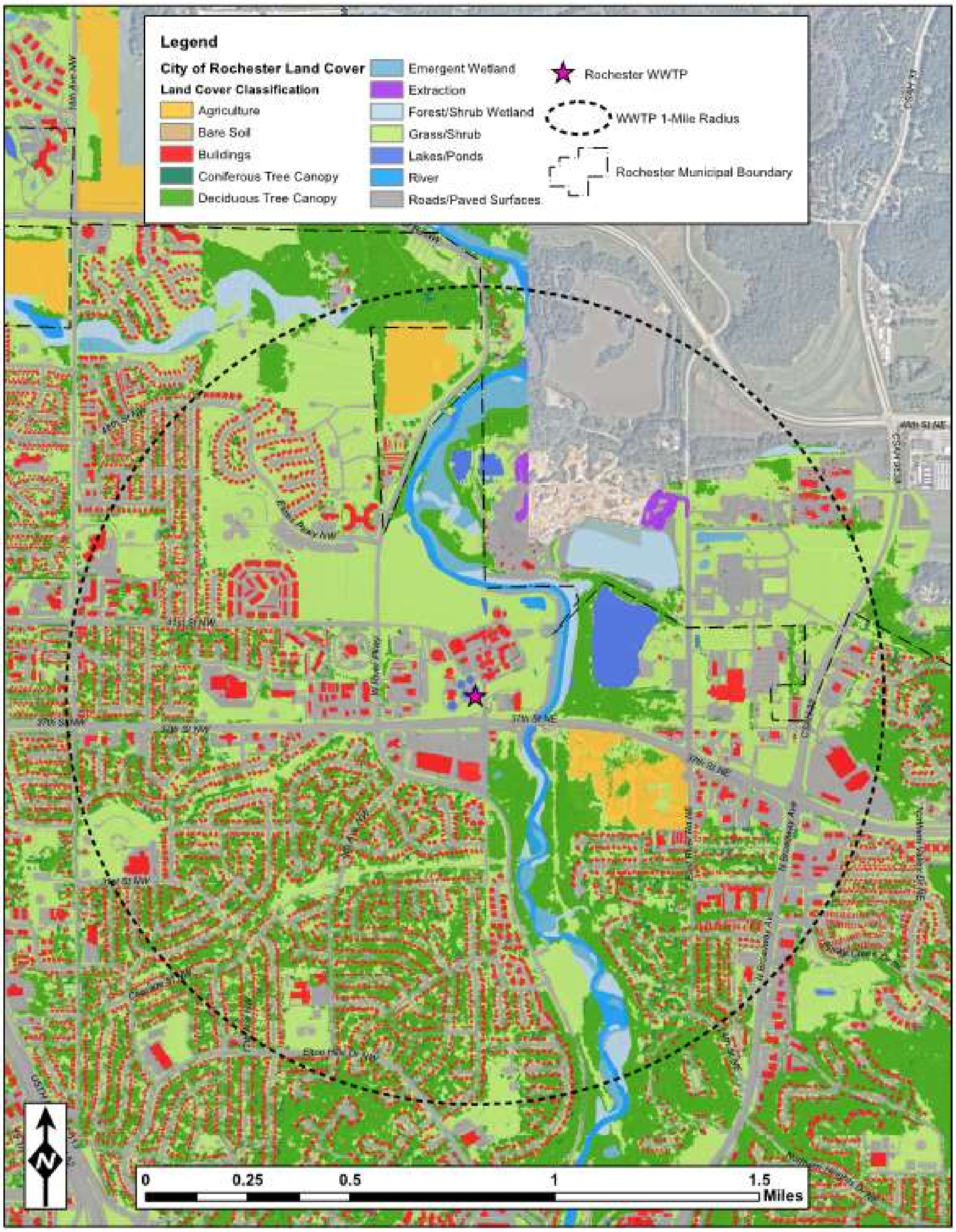


Figure 4-1. Land use map surrounding WRP

Image source: Joe Knight, 2016.

Several communities in the region currently reuse treated wastewater but do so with a higher level of treatment. The most common reuse application in Minnesota is for irrigation and, within that context, parks/open spaces and sports fields are the most common. Park and sport field uses with high potential for public exposure require tertiary filtration and disinfection. Industrial processes with potential human exposure, which would also require higher treatment, are also a significant reuse application. Table 4-2 summarizes a few examples of reuse in the region.

Table 4-2. Example Minnesota Water Reuse Applications

Community	Use
Shakopee Mdewankaton Sioux	Golf course irrigation
East Bethel Wastewater Treatment Plant Metropolitan Council Environmental Services	Subsurface infiltration
Empire Wastewater Treatment Plant Metropolitan Council Environmental Services	Cooling water and process water for industrial facility (not yet constructed) [a]
City of Mankato	Power plant cooling water and vehicle washing

a. Project objective is to reduce local groundwater use.

