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PHASE 1 SWWRF PROCESS ALTERNATIVES EVALUATION

1.0 INTRODUCTION

Orange County Utilities (OCU) plans to construct a new treatment facility to serve the Southwest Service Area (SWSA), and the existing portion of the South Service area (SSA) now served by the South Water Reclamation Facility (SWRF). The new Southwest Water Reclamation Facility (SWWRF) will be constructed with an initial (Phase 1) treatment capacity of 5 million gallons per day (mgd) on an annual average day flow (AADF) basis. The 2007 Facilities Plan recommended a five-stage Bardenpho® (B5) process combined with a membrane bioreactor (MBR) process. The reclaimed effluent from the treatment plant will be primarily used for Public Access Reuse (PAR) with possible wet weather discharge to the Water Conserv II (WC II) rapid infiltration basins (RIBs).

2.0 OBJECTIVES

OCU, as part of the scope of services of this Task Authorization, retained the Carollo team to re-evaluate the technology selected for the biological process, in particular the MBR process recommended in the 2007 Facilities Plan. The purpose of this technical memorandum (TM) is to perform a detailed evaluation of five treatment process configurations including the MBR alternative to recommend the most efficient process for implementation.

The biological treatment process re-evaluation was completed using economic and non-economic considerations. The economic evaluation developed planning level costs for capital, operations and maintenance (O&M), and net present worth costs for the five alternatives. The non-economic evaluation used a weighted matrix approach, based on both cost and non-cost factors, to compare the five alternatives. The non-economic evaluation factors included the flexibility to upgrade or expand the facility in the future, effluent water quality, facility footprint, energy consumption, biosolids production, and facility staffing requirements.

3.0 ALTERNATIVE EVALUATION DESIGN CRITERIA

3.1 Phase I Influent Wastewater Characteristics

Phase I of the SWWRF will be designed to treat a flow of 5 mgd, on an (AADF) basis. TM No. 1 – SWWRF Basis of Design Criteria provided the basis for selection of the influent wastewater characteristics used to compare the treatment processes. TM No. 3 – Wastewater Load Projections provides the wastewater pollutant loading for design of the

Phase I SWWRF. Anticipated influent wastewater flows for Phase I are presented in Table 3.1

Table 3.1 SWWRF Phase I Influent Wastewater Flow Characteristics SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Design Parameter	Unit	Value
Annual Average Influent Flow (AADF)(1)	mgd	5.0
Maximum Month Flow (MMF) Peaking Factor	–	1.3
Maximum Day Flow (MDF) Peaking Factor	–	1.7
Peak Hour Flow (PHF) Peaking Factor	–	3.0
Minimum Day Flow (MnDF) Peaking Factor(2)	–	0.3
Maximum Month Influent Flow (MMF)(3)	mgd	6.5
Maximum Day Influent Flow (MDF)(4)	mgd	8.5
Peak Hour Influent Flow (PHF)(5)	mgd	15.0
Minimum Day Influent Flow (MnDFf)	mgd	1.5
First Year Average Day Flow	mgd	2.0

Notes:

(1) AADF is the flow rate occurring over a 24-hour period based on the annual average flow.

(2) Assumed based on data available from OCU's South Water Reclamation Facility (SWRF).

(3) MMF is the average flow rate occurring over a 24-hour period based on the average flow during the calendar month with the highest average influent flow.

(4) MDF is the maximum flow rate sustained over a 24-hour period during a calendar year.

(5) PHF is maximum flow rate sustained over a 1-hour period during a calendar year.

Table 3.2 presents the influent wastewater pollutant concentrations and mass loadings that were used to size the treatment processes. The maximum month pollutant mass loadings were used to size the biological process reactors while the maximum day flow was used to size the secondary clarifiers. The PHF was used to size the tertiary filters, and the aeration system was sized to handle the maximum day demands. The PHF should be used to size the hydraulic elements in the facility.

Table 3.2 SWWRF Phase I Influent Wastewater Pollutant Characteristics SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Parameter	Design Parameter	Unit	Value
Carbonaceous 5-day Biochemical Oxygen Demand ($cBOD_5$)	$cBOD_5$, AA	mg/l	290
	$cBOD_5$ mass loading, AA	lb/day	12,093
	$cBOD_5$ mass loading MM/AA Peaking Factor	–	1.2
	$cBOD_5$ mass loading MD/AA peaking factor	–	1.8
	$cBOD_5$ mass loading MM	lb/day	14,512
	$cBOD_5$ mass loading MD	lb/day	21,767
Chemical Oxygen Demand (COD)	COD, AA	mg/l	695
	COD mass loading, AA	lb/day	28,982
	COD mass loading MM/AA peaking factor	–	1.2
	COD mass loading MM	–	34,778
Total Suspended Solids (TSS)	TSS, AA	mg/l	300
	TSS mass loading, AA	lb/day	12,510
	TSS mass loading MM/AA peaking factor	–	1.2
	TSS mass loading, MM	lb/day	15,012
Volatile Suspended Solids (VSS)	VSS, AA	mg/l	240
	VSS mass loading, AA	lb/day	10,008
	VSS mass loading MM/AA Peaking factor	–	1.2
	VSS mass loading, MM	–	12,010
Total Kjeldahl Nitrogen (TKN)	TKN, AA	mg/l	46
	TKN mass loading, AA	lb/day	1,918
	TKN mass loading MM/AA peaking factor	–	1.2
	TKN Mass loading MD/AA Peaking factor	–	1.6
	TKN mass loading, MM	lb/day	2,302
	TKN mass loading, MD	lb/day	3,069
Total Phosphorus (TP)	TP, AA	mg/l	8
	TP mass loading, AA	lb/day	334
	TP mass loading, MM/AA peaking factor	–	1.2
	TP mass loading, MM	lb/day	400

Table 3.3 presents various other influent wastewater and site characteristics that will influence the design of the biological process.

Table 3.3 **SWWRF Phase I Other Characteristics[1]**
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Design Parameter	Unit	Value
Wastewater Minimum Winter Temperature	^oC	20
Wastewater Maximum Summer Temperature	^oC	30
Wastewater Influent Ph	pH units	7.4[1]
Site Elevation (Above MSL)	ft	130
Barometric Pressure	psia	14.7
Minimum Winter Air Temperature	^oC	0
Maximum Summer Air Temperature	^oC	35
Maximum Relative Humidity	%	90
Wastewater Influent Alkalinity	mg/l as $CaCO_3$	270[1]

Notes:

(1) Assumed based on data available from OCU's SWRF.

3.2 Phase I Effluent Water Quality Goals

Phase I of the SWWRF will be designed to produce reclaimed water meeting the water quality criteria for both Advanced Wastewater Treatment (AWT) and Public Access Reuse (PAR) in Florida with effluent meeting the Florida "5:5:3:1 standard (5 mg/L $cBOD_5$, 5 mg/L TSS, 3 mg/L total nitrogen [TN], and 1 mg/L TP, respectively) with high level disinfection (Title XXIX Chap. 403.086 (4) (a) (b) F.S.). Table 3.4 provides a summary of the effluent water quality goals for Phase I of SWWRF. Effluent from Phase I of the SWWRF is anticipated to be used for PAR, with possible wet weather discharge to the Water Conserv II (WC II) rapid infiltration basins (RIBs).

Table 3.4 SWWRF Phase I – Effluent Water Quality Goals
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Parameter	**SWWRF Phase I WQ Goal(1)**
$cBOD_5$	≤ 5 mg/l (annual average)
TSS	≤ 5 mg/l (annual average)
TN	≤ 3 mg/l (annual average)
TP	≤ 1 mg/l (annual average)
pH	6.0 – 8.5 pH units
Chlorine Disinfection Mixing Criteria(2)	Rapid and uniform
Fecal Coliform(2), #/100 Ml	Over a 30-day period, 75% of values below detection limits. Any one sample ≤ 25 per 100 mL sample
Chlorine Residual(2), Mg/L	1.0 mg/l single sample minimum
Chlorine Contact Time At Peak Hour(2)	≥ 15 minutes
Product Of Total Chlorine Residual And Contact Time (CT) At Peak Hour Flow(3)	≥ 25 mg/l-min

Notes:
(1) OCU has adopted a policy that regardless of the reclaimed water management alternative, the SWWRF will be designed to produce effluent water quality to meet Florida AWT standards.
(2) High-level disinfection requirements are specified in Rules 62-600.440(5) and 62-610.460 of the F.A.C.
(3) Assuming a fecal coliform concentration less than 1000 /100 ml prior to chlorine disinfection.

The alternatives evaluation in this memorandum does not include a qualitative review of technologies or evaluations of unit processes that are common to the five alternatives such as screening, grit removal, odor control, secondary clarification, tertiary filtration (unless specific and special to the biological alternative being evaluated), disinfection, and biosolids handling. Design criteria for these unit processes are adopted from the 2007 Facilities Plan (PBS&J/CDM) recommendations. However, planning level cost estimates (capital, O&M, and life cycle costs) developed for each of the five alternatives included all unit processes

Each of the five alternatives will have similar preliminary treatment (center flow traveling band screens (6 mm opening) followed by a vortex type grit removal system and odor control. The filtered secondary effluent will be disinfected using bulk sodium hypochlorite in chlorine contact tanks with a serpentine flow path. The disinfected water will be transferred to a storage tank with vertical turbine type pumps mounted in a sump at the end of the chlorine contact tanks. Reclaimed water will be pumped using another set of vertical turbine type pumps from the ground storage tank(s) to the reclaimed water distribution system. In the event the treated secondary effluent does not meet the reclaimed water quality (typically when an alarm is registered for high turbidity, > 2 NTU, or low chlorine residual, < 0.5 mg/l or pH outside the 6.0 – 9.0 range), the transfer pumps will divert the water to a reject storage tank. Substandard reclaimed water (reject water) is required to be either stored for subsequent additional treatment or discharged to another permitted effluent disposal system (as specified under 62:610.463(2) of F.A.C). The reject water will either be pumped to RIB Site 6 for disposal or pumped back to the head of the facility for re-treatment or to the head of the tertiary filters similar to operating permit requirements for OCU's South Water Reclamation Facility (SWRF). This analysis assumes reject water will be stored in a pre-stressed concrete tank(s) before being diverted to appropriate disposal system.

Waste activated sludge (WAS) from the biological process will be initially held in aerobic holding tanks. WAS will be thickened using rotary drum thickeners and stored in aerobic, thickened sludge holding tanks. The thickened waste activated sludge will be dewatered using belt filter presses. It is assumed that dewatered cake will be either further processed on-site or hauled off-site for further processing. The economic analysis performed as part of this task does not include dewatered cake processing. Detailed design criteria for each of the unit processes are provided in Appendix B of this memorandum.

4.0 SECONDARY LIQUID TREATMENT ALTERNATIVES ANALYSIS

TM No. 2 provided the basis for selection of the five alternatives that are listed below:

- Alternative No. 1 – B5 process, secondary clarifiers, and disk filters.
- Alternative No. 2 – B5 process, secondary clarifiers, and tertiary membranes.
- Alternative No. 3 - Step-feed BNR process with post-anoxic zones, secondary clarifiers, and disk filters.
- Alternative No. 4 - Three-stage BNR process, secondary clarifiers, and denitrification filters.
- Alternative No. 5 – B5 / MBR process (recommended in the 2007 Facilities Plan).

The following paragraphs provide a brief description of each of the five secondary liquid treatment alternatives.

4.1 Alternative No. 1 – B5 Process with Secondary Clarifiers and Disk Filters

Alternative No. 1 is a B5 process followed by secondary clarifiers and cloth disk type filters. The conventional B5 process consists of a sequence of anaerobic, pre-anoxic, aerobic, post-anoxic, and re-aeration zones. Secondary clarifiers separate the mixed liquor generated within the B5 process. Secondary effluent is filtered using cloth disk type filters. Figure 4.1 presents the process flow diagram for the conventional B5 alternative.

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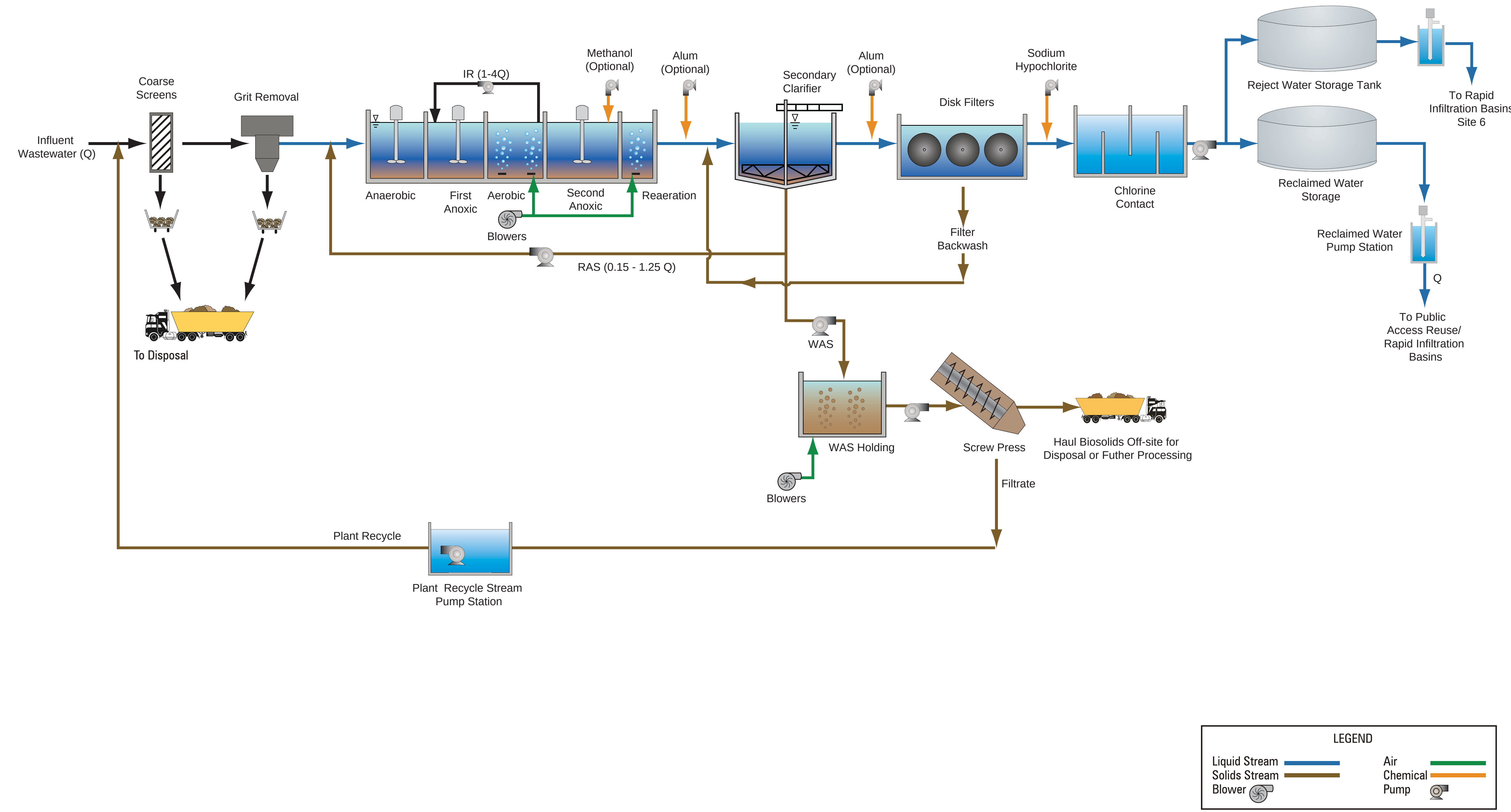

TM 6 – PHASE 1
SWWRF PROCESS ALTERNATIVES EVALUATION

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SWWRF PHASE I ALTERNATIVE NO. 1 - FIVE STAGE BARDENPHO (B5) WITH SECONDARY CLARIFIERS AND DISK FILTERS

FIGURE 4.1

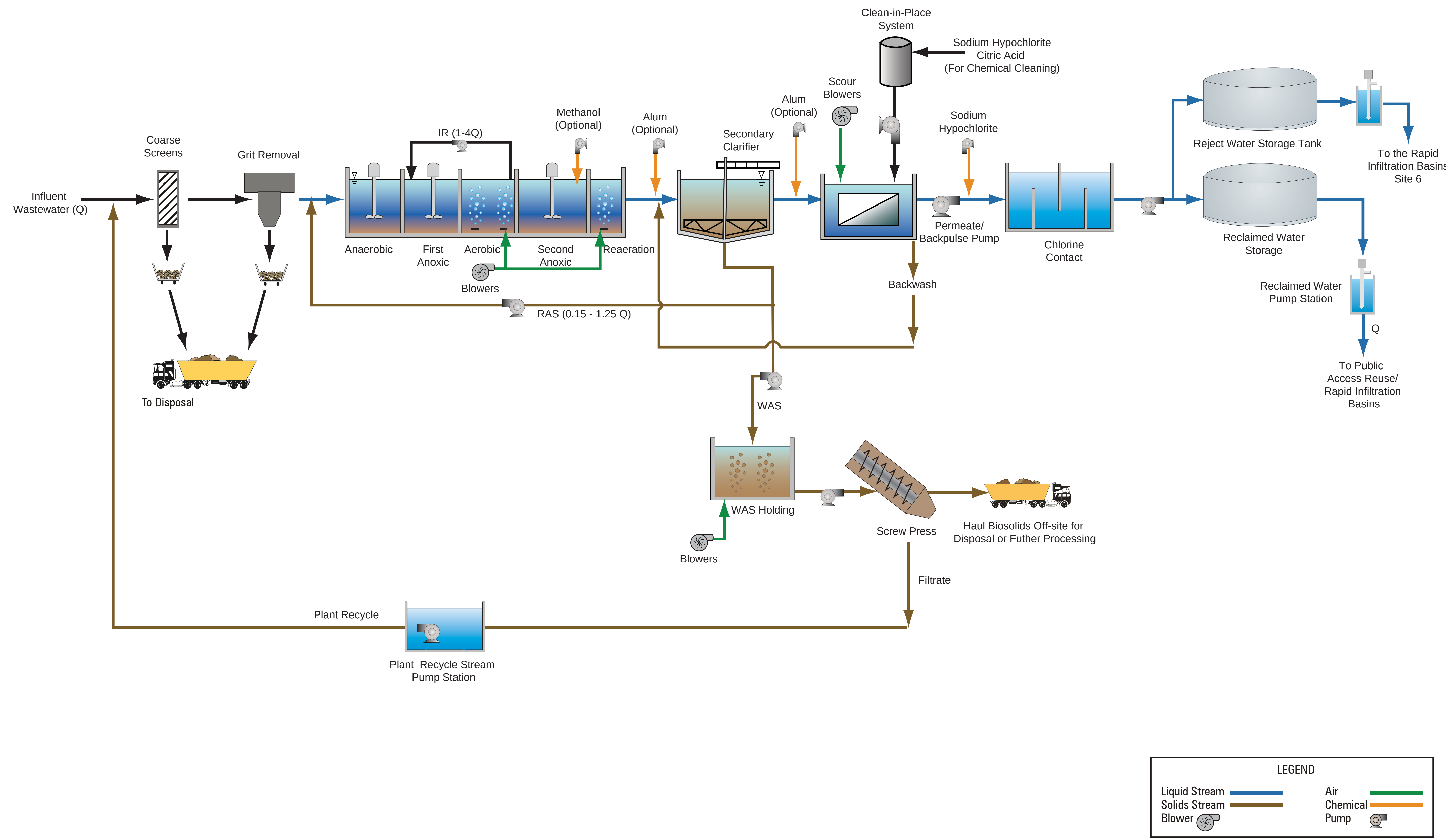
The anaerobic zone primarily provides reaction time for the adsorption of volatile fatty acids (VFAs) by the polyphosphate accumulating organisms (PAOs) with the concurrent release of phosphorus. The anaerobic zone also allows for additional fermentation of the influent $cBOD_5$ for generating easily bio-degradable short-chain VFAs, primarily acetic and propionic acids. The mixed liquor then enters the pre-anoxic zone where $cBOD_5$ is used by heterotrophic bacteria to reduce the nitrates recycled from the aerobic zone to nitrogen gas. The denitrification in the pre-anoxic zone is typically not limited by the availability of carbon. The remaining $cBOD_5$ and ammonia is oxidized in the aerobic zone concurrently with the uptake of orthophosphate by the PAOs. Ammonia is converted to nitrate, and a portion of this nitrate is recycled back to the pre-anoxic zone for denitrification. The post-anoxic zone removes the nitrates leaving the aerobic zone that were not recycled back to the pre-anoxic zone. Denitrification in the post-anoxic zones is generally limited by the availability of carbon. Supplemental carbon can be added as needed to the post-anoxic zone to provide the necessary carbon substrate for the denitrification process. The fifth stage is the re-aeration zone where any bubbles of nitrogen gas are stripped from the mixed liquor suspended solids, and any ammonia released within the post-anoxic zone is converted to nitrate. This re-aeration zone also helps increase the dissolved oxygen concentration of the mixed liquor and reduces further denitrification within the sludge blanket in the secondary clarifier.

Mixed liquor suspended solids (MLSS) from the B5 process will be conveyed to the secondary clarifiers. Sludge from the bottom of the clarifiers will be collected in a slowly rotating rectangular shaped header pipe with orifices (hydraulic suction type sludge header pipe). The sludge enters the header pipe via the orifices and is drained into a sludge draw-off pipe that is directly connected to variable-speed, horizontal, non-clog centrifugal pumps (called the return activated sludge or RAS pumps). The RAS pumps return most of the MLSS back to the anaerobic zone to maintain the design MLSS concentration as required for the biological process. A separate set of horizontal, non-clog centrifugal pumps transfer a portion of the MLSS (WAS) for further treatment and disposal to maintain the appropriate solids retention time (SRT) as required for the process.

The clarified effluent from the secondary clarifiers will be filtered using submerged cloth media filters. Cloth fabric is wrapped over five of six individual pie shaped polygon support frames which are then connected together to form a circular shaped disk. A total of up to 12 such disks are mounted vertically in a stainless steel tank. The disks are supported by a hollow shaft in the center of each filter tank that forms the collection pipe for the filtrate. Inlet wastewater enters each filter tank and flows by gravity through the cloth media. The filtered water collects inside each disk and is directed to the center shaft. The flow configuration is from outside to inside of the cloth media. The nominal pore size of the cloth media filters is around 10 microns, and hence particles 10 microns and large will be removed by the filters. As the head loss increases across the disk, a backwash cycle is initiated to clean each of the disks individually, while the remaining disks continue filtering the wastewater. Backwash water is returned back to the head of the plant together with other plant recycles. The backwash volume is typically 2 - 5 percent of the influent flow. Periodically, the solids collected at the bottom of the steel tank are pumped back to the head of the plant. Typically the peak hydraulic loading rate for cloth disk filters for secondary effluent is about 6.5 gpm/ft^2.

4.2 Alternative No. 2 – B5 Process with Secondary Clarifiers and Tertiary Membrane Filters

Alternative No. 2 is similar to Alternative No. 1 with the exception that the secondary effluent is filtered using submerged ultrafiltration (UF) membranes in place of cloth disk filters. Figure 4.2 presents the process flow diagram for this alternative. The commercially available low-pressure membranes can be grouped into two categories. These are submerged and pressurized membranes. This evaluation is based on submerged membranes. The submerged membranes have cassettes or modules that are placed in a tank. Water flows by gravity into the tank and the filtrate is “pulled” through the membranes using vacuum pumps on the filtrate side of the membranes. The nominal pore size for ultrafiltration membranes for this application is typically about 0.04 microns with a typical operating transmembrane pressure (TMP) of 1 - 13 psig. Typical average flux values when filtering secondary effluent with UF membranes are between 15 - 30 gfd (gallons per day per ft^2). A more detailed description of the commercially available tertiary membrane filters is presented in Appendix B of TM2.



SWWRF PHASE I ALTERNATIVE NO. 2 - FIVE STAGE BARDENPHO (B5) WITH SECONDARY CLARIFIERS AND TERTIARY MEMBRANE FILTERS

FIGURE 4.2

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TM 6 – PHASE 1
SWWRF PROCESS ALTERNATIVES EVALUATION

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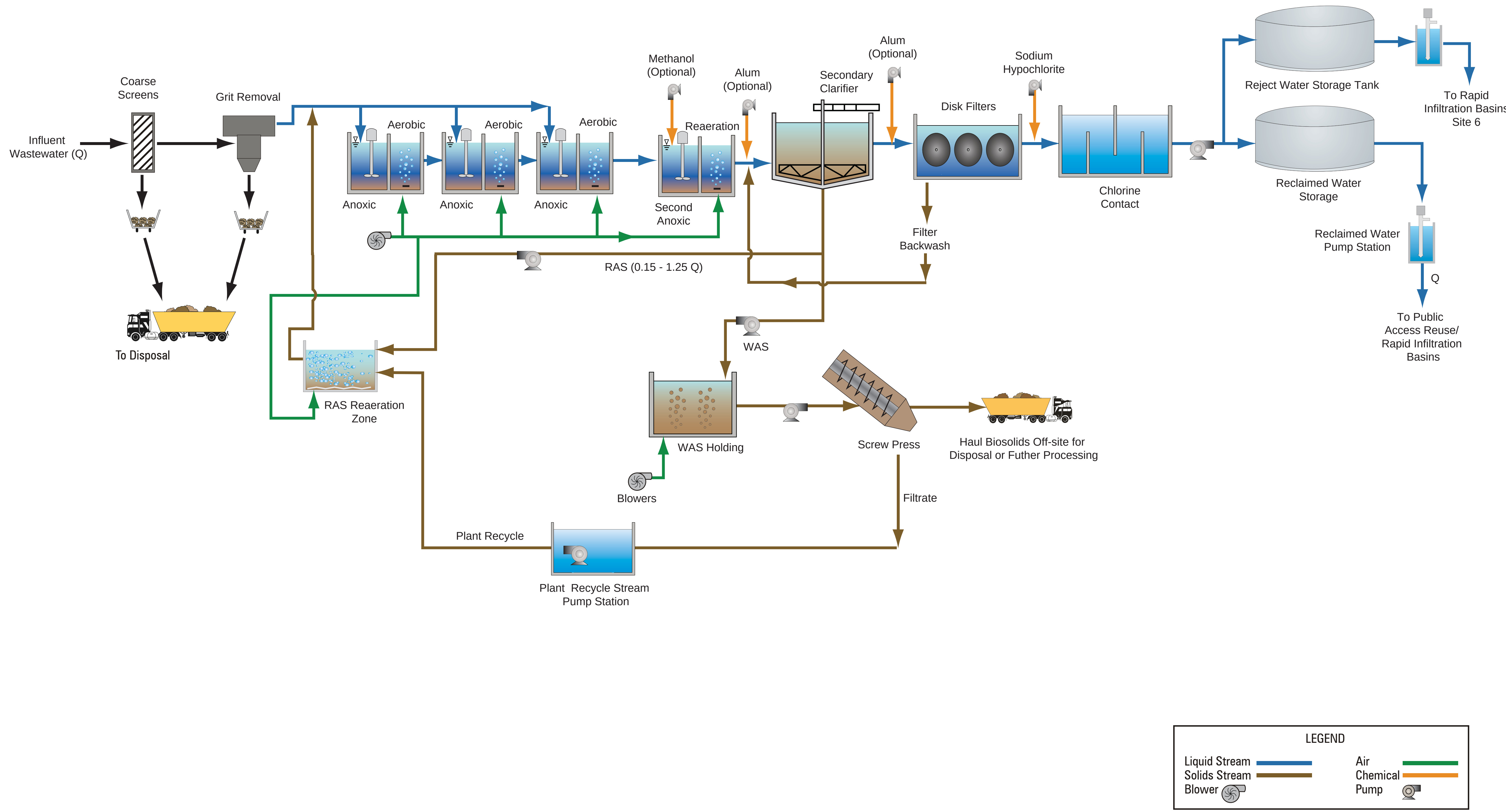
4.3 Alternative No. 3 – Step-Feed BNR Process with Secondary Clarifiers and Cloth Disk Filters

Step-feed BNR is a specific arrangement of an activated sludge reactor where the feed is split and distributed to multiple locations within the process tank. Step-feed was originally developed to equalize the spatial distribution of the oxygen demand throughout the aeration tank. However, the split feed arrangement also creates a gradient in the MLSS concentration with the highest concentration occurring in the first pass, with the MLSS concentration reducing after each subsequent feed point in proportion to the dilution factor of the wastewater added at each feed point. As a result, the total biomass inventory in a step-feed bioreactor is significantly higher than in a conventional bioreactor of the same volume with a single MLSS feed point at the beginning of the tank. The Step-feed BNR process alternative uses un-aerated zones at each feed point thus creating a sequence of anoxic and aerobic zones along the length of the bioreactor. Post anoxic tanks are needed to achieve the TN goal of ≤3 mg/L. A small re-aeration zone after the post anoxic tank will strip nitrogen gas from the biomass and nitrify any residual ammonia produced in the post anoxic zone. Secondary clarifiers will be used to separate MLSS in the secondary effluent. The secondary effluent is filtered using cloth disk filters. The configuration used for this evaluation is based on a three pass step-feed BNR basin with each of the three passes having a series of three pre-anoxic zones followed by an aerobic zone. The evaluation did not include internal recycle between the aerobic and the pre-anoxic zone, although this feature could be investigated during detailed design for further optimization of the step-feed process. Also, this alternative does not include an upstream anaerobic zone although modeling suggests that the first pass anoxic zone will function as an anaerobic zone. Biological phosphorus removal could be limited with this configuration and chemical (alum) addition may be necessary to achieve the effluent TP goal of <1 mg/l. Figure 4.3 presents the process flow diagram for this alternative.



TM 6 – PHASE 1
SWWRF PROCESS ALTERNATIVES EVALUATION

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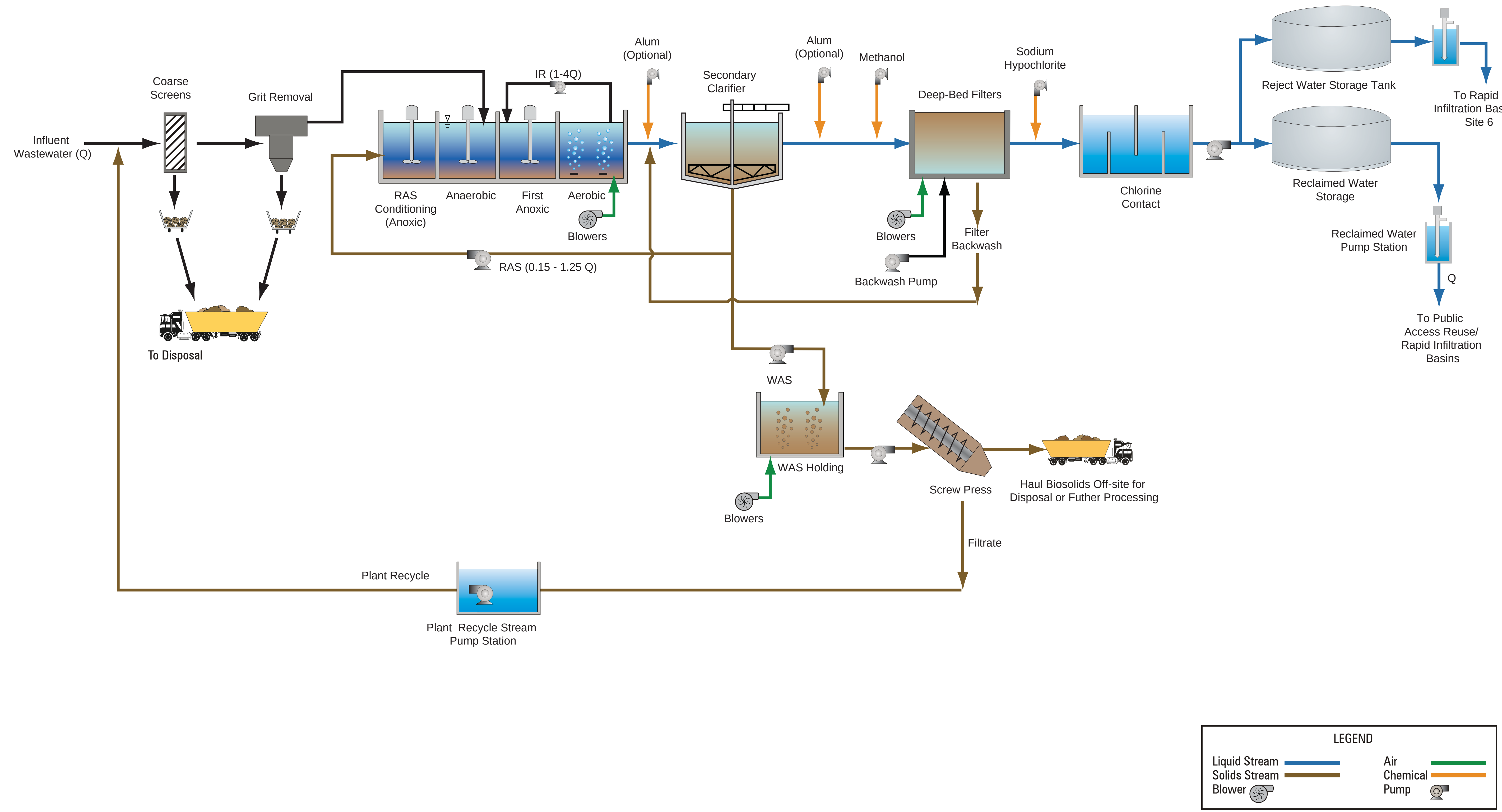
SWWRF PHASE I ALTERNATIVE NO. 3 - STEP-FEED BNR WITH SECONDARY CLARIFIERS AND DISK FILTERS

FIGURE 4.3

4.4 Alternative No. 4 – Three-stage BNR Process with Secondary Clarifiers and Denitrification Filters

The proposed three-stage BNR process uses a sequence of anaerobic, anoxic and aerobic stages to obtain both nitrogen and phosphorus removal. The process configuration for this alternative consists of an anaerobic zone followed by an anoxic zone followed by an aerobic zone. A RAS conditioning zone (anoxic) is included on the RAS feed upstream of the anaerobic zone to reduce any nitrates in the RAS thus protecting the anaerobic zone. This process configuration is typically called the Johannesburg. In this process configuration the screened and degritted wastewater is fed to the anaerobic zone. A portion of the mixed liquor from the aerobic zone is recycled back to the pre-anoxic zone for partial denitrification. Typical internal mixed liquor recycle rates (IMLR) vary from 2Q to 4Q (where Q is the influent flow). Higher IMLR rates provide marginal benefits, and could increase the potential for dissolved oxygen recycle back to the anoxic zone. The effluent TN concentrations achievable with three-stage BNR processes are in the range of 8 – 12 mg/L. Hence, an additional process is required downstream of the secondary clarifiers to reduce the TN to 3 mg/L. The use of denitrification filters provides this capability. The denitrification filters will also remove solids to meet the TSS limit of 5 mg/L. A detailed description of denitrification filters is provided in Appendix B of TM2. Figure 4.4 presents the process flow diagram for this alternative.



