City of Bend

Water Reclamation Facilities Plan

TECHNICAL MEMORANDUM NO. 4
LIQUIDS PROCESS ASSESSMENT

DRAFT

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CITY OF BEND

WATER RECLAMATION FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 4

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LIQUIDS PROCESS ASSESSMENT

1.0 INTRODUCTION

The Bend Water Reclamation Facility (WRF) currently consists of the following liquid treatment processes:

- Preliminary treatment;
- Primary clarification;
- Activated sludge using a Modified Ludzack Ettinger (MLE) process;
- Secondary clarification;
- Tertiary filtration (seasonal usage for production of Level IV reclaimed water); and
- Chlorine disinfection.

This Technical Memorandum (TM) summarizes the evaluation of the preliminary, primary, secondary, and tertiary processes. The evaluation of the disinfection facilities is developed in TM No. 6.

An evaluation of the existing facilities was completed to determine the current capacity for treating peak wet weather flows, as well as monthly, weekly and daily permit limits for TSS and BOD and the annual monthly average permit limit for total nitrogen (TN). Alternatives for increasing the process capacity were developed based on the existing permit limits and the potentially lower TN limits developed in TM No. 3.

2.0 BASIS OF DESIGN

The following sections summarize the projected flows and loads, regulatory requirements, reliability and redundancy requirements, and design criteria used in establishing the existing capacity and developing the recommended alternatives for expansion.

2.1 Flows and Loads

Evaluations of the alternatives for future expansion were based on the projected flows and loads developed in TM No. 1, which are summarized in Table 1.

Table 1 Flow and Waste Load Projections Summary
Water Reclamation Facilities Plan
City of Bend

Parameter	Year 2010	Year 2020	Year 2030
Influent Flows, mgd			
AAF	6.7	9.0	10.9
ADMMF	7.3	9.8	11.9
PDF	8.4	11.2	13.6
PDWF	13.1	17.6	21.4
PWWF	17.9	24.0	29.1
BOD, pounds/day			
Annual Average	19,700	26,200	31,800
Average Day Maximum Month	24,000	32,000	38,800
TSS, pounds/day			
Annual Average	19,300	25,800	31,300
Average Day Maximum Month	26,200	35,100	42,600
TKN, pounds/day			
Annual Average	2,800	3,700	4,500
Average Day Maximum Month	3,600	4,800	5,900
NH_3-N, pounds/day			
Annual Average	1,800	2,400	2,900
Average Day Maximum Month	2,300	3,000	3,600

2.2 Regulatory Requirements

Design criteria were developed based on meeting the current permit limits outlined in Table 2, as well as potential future permit limits. Based on the permit evaluation presented in TM No. 3, it is assumed that future permit limits for BOD and TSS will not change, but that the TN permit limit may be reduced from 10 mg/L to either 6 mg/L or 3 mg/L. Process alternatives were developed to meet each of the three potential TN limits.

Table 2 Discharge Permit Conditions Water Reclamation Facilities Plan City of Bend					
	Average Effluent Concentrations		**Monthly[1] Average**	**Weekly[1] Average**	**Daily[1] Maximum**
Parameter	Monthly	Weekly	Lb/day	Lb/day	Lbs
BOD_5	20 mg/L	30 mg/L	1,150	1,700	2,300
TSS	20 mg/L	30 mg/L	1,150	1,700	2,300
FC/100 ml[(2)]	200	400			
Other Parameters:					
Total Nitrogen	Annual monthly average of 10 mg/L				
pH	Shall be within range of 5.5 to 9.0				

Notes:

1. Based on average dry weather design flow of 7.0 mgd
2. FC = Fecal coliform

In addition to general effluent parameters, Level IV reclaimed water must meet the following additional standards:

(1) Total Coliform shall not exceed a 7-day median of 2.2 organisms/100 ml, and no single sample to exceed 23 organisms/100 ml.

(2) Turbidity shall not exceed a 24-hour mean of 2 NTU, and shall not exceed 5 NTU for more than 5 percent of the time during a 24-hour period.

2.3 Plant Reliability Criteria

The EPA has defined three levels of system reliability in the document *Design Criteria for Mechanical, Electrical, and Fluid System and Component Reliability*. The levels are primarily based on the nature of the receiving water body. The Bend WRF's system of discharge does not clearly fit into any one of the classification schemes, but most likely would be considered a Class II facility as described below:

- Reliability Class I: Works which discharge into navigable waters that could be permanently or unacceptably damaged by effluent, which was degraded in quality for only a few hours.

- Reliability Class II: Works which discharge into waterways that would not be permanently or unacceptably damaged by short-term effluent quality degradation, but could be damaged by continued (on the order of several days) effluent quality degradation.

Table 3 presents a summary of the relevant criteria for the liquid processes for both classes. Note that although the EPA has requirements for filters, they are not applicable for the Bend WRF because the filters are only needed for reuse and the ponds have the capacity to take all flows if the filters are out of service.

The only difference between the Class I and Class II requirements is the capacity required for the secondary clarifiers with one unit out of service. The Class I requirements are a minimum of four secondary clarifiers, such that when one is out of service the three remaining will be able to provide 75% of design capacity. The Class II requirements are for a minimum of two secondary clarifiers. Currently the plant has three secondary clarifiers; therefore, any expansion of the secondary clarification facilities will meet the more stringent Class I requirements as defined by the EPA. At a minimum, all other facilities will meet the EPA reliability requirements for Class I. Additional redundancy requirements are evaluated for each process to insure that permit limits can be met.

Table 3 Component Reliability Standards
Water Reclamation Facilities Plan
City of Bend

Component	Class I	Class II
Screening	Backup screen required for peak flow.	Backup screen required for peak flow.
Primary clarifiers	Multiple basins; with largest unit out of service, remaining basins have capacity for at least 50% design flow.	Multiple basins: with largest unit out of service, remaining basins have capacity for at least 50% design flow.
Aeration basins	Minimum of two of equal volume; no backup required.	Minimum of two of equal volume; no backup required.
Secondary clarifiers	Multiple basins; with largest unit out of service, remaining basins have capacity for at least 75% design flow.	Multiple basins; with largest unit out of service, remaining basins have capacity for at least 50% design flow
Filters	Multiple units; with largest unit out of service, remaining basins have capacity for at least 75% design flow.	No back-up.

3.0 PRELIMINARY TREATMENT

3.1 Background and Design Criteria

Table 4 presents the sizing of the headworks, which are currently under construction. The new headworks will include three 6 mm perforated plate band screens rated at 15 mgd each. The facility can also accommodate one additional screen, which will provide a total firm capacity of 45 mgd. The channels have been sized such that the 6 mm screens could be replaced with 3 mm screens in future process expansion, including membrane bioreactors (MBRs) or tertiary membranes. In this case the 3 mm fine screens would be rated at 10 mgd each.