To achieve higher treatment levels to broaden the reuse possibilities, addition of filtration and disinfection would be required. This typically includes granular media filtration, although membrane-based technologies are sometimes used. Disinfection is typically achieved through chlorine addition or ultra-violet disinfection. High-effluent chlorides can also be a problem for irrigation and cooling tower customers, sometimes requiring side-stream reverse osmosis (RO) treatment.

Currently, there is no significant driver for wastewater reuse in Rochester. If the City decides to consider reuse in the future, a comprehensive review of regulatory requirements, treatment needs and footprint, and potential customers will be required.

Section 5: Feasibility of Micro Hydropower Generation from Outfall

Micro-hydropower generating potential varies widely, depending on flow rate and vertical head. While traditional installations have focused on high-head applications, newer configurations are suitable for use in low-head (minimum 10 feet) sites. The WRP has a 10 foot drop downstream of disinfection, so it is on the low end of the practical head requirement. A micro-hydro turbine could be configured on the WRP outfall, with an estimated output of approximately 22 kW at the current average (14 mgd) plant flow. A small system micro-hydro turbine system like this would cost roughly $500,000 to $1,000,000 (installed). The cost per kW is higher than comparable renewable energy investments such as biogas and solar power generation.

The key unknown factor in the viability of the WRP site for micro-hydropower is maintaining the effluent DO level of 5 mg/L required by the NPDES permit because some of the 10-foot drop is planned to be used for future cascade aeration. The micro-hydro turbine would need to provide equivalent aeration in a parallel configuration (in case the micro-hydro turbine is out of service). Some micro-hydro turbines claim to have the ability to incorporate air via an air pocket with a vacuum breaker in the tail race, as shown in the Ossberger configuration in Figure 5-1 and Attachment C. This manufacturer is currently planning to conduct measurements to quantify the ability of their system to aerate. The St. Anthony Falls Hydraulic laboratory has done some research in aeration in hydropower installations and could be consulted. If the turbine configuration was unable to transfer sufficient oxygen, either supplemental air diffusers or other oxygen transfer devices (e.g., Speece cone with oxygen) would be required, and the necessary blower, if aerated, power would likely negate the energy benefits of the micro-hydro turbine.

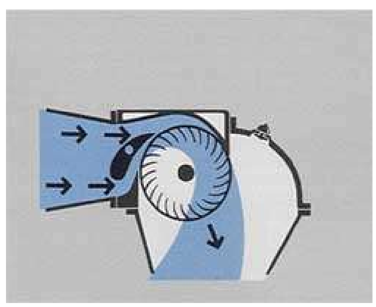


Figure 5-1. Aeration of turbine flow via air pocket

Source: OSSBERGER Turbine

Section 6: Summary and Opinion of Probable Costs

Table 6-1 provides a summary of the preliminary estimate of construction costs associated with the projects recommended in this TM, including:

- Chlorine solution equipment
- Distribution piping and diffusers for chlorine and sodium bisulfite piping
- Inlet revisions and baffling to create a serpentine flow pattern in the existing CCT
- Effluent flume and cascade aeration in center zone of CCT
- Small diffused air system

These Class 5 estimates represent a conceptual level or project viability estimate consistent with the Association for the Advancement of Cost Engineering International (AACEI). Engineering for a Class 5 estimate typically represents zero to 2 percent completeness. The accuracy of a Class 5 estimate ranges from -50 to +100 percent.

Table 6-1. Disinfection and Outfall Capital Improvements Opinion of Probable Costs

Item	Cost
Chlorine solution equipment	$160,000
Chlorine and sodium bisulfite piping and chemical diffusers	$150,000
Inlet and serpentine flow revisions in existing CCTs	$230,000
Temporary bypass pumping	$200,000
Effluent flume	$50,000
Cascade aeration	$10,000
Small diffused air system	$20,000
Engineering and administration (20 percent)	$160,000
Total capital cost	$1,000,000

Table 6-2 provides a summary of the anticipated energy and chemical savings based on the projects recommended in this TM.

Table 6-2. Disinfection and Outfall Capital Improvements Estimated Savings

Item	Savings per year
Energy savings	$47,000
Chemical savings	$24,000
Total estimated savings	$71,000

References

Barr. 2017. *Preliminary Evaluation of Alternative Water Supply Options.* October 3.

Brown and Caldwell (BC). 2019. *Water Reclamation Plant Facilities Plan Plant Hydraulic Evaluation.* August 30, 2019.

CH2M Hill, 2004. Water Reclamation Plant – City of Rochester, Minnesota – 2004 Plant Upgrade, October 27.

Kirkham Michael & Associates, Wallace Holland Kestler Schmitz & Company. 1979. Advanced Wastewater Treatment Rochester, Minnesota Water Reclamation Plant. November 19.

Knight, Joe. 2016. Rochester 1-Meter Land Cover Classification. June 30.

Nakasone, Hideo. 1987. *Story of Aeration at Weirs and Cascades*.