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TM 6 – PHASE 1
SWWRF PROCESS ALTERNATIVES EVALUATION

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SWWRF PHASE I ALTERNATIVE NO. 4 - THREE STAGE BNR WITH SECONDARY CLARIFIERS AND DEEP-BED DENITRIFICATION FILTERS

FIGURE 4.4

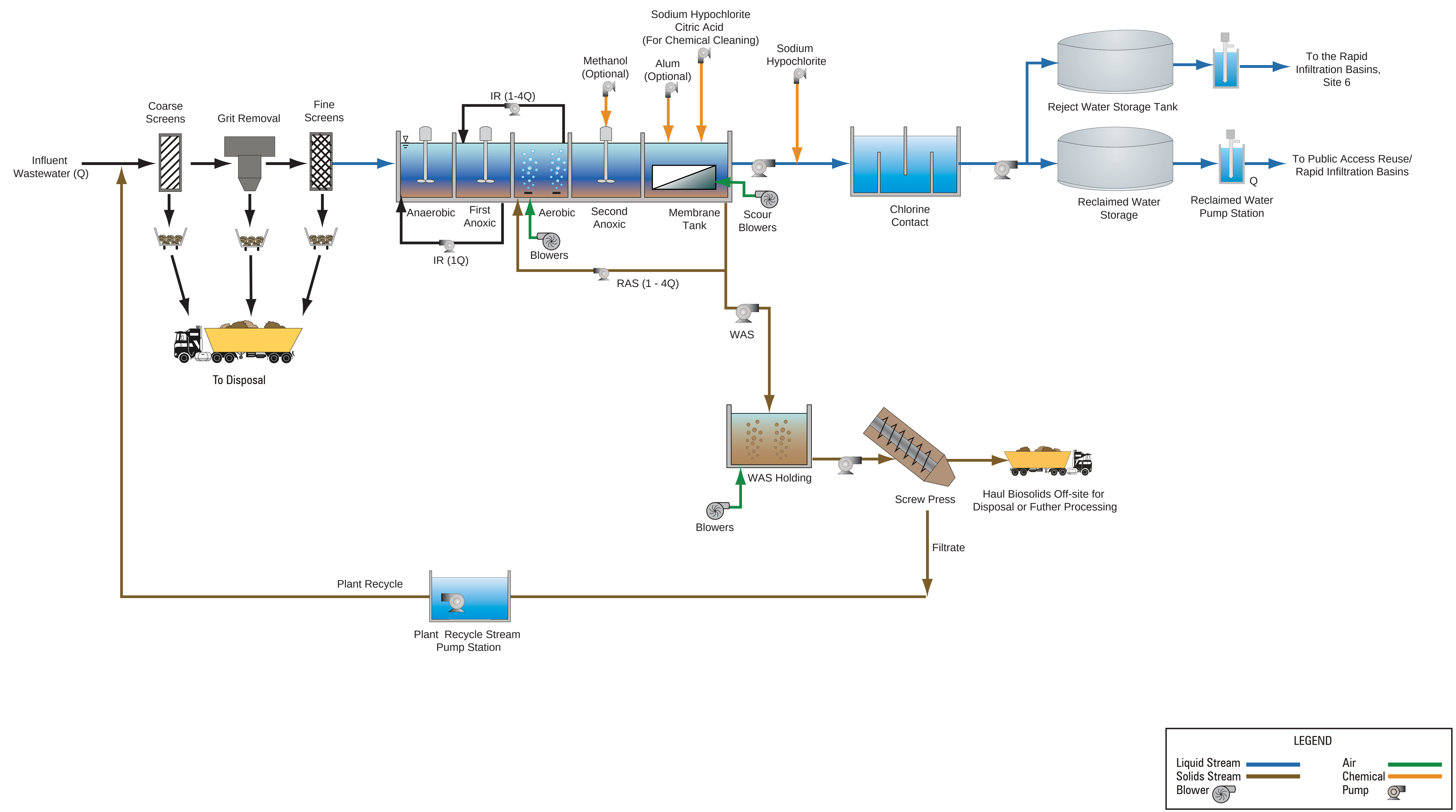
4.5 Alternative No. 5 – B5 / Membrane Bioreactor (MBR) Process

The MBR process couples the activated sludge process with low-pressure membranes. The membranes provide solids separation, and combine the secondary clarification and tertiary filtration processes with one unit process. The upstream biological treatment process is similar as described Alternative No. 1 with the exception that the membrane tanks also provide re-aeration. Figure 4.5 shows the process schematic for this alternative.

As a result of using membranes for solids separation, MBR processes can operate at much higher MLSS concentrations as compared to a conventional activated sludge process. The higher MLSS concentrations result in a small overall footprint. As shown in Figure 4.5, all of the RAS flow is routed to the aerobic zone to take advantage of the high dissolved oxygen (almost near saturation) in the membrane tanks reducing the process air requirements in the aerobic zone. Recycle from the end of the first anoxic to the anaerobic zone returns denitrified mixed liquor to provide the necessary biomass to facilitate biological phosphorus removal.

The effluent water quality from an MBR process with respect to TSS, turbidity and microbiological quality is similar to that anticipated from Alternative No. 2 and superior to the other three alternatives. Comparison of the effluent water quality, that can be achieved with various filtration technologies, was presented in more detail in Appendix B of TM2.

One of the major MBR manufacturers has very recently introduced a few advancements (July 2011) in their MBR system which was not included as part of this analysis. With these advancements, the manufacturer claims that the cost of the MBR equipment can be reduced by 15% and additional energy savings of 20% in the operation of the MBR equipment can be achieved.



TM 6 – PHASE 1
SWWRF PROCESS ALTERNATIVES EVALUATION

SWWRF PHASE I ALTERNATIVE NO. 5 - FIVE STAGE BARDENPHO (B5) WITH MBR

FIGURE 4.5

5.0 RELIABILITY AND REDUNDANCY

EPA Class 1 criteria (EPA, 1974) were assumed as the minimum acceptable standards for facility reliability. This criteria could be modified based on input and discussions with OCU operations staff on their requirements for process and equipment redundancy. Table 5.1 presents a summary of the EPA reliability criteria as they were used to prepare layouts for each of the process alternatives.

Table 5.1 EPA Class 1 Reliability as Applicable to Phase I SWWRF
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Plant Component	Design Flow/Load	Required Reliability
Hydraulic Elements	PHF	Peak flow w/ largest unit out of service
Aeration System	MDF/Max. Wk	Design oxygen transfer w/ largest unit out; backup may be uninstalled; minimum 2 installed units
Biological Treatment	AADF/MMF	Minimum 2 equal volume cells or zones; no backup required
Secondary Clarifiers	MDF/PHF	75% design flow w/ largest unit out of service
Filtration	AAF/PHF	75% design flow w/ largest unit out of service
Disinfection	AAF/PHF	50% design flow w/ largest unit out of service
Biosolids Handling	MMF	
• Digestion		Minimum 2 tanks
• Mixing		Design capacity w/ one unit out
• Dewatering		Design capacity w/ one unit out

6.0 EVALUATION OF PROCESS ALTERNATIVES

6.1 Evaluation Based on Process Parameters

A combination of spreadsheet calculations followed by steady state and dynamic process simulations were conducted as part of the evaluation of each alternative to determine the required unit process volumes and other process requirements. All process simulations were completed using the BioWin software (Version 3.1) from EnviroSim Associates Ltd using the default kinetic and stoichiometric coefficients. Table 6.1 presents a summary of the process volumes and other key process parameters for the biological process for each of the five alternatives compared. Figures 6.1 through 6.5 provide preliminary layouts for each of the process alternatives.

Key assumptions used in the process calculations and modeling are presented in Appendix B.

Table 6.1 Summary of the Process Parameters for the Five Treatment Process Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Parameter	**Alternative No. 1**	**Alternative No. 2**	**Alternative No. 3**	**Alternative No. 4**	**Alternative No. 5**
	B5 process with disk filters	B5 process with tertiary membrane filters	Step-feed BNR process with disk filters	Three-stage BNR process with denitrification filters	B5/MBR Process
Unit Process Tank Volumes	**(All volumes in million gallons)**				
RAS Conditioning	-	-	0.14	0.19	-
Anaerobic Tank	0.27	0.27	-	0.27	0.27
Pre-anoxic Tank	1.36	1.36	0.98	0.58	0.66
Aerobic Tank	2.92	2.92	2.41	3.18	1.25
Post-anoxic Tank	0.86	0.86	1.0	-	0.21
Re-aeration Tank	0.14	0.14	0.14	-	-
MBR tank	-	-	-	-	0.21
Total Process Tank Volume	**5.55**	**5.55**	**4.67**	**4.22**	**2.60**
Other Key Parameters					
Average MLSS, (mg/l)	3,200	3,200	4,098	3,200	7,000
Aerobic SRT, (days)	6	6	6	6	6
Total SRT, (days)	11.8	11.8	9.4	8.4	11.6

Table 6.1 Summary of the Process Parameters for the Five Treatment Process Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Parameter	Alternative No. 1	Alternative No. 2	Alternative No. 3	Alternative No. 4	Alternative No. 5
	B5 process with disk filters	B5 process with tertiary membrane filters	Step-feed BNR process with disk filters	Three-stage BNR process with denitrification filters	B5/MBR process
Secondary Clarifier Surface Area (Ft^2)	20,106	20,106	20,106	20,106	
No. Of Secondary Clarifiers	4	4	4	4	-
Diameter Of Secondary Clarifier (Ft)	80	80	80	80	-
Process Air, (Scfm) (Adf)	4,900	4,900	5,100	5,700	5,100
Instantaneous Membrane Scour Air (Scfm)	-	-	-	-	9,600
Type Of Filters	Cloth disk	Immersed UF membranes	Cloth disk	Denitrification filters	Immersed UF membranes
Filter Surface Area Required (Ft^2)	1,940	540,000	1,900	2,100	482,000
Chlorine Contact Tank (CCT) - Minimum Detention Time At PHF (Minutes)	15	15	15	15	15
CCT Minimum Volume (Gallons)	156,400	156,400	156,400	156,400	156,400
WAS, (Lb/Day)	11,800	11,800	12,190	12,600	12,100
WAS, (Gpd)	201,000	201,000	207,000	214,000	206,000

6.2 Preliminary Site Layouts

OCU is currently in the process of acquiring a 52-acre parcel of property on the current WC II RIB Site 6, owned jointly by the City of Orlando and Orange County, for the construction of the SWWRF. Figure 6.1 presents an aerial photograph of the property selected for the SWWRF. The shape of the proposed site (essentially two parcels separated by existing RIBs and connected on the Southern end with a 100 feet wide strip of land) is not well suited for an efficient facility layout. The east parcel is approximately 31 acres while the west parcel is approximately 21 acres. The shape of the proposed site will require the various unit treatment processes to be located as necessary to fit within the available site restrictions. This will also add additional impervious area (pavement). OCU should consider acquiring the two RIBs located between the parcels of land to facilitate a more efficient design for the overall facility.

Figure 6.2 through Figure 6.6 provide preliminary layouts for each of the process alternatives. The intent of presenting the layouts for the five alternatives is to show how the major unit processes could fit together on the proposed site and provide an illustration of the overall site requirements for the five alternatives. The site layouts show all major unit processes for the Phase 1 facility (5 mgd), as well as adequate space for two additional 5 mgd future phases designed to treat the projected future flows to meet Florida AWT standards. This will be sufficient to treat up to the maximum projected build-out wastewater flow of 15 mgd. The layout for Alternative No. 5 (B5/MBR process) is the most compact as shown on Figure 6.6.

TM 4 of this task authorization discussed potential alternatives available for the used reclaimed water produced by future phases of this facility, such as surface water discharge, lake augmentation and direct aquifer recharge in addition to PAR and RIBs, and concluded that for the long term approach, direct aquifer recharge or aquifer recharge and recovery (ARR) could be attractive as a means of liberating some of the RIB sites for other uses. Therefore, planning for the SWWRF should consider reserving appropriate space on the proposed site plan for treatment facilities to treat a portion or all of the AWT effluent to meet the water quality required for direct potable aquifer recharge and recovery (Rule 62-610.560, F.A.C.).

OCU has already successfully performed a comprehensive 21 month pilot study, using filtered, un-chlorinated effluent from the SWRF and the Eastern Water Reclamation Facility (EWRF), to demonstrate the efficacy of a combination of a low pressure (UF) membrane followed by a high pressure (nanofiltration) membrane to meet the requirements for “full treatment and disinfection” (Rule 62-610.563(3), F.A.C.). The results of the study were accepted by FDEP.

As part of this task authorization, the Carollo team will evaluate other advanced treatment technologies that have the potential merit to provide similar high level treatment to meet the "full treatment and disinfection" requirements of Rule 62-610.563(3), F.A.C. and will summarize the facility requirements for up to two such treatment technologies in a subsequent technical memorandum.

For this memorandum, the site plans for Alternative No's 1, 3, and 4 have allocated adequate space for the addition of an integrated membrane treatment process, in the future, should it become necessary to produce an effluent meeting the water quality required for direct aquifer recharge. Similarly, Alternative No. 2 and Alternative No. 5 show adequate space for the addition of only high-pressure membrane treatment as both these alternatives already employ low-pressure membranes as part of the Phase 1 facilities.

AERIAL PHOTO OF THE PROPOSED LOCATION FOR THE SWWRF

FIGURE 6.1

TM 6 - IDENTIFICATION OF ALTERNATIVE TREATMENT TECHNOLOGIES

ORANGE COUNTY GOVERNMENT FLORIDA

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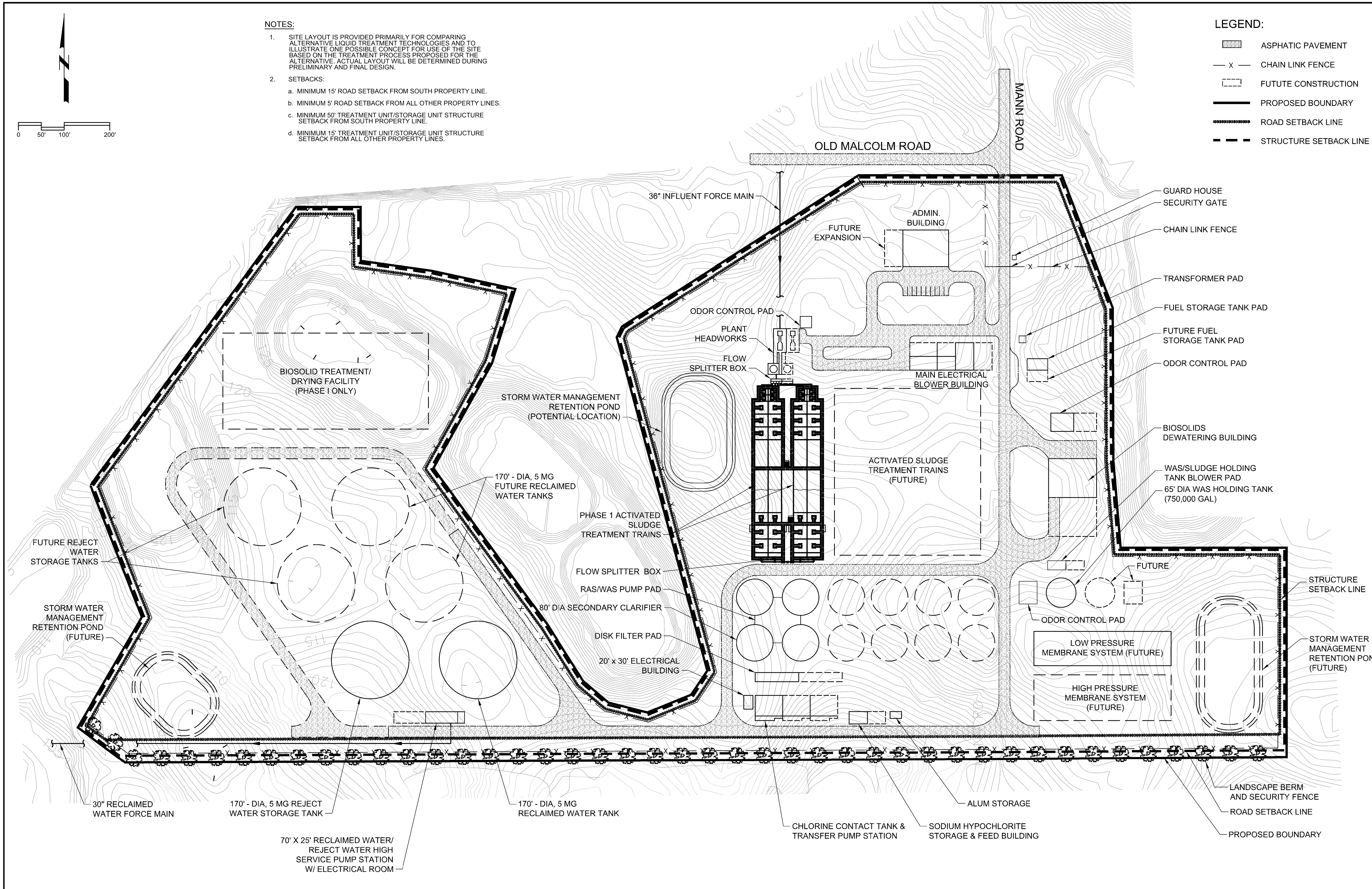

ALTERNATIVE No. 1 : B5 PROCESS WITH SECONDARY CLARIFIERS & DISK FILTERS - CONCEPTUAL SITE LAYOUT

FIGURE 6.2

TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

ORANGE COUNTY GOVERNMENT FLORIDA

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NOTES:

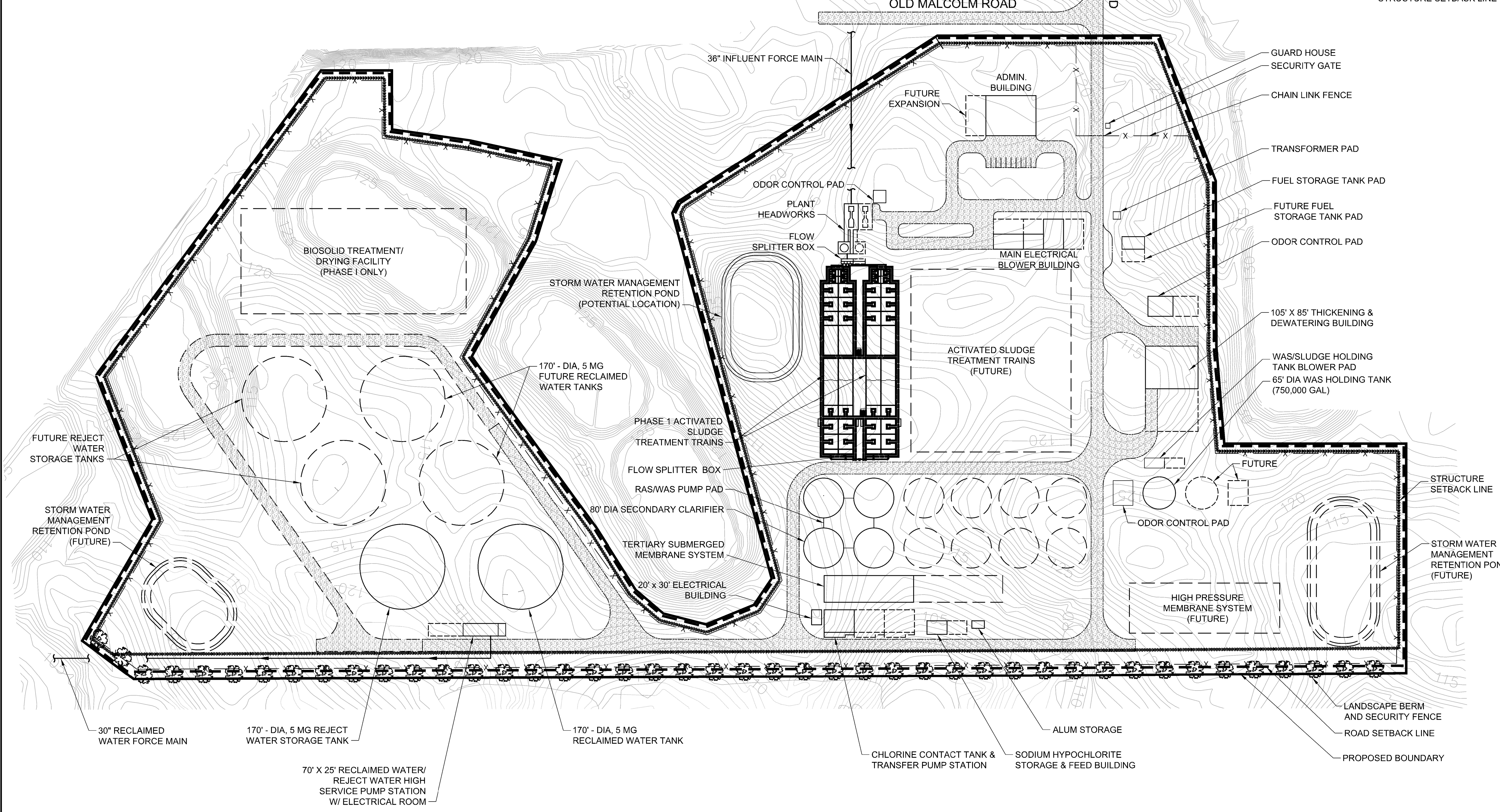
1. SITE LAYOUT IS PROVIDED PRIMARILY FOR COMPARING ALTERNATIVE LIQUID TREATMENT TECHNOLOGIES AND TO ILLUSTRATE ONE POSSIBLE CONCEPT FOR USE OF THE SITE BASED ON THE TREATMENT PROCESS PROPOSED FOR THE ALTERNATIVE. ACTUAL LAYOUT WILL BE DETERMINED DURING PRELIMINARY AND FINAL DESIGN.
2. SETBACKS:
   a. MINIMUM 15' ROAD SETBACK FROM SOUTH PROPERTY LINE.
   b. MINIMUM 5' ROAD SETBACK FROM ALL OTHER PROPERTY LINES.
   c. MINIMUM 50' TREATMENT UNIT/STORAGE UNIT STRUCTURE SETBACK FROM SOUTH PROPERTY LINE.
   d. MINIMUM 15' TREATMENT UNIT/STORAGE UNIT STRUCTURE SETBACK FROM ALL OTHER PROPERTY LINES.

0 50' 100' 200'

LEGEND:

- ASPHATIC PAVEMENT
- CHAIN LINK FENCE
- FUTUTE CONSTRUCTION
- PROPOSED BOUNDARY
- ROAD SETBACK LINE
- STRUCTURE SETBACK LINE

ORANGE COUNTY GOVERNMENT FLORIDA



TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

ALTERNATIVE No. 2 : B5 PROCESS WITH SECONDARY CLARIFIERS & MEMBRANES - CONCEPTUAL SITE LAYOUT

FIGURE 6.3

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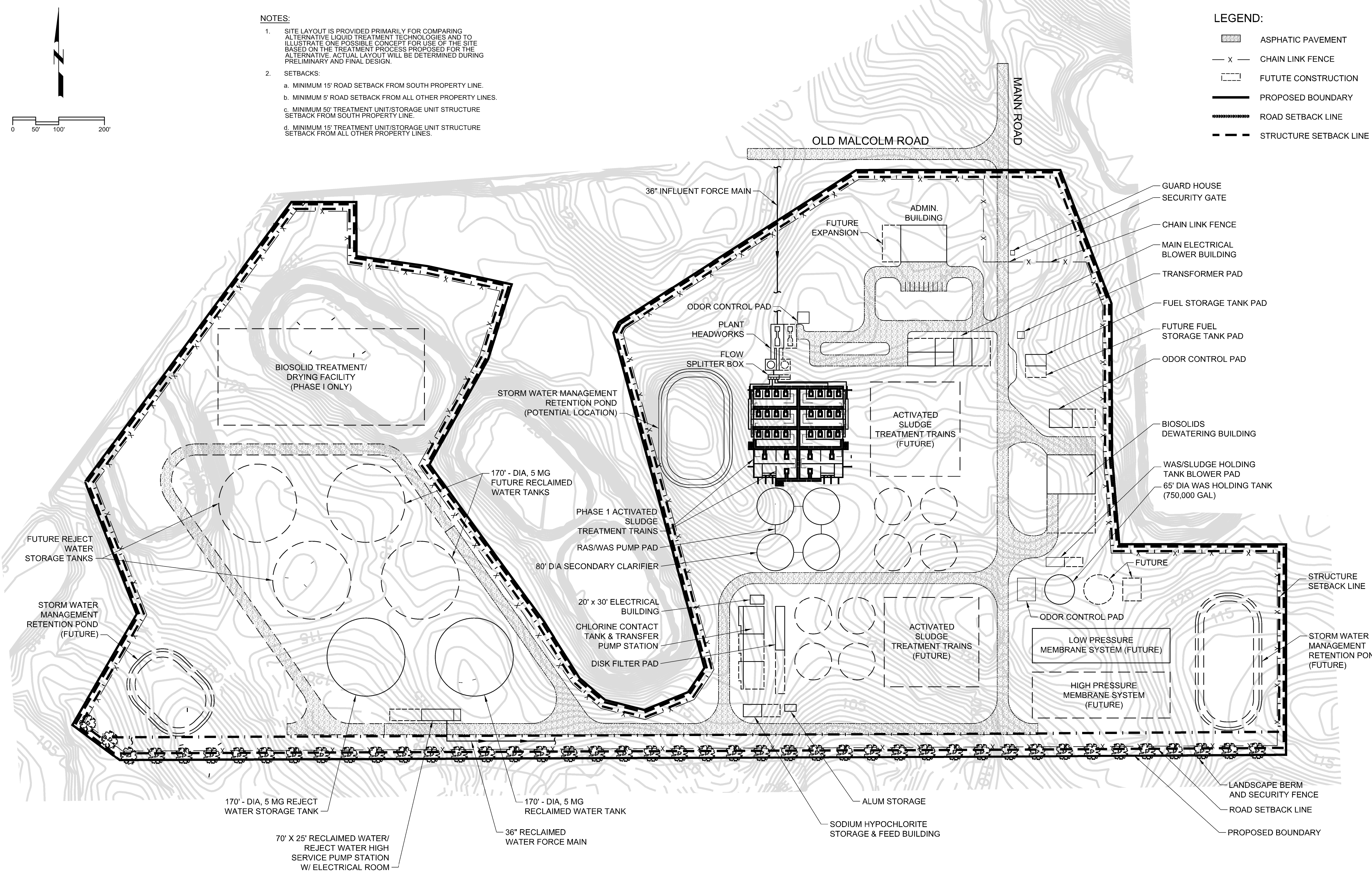
NOTES:

1. SITE LAYOUT IS PROVIDED PRIMARILY FOR COMPARING ALTERNATIVE LIQUID TREATMENT TECHNOLOGIES AND TO ILLUSTRATE ONE POSSIBLE CONCEPT FOR USE OF THE SITE BASED ON THE TREATMENT PROCESS PROPOSED FOR THE ALTERNATIVE. ACTUAL LAYOUT WILL BE DETERMINED DURING PRELIMINARY AND FINAL DESIGN.
2. SETBACKS:
   a. MINIMUM 15' ROAD SETBACK FROM SOUTH PROPERTY LINE.
   b. MINIMUM 5' ROAD SETBACK FROM ALL OTHER PROPERTY LINES.
   c. MINIMUM 50' TREATMENT UNIT/STORAGE UNIT STRUCTURE SETBACK FROM SOUTH PROPERTY LINE.
   d. MINIMUM 15' TREATMENT UNIT/STORAGE UNIT STRUCTURE SETBACK FROM ALL OTHER PROPERTY LINES.

LEGEND:

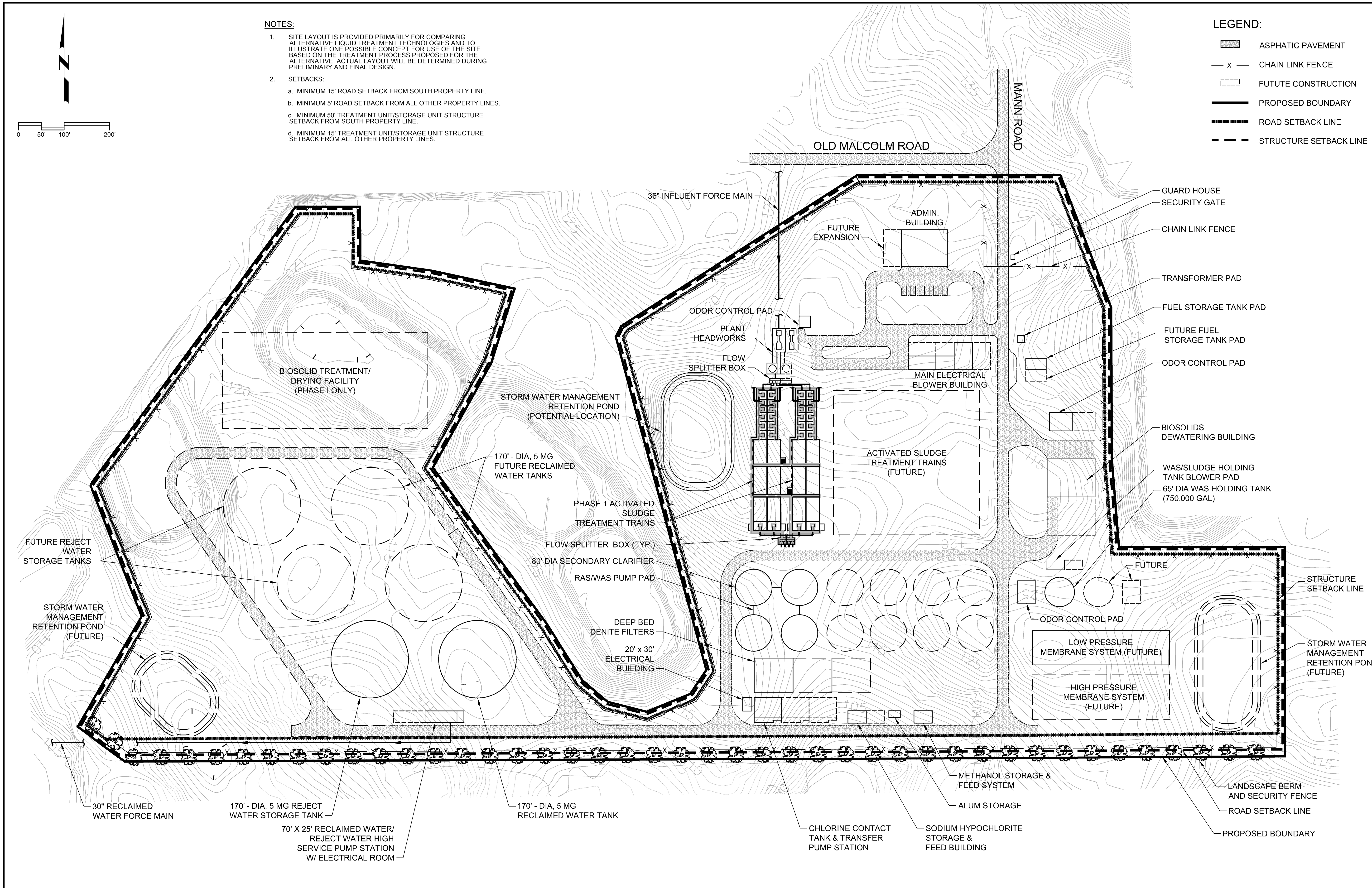
- ASPHATIC PAVEMENT
- CHAIN LINK FENCE
- FUTUTE CONSTRUCTION
- PROPOSED BOUNDARY
- ROAD SETBACK LINE
- STRUCTURE SETBACK LINE



ALTERNATIVE No. 3 : STEP-FEED WITH SECONDARY CLARIFIERS & DISK FILTERS - CONCEPTUAL SITE LAYOUT

FIGURE 6.4

TM6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION



ORANGE COUNTY GOVERNMENT F L O R I D A

TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

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ALTERNATIVE No. 4 : THREE-STAGE BNR PROCESS WITH SECONDARY CLARIFIERS AND DISK FILTERS - CONCEPTUAL SITE LAYOUT

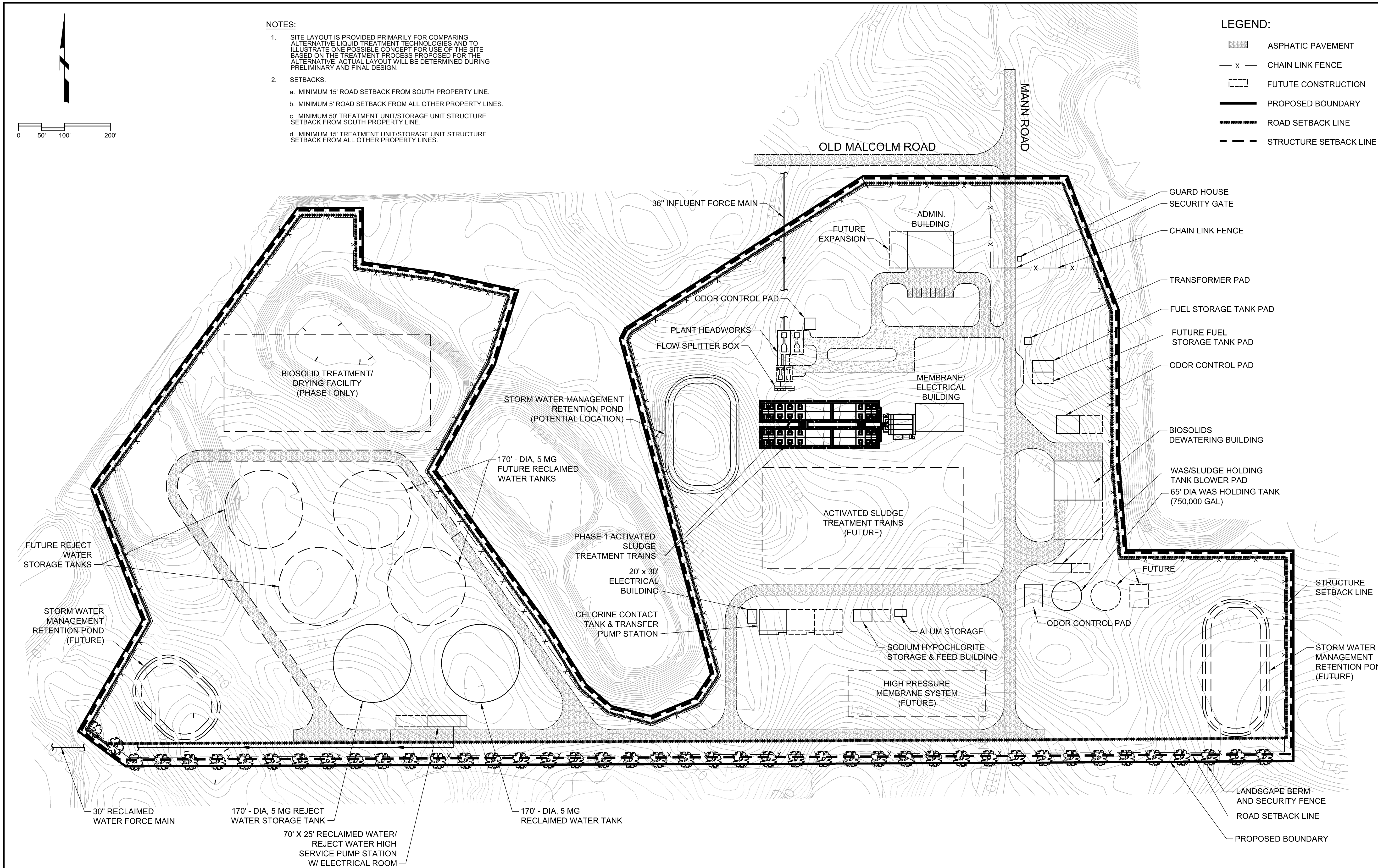
FIGURE 6.5

NOTES:

1. SITE LAYOUT IS PROVIDED PRIMARILY FOR COMPARING ALTERNATIVE LIQUID TREATMENT TECHNOLOGIES AND TO ILLUSTRATE ONE POSSIBLE CONCEPT FOR USE OF THE SITE BASED ON THE TREATMENT PROCESS PROPOSED FOR THE ALTERNATIVE. ACTUAL LAYOUT WILL BE DETERMINED DURING PRELIMINARY AND FINAL DESIGN.
2. SETBACKS:
   a. MINIMUM 15' ROAD SETBACK FROM SOUTH PROPERTY LINE.
   b. MINIMUM 5' ROAD SETBACK FROM ALL OTHER PROPERTY LINES.
   c. MINIMUM 50' TREATMENT UNIT/STORAGE UNIT STRUCTURE SETBACK FROM SOUTH PROPERTY LINE.
   d. MINIMUM 15' TREATMENT UNIT/STORAGE UNIT STRUCTURE SETBACK FROM ALL OTHER PROPERTY LINES.