Table 4 Existing Preliminary Treatment Facilities Water Reclamation Facilities Plan City of Bend

Parameter	Unit	Value
Type Screens	-	Perforated Plate Band Screens
Number of Units	-	3
Width	ft	4’8”
Opening	mm	6
Peak Capacity, each	mgd	15

Based on the reliability and redundancy requirements outlined in Section 2.3, the capacity should be based on one unit out of service during a peak flow event or with a manually cleaned bar screen.

The Solids Master Plan recommended that grit removal not be included in the new headworks due to the following factors:

- A relatively small amount of grit is received at the facility as compared to plants on the west side of the Cascade Mountains.
- The majority of this grit is the result of lime addition for alkalinity control. The fine screens will remove a portion of this grit.
- Digester No. 3 is designed so that grit can be removed periodically from the bottom of the digester and passed on to dewatering.
- The recently installed belt filter press is not affected by the presence of grit in the feed sludge.
- Grit in the final dewatered biosolids does not degrade the quality for land application.
- Eliminating the grit removal step improves the hydraulic profile by saving the 3 feet of head it takes to get through this unit process.

Provisions have been made in the design of the new headworks for the addition of grit removal in the future, if necessary.

3.2 Existing Capacity

The capacity of the new headworks with one screen out of service is 30 mgd. As shown in Table 5, the existing capacity is adequate for flows through 2030.

Table 5 Capacity of Existing Preliminary Treatment Facilities Water Reclamation Facilities Plan City of Bend					
		Current Capacity (mgd)	**Required Capacity (mgd)**		
Criteria	**Redundancy Criteria**		**2010**	**2020**	**2030**
PHF	One unit out of service	30	17.9	24.0	29.1

3.3 Recommended Upgrades

Based on existing capacity, there is not a need for additional screens until after 2030.

If MBRs or tertiary membranes are included in the future expansion, the existing screens will need to be replaced with 3 mm fine screens to provide adequate protection of the membranes. The estimated capacity of each 3 mm screen is 10 mgd; therefore four screens would meet capacity requirements with one unit out of service.

4.0 PRIMARY TREATMENT

4.1 Background and Design Criteria

The sizing of the existing primary clarifiers is presented in Table 6.

Table 6 Existing Primary Clarifier Size Water Reclamation Facilities Plan City of Bend		
Parameter	**Unit**	**Value**
Type of clarifier	-	Circular
Number of Units	-	2
Diameter	ft	65
Side water depth	ft	9
Average BOD removal	%	39
Average TSS removal	%	75

The purpose of the primary clarifiers is to reduce loading on the secondary process. Primary clarifier performance was reviewed to establish design criteria for surface overflow rates (SORs). During that period, the SORs did not vary significantly and averaged approximately 750 gpd/sf with an average BOD removal of 38% and an average TSS removal of 75%. A primary clarification model was developed to estimate clarifier performance at higher overflow rates and to determine the effects on the secondary process performance. A hydraulic model was also developed to determine the capacity of the primary clarifiers under peak wet weather events.

Table 7 Primary Clarifier Design Criteria Water Reclamation Facilities Plan City of Bend		
Condition	**SOR (gpd/sf)**	**Notes**
ADMMF	1000	All units in service
ADMMF	1500	One unit out of service
PWWF	3100	All units in service

The Primary Clarifier design criteria presented in Table 7 were developed based on both process performance and hydraulic capacity. The criteria for the ADMMF conditions were chosen to provide adequate BOD and TSS removal to minimize secondary expansion requirements. The design criteria also include provisions to take one unit out of service for maintenance. Peak wet weather criterion is based upon hydraulic capacity of the clarifiers. Because EPA redundancy requires capacity to treat 50% of design flow with one unit out of service, at least two equally sized units must be provided. This criterion is met by the current design and does not drive any improvements.

4.2 Existing Capacity

As illustrated in Table 8, the capacity of the existing primary clarifiers is limited by the ADMMF condition and additional primary clarifiers will need to be added to meet future flows.

Table 8 Capacity of Existing Primary Clarifiers Water Reclamation Facilities Plan City of Bend				
	Current Capacity (mgd)	**Required Capacity (mgd)**		
Condition		**2010**	**2020**	**2030**
ADMMF - All units in service	6.2	6.7	9.0	10.9
ADMMF - One unit out of service	5.0	7.3	9.8	11.9
PWWF	20.6	17.9	24.0	29.1

4.3 Recommended Upgrades

Because the existing primary clarification performance is acceptable, it is recommended that expansion of the facilities be based on the addition of new primary clarifiers with designs similar to the existing clarifiers. As shown in Table 9, adding one new clarifier by 2009 and a second by 2020 will provide sufficient capacity for all scenarios through 2030.

Table 9	Recommended Primary Clarifier Upgrades Water Reclamation Facilities Plan City of Bend		
	2010	**2020**	**2030**
Number of Clarifiers	3	4	4
Capacity			
ADMMF - All units in service	9.3	12.4	12.4
ADMMF - One unit out of service	10.0	15.0	15.0
PWWF	20.6	30.9	30.9

5.0 SECONDARY TREATMENT

5.1 Background and Design Criteria

The existing secondary process consists of three aeration basins and three secondary clarifiers, which are described in Table 10. The current configuration of the aeration basins is shown in Figure 1. The aeration basins are operated in the MLE mode, with all primary effluent (PE) fed to Zone 1. The PE piping is configured to allow PE to be fed to the first aerobic zone (Zone 4) and operated in a “step-feed” mode under high flow conditions. The aeration basins are followed by three secondary clarifiers.

Table 10	Sizing of Existing Secondary Facilities Water Reclamation Facilities Plan City of Bend	
Parameter	**Unit**	**Value**
Aeration Basins		
Type of process	-	MLE
Number of basins	-	3
Length x width	ft x ft	210 x 44
Side water depth	ft	15
Volume per basin		
Total anoxic volume	MG	1.08
Total aerobic volume	MG	2.07
Total volume	MG	3.15

Table 10	Sizing of Existing Secondary Facilities Water Reclamation Facilities Plan City of Bend	
Parameter	**Unit**	**Value**
Number of anoxic zones per basin	-	3
Volume of Zone 1	MG	0.09
Volume of Zone 2	MG	0.09
Volume of Zone 3	MG	0.18
Number of Aerobic Zones per Basin	-	2
Volume of Zone 4	MG	0.34
Volume of Zone 5	MG	0.34
Mixed liquor return pumps		
Number	-	3
Flow rate, each	gpm	6,000
Aeration System		
Type of aeration	-	Fine bubble diffusers
Number of blowers installed	-	4
Capacity, each	scfm	3,800
Power, each	HP	250
Top of Aeration Basins	ft	3,360
Secondary Clarification		
Type of clarifiers	-	Circular
Number of clarifiers	-	3
Diameter	ft	80
Side water depth	ft	2 units @12 1 unit @ 14
Surface area per unit	sf	5,027
Total surface area	sf	15,080