Attachment A: Baffle Walls Data Sheet

AquaSpan FRP Flat Plate

Lasting Solutions for Challenging Conditions

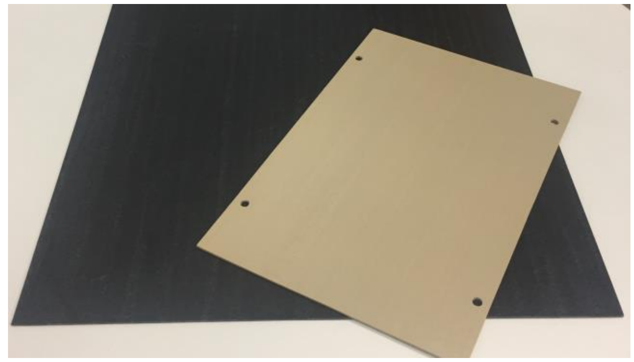
With combination of exceptional strength and corrosion resistance, AquaSpan FRP Flat Plate is the optimum material for demanding environmental conditions requiring flat panels.

The FRP plate is manufactured by advanced pultrusion process that produces optimum strength and stiffness, consistent properties, close tolerances, and good surface finish.

To optimize structural properties, AquaSpan has high content of glass fiber reinforcements strategically placed in straight and continuous, alignment.

To resist attack from chemical exposure, AquaSpan glass fiber reinforced plastic (FRP/GRP) material is formulated with premium, iso-polyester or vinyl ester resin.

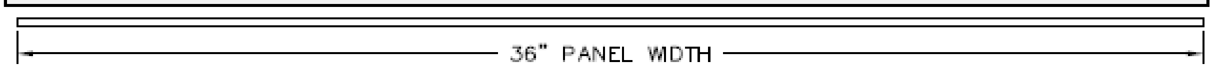
AquaSpan Flat Plate is offered in opaque, charcoal gray color and UL Class I flame spread



Qualities
- Corrosion resistance
- High strength to weight
- Fire retardant

User Value
- Life-cycle cost savings
- Maintenance-free

Tuff Span 1/4" Flat Plate



I=.015 in^4/ft. of width, S=.125 in^3/ft. of width

Material	PE / VE
Nominal Thickness, In.	.25 Inch
Nominal Glass Content	55% by weight
Standard Resin / Color	Iso-Polyester (PE) / Charcoal Gray
Standard Resin / Color	Vinyl Ester (VE) / Beige
Standard Size / Weight	36" x 120" / 2.34 Lbs PSF
Flame Spread Rating, ASTM E-84	Class 1: 25 or less
Water Absorption, ASTM D 570	.10%
Tensile Strength, ASTM D 638	25,000 psi
Flexural Strength ASTM D 790	35,000 psi
Flexural Modulus ASTM D 790	1,000,000 psi
Barcol Hardness ASTM D 2583	40
Izod Impact Strength ASTM D 256	30.14 ft-lb/in

	Maximum Span / Deflection (In)			
	5.202	**10.4**	**15.61**	**20.81**
Span	36"	29"	25"	23"
Defl	.403"	.32"	.28"	.254"

1) Maximum spans are based on: Single span condition; Supports on two edges of plate and located parallel to each other; Plates spanning in length direction. For spans in cross direction, multiply values by .55.
2) Maximum allowable deflection (In.) = L/90.

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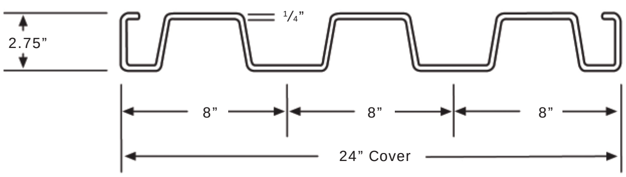
Tel: 713.358.4000
Fax: 713.358.4100
www.endurocomposites.com

Enduro "H" Structural Baffle & Partition Wall

System Overview

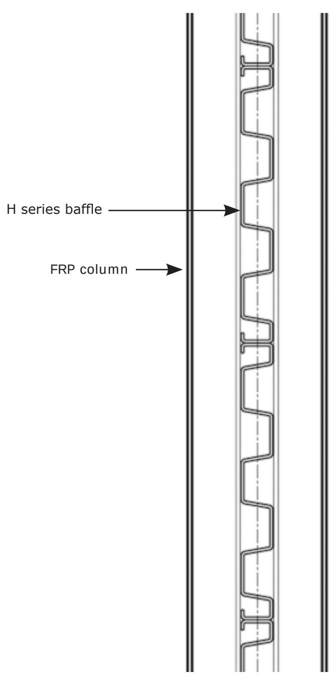
As a global leader for FRP structural systems, Enduro developed the "H" Series baffle panel and the innovative SlideGuide assembly system.

The 1⁄4" thick, Enduro "H" series are the strongest FRP baffle panels available and are utilized in both bolted and non-bolted installations. In the SlideGuide system, the "H" baffle panels, which do not require fastening, are inserted between and held in place by FRP angles. With a long and proven track record of outstanding performance, the Enduro "H" series and SlideGuide assembly has led a movement away from concrete and wood to the Enduro FRP baffle system.