LEGEND:

- ASPHATIC PAVEMENT
- CHAIN LINK FENCE
- FUTUTE CONSTRUCTION
- PROPOSED BOUNDARY
- ROAD SETBACK LINE
- STRUCTURE SETBACK LINE



ORANGE COUNTY GOVERNMENT FLORIDA

TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

ALTERNATIVE No. 5 : B5 PROCESS WITH MEMBRANE BIOREACTOR - CONCEPTUAL SITE LAYOUT

FIGURE 6.6

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6.3 Economic Evaluation

6.3.1 Construction Costs

The estimated probable construction costs for the five treatment process alternatives evaluated are summarized in Table 6.2. Detailed estimates for each alternative are provided in Appendix A.

These estimates of the probable cost of construction are considered Class 4 "Budget Level" estimates per the *Recommended Practice 18R-97 Cost Estimate Classification System for the Process Industries*, published in 1998 by the Association for the Advancement of Cost Engineering (AACE). Class 4 estimates are generally prepared based on limited information and subsequently have a fairly wide range of accuracy. Typically, engineering is from 1 percent to 15 percent complete, and would include at a minimum the following: estimates of plant capacity, preliminary layouts, process flow diagrams (PFDs) for the main process systems, preliminary engineering for the process, and preliminary equipment lists. Class 4 cost estimates are estimates made without detailed engineering data. An estimate of this type is normally used for budgetary and planning purposes, and was used here for the screening of alternative concepts. The expected accuracy range for Class 4 estimates is within +30 percent to -15 percent. This means that construction bids can be expected to fall within a range of 30 percent over the estimate to 15 percent under the estimate.

The cost estimates were developed by obtaining vendor quotes for supply of the major items of process equipment for the five alternatives. Installation costs, concrete costs, buildings and other incidental costs were developed using the assumptions presented in Table 6.2. The total estimated construction costs include the mechanical costs, installation costs, concrete and masonry work, paints, finishes, and other incidentals.

The following buildings were included in the cost estimate:

- Plant Administration and Operations Building – This building was assumed to be the same size (~8,000 ft^2) as the one included in the 2007 Facilities Plan.
- Main Electrical/Blower Building – Alternative No. 1 through Alternative No. 4 assumed that this building will house three single stage centrifugal blowers (2 duty/1 standby), an electrical room to house motor control centers (MCCs), variable frequency drives (VFDs) and other panels, and emergency back-up power generator(s) (~5,400 ft^2). Alternative No. 5 (B5/MBR process) assumed that the building, in addition to the electrical room, will also house the permeate pumps, RAS and WAS pumps, membrane back pulse pumps, membrane scour blowers and other ancillary equipment for the membrane system (~6,800 ft^2) as shown on the site layout in Figure 6.5.
- Thickening and Dewatering Building – It was assumed that this building will house

three screw presses (2 duty/1 standby) with space for one future screw press, screw press feed pumps, dewatered cake conveyor, truck bay, polymer storage and pump room, and other facilities (~6,800 ft^2)

- Sodium Hypochlorite Storage Building – This building will house two 5,000 gallon storage tanks and pumping equipment (~1,080 ft^2).

Appropriate percentages were applied to the total installed cost of the equipment and structures to estimate the cost for site civil work, yard piping, electrical equipment, and instrumentation and controls as presented in Table 6.2. Project contingency, sales tax, contractor's general conditions, fees, overhead, and profit were assumed as appropriate percentages of the total direct costs. Project contingency is by definition an allowance to account for the items that are not quantified in a planning level design, and includes the costs for unforeseeable elements that are within the defined project scope and are expected to be incurred even though they cannot be explicitly determined at the time the estimate is prepared. The AACE guideline for project contingency is around 30 percent for Class 4 estimates.

The total direct costs were defined as the sum of the total installed cost of major structures and equipment including concrete work, masonry work, paints, finishes, and other incidentals and also include site development, piping, valves, appurtenances, electrical, instrumentation, and controls as presented in Table 6.2.

Based on the preliminary estimates, Alternative No. 3 (Step-feed BNR process) has the lowest estimated construction cost followed closely by Alternative No. 1 (B5 process) and Alternative No. 4 (Three-stage BNR process with denitrification filters). Alternative No. 2 (B5 process with tertiary membrane filters) has the highest estimated construction cost while Alternative No. 5 (B5/MBR process) has the second highest construction cost. The difference between Alternative No. 3 (the lowest cost alternative) and the next lowest construction cost alternative (Alternative No. 4) is less than 10 percent which is within the level of accuracy of this planning level cost estimate. The project costs for Alternative No. 4 and Alternative No. 1 are almost equal and the difference between Alternative No. 4 and Alternative No. 5 is less than 4 percent. Overall the difference between the lowest and highest cost alternatives is slightly less than 20 percent. While at face value this appears significant, this difference is within the level of accuracy of the estimates at this stage of the project. As a result of the relatively small differences in the estimated capital costs for the alternatives, it is difficult to accurately distinguish between the alternatives on the basis of cost. To more clearly distinguish between the alternatives, and to ultimately recommend one alternative, a qualitative evaluation based on both cost and several important non-cost factors is suggested and discussed in Section 7.

The capital costs prepared for this TM are intended to be used solely for screening the alternatives for the purpose of selecting a technology for secondary liquid treatment. A more detailed estimate should be developed during preliminary design for the proposed facility by the selected design engineer.

Table 6.2 Summary of Opinion of Probable Cost of Construction for the Five Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Cost Component	Probable Cost of Construction (1)									
	Alternative No. 1 B5 Process, Disk Filters		**Alternative No. 2** B5 Process, Tertiary Membrane Filters		**Alternative No. 3** Step-Feed BNR, Disk Filters		**Alternative No. 4** Three-Stage BNR, Denitrification Filters		**Alternative No. 5** B5/MBR Process	
Headworks (2)		$1,810,000		$1,810,000		$1,810,000		$1,810,000		$2,640,000
Activated Sludge System(2)		$7,420,000		$7,420,000		$5,470,000		$6,190,000		$5,550,000
Secondary Clarifiers(2)		$3,410,000		$3,410,000		$3,410,000		$3,410,000		-
Membrane System(2)		-		-		-		-		$7,030,000
Tertiary Filters(2)		$1,580,000		$5,200,000		$1,580,000		$2,680,000		-
Disinfection(2)		$740,000		$740,000		$740,000		$740,000		$740,000
Reclaimed Water Storage & Pumping(2)		$4,200,000		$4,200,000		$4,200,000		$4,200,000		$4,200,000
WAS Holding Tanks(2)		$1,250,000		$1,250,000		$1,250,000		$1,250,000		$1,250,000
Dewatering(2)		$3,280,000		$3,280,000		$3,280,000		$3,280,000		$3,280,000
Buildings(2)		$2,500,000		$2,500,000		$2,500,000		$2,500,000		$2,720,000
Total Installed Cost (Subtotal 1) (2)		**$26,190,000**		**$29,810,000**		**$24,240,000**		**$26,060,000**		**$27,410,000**
Site Development (2)	10%	$2,620,000	10%	$2,990,000	10%	$2,430,000	10%	$2,610,000	7.5%	$2,060,000
Piping, Valves & Appurtenances(2)	20%	$5,240,000	20%	$5,970,000	20%	$4,850,000	20%	$5,220,000	17.5%	$4,800,000
Electrical, Instrumentation & Controls (2)	25%	$6,550,000	25%	$7,460,000	25%	$6,060,000	25%	$6,520,000	25%	$6,860,000
Total Direct Cost (Subtotal 2) (2)		**$40,600,000**		**$46,230,000**		**$37,580,000**		**$40,410,000**		**$41,130,000**

Table 6.2 Summary of Opinion of Probable Cost of Construction for the Five Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Cost Component	**Probable Cost of Construction (1)**				
	Alternative No. 1 B5 Process, Disk Filters	**Alternative No. 2** B5 Process, Tertiary Membrane Filters	**Alternative No. 3** Step-Feed BNR, Disk Filters	**Alternative No. 4** Three-Stage BNR, Denitrification Filters	**Alternative No. 5** B5/MBR Process
Project Contingency (30%)	$12,180,000	$13,870,000	$11,280,000	$12,130,000	$12,340,000
Contractor's General Conditions (10%)(2)	$4,060,000	$4,630,000	$3,760,000	$4,050,000	$4,120,000
Contractor's Overhead & Profit (10%)(2)	$4,060,000	$4,630,000	$3,760,000	$4,050,000	$4,120,000
Sales Tax (6.5%)(2)	$700,000	$890,000	$630,000	$640,000	$960,000
Total Estimated Project Costs(3)	**$61,600,000**	**$70,300,000**	**$57,100,000**	**$61,300,000**	**$62,700,000**

Notes:
(1) All values in 2011 dollars ($)
(2) Sales Tax estimated is for major mechanical equipment only. Number rounded to the next $10,000.
(3) Number rounded to the next $100,000.
(4) See more detailed costs as provided in Appendix A.
(5) July 2011 ENR 20-Cities Index is 9080

6.3.2 Operations and Maintenance Costs

The estimated costs for the annual operations and maintenance of each alternative include three major components – power, labor, and chemical use. The analysis assumes that dewatered biosolids would be either hauled offsite or further processed. OCU is currently in the process of developing a countywide biosolids master plan as part of the Biosolids Program Management Contract. Hence, costs for biosolids disposal were not included in this analysis. Estimates of the annual power, chemical, and labor costs of the five alternatives are presented in Table 6.3. The detailed estimates are provided in Appendix A.

Table 6.3 Summary of Estimated Annual Operations and Maintenance Costs for the Five Treatment Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Cost Component	**Estimated Annual Operations and Maintenance Costs [1]**				
	Alternative No. 1	**Alternative No. 2**	**Alternative No. 3**	**Alternative No. 4**	**Alternative No. 5**
	B5 Process With Disk Filters	B5 Process With Tertiary Membrane Filters	Step-Feed BNR Process With Disk Filters	Three-Stage BNR Process With Denitrification Filters	B5/MBR Process
Annual Power Costs	$530,000	$550,000	$540,000	$540,000	$630,000
Annual Labor Costs	$320,000	$340,000	$320,000	$330,000	$350,000
Annual Chemical Costs	$180,000	$190,000	$180,000	$280,000	$190,000
Annual Equipment Maintenance Costs	$490,000	$640,000	$430,000	$490,000	$690,000
Total Annual O&M Costs	$1,510,000	$1,690,000	$1,460,000	$1,620,000	$1,840,000

Notes:

(1) All costs in 2011 dollars ($).
(2) All costs are rounded to the nearest $10,000.
(3) See more detailed costs as provided in Appendix A.

Power requirements are proportional to the power demand of the equipment that is in use and the expected run time for each piece of equipment. Daily power usage was estimated by multiplying the connected power by the estimated daily run time of the equipment. Annual power cost was calculated by multiplying the daily power usage by 365 days per year and the unit power cost. A unit power cost of $0.082 per kilowatt-hour (kWh) was used to estimate power costs, based on information available from OCU. Annual power usage for the membrane systems was obtained from the membrane system manufacturer and used as the basis for the cost estimate.

Chemical costs were based on several recent bid prices for the chemicals required for each alternative. The quantities of sodium hypochlorite and citric acid (for membrane cleaning) were requested from the membrane system manufacturer used as the basis for the cost estimate. The following chemicals were assumed to be required for day-to-day operations:

- Aluminum sulfate (alum) will be used to precipitate phosphorus as a supplement to enhanced biological phosphorus removal (EBPR) to achieve the anticipated effluent TP limit of ≤ 1 mg/l for the Phase I facility. Preliminary process sizing using spreadsheet calculations supplemented by BioWin model simulations show that all five process alternatives will provide sufficient EBPR to achieve the effluent TP limit of ≤ 1 mg/l. Hence, a cost for alum for phosphorus removal was not used in estimating the average annual operating costs for the five alternatives.

- Sodium hypochlorite will be used for disinfection. Additionally, sodium hypochlorite will be used to periodically clean the membranes (under Alternative No. 2 and Alternative No. 5).

- Citric acid will also be used in conjunction with hypochlorite for cleaning the membranes (under Alternative No. 2 and Alternative No. 5).

- Methanol will be used as a carbon source for the denitrification filters (Alternative No. 4). Supplementary carbon source for achieving adequate denitrification in the anoxic basins for the other four alternatives may be required. Preliminary process simulations using the BioWin model show that additional carbon may be necessary to provide sufficient carbon to achieve the effluent TN limit of < 3 mg/l. However, full-scale experience at several other BNR facilities in Florida, including OCU's EWRF show that supplemental carbon is not necessary to achieve the effluent TN limit of < 3 mg/l for single sludge BNR processes such as those proposed in this study. Hence, an annual cost for methanol for Alternative No's 1, 2, 3, and 5 was not used in estimating the average operating costs for these alternatives. Alternate less hazardous supplemental carbon sources such as acetic acid or Micro-C should be investigated if required in the future.

Annual labor hours for operating the facility were extrapolated from the 2008 New England

Interstate Water Pollution Control Commission publication, *The Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants*. The report serves as a guide to estimate staffing needs of publicly and privately owned wastewater plants and provides annual labor hours for O&M for facilities with labor hours categorized by unit process type (See Appendix A). The New England Guide includes recent innovations in treatment process and equipment such as screens with washer/compactors, membranes, disk filters and others. The actual staffing levels and O&M hours required will vary from plant to plant, and will depend on several factors such as experience and skill of the operations staff, staff training, staff longevity, process automation, number of shifts, equipment/process redundancy, age of the treatment system, and other responsibilities outside of operating the treatment plant. An average hourly rate of $30 including all benefits was used to calculate the annual labor costs. The analysis did not specifically include the minimum staffing required by FDEP in 62-699 (Classification and Staffing of Water or Domestic Wastewater Treatment Plants and Water Distribution Systems) as all five alternatives fall within Category IA (nutrient removal with a flow greater than 3.0 mgd). Thus, at least initially, the SWWRF would require staffing 24 hours per day/7 days per week regardless of the treatment technology selected and was the basis of estimation of the labor hours for this evaluation. Per 62-699.311 (4), the staffing requirements could be reduced in the future and all five alternatives evaluated have the potential to be automated adequately to allow a successful petition for reduced staffing, up to 16 hours/day.

In addition to the three major O&M expenses discussed above, other miscellaneous costs are considered essential to operating and maintaining a facility. These costs include:

- <u>Repair and Replacement Cost</u> - Annual costs for repair and replacement was assumed to be 5 percent of the cost of the major process equipment installed at the facility. Appendix A provides details of the total cost for the major items of equipment for each alternative.

- <u>Membrane Replacement Cost</u> – This cost was obtained from the membrane manufacturer (applicable for Alternative No. 2 and Alternative No. 5) and was used to estimate the net-present worth costs as discussed below.

- <u>Filter Medium Replacement Cost –</u> This cost was obtained from a filter manufacturer (applicable for Alternative No's 1, 3, and 4), and was used to estimate the net-present worth costs as discussed below.

6.3.3 Net Present Worth (NPW) Costs

NPW costs estimated for each of the five alternatives based on a 20-year period are presented in Table 6.4. For calculating life cycle costs, a discount rate of 3.9 percent was used. This discount rate is based on the discount rates (for a 20-year period) proposed by the Office of Budget and Management in the *2011 Discount Rates for OMB Circular No. A-94* M-11-12, February 3, 2011.

Table 6.4 Summary of Net Present Worth Costs for the Five Treatment Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Cost Item	**Alternative No. 1**	**Alternative No. 2**	**Alternative No. 3**	**Alternative No. 4**	**Alternative No. 5**
	B5 Process With Disk Filters	B5 Process With Tertiary Membrane Filters	Step-Feed BNR Process With Disk Filters	Three-Stage BNR Process With Denitrification Filters	B5/MBR Process
Total Capital Costs	$61,600,000	$70,300,000	$57,100,000	$61,300,000	$62,700,000
Annual O&M Costs	$1,510,000	$1,690,000	$1,460,000	$1,620,000	$1,840,000
Equipment Replacement Costs (4)	$9,700,000	$12,600,000	$8,600,000	$9,800,000	$13,700,000
Filter Media/Membrane Replacement Costs (4)	$200,000	$1,200,000	$200,000	$0.00	$1,600,000
Net Present Worth Costs(1) (2) (3)	$92,200,000	$107,300,000	$85,900,000	$93,400,000	$103,200,000

Notes:

(1) All costs are in 2011 dollars
(2) Values rounded to the next $100,000.
(3) NPW cost based on a 20-year life cycle and an interest rate of 3.9%. This results in a uniform series compound factor of 13.71.
(4) Assumptions for estimating replacement costs:
   a. Screens, grit removal equipment, mixers, pumps and blowers – Assumes one replacement during the 20-year design period.
   b. Aeration Diffusers - Assumes two replacements during the 20-year design period.
   c. Disk Filters – Assumes four replacement during the 20-year design period
   d. Denitrification Filters – Assumes, filter media will not be required during 20-year design period.
   e. Membranes - Assumes all modules will be replaced once during the 20-year design period.
   f. Screw Presses - Assumes one replacement during the 20-year design period.

6.4 Non-Economic Evaluation

The following sections describe non-economic parameters for comparing the five secondary liquid treatment processes evaluated. In general, the implementation of the B5 process (Alternative No's 1, 2, 3, and 5) is similar for each alternative. The use of low-pressure membranes in place of conventional gravity clarification and disk or deep-bed filtration; however, results in a number of differences between the alternatives in terms of bioreactor volumes, overall plant footprint, effluent quality, and power consumption.

6.4.1 Water Quality

Beyond the capabilities of the biological process, the ability of the treatment system to separate suspended and colloidal matter from the water constitutes the most significant difference between the five alternatives evaluated. There is a distinct difference in the particulate removal achieved by conventional media filters such as cloth-disk filters, deep-bed granular media filters, and membranes. MF or UF membranes have pore sizes that are orders of magnitude smaller than conventional media filters. As a result, membrane filters (Alternative No. 2 and Alternative No. 5) provide significantly greater removal of particulate matter and typically produce an effluent with turbidities less than 0.2 NTU. Similarly, there is a distinct difference between conventional media filters and low-pressure membrane filters (including those used in MBR processes) for removal of microbiological contaminants as a result of the ability of membranes to remove nearly all pathogens based on size exclusion. A summary of the relative sizes of some common contaminants and the typical pore sizes for common filtration technologies used to remove them is presented in Table 6.5. A detailed comparison of various filtration technologies is provided in Appendix C of TM2.

Table 6.5 **Summary of Anticipated Effluent Water Quality Characteristics for the Five Treatment Alternatives SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**

Parameter	Alternative No. 1	Alternative No. 2	Alternative No. 3	Alternative No. 4	Alternative No. 5
	B5 Process With Disk Filters	B5 Process With Tertiary Membrane Filters	Step-Feed BNR Process With Disk Filters	Three-Stage BNR Process With Denitrification Filters	B5/MBR Process
Effluent TSS, mg/L	< 5	< 2	< 5	< 5	< 2
Effluent Turbidity, NTU	< 2	< 0.2	< 2	< 2	< 0.2
Minimum Size Particles Removed (μm)[(1)]	1 - 10	< 0.1	1 – 10	1 – 10	< 0.1
Log Removal Fecal Coliform	3.0[(2)]	3 – 9	3.0[(2)]	2.5[(2)]	3 - 9
Log Removal Protozoan Cysts	0.4 – 0.5[(2)]	6 - 9	0.4 – 0.5[(2)]	0.4 – 1.5[(2)]	6 - 9
Log Removal Virus	0 – 0.6	0.5 – 4.0	0 – 0.6	0 – 1.3	0.5 – 4.0

Notes:

(1) The minimum particle size that can be removed depends on the characteristics of the filter medium, and the type and performance of the upstream treatment processes.

(2) Levine, et al., 2008. The influent to the filter was not pretreated with any chemicals.

6.4.2 Facility Footprint

The amount of land required to construct the treatment facility is important when there is limited land available. Reducing the amount of land required for the facility also reduces the cost of civil/site work. Compact facility designs minimize the visual impact on neighboring areas through the construction of perimeter berms and plantings, or enclosure of the treatment processes within one or more buildings. Table 6.6 provides a comparison of the five alternatives on the basis of the required liquid treatment footprint. As shown in Table 6.6, Alternative No. 5 (B5/MBR) results in the smallest footprint, almost half the size of the conventional alternatives.

Table 6.6 Summary of Estimated Footprint of the Liquid Treatment Process for the Five Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Alternative	Activated Sludge Treatment Process Footprint (ft^2)(1)	Filtration Process Footprint (ft^2)	Total Footprint (ft^2)
Alternative No. 1 – B5 Process With Secondary Clarifiers And Disk Filters	75,000	1,900	76,900
Alternative No. 2 – B5 Process With Secondary Clarifiers And Membrane Filters	75,000	2,700	77,700
Alternative No. 3 – Step-Feed BNR With Secondary Clarifiers And Disk Filters	69,700	1,900	71,600
Alternative No. 4 – Three-Stage BNR Process With Secondary Clarifiers And Disk Filters	65,700	6,400	72,100
Alternative No. 5 – B5/MBR Process	19,800	0	19,800

Notes:
(1) Includes footprint for activated sludge basins and secondary clarifiers.

6.4.3 Energy Consumption

Table 6.7 provides comparison of the five alternatives based on the anticipated energy consumption to operate the Phase 1 facility (5 mgd ADF flow). Alternative No’s 1 through 4 are estimated to have similar energy consumption to treat the design flows. However, Alternative No. 5 is estimated to have an energy consumption of 15% more than the other alternatives. The additional power for Alternative No. 5 results from increased RAS and permeate pumping, and the additional blowers needed to provide the air required for membrane scouring. For Alternative No. 5, RAS flow rates are estimated to be in the range of 2Q – 4 Q as compared to the 0.5Q to 1.0 Q range for the other alternatives. Similarly, permeate pumps are necessary to filter the water through the membranes by applying a small vacuum on the membranes. As stated earlier, recent advancements as advertized by one of the major MBR manufacturer's was not included as part of this analysis.

Table 6.7 Summary of Estimated Annual Energy Consumption for the Five Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Alternative	Annual Energy Consumption, kWh/yr	Specific Energy Consumption, kWh/1000 gallons
Alternative No. 1 – B5 Process With Secondary Clarifiers And Disk Filters	6,447,700	2.9
Alternative No. 2 – B5 Process With Secondary Clarifiers And Membrane Filters	6,617,200	3.0
Alternative No. 3 – Step-Feed BNR Process With Secondary Clarifiers And Disk Filters	6,502,400	3.0
Alternative No. 4 – Three-Stage BNR Process With Secondary Clarifiers And Disk Filters	6,486,300	3.0
Alternative No. 5 – B5/MBR Process	7,590,100	3.5

6.4.4 Chemical Consumption

Table 6.8 provides comparison of the five alternatives based on the anticipated chemical consumption to operate the Phase 1 facility (5 mgd ADF flow). The data indicates that Alternative No. 1 is anticipated to use the least amount of chemicals while, Alternative No. 5 is estimated to use the most. As shown in the table, none of the process alternatives will consume significant amounts of chemicals. However, Alternative No. 4 will require additional supplemental carbon in the form of methanol.

Table 6.8 Summary of Estimated Annual Consumption of various Chemicals for the Five Alternatives SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities					
Alternative	**Alum (gallons)**	**Sodium Hypochlorite (gallons)**	**Methanol (gallons)**	**Polymer (lb)**	**Citric Acid (gallons)**
Alternative No. 1	None	153,200	None	43,100	–
Alternative No. 2	None	154,300	None	43,100	1,450
Alternative No. 3	None	152,200	None	43,100	–
Alternative No. 4	None	152,200	62,050	46,000	–
Alternative No. 5	None	157,000	None	43,800	3,300

6.4.5 Biosolids Production

Table 6.9 provides comparison of the five alternatives based on the anticipated biosolids production to operate the Phase 1 facility (5 mgd ADF flow). The data shows that all five alternatives will generate approximately the same mass of biosolids.

Table 6.9 Summary of Estimated Monthly Sludge Production for the Five Alternatives SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities	
Alternative	**Monthly Sludge Production, tons/month**
Alternative No. 1 – B5 Process With Secondary Clarifiers And Disk Filters	177
Alternative No. 2 – B5 Process With Secondary Clarifiers And Membrane Filters	177
Alternative No. 3 – Step-Feed BNR Process With Secondary Clarifiers And Disk Filters	183
Alternative No. 4 – Three-Stage BNR Process With Secondary Clarifiers And Disk Filters	189
Alternative No. 5 – B5/MBR Process	180

7.0 QUALITATIVE EVALUATION

To help compare the five alternatives, a weighted evaluation matrix was created. Table 7.1 provides a list of six criteria that could influence the choice of the liquid treatment alternative. Also included is a qualitative rating of each criterion for each alternative. For each alternative, each criterion was individually scored on a scale of 1 to 5 depending on how the alternative was judged to perform relative to that criterion with 1 being the least favorable score and 5 being the most favorable score. The estimates for capital and life cycle costs, footprint, energy consumption, chemical consumption, and sludge production were converted to a numeric score based on a linear interpolation between the lowest estimate and the highest estimate.

The evaluation criteria were assigned a subjective weight from 1 to 6 based on the perceived overall significance of the criteria to the project. The criteria with the most significance received a weight of 6 and those with the least significance received a weight of 1. The numeric scores for these criteria are included in a matrix scoring as presented in Table 7.2.

For each alternative, the score for each criterion was then multiplied by the criterion weight and the multiplication products were summed to obtain the overall score for each alternative. The best alternative is the one with the highest score.

Table 7.1 Scoring for Evaluation Criteria Used for Comparing the Five Treatment Alternatives SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Evaluation Criteria	Alternative No. 1		Alternative No. 2		Alternative No. 3		Alternative No. 4		Alternative No. 5	
	B5 process with disk filters		B5 process with tertiary membrane filters		Step-feed BNR process with disk filters		Three-stage BNR process with denitrification filters		B5/MBR process	
	Estimate	Raw Score	Estimate	Raw Score	Estimate	Raw Score	Estimate	Raw Score	Estimate	Raw Score
Total Installed Cost	$26,190,000		$29,810,000		$24,240,000		$26,060,000		$27,410,000	
Capital Cost	$61,600,000	3	$70,300,000	1	$57,100,000	5	$61,300,000	4	$62,700,000	2
Life Cycle Cost	$92,200,000	4	$107,300,000	1	$85,900,000	5	$93,400,000	3	$103,200,000	2
Facility Footprint(1) (Ft^2)	76,900	2	77,700	1	71,600	4	72,100	3	19,800	5
Energy Consumption (Kwh/Yr)	6,447,700	5	6,617,200	3	6,502,400	4	6,486,300	3	7,590,100	1
Chemical Consumption (Gallons/Yr)(2)	152,000	5	156,000	3	152,000	5	214,000	1	160,000	2
Sludge Production (Tons/Month)	177	3	177	3	183	3	189	3	180	3

Notes:

(1) Estimated facility footprints include the land area required for the activated sludge treatment basins, secondary clarifiers, and filters. The remaining unit processes will be same for all five alternatives.

(2) Based on the total quantity of liquid chemicals used annually for facility O&M. Quantity of dewatering polymer is estimated to be almost equal for all the five alternatives and is not included.

Table 7.2 Weighted Matrix for Comparing the Five Treatment Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Evaluation Criteria	**Weighting (1 – 6)(1)**	**Alternative No. 1** B5 Process With Disk Filters		**Alternative No. 2** B5 Process With Tertiary Membrane Filters		**Alternative No. 3** Step-Feed BNR Process With Disk Filters		**Alternative No. 4** Three-Stage BNR Process With Denitrification Filters		**Alternative No. 5** B5/MBR Process	
		Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Capital Cost	6	3	18	1	6	5	30	4	24	2	12
Life Cycle Cost	5	4	20	1	5	5	25	3	15	2	10
Facility Footprint	2	2	4	1	2	4	8	3	6	5	10
Energy Consumption	4	5	20	3	12	4	16	3	12	1	4
Chemical Consumption	3	5	15	3	9	5	15	1	3	2	6
Sludge Production	1	3	3	3	3	3	3	3	3	3	3
Total Score			80		37		97		63		45
Overall Rank		**2**		**5**		**1**		**3**		**4**	

Notes:
(1) The weight is proportional to the importance of the criteria. The criterion judged most important has the highest weight, while the criterion judged to be least important has the least weight.

8.0 RECOMMENDATIONS

Based on the weighted matrix analysis shown in Table 7.2, Alternative No. 3 (Step-feed BNR with secondary clarifiers and cloth disk filters) had the highest score followed by Alternative No. 1 (B5 process with secondary clarifiers and cloth disk filters). Alternative No. 5 (B5/MBR process), the baseline alternative recommended by the 2007 Facilities Plan, has the second lowest score. The weighted analysis is a highly subjective method for ranking the various alternatives and a difference of less than 10 percent in the scores cannot justify selecting one alternative over the other on this method alone. However, the highest ranked alternative, Alternative No. 3, has a score more than 20 percent higher than the next best alternative (Alternative No. 1). Moderate changes to the criteria weights or slight changes to the individual scores do not change the relative rank of the alternatives.

The above results were presented to OCU during Workshop No. 3 held on August 24, 2011 to confirm the ranking of the alternatives. Based on OCU's concurrence, Alternative No. 3 – the Step-feed BNR with secondary clarifiers and cloth disk filters is recommended as the preferred secondary liquid treatment technology for the proposed SWWRF.

The capital costs prepared for this TM are intended to be used solely for screening the alternatives for the purpose of selecting a technology for secondary liquid treatment. A more detailed estimate should be developed during preliminary design for the proposed facility by the selected design engineer.