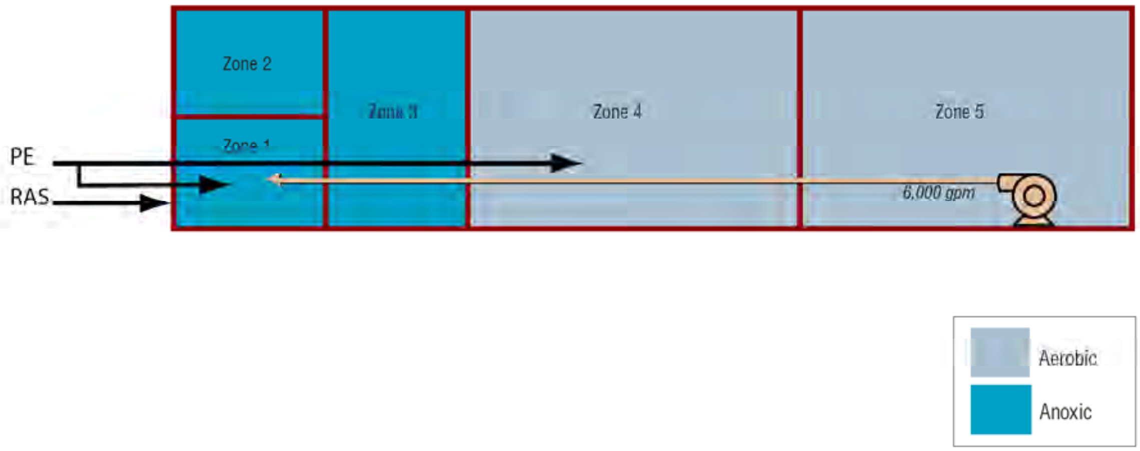

Figure 1 Existing Aeration Basin Configuration and Flow Distribution

The evaluation of alternatives for the expansion of the secondary process was based on two key objectives: (a) meeting the effluent TN permit limits, and (b) providing for cost-effective peak wet weather flow treatment. As previously stated, the future discharge requirements may include average annual TN limits of 10 mg/L, 6 mg/L or 3 mg/L. Therefore, expansion alternatives were developed to meet these permit limits under average annual conditions and to assure that full nitrification is maintained during maximum month conditions. The recommended alternative was then evaluated for peak wet weather flow treatment. Wet weather operational and design modifications were developed to address short term (<1 day) events, with the primary focus being on biomass retention in the secondary process to meet the daily maximum permit limits for TSS and BOD.

The effluent TN is comprised of two main components: total inorganic nitrogen or TIN (ammonia + nitrates + nitrites), and organic nitrogen. Because the organic nitrogen in the effluent is largely refractory, the design focus is typically on the TIN component. The desired effluent ammonia concentration typically controls the design solids retention time (SRT) and basin sizing, while the desired nitrate concentration controls the basin configuration and mode of operation. For each of the three effluent TN limits, the design aerobic SRT values were selected based on achieving the limits during the average annual condition and ensuring that the plant would not slip out of nitrification during the coldest month under maximum monthly flow and load conditions. Higher SRT safety factors were selected for the stringent regulatory scenario requiring an effluent TN concentration of 3 mg/L. Additionally, to reduce effluent TN from 10 mg/L to 6 mg/L, the MLR rate will need to be increased. This will recycle more nitrate into the anoxic zone for denitrification reducing the effluent nitrate concentrations.

Another key criteria in secondary treatment process evaluations relates to the sludge settleability, as this directly impacts secondary clarifier (and overall process) capacity. For this analysis, settling curves were used to characterize the sludge settling velocity as a function of the sludge volume index (SVI).

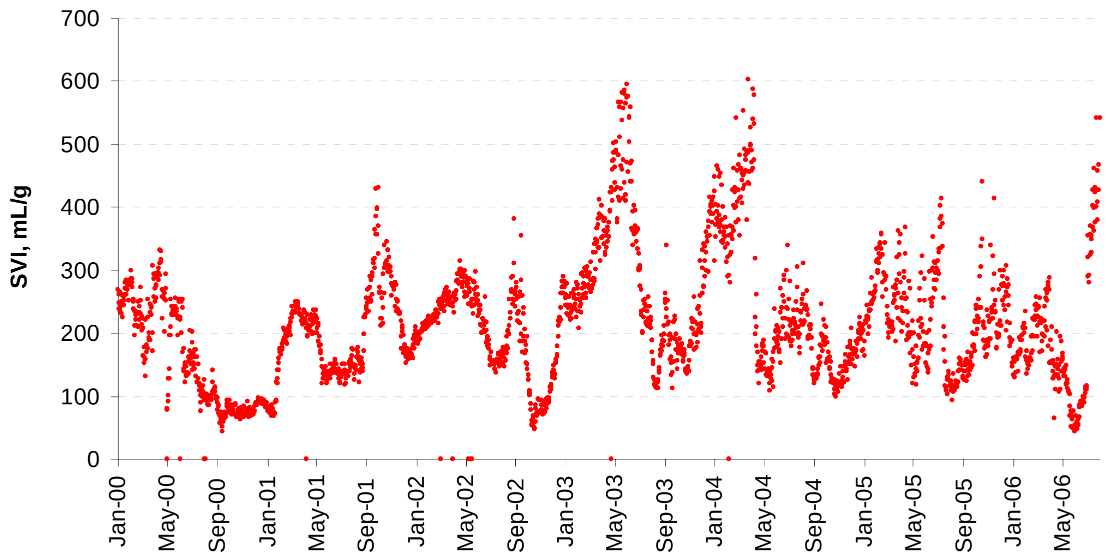

Figure 2 Sludge Volume Index

Figure 2 shows the variation in historical SVI values. According to information from the plant staff, the uncommonly high values (>300 mL/g) are due to bulking that is due to filamentous bacteria growth, particularly M. *parvicella,* in the activated sludge.

Designing the plant using SVI values observed during bulking problems such as 300 or 400 mL/g will result in a significant derating of secondary treatment capacity. For example, the current capacity rating of the existing MLE process at an SVI of 200 mL/g is approximately 16% higher than the capacity at an SVI of 300 mL/g, and approximately 30% higher than the capacity at an SVI value of 400 mL/g. A more cost effective approach is to control the filamentous bacteria growth, and design for lower SVI values.

Successful control of bulking problems associated with filamentous organisms has been achieved through the addition of chemicals such as disinfectants (mainly chlorine) to the aeration basin or the RAS stream. M. *parvicella* bulking impacting Bend, however, has been shown resistant to most methods for bulking control, including the chlorination and selector systems currently available at the plant.

Recent research has shown that polyaluminum chloride (PAX) is an effective chemical for controlling M. *parvicella* and reducing SVI levels (Roels et al. 2002; Jenkins et al. 2003). At full scale, PAX has been dosed at concentrations between 1.5 and 4.5 g Al^{3+}/kg MLSS/d to successfully reduce SVI values greater than 400 mL/g to less than 100 mL/g.