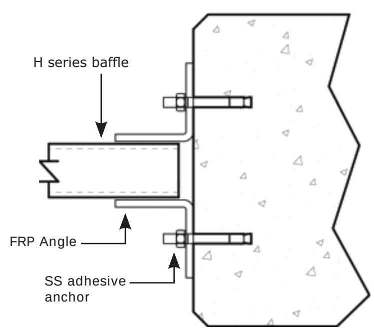


Enduro "H" slotted flow-thru baffle wall system
Settling Basin

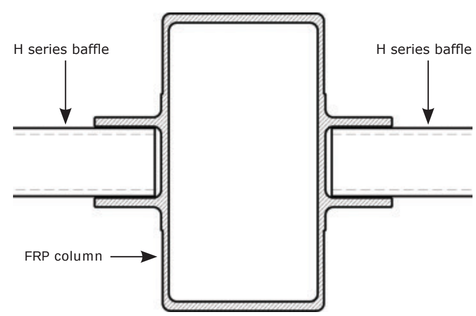
Typical Details



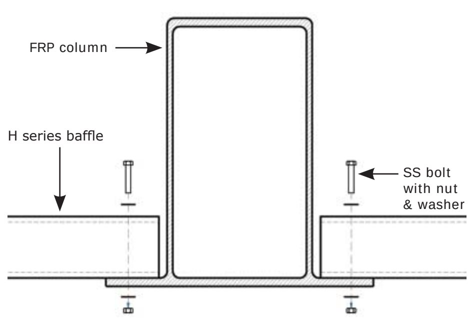
Baffle Panel Stacking



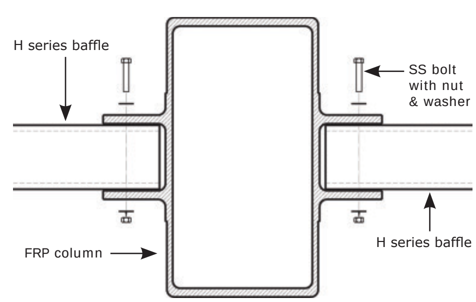
SlideGuide Concrete Wall



SlideGuide 12S12 FRP Column



Bolted 12F12 FRP Column



Bolted 12S12 FRP Column

Enduro "H" Structural Baffle & Partition Wall

Load Span Table

Water Differential	2"		3"		4"		5"		6"		8"		10"		12"	
Uniform Load	10.4 psf		15.6 psf		20.8 psf		26.0 psf		31.2 psf		41.6 psf		52.0 psf		62.4 psf	
Span (Ft)	L/D	FOS	L/D	FOS	L/D	FOS	L/D	FOS	L/D	FOS	L/D	FOS	L/D	FOS	L/D	FOS
9	>360	>6	>360	>6	>360	>6	>360	>6	>360	>6	309	>6	247	>6	206	5.2
10	>360	>6	>360	>6	>360	>6	>360	>6	300	>6	225	>6	180	5.0	150	4.2
11	>360	>6	>360	>6	339	>6	271	>6	226	>6	169	5.2	135	4.2	113	3.5
12	>360	>6	348	>6	261	>6	209	>6	174	5.8	130	4.4	104	3.5		
13	>360	>6	273	>6	205	>6	164	5.9	137	5.1	103	3.7				
14	328	>6	219	>6	164	>6	131	5.1	109	4.5						
15	267	>6	178	>6	134	5.6	107	4.5								
16	220	>6	147	>6	110	4.9										
17	183	>6	122	5.8	92	4.3										
18	155	>6	103	5.2												
19	131	>6														
20	113	>6														
21	97	5.7														

Maximum spans are based on non-fixed connection with panels being restrained by SlideGuide angles on each side.
Please contact Enduro for Load/Span data with a bolted H Series installation.

Specification: Fiberglass Reinforced Plastic Baffle Wall - H Series

Part 1 – General

1.01 Description of Work

The scope of this specification shall include materials for the fiberglass reinforced plastic (FRP) Baffle Wall System including FRP baffle wall panels; FRP columns; FRP angles; column base plates/angles; fasteners and connections.

1.02 Design Criteria

A. Design Load (greater of water differential or wind load)
   1. Water Differential: _____ in. (uniform load over wall)
   2. Wind Load: _____ lbs./SF uniform load

B. Deflection Limit and Factor of Safety
   1. Baffle Panels: L/D=_____; Max Defl=Panel Depth; FOS = 2.0
   2. Columns: L/D=100; FOS=2.5

Part 2 – Products

2.01 Manufacturer

Standard for design, characteristics, and performance is Enduro H Series Baffle Wall manufactured by Enduro Composites, Inc.