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Appendix A

DETAILED CAPITAL AND O&M COST ESTIMATES

A.1. CAPITAL COST ESTIMATES

Table A.1 Probable Cost of Construction for Alternative No. 1 – B5 Process with Secondary Clarifiers and Disk Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Headworks (Coarse Screens, Grit Removal & Odor Control)							
Base slab	207	yd^3	$600	$103,338	1	$103,400	
Walls	184	yd^3	$750	$117,760	1	$117,800	
Elevated slab	74	yd^3	$730	$45,662	1	$45,700	
Elevated channel walls	184	yd^3	$750	$117,760	1	$117,800	
Equipment (coarse screens)	2	each	$236,069	$472,138	1.15	$543,000	$30,689
Equipment (washer/compactors)	2	each	$75,500	$151,000	1.15	$173,700	$9,815
Equipment (Headcell with Slurry Cup and Grit Snail)	1	each	$440,000	$440,000	1.15	$506,000	$28,600
Base slab (odor control)	25	yd^3	$500	$14,700	1	$12,300	
Equipment (odor control unit)	1	each	$165,000	$165,000	1.15	$189,800	$10,725
Anaerobic Tanks							
Base slab	206	yd^3	$500	$102,900	1	$102,900	
Tank walls (20-ft tall)	347	yd^3	$640	$221,867	1	$221,900	
Platform mechanical mixers	8	each	$22,000	$176,000	1.15	$202,400	$11,440
Walkway (elevated slab)	41	yd^3	$620	$25,259	1	$25,300	
Pre-anoxic tanks							
Base slab	1,029	yd^3	$500	$514,500	1	$514,500	
Tank walls (20-ft tall)	960	yd^3	$640	$614,400	1	$614,400	
Platform mechanical mixers	12	each	$22,000	$264,000	1.15	$303,600	$17,160
Walkway (elevated slab)	107	yd^3	$620	$66,133	1	$66,200	
Aeration Tanks							
Base slab	2,230	yd^3	$500	$1,114,750	1	$1,114,800	
Tank walls (20-ft tall)	1,347	yd^3	$640	$861,867	1	$861,900	
Walkway	157	yd^3	$620	$97,363	1	$97,400	
Fine pore aeration system	Lump sum			$163,636	1.15	$188,200	$10,636

Table A.1	**Probable Cost of Construction for Alternative No. 1 – B5 Process with Secondary Clarifiers and Disk Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
Aeration blowers	Lump sum			$430,000	1.15	$494,500	$27,950
Internal recycle pumps	12	each	$89,800	$1,077,600	1.15	$1,239,300	$70,044
Swing zone mechanical mixers	4	each	$22,000	$88,000	1.15	$101,200	$5,720
Post-anoxic tanks							
Base slab	735	yd^3	$500	$367,500	1	$367,500	
Tank walls (18-ft tall)	600	yd^3	$640	$384,000	1	$384,000	
Platform mechanical mixers	8	each	$22,000	$176,000	1.15	$202,400	$11,440
Walkway (elevated slab)	67	yd^3	$620	$41,333	1	$41,400	
Reaeration tanks							
Base slab	123	yd^3	$500	$61,250	1	$61,300	
Tank Walls (18-ft tall)	300	yd^3	$640	$192,000	1	$192,000	
Walkway (elevated slab)	30	yd^3	$620	$18,370	1	$18,400	
Secondary clarifiers							
Base slab	2,979	yd^3	$500	$1,489,348	1	$1,489,400	
Tank walls (16-ft tall)	894	yd^3	$640	$571,909	1	$572,000	
Clarifier equipment	4	each	$186,250	$745,000	1.15	$856,800	$48,425
Density current baffles	4	each	$10,875	$43,500	1.15	$50,100	$2,828
Scum pumps	4	each	$15,000	$60,000	1.15	$69,000	$63,900
RAS pumps	5	each	$54,200	$271,000	1.15	$311,700	$17,615
WAS pumps	3	each	$17,000	$51,000	1.15	$58,700	$3,315
Disk filters							
Base slab	176	yd^3	$500	$87,963	1	$88,000	
Disk filters	Lump sum			$1,297,491	1.15	$1,492,200	$84,337
Chlorine contact tanks							
Base slab	184	yd^3	$500	$91,875	1	$91,900	
Tank Walls	34	yd^3	$640	$22,044	1	$22,100	
Sodium hypochlorite storage and feed system	Lump sum			$80,000	1.15	$92,000	$5,200
Sodium hypochlorite storage building	1,080	ft^2	$100	$108,000	1	$108,000	
Disinfected effluent transfer pumps	5	each	$65,200	$326,000	1.15	$374,900	$21,190
Plant water pumps	3	each	$13,350	$40,050	1.15	$46,100	$2,603

Table A.1 Probable Cost of Construction for Alternative No. 1 – B5 Process with Secondary Clarifiers and Disk Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Electrical building	600	ft^2	$150	$90,000	1	$90,000	
Reclaimed water storage and pumping							
Reclaimed water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Reject water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Large Reclaimed water high service pumps	5	each	$78,900	$394,500	1.15	$453,700	$25,643
Small Reclaimed water high service pumps	2	Each	$20,000	$40,000	1.15	$46,000	$2,600
Reject water transfer pumps	5	each	$76,065	$380,325	1.15	$437,400	$24,721
Pump station building	1,875	ft^2	$150	$281,250	1	$281,300	
WAS holding tanks							
WAS holding tank (0.75 MG pre-stressed concrete tank)	1	each	$423,000	$423,000	1	$423,000	
Diffused aeration system	Lump sum			$28,000	1.15	$32,200	$1,820
Aeration blowers	Lump sum			$96,000	1.15	$110,400	$6,240
Concrete coating	12,763	ft^2	$15	$191,441	1	$191,500	
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	$24,375
Equipment (odor control)	1	each	$375,000	$375,000	1.15	$431,300	
Dewatering building							
Building	6,800	ft^2	$150	$1,020,000	1	$1,020,000	
Equipment (screw press)	3	each	$400,000	$1,200,000	1.15	$1,380,000	$78,000
Equipment (screw press feed pumps)	3	each	$25,000	$75,000	1.15	$86,300	$4,875
Equipment (dewatered biosolids conveyor system)	110	L.F.	$2,000	$220,000	1.15	$253,000	$14,300
Equipment (polymer system)	2	each	$20,000	$40,000	1.15	$46,000	$2,600
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	
Equipment (odor control equipment)	1	each	$375,000	$375,000	1.15	$431,300	$24,375
Main electrical/blower building							
Building (to house	5,400	ft^2	$150	$810,000	1	$810,000	

Table A.1	Probable Cost of Construction for Alternative No. 1 – B5 Process with Secondary Clarifiers and Disk Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
aeration blowers, electrical, etc)							
Administration/Operations Building							
Building	8,000	ft^2	$200	$1,600,000	1	$1,600,000	
					Total Installed Cost (Subtotal 1)(1)	**$26,190,000**	**$700,000**
Site development (excavation, dewatering & site preparation) (10%)(1)						$2,620,000	
Piping, valves & appurtenances (20%)(1)						$5,240,000	
Electrical, instrumentation and controls (25%)(1)						$6,550,000	
					Total Direct Cost (Subtotal 2) (1)	**$40,600,000**	
Project contingency (30%)(1)						$12,180,000	
Contractors' general conditions (10%)(1)						$4,060,000	
Contractor fees, overhead, & profit (10%)(1)						$4,060,000	
Sales tax (6.5%)(1)						$700,000	
					Total Project Cost (2011 Dollars)(2)		**$61,600,000**
Minimum (-15%)(2)							$52,400,000
Maximum (+30%)(2)							$80,100,000

Notes:
(1) Values rounded to the next $10,000.
(2) Values rounded to the next $100,000.

Table A.2	Probable Cost of Construction for Alternative No. 2 – B5 Process with Secondary Clarifiers and Tertiary Membrane Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
Headworks (coarse screens, grit removal & odor control)							
Base slab	207	yd^3	$600	$103,338	1	$103,400	
Walls	184	yd^3	$750	$117,760	1	$117,800	
Elevated slab	74	yd^3	$730	$45,662	1	$45,700	
Elevated walls	184	yd^3	$750	$117,760	1	$117,800	
Equipment (coarse screens)	2	each	$236,069	$472,138	1.15	$543,000	$30,689
Equipment (washer/compactors)	2	each	$75,500	$151,000	1.15	$173,700	$9,815
Equipment (Headcell with Slurry Cup and Grit Snail)	1	each	$440,000	$440,000	1.15	$506,000	$28,600
Base slab (odor control)	25	yd^3	$500	$14,700	1	$12,300	
Equipment (odor control unit)	1	each	$165,000	$165,000	1.15	$189,800	$10,725
Anaerobic tanks							
Base slab	206	yd^3	$500	$102,900	1	$102,900	
Tank walls (20-ft tall)	347	yd^3	$640	$221,867	1	$221,900	
Platform mechanical mixers	8	each	$22,000	$176,000	1.15	$202,400	$11,440
Walkway (elevated slab)	41	yd^3	$620	$25,259	1	$25,300	
Pre-anoxic tanks							
Base slab	1,029	yd^3	$500	$514,500	1	$514,500	
Tank walls (20-ft tall)	960	yd^3	$640	$614,400	1	$614,400	
Platform mechanical mixers	12	each	$22,000	$264,000	1.15	$303,600	$17,160
Walkway (elevated slab)	107	yd^3	$620	$66,133	1	$66,200	
Aeration tanks							
Base slab	2,230	yd^3	$500	$1,114,750	1	$1,114,800	
Tank walls (20-ft tall)	1,347	yd^3	$640	$861,867	1	$861,900	
Walkway	157	yd^3	$620	$97,363	1	$97,400	
Fine pore Aeration System	Lump sum			$163,636	1.15	$188,200	$10,636
Aeration blowers	Lump sum			$430,000	1.15	$494,500	$27,950
Internal recycle pumps	12	each	$89,800	$1,077,600	1.15	$1,239,300	$70,044
Swing zone mechanical mixers	4	each	$22,000	$88,000	1.15	$101,200	$5,720

Table A.2	Probable Cost of Construction for Alternative No. 2 – B5 Process with Secondary Clarifiers and Tertiary Membrane Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
Post-anoxic tanks							
Base slab	735	yd^3	$500	$367,500	1	$367,500	
Tank walls (18-ft tall)	600	yd^3	$640	$384,000	1	$384,000	
Platform mechanical mixers	8	each	$22,000	$176,000	1.15	$202,400	$11,440
Walkway (elevated slab)	67	yd^3	$620	$41,333	1	$41,400	
Reaeration tanks							
Base slab	123	yd^3	$500	$61,250	1	$61,300	
Tank walls (18-ft tall)	300	yd^3	$640	$192,000	1	$192,000	
Walkway (elevated slab)	30	yd^3	$620	$18,370	1	$18,400	
Secondary clarifiers							
Base slab	2,979	yd^3	$500	$1,489,348	1	$1,489,400	
Tank walls (16-ft tall)	894	yd^3	$640	$571,909	1	$572,000	
Clarifier equipment	4	each	$186,250	$745,000	1.15	$856,800	$48,425
Density current baffles	4	each	$10,875	$43,500	1.15	$50,100	$2,828
Scum pumps	4	each	$15,000	$60,000	1.15	$69,000	$63,900
RAS pumps	5	each	$54,200	$271,000	1.15	$311,700	$17,615
WAS pumps	3	each	$17,000	$51,000	1.15	$58,700	$3,315
Tertiary membrane filters							
Base slab	58	yd^3	$500	$28,971	1	$29,000	
Tank walls (13-ft tall)	27	yd^3	$640	$17,124	1	$17,200	
Membrane equipment (membrane cassettes, blowers, permeate pumps, controls)	Lump sum			$4,200,000	1.15	$4,830,000	$273,000
Membrane building	2,130	ft^2	$150	$319,568	1	$319,600	
Chlorine contact tanks							
Base slab	184	yd^3	$500	$91,875	1	$91,900	
Tank walls	34	yd^3	$640	$22,044	1	$22,100	
Sodium hypochlorite storage and feed system	Lump sum			$80,000	1.15	$92,000	$5,200
Sodium hypochlorite storage building	1,080	ft^2	$100	$108,000	1	$108,000	
Disinfected effluent transfer pumps	5	each	$65,200	$326,000	1.15	$374,900	$21,190
Plant water pumps	3	each	$13,350	$40,050	1.15	$46,100	$2,603

Table A.2 Probable Cost of Construction for Alternative No. 2 – B5 Process with Secondary Clarifiers and Tertiary Membrane Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Electrical building	600	ft^2	$150	$90,000	1	$90,000	
Reclaimed water storage and pumping							
Reclaimed water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Reject water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Large Reclaimed water high service pumps	5	each	$78,900	$394,500	1.15	$453,700	$25,643
Small Reclaimed water high service pumps	2	Each	$20,000	$40,000	1.15	$46,000	$2,600
Reject water transfer pumps	5	each	$76,065	$380,325	1.15	$437,400	$24,721
Pump station building	1,875	ft^2	$150	$281,250	1	$281,300	
WAS holding tanks							
WAS holding tank (0.75 MG pre-stressed concrete tank)	1	each	$423,000	$423,000	1	$423,000	
Diffused aeration system	Lump sum			$28,000	1.15	$32,200	$1,820
Aeration blowers	Lump sum			$96,000	1.15	$110,400	$6,240
Concrete coating	12,763	ft^2	$15	$191,441	1	$191,500	
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	$24,375
Equipment (odor control)	1	each	$375,000	$375,000	1.15	$431,250	
Dewatering building							
Building	6,800	ft^2	$150	$1,020,000	1	$1,020,000	
Equipment (screw press)	3	each	$400,000	$1,200,000	1.15	$1,380,000	$78,000
Equipment (screw Press Feed Pumps)	3	each	$25,000	$75,000	1.15	$86,300	$4,875
Equipment (dewatered biosolids conveyor system)	110	L.F.	$2,000	$220,000	1.15	$253,000	$14,300
Equipment (polymer system)	2	each	$20,000	$40,000	1.15	$46,000	$2,600
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	
Equipment (odor control equipment)	1	each	$375,000	$375,000	1.15	$431,300	$24,375
Main electrical/blower building							
Building (to house	5,400	ft^2	$150	$810,000	1	$810,000	

Table A.2	**Probable Cost of Construction for Alternative No. 2 – B5 Process with Secondary Clarifiers and Tertiary Membrane Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
aeration blowers, electrical, etc)							
Administration/operations building							
Building	8,000	ft^2	$200	$1,600,000	1	$1,600,000	
Total Installed Cost (Subtotal 1) (1)						**$29,810,000**	**$890,000**
Site development (excavation, dewatering & site preparation) (10%)(1)						$2,990,000	
Piping, valves & appurtenances (20%)(1)						$5,970,000	
Electrical, instrumentation and controls (25%)(1)						$7,460,000	
Total Direct Cost (Subtotal 2) (1)						**$46,230,000**	
Project contingency (30%)(1)						$13,870,000	
Contractors' general conditions (10%)(1)						$4,630,000	
Contractor fees, overhead, & profit (10%)(1)						$4,630,000	
Sales tax (6.5%)(1)						$890,000	
Total Project Cost (2011 Dollars)(2)						**$70,300,000**	
Minimum (-15%)(2)						$59,800,000	
Maximum (+30%)(2)						$91,400,000	

Notes:
(1) Values rounded to the next $10,000.
(2) Values rounded to the next $100,000.

**Table A.3 Probable Cost of Construction for Alternative No. 3 – Step-feed BNR Process with Secondary Clarifiers and Disk Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities**

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Headworks (coarse screens, grit removal & odor control)							
Base slab	207	yd^3	$600	$103,338	1	$103,400	
Walls	184	yd^3	$750	$117,760	1	$117,800	
Elevated slab	74	yd^3	$730	$45,662	1	$45,700	
Elevated walls	184	yd^3	$750	$117,760	1	$117,800	
Equipment (coarse screens)	2	each	$236,069	$472,138	1.15	$543,000	$30,689
Equipment (washer/compactors)	2	each	$75,500	$151,000	1.15	$173,700	$9,815
Equipment (Headcell with Slurry Cup and Grit Snail)	1	each	$440,000	$440,000	1.15	$506,000	$28,600
Base slab (odor control)	25	yd^3	$500	$14,700	1	$12,300	
Equipment (odor control unit)	1	each	$165,000	$165,000	1.15	$189,800	$10,725
Step-feed treatment tanks							
Base Slab	4,278	yd^3	$500	$2,138,889	1	$2,138,900	
Tank Walls (20-ft tall)	2,705	yd^3	$640	$1,731,129	1	$1,731,200	
Walkway (elevated slab)	241	yd^3	$620	$149,259	1	$149,300	
Platform Mechanical Mixers	24	each	$22,000	$528,000	1.15	$607,200	$34,320
Fine Pore Aeration System	Lump sum			$169,697	1.15	$225,400	$11,030
Aeration Blowers	Lump sum			$430,000	1.15	$494,500	$27,950
Swing Zone Mechanical Mixers	6	each	$22,000	$132,000	1.15	$151,800	$8,580
Secondary Clarifiers							
Base slab	2,979	yd^3	$500	$1,489,348	1	$1,489,400	
Tank walls (16-ft tall)	894	yd^3	$640	$571,909	1	$572,000	
Clarifier equipment	4	each	$186,250	$745,000	1.15	$856,800	$48,425
Density current baffles	4	each	$10,875	$43,500	1.15	$50,100	$2,828
Scum pumps	4	each	$15,000	$60,000	1.15	$69,000	$63,900
RAS pumps	5	each	$54,200	$271,000	1.15	$311,700	$17,615
WAS pumps	3	each	$17,000	$51,000	1.15	$58,700	$3,315
Disk filters							
Base slab	176	yd^3	$500	$87,963	1	$88,000	
Disk filters	Lump sum			$1,297,491	1.15	$1,492,200	$84,337
Chlorine contact tanks							
Base slab	184	yd^3	$500	$91,875	1	$91,900	

Table A.3 Probable Cost of Construction for Alternative No. 3 – Step-feed BNR Process with Secondary Clarifiers and Disk Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Tank walls	34	yd^3	$640	$22,044	1	$22,100	
Sodium hypochlorite storage and feed system	Lump sum			$80,000	1.15	$92,000	$5,200
Sodium hypochlorite storage building	1,080	ft^2	$100	$108,000	1	$108,000	
Disinfected effluent transfer pumps	5	each	$65,200	$326,000	1.15	$374,900	$21,190
Plant water pumps	3	each	$13,350	$40,050	1.15	$46,100	$2,603
Electrical building	600	ft^2	$150	$90,000	1	$90,000	
Reclaimed water storage and pumping							
Reclaimed water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Reject water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Large Reclaimed water high service pumps	5	each	$78,900	$394,500	1.15	$453,700	$25,643
Small Reclaimed water high service pumps	2	Each	$20,000	$40,000	1.15	$46,000	$2,600
Reject water transfer pumps	5	each	$76,065	$380,325	1.15	$437,400	$24,721
Pump station building	1,875	ft^2	$150	$281,250	1	$281,300	
WAS holding tanks							
WAS holding tank (0.75 MG pre-stressed concrete tank)	1	each	$423,000	$423,000	1	$423,000	
Diffused aeration system	Lump sum			$28,000	1.15	$32,200	$1,820
Aeration blowers	Lump sum			$96,000	1.15	$110,400	$6,240
Concrete coating	12,763	ft^2	$15	$191,441	1	$191,500	
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	
Equipment (odor control)	1	each	$375,000	$375,000	1.15	$431,300	$24,375
Dewatering building							
Building	6,800	ft^2	$150	$1,020,000	1	$1,020,000	
Equipment (screw press)	3	each	$400,000	$1,200,000	1.15	$1,380,000	$78,000
Equipment (screw press feed pumps)	3	each	$25,000	$75,000	1.15	$86,300	$4,875
Equipment (dewatered biosolids conveyor system)	110	L.F.	$2,000	$220,000	1.15	$253,000	$14,300
Equipment (polymer system)	2	each	$20,000	$40,000	1.15	$46,000	$2,600

Table A.3 Probable Cost of Construction for Alternative No. 3 – Step-feed BNR Process with Secondary Clarifiers and Disk Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	
Equipment (odor control equipment)	1	each	$375,000	$375,000	1.15	$431,300	$24,375
Main electrical/blower building							
Building (to house aeration blowers, electrical, etc)	5,400	ft^2	$150	$810,000	1	$810,000	
Administration/operations building							
Building	8,000	ft^2	$200	$1,600,000	1	$1,600,000	
					Total Installed Cost (Subtotal 1) (1)	**$24,240,000**	**$630,000**
Site Development (excavation, dewatering & site preparation) (10%)(1)						$2,430,000	
Piping, valves & appurtenances (20%)(1)						$4,850,000	
Electrical, instrumentation and controls (25%)(1)						$6,060,000	
					Total Direct Cost (Subtotal 2) (1)	**$37,580,000**	
Project contingency (30%)(1)						$11,280,000	
Contractors' general conditions (10%)(1)						$3,760,000	
Contractor fees, overhead, & profit (10%)(1)						$3,760,000	
Sales tax (6.5%)(1)						$630,000	
					Total Project Cost (2011 Dollars) (2)		**$57,100,000**
Minimum (-15%)(2)							$48,600,000
Maximum (+30%)(2)							$74,300,000

Notes:
(1) Values rounded to the next $10,000.
(2) Values rounded to the next $100,000.

Table A.4 Probable Cost of Construction for Alternative No. 4 – Three-stage BNR Process with Secondary Clarifiers and Denitrification Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Headworks (coarse screens, grit removal & odor control)							
Base slab	207	yd^3	$600	$103,338	1	$103,400	
Walls	184	yd^3	$750	$117,760	1	$117,800	
Elevated slab	74	yd^3	$730	$45,662	1	$45,700	
Elevated walls	184	yd^3	$750	$117,760	1	$117,800	
Equipment (coarse screens)	2	each	$236,069	$472,138	1.15	$543,000	$30,689
Equipment (washer/compactors)	2	each	$75,500	$151,000	1.15	$173,700	$9,815
Equipment (Headcell with Slurry Cup and Grit Snail)	1	each	$440,000	$440,000	1.15	$506,000	$28,600
Base slab (odor control)	25	yd^3	$500	$14,700	1	$12,300	
Equipment (odor control unit)	1	each	$165,000	$165,000	1.15	$189,800	$10,725
RAS anoxic tanks							
Base slab	88	yd^3	$500	$44,100	1	$44,100	
Tank walls (20-ft tall)	213	yd^3	$640	$136,533	1	$136,600	
Platform mechanical mixers	4	each	$22,000	$88,000	1.15	$101,200	$5,720
Walkway (elevated slab)	28	yd^3	$620	$17,452	1	$17,500	
Anaerobic tanks							
Base slab	206	yd^3	$500	$102,900	1	$102,900	
Tank walls (20-ft tall)	347	yd^3	$640	$221,867	1	$221,900	
Platform mechanical mixers	8	each	$22,000	$176,000	1.15	$202,400	$11,440
Walkway (elevated slab)	41	yd^3	$620	$25,259	1	$25,300	
Pre-anoxic tanks							
Base slab	441	c. yd.	$500	$220,500	1	$220,500	
Tank walls (20-ft tall)	640	c. yd.	$640	$409,600	1	$409,600	
Platform mechanical mixers	12	each	$22,000	$264,000	1.15	$303,600	$17,160
Walkway (elevated slab)	71	c. yd.	$620	$44,089	1	$44,100	
Aeration tanks							
Base slab	2,450	yd^3	$500	$1,225,000	1	$1,225,000	
Tank walls (20-ft tall)	1,467	yd^3	$640	$938,667	1	$938,700	
Walkway	170	yd^3	$620	$105,630	1	$105,700	

Table A.4 Probable Cost of Construction for Alternative No. 4 – Three-stage BNR Process with Secondary Clarifiers and Denitrification Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Fine pore aeration system	Lump sum			$172,727	1.15	$198,700	$11,227
Aeration blowers	Lump sum			$480,000	1.15	$552,000	$31,200
Internal recycle pumps	12	each	$89,800	$1,077,600	1.15	$1,239,300	$70,044
Swing zone mechanical mixers	4	each	$22,000	$88,000	1.15	$101,200	$5,720
Secondary clarifiers							
Base slab	2,979	yd^3	$500	$1,489,348	1	$1,489,400	
Tank walls (16-ft tall)	894	yd^3	$640	$571,909	1	$572,000	
Clarifier equipment	4	each	$186,250	$745,000	1.15	$856,800	$48,425
Density current baffles	4	each	$10,875	$43,500	1.15	$50,100	$2,828
Scum pumps	4	each	$15,000	$60,000	1.15	$69,000	$63,900
RAS pumps	5	each	$54,200	$271,000	1.15	$311,700	$17,615
WAS pumps	3	each	$17,000	$51,000	1.15	$58,700	$3,315
Deep-bed denitrification filters							
Base slab	552	yd^3	$500	$276,197	1	$276,200	
Tank walls (18-ft tall)	261	yd^3	$640	$167,076	1	$167,100	
Mudwell & clearwell (base slab)	459	yd^3	$500	$229,647	1	$229,700	
Mudwell & clearwell (walls)	285	yd^3	$640	$182,542	1	$182,600	
Deep-bed filter equipment	Lump sum			$1,400,000	1.15	$1,610,000	$91,000
Canopy structure over filter pipe gallery	1,680	ft^2	$75	$126,000	1	$126,000	
Methanol storage and feed system structure	1,080	ft^2	$75	$81,000	1	$81,000	
Chlorine contact tanks							
Base slab	184	yd^3	$500	$91,875	1	$91,900	
Tank walls	34	yd^3	$640	$22,044	1	$22,100	
Sodium hypochlorite storage and feed system	Lump sum			$80,000	1.15	$92,000	$5,200
Sodium hypochlorite storage building	1,080	ft^2	$100	$108,000	1	$108,000	
Disinfected effluent transfer pumps	5	each	$65,200	$326,000	1.15	$374,900	$21,190
Plant water pumps	3	each	$13,350	$40,050	1.15	$46,100	$2,603
Electrical building	600	ft^2	$150	$90,000	1	$90,000	
Reclaimed water storage and pumping							

Table A.4	Probable Cost of Construction for Alternative No. 4 – Three-stage BNR Process with Secondary Clarifiers and Denitrification Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
Reclaimed water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Reject water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Large Reclaimed water high service pumps	5	each	$78,900	$394,500	1.15	$453,700	$25,643
Small Reclaimed water high service pumps	2	Each	$20,000	$40,000	1.15	$46,000	$2,600
Reject water transfer pumps	5	each	$76,065	$380,325	1.15	$437,400	$24,721
Pump station building	1,875	ft^2	$150	$281,250	1	$281,300	
WAS holding tanks							
WAS holding tank (0.75 MG pre-stressed concrete tank)	1	each	$423,000	$423,000	1	$423,000	
Diffused aeration system	Lump sum			$28,000	1.15	$32,200	$1,820
Aeration blowers	Lump sum			$96,000	1.15	$110,400	$6,240
Concrete coating	12,763	ft^2	$15	$191,441	1	$191,500	
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	$24,375
Equipment (odor control)	1	each	$375,000	$375,000	1.15	$431,300	
Dewatering building							
Building	6,800	ft^2	$150	$1,020,000	1	$1,020,000	
Equipment (screw press)	3	each	$400,000	$1,200,000	1.15	$1,380,000	$78,000
Equipment (screw press feed pumps)	3	each	$25,000	$75,000	1.15	$86,300	$4,875
Equipment (dewatered biosolids conveyor system)	110	L.F.	$2,000	$220,000	1.15	$253,000	$14,300
Equipment (polymer system)	2	each	$20,000	$40,000	1.15	$46,000	$2,600
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	
Equipment (odor control equipment)	1	each	$375,000	$375,000	1.15	$431,300	$24,375
Main electrical/blower building							
Building (to house aeration blowers, electrical, etc)	5,400	ft^2	$150	$810,000	1	$810,000	

Table A.4	Probable Cost of Construction for Alternative No. 4 – Three-stage BNR Process with Secondary Clarifiers and Denitrification Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
Administration/operations building							
Building	8,000	ft^2	$200	$1,600,000	1	$1,600,000	
Total Installed Cost (Subtotal 1) (1)						**$26,060,000**	**$640,000**
Site Development (excavation, dewatering & site preparation) (10%)(1)						$2,610,000	
Piping, valves & appurtenances (20%)(1)						$5,220,000	
Electrical, instrumentation and controls (25%)(1)						$6,520,000	
Total Direct Cost (Subtotal 2) (1)						**$40,410,000**	
Project contingency (30%)(1)						$12,130,000	
Contractors' general conditions (10%)(1)						$4,050,000	
Contractor fees, overhead, & profit (10%)(1)						$4,050,000	
Sales tax (6.5%)(1)						$640,000	
Total Project Cost (2011 Dollars) (2)						**$61,300,000**	
Minimum (-15%)(2)						$52,100,000	
Maximum (+30%)(2)						$79,700,000	

Notes:
(1) Values rounded to the next $10,000.
(2) Values rounded to the next $100,000.

Table A.5	**Probable Cost of Construction for Alternative No. 5 – B5 / MBR Process SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
Headworks (coarse screens, grit removal & odor control)							
Base slab	207	yd^3	$600	$103,338	1	$103,400	
Walls	184	yd^3	$750	$117,760	1	$117,800	
Elevated slab	74	yd^3	$730	$45,662	1	$45,700	
Elevated walls	184	yd^3	$750	$117,760	1	$117,800	
Equipment (coarse screens)	2	each	$236,069	$472,138	1.15	$543,000	$30,689
Equipment (washer/compactors)	2	each	$75,500	$151,000	1.15	$173,700	$9,815
Equipment (Headcell with Slurry Cup and Grit Snail)	1	each	$440,000	$440,000	1.15	$506,000	$28,600
Base slab (odor control)	25	yd^3	$500	$14,700	1	$12,300	
Equipment (odor control unit)	1	each	$165,000	$165,000	1.15	$189,800	$10,725
Fine screens							
Base slab	55	yd^3	$600	$27,563	1	$27,600	
Walls	37	yd^3	$750	$23,520	1	$23,600	
Equipment (Fine screens)	2	each	$260,821	$521,642	1.15	$599,900	$33,907
Equipment (washer/compactors)	2	each	$75,500	$151,000	1.15	$173,700	$9,815
Anaerobic tanks							
Base slab	206	yd^3	$500	$102,900	1	$102,900	
Tank walls (20-ft tall)	347	yd^3	$640	$221,867	1	$221,900	
Platform mechanical mixers	8	each	$22,000	$176,000	1.15	$202,400	$11,440
Walkway (elevated slab)	41	yd^3	$620	$25,259	1	$25,300	$15,600
Anaerobic recycle pumps	8	Each	$30,000	$240,000	1.15	$276,000	
Pre-anoxic tanks							
Base slab	485	yd^3	$500	$242,550	1	$242,600	
Tank walls (20-ft tall)	680	yd^3	$640	$435,200	1	$435,200	
Platform mechanical mixers	12	each	$22,000	$264,000	1.15	$303,600	$17,160
Walkway (elevated slab)	76	yd^3	$620	$46,844	1	$46,900	
Aeration tanks							
Base slab	956	yd^3	$500	$477,750	1	$477,800	
Tank walls (20-ft tall)	947	yd^3	$640	$605,867	1	$605,900	
Walkway	110	yd^3	$620	$67,970	1	$68,000	
Fine pore aeration system	Lump sum			$169,697	1.15	$195,200	$11,030

Table A.5 Probable Cost of Construction for Alternative No. 5 – B5 / MBR Process
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Description	Unit Qty	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost	Sales Tax
Aeration blowers	Lump sum			$430,000	1.15	$494,500	$27,950
Internal recycle pumps	12	each	$89,800	$1,077,600	1.15	$1,239,300	$70,044
Swing zone mechanical mixer	4	Each	$22,000	$88,000	1.15	$101,200	$5,720
Post-anoxic tanks							
Base slab	191	yd^3	$500	$95,550	1	$95,600	
Tank walls (18-ft tall)	300	yd^3	$640	$192,000	1	$192,000	
Platform mechanical mixers	8	each	$22,000	$176,000	1.15	$202,400	$11,440
Walkway (elevated slab)	33	yd^3	$620	$20,207	1	$20,200	
Membrane tanks							
Base slab	250	yd^3	$500	$125,000	1	$125,000	
Tank walls (13-ft tall)	423	yd^3	$640	$270,400	1	$270,400	
Membrane equipment (membrane cassettes, blowers, permeate pumps, RAS pumps, controls)	Lump sum			$5,400,000	1.15	$6,210,000	$351,000
Scum pumps	4	each	$15,000	$60,000	1.15	$69,000	$63,900
WAS pumps	3	each	$17,000	$51,000	1.15	$58,700	$3,315
Membrane tanks – canopy	3,900	ft^2	$75	$292,500	1	$292,500	
Chlorine contact tanks							
Base slab	184	yd^3	$500	$91,875	1	$91,900	
Tank walls	34	yd^3	$640	$22,044	1	$22,100	
Sodium hypochlorite storage and feed system	Lump sum			$80,000	1.15	$92,000	$5,200
Sodium hypochlorite storage building	1,080	ft^2	$100	$108,000	1	$108,000	
Disinfected effluent transfer pumps	5	each	$65,200	$326,000	1.15	$374,900	$21,190
Plant water pumps	3	each	$13,350	$40,050	1.15	$46,100	$2,603
Electrical building	600	ft^2	$150	$90,000	1	$90,000	
Reclaimed Water Storage and Pumping							
Reclaimed water storage tank (5 MG pre-stressed concrete tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Reject water storage tank (5 MG Pre-stressed Concrete Tank)	1	each	$1,486,000	$1,486,000	1	$1,486,000	
Large Reclaimed water high	5	each	$78,900	$394,500	1.15	$453,700	$25,643

Table A.5	**Probable Cost of Construction for Alternative No. 5 – B5 / MBR Process SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**						
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
service pumps							
Small Reclaimed water high service pumps	2	Each	$20,000	$40,000	1.15	$46,000	$2,600
Reject water transfer pumps	5	each	$76,065	$380,325	1.15	$437,400	$24,721
Pump station building	1,875	ft^2	$150	$281,250	1	$281,300	
WAS holding tanks							
WAS holding tank (0.75 MG pre-stressed concrete tank)	1	each	$423,000	$423,000	1	$423,000	
Diffused aeration system	Lump sum			$28,000	1.15	$32,200	$1,820
Aeration blowers	Lump sum			$96,000	1.15	$110,400	$6,240
Concrete coating	12,763	ft^2	$15	$191,441	1	$191,500	
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55,600	$24,375
Equipment (odor control)	1	each	$375,000	$375,000	1.15	$431,300	
Dewatering building							
Building	6,800	ft^2	$150	$1,020,000	1	$1,020,000	
Equipment (screw press)	3	each	$400,000	$1,200,000	1.15	$1,380,000	$78,000
Equipment (screw press feed pumps)	3	each	$25,000	$75,000	1.15	$86,300	$4,875
Equipment (dewatered biosolids conveyor system)	110	L.F.	$2,000	$220,000	1.15	$253,000	$14,300
Equipment (polymer system)	2	each	$20,000	$40,000	1.15	$46,000	$2,600
Base slab (odor control)	111	yd^3	$500	$55,556	1	$55600	
Equipment (odor control equipment)	1	each	$375,000	$375,000	1.15	$431,300	$24,375
Main electrical/blower building							
Building (to house aeration blowers, permeate pumps, backpulse pumps, electrical, etc)	6,825	ft^2	$150	$1,023,750	1	$1,023,800	
Administration/Operations Building							
Building	8,000	ft^2	$200	$1,600,000	1	$1,600,000	
					Total Installed Cost (Subtotal 1) (1)	**$27,410,000**	**$960,000**
Site Development (excavation, dewatering & site preparation) (7.5%)(1) (2)						$2,060,000	
Piping, valves & appurtenances (17.5%)(1) (3)						$4,800,000	
Electrical, instrumentation and controls (25%)(1)						$6,860,000	

Table A.5 Probable Cost of Construction for Alternative No. 5 – B5 / MBR Process SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities							
Description	**Unit Qty**	**Std. Unit**	**Unit Price**	**Item Total**	**Install Factor**	**Total Cost**	**Sales Tax**
Total Direct Cost (Subtotal 2) [(1)]						**$41,130,000**	
Project contingency (30%)[(1)]						$12,340,000	
Contractors' general conditions (10%)[(1)]						$4,120,000	
Contractor fees, overhead, & profit (10%)[(1)]						$4,120,000	
Sales tax (6.5%)[(1)]						$960,000	
Total Project Cost (2011 Dollars) [(4)]							**$62,700,000**
Minimum (-15%)[(4)]							$53,300,000
Maximum (+30%)[(4)]							$81,500,000

Notes:
(1) Values rounded to the next $10,000.
(2) A lower factor of 7.5% of the total installed cost as compared to 10% for the other alternatives was used for site development cost, since the site work for this alternative will be comparatively less than the other alternatives.
(3) A lower factor of 17.5% of the total installed cost as compared to 20% for the other alternatives was used for piping, valves & appurtenances cost, since the footprint for this alternative will be comparatively less than the other alternatives.
(4) Values rounded to the next $100,000.