The LOTT Alliance (Lacey-Olympia-Tumwater-Thurston County) WWTP in Olympia, WA has been controlling a previously unsolvable M. *parvicella* bulking problem over the past two years through a seasonal PAX dosing schedule coupled with scum removal. By adding approximately 1.5 g Al^{3+}/kg MLSS/d as PAX to the aeration basin over a nine-week period of problematic bulking, SVI values have been successfully reduced from 250 mL/g to 150 mL/g. In addition, utilizing scum removal strategies has allowed the LOTT Plant to reduce PAX consumption over the past year and minimize the duration of the annual bulking problem.

For the purposes of this evaluation, it is assumed that the implementation of appropriate bulking control strategies at the Bend WRF will achieve an improvement of year-round sludge settleability to SVI values at or below 200 mL/g. Accordingly, all of the process analysis of the different secondary treatment alternatives is based on an SVI of 200 mL/g. The installation of facilities to feed PAX will be further investigated and field-testing will be performed to evaluate the efficiency of chemical addition for bulking control at this facility.

5.2 Existing Secondary Treatment Process Capacity

Table 5 presents the capacity of the existing secondary facilities. The existing facilities have enough process capacity to treat current AAF and ADMMF, as well as the PWWF conditions if operated in the step feed mode. However, the capacity of the existing system will be exceeded for all conditions by 2010. As previously discussed, the capacities listed in Table 11 assume that the incidences of high SVI can be reduced. If the SVI cannot be reduced, the listed capacities will need to be derated.

Table 11 Capacity of the Existing Secondary Process in the MLE Configuration
Water Reclamation Facilities Plan
City of Bend

Condition	Configuration	Current Capacity (mgd)	Required Capacity (mgd)			
			2006	2010	2020	2030
AAF	MLE	5.5	5.1	6.7	9.0	10.9
ADMMF	MLE	6.0	5.5	7.3	9.8	11.9
PWWF	MLE	11.0	14.8	17.9	24.0	29.1
	Step Feed	15.0				

The capacities listed in Table 11 are based upon the current requirement to nitrify, and are lower than the previous non-nitrifying (permitted) plant capacity rating of 7 mgd.

5.3 Alternatives Evaluation

The alternatives evaluation section include the following:

- Recommendations to meet near term capacity deficiencies for normal operation and peak wet weather flows.
- Review of alternatives to meet future treatment requirements based upon the 10 mg/L TN limit, which is anticipated in the upcoming permit renewal.

- Identification of modifications for the recommended alternative to meet the 6 mg/L and 3 mg/L TN limits.

Alternatives for treating PWWF, including blending, for the recommended alternative were also developed.

5.3.1 Near Term Upgrades

5.3.1.1 Dry Weather Operation

As previously discussed, sludge bulking due to filamentous bacteria needs to be addressed. A pilot-scale evaluation of PAX addition is recommended to determine its effectiveness in controlling bulking.

5.3.1.2 Peak Wet Weather Operation

The current facilities cannot treat current PWWF when operating in the MLE configuration. To increase the wet weather flow capacity of the existing plant, it is essential to protect the secondary treatment system from losing solids through washout under high flows. One way to achieve this is by operating in a step feed mode. The step feed mode of operation requires routing part of the incoming PE to the aerobic zone during wet weather events through the existing lines that feed the aerobic zone. The plant is currently operating under this mode to accommodate peak wet weather flows.

5.3.2 Future Expansions with 10 mg/L TN Permit Limit

The following three alternatives were developed for meeting a TN limit of 10 mg/L.

- **Alternative1: Existing Configuration:** All future aeration basins designed with a configuration identical to the existing aeration basins.

- **Alternative 2: Reduced Anoxic Zone:** All aeration basins designed with a configuration identical to the existing aeration basins, except that the anoxic zone is decreased from 34% to 17% (Figure 3). The existing aeration basins will also be reconfigured with the reduced anoxic zone. To implement this alternative, the existing anoxic Zone 3 would be converted to an aerobic zone with a target oxygen concentration of 2 mg/L. This configuration results in an increased aerobic volume for nitrification, while continuing to provide sufficient anoxic volume to denitrify.

- **Alternative 3: Filtrate Reaeration:** All aeration basins designed with a configuration identical to the existing aerations basins, but the ammonia rich filtrate from solids dewatering will be pretreated in two newly constructed small aeration basins before being combined with primary effluent for treatment in the existing aeration basins. This configuration is shown in Figure 4. During side stream treatment, filtrate is brought in contact with RAS at high mixed liquor concentrations, resulting in almost complete nitrification of the ammonia. Consequently, ammonia loads to the aeration basins are greatly reduced and substantial capacity gains of the secondary treatment system can be achieved.