2.02 Materials

A. FRP Baffle Panels, Columns, and Angles
   1. FRP baffle panels, columns, angles, and associated components shall be ANSI/NSF Standard 61 certified for potable water application (as required).
   2. FRP Baffle Panels shall exhibit these minimum properties:
      Stiffness (EI) 1,780,000 lb-in^2/ft
      Moment Capacity 39,200 lb-in/ft
   3. FRP structural materials shall exhibit these minimum properties:

Tensile Strength	48,000 psi	ASTM D 638
Flexural Strength	58,000 psi	ASTM D 790
Flexural Modulus	2,000,000 psi	ASTM D 790
Izod Impact (Notched)	25	ASTM D 256
Water Absorption	.25% maximum	ASTM D 570

   4. FRP Materials shall include UV stabilized polyester resin; surfacing veil at top and bottom sides; gray color.
   5. Factory cut edges and drilled holes shall be sealed with ANSI/NSF approved material.
   6. FRP baffle panels shall be Enduro Series H, 2.75 x .25 profile; 2.75" depth; 1/4" nominal thickness; 50% glass fiber reinforcing (by wt.); with top, horizontal ribs sloped downward not less than 10 degrees to minimize sediment build-up.
   7. FRP Columns shall be Enduro Type ________ with 50% glass fiber reinforcing (by wt.). Column base plates or angles shall be 304/316 Stainless Steel.
   8. FRP Angles shall be 3/8" thick and 90 degrees.

B. Hardware
   1. Fasteners, anchors, and other structural hardware shall be 304/316 Stainless Steel.
   2. Submerged anchors shall be epoxy adhesive type.

For expanded specification, please contact us.

FRP Technical Data

Corrosion Resistance - Resin Systems

Two standard composite resin systems are available. For most applications, isophthalic polyester fire-retardant (FR-P) is the more widely used. A vinyl ester composite fire-retardant resin system (FR-VE) is recommended where strong acids (such as hydrochloric acid), strong alkalies (such as caustic soda), organic solvents and halogenated organic conditions exist. An abbreviated Guide is provided below to assist in the selection of the proper resin system for individual application.

Chemicals	75°F	160°F
Acetic Acid 5%	FR-P	FR-P
Acetic Acid 25%	FR-P	FR-VE-210° (*)
Ammonium Hydroxide 10%	FR-P	FR-VE-150°
Ammonium Nitrate	FR-P	FR-P
Calcium Chloride	FR-P	FR-P
Chlorine Dioxide 15%	FR-P	FR-VE-150° (*)
Chromic Acid 5%	FR-P	FR-VE-150° (*Call)
Diesel Fuel No.1	FR-P	FR-P
Diesel Fuel No. 2	FR-P	FR-P
Ethylene Glycol	FR-P	FR-P
Fatty Acids 100%	FR-P	FR-P
Ferric Chloride	FR-P	FR-VE
Hydrochloric Acid 1%	FR-P	FR-P
Hydrochloric Acid 15%	FR-P	FR-VE-180° (*)
Hydrochloric Acid 37%	FR-P	FR-VE-150° (*)
Hydrogen Sulfide	FR-P-140°	FR-VE-210°
Magnesium Chloride	FR-P	FR-P
Methyl Alcohol 10%	FR-P	FR-VE-150° (*)
Nitric Acid 5%	FR-P	FR-P
Nitric Acid 20%	FR-VE	FR-VE-120° (*)
Phosphoric Acid 10%	FR-P	FR-P
Phosphoric Acid 30%	FR-P	FR-P
Phosphoric Acid 85%	FR-P	FR-P
Sodium Bicarbonate 10%	FR-P	FR-P
Sodium Bisulfate	FR-P	FR-P
Sodium Carbonate	FR-P	FR-VE
Sodium Chloride	FR-P	FR-P
Sodium Hydroxide 1-50%	FR-VE	FR-VE-120° (*)
Sodium Hypochlorite 5%	FR-P	FR-VE-120° (*)
Sulfuric Acid 0-30%	FR-P	FR-P
Sulfuric Acid 30-50%	FR-VE	FR-VE
Sulfuric Acid 50-70%	FR-VE	FR-VE-180° (*)

FR = Fire-Retardant;
P = Polyester Resin;
VE = Vinyl Ester Resin;
(*) = Not recommended to exceed this temperature;
Call = Call for recommendations.

Information contained in this chart is based on data from raw material suppliers and collected from several years of actual industrial applications. Temperatures are not the minimum nor the maximum (except where specifically stated) but represent standard test conditions. The products may be suitable at higher temperatures, but individual test data should be required to establish such suitability. The recommendations or suggestions contained in this chart are made without guarantee or representation as to results. We suggest that you evaluate these recommendations and suggestions in your own laboratory or by actual field trial prior to use.