Table A.6 Estimate of Annual Power Costs for Alternative No. 1 – B5 Process with Secondary Clarifiers and Disk Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
Preliminary treatment									
Coarse screens	2	2	1	1	2	1.5	8	4,357	$357
Screenings compactor	2	2	1	1	1.5	1.1	8	3,267	$268
Odor control unit no. 1 - fan	1	10	0	1	10	7.5	24	65,350	$5,359
Odor control unit no. 1 - recirculation pump	1	5	1	1	5	3.7	24	32,675	$2,679
Activated sludge process blowers									
Process mixers	32	3	0	32	65	48.0	24	420,329	$34,467
Activated Sludge process Blowers	3	250	1	2	269.7	224	24	1,965,136	$161,141
Scum pumps	4	5	0	2	20	7.5	2	5,446	$447
IR pumps	12	10	4	8	59	45.5	24	398,236	$32,655
Secondary clarifiers									
Secondary clarifier mechanisms	4	10	0	2	20	14.9	24	130,699	$10,717
RAS pumps	5	15	1	4	20	15.1	24	132,612	$10,874
Disk filtration									
Disk filters backwash pumps	6	2	0	2	4	3.0	8	8,713	$714
Disk filters drive unit	3	0.8	0	1	0.75	0.6	8	1,634	$134
Effluent Disinfection and Pumping									
Effluent transfer pumps to reuse tank	5	40	1	3	59	45.5	24	398,236	$32,655
Reclaimed water pumps	5	300	1	3	254	196.9	24	1,724,858	$141,438
Sodium hypochlorite feed pumps	2	1	1	1	0.5	0.4	24	3,267	$268
Plant water pumps	2	40	1	1	20	29.8	12	130,699	$10,717

Table A.6 Estimate of Annual Power Costs for Alternative No. 1 – B5 Process with Secondary Clarifiers and Disk Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
WAS holding tanks									
WAS pumps	3	10	1	2	20	14.9	6	32,675	$2,679
Holding tanks process blowers	2	125	1	1	90	74	24	645,802	$52,956
Sludge dewatering									
Screw press feed pumps	3	10	1	2	20	14.9	13	70,795	$5,805
Screw press	3	5	1	2	10	7.5	13	35,398	$2,903
Dewatered cake conveyors	1	15	0	1	15	11.2	13	53,097	$4,354
HVAC, heating & lighting									
Site lighting, process area lighting, bldg, lighting, HVAC & heating								184,431	$15,123
							Total Annual Power	**6,447,711**	**$528,712**

Notes:
(1) Using average cost of power of 8.2 cents/kWhr

Table A.7 Estimate of Annual Power Costs for Alternative No. 2 – B5 Process with Secondary Clarifiers and Tertiary Membrane Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
Preliminary treatment									
Coarse screens	2	2	1	1	2	1.5	8	4,357	$357
Screenings compactor	2	2	1	1	1.5	1.1	8	3,267	$268
Odor control unit no. 1 - fan	1	10	0	1	10	7.5	24	65,350	$5,359
Odor control unit no. 1 - recirculation pump	1	5	1	1	5	3.7	24	32,675	$2,679
Activated sludge process blowers									
Process mixers	32	3	0	32	65	48.0	24	420,329	$34,467
Activated sludge process blowers	3	250	1	2	269.7	224	24	1,965,136	$161,141
Scum pumps	4	5	0	2	20	7.5	2	5,446	$447
IR pumps	12	10	4	8	59	45.5	24	398,236	$32,655
Secondary clarifiers									
Secondary clarifier mechanisms	4	10	0	2	20	14.9	24	130,699	$10,717
RAS pumps	5	15	1	4	20	15.1	24	132,612	$10,874
Membrane filtration									
Membrane permeate pumps	4	40	0	2				156,220	$12,810
Membrane back pulse pumps	2	40	1	1				2,920	$239
Membrane air compressors	2	7.5	1	1				6,935	$569
CIP drain pumps	2	5	1	1				365	$30
Membrane scour blowers	2	25	1	1				13,140	$1,077

Table A.7 Estimate of Annual Power Costs for Alternative No. 2 – B5 Process with Secondary Clarifiers and Tertiary Membrane Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
<u>Effluent disinfection and pumping</u>									
Effluent transfer pumps to reuse tank	5	40	1	3	59	45.5	24	398,236	$32,655
Reclaimed water pumps	5	300	1	3	254	196.9	24	1,724,858	$141,438
Sodium hypochlorite feed pumps	2	1	1	1	0.5	0.4	24	3,267	$268
Plant water pumps	2	40	1	1	20	29.8	12	130,699	$10,717
<u>WAS holding tanks</u>									
WAS pumps	3	10	1	2	20	14.9	6	32,675	$2,679
Holding tanks process blowers	2	125	1	1	90	74	24	645,802	$52,956
<u>Sludge dewatering</u>									
Screw press feed pumps	3	10	1	2	20	14.9	13	70,795	$5,805
Screw press	3	5	1	2	10	7.5	13	35,398	$2,903
Dewatered cake conveyors	1	15	0	1	15	11.2	13	53,097	$4,354
<u>HVAC, heating & lighting</u>									
Site lighting, process area lighting, bldg, lighting, HVAC & heating								184,691	$15,145
							Total Annual Power	**6,617,203**	**$542,611**

Notes:
(1) Using average cost of power of 8.2 cents/kWhr

**Table A.8 Estimate of Annual Power Costs for Alternative No. 3 – Step-feed BNR Process with Secondary Clarifiers and Disk Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities**

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
Preliminary treatment									
Coarse screens	2	2	1	1	2	1.5	8	4,357	$357
Screenings compactor	2	2	1	1	1.5	1.1	8	3,267	$268
Odor control unit no. 1 - fan	1	10	0	1	10	7.5	24	65,350	$5,359
Odor control unit no. 1 - recirculation pump	1	5	1	1	5	3.7	24	32,675	$2,679
Activated sludge process blowers									
Process mixers	30	3	0	30	61	45.0	24	394,058	$32,313
Activated sludge process blowers	3	250	1	2	280.7	233	24	2,045,345	$167,718
Scum pumps	4	5	0	2	20	15	2	10,892	$893
IR pumps	12	10	4	8	59	45.5	24	398,236	$32,655
Secondary clarifiers									
Secondary clarifier mechanisms	4	10	0	2	20	14.9	24	130,699	$10,717
RAS pumps	5	15	1	4	20	15.1	24	132,612	$10,874
Disk filtration									
Disk filters backwash pumps	6	2	0	2	4	3.0	8	8,713	$714
Disk filters drive unit	3	0.8	0	1	0.75	0.6	8	1,634	$134
Effluent disinfection and pumping									
Effluent transfer pumps to reuse tank	5	40	1	3	59	45.5	24	398,236	$32,655
Reclaimed water pumps	5	300	1	3	254	196.9	24	1,724,858	$141,438
Sodium hypochlorite feed pumps	2	1	1	1	0.5	0.4	24	3,267	$268

Table A.8 Estimate of Annual Power Costs for Alternative No. 3 – Step-feed BNR Process with Secondary Clarifiers and Disk Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
Plant water pumps	2	40	1	1	20	29.8	12	130,699	$10,717
WAS holding tanks									
WAS pumps	3	10	1	2	20	14.9	6	32,675	$2,679
Holding tanks process blowers	2	125	1	1	90	74	24	645,802	$52,956
Sludge dewatering									
Screw press feed pumps	3	10	1	2	20	14.9	14	76,241	$6,252
Screw press	3	5	1	2	10	7.5	14	38,121	$3,126
Dewatered cake conveyors	1	15	0	1	15	11.2	14	57,181	$4,689
HVAC, heating & lighting									
Site lighting, process area lighting, bldg, lighting, HVAC & heating								172,934	$14,181
							Total Annual Power	**6,502,405**	**$533,197**

Notes:
(1) Using average cost of power of 8.2 cents/kWhr

Table A.9 Estimate of Annual Power Costs for Alternative No. 4 – Three-stage BNR Process with Secondary Clarifiers and Denitrification Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
Preliminary treatment									
Coarse screens	2	2	1	1	2	1.5	8	4,357	$357
Screenings compactor	2	2	1	1	1.5	1.1	8	3,267	$268
Odor control unit no. 1 - fan	1	10	0	1	10	7.5	24	65,350	$5,359
Odor control unit no. 1 – recirculation pump	1	5	1	1	5	3.7	24	32,675	$2,679
Activated sludge process blowers									
Process mixers	28	3	0	28	57	42.0	24	367,788	$30,159
Activated sludge process blowers	3	250	1	2	275.2	229	24	2,005,240	$164,430
Scum pumps	4	5	0	2	20	15	2	10,892	$893
IR pumps	12	10	4	8	59	45.5	24	398,236	$32,655
Secondary clarifiers									
Secondary clarifier mechanisms	4	10	0	2	20	14.9	24	130,699	$10,717
RAS pumps	5	15	1	4	20	15.1	24	132,612	$10,874
Denitrification filters									
Backwash pump	2	35	1	1				6,550	$537
Backwash blower	2	150	1	1				24,000	$1,968
Bump pump	1		0	1				3,310	$271
Mud-well pump	2	5	1	1				5,240	$430
Nitrate analyzer	1		0					6,310	$517
Analyzer sample pump	4	0.5	0	4				3,000	$246

Table A.9 Estimate of Annual Power Costs for Alternative No. 4 – Three-stage BNR Process with Secondary Clarifiers and Denitrification Filters
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
Methanol feed pumps	3	0.5	1	2				700	$57
Effluent disinfection and pumping									
Effluent transfer pumps to reuse tank	5	40	1	3	59	45.5	24	398,236	$32,655
Reclaimed water pumps	5	300	1	3	254	196.9	24	1,724,858	$141,438
Sodium hypochlorite feed pumps	2	1	1	1	0.5	0.4	24	3,267	$268
Plant water pumps	2	40	1	1	20	29.8	12	130,699	$10,717
WAS holding tanks									
WAS pumps	3	10	1	2	20	14.9	6	32,675	$2,679
Holding tanks process blowers	2	125	1	1	90	74	24	645,802	$52,956
Sludge dewatering									
Screw press feed pumps	3	10	1	2	20	14.9	14	76,241	$6,252
Screw press	3	5	1	2	10	7.5	14	38,121	$3,126
Dewatered cake conveyors	1	15	0	1	15	11.2	14	57,181	$4,689
HVAC, heating & lighting									
Site lighting, process area lighting, bldg, lighting, HVAC & heating								184,431	$15,123
							Total Annual Power	**6,486,290**	**$531,876**

Notes:
(1) Using average cost of power of 8.2 cents/kWhr

Table A.10 Estimate of Annual Power Costs for Alternative No. 5 – B5 / MBR Process SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
Preliminary treatment									
Coarse screens	2	2	1	1	2	1.5	8	4,357	$357
Screenings compactor	2	2	1	1	1.5	1.1	8	3,267	$268
Odor control unit no. 1 - fan	1	10	0	1	10	7.5	24	65,350	$5,359
Odor control unit no. 1 - recirc pump	1	5	1	1	5	3.7	24	32,675	$2,679
Activated sludge process blowers									
Process mixers	32	3	0	32	65	48.0	24	420,329	$34,467
Activated sludge process blowers	3	250	1	2	280.7	233	24	2,045,345	$167,718
Scum pumps	4	5	0	2	20	15	2	10,892	$893
IR pumps	12	10	4	8	59	45.5	24	398,236	$32,655
MBR processes & equipment									
Fine screens	2	2	1	1	2	1.5	8	4,357	$357
Screenings compactor	2	2	1	1	1.5	1.1	8	3,267	$268
Membrane permeate pumps	4	40	0	4			24	153,300	$12,571
Membrane air compressors	2	7.5	1	1			24	7,300	$599
Membrane scour blowers	3	200	1	2			24	682,550	$55,969
RAS pumps	4	40	0	4			24	511,000	$41,902
Effluent disinfection and pumping									
Effluent transfer pumps to reuse tank	5	40	1	3	59	45.5	24	398,236	$32,655
Reclaimed water pumps	5	300	1	3	254	196.9	24	1,724,858	$141,438
Sodium hypochlorite feed pumps	2	1	1	1	0.5	0.4	24	3,267	$268
Plant water pumps	2	40	1	1	20	29.8	12	130,699	$10,717

Table A.10 Estimate of Annual Power Costs for Alternative No. 5 – B5 / MBR Process
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Equipment	No. of Units	HP per Unit	Standby Units	No. of Units at Avg. Condition	Connected bHP	Connected KW Avg. Day	Run Time Hr/Day	Average Power Usage kWh/d	Average Annual Power Cost $/Year
WAS holding tanks									
WAS pumps	3	10	1	2	20	14.9	6	32,675	$2,679
Holding tanks process blowers	2	125	1	1	90	74	24	645,802	$52,956
Sludge dewatering									
Screw press feed pumps	3	10	1	2	20	14.9	14	76,241	$6,252
Screw press	3	5	1	2	10	7.5	14	38,121	$3,126
Dewatered cake conveyors	1	15	0	1	15	11.2	14	57,181	$4,689
HVAC, heating & lighting									
Site lighting, process area lighting, bldg, lighting, HVAC & heating								146,207	$11,989
							Total Annual Power	**7,590,064**	**$622,385**

Notes:
(1) Using average cost of power of 8.2 cents/kWhr

<u>Operations and Maintenance (O&M) Flow / Manpower Relationships (for plants staffed 24/7)</u>

Applicable data taken from Chapter 8 of *Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants*, NEIWPCC, 2008

For a 5 mgd, AADF plant

Table A.11 O & M Flow / Manpower Relationship (for plants staffed 24/7)
Operations for Applicable Unit Processes
SWWRF Conceptual Design and Facilities Plant Update
Orange County Utilities

Process Description	Annual Operations Man-Hours
Preliminary Treatment	365
Activated Sludge with BNR	2,920
Membrane Processes	183
Granular Media Filters	365
Cloth Filtration	182
Centrifuges	1,095
Wet Odor Control	182(2)
Chlorination	365
Plant Reuse Water	37

Notes:
(1) Per Appendix D of *Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants*, NEIWPCC, 2008.
(2) Multiply by number of units or systems.

Table A.12 O&M Flow / Manpower Relationship (for plants staffed 24/7)
Operations for Applicable Equipment
SWWRF Conceptual Design and Facilities Plant Update
Orange County Utilities

Process Description	Annual Maintenance Man-Hours
Mechanically cleaned screens with washer/compactors	365$^{(2)}$
Fine screens	37$^{(2)}$
Vortex Grit Removal	92$^{(2)}$
Circular Clarifiers	182$^{(2)}$
Pumps	250
Mechanical Mixers	37$^{(2)}$
Aeration Blowers	73$^{(2)}$
Membrane Bioreactor (MBR)	37$^{(3)}$
Granular Media Filters	73$^{(2)}$
Anaerobic Digestion	73$^{(2)}$
Chlorination (liquid)	73

Notes:
(1) Per Appendix D of *Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants*, NEIWPCC, 2008.
(2) Multiply by number of units.
(3) Multiply by number of cassettes.

Table A.13 Estimate of Annual Operations and Maintenance Labor Costs for Alternative No. 1 B5 Process with Secondary Clarifiers and Disk Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities				
Unit Process	**Annual Operations Hours**	**Annual Maintenance Hours**	**Total Annual Hours**	**Annual Labor Cost ($)**
Coarse Screens	182.5	730	912.5	$27,375
Vortex Grit Removal	182.5	92	274.5	$8,235
Pumps	0	250	250	$7,500
Activated Sludge w/ BNR	2920	0	2920	$87,600
Mechanical Mixers	0	1184	1184	$35,520
Aeration Blowers	0	365	365	$10,950
Secondary Clarifiers	0	732	732	$21,960
Cloth Disk Filters	183	109.5	292.5	$8,775
Disinfection using Hypochlorite	365	73	438	$13,140
Screw Presses	1095	165	1260	$37,800
Biosolids Handling and Disposal Offsite	1460	0	1460	$43,800
Yard Work			400	$12,000
Total	**6,388**	**3,701**	**10,489**	**$314,655**

Notes:

(1) Operations and maintenance hours are based on following equipment for Alternative No. 1
  a. No. of coarse screens – 2
  b. No. of vortex grit removal units – 1
  c. No. of pumps – 46
  d. No. of mechanical mixers – 32
  e. No. of aeration blowers – 5
  f. No. of secondary clarifiers – 4
  g. No. of disk filters - 3
  h. No. of screw presses – 3

(2) Using average labor rate of $30/hour including all fringe benefits.

Table A.14	**Estimate of Annual Operations and Maintenance Labor Costs for Alternative No. 2 B5 Process with Secondary Clarifiers and Tertiary Membrane Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**			
Unit Process	**Annual Operations Hours**	**Annual Maintenance Hours**	**Total Annual Hours**	**Annual Labor Cost ($)**
Coarse Screens	182.5	730	912.5	$27,375
Vortex Grit Removal	182.5	92	274.5	$8,235
Pumps	0	250	250	$7,500
Activated Sludge w/ BNR	2920	0	2920	$87,600
Mechanical Mixers	0	1184	1184	$35,520
Aeration Blowers	0	511	511	$15,330
Secondary Clarifiers	0	732	732	$21,960
Tertiary Membrane Filters	0	740	740	$22,200
Disinfection using Hypochlorite	365	73	438	$13,140
Screw presses	1095	165	1260	$37,800
Biosolids Handling and Disposal Offsite	1460	0	1460	$43,800
Yard Work			400	$12,000
Total	**6,205**	**4,477**	**11,082**	**$332,460**

Notes:

(1) Operations and maintenance hours are based on following equipment for Alternative No. 2

a. No. of coarse screens – 2
b. No. of vortex grit removal units – 1
c. No. of pumps – 46
d. No. of mechanical mixers – 32
e. No. of aeration blowers – 7
f. No. of secondary clarifiers – 4
g. No. of membrane cassettes - 20
h. No. of screw presses – 3

(2) Using average labor rate of $30/hour including all fringe benefits.

Table A.15	**Estimate of Annual Operations and Maintenance Labor Costs for Alternative No. 3 Step-feed BNR Process with Secondary Clarifiers and Disk Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**			
Unit Process	**Annual Operations Hours**	**Annual Maintenance Hours**	**Total Annual Hours**	**Annual Labor Cost ($)**
Coarse Screens	182.5	730	912.5	$27,375
Vortex Grit Removal	182.5	92	274.5	$8,235
Pumps	0	250	250	$7,500
Activated Sludge w/ BNR	2920	0	2920	$87,600
Mechanical Mixers	0	1110	1110	$33,300
Aeration Blowers	0	365	365	$10,950
Secondary Clarifiers	0	732	732	$21,960
Cloth disk Filters	183	109.5	292.5	$8,775
Disinfection using Hypochlorite	365	73	438	$13,140
Screw Presses	1095	165	1260	$37,800
Biosolids Handling and Disposal Offsite	1460	0	1460	$43,800
Yard Work			400	$12,000
Total	**6,388**	**3,627**	**10,415**	**$312,435**

Notes:

(1) Operations and maintenance hours are based on following equipment for Alternative No. 3

a. No. of coarse screens – 2
b. No. of vortex grit removal units – 1
c. No. of pumps – 46
d. No. of mechanical mixers – 30
e. No. of aeration blowers – 5
f. No. of secondary clarifiers – 4
g. No. of disk filters - 3
h. No. of screw presses – 3

(2) Using average labor rate of $30/hour including all fringe benefits

Table A.16	**Estimate of Annual Operations and Maintenance Labor Costs for Alternative No. 4 Three-stage BNR Process with Secondary Clarifiers and Deep-Bed Filters SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**			
Unit Process	**Annual Operations Hours**	**Annual Maintenance Hours**	**Total Annual Hours**	**Annual Labor Cost ($)**
Coarse Screens	182.5	730	912.5	$27,375
Vortex Grit Removal	182.5	92	274.5	$8,235
Pumps	0	250	250	$7,500
Activated Sludge w/ BNR	2920	0	2920	$87,600
Mechanical Mixers	0	1036	1036	$31,080
Aeration Blowers	0	511	511	$15,330
Secondary Clarifiers	0	732	732	$21,960
Deep bed Filters	365	292	657	$19,710
Disinfection using Hypochlorite	365	73	438	$13,140
Screw Presses	1095	165	1260	$37,800
Biosolids Handling and Disposal Offsite	1460	0	1460	$43,800
Yard Work			400	$12,000
Total	**6,570**	**3,881**	**10,851**	**$325,530**

Notes:

(1) Operations and maintenance hours are based on following equipment for Alternative 4

a. No. of coarse screens – 2
b. No. of vortex grit removal units – 1
c. No. of pumps – 45
d. No. of mechanical mixers – 28
e. No. of aeration blowers – 7
f. No. of secondary clarifiers – 4
g. No. of deep-bed filters - 4
h. No. of screw presses – 3

(2) Using average labor rate of $30/hour including all fringe benefits.

Table A.17	**Estimate of Annual Operations and Maintenance Labor Costs for Alternative No. 5 B5 / MBR Process SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities**			
Unit Process	**Annual Operations Hours**	**Annual Maintenance Hours**	**Total Annual Hours**	**Annual Labor Cost ($)**
Coarse Screens	182.5	730	912.5	$27,375
Fine Screens	182.5	74	256.5	$7,695
Vortex Grit Removal	182.5	92	274.5	$8,235
Pumps	0	250	250	$7,500
Activated Sludge w/ BNR	2920	0	2920	$87,600
Mechanical Mixers	0	1184	1184	$35,520
Aeration Blowers	0	730	730	$21,900
MBR Membranes	0	1540	1540	$46,200
Disinfection using Hypochlorite	365	73	438	$13,140
Screw Presses	1095	165	1260	$37,800
Biosolids Handling and Disposal Offsite	1460	0	1460	$43,800
Yard Work			400	$12,000
Total	**6,388**	**4,838**	**11,626**	**$348,765**

Notes:

(1) Operations and Maintenance hours are based on following equipment for Alternative 5
  a. No. of coarse screens – 2
  b. No. of fine screens - 2
  c. No. of vortex grit removal units – 1
  d. No. of pumps – 43
  e. No. of mechanical mixers – 32
  f. No. of aeration blowers – 10
  g. No. of membrane cassettes - 28
  h. No. of screw presses – 3

(2) Using average labor rate of $30/hour including all fringe benefits.

PROCESS DESIGN CRITERIA

B.1. Biological Process Design Parameters and Assumptions

Table B.1 presents assumptions used for the influent wastewater characteristics, and kinetic and stoichiometric coefficients used for the biological process calculations for the five alternatives evaluated. Table B.2 presents additional process and equipment assumptions used for Alternative No's 1 through 4. Similarly, Table B.3 presents additional process and equipment assumptions used for Alternative No. 5 (B5/MBR). This information was ultimately used to select the major mechanical equipment for use in preparing capital and O&M costs for each of the five process alternatives.

Table B.1 Influent Characteristics, and Kinetic and Stoichiometric Coefficients for Biological Process Design
SWWRF Conceptual Design and Facilities Plant Update
Orange County Utilities

Parameter	Unit	Value
Organic fraction of influent TSS, f_o		0.80
Non-degradable fraction in influent VSS, α		0.30
Non-degradable fraction of biomass, β		0.24
Organic biomass yield coefficient, y_o	lb VSS/lb $cBOD_5$ removed	0.65
Decay coefficient of biomass, k_d @ 20 °C		0.12
Phosphorus in MLVSS(1)	%	4.0
Nitrogen in MLVSS(1)	%	8.0
Ammonia half-saturation coefficient, $k_{(n)}$		0.84
Oxygen half-saturation coefficient, k_o		0.5
Nitrification safety factor		1.5
Aerobic SRT, θ_c	days	6.0
Design net yield, y_n	lb TSS/lb BOD_5	0.95 (2)

Notes:
(1) Assumed as a typical nutrient content of mixed liquor volatile suspended solids in an enhanced biological phosphorus removal process.
(2) Varies slightly depending on the alternative.

Table B.2 **Additional Process and Equipment Assumptions for Alternative No's 1 - 4 SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities**		
Parameter	**Unit**	**Value**
Design MLSS concentration, X	mg/l	3,200
Type of secondary clarifiers	Cast-in place circular tank	
Type of sludge collection mechanism	suction type (Tow-Bro®)	
Clarifier minimum side water depth (SWD)	ft	14.0
Clarifier surface overflow rate, ADF [(1)]	gpd/ft^2	250
Clarifier maximum surface overflow rate, phf [(1)]	gpd/ft^2	750
RAS ratio	% of influent flow	50 – 125
Type of RAS pumps	horizontal non-clog centrifugal w/VFD	
Internal recycle (IR) flow range (for denitrification)	% of influent flow	100 - 400
Type of IR pumps	horizontal non-clog centrifugal w/VFD	
Notes: (1) Estimated using a modification of the Vesilind equation with X_o = 19.5 ft/hour and X_M = 2,300 mg/L, and a clarifier safety factor of 2.65.		

Table B.3 **Additional Process and Equipment Assumptions for Alternative No. 5 SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities**		
Parameter	**Unit**	**Value**
Design MLSS concentration, X	mg/l	7,000
RAS flow range	% of influent flow	100 – 400
Type of RAS pumps	horizontal non-clog centrifugal w/ VFD	
Internal recycle (IR) ratio	% of influent flow	100 - 400
Type of IR Pumps	horizontal non-clog centrifugal w/ VFD	

B.2. Aeration System Design Parameters and Assumptions

Aeration systems are used in the activated sludge process to provide oxygen for the biological oxidation of carbonaceous and nitrogenous matter and to maintain the biological solids uniformly mixed within the reactor. Estimated maximum day oxygen demands and a minimum dissolved oxygen (D.O.) concentration of 2.0 mg/l were used to size the capacity of the aeration system. The average oxygen demand was used to size the aeration basins and to estimate the annual power consumption. Peak oxygen demand was estimated as 1.6 times the average day demand and used to size the blowers and diffused aeration equipment. Table B.4 summarizes the aeration system design parameters and assumptions for the five treatment alternatives evaluated.

Table B.4 Aeration System Design Parameters and Assumptions
SWWRF Conceptual Design and Facilities Plant Update
Orange County Utilities

Parameter	Unit	Value
Type of air diffusers		fine bubble membrane diffusers(1)
Universal gas constant	lbf /sf(cf)/lbair(^{o}R)	53.5
Weight of standard air	lb air/scf	0.075
Oxygen content of air	lb O_2/lb air	0.2095
Effect of dissolved organics in wastewater on oxygen transfer (K_{La}), α		~0.45
Correction factor for effect of wastewater constituents on oxygen saturation, β		0.99
Effect of barometric pressure on oxygen saturation, Ω		1.0
Temperature correction factor for the oxygen saturation value, τ		1.0
Temperature correction factor, θ		1.024
Saturated clean water dissolved oxygen, Cs_{20}	mg/l	9.09
Spatial average dissolved oxygen in aeration tank	mg/l	2.0
Aeration tank side water depth (SWD)	ft	18.0(2)
Diffuser submergence	ft	16.5(3)
Diffuser equivalent depth factor		0.40
Equivalent depth	ft	6.6
Diffuser air flow/diffuser (average)	scfm	1.3
Diffuser transfer efficiency	%/ft	per manufacturer
Type of aeration blowers		single stage centrifugal (4)

Notes:
(1) From Orange County Utilities Facilities Plan, (PBS&J/CDM, 2007).
(2) 2007 Facilities Plan recommended a minimum 15 ft water depth. Phase III of OCU North Water Reclamation Facility (NWRF) is designed with a water depth of 18 ft. Hence assumption is that the aeration tank will be 20 ft deep including 2.0 ft freeboard.
(3) Assuming diffusers are mounted approximately 1.5 ft above floor of the tank.
(4) SWRF Phase V is currently designed with single-stage (SS) centrifugal blowers. SS blowers are reported to be one of the most energy efficient blowers available in the market

B.3. Design Parameters and Assumptions for Filtration Systems

Table B.5 provides design parameters and assumptions used for preliminary sizing of the filtration systems for the various alternatives.

Table B.5 Design Parameters and Assumptions for Filtration Systems SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities

Unit Process	Parameter	Unit	Value
Tertiary Filters(1)	Type of tertiary filters(1)		disk filters(2)
	Manufacturer		Aqua Aerobics AquaDisk®
	Filter influent average TSS	mg/l	10
	Filter influent maximum TSS	mg/l	15
	Filter effluent maximum TSS	mg/l	5
	Filter effluent maximum turbidity	NTU	2.0
	Filter Hydraulic Loading Rate		
	Average	gpm/ft^2	per manufacturer
	Peak (w/one filter out of service)	gpm/ft^2	6.5
Tertiary Filters(3)	Type of tertiary filters(3)		down-flow, deep-bed filters
	Manufacturer		Severn Trent Services (TETRA Denite® filters)
	Filter influent average TSS	mg/l	10
	Filter influent maximum TSS	mg/l	15
	Average filter influent TN	mg/l	10 (8.5 mg/l NO_3-N; 0.5 mg/l NH_3-N; 1 mg/l Org. N)
	Maximum filter influent TN	mg/l	12 (10 mg/l NO_3-N; 1 mg/l NH_3-N; 1 mg/l Org. N)
	Filter effluent nitrate (NO_3-N)	mg/l	≤ 1.0
	Filter effluent TP	mg/l	≤ 1.0
	Filter effluent maximum TSS	mg/l	5
	Filter effluent maximum turbidity	NTU	2.0
	Filter Hydraulic Loading Rate		
	Average	gpm/ft^2	per manufacturer
	Peak (w/one filter out of service)	gpm/ft^2	5.0
Tertiary Filters(4)	Type of tertiary filters(4)		submerged ultrafiltration membrane filters

Table B.5 Design Parameters and Assumptions for Filtration Systems SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities			
Unit Process	**Parameter**	**Unit**	**Value**
	Manufacturer		GE ZeeWeed® 1000
	Design permeate production capacity, (average/peak)	mgd	5/15
	Filter influent average TSS	mg/l	10
	Filter influent maximum TSS	mg/l	15
	Minimum no. of membrane trains		4
	Maximum allowable flux	gfd	31
	Membrane trains		4
	Total membrane cassettes installed per train		5
	Total membrane cassette space per train		6
	Membrane modules per train		300
	Membrane modules installed		1,200
	Percent spare space	%	16.7
	Total membrane area installed	ft^2	482,315
	Permeate turbidity	NTU	< 0.2 (avg.) < 0.5 (max.)
Tertiary Filters(5)	Type of tertiary filters(5)		submerged ultrafiltration membrane filters
	Manufacturer		GE ZeeWeed® 500
	Design permeate production capacity, (average/peak)	mgd	5/15
	Minimum no. of membrane trains		4
	Maximum allowable flux	gfd	31
	Membrane trains		4
	Total membrane cassettes installed per train		7
	Total membrane cassette space per train		8
	Membrane modules per train		326
	Membrane modules installed		1,304
	Percent spare space	%	15.1

Table B.5	Design Parameters and Assumptions for Filtration Systems SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities		
Unit Process	**Parameter**	**Unit**	**Value**
	Total membrane area installed	ft^2	482,315
	Permeate turbidity	NTU	< 0.2 (avg.) < 0.5 (max.)

Notes:
(1) For Alternative No's 1 and 3.
(2) From Orange County Utilities Facilities Plan, (PBS&J/CDM, 2007).
(3) For Alternative No. 4 only.
(4) For Alternative No. 2 only.
(5) For Alternative No. 5 only.

B.4. Design Criteria for Activated Sludge treatment

Table B.6 presents the design criteria for the activated sludge processes for the five process alternatives. The design criteria are derived from the process assumptions in combination with simple flow and mass balance spreadsheet models. Figure B.1 through Figure B.4 present preliminary layouts for the activated sludge basins based on the design criteria.