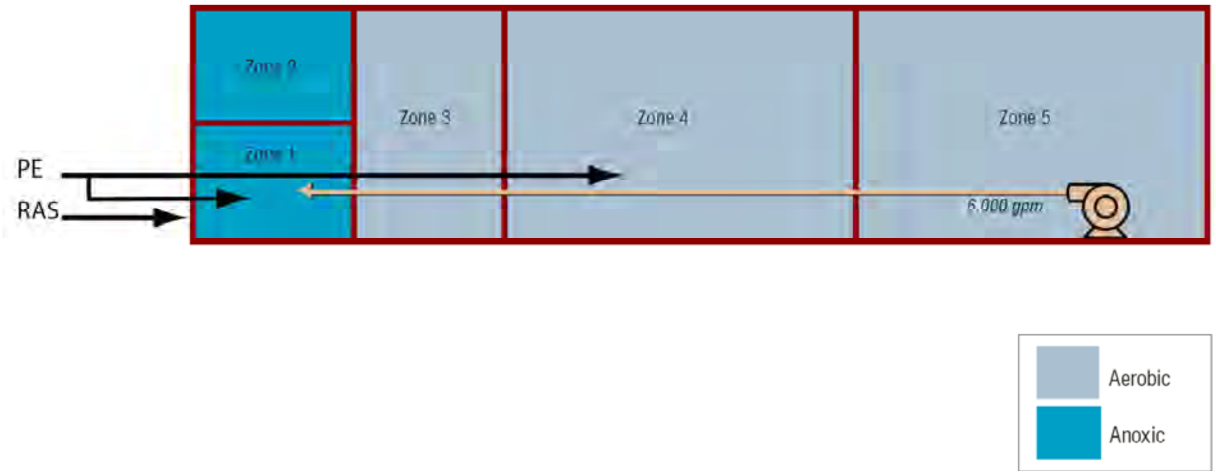

Figure 3 Alternative 2: Reduced Anoxic Zone

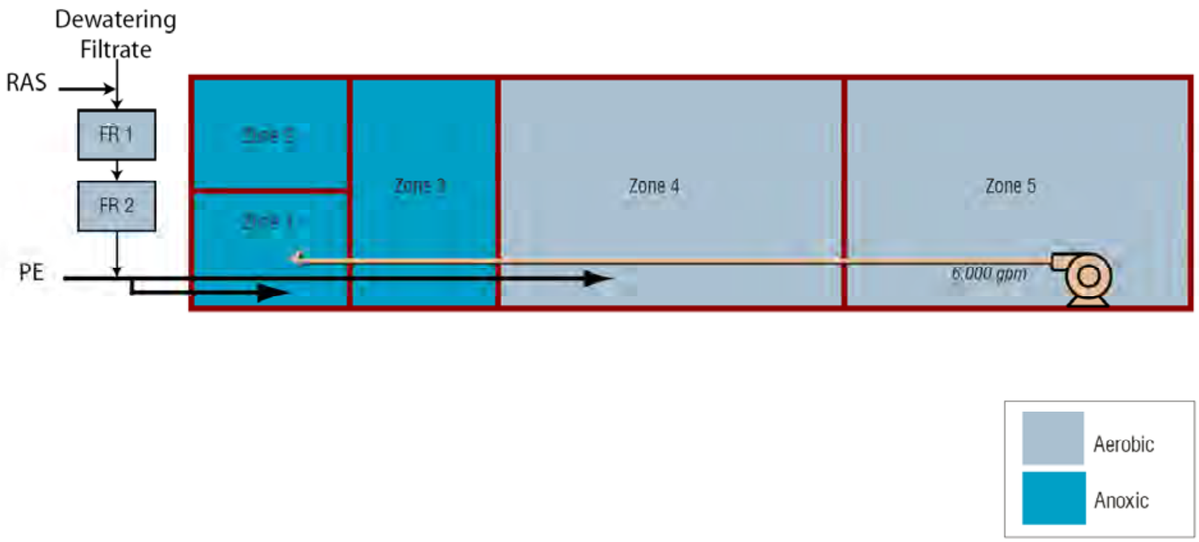

Figure 4 Alternative 3: Filtrate Reaeration

Process modeling was completed for all three alternatives. Estimated capacity for normal and peak wet weather for each aeration basin for each alternative is summarized in Table 12.

Table 12 Comparison of Alternatives for meeting a TN limit of 10 mg/L
Water Reclamation Facilities Plan
City of Bend

Alternative		**1**	**2**	**3**
Parameter	Unit	Existing	Reduced Anoxic Zone	Filtrate Reaeration
Capacity Per Basin / Total Capacity of Existing Basins				
AAF	mgd	1.83 / 5.5	2.0 / 6.0	2.4 / 7.2
ADMMF	mgd	2.0 / 6.0	2.2 / 6.5	2.6 / 7.8
PWWF (no step-feed)	mgd	3.7 / 11.0	4.0 / 12	4.8 / 14
PWWF (with step feed)	mgd	5.0 / 15	5.3 / 16	5.5 / 16.5
Basin Volume				
Aerobic, total	MG	2.04	2.61	2.04 + (2 x 0.2)
Anoxic, total	MG	1.08	0.54	1.08
All Basins	MG	3.12	3.12	3.12 + 0.4
MLR Rate				
Per basin	gpm	6,000	6,000	6,000

Table 12 indicates that the capacity of the existing MLE configuration is 5.5 mgd ADAF. Alternative 2 can use the same basin volume and achieve a 0.5 mgd increase in ADAF capacity by reducing the anoxic zone from currently 35% to 17%. This upgrade would require the addition of diffusers into the last existing anoxic zone to convert this zone into an aerobic zone.

An even larger capacity increase will be achieved by implementing Alternative 3 via filtrate reaeration. By constructing two basins with a capacity of 0.2 mg each to treat dewatering filtrate, the capacity of the existing secondary facilities will be increased to 7.2 mgd without modifications to the existing aeration basins.

Filtrate reaeration has been successfully implemented at full-scale at numerous facilities world-wide and has the following benefits:

- Lower effluent TN concentrations.
- Reducing filtrate ammonia loads prior to returning back to the main activated sludge process.

- Increasing the overall SRT for a given MLSS concentration entering the secondary clarifiers, by achieving a solids tapering effect (this is similar to a step feed approach).
- Seeding of the main activated sludge process with nitrifiers from the filtrate reaeration basin.
- Increased nitrate return to the anoxic zones without having to increase the mixed liquor return flow. With the traditional MLE process, nitrate return to the anoxic zones can only be increased by returning more mixed liquor from the end of the aerobic zone. Because this adversely impacts the flow regime inside the tank, it becomes counter-productive to increase MLR flow after a certain point. With filtrate reaeration, a significant amount of nitrate can be returned to the anoxic zones via the nitrified mixture of RAS and filtrate leaving the reaeration basin. This eliminates the need to significantly increase MLR flow to achieve improved denitrification.

Tables 13 - 15 summarize expansion requirements for each of the three alternatives. The size and dimensions of all future aeration basins and secondary clarifiers will match the existing facilities except that new secondary clarifiers will be 14 feet deep instead of 12 feet deep.

For Alternative 1, the plant will need a total of six aeration basins and six secondary clarifiers to treat flows in 2030. Alternative 2 will require one less aeration basin in 2030 because of the greater aerated volume.

Alternative 3 provides the smallest overall footprint of all three configurations by requiring only four aeration basins. Alternative 3 also increases the plant capacity under normal operation by 30% and is expected to result in a slightly better effluent quality in terms of TN concentration. Two additional filtrate sides stream basins will need to be constructed with a volume of 0.2 MG each. Modifications to the RAS pump station and piping will be required to direct the flow through the side stream basins back to the anoxic zone of the aeration basins. The MLR rate in Alternative 3 was designed to be consistent with pump capacity in the existing aeration basins. However, from a process standpoint this capacity can be reduced in future basins due to the increased nitrate return from the reaeration basin.

Table 13 Alternative 1: Existing MLE / Process Expansion and Design Criteria
Water Reclamation Facilities Plan
City of Bend

Parameter	Unit	2006	2010	2020	2030
Aeration Basins					
Number of basins	-	3	4	5	6
MLSS concentration (all clarifiers in service)	mg/L	3,260	3,300	3,140	3,120
MLR, total	mgd	26	35	43	43
Aeration					
Peak air requirements	scfm	8,400	10,500	14,200	19,000
Aeration Blowers					
Number in service	-	3	3	4	5
Standby units	-	1	1	1	1
Capacity each	scfm	3,800	3,800	3,800	3,800
Firm Capacity	scfm	11,400	11,400	15,200	19,000
Secondary Clarifiers					
Number of clarifiers	-	3	4	5	6

Table 14 Alternative 2: Reduced Anoxic Zone / Process Expansion and Design Criteria
Water Reclamation Facilities Plan
City of Bend

Parameter	Unit	2006	2010	2020	2030
Aeration Basins					
Number of basins	-	3	4	5	5
MLSS concentration (all clarifiers in service)	mg/L	3,250	2,670	2,950	3,160
MLR, total	mgd	26	35	43	43
Aeration					
Peak air requirements	scfm	9,200	11,300	15,300	19,700
Aeration Blowers					
Number in service	-	3	3	4	5
Standby units	-	1	1	1	1
Capacity each	scfm	3,800	3,800	3,800	3,800
Firm capacity	scfm	11,400	11,400	15,200	19,000
Secondary Clarifiers					
Number of clarifiers	-	3	4	5	6