Typical Properties of Structural FRP

Mechanical (coupon)	FR-P	FR-VE
Logitudinal Direction		
Ultimate Tensile Strength, PSI (ASTM D638)	42,000	42,000
Ultimate Compressive Strength, PSI (ASTM D695)	37,000	37,000
Ultimate Flexural Strength, PSI (ASTM D790)	32,000	35,000
Tensile Modulus, PSI x 10^6	2.5	3.0
Compressive Modulus, PSI x 10^6	2.5	2.5
Flexural Modulus, PSI x 10^6	1.6	2.0
Ultimate Shear Strength, PSI	5,500	7,000
Ultimate Bearing Stress, PSI	30,000	35,000
Izod Impact Strength, Ft.-Lbs. per inch of notch (ASTM D256) (sample thickness ⅛" except ¼" for rod)	25	30
Electrical		
Electric Strength, short term in oil, ⅛", vpm (ASTM D149)*	200	200
Electric Strength, short term in oil, KV per inch	35	35
Dielectric Constant, 60 Hz. (ASTM D150)*	5.6	5.2
Dissipation Factor, 60 Hz. (ASTM D150)*	0.03	0.03
Arc Resistance, seconds (ASTM D495)**	120	120
Fire Retardant Properties		
Flame Resistance, ign/burn, seconds (FTMS 406-2023)	75/75	75/75
Intermittent Flame Test, rating (HLT-15)	100	100
Flammability Test, (ASTM D635)	average time of burning 5 seconds, average extent of burning 15mm	
Surface Burning Characteristics, maximum (ASTM E84)	15	15
Transverse Direction		
Ultimate Tensile Strength, PSI	7,000	10,000
Ultimate Compressive Strength, PSI	15,000	20,000
Ultimate Flexural Strength, PSI	10,000	14,000
Tensile Modulus, PSI x 10^6	0.8	1.0
Compressive Modulus, PSI x 10^6	1.0	1.2
Flexural Modulus, PSI x 10^6	0.8	1.0
Ultimate Shear Strength, PSI	5,500	6,000
Ultimate Bearing Stress, PSI	30,000	35,000
Izod Impact Strength, Ft.-Lbs. per inch of notch (ASTM D256)	4	5
Barcol Hardness (ASTM D2583-75)	50	50
Full Section in Bending		
Modulus of Elasticity, PSI x 10^6	2.5	3.0
Tensile Strength, PSI	20,000	25,000
Compressive Strength, PSI	20,000	25,000
Thermal		
Thermal Coefficient of Expansion, Inches/Inch/°F (ASTM D696)**	5 x 10^{-6}	5 x 10^{-6}
Thermal Conductivity, BTU per Sq. Ft./Ht./ °F/In. (ASTM C-1776-76)	4	4
Specific Heat, BTU/Lb/°F	0.28	0.28
Other		
Density, Lbs./In.3 (ASTM D792)	0.065	0.065
Specific Gravity (ASTM D792)	1.80	1.80
Water Absorption, Max. % by weight (24 hour immersion) (ASTM D570)	.50	.50

* Speciman tested perpendicular to laminate face.
Note: 1 PSI = 6.894 K Pa, 1 Ft.-Lb./In. = 5.443 kg-m/m
** Indicates reported value measured in logitudinal direction.
Note: Depending on the specific glass content and resin, the strength and stiffness properties may be significantly higher.

Attachment B: MPCA Municipal Wastewater Reuse

Municipal Wastewater Reuse

Definition of Municipal Wastewater Reuse, Recycling, or Reclamation

Wastewater Reuse, Recycling, or Reclamation are interchangeable terms commonly used when treated wastewater effluent is used as a substitute for another source of water. Typically, the recycled wastewater is used in place of water from a lake, stream, groundwater, or drinking water supply for use in various agricultural, industrial, commercial or municipal activities.

Historical municipal wastewater reuse in Minnesota

The reuse of treated municipal wastewater in Minnesota is not new and has been practiced for more than 40 years. The most common reuse is for irrigation of agricultural crops, grassland, or forests and is commonly referred to as “spray irrigation”. In 2009, there were approximately 32 Minnesota cities that reused treated effluent for irrigation of this type. More recently, there has been the emergence of recycling wastewater for golf course irrigation, industrial cooling, and for toilet flushing.

Concern is

The primary concern with the reuse of municipal wastewater is the protection of public health. Municipal wastewater contains pathogens and other microorganisms that could cause illness. Therefore, the regulation of reuse is based on the potential for human exposure with the wastewater. Reuse activities are categorized based on public access and the risk for the potential for human exposure with the effluent.

Treatment limits and types of reuse

Since 1992, the Minnesota Pollution Control Agency (MPCA) has used the State of California Regulations as guidance for the permitting of wastewater reuse. California was one of the first states to develop detailed regulations to ensure that the reuse of wastewater would be protective of human health. Like Minnesota, many other states have used California regulations as a template for their own requirements.

The required level and type of treatment is based on the type of reuse and establishes the total coliform bacteria that are allowed to be detected in the final treated water. Total coliform is used for the regulation of wastewater reuse rather than fecal coliform. A total coliform limit is more restrictive than a fecal coliform limit and is used as an additional safety measure.