Table B.6 Summary of Activated Sludge Treatment Design Criteria for the Five Liquid Treatment Alternatives
SWWRF Conceptual Design and Facilities Plant Update
Orange County Utilities

Parameter	**Alternative No. 1** B5 process with disk filters	**Alternative No. 2** B5 process with tertiary membrane filters	**Alternative No. 3** Step-feed BNR process with disk filters	**Alternative No. 4** Three-stage BNR process with denitrification filters	**Alternative No. 5** B5/MBR
			Activated Sludge Treatment		
No. of treatment basins	**4**	**4**	**2**	**4**	**4**
Total process volume, mg (ft^3)	**5.55 (741,980)**	**5.55 (741,980)**	**4.67 (624,330)**	**4.22 (564,170)**	**2.60 (347,594)**
Average MLSS, mg/l	3,200	3,200	4,098	3,200	7,000
Aerobic SRT, days	6	6	6	6	6
Total SRT, days	11.8	11.8	9.4	8.4	11.6
RAS conditioning volume, mg (ft^3)	-	-	0.14 (18,720)	0.19 (25,400)	-
No. of reactors per basin	-	-	1	1	-
Total no. of reactors	-	-	2	4	
Volume per reactor, mg (ft^3)	-	-	0.07 (9,360)	0.048 (6,350)	-
Reactor dimensions(1)	-	-	30’ x 16’ x 20’	20’ x 18’ x 20’	-
Anaerobic volume, mg (ft^3)	0.27 (36,100)	0.27 (36,100)	-	0.27 (36,100)	0.27 (36,100)
No. of reactors per basin	2	2	-	2	2
Total no. of reactors	8	8	-	8	8
Volume per reactor, mg (ft^3)	0.034 (4,512)	0.034 (4,512)	-	0.034 (4,512)	0.034 (4,512)
Reactor dimensions(1)	14’ x 18’ x 20’	14’ x 18’ x 20’	-	14’ x 18’ x 20’	14’ x 18’ x 20’
Pre-anoxic volume, mg (ft^3)	1.36 (181,820)	1.36 (181,820)	0.98 (131,020)	0.58 (77,540)	0.66 (88,240)
No. of reactors per basin	3	3	9	3	3
Total no. of reactors	12	12	18	12	12
Volume per reactor, mg (ft^3)	0.113 (15,150)	0.113 (15,150)	0.054 (7,280)	0.048 (6,460)	0.055 (7,360)
Reactor dimensions(1)	28’ x 30’ x 20’	28’ x 30’ x 20’	20’ x 22’ x 20’	20’ x 18’ x 20’	22’ x 18’ x 20’
Aerobic volume, mg (ft^3)	2.92 (390,375)	2.92 (390,375)	2.41 (322,190)	3.18 (425,130)	1.25 (167,110)
No. of reactors per basin	1	1	3	1	1
Total no. of reactors	4	4	6	4	4
Volume per reactor, mg (ft^3)	0.73 (97,594)	0.73 (97,594)	0.40 (53,698)	0.795 (106,283)	0.31 (41,778)
Reactor dimensions(1)	182’ x 30’ x 20’	182’ x 30’ x 20’	136’ x 22’ x 20’	200’ x 30’ x 20’	130’ x 18’ x 20’

Table B.6	Summary of Activated Sludge Treatment Design Criteria for the Five Liquid Treatment Alternatives SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities				
Parameter	**Alternative No. 1** B5 process with disk filters	**Alternative No. 2** B5 process with tertiary membrane filters	**Alternative No. 3** Step-feed BNR process with disk filters	**Alternative No. 4** Three-stage BNR process with denitrification filters	**Alternative No. 5** B5/MBR
Post-anoxic volume, mg (ft^3)	0.86 (114,975)	0.86 (114,975)	1.0 (133,690)	-	0.21 (28,075)
No. of reactors per basin	2	2	3	-	2
Total no. of reactors	8	8	6	-	8
Volume per reactor, mg (ft^3)	0.107 (14,372)	0.108 (14,372)	0.17 (22,282)	-	0.026 (3,509)
Reactor dimensions(1)	30' x 30' x 18'	30' x 30' x 18'	46' x 32' x 18'	-	13' x 18' x 18'
Re-aeration volume, mg (ft^3)	0.14 (18,720)	0.14 (18,720)	0.14 (18,270)	-	-
No. of reactors per basin	1	1	1	-	-
Total no. of reactors	4	4	4	-	-
Volume per reactor, mg (ft^3)	0.035 (4,680)	0.035 (4,680)	0.035 (4,680)		
Reactor dimensions(1)	8' x 30' x 18'	8' x 30' x 18'	30' x 20' x 18'		
MBR tank volume, mg (ft^3)	-	-	-	-	0.21 (28,080)
No. of reactors per basin	-	-	-	-	1
Total no. of reactors	-	-	-	-	4
Volume per reactor, mg (ft^3)	-	-	-	-	0.05 (7,020)
Reactor dimensions(2)	-	-	-	-	55' x 10' x 13'
Internal recycle ratio (range)	1Q – 4Q	1Q – 4Q	-	1Q – 3Q	2Q – 4Q
Max. Internal recycle flow, gpm	13,900	13,900	-	10,425	13,900
No. of IR pumps	8 duty/4 stby	8 duty/4 stby	-	8 duty/4 stby	8 duty/4 stby
Max. IR flow per pump, gpm	1,738	1,738	-	1,390	1,738
Secondary Clarification					
No. of secondary clarifiers	4	4	4	4	-
Diameter of secondary clarifier, ft	80	80	80	80	-
Design SVI	160	160	160	160	-
Total surface area, ft^2	20,106	20,106	20,106	20,106	
Minimum side water depth, ft	14	14	14	14	
Surface overflow rate, gpd/ft^2					-

Table B.6 Summary of Activated Sludge Treatment Design Criteria for the Five Liquid Treatment Alternatives
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Orange County Utilities

Parameter	Alternative No. 1	Alternative No. 2	Alternative No. 3	Alternative No. 4	Alternative No. 5
	B5 process with disk filters	B5 process with tertiary membrane filters	Step-feed BNR process with disk filters	Three-stage BNR process with denitrification filters	B5/MBR
@AADF @PHF	250 750	250 750	250 750	250 750	
Solids loading rate(3), lb/d/ft^2 @AADF @MMF	 12 15	 12 15	 12 15	 12 15	-
Weir loading rate, gpd/ft @ PHF	 14,920	 14,920	 14,920	 14,920	
RAS ratio (range)	0.5Q – 1.25Q	0.5Q – 1.25Q	0.5Q – 1.25Q	0.5Q – 1.25Q	1Q – 4Q
Max. RAS flow, gpm	4,345	4,345	4,345	4,345	13,900
No. of RAS pumps	4 duty/1 stby	4 duty/1 stby	4 duty/1 stby	4 duty/1 stby	4 duty/1 stby
Max. RAS flow per pump, gpm	1,086	1,086	1,086	1,086	3,475
WAS sludge, lb/day	11,800	11,800	12,190	12,600	12,100
WAS sludge, gpd	200,820	200,820	207,370	214,070	205,750
Hours WAS wasted per day	6	6	6	6	6
No. of WAS pumps	2 duty/1 stby	2 duty/1 stby	2 duty/1 stby	2 duty/1 stby	2 duty/1 stby
WAS pump capacity, gpm	280	280	290	300	290
Aeration System Details					
Total carbonaceous oxygen demand (lb O_2/day), adf	12,120	12,120	12,120	12,120	12,500
Total nitrogenous oxygen demand (lb O2/day), adf	5,375	5,375	5,410	5,200	5,350
Total denitrification credit (lb O2/day), adf	2,700	2,700	2,200	2,300	2,500
Total AOR, (lb O2/day), adf	14,800	14,800	15,400	15,100	15,400
AOR/SOR(4)	0.34	0.34	0.34	0.34	0.34
Total SOR (lb O2/day), adf	43,530	43,530	45,290	44,410	45,290
Process air, scfm (adf)	4,900	4,900	5,100	5,700	5,100
Process air, scfm (mdf)	8,300	8,300	8,200	9,700	8,700
No. of aeration blowers (single stage centrifugal)	3 (2 duty/1 standby)	3 (2 duty/1 standby)	3 (2 duty/1 standby)	3 (2 duty/1 standby)	3 (2 duty/1 standby)
Blower capacity, scfm	4,150	4,150	4,150	(2) 5,700 + (1) 4,000	4,350

Table B.6 Summary of Activated Sludge Treatment Design Criteria for the Five Liquid Treatment Alternatives
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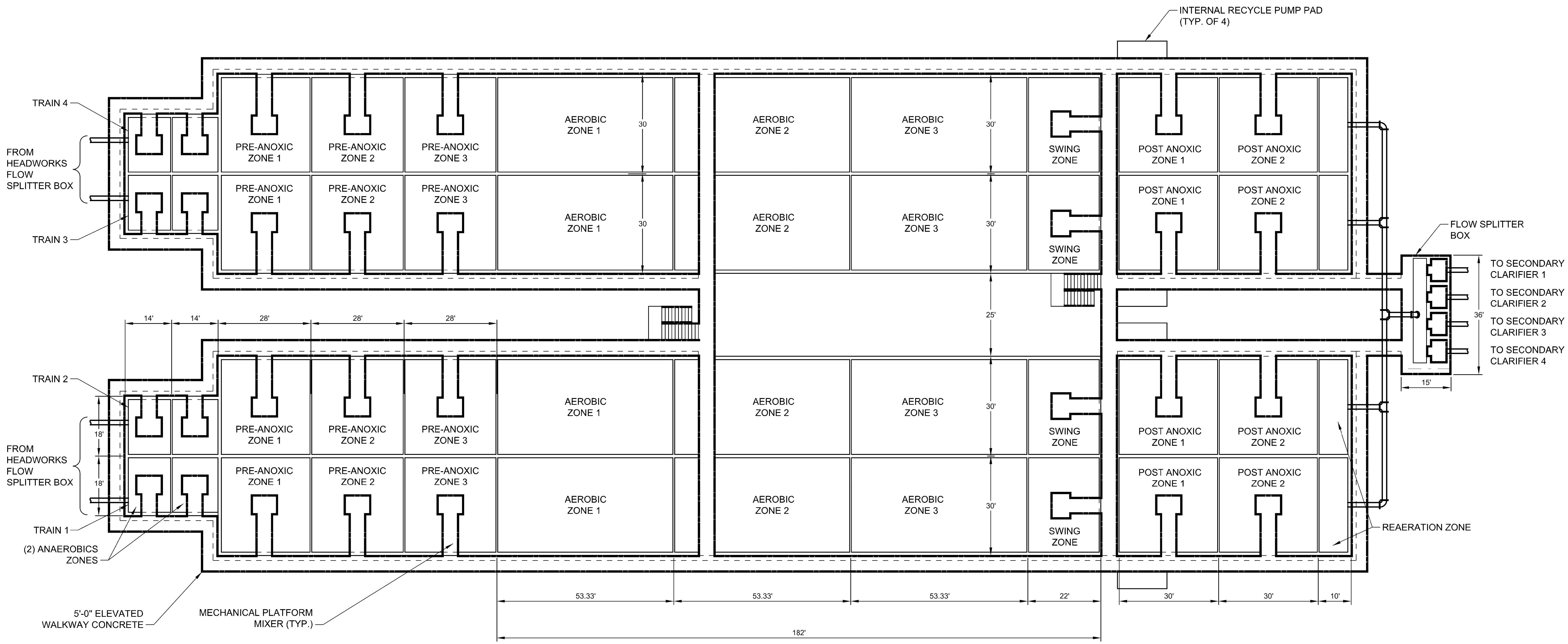
Orange County Utilities

Parameter	**Alternative No. 1**	**Alternative No. 2**	**Alternative No. 3**	**Alternative No. 4**	**Alternative No. 5**
	B5 process with disk filters	B5 process with tertiary membrane filters	Step-feed BNR process with disk filters	Three-stage BNR process with denitrification filters	B5/MBR
Tertiary Filtration					
Type of tertiary filters	cloth disk	ultrafiltration membrane	cloth disk	deep-bed denite®	ultrafiltration membrane
No. of installed filters or filtration cassettes	3	20(5)	3	4	28(6)
Total filter area provided (ft^2)	1,940	482,000	1,900	2,100	482,000
hydraulic loading rate or flux @ADF @MDF @PHF	 1.79 (gpm/ft^2) 3.05 (gpm/ft^2) 5.38 (gpm/ft^2)	 10.4 (gpd/ft^2) 17.6 (gpd/ft^2) 31.1 (gpd/ft^2)	 1.79 (gpm/ft^2) 3.05 (gpm/ft^2) 5.38 (gpm/ft^2)	 1.67 (gpm/ft^2) 2.85 (gpm/ft^2) 5.01 (gpm/ft^2)	 10.4 (gpd/ft^2) 17.6 (gpd/ft^2) 31.1 (gpd/ft^2)
Filter or filter tank size (per filter),	9.8' x 20.6'	16.3 x 8.6'(5)	9.8' x 20.6'	9.5' x 54.8'	55' x 10'(6)

Notes:
(1) Assuming 18 ft water depth and 2 ft of freeboard, total of 20 ft high.
(2) Assuming 16 ft water depth and 2 ft of freeboard) total of 18 ft high.
(3) Assuming a design RAS ratio of 0.74.
(4) Assuming an alpha factor of 0.455 for diffuser transfer efficiency.
(5) Assuming a total of four membrane tanks each with 5 installed cassettes with space for one additional cassette.
(6) Assuming a total of four membrane tanks each with 7 installed cassettes with space for one additional cassette.

NOTES:

THIS DRAWING HAS BEEN PREPARED PRIMARILY FOR THE PURPOSE OF PREPARING A BUDGET LEVEL OPINION OF PROBABLE COST. THE ACTUAL FACILITY DESIGN WILL BE DETERMINED DURING PRELIMINARY AND FINAL DESIGN.



PLAN

SCALE: 3/4"=1'-0"
FILE:

TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

ALTERNATIVES No. 1 & 2: B5 PROCESS ACTIVATED SLUDGE BASINS

EXHIBIT B.1

ORANGE COUNTY GOVERNMENT FLORIDA

Carollo Engineers...Working Wonders With Water

NOTES:

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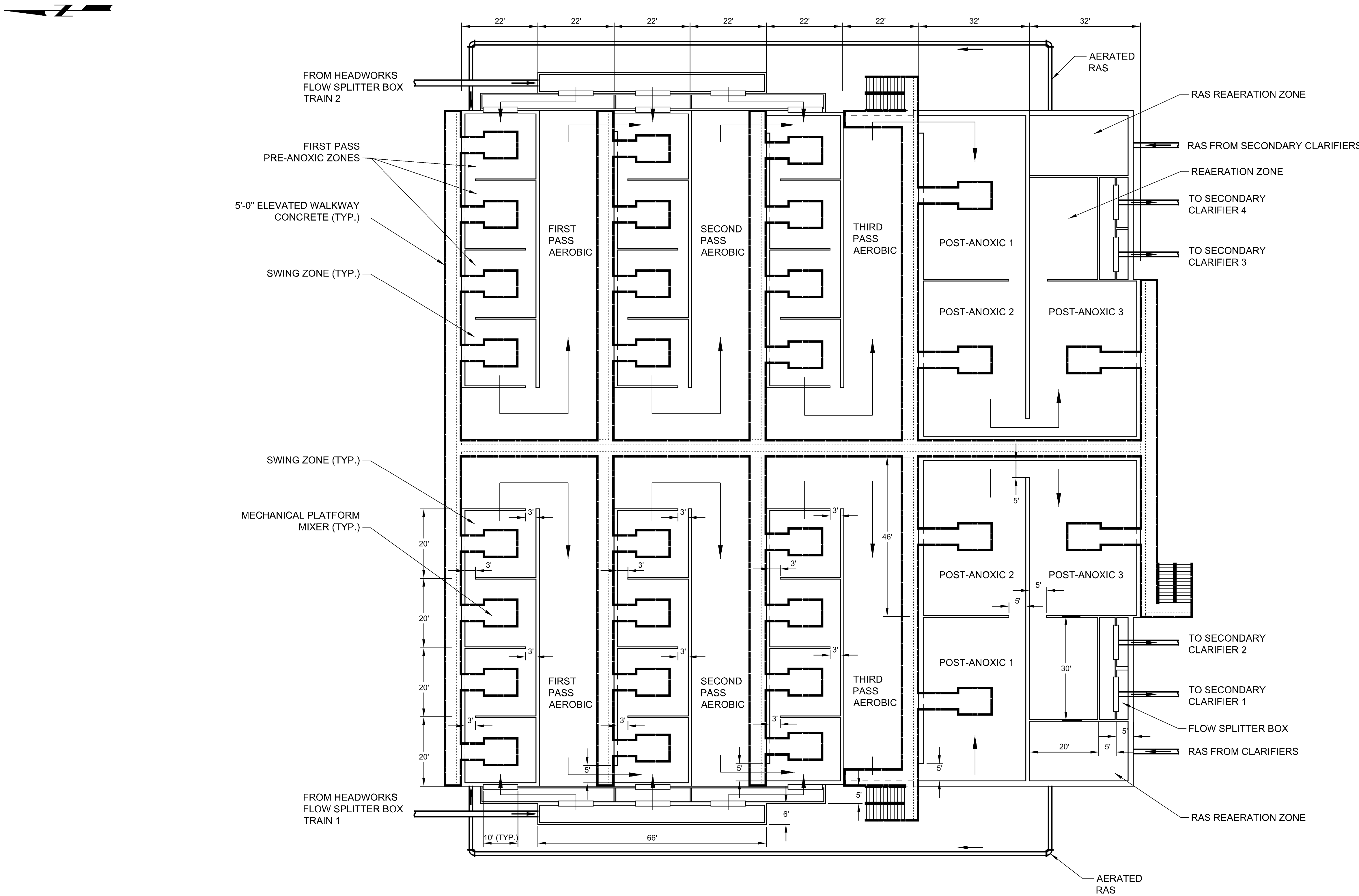

PLAN

SCALE: 3/4"=1'-0"
FILE:

TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

Engineers...Working Wonders With Water

ALTERNATIVE No. 3: THREE PASS STEP-FEED BNR ACTIVATED SLUDGE BASINS

EXHIBIT B.2

NOTES:

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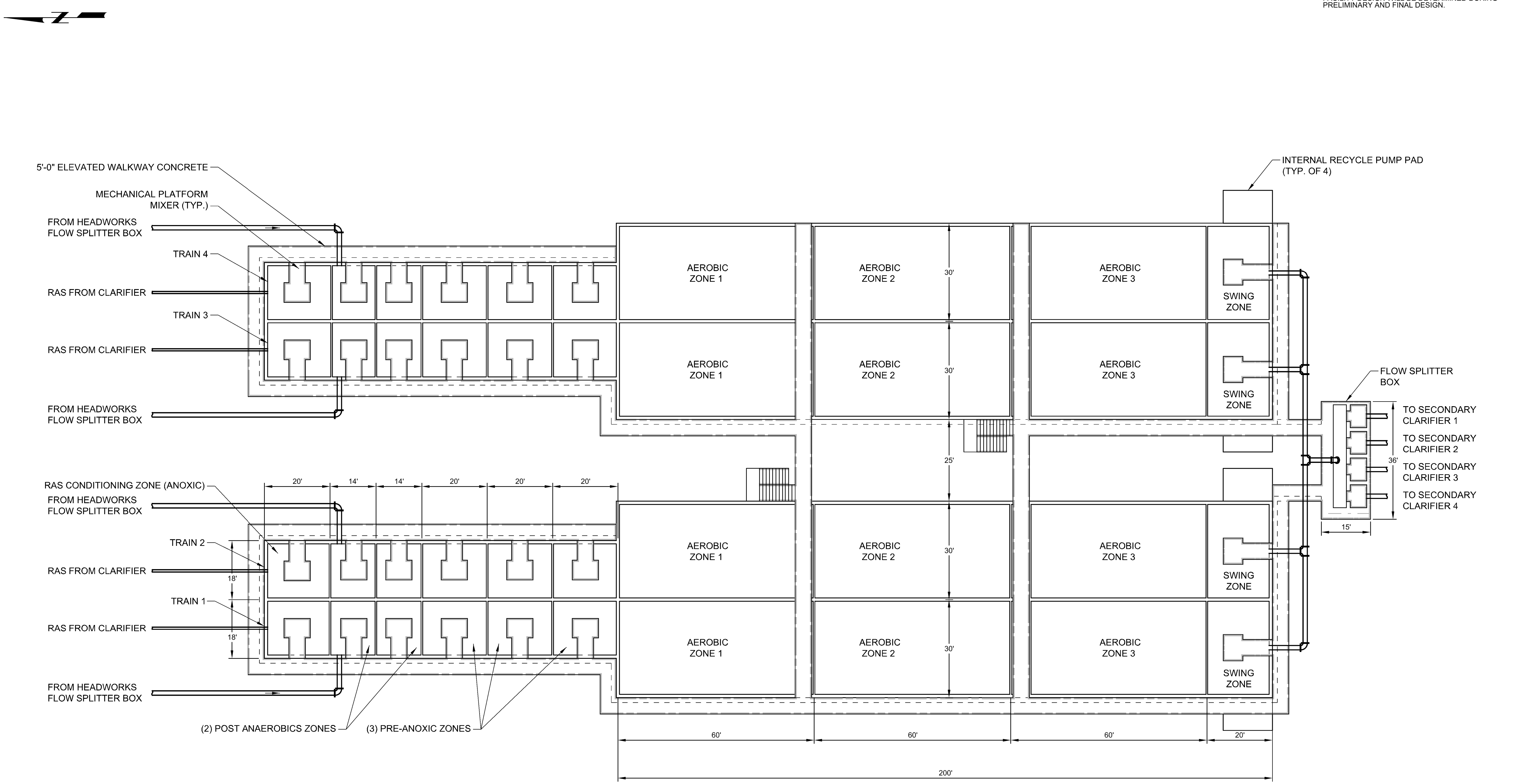

PLAN

SCALE: 3/4"=1'-0"
FILE:

0 1' 2' 3'

ORANGE COUNTY GOVERNMENT
FLORIDA

TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

ALTERNATIVE No. 4: THREE-STAGE BNR ACTIVATED SLUDGE BASINS

EXHIBIT B.3

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NOTES:

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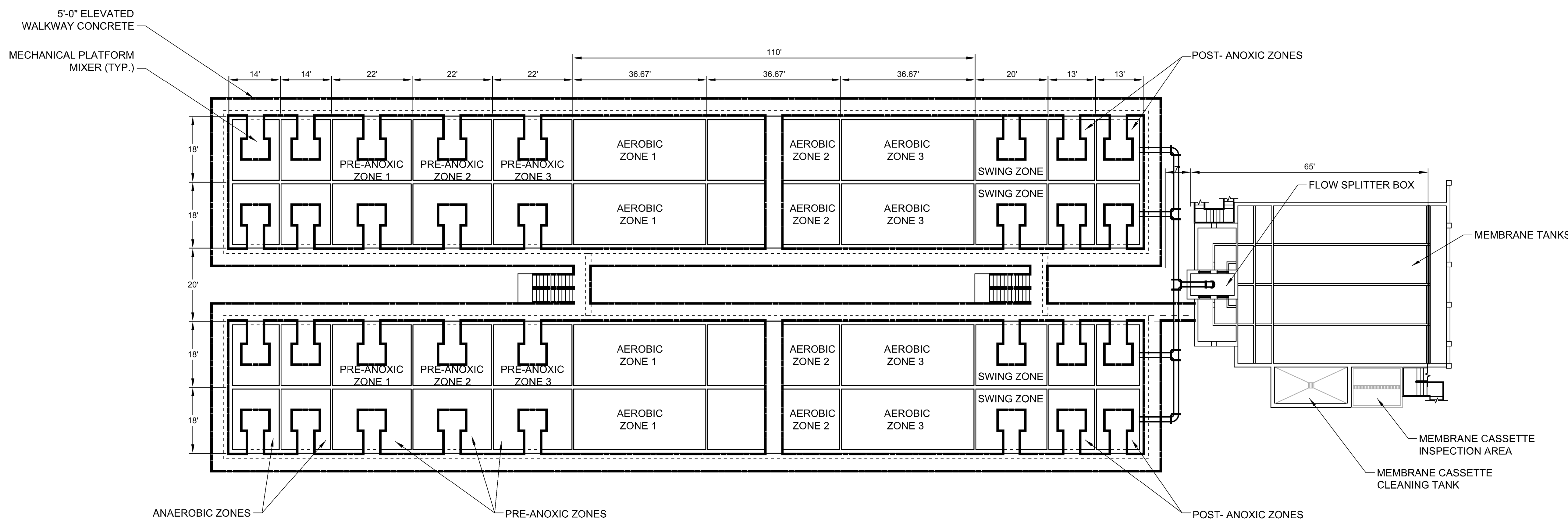

PLAN

SCALE: 3/4"=1'-0"
FILE:

0 1' 2' 3'

TM 6 - PHASE I SWWRF
PROCESS ALTERNATIVES EVALUATION

ORANGE COUNTY GOVERNMENT FLORIDA

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ALTERNATIVE No. 5: B5 PROCESS WITH MBR ACTIVATED SLUDGE BASINS

EXHIBIT B.4

B.5. Design Parameters and Assumptions for Unit Processes Common to All Treatment Alternatives

Table B.7 presents the design parameters and assumptions used to size the various plant unit processes other than for the main biological treatment process. These plant components are common to all five treatment alternatives. The manufacturers listed in the table were contacted to obtain price quotations for their equipment. The approved list of manufacturers will be determined by OCU and the selected design consultant during final design.

Table B.7 Design Parameters and Assumptions for Common Unit Processes
SWWRF Conceptual Design and Facilities Plant Update
Orange County Utilities

Unit Process	Parameter	Unit	Value
Pretreatment Structure	Influent coarse screens(1)		in-channel band screens each with screenings washer compactor(1)
	No. of channels		2
	No. of coarse screens		2
	Capacity (avg./peak) per screen	mgd	5/15
	Coarse screen opening size	mm	6
	Minimum channel width	ft	4
	Minimum channel depth	ft	6
	Grit removal		forced vortex (Headcell®)(1)
	No. of grit removal units		1
	Capacity (avg./peak) per screen		5/15
	Grit removal efficiency required		remove 95% or more of 75 microns @ AADF and 90% or more 100 microns @ PHF
	Pretreatment odor control		biofilter
	No. of units		1
Fine Screens(2)	Influent fine screens(2)		in-channel band screens each with screenings washer compactor(1)
	No. of channels		3
	No. of fine screens		2
	Capacity (avg./peak) per screen	mgd	5/15
	Fine screen opening size	mm	2
	Minimum channel width	ft	4

Table B.7	**Design Parameters and Assumptions for Common Unit Processes SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities**		
Unit Process	**Parameter**	**Unit**	**Value**
	Minimum channel depth	ft	6
Disinfection	Chlorine contact tanks (CCT)		
	Minimum detention time at AA flow	minutes	30
	Minimum detention time at PH flow	minutes	15
	CCT SWD	ft	13.5
	No. of CCTs		2
	Chlorination system		bulk sodium hypochlorite
	Maximum chlorine dose	mg/l	10
	Bulk sodium hypochlorite storage (average demand)	days	15
	No. of storage tanks		2
Biosolids Handling	Biosolids holding[1]		
	Type of biosolids holding		aerobic holding tanks with diffused aeration[1]
	Minimum holding tank detention provided (MM)	Days	4[1]
	Maximum % solids loading to holding tank	%	0.8[1]
	No. of aerobic holding tanks		1
	Holding tank blowers		positive displacement type blowers[1]
	No. of blowers		2
	Biosolids holding odor control		biofilter
	No. of units		1
	Biosolids dewatering		screw presses[1]
	No. of screw presses		2
	Days of operation/week	Days	5[1]
	Screw press dewatering capacity	lb/hr	700[1]
	Minimum cake % solids	%	18
	Dewatering bldg. odor control		biofilter
	No. of units		1
Chemicals for	Chemical for P-removal[3]		alum

Table B.7 Design Parameters and Assumptions for Common Unit Processes SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities			
Unit Process	**Parameter**	**Unit**	**Value**
Process Control	Chemical for supplementary carbon addition(4)		methanol
	Chemical for membrane cleaning(2)(5)		sodium hypochlorite and citric acid
Effluent Storage and Pumping	No. of disinfected effluent transfer pumps (to storage tank)		5 (4 duty/1standby)
	Type		vertical turbine with VFD
	Capacity per pump	gpm	2,606
	Total firm capacity	gpm	10,424
	Anticipated TDH	ft	40

Notes:
(1) From Orange County Utilities Facilities Plan, (PBS&J/CDM, 2007).
(2) For Alternative No. 5 – B5/MBR.
(3) Chemical such as alum will be used for P-removal as necessary to achieve effluent TP < 1 mg/l. Process modeling suggests that alum is not required.
(4) Supplementary carbon for post-denitrification may or may not be necessary.
(5) For Alternative No. 2 – B5 with tertiary membrane filters.

There are at least two options available for OCU for effluent storage and pumping at the SWWRF. The first option (Option A) would be to connect to the SWSA reclaimed water mains for distribution of the reclaimed water for PAR. Option A would require SWWRF to have two different sets of pumps – one set to pump reclaimed water into the SWSA distribution system and a second set to send reject water to the head of the plant. Based on the preliminary hydraulic modeling for the SWSA Conveyance Plan, the year 2030 peak hour reclaimed water demand could be about 22.5 mgd (16,000 gpm; based on a peaking factor of 4.5) with line pressures in the 100 psi range. The initial average reclaimed water demand from the SWWRF (year 2017 when the SWWRF is assumed to be online) could be in the range of 3.0 to 3.5 mgd based on a projection of recent WCII reclaimed water supplies to the SWSA. The initial peak hour demand could be in the 13.5 – 15.75 mgd range.

The second option (Option B) would be to have a separate pipeline to send all of the effluent preferentially to RIB Site 6 as recommended in TM 4. Option B would require the SWWRF to have only one set of pumps if both reclaimed water and reject water could be sent to RIB Site 6. The pressure to pump the flow to RIB Site 6 would be less than Option A (assumed to be about 40 psi). Additionally the peak instantaneous flow would be the plant peak hour flow of 15 mgd as opposed to 22.5 mgd. If OCU desires to have added flexibility in management of reclaimed water this pump station could be sized for 100 psi discharge pressure so that it could discharge into the OCU SWSA reclaimed water system, the WCII transmission pipeline, or the WCII distribution system.

Table B-8 provides design criteria for both options. However, the preliminary cost estimates developed are based on Option A.

Table B.8	**Basis of Design for Effluent Storage and Pumping System SWWRF Conceptual Design and Facilities Plant Update Orange County Utilities**	
Parameter	**Unit**	**Value**
OPTION A – Connect to WC II Reclaimed Water Main		
Reclaimed Water High Service Pumps		
Average day demand	mgd	5
Instantaneous peak demand (1)	mgd	22.5
Minimum demand (2)	mgd	3.0
No. of large pumps		5 (4 duty/1 standby)
Capacity of each large pump	gpm	3,910 gpm
Anticipated discharge pressure (3)	psi	100
Anticipated motor power per largest pump	hp	300
No. of small pumps		2
Capacity of each small pump	gpm	1,043 gpm
Anticipated discharge pressure (3)	psi	100
Anticipated motor power per largest pump	hp	80
Total firm pumping capacity	mgd	25.5
No. of days of reclaimed water storage(4)		1
Capacity per tank	gallons	5,000,000
Reject Water Pumps		
No. of pumps		5 (4 duty/1 standby)
Capacity per pump	gpm	2,610
Anticipated discharge pressure	psi	100
Anticipated motor power per pump	hp	200
No. of days of reject water storage(4)		1
Capacity per tank	gallons	5,000,000
OPTION B – Separate Connection to RIB Site 6		
Reclaimed/Reject Water Pumps		
Average day flow	mgd	5
Peak hour flow	mgd	15
Minimum day flow	mgd	2.0
No. of pumps		5 (4 duty/1 standby)
Capacity of pumps	gpm	2,610 gpm
Anticipated discharge pressure (5)	psi	40
Anticipated motor power per pump	hp	80

Notes:

(1) Based on preliminary hydraulic modeling of the SWSA reclaimed water model for year 2030 as performed under Y9-901 Task Authorization C09901011.

(2) Based on projecting reclaimed water demand using current reclaimed water demand in the SWSA.

(3) Anticipated discharge pressure to connect to the Water Conserve reuse transmission main based on reclaimed water system modeling performed under Y9-901 Task Authorization C09901011.

(4) Assumed for cost estimation purpose. Storage could be eliminated if OCU decided to use Option B as described in Table above.

(5) To provide additional flexibility, OCU could consider tie-in to the SWSA reclaimed water piping. This will change the discharge pressure required to design the pumping system.

(6) Preliminary cost estimates provided in Appendix A are based on Option A.

SWWRF CONCEPTUAL DESIGN AND FACILITIES PLAN UPDATE

TECHNICAL MEMORANDUM NO. 7

ADD-ON TREATMENT TECHNOLOGIES FOR FUTURE PHASES

FINAL
NOVEMBER 2011

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SWWRF CONCEPTUAL DESIGN AND FACILITIES PLAN UPDATE

ADD-ON TREATMENT TECHNOLOGIES FOR FUTURE PHASES

TECHNICAL MEMORANDUM NO. 7

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Technical Memorandum No. 7

ADD-ON TREATMENT TECHNOLOGIES FOR FUTURE PHASES

1.0 INTRODUCTION

Under Task Authorization (TA) 16 of Contract Y9-901, the Carollo team was retained by Orange County Utilities (OCU) to prepare a conceptual design for the proposed Southwest Water Reclamation Facility (SWWRF). This included a review and update of the previous Capital Improvements and Facilities Plan (CDM/PBSJ 2007) prepared for the SWWRF. OCU has adopted a policy stating that Phase 1 of the SWWRF will be designed to meet water quality criteria for Advanced Wastewater Treatment (AWT) in Florida with effluent meeting the "5:5:3:1" standard (5 mg/L of carbonaceous, five-day biological oxygen demand ($cBOD_5$), 5 mg/L total suspended solids (TSS), 3 mg/L total nitrogen (TN), and 1 mg/L total phosphorus (TP), respectively), with high level disinfection and filtration. Table 1.1 presents the water quality goals for Phase 1 of SWWRF. Effluent from Phase 1 of the SWWRF will be used for public access reuse (PAR), with possible wet weather discharge to the Water Conserv II (WC II) Site 6 rapid infiltration basins (RIBs).

Depending on the future capacity of the PAR and RIB systems, alternate reclaimed water management options may be required for future phases. These options include lake augmentation, discharge to a surface waterbody, or direct aquifer injection into the Floridan aquifer. These alternate disposal and reuse options will require higher levels of treatment beyond the AWT standard provided by Phase 1. As described in the scope of services for this task authorization, for the purpose of long-range planning, the Carollo team will evaluate up to two combinations of "add-on" treatment technologies for the future phases to meet the water quality requirements for alternate reclaimed water management options. Technical Memorandum (TM) No. 4 – Reclaimed Water Utilization addresses potential water reuse alternatives for the SWWRF as they relate to reclaimed water quality for both the Phase 1 design and planning for future phases, depending on the type of water reuse practiced. This TM screens the feasibility of various "add-on" processes that can potentially be used at SWWRF for the future phases.

Table 1.1	SWWRF Phase I – Effluent Water Quality Goals SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities
Water Quality Parameter	**Goal for SWWRF Phase 1 (1)**
$cBOD_5$, mg/l	≤ 5 mg/l (annual average)
TSS, mg/l	≤5 mg/l (annual average)
TN, mg/l	≤3 mg/l (annual average)
TP, mg/l	≤1 mg/l (annual average)
pH (s.u.)	6.0 – 8.5
Chlorine disinfection mixing criteria(2)	Rapid and uniform
Fecal coliform(2)(3), #/100 ml	• Over a 30-day period, 75% of values below detection limits. • Any one sample ≤ 25 per 100 mL sample.
Chlorine residual(2), mg/l	1.0 mg/l single sample minimum
Chlorine contact time at peak hour(2)	≥ 15 minutes
Product of total chlorine residual and the contact time (CT) at peak hour flow(2)	≥ 25 mg/l-min

Notes:
(1) OCU has adopted a policy that the SWWRF will be designed to produce effluent water quality that meets Florida AWT standards regardless of the reclaimed water management alternative.
(2) High-level disinfection requirements are specified in Rules 62-600.440(5) and 62-610.460 of the F.A.C.
(3) Assuming a fecal coliform concentration less than 1000 /100 ml prior to chlorine disinfection which requires a minimum CT of 25 mg/L-min.

2.0 FUTURE RECLAIMED WATER MANAGEMENT ALTERNATIVES

Phase I of SWWRF will produce reclaimed water meeting Florida AWT standards, and will use PAR and RIBs for managing its reclaimed effluent. AWT treatment meets the requirements for land application and reuse systems located in the Primary Protection Zone of the Wekiva Study Area as described in Section 369.318, F.S. AWT treatment would also help reduce the nitrate concentrations in the surficial aquifer near the RIB site. For the long term, beyond using PAR and RIBs, three other potential reuse alternatives were identified. These three alternatives are evaluated and discussed below.

2.1 Surface Water Discharge

One possible option for future management of reclaimed water is discharge to a surface waterbody. Potential discharge locations include Lake Apopka (Ocklawaha River system) and Reedy Creek (Kissimmee River/Lake Okeechobee system). Surface water discharge would require effluent to meet water quality based effluent limits (WQBELs) as well as the numeric nutrient criteria (NNC) limits promulgated by EPA in 2010 (40 C.F.R. §131.43).

Under a previous task authorization, the Carollo team reviewed existing Total Maximum Daily Loads (TMDLs) established near OCU's wastewater facilities and addressed how these TMDLs might affect the OCU systems (CDM, 2010).

For the Peninsula Nutrient Watershed Region in which the SWWRF is located, the NNC for lakes set limits on total nitrogen (TN) ranging from 0.51-1.27 mg/l and for total phosphorus (TP) ranging from 0.01 – 0.05 mg/L. Based on available information, Lake Apopka is classified as a clear alkaline lake (color < 40 PCU and alkalinity > 20 mg/l as $CaCO_3$; data based on a 7 year rolling average). Table 2.1 provides EPA's NNC for Florida Lakes. For discharge to Lake Apopka, the EPA NNC would require an effluent concentration TN limit of ≤1.05 mg/l and TP limit of ≤0.03 mg/l. Additionally, there would be a limit of 0.02 mg/l for chlorophyll *a*. All concentrations are based on geometric means not to be surpassed more than once in a three-year period.