Table 15 Alternative 3: Filtrate Reaeration / Process Expansion and Design Criteria Water Reclamation Facilities Plan City of Bend					
Parameter	**Unit**	**2006**	**2010**	**2020**	**2030**
Main Aeration Basins					
Number of basins	-	3	3	4	4
MLSS concentration (all clarifiers in service)	mg/L	2,000	2,500	2,600	2780
MLR, total	mgd	26	35	43	43
Aeration					
Peak air requirements	scfm	7,820	9,520	13,770	17,830
Side Stream Aeration Basins					
Number of basins	-	2	2	2	2
Basin Volume, each	MG	0.21	0.21	0.21	0.21
Aerobic, total	MG	0.42	0.42	0.42	0.42
MLSS concentration	mg/L	5,600	5,500	7,200	7,900
Aeration					
Peak air requirements	scfm	3,300	3,210	3,990	5,200
Total Aeration Blowers Needs					
Total peak air demand	scfm	11,120	12,730	17,760	23,030
Number blowers in service	-	3	4	5	6
Standby units	-	1	1	1	1
Capacity each	scfm	3,800	3,800	3,800	3,800
Firm capacity	scfm	11,400	15,200	19,000	22,800
Secondary Clarifiers					
Number of clarifiers	-	3	3	4	5

All three configurations utilize the same MLR rate, so that modifications of the MLR pumps in the existing aeration basins and associated hydraulic plant upgrades will not be required for normal plant operation.

Table 16 provides a summary of the estimated total present worth of the costs for each of the three alternatives. For all configurations, the differences in operating and maintenance costs are insignificant, so the costs shown are based on the net present worth of capital costs. These costs are based on construction costs, and are meant for comparison purposes. The costs for adding the capability to operate in the contact stabilization mode or facilities to feed chemicals for bulking control are not included, as these are common to all configurations.

Cost estimates were developed by first estimating total direct costs (based on recent project experience, project bids, and vendor quotes), then applying factors for contingencies, engineering, and electrical, instrumentation and control (EI&C). A contingency factor is often used to compensate for lack of detailed information, oversights, anticipated changes, and imperfection in the estimating methods used. As the project design progresses and elements become better defined, smaller contingencies may be applied. Percentages (as opposed to discrete dollar amount allowances) are typically used for contingencies as well as other elements in an estimate. Percentages (typically part of total direct costs) used in the development of this cost estimate include the following:

- Electrical, Instrumentation & Control: 35%
- Construction Contingency: 35%
- Engineering, Legal and Administration: 25%

The accuracy of a cost estimate depends on the quantity and quality of the information available to prepare that estimate. Typically, as a project progresses from master planning studies, to conceptual design, to final design, the project elements become better defined, thereby providing more and better information for development of progressively more accurate estimates. The Association for Advancement of Cost Engineers (AACE) has suggested a level of accuracy for planning of +30 to -15 percent.

In order to develop net present worth (in 2007$) for the secondary treatment alternatives, interest (6%), inflation (3%), and construction cost escalation (ranging from 9% in 2009 to 4% in 2030) were considered. Individual expansion components were sequenced based on flow projections in the years 2010, 2020, and 2030.

Table 16 Representative Costs for TN Target 10 mg/L
Water Reclamation Facilities Plan
City of Bend

	Alternative	NPW Cost
1	Existing MLE	$18,780,000
2	Reduced Anoxic Zone	$17,030,000
3	Filtrate Reaeration	$14,830,000

Based on cost, footprint, and process benefits, Filtrate Reaeration (Alternative 3) is recommended.

5.3.3 Peak Wet Weather Capacity Expansion

As shown in Table 17, Alternative 3 will be able to treat all flows up to the PDWF condition when operated in the MLE configuration. However, the secondary facilities will not be able to treat PWWF in the step feed mode of operation if all aeration basins have the same design as the existing basins.

Table 17 Peak Hour Flow Process Capacities for Alternative 3 Water Reclamation Facilities Plan City of Bend					
Parameter	**Unit**	**2006**	**2010**	**2020**	**2030**
Peak Hour Flow Projections					
PDWF	mgd	10	13.1	17.6	21.4
PWWF	mgd	14.8	17.9	24.0	29.1
Capacities					
MLE	mgd	14.8	14.8	20	22
Step-Feed	mgd	16.5	16.5	24	27

The following three alternatives have been evaluated for meeting a PWWF based on implementation of the recommended Filtrate Reaeration alternative:

- Alternative 3a: Full secondary treatment using contact stabilization for PWWF. Contact stabilization would be achieved by routing all PE flows to Zone 4 under PWWF conditions. Implementation of this alternative requires that an additional 8-inch pipe be routed from the PE header to Zone 4 in each basin.

- Alternative 3b: Bypass PE in excess of secondary treatment capacity. For this alternative, it is assumed that the plant will operate in the step feed mode under PWWF conditions and flows to the secondary will be maximized. Flows in excess of the secondary capacity would be diverted through a diversion structure with a weir gate to approximately 200 feet of 24" diameter pipe connected to the head of the chlorine contact basin.

- Alternative 3c: Equalization of PE flows to allow for full secondary treatment. Flows in excess of the secondary treatment capacity would be diverted through a bypass structure with a weir gate to approximately 730 feet of 24" diameter pipe connected to the head of the degasification basins. The flows would then be pumped back to the secondary facilities under lower flow conditions.

Note that for all alternatives, it is assumed that the tertiary filters are used to filter up to 6 mgd of secondary effluent. By 2030, this will be required to meet the daily mass limits for BOD and TSS of 2,300 lb/d. It will not require an increase in filtration capacity.

Alternative 3a will allow for 100% of the PE to be routed to the first aerobic zone under PWWF conditions. The existing 12" pipe feeding this zone does not have enough capacity. Therefore, a second parallel pipe would need to be added. Control of flows to the different zones could be manual or automated based on flows. Each basin will have a capacity of 7 MGD in contact stabilization made.

In the contact stabilization mode, return activated sludge (RAS) would continue to be directed to the first anoxic zone. Therefore, the first three anoxic zones will contain high solids concentrations representative of RAS return. The solids concentrations in the subsequent aerated zones of the aeration basin would be significantly lower, as a result of dilution with primary effluent. The resulting tapered solids concentration profile in the basin effectively reduces the solids loading on the secondary clarifiers, thereby increasing capacity.

Alternative 3b does not require any modifications to the design of the existing aeration basins. It will require that a diversion structure be built which allow plant to bypass PE based on either flow or level in the aeration basins. To meet daily mass limits, the aeration basins will need to be operated in the step feed mode and flows to the secondary process will need to be maximized.

Alternative 3c will allow for full secondary treatment of all flows without going into the step feed mode and without modifying the aeration basin design; however, it will require changes to how the degasification basins are operated and significant capital improvements.