Treatment design requirements

At a minimum, all reused municipal wastewater must be treated by a secondary treatment process or its’ equivalent. The highest level of treatment, “disinfection tertiary” also requires filtration. The State of California Department of Public Health has published a report titled, “Treatment Technology Report for Recycled Water,” and lists specific brand name technologies which have been demonstrated to meet the above treatment requirements. These technologies will be allowed with no additional testing required for verification. Other technologies may be allowed but additional justification will be necessary to document the performance capability with respect to the above requirements. A copy of the latest report can be found at the link provided at the end of this factsheet.

Storage requirements

Municipal facilities that irrigate all of their wastewater or a large volume of it must have sufficient storage to account for the fact that irrigation during the winter is not allowed in Minnesota. Facilities that propose to irrigate and do not have the ability to discharge elsewhere must have a minimum of 210-days of storage for flow during the period when vegetation is dormant and the ground is frozen. Facilities must also have a reuse contingency plan to ensure that insufficiently treated wastewater is not reused.

Minnesota Pollution Control Agency • 520 Lafayette Rd. N., St. Paul, MN 55155-4194 • www.pca.state.mn.us
651-296-6300 • 800-657-3864 • TTY 651-282-5332 or 800-657-3864 • Available in alternative formats

Treatment Limits

Types of reuse	Reuse permit limits	Minimum level of treatment
• Food crops where the recycled water contacts the edible portion of the crop, including root crops • Irrigation of residential landscape, parks, playgrounds, school yards, golf courses • Toilet flushing • Decorative fountains • Artificial snow making, structural fire fighting • Backfill consolidation around potable water pipe • Industrial process water that may come in contact with workers • Industrial or commercial cooling or air conditioning involving cooling towers, evaporative condensers, or spray that creates mist	2.2 MPN/100 ml. Total Coliform 2 NTU daily average; 10 NTU daily maximum turbidity	**Disinfected** **Tertiary** secondary, filtration, disinfection
• Cemeteries • Roadway landscaping • Ornamental nursery stock and sod farms with restricted access • Pasture for animals producing milk for human consumption • Nonstructural fire fighting • Backfill consolidation around nonpotable water pipe • Soil compaction, mixing concrete, dust control on roads and streets • Cleaning roads, sidewalks, and outdoor work areas • Industrial process water that will not come into contact with workers • Industrial boiler feed • Industrial or commercial cooling or air conditioning not involving cooling towers, evaporative condenser, or spray that creates mist	23 MPN/100 ml. Total Coliform	**Disinfected Secondary 23** Secondary, disinfection
• Fodder,fiber, and seed crops • Food crops not for direct human consumption • Orchards and vineyards with no contact between edible portion • Non food bearing trees, such as Christmas trees, nursery stock and sod farms not irrigated less than 14 days before harvest • In Minnesota, this is commonly called “spray irrigation”	200 MPN/100 ml. Fecal Coliform	**Disinfected secondary 200** Secondary, disinfection (stabilization pond systems with 210 days of storage do not need a separate disinfection process)

Use area restrictions

In addition to the treatment requirements for the recycling of wastewater, the permit will include additional requirements to ensure protection of public health and the environment.

- All use areas must be posted with signs that state that the water used is recycled, nonpotable, and not fit for consumption.
- Setback distance from wells must be in accordance with Well Code, Minn. R. 4725.
- No spray irrigation can occur, other than disinfected tertiary water, within 100 feet of a residence, park, playground, school, or other area with similar public exposure.
- Irrigation must be done in such a manner as to prohibit runoff of recycled wastewater from the site.
- No physical connection shall be allowed between any recycled wastewater source and a potable water source.
- No hose bibs can be installed in areas subject to access by the general public. Only quick connect couplers that differ from those used on the potable water system can be used on the recycled wastewater.

Annual report

In addition to monthly reporting, an annual report is required. The report should include an itemized list of where the wastewater was reused, the volume used at each location, a summary of monitoring results.

Recycled wastewater returned from an industry

In some reuse situations, such as industrial reuse, the industry may not have a separate National Pollutant Discharge Elimination Systems (Permits Program)/State Disposal System (Permit) discharge permit and will return the recycled wastewater to the municipality. While this can be allowed, additional concerns need to be addressed to ensure the returned water does not overload or upset the permitted facility's treatment process.