The Florida Department of Environmental Protection (FDEP) has prepared a draft rule on NNC for inland and estuarine waters. In April 2011, FDEP sought EPA's review of this draft rule. In a recent letter to the FDEP, EPA acknowledged that the criteria prepared by the FDEP appears to comply with the Clean Water Act and if approved EPA may delegate the implementation of the NNC to FDEP. Consequently, EPA will initiate rulemaking to withdraw the federal NNC for fresh waters of the State and in its place; FDEP determined NNC criteria would be implemented. A final decision to delegate this responsibility will be made after the State's Environmental Review Commission and Legislature approve the proposed draft rule prepared by FDEP, and any modifications/changes made in the process are accepted by EPA.

2.2 Lake Augmentation

A second option for future management of reclaimed water would be surface water discharge for lake augmentation. This alternative assumes direct discharge of reclaimed water from SWWRF to nearby publicly accessible lakes. This strategy could potentially be used as a mitigation measure to assist with meeting the pending Minimum Flows and Levels (MFL) regulations. Potential lake candidates for augmentation include Lake Avalon, Lake Ingram, Johns Lake, and Flat Lake. Lake augmentation would require effluent to meet the requirements of the WQBELs established for the respective waterbody (CDM, March 2010), and likely would also require meeting the numeric nutrient criteria (NNC) limits promulgated by EPA in 2010 (40 C.F.R. §131.43). Again, see Table 2.1 for EPA's NNC for Florida Lakes.

Table 2.1 EPA NNC for Florida Lakes
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities[1]

Lake Color and Alkalinity	Chlorophyll a (mg/l)	Criteria[2] (mg/l)	
		TN	TP
Colored lakes (long-term color > 40 pcu)	0.020	1.27 [1.27 – 2.23]	0.05 [0.05 – 0.16]
Clear lakes, high alkalinity (long-term color ≤ 40 pcu and Alkalinity > 20 mg/l $CaCO_3$)	0.020	1.05 [1.05 – 1.91]	0.03 [0.03 – 0.09]
Clear lakes, low alkalinity (long-term color ≤ 40 pcu and alkalinity ≤ 20 mg/l $CaCO_3$)	0.006	0.51 [0.51 – 0.93]	0.01 [0.01 – 0.03]

Notes:
(1) All concentrations are natural geometric means, not to be surpassed more than once in a three-year period.
(2) Bracketed numbers reflect the range over which TN and TP may be surpassed if the lake is meeting the relevant chlorophyll a criteria.

2.3 Direct Aquifer Injection

A third alternative for future reclaimed water management is direct injection of reclaimed water into the Floridan Aquifer. Since no high TDS aquifer (> 3,000 mg/L) exists in the Southwest Service Area (SWSA) or the Water Conserv II area, direct aquifer injection will require that reclaimed water from the SWWRF meet drinking water quality requirements. Aquifer recharge by direct injection of reclaimed water into a zone containing total dissolved solids (TDS) of 3,000 mg/l or less requires the water to meet the "full treatment and disinfection" requirements of Rule 62-610.563(3), F.A.C. In addition to meeting a TSS of less than 5 mg/l and total nitrogen of less than 10 mg/l (annual average), the effluent must meet full treatment requirements that specify the injected water contain no more than 3 mg/L of total organic carbon (TOC) on a monthly average basis with a maximum (single sample) of less than 5 mg/l of TOC and 0.2 mg/L (as Cl^-) of total organic halogen (TOX) with a maximum single sample limit of 0.3 mg/l (as Cl^-). In addition, all primary and secondary drinking water standards (Rule 62-610.560 F.A.C.) must be met. The treatment processes must be designed and operated to provide multiple barriers for control of organic compounds and pathogens. Depending on the proposed treatment processes, injection of reclaimed water into a zone with TDS less than 3,000 mg/l may require that the proposed treatment train be pilot tested for at least one year. In addition, the injection of reclaimed water into an aquifer zone with TDS less than 500 mg/l requires two years of treatment train operational and mutagenicity testing under review of a panel of nationally recognized experts.

2.4 Effluent Water Quality Requirements

Table 2.2 summarizes the major SWWRF effluent water quality parameters required to satisfy the anticipated permit limits for the various reclaimed water management alternatives discussed previously. Table 2.2 also includes, for comparison, the various water quality requirements chosen by OCU for Phase 1 of the SWWRF.

Table 2.2 Anticipated Effluent Water Quality Criteria for Various Future Reclaimed Water Management Alternatives
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Parameter	OCU Policy[(1)]	PAR and RIBs[(2)]	Lake Augmentation and Surface Water Discharge[(3)]	Direct Aquifer Recharge[(4)]
$cBOD_5$, mg/l	≤ 5	≤ 20	NA	NA
TSS, mg/l	≤ 5	≤ 5	≤ 5	≤ 5
TN, mg/l	≤ 3	≤ 10	0.51 – 1.27[(5)]	≤ 10
TP, mg/l	≤ 1	NA	0.01 – 0.05[(5)]	NA
TOC, mg/l	NA	NA	NA	≤ 3 (average); ≤ 5 (single sample)
TOX, mg/l	NA	NA	NA	≤ 0.2 (average); ≤ 0.3 (single sample)
Other	High Level Disinfection[(6)]	High Level Disinfection[(6)]	Chlorophyll *a*[(5)]	Meet all primary and secondary drinking water standards and high level disinfection

Notes:
(1) OCU has adopted a policy that regardless of the reclaimed water management alternative, the SWWRF will be designed to produce effluent water quality to meet the Florida AWT standards.
(2) Phase 1 reclaimed water management alternative. In accordance with Chapter 62-610 F.A.C., Part III for Slow-Rate Land Application Systems for Public Access Areas, Residential irrigation, and Edible Crops and Part IV for Rapid-Rate Land Application Systems (Rapid Infiltration Basins and Absorption Fields)
(3) Possible reclaimed water management alternative for future phases. Water quality limits in accordance with 62-600.430 F.A.C. for Additional Treatment – Water Quality Based Effluent Limitations (WQBELs)
(4) Possible reclaimed water management alternative for future phases. Water quality limits in accordance with Chapter 62-610 F.A.C., Part V for Ground Water Recharge and Indirect Potable Reuse.
(5) Numeric nutrient criteria (NNC) for the Peninsula Nutrient Watershed Region in accordance with 40 C.F.R. §131.43 and as described in Table 2.1.
(6) High-level disinfection requirements are specified in Rules 62-600.440(5) and 62-610.460 F.A.C.

2.5 Other Potential Future Regulations

In addition to the water quality criteria requirements as described in Table 2.2, other parameters may be regulated in the future such as protozoan cysts and microconstituents or emerging substances of concern (ESOC) that are currently not regulated.

The Florida Department of Environmental Protection (FDEP) currently requires utilities to monitor reclaimed water for *Giardia* and *Cryptosporidium* cysts no less than once every two years. Current guidelines published by FDEP for the maximum concentrations of *Giardia* and *Cryptosporidium* are provided in Table 2.3.

Table 2.3 FDEP Suggested Guidelines for Protozoan Cysts in Reclaimed Wastewater
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Organism	Units	Suggested Guidelines	
		Average	Maximum
Giardia lamblia	Viable cysts/100 ml	1.4	5.0
Cryptosporidium	Viable oocysts/100 ml	5.8	22

ESOC is a term used by FDEP to describe all currently unregulated substances that have been identified in water resources that may pose environmental or public health risks. ESOC include synthetic organic contaminants, pharmaceutical and personal care products (PPCPs), endocrine-disrupting chemicals (EDCs), nanoparticles, industrial chemicals, biological metabolites, and toxins. A detailed list of ESOC compounds and pertinent information is presented in a report dated December 2008 prepared by an internal FDEP Workgroup that was formed to evaluate strategies to address ESOC. A copy of this report is available electronically on FDEP's website at http://www.dep.state.fl.us/water/esoc.htm.

At the national level, the U.S. Environmental Protection Agency (EPA) published the third Candidate Contaminant List (CCL3) in September 2009 that also deals with some ESOC. A total of 104 chemicals or chemical groups and 12 microbiological contaminants are included in the list. The Safe Drinking Water Act (SDWA) requires EPA to determine every five years whether to regulate at least five of the chemicals on the CCL. The SDWA also authorizes EPA to require all large, and a subset of small utilities, to monitor up to 30 unregulated contaminants every five years under the Unregulated Contaminant Monitoring Regulation (UCMR). The UCMR and the CCL provide the framework for regulating contaminants in drinking water that pose potential harm to human health.

There could be potential regulations or a regulatory requirement for monitoring certain ESOC similar to the recommendations by the Science Advisory Panel to the California State Water Resources Control Board as part of the Recycled Water Policy adopted in

2009 (CEC Panel, Final Report, June 2010). The recommendations included a four-step approach as follows:

- A conceptual framework for determining which ESOC to monitor.
- Application of the framework to identify a list of chemicals that should be monitored initially.
- A phased, performance-based approach for implementing CEC recycled water monitoring programs and a multi-tiered framework for interpreting the resulting data.
- Priorities for future improvements in monitoring and interpretation of ESOC data.

At present, a total of 490 compounds are included in draft regulations for groundwater recharge in California.

2.6 Most Feasible Reclaimed Water Utilization Alternative(s)

TM 4 – Reclaimed Water Utilization, concluded that the best short-term options for implementing reclaimed water management for the SWWRF are PAR plus RIBs or RIBs alone. In the long term, direct aquifer recharge or aquifer recharge and recovery (ARR) could be attractive as a means of liberating some of the RIB sites for other uses, including land sale. This could cover much of the capital cost of the required treatment. Part of the attraction of this option depends on the future course of regulation and its affect on the current PAR and RIB operations. Considerations for future treatment at the SWWRF should therefore focus on alternatives that facilitate (or at least preserve) the option of direct aquifer recharge and recovery facilities. If direct aquifer recharge is the sole wet weather management option available to the SWWRF in the future, the treatment and injection capacity of such a system may need to be sized to accommodate the full peak plant flow.

The pending MFL regulations to be established by the St. Johns River Water Management District (SJRWMD) make lake augmentation, especially to Lake Avalon, a potentially attractive option for maintaining OCU's full allocation of groundwater. If reclaimed water from SWWRF were used for lake augmentation, only a portion of the reclaimed water would require treatment to higher water quality standards. Side-stream treatment significantly reduces the amount of flow that must be treated to higher levels; however, it is not the most favored option from a facilities permitting perspective. FDEP does not favor surface water discharge as a reclaimed water management tool, except as a necessary wet-weather backup. From an economic standpoint, however, using groundwater rather than reclaimed water for lake augmentation may be more feasible.

In summary, direct aquifer injection and lake augmentation are the most feasible reclaimed water management alternatives to supplement PAR and RIBs in the future. The following sections discuss several treatment technologies that could be implemented in future phases at SWWRF to provide reclaimed water amenable for discharge to either the Floridan aquifer or local lakes.

3.0 TARGET CONSTITUENTS

The following paragraphs summarize the key pollutants and anticipated water quality limits for these pollutants for discharge to the respective reclaimed water management alternatives. Based on the current water quality requirements for aquifer injection and surface water discharge, appropriate treatment technologies are then discussed in detail in subsequent paragraphs.

3.1 Reclaimed Water Management Using Surface Water Discharge

Reclaimed water management using lake augmentation (i.e., discharge to Lake Avalon) would require treatment technologies capable of meeting the applicable NNC (TN ≤1.27 mg/l and TP ≤0.05 mg/l as annual geometric mean values not to be exceeded more than once in three years). Based on available information and proposed lake nutrient criteria, Lake Avalon can be classified as a colored lake (color > 40 PCU; as reported by Florida LAKEWATCH for average values for one month sampled in 1999). Alternately, if implementation of the NNC rule is delayed, the SWWRF may be subject to water quality limitations in the future as part of the TMDL program for Lake Avalon and its associated wetland system. There is also a possibility for monitoring or limits on other parameters such as protozoan cysts and ESOC as described above.

3.2 Reclaimed Water Management Using Direct Aquifer Injection

Aquifer recharge by direct injection of reclaimed water into a zone containing total dissolved solids (TDS) of 3,000 mg/l or less requires that the water meet the following requirements:

- ≤ 3 mg/L of total organic carbon (TOC) on a monthly average basis with a maximum (single sample) of less than 5 mg/l of TOC;
- ≤ 0.2 mg/L (as Cl^-) of total organic halogen (TOX) with a maximum (single sample) of 0.3 mg/l (as Cl^-); and
- All primary and secondary drinking water standards (Rule 62-610.560 F.A.C.).

4.0 OVERVIEW OF TREATMENT TECHNOLOGIES

This section provides a discussion of possible treatment technologies that could be added downstream of the Phase 1 AWT treatment processes to achieve the effluent water quality that would be required for direct aquifer injection or lake augmentation in the future. A list of add-on treatment technologies with the potential to remove incremental concentrations of

TN, TP, and other parameters that may be regulated in the future for surface water discharge is provided in Table 4.1.

Table 4.1 Potential Add-on Treatment Technologies Facilitating Surface Water Discharge in the Future
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Treatment Process	Removal of TN	Removal of TP	Removal of Protozoan Cysts(1)	Removal of ESOC
Tertiary coagulation/flocculation/ sedimentation	Partial	Excellent	-	-
Tertiary filtration (conventional)(2)	Little	Little	Little	-
Tertiary filtration (MF/UF)(3)	Little	Good	Excellent	-
Tertiary filtration (NF/RO)	Good	Excellent	Excellent	Good
Tertiary biologically active filtration (BAF)(4)	Good	Little	Little	Little
Reactive filtration(5)	Little	Excellent	Little	--
Ion wxchange	Good	Good	Little	Little
Tertiary moving bed bioreactor (MBBR)	Good	-	-	-
Constructed wetlands	Good	Good	-	-

Notes:
(1) Protozoan cysts such as *Cryptosporidium* and *Giardia* cysts.
(2) Conventional filtration includes granular media and cloth media filters. Particulate TN and TP are removed.
(3) MF/UF coupled with coagulation can provide excellent removal of phosphorus.
(4) Tertiary biologically active filtration is limited to denitrification. Good removal of nitrate can be achieved.
(5) Reactive filtration uses adsorptive media to remove dissolved species of nitrogen and phosphorus.

The first phase of the SWWRF will use a biological nutrient removal (BNR) technology to meet effluent limits of ≤3 mg/l for TN and ≤1 mg/l for TP. A review of the typical composition of the TN and TP in effluent from BNR/AWT treatment processes provides some insight into the add-on treatment technologies that might effectively remove sufficient incremental concentrations of TN and TP to meet the more stringent limits imposed by the EPA NNC.

A. Nitrogen

TN includes all forms of organic and inorganic nitrogen in the wastewater effluent. Organic nitrogen exists in dissolved, colloidal, and particulate forms, while all the inorganic nitrogen species (ammonia, nitrate, and nitrite) are soluble. Traditional nitrification and denitrification processes, assuming conservative design and good operations, have demonstrated the ability to remove NH_3 and NO_3 down to about 0.5 mg/L while nitrite is typically not present in significant concentrations. While it may be possible for a BNR process to produce effluent with less than 0.5 mg/L NH_3 and NO_3, this has not yet been consistently proven. Eventually biological processes reach a minimum possible effluent concentration dependent on the specific kinetic coefficients of the biological processes. The particulate organic nitrogen (PON) and some fraction of the colloidal organic nitrogen can be removed by physical separation processes such as chemical coagulation, clarification, and filtration. Dissolved organic nitrogen (DON) is comprised of two fractions–a recalcitrant fraction of influent DON, which passes through the treatment process, and second fraction of DON produced within the treatment plant biological processes. The influent DON can be naturally occurring organic nitrogen forms from the potable water supply and from industrial or domestic sources. Figure 4.1 illustrates the typical composition of effluent TN in a well-operated BNR plant meeting a limit of 3 mg/L TN (Mulholland et al., 2009). This figure also shows one possible effluent TN speciation in a plant that will be required to meet the TN limit of 1.27 mg/l for discharge to Florida lakes as part of the proposed NNC. The residual concentrations of individual organic and inorganic species of TN are small and would most likely not be candidate species for removal by optimization or modification of the BNR process. Hence, add-on treatment technologies to meet the NNC TN limits (i.e., ≤ 1.27 mg/l for discharge to Lake Avalon) should focus on technologies that individually or collectively target a combination of the organic and inorganic species present in BNR/AWT effluents. Both inorganic and organic species of TN must be removed to achieve the TN limit of 1.27 mg/l (an additional 57% reduction in the TN assuming the conventional BNR process would produce an effluent with TN of 3 mg/l or less).

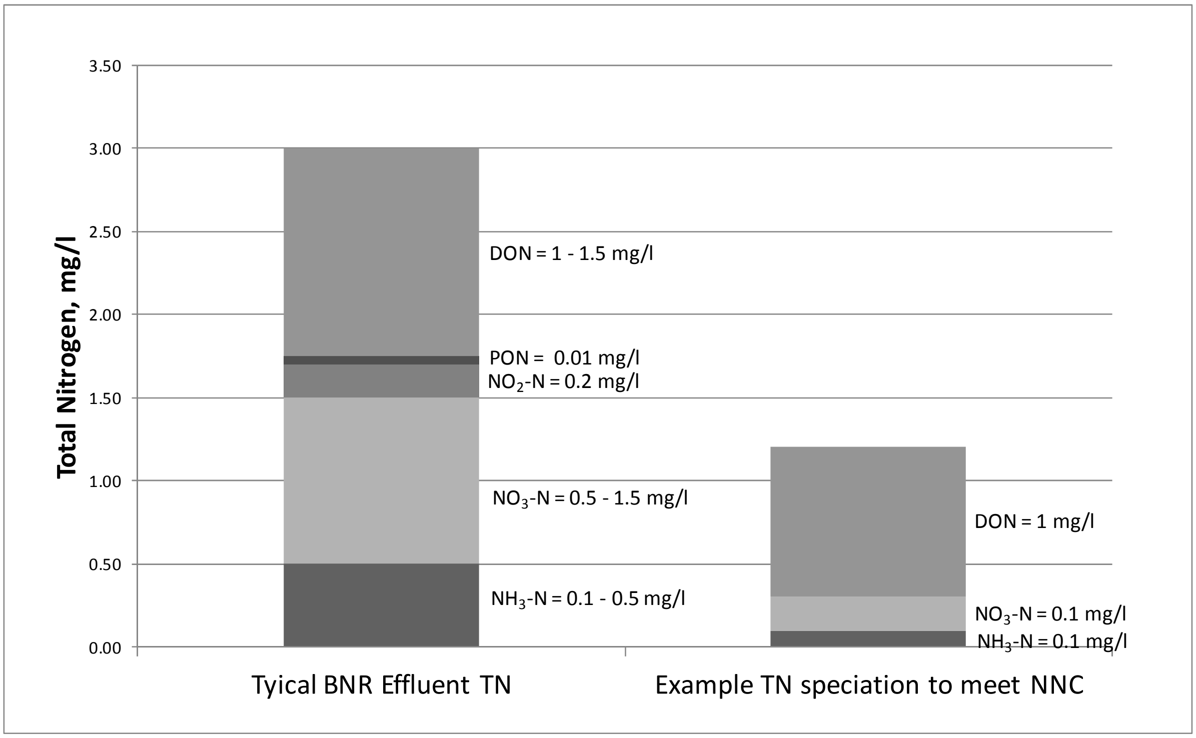

Figure 4.1 Typical BNR Effluent TN Concentration Compositions (modified from Mulholland, 2009)

The key process design parameters that affect the ability to achieve minimal effluent TN concentrations include optimized sludge retention times (SRT) (long enough to achieve low ammonia concentrations without increasing DON), provision of multiple barriers and increased redundancy, use of bioreactors in series, provision of sufficient carbon for denitrification, enhanced effluent solids removal by clarification and filtration, and more intense monitoring and control. Other factors, which may affect the ability to met NNC limits, include variable loadings due to seasonal or wet-weather conditions and the affect of in-plant recycle streams such as return streams from dewatering digested biosolids. Thus, design of the Phase 1 facilities at SWWRF will play a crucial role in determining the efficiency of the treatment system to meet more stringent water quality requirements for nutrients in the future. Figure 4.2 illustrates the affect that design parameters have in achieving low effluent TN concentrations. While some design and operating parameters influence how efficiently the process can reduce inorganic forms of nitrogen, current research does not provide sufficient understanding of how these parameters can be selected to simultaneously minimize effluent DON concentrations. For example, is the optimal SRT required to achieve minimal effluent DON compatible with the SRT required to maximize inorganic nitrogen removal? Additionally, SRT plays a significant role in the removal of some ESOC. SRT influences biological degradation mainly due to the diversity of microbial population and thus on the multitude of metabolic pathways for degradation of ESOC. Longer SRTs have been shown to result in the removal of higher percentages of some ESOC.

Orange County Government Florida

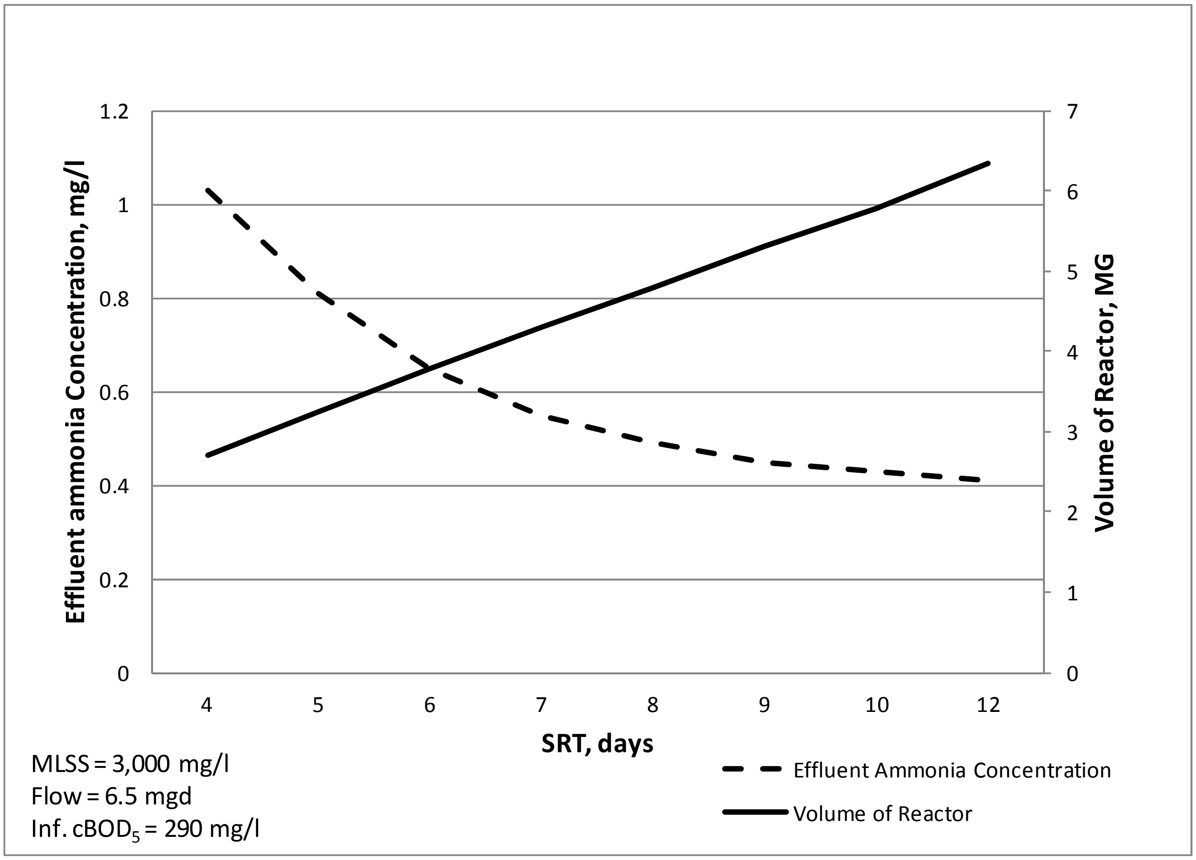

Figure 4.2 Illustration of Effect of Design Parameters (in this example SRT) on the Ability of a Facility to Achieve Low TN Concentrations

B. Phosphorus

The effluent TP from BNR processes is the sum of the insoluble (particulate) reactive and non-reactive fractions, and soluble reactive and non-reactive fractions of phosphorus. Most of the soluble phosphorus in BNR effluent is orthophosphate, although a small fraction of condensed phosphates also exists (Arnaldos et al., 2010). While some of the particulate fractions can be removed by filtration, the soluble reactive fraction can only be removed by chemical precipitation and physical separation (clarification and filtration), adsorption or ion exchange. The soluble non-reactive fraction (mainly organic phosphorus) is the most difficult to remove and becomes more relevant when trying to achieve extremely low TP concentrations such as the NNC proposed by EPA (Arnaldos et al., 2010).

The Phase 1 SWWRF facilities will be designed to achieve an effluent TP of less than or equal to 1 mg/l using enhanced biological phosphorus removal (EBPR) in combination with chemical addition, as necessary. A Water Environment Research Foundation (WERF) project (WERF 01CTS3, 2005) studied five full-scale facilities to develop a better understanding of the performance of EBPR. The study showed that EBPR is capable of achieving very low effluent orthophosphate concentrations. When operating well, orthophosphate concentrations <0.1 mg/L can be achieved for extended periods (more than a month). However, excursions above these levels are common. EBPR performance will be affected by the plant influent BOD and TP loadings, the level of oxidants (primarily dissolved oxygen and nitrate) in the anaerobic zone, the amount of phosphorus recycled from sludge handling processes, and operating parameters.

Under a scenario where discharge to nearby lakes in the future is deemed suitable as a supplemental reclaimed water management alternative, the effluent will be required to meet the EPA numeric nutrient criteria for freshwater lakes, streams, and springs in Florida. Carollo recommends that OCU analyze samples of the reclaimed water from the SWWRF Phase 1 at a later time to measure the concentrations of non-degradable, soluble, organic nitrogen and phosphorus. Knowing the quantity and particle size distributions (or molecular weight distributions) of the DON and DOP in the effluent from the existing treatment facilities will assist in evaluating in greater detail potential treatment technologies that may be needed at the proposed SWWRF in the future. Under the current scope of work, Carollo will use published data on quantity of the DON and DOP in AWT effluents to screen several applicable “add-on” process technologies to recommend up to two process trains for each - surface water discharge to nearby lakes or direct aquifer recharge to supplement the PAR and RIB systems in the future.

C. TOC, TOX, ESOC and Pathogens

Table 4.2 provides a list of treatment processes that can provide significant removal of organic carbon, pathogens, and trace organic compounds whose removal may be required in the future for direct aquifer recharge. Only TOC and pathogens are currently regulated pollutants in Florida.

A large majority (almost 98%) of ESOC is unregulated and there is a high degree of uncertainty associated with their environmental fate, transport, and toxicological effects. Although a review by the World Health Organization concluded that the low-level exposure resulting from the presence of these compounds in water has not yet demonstrated harm to human health, other studies point to their ill effects in the environment with interference in the reproduction of fish and amphibians. Wastewater treatment plants serve as a collection point for compounds originating from or used in residential, commercial, and industrial applications and thus represent a good location for removing ESOC, if necessary, before they are released into the environment. Depending on the processes employed at the wastewater treatment plants, ESOC may be removed to various degrees by conventional wastewater treatment facilities.

Table 4.2 Potential List of Add-on Advanced Treatment Processes with the Potential to Meet Water Quality Requirements for Aquifer Injection SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities

Treatment Process	Removal of TOC and TOX (1)	Removal of Pathogens and Virus(2)	Removal of ESOC
Low-pressure membranes (MF) / (UF)	–	Good	–
Nanofiltration (NF) or reverse osmosis (RO)	Excellent	Excellent	Good
Granular activated carbon (GAC)	Excellent	–	Good
Ion exchange	Good	–	–
Advanced oxidation processes (AOP)	Good	Excellent	Good
Soil aquifer treatment (SAT)	Excellent	–	Good

Notes:
(1) TOC is limited to 3 mg/l and TOX to 0.2 mg/l (Cl^-) for direct injection into the aquifer.
(2) Including protozoan cysts such as *Cryptosporidium* and *Giardia* cysts.

Typical average TOC concentrations in conventionally treated reclaimed water range from 10 – 15 mg/l. TOC concentrations in OCU's Eastern Water Reclamation Facility (EWRF) and South Water Reclamation Facility (SWRF) as measured during a recent reclaimed water pilot study were reported to average about 10 mg/l and 7 mg/l respectively. Achieving TOC concentrations of less than 3 mg/l will require technologies that can provide about 70% removal of TOC.

Since there appears to be a significant overlap between the treatment technologies that could be used to achieve an effluent quality suitable for both of the future reclaimed water alternatives (surface discharge or direct aquifer recharge or a combination of both), the following sections provide discussions on each of the treatment technologies listed above and how they might be applied in future phases of the SWWRF.

4.1 Tertiary Coagulation/Flocculation/Sedimentation

The simplest, and perhaps the most commonly used, add-on process configuration is to construct facilities for chemical coagulation and flocculation followed by sedimentation and filtration. This add-on process scheme would be implemented downstream of the Phase 1 final clarifiers and could be used for additional removal of TP, TSS, metals, and pathogens. The most efficient process configuration consists of separate tanks for coagulation and flocculation to allow for floc creation and agglomeration followed by tertiary sedimentation.

Final filtration provides incremental removal of suspended solids from the clarified effluent. Typical design overflow rates for conventional tertiary sedimentation is around 800 – 1,000 gpd/ft^2. High-rate clarification (HRC) is an enhancement to the conventional tertiary coagulation/clarification process where the coagulation/clarification process is aided by the addition of inert ballast to create larger, denser floc with higher settling velocities. With design overflow rates of about 40 gpm/ft^2 (57,600 gpd/ft^2), use of high-rate clarification processes makes the overall footprint three to four times smaller than a conventional clarification process. About 22 tertiary HRC facilities have been constructed specifically to treat activated sludge effluent primarily for phosphorus removal including one at the Metropolitan Syracuse Wastewater Treatment Plant that is designed to treat 84 mgd (150 mgd peak) with a permit limit for TP of less than or equal to 0.12 mg/l (as a 12-month rolling average). The permit limit will be reduced to 0.02 mg/l in year 2012.

Several commercial versions of high-rate clarification processes are available including Actiflo®, DensaDeg®, and CoMag®. A high-rate ballasted flocculation process would provide significant advantages compared with conventional coagulation/flocculation/sedimentation for implementation at SWWRF due to its very small footprint.

4.1.1 P-Removal

A study published by EPA in 2007 titled "*Advanced Wastewater Treatment to Achieve Low Concentration Phosphorus*" (EPA 910-R-07-002) surveyed 23 advanced wastewater treatment plants in the United States designed to meet low TP limits, and found that most of the plants included in the survey were able to achieve very low effluent TP levels using tertiary chemical P-removal. Only three of the plants surveyed used filtration following chemical coagulation and settling. Table 4.3 summarizes the performance of the various phosphorus removal technologies for the surveyed facilities.

The results of several studies conducted to achieve very low effluent phosphorus levels using various types of clarifiers alone and followed by filtration suggest that the lowest attainable phosphorus concentrations using chemical precipitation is in the range of 0.05 – 0.07 mg/l (Reardon, 2005).

Typical effluent TP concentrations for the facilities listed in Table 4.3 demonstrate that tertiary coagulation/sedimentation followed by filtration can achieve effluent phosphorus levels in the range of EPA's NNC. Consistently meeting the NNC limit of TP of 0.05 mg/l necessary for lake augmentation; however, will be challenging with this technology alone. As mentioned above the limiting components will be the concentrations of DOP and particulate phosphorus present in the reclaimed water from Phase 1 at the SWWRF.

Table 4.3 Summary of Results from EPA Survey of 23 Full-scale Facilities Designed to Meet Low TP Limits (EPA 910-R-07-002)
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Facility Name and Location	Capacity (mgd)	Treatment Technology Used for P Removal	Effluent TP Concentrations (mg/l)	
			NPDES Permit Limit	Range of monthly average values
Sand Creek WWRP, Aurora, CO	5	BNR, filtration	None	0.1 – 0.2
Breckenridge S.D. Iowa Hill WWRP, CO	1.5	BNR, chemical addition, tertiary settlers, filtration	0.5 daily max.	0.017 – 0.013
Breckenridge S.D. Farmers Korner WWRP, CO	3	BNR, chemical addition, tertiary settlers, filtration	0.5 daily max.	0.002 – 0.036
Summit County Snake River WWTP, CO	2.6	BNR, chemical addition, tertiary settlers, filtration	0.5 daily max.	<0.01 – 0.04
Pinery WWRF, Parker, CO	2	BNR, chemical addition, two-stage filtration	0.05	0.021 – 0.074
Clean Water Services, Rock Creek WWTP, OR	39	Chemical addition, filtration	0.1	0.04 – 0.09
Clean Water Services, Durham WWTP, OR	24	BNR, chemical addition, filtration	0.11	0.05 – 0.1
Stamford WWTP, Stamford, NY	0.5	Chemical addition, two-stage filtration	0.2	<0.005 – 0.06
Walton WWTP, Walton, NY	1.5	Chemical addition, two-stage filtration	0.2	<0.005 – 0.06
Milford WWTP, Milford, MA	4.8	Multi-point chemical addition, filtration	0.2	0.04 – 0.16
Alexandria Sanitation Authority WWTP, Alexandria, VA	54	BNR, multi-point chemical addition, tertiary settling, filtration	0.18	0.04 – 0.1

Table 4.3 Summary of Results from EPA Survey of 23 Full-scale Facilities Designed to Meet Low TP Limits (EPA 910-R-07-002) SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities				
Facility Name and Location	**Capacity (mgd)**	**Treatment Technology Used for P Removal**	**Effluent TP Concentrations (mg/l)**	
			NPDES Permit Limit	**Range of monthly average values**
Upper Occoquan Sewerage Authority WWTP, VA	42	Chemical (lime) and filtration	0.1	0.023 – 0.28
Fairfax County, Norman Cole WWTP, VA	67	BNR, chemical addition, tertiary settlers, filtration	0.18	0.02 – 0.13
Delhi, NY	0.82	BNR, chemical addition, filtration	0.11	0.02 – 0.085
Pine Hill WWTP, NY	0.5	Sand filters, chemical addition, microfiltration	0.2	< 0.12
Grand Gorge WWTP, NY	0.5	Sand filters, chemical addition, microfiltration	0.2	<0.05
Hobart V, NY	0.18	Sand filters, chemical addition, microfiltration	0.5	0.026 – 0.07
Synderville Basin Water Reclamation District, UT	4	BNR, chemical addition, filtration	0.1	0.03 – 0.06
Ashland WWTP, OR	2.3	Chemical addition, membrane filtration	1.6 lb/d (~ 0.08)	0.05 – 0.12
McMinneville WWTP, OR	5.6	BNR, chemical addition, traveling bed filters	0.07	0.036 – 0.092

4.1.2 Nitrogen Removal

Very few studies have been conducted at bench, pilot, or full-scale to demonstrate the effectiveness of coagulation, sedimentation, and filtration for removal of nitrogen. Tertiary solids separation processes would be expected to provide only incremental nitrogen removal as most of the nitrogen in the effluent from Phase 1 should be predominantly DON. DON is reported to be from 40-85% of the TN in low TN effluents (Pagilla et. al, 2006). Even so, a few published studies suggest that chemical coagulation alone or coupled with membrane filtration can remove some nitrogenous organic compounds. Detailed characterization of the effluent from Phase 1 coupled with bench or pilot testing will be required to determine if coagulation and filtration alone could remove sufficient incremental nitrogen to meet TN limits for lake augmentation.

4.2 Adsorption

Adsorption removes constituents from water by binding them to the surface of a sorbent through various physical or chemical forces such as hydrogen bonds, dipole interactions, or Van der Waals forces. Adsorption processes used for removal of phosphorus include adsorptive media filtration, reactive filtration, ion exchange, and GAC. These processes are described in more detail below.

4.2.1 <u>Adsorptive Media Filtration</u>

In theory, filtration for removal of particulate pollutants involves six distinct mechanisms including straining, sedimentation, impaction, interception, adhesion, and flocculation (Metcalf & Eddy, 2003). Adsorptive media filtration involves three additional mechanisms chemical adsorption, physical adsorption, and biological growth. Filter media made of iron oxide like the synthetic iron oxide media “BayOxide®” has been used primarily for arsenic removal in potable water applications; however, these media also have a strong affinity for phosphate, and can be used to remove phosphorus in wastewater effluents down to trace levels. Spent media is non-hazardous and can be sent to the landfill for disposal.

4.2.2 <u>Reactive Filtration</u>

In reactive filtration, ferric salt is added to the influent upstream of the filters and a hydrous ferric oxide (HFO) coating is formed on the media surface. HFO allows adsorption of phosphorus. Precipitates, including the iron and phosphorus, are continuously separated from the process flow by continuous backwashing. Reactive filtration can play a major role in the removal of dissolved constituents and very fine particles. At present, the Blue PRO® system is the only commercially available technology for phosphorus removal using reactive filtration.

4.2.2.1 <u>P-Removal</u>

Reactive filtration for phosphorus removal is a relatively new technology compared to tertiary coagulation/flocculation/sedimentation with less than five full-scale installations in sizes comparable to that of the proposed SWWRF. A few recent pilot studies conducted using reactive filtration have reported achieving very low phosphorus levels (~ 0.01 mg/l).

Typically, TP concentrations <0.3 mg/l have been achieved using a single pass system while a dual pass system has been found to achieve even lower effluent TP concentrations. Table 4.4 provides a summary of the various pilot studies. Achieving the NNC TP limit of 0.05 mg/l for SWWRF may require a two-pass system.

Table 4.4 Summary of Results from Recent Pilot-Scale Tests Using Reactive Filtration
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Facility Name & Location	Hydraulic Loading rate, gpm/ft^2	Influent TP, mg/l	Single Pass Effluent TP, mg/l	Second Pass Effluent TP, mg/l
Hayden WWTP, Idaho	3 – 4	1.34	0.189	0.009
Town of Innisfil, Ontario, Canada	4 - 5	0.22	0.024	0.012
Southeast Florida	3.5	2.29	0.204	0.023
City of Coeur D'Alene, ID	-	0.86	0.064	0.02
North Koochiching Area Sewer District WWTP, MN	-	2.34	0.87	0.30
Hibbing WWTP, MN	3.0	1.75	0.062	0.019
Logan WWTP, UT	3.5	6.81	0.72	0.23
Georgetown WWTP, CO	3.4	0.9	0.18	-
East Helena WWTP, MT	3.0	1.8	0.20	0.02

4.2.2.2 N-Removal

At present, no full-scale installations exist that provide a combination of phosphorus and nitrogen removal using reactive filtration processes. However, BluePro® literature suggests that denitrification can be achieved in the same filter. Pilot scale studies would be needed to confirm and quantify the additional denitrification that can be achieved post AWT treatment.

4.2.2.3 Other Parameters

No studies have been conducted to report the protozoan removal achieved by reactive filters, although removal efficiencies equal to those of deep-bed sand filters can be anticipated. A two pass reactive filter may be able to achieve slightly better results. The Parkson DynaSand D2 filters (a two-pass filtration system similar to the BluePro® system) has been reported to provide up to 7-log removal of protozoan cysts.

4.2.3 Ion Exchange

Ion exchange (IX) is an adsorption process where the chemical reaction takes place on the surface of a resin. Once breakthrough occurs, the resin or media is regenerated. The process uses a strong base, anion exchange resin, which is regenerated with common salt. IX systems usually require filtration and dechlorination (if chlorine is present) as pretreatment to protect the resin bed from oxidation and physical fouling.

IX based on the use of clinoptilolite, a natural zeolite, has been used for removal of ammonia from waters for a long time. Additionally, pilot and demonstration scale studies have been successfully performed using wastewater secondary effluent for removal of phosphorus (orthophosphate) and NO_3-N. Removal efficiencies typically are more than 90 percent; however, there are no reported full-scale facilities that are using IX technology for removal of total nitrogen and phosphorus down to trace concentrations.

A pilot study conducted at a wastewater treatment plant in Easton, Pennsylvania (Kney et. al., 2004), demonstrated effluent TP and NO_3-N concentrations of less than 0.1 mg/l for both compounds. Values for TP and NO_3-N influent concentrations in the pilot study were typical for nitrified secondary effluent (4.0 mg/l and 16.0 mg/l, respectively).

Experiments conducted thirty years ago (Randtke et al., 1978) evaluated a series of physical-chemical processes for removal of DON from secondary effluents. They found that at neutral pH, cation exchange removed approximately 11% of the DON in secondary effluent while anion exchange removed approximately 12% of the DON. Removals increased significantly, as pH was reduced from 7 to 2.

Siemens Water Technology and Purolite have indicated that their commercial IX systems based on the use of synthetic polymeric resins can achieve very high nutrient removal efficiencies to trace levels; however, this experience has been on potable water. Experience with the use of synthetic polymeric IX resins in wastewater treatment at full-scale is very limited due to various reasons including the extensive pretreatment requirements, concerns about the life of the resin, and the complex regeneration systems required. However, IX could be a viable technology for removal of inorganic species of nitrogen and phosphorus to trace levels as may be necessary to target the TN limit of 1.27 mg/l for discharge to Lake Avalon. Appropriate pilot testing should be done to determine the cost effectiveness of this technology to produce effluent suitable for lake augmentation.

4.2.4 Activated Carbon

4.2.4.1 Nutrient Removal

Similar to IX, very little information can be found on the effectiveness of activated carbon to remove nutrients from secondary effluent to trace levels to meet NNC criteria. Randtke et. al. (1978) reported that activated carbon adsorption could be a very effective method for removal of DON. The study reported that 70% of the DON in secondary effluent is relatively non-polar making it amenable for removal with activated carbon adsorption. There are several full-scale facilities using activated carbon adsorption for removal of COD and other organics from secondary effluent; however, none exists for removal of DON and DOP. Bench scale and pilot scale testing should be performed to confirm the effectiveness of activated carbon for removal of DON and DOP to sufficiently low levels to meet the NNC criteria. Activated carbon adsorption has also been shown to be effective in removal of certain ESOC.

4.2.4.2 Organics Removal

Adsorption using GAC filters is an advanced tertiary treatment process primarily used for removal of organic compounds during wastewater treatment for applications such as indirect potable reuse or groundwater recharge. Organic compounds are removed by a combination of adsorption, filtration, and degradation mechanisms. Activated carbon is most effective at removing less polar material. DeWalle et al. (1982) reported 60% TOC removal using GAC filter columns using secondary effluent from the Water Factory 21 facility. GAC filters are also highly effective for removal of most ESOC. Steroid hormones and other hydrophobic contaminants are effectively removed with minimal breakthrough after 50,000 bed volumes. On the other hand, X-ray contrast media (such as iopromide) and some pharmaceuticals are the most recalcitrant for GAC removal. Additionally, GAC must be regenerated or replaced regularly to ensure efficient ESOC removals (Ternes et al., 2004).

GAC filtration is typically preceded by media filtration or comparable other processes to reduce suspended solids in the filter influent. Oxidants such as chlorine or dissolved oxygen reduce the adsorption capacity of activated carbon. Hence, feed water should be free of any oxidants.

Several types of activated carbon contactor systems are used. Carbon adsorption columns are either pressure or gravity fed. They can be operated in upflow-countercurrent mode with packed or expanded carbon beds or as fixed bed units with two or three columns in series. The empty bed contact time (EBCT) for GAC filters typically ranges from 15 to 35 minutes depending on the application, wastewater constituents, and desired effluent quality. In terms of chemical oxygen demand (COD) removal, EBCT of 15 to 20 minutes are typical to reduce effluent concentrations of COD to 10 to 20 mg/L, and 30 to 35 minute EBCT to reduce COD to 5 to 15 mg/L.

<u>Powdered Activated Carbon (PAC)</u>

Addition of PAC to secondary treatment provides improved BOD, COD and TOC removal. At the same time, settling of suspended solids is generally improved and foaming potential reduced. By binding refractory organic compounds to the PAC surface, their residence time in the secondary treatment is increased, increasing the effectiveness of microbial breakdown. Since 1985, the 10 mgd Fred Hervey Water Reclamation Plant in El Paso

Texas has provided advanced wastewater treatment for the purpose of indirect potable water reuse. Treatment processes include a two-stage powdered activated carbon process (PACT), lime treatment, two-stage recarbonation, sand filtration, ozonation, granular activated carbon filtration, followed by chlorination.

The performance of Fred Hervey Water Reclamation Plant has been well within the design standards for conventional pollutants. A study of trace organic compounds in the plant wastewater was conducted in 2005 indicating that none of the target compounds (Bisphenol A, 17α-ethinylestradiol (synthetic estrogen) and 4-nonylphenol (surfactant)) was present in the influent or effluent. Eighteen wastewater effluent samples were collected in June of 2005. Another 21 samples were collected in August of 2005 from drinking water wells down gradient from the Fred Harvey wastewater treatment plant. None of the same three target organic compounds was detected in the water samples. Technical nonylphenol (a relatively low-grade mixture of para-C_9H_{19}-substituted phenols) was present in the wastewater influent; however, the plant was able to remove most of this compound. Only trace amounts (less than 1 ppb) were found in the treated water samples and in monitoring wells.

Like GAC, further testing would be necessary to quantify performance, design criteria, and expected costs of PAC as a potential treatment technology at SWWRF for future use.

4.3 Denitrification Filters

Denitrifying filters have been used for wastewater treatment for many years for tertiary NO_3-N removal after nitrifying activated sludge and BNR processes. The addition of methanol to water for the purpose of biologically removing nitrates was first patented in the 1970s. There are currently three commercially available denitrification filter configurations, deep-bed downflow filters, continuous backwash upflow filters, and upflow submerged packed-bed reactors or biologically active filters (BAFs).

Denitrification filters have been proven to be a robust and reliable technology for nitrogen removal at full-scale plants. A recent Water Environment Research Foundation (WERF) study of nutrient removal plants designed and operated to meet very low effluent TN and TP reviewed operational data from twenty-two full-scale facilities (WERF NUTRIR06K 2011). One of the conclusions of the study was that separate-stage nitrogen removal processes (for example nitrifying activated sludge followed by denitrification filters) outperform combined nitrogen removal processes (single sludge BNR processes).

Despite their exemplary process for tertiary denitrification, like the other processes discussed here, denitrification filters have not been used to meet effluent TN limits comparable to the EPA NNC. Results from several full-scale facilities and a pilot plant study suggest that denitrification filters should be able to achieve effluent NO_3-N concentrations $\leq$0.5 mg/L. However, denitrification filters alone may not achieve TN concentrations meeting NNC unless the NH_3, DON, and PON concentrations are also exceptionally low.

Performance data from a full-scale plant (30 mgd, AADF) in Arlington, VA, which uses nitrifying activated sludge followed by denitrification filters, is provided in Figure 4.3.

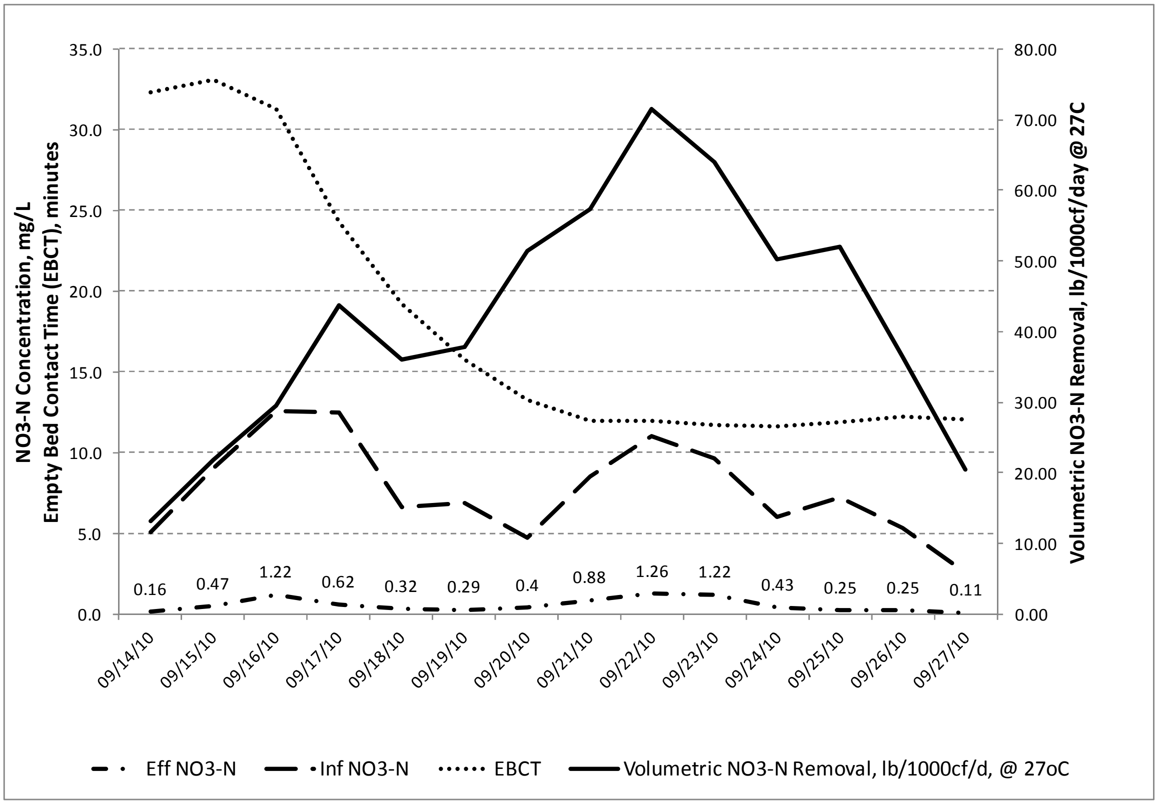

Figure 4.3 Pilot Scale Data for Denitrification Filters at the Arlington, VA Plant (Courtesy of Severn Trent Services)

Full-scale operational data from 40 large (> 2 mgd treatment capacity) Florida AWT plants showed that A^2O process with denitrification filters averaged effluent TN concentrations of 1.87 mg/l, which is slightly better than other BNR processes in use in Florida such as five-stage Bardenpho, SBRs, and multi-stage nitrification/denitrification processes.

Therefore, implementation of denitrification filters for additional nitrogen removal at SWWRF should be considered for further evaluation in combination with processes to remove ammonia, particulate TKN, and DON.

4.4 Membrane Filtration

4.4.1 Low-Pressure Membranes

Low-pressure microfiltration (MF) or ultrafiltration (UF) membranes separate solids from wastewater. The nominal pore size for low-pressure membranes ranges between 0.1 µm and 0.01 µm. Commercially available low-pressure membranes operate under either submerged or pressurized conditions. About ten percent of the product water is used for backwashing. Spent backwash can be recycled to an upstream process.

Membrane cleaning is accomplished by applying an air scour and reversing flow to the membranes. A more detailed description of low-pressure membrane systems including a discussion of manufacturers and system performances is presented in the TM 2 – “Identification of Alternative Treatment Technologies.”

Low-pressure membranes remove particulate and colloidal forms of TP to concentrations below the NNC. Soluble nitrogen species are not removed through low-pressure membranes alone; however, particulate nitrogen and some of fraction of colloidal nitrogen will be removed depending on the pore size distribution of the membranes relative to the particle size distribution of the colloidal nitrogen. Similarly, no appreciable TOC removal can be accomplished by low-pressure membranes alone.

4.4.2 High-Pressure Membranes

Nanofiltration (NF) and reverse osmosis (RO) are the two types of high-pressure membranes commonly used for wastewater treatment. Pretreatment is critical to minimize fouling of high-pressure membranes, and is typically provided by low-pressure membranes or an equivalent solids separation process. The nominal pore size of high-pressure membranes is less than 0.002 µm or molecular weight cut-off of 200 - 100 Da. Typical feed pressures exceed 100 psi and increase with total dissolved solids (TDS) concentrations in the feed water and fouling of the membranes.

High-pressure membranes produce a concentrate stream, consisting of the materials rejected by the membranes. This can pose a disposal challenge depending on site-specific conditions. Assuming a wastewater TDS below 500 mg/l (the secondary drinking water standard and typical for inland residential areas such as the SWSA) the concentrate TDS concentrations could be as high as 3,500 mg/l, depending on the recovery at which the system operates. One disposal option that has been proposed is to blend the concentrate with sufficient quantity of reclaimed water from the other facilities for PAR, or pumping into an aquifer below the low TDS potable water zone.

4.4.2.1 Nitrogen and Phosphorus Removal

Most high-pressure membranes (RO) are reported to be less effective at rejecting inorganic nitrogen species such as NH_3-N, NO_2-N, and NO_3-N than other ions such as sodium and chloride. The rejection for NH_3-N, NO_2-N, and NO_3-N varies with pH but is typically around 80 to 90% at near neutral pH values as compared to more than 98% rejection for other multivalent anions. Rejection can decrease as the membranes age or foul. Therefore, removal of inorganic forms of nitrogen in the upstream biological process increases the ability of high-pressure membranes to meet the NNC for total nitrogen.

Jimenez et al. (2011) reported results from a survey of several full-scale water reclamation facilities using RO membranes and concluded that while the average removal of inorganic nitrogen species was in the 80 - 90% range, the most variable removal was reported for

DON (68 – 94%). The authors concluded that nitrogen removal should be maximized in upstream processes to ensure that the RO effluent is more likely to achieve TN concentrations that satisfy the NNC.

In contrast to inorganic nitrogen species, RO membranes reject around 99% of orthophosphorus and thus can achieve TP concentrations consistently less than 0.01 mg/l.

OCU conducted a comprehensive 21-month long pilot study using filtered, un-chlorinated effluent from the SWRF and the EWRF (OCU, 2007). The pilot plant used UF membranes as pretreatment for NF membranes. UV disinfection was provided after the NF membranes. A summary of the results from this study with respect to nitrogen and phosphorus are provided in Table 4.5. NF membranes were used in the pilot study, which accounts for the significantly lower rejections shown in Table 4.5 compared to those mentioned above for a typical RO performance.

Table 4.5 OCU Reclaimed Water Pilot Study Results for Nitrogen and Phosphorus removal using NF membranes (OCU, 2007)
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Parameter	SWRF Pilot Data		EWRF Pilot Data(1)	
	Average Influent	Average Effluent	Average Influent	Average Effluent
Ammonia, mg/l	3.8	1.18	0.57	0.32
NO_3-N, mg/l	2.47	2.47	2.56	2.56
Nitrite, mg/l	2.60	3.56(2)	0.82	0.83(2)
TKN, mg/l	4.79	1.16	2.0	0.42
Organic nitrogen, mg/l(3)	0.99	Negligible	1.43	0.1
TN, mg/l	9.0	7.1		3.47
Orthophosphorus, mg/l	2.0	0.21	0.17	0.02
Total phosphorus, mg/l	2.1	0.23	0.23	0.02

Notes:
(1) EWRF uses a BNR process and has effluent nitrogen concentrations of less than 6 mg/l and total phosphorus concentrations of less than 1 mg/L
(2) It was reported that ammonia in the pilot plant influent was oxidized to nitrite by residual nitrifying biomass in the influent TSS in combination with the air that was added as part of the UF membrane process.
(3) TKN is a sum of ammonia and organic nitrogen. Organic nitrogen values presented were derived by subtracting ammonia from TKN values.

4.4.2.2 TOC Removal

The effectiveness of RO membranes for TOC removal is excellent. For example, at the West Basin Water Reclamation Plant, California, secondary effluent TOC of around 10 mg/l was reduced to less than 1 mg/l after treatment (WERF 01-CTS-6, 2003). Similar results were reported for RO in pilot studies for Orange County Sanitation District's Groundwater Replenishment System (GWRS), the Scottsdale Arizona Water Campus Advanced Wastewater Treatment Facility, and Singapore's Bedok NEWater Facility. For direct aquifer injection, the USEPA Reuse Guidelines recommend filtration ("low-pressure" membranes such as MF or UF) followed by disinfection and advanced treatment using "high-pressure" membranes. The TOC concentrations reported in the RO permeate from a number of full-scale and pilot-scale facilities are listed in Table 4.6. TOC concentrations are typically well below 1.0 mg/l. TOC is a broad, lumped parameter or marker, and TOC is not typically indicative of specific organic contaminants. Most of the TOC in secondary effluent derives from natural organic matter (NOM) and products of microbial degradation from biological treatment rather than from synthetic organics. Typically, about 50% of TOC in secondary effluents is found in the molecular weight cut-off (MWCO) fractions greater than 10,000 Daltons (Da) and about 25% is greater than 50,000 Da in size. This size range is well retained by RO membranes. Certain trace organics, however, are less than 500 Da in size and have been shown to pass through RO membranes (WERF 01-CTS-6, 2003).

In fact, 40 to 50% of the TOC remaining in RO permeates consist of low molecular weight acids and neutrals in the size range of 500 Da or less (WERF 01-CTS-6, 2003). Other trace organic compounds, such as ethylenediaminetetraacetic acid (EDTA), nitrilotriacetic acids (NTA), alkylphenol polyethoxy carboxylates (APECs), and selected EDCs (such as surface active agents, pesticides, plasticizers, food additives, birth control pills, herbal supplements, and cosmetics) and pharmaceutically active compounds (PhACs) (such as anti-inflammatory drugs, anti-epileptics, blood-lipid regulators, and diagnostic contrast agents) were found to be present in the tertiary effluents, but were absent in the NF or RO permeates.

Table 4.6	TOC Concentrations in RO Permeate from Various Water Reclamation Facilities (WERF 01-CTS-6, 2003) SWWRF Conceptual Design and Facilities Plan Update Orange County Utilities
Description of Cited Study	**TOC, mg/l**
Arizona State Pilot Study	0.28
Dublin San Ramon Full-Scale Facility	< 0.03
San Diego Repurification Pilot Study	0.15 – 0.47
City of Tampa Pilot Study	0.38
San Diego MBR Pilot Study	0.15 - 0.7
West Basin Full-scale Facility	0.66 – 0.93
San Diego Full-Scale Industrial	0.2
Wulpen Pilot Study, Belgium	3.3
Livermore Pilot Study	< 1.0
Scottsdale Pilot Study	0.6 – 2.0
Lake Arrowhead Pilot Study	0.85
Water Factory 21 Full-Scale Facility	0.5
Tampa Pilot Plant	0.2 – 0.6

Table 4.7 presents the results of the 21-month comprehensive UF/NF pilot study conducted by OCU. The pilot study demonstrated that the high-pressure NF membrane followed by UV disinfection processes produced effluent that meets the FDEP's treatment requirements for direct aquifer injection.

ESOC analysis performed during the OCU pilot study was grouped into four categories: wastewater organics; pharmaceuticals; antibiotics and estrogenic compounds. Of the 619 sampling events during the SWRF pilot study, ESOC compounds were not detected in the pilot effluent in 102 cases, or approximately 17 percent of the time. In 250 sampling events, ESOC were detected in the pilot plant influent, but not in the pilot plant effluent. In these events, the pilot plant provided sufficient level of treatment to remove the compounds to below detection. For the remaining 267 sampling events, the ESOC compounds were found in both the pilot plant influent and effluent. In 252 of these events, the concentration of the ESOC compound was lower in the pilot plant effluent than in the influent. Mutagenicity analysis was also performed for the pilot effluent, using a testing protocol approved by the FDEP. The results indicated that the water produced by the pilot plant was not mutagenic.

Robust pretreatment is an essential pre-requisite for the efficient operation of high-pressure membranes. This increases the overall capital cost of the process, but significantly lowers operating costs, minimizes maintenance, and maximizes membrane life. Ever since the MF system was proven to work on wastewater at the Orange County Water District (California) Water Factory 21 water reclamation facility, MF or UF has been used as an effective pretreatment process for RO membranes treating secondary effluent.

Table 4.7 Summary Results from the OCU Reclaimed Water UF/NF Pilot Study (OCU, 2007)
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Full Treatment Parameter	SWRF Pilot Effluent		EWRF Pilot Effluent		Full Treatment Requirement	
	Average	Maximum	Average	Maximum	Annual Average	Single Sample
TOC, mg/l	0.68	2.59	0.71	1.48(3)	3	5
TOX, mg/l	0.1	0.38	0.19(2)	2.6	0.2	0.3
TN, mg/l	7.1	17.4	3.47	10.5	10	NA
TSS(1), mg/l	1.1	3(3)	1.29	14	5	NA
Enterovirus (MPN/100 ml)	U	U	U	2	U	U
Cryptosporidium (Oocysts/100 L)	U	1	U	U	U	U
Giardia (Cysts/100 L)	U	3.1	U	U	U	U
Helminths (Ova/100 L)	U	U	U	U	U	U

Notes:
(1) TSS in NF permeate, prior to disinfection (per rule).
(2) Average higher than at SWRF due to higher detection limit.
(3) Excludes one outlier that appeared to be switched with NF concentrate in lab analysis.
(4) U – Undetected

The disposal of RO concentrate can be expensive and may be difficult to permit for the SWWRF. The most commonly used concentrate disposal methods include discharge to a sewer system (preferably not one tributary to the RO facility), deep-well injection, evaporation ponds, surface water discharge, and spray irrigation.

High-pressure membranes should be considered for further evaluation since OCU has already conducted a 21-month pilot study using a UF/NF processes followed by UV disinfection.

4.5 Tertiary MBR

A tertiary membrane bioreactor (MBR) process is similar to a traditional MBR, with the exception that the MBR process is fed effluent from an upstream activated sludge process. Tertiary MBR systems have a smaller footprint than MBRs used for secondary treatment and target primarily removal of nitrogen and phosphorus.

With an AWT effluent meeting a TN goal of 3 mg/l, the concentrations of inorganic nitrogen (ammonia, nitrite and NO3-N), and the concentration and size distribution of DON will establish the efficacy of a tertiary MBR system to meet NNC nitrogen limits. Adding a metal salt to bind and remove phosphorus within the tertiary MBR should be sufficient to achieve low effluent phosphorus concentrations to meet the NNC limits.

As described above, no appreciable TOC removal can be accomplished by a tertiary MBR process downstream of the Phase 1 treatment alone.

4.6 Moving Bed Biofilm Reactor (MBBR)

MBBR technology is a biofilm process that has been used to provide tertiary treatment. A free-floating inert media is used to provide a surface for biomass growth within the basin. The MBBR process does not require recycle of return activated sludge. MBBR can be used for tertiary denitrification by operating all or part of the reactor under anoxic conditions with addition of a supplemental carbon source. Mechanical mixers keep the media in suspension and provide sufficient shear to slough excess growth. The mobility of the media is a design and operational consideration for dispersed media MBBR systems. Retention screens are required to keep the media in the basin. Some dispersed media migrate downstream in the bioreactors, and must be returned to the front of the reactor using an airlift pump. MBBR technology is widely used in Europe. There are 12 full-scale MBBR installations in North America to date.

4.7 Fluidized Bed Bioreactor (FBBR)

In FBBR processes, water is pumped upward through the reactor at sufficient velocity to fluidize the fine media used to provide the surface area for biological growth. The detention time in a FBBR basin is only a few minutes and thus FBBRs have a very small footprint. Although biomass wasting is provided integral to FBBRs, filtration is typically needed downstream of an FBBR to remove suspended solids. Two types of media have been used for installations in the past, silica sand or granular activated carbon (GAC). Few full-scale installations currently exist using FBBRs for tertiary denitrification. However, one large installation has been operating successfully for many years at the Truckee Meadows Water Reclamation Facility in Nevada.

4.8 Advanced Oxidation Processes (AOP)

AOPs are efficient for the destruction of ESOC and pathogens. AOPs used for water treatment include UV, ozone (O_3), hydrogen peroxide (H_2O_2), peracetic acid (PAA), Fenton's reagent (Fe_2 + H_2O_2), and process combinations such as photocatalytic oxidation (UV +TiO_2), UV-peroxide (UV + H_2O_2), and ozone-peroxide (O_3 + H_2O_2). The majority of the AOP processes focus on the generation of hydroxyl radicals, which break down the organic substances.

While UV disinfection alone can destroy some chemical constituents through photolysis, the ability to destroy chemical constituents is highly dependent upon the absorbance of UV light by the chemical. Photocatalytic oxidation (UV +TiO_2) is achieved when UV light rays are combined with a titanium oxide (TiO_2) coated filter. This process creates hydroxyl radicals and superoxide ions.

Simple ozonation can be considered as an advanced oxidation process (AOP) because ozone spontaneously converts to O_2 in water through a complicated decomposition mechanism whose intermediates include superoxide and hydroxyl radicals. As a preoxidant, ozone oxidizes compounds that can cause taste and odor; breaks apart larger organic compounds that can act as precursors for chlorine disinfection by-products; and brings about an increase in the transmittance of UV light, thus leading to more energy efficient UV disinfection following ozonation (Kleiser and Frimmel, 2000).

A recent study conducted by the WaterReuse Research Foundation, compared various AOP technologies for the removal of several pollutants and pathogens in qualitative terms Table 4.8. This study concluded that UV-peroxide (UV+H_2O_2) and ozone-peroxide (O_3+H_2O_2) are the two most effective AOP technologies. Both should be considered for future use at the SWWRF.

DeWalle et al. (1982) compared fourteen physical-chemical processes singularly or in combination for their ability to remove DOC from the secondary effluent from Water Factory 21 in Fountain Valley, CA. The largest organic carbon removals (greater than 90%) were obtained with RO membranes (influent TOC was around 12.8 mg/l, while RO permeate TOC was less than 1 mg/l). Adsorption with GAC obtained about 60% TOC removal (effluent TOC was around 5.5 mg/l). However, subsequent treatment of the GAC effluent with IX resins showed further reduction in TOC, for a combined TOC removal of greater than 70% (effluent TOC was around 3.8 mg/l). Treatment of the GAC effluent with ozone and ozone/UV provide significant additional TOC removal. Ozone achieved an additional 65% removal while the ozone/UV achieved 77% TOC removal. UV alone did not show any organics removal. On the other hand, reversing the flow scheme to activated carbon treatment after 15 minutes of ozone/UV exposure resulted in TOC reduction to less than 1 mg/l TOC. Similarly, activated carbon treatment of the H_2O_2/UV treated effluent resulted in an effluent TOC of 1.3 mg/l.

Table 4.8 Qualitative Evaluation of AOP Technologies (Study of Innovative Treatments for Reclaimed Water, WateReuse Research Foundation, Final Report in Press)
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Technology	Bacteria Disinfection	Virus Inactivation	Protozoa Disinfection	Chemical Constituents Destruction
UV	Excellent	Very Good	Excellent	Poor
Ozone	Excellent	Excellent	Good	Excellent
UV+H_2O_2 AOP	Excellent	Excellent	Excellent	Excellent
O_3+H_2O_2 AOP	Excellent	Excellent	Good	Excellent
Free chlorine	Very Good	Very Good	Poor	Good
UV+TiO_2 AOP	Excellent	Very Good	Untested	Very Good
PAA	Very Good	Poor	Poor	Good

The City of Reno Nevada conducted a pilot study to evaluate alternatives to RO to produce effluent suitable for subsurface storage (Sundaram et al., 2010). The target constituents were refractory organics (ESOC), salinity, and corrosivity of the product water to be stored in the subsurface aquifer. The pilot treatment train comprised ozonation of filtered (using MF) secondary effluent followed by biologically activated carbon (BAC) filters followed by a low dose of UV for final disinfection. Table 4.9 summarizes the results of the pilot study.

Table 4.9 Pilot Study Results, City of Reno, NV (Sundaram et al., 2010)
SWWRF Conceptual Design and Facilities Plan Update
Orange County Utilities

Constituent	Pilot Study Water Quality			
	Secondary Effluent	Microfiltration Effluent	Ozone Effluent	BAC Filter Effluent
TOC (mg/L)	8.8	6.2	6.1	1.2
BDOC (mg/L)	0.78	0.73	1.3	0.6
Plate count (cfu/mL)	–	–	1.5E+02	2.8E+05
Bromate (μg/L)	<1	<1	3.9	<1

Results from optimization of the process showed that a dose of 5 mg/l of ozone was sufficient to reduce the desired ESOC. BAC filters providing a minimum of 30 minutes of empty bed contact time performed well as a polishing step with the ozonated effluent. A total of 490 constituents (all compounds in the draft regulations for groundwater recharge in California) were monitored three times before and after each treatment step. The results showed that the ozone-BAC filters are as effective as RO in the removal of ESOC.

Another recently completed study (Rogers et al., 2009) compared GAC adsorption, ozone/H_2O_2 and UV/H_2O_2 AOP processes for removal of ESOC at the East Canyon Water Reclamation Facility (ECWRF) for the Synderville Basin Water Reclamation District, Utah. The study concluded that both GAC adsorption and ozone were effective in removal of ESOC with ozone being the most cost effective treatment. However, since the ECWRF already has existing, continuous backwash upflow sand filters, the District is in the process of replacing the sand media with GAC media for ESOC treatment.

4.9 Soil Aquifer Treatment (SAT)

Treatment of wastewater by a high rate land infiltration system is known as Soil Aquifer