Table 18 presents estimated net present worth costs for implementing each of the three alternatives. Cost estimates are based on the same assumptions as described in section 5.3.2. Note that because Alternative 3a involves adding several pipes as aeration basins are built, approximately 25% of these costs could be deferred until 2020. For Alternatives 3b and 3c, it is likely that any diversion structure and pipeline would be sized for 2030 flows; therefore, all costs will be incurred by 2010 for these options.

Table 18 Representative Costs for Treating PWWF
Water Reclamation Facilities Plan
City of Bend

	Alternative	NPW Cost
3a	Contact Stabilization	$250,000
3b	PE Bypass	$300,000
3c	PE Equalization	$700,000

Based on cost and the ability to provide full secondary treatment, it is recommended that contact stabilization be implemented for PWWF treatment. The total NPW cost for the recommended secondary improvements, including contract stabilization and filtrate reaeration, is approximately $15.1 million.

5.3.4 Expansion Requirements for Lower TN limits

The recommended filtrate reaeration option provides the plant with the flexibility to be upgraded to meet a future limit of 6 mg/L and 3 mg/L TN. The additional upgrades needed to produce a TN effluent limit of 6 mg/L are as follows:

- Increase the MLR capacity in each $_{basin}$ to 20 mgd (new MLR pumps, modifications to piping, gates, etc.),
- Increase hydraulic capacity of the existing aeration basins (modifications to existing baffle walls, addition of gates, associated instrumentation control, etc.).

Total NPW costs for retrofitting the plant to meet effluent TN concentration of 6 mg/L are approximately $17 million, which is approximately $2 million more than the NPW cost for meeting the 10 mg/L TN limit.

For the case of a permitted effluent TN limit of 3 mg/L, it is recommended that the plant convert to a 4-stage Bardenpho process, including two-stage denitrification and methanol addition. Upgrades to the Filtrate Reaeration configuration to meet a TN limit of 3 mg/L consist of:

- Modifications to existing aeration basins, as shown in Figure 5, including:
  - Additional compartmentalization
  - Conversion of Zone 8 from aerobic to anoxic operation
  - Relocation of MLR pumps from existing Zone 5 to newly constructed zone 6
  - Addition of methanol feed into anoxic Zone 8
- Construction of three more aeration basins (total of 6)
- Construction of two more secondary clarifiers (total of 5)
- Construction of four filtrate reaeration basins
- New methanol storage and feed facility.

Major changes in construction sequencing and facility sizing are necessary to implement the Bardenpho process with Filtrate Reaeration. The NPW total project cost for this implementing Bardenpho with Filtrate Reaeration is approximately $27 million, which is nearly double the cost to meet the 10 mg/L TN limit.

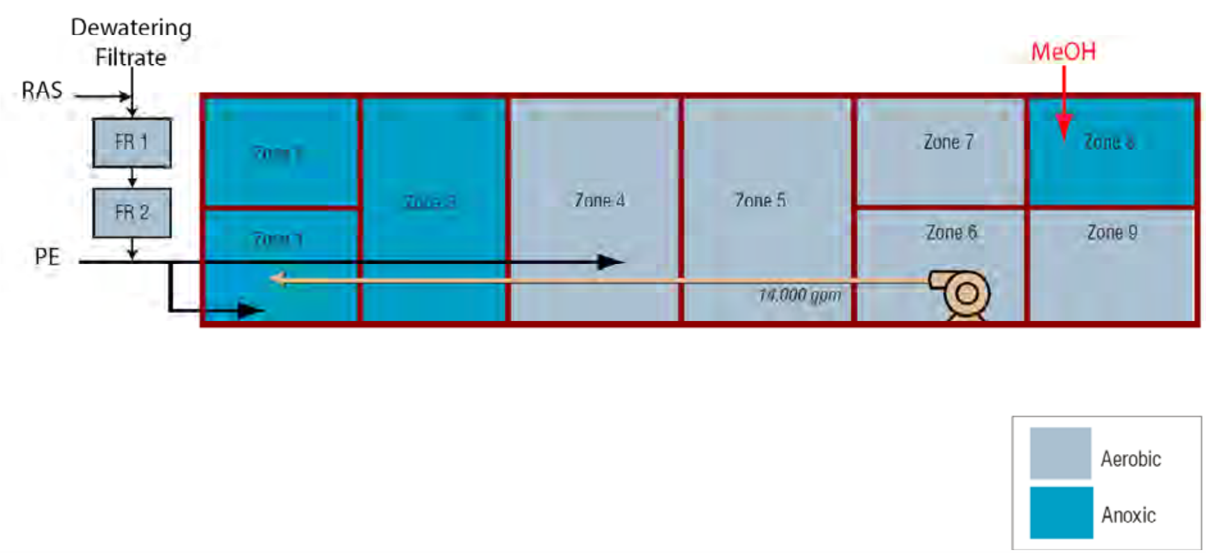

Figure 5 **Layout of the aeration basins in the 4-Stage Bardenpho / Filtrate Reaeration configuration (TN = 3 mg/L)**

It should be noted that the integration of Filtrate Reaeration with the Bardenpho process results in significant savings compared to other process alternatives evaluated to achieve TN effluent limits of 6 and 3 mg/L. For example, using a 4-stage Bardenpho process without Filtrate Reaeration to achieve a TN effluent limit of 3 mg/L would require at least 2 more aeration basins and one additional clarifier in 2030.

5.4 Summary of Recommended Secondary Treatment Upgrades

The following summarizes the upgrades and expansion requirements to implement the recommended filtrate reaeration alternative:

1) Miscellaneous improvements:

- Modifications to blower building and addition of one new blower in 2009, 2019, and 2024.
- New secondary clarifier splitter box and secondary clarifier piping modifications in 2013.
- Upgrade RAS/WAS Pump Station

2) Filtrate Reaeration

- Construction of two aerated Filtrate Reaeration basins at 0.21 mg each
- Reconfiguration of RAS/WAS pumping station and RAS / WAS piping configuration. Conservative cost based upon adding a new RAS pumping station was included in the CIP and shall be refined during Predesign.
- Modifications to piping associated with dewatering filtrate

3) Aeration Basins and Secondary Clarifiers

- Construction of one additional aeration basin in 2019
- Construction of one additional clarifier in 2013 and 2024

4) Peak Flow Treatment

- Extend PE header and add 8-inch pipes to feed PE to Zone 4 in all aeration basins

5) Solids Bulking and Elevated SVI Values:

- Confirm seasonal identification of bulking agents and confirmation of M. *parvicella* as the primary agent causing poor settleability during winter months.
- Conduct pilot scale testing of a PAX chemical feed system to evaluate the efficiency to control bulking caused by M. parvicella under site specific treatment conditions, dosage requirements, and other design parameters.

- If PAX proves to be a feasible and effective control strategy, add a chemical feed system capable of dosing PAX into the RAS stream before the aeration basin.