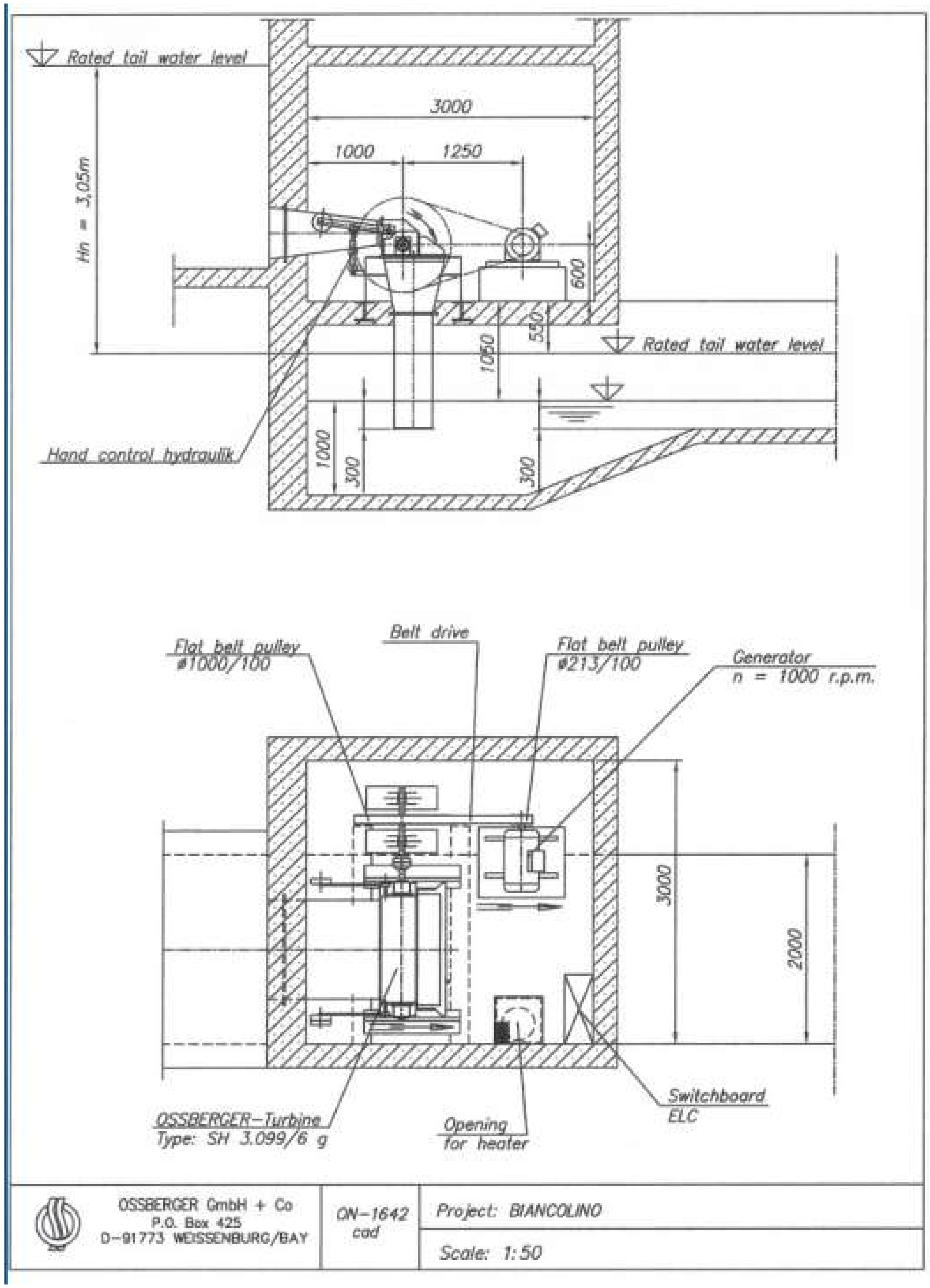
Additional information

Additional details and information regarding the requirements can be found in the California regulation related to recycled water, January 2009 http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Lawbook/RWregulations-01-2009.pdf.

Additional details and information regarding the design and operation of disinfection process can be found in the California "Treatment Technology Report for Recycled Water" http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWdocuments/RecycledWaterTechnologylisting2-09.pdf.

Attachment C: Effluent Hydropower

Sample Arrangement, Ossberger Turbine


Rated tail water level
3000
1000
1250
Hn = 3,05m
600
550
1050
Rated tail water level
Hand control hydraulik
1000
300
300
Belt drive
Flat belt pulley
ø1000/100
Flat belt pulley
ø213/100
Generator
n = 1000 r.p.m.
3000
2000
OSSBERGER–Turbine
Type: SH 3.099/6 g
Opening
for heater
Switchboard
ELC
OSSBERGER GmbH + Co
P.O. Box 425
D-91773 WEISSENBURG/BAY
ON–1642
cad
Project: BIANCOLINO
Scale: 1:50

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Technical Memorandum 1	Influent Flows and Loadings
Technical Memorandum 2	Wastewater Characterization and BioWin Calibration
Technical Memorandum 3	Plant Hydraulic Evaluation
Technical Memorandum 4	Primary Clarifier Computational Fluid Dynamics Modeling
Technical Memorandum 5	Final Clarifier Computational Fluid Dynamics Modeling
Technical Memorandum 6	Liquid Stream Alternative Evaluation
Technical Memorandum 7	Solids Alternative Evaluation
Technical Memorandum 8	Digester Gas Management
Technical Memorandum 9	Disinfection and Outfall Evaluation
Technical Memorandum 10	Whole Plant Evaluation
Technical Memorandum 11	Heat Recovery Loop Alternative
Technical Memorandum 12	NPDES Permitting Process
Technical Memorandum 13	Industrial Discharge Wasteloads and Practices