- Continued use of RAS chlorination to control other sources of bulking organisms.

- Implement scum removal strategies for the secondary treatment design to reduce filamentous bacteria growth and recycle throughout the system.

6.0 TERTIARY FILTRATION

As outlined in Table 19, the existing tertiary filtration systems consists of a 12-disc cloth filtration system with an ADMMF capacity of approximately 6 mgd. The system was designed to treat secondary effluent to meet Level IV reuse requirements. The filters are used to provide reuse water from approximately March through October, but are also operated during non-reuse periods.

Based on the existing permit and the proposed conversion of the secondary system to contact stabilization for PWWF conditions, tertiary filtration will not be needed to meet permit requirements. If the TN permit limit is reduced to 3 mg/L, tertiary filtration may be used to remove particulate organic nitrogen (PON). Typically, SE contains less than 1 mg/L of PON and a fraction of that could be removed through filtration. This would not be enough to meet the TN limit without using the Bardenpho process, which will not drive an expansion of the filtration process.

Based on the permitting scenarios that have been evaluated, the only reason to increase tertiary filtration capacity will be to meet increased reuse demand. Currently, there are no projected increases in reuse demand; therefore, near-term expansion of the tertiary facilities is not anticipated.

Table 19 Sizing and Capacity of Existing Tertiary Filtration System
Water Reclamation Facilities Plan
City of Bend

Parameter	Unit	Value
Effluent Filters		
Number of filters	-	2
Number of disks per filter unit	-	12
Type	-	Cloth Disk
Capacity		
Average, each	mgd	3
Peak, each	mgd	5
Disc area, total	sf	1,290
Area per disk	sf	53.8
Hydraulic Loading Rate		

Table 19 Sizing and Capacity of Existing Tertiary Filtration System Water Reclamation Facilities Plan City of Bend		
Parameter	**Unit**	**Value**
@ ADMMF	gpm/sf	2.7
@ PHF	gpm/sf	9.5
Filter Feed Pumps		
Number	-	2
Type	-	Submersible, VFD
Capacity, each	mgd	5
Horsepower, each	HP	50
Reuse Pumps		
Number	-	2
Type	-	Horizontal screw centrifugal, VFD
Capacity, each	mgd	2.5
Horsepower, each		50

7.0 SUMMARY

The phasing plan for the recommended improvements is summarized below:

- Near term:
  - Complete study of solids bulking problems and implement necessary improvements to reduce SVI
  - Utilize step feed operation under PWWF conditions
- 2009
  - Construct one new primary clarifier
  - Construct two filtrate reaeration basins
  - Add piping to existing aeration basins to allow for operation in contact stabilization mode
  - Add one blower
  - Upgrade RAS/WAS Pump Station
- 2013
  - Construct one new secondary clarifier and secondary clarifier splitter box
- 2019
  - Construct one new primary clarifier
  - Construct one new aeration basin
  - Add one blower
- 2024
  - Construct one new secondary clarifier
  - Add one blower

Figure 6 presents the recommended liquids process flow schematic for 2030.

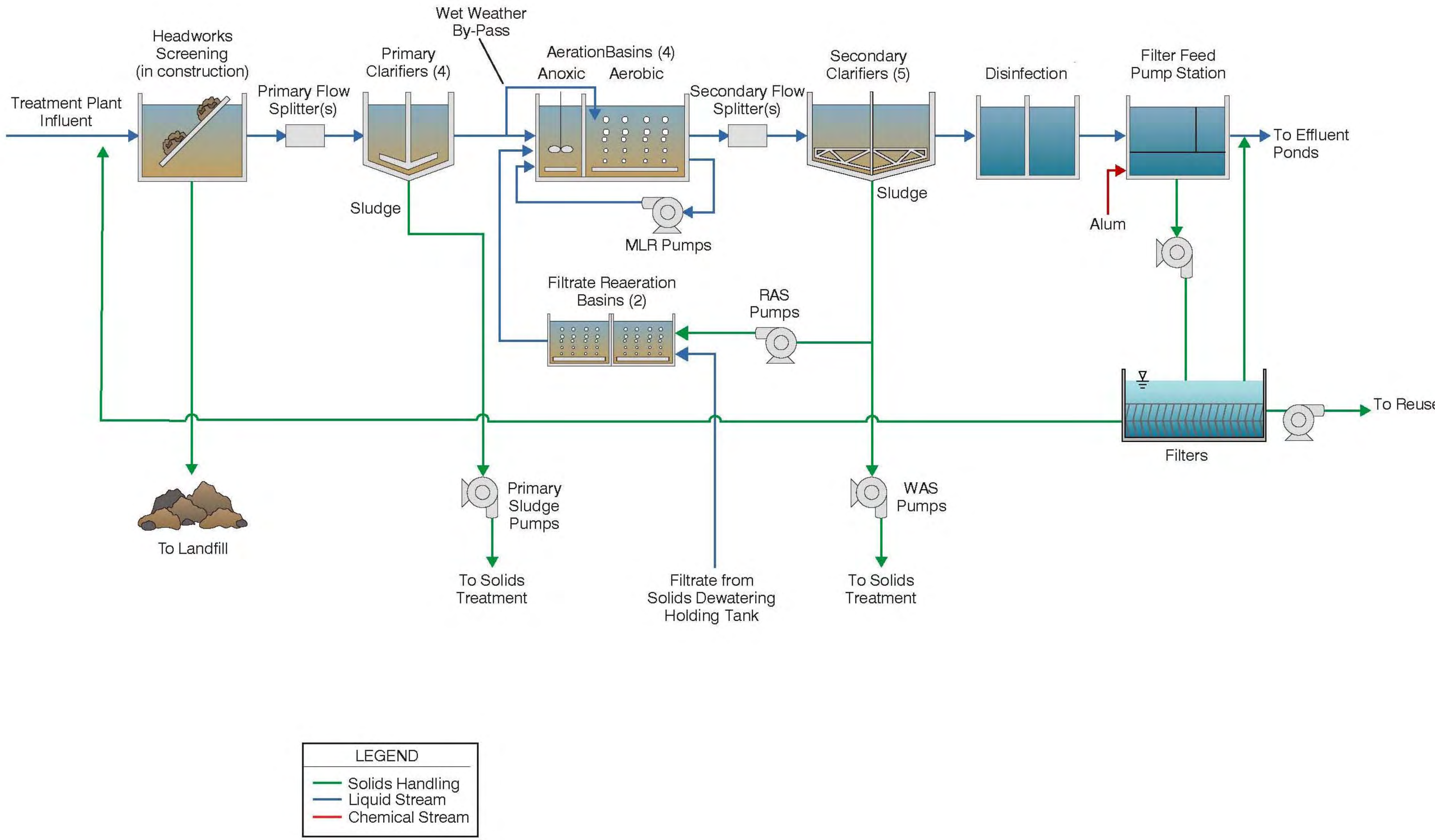

Figure 6 Process Flow Schematic for 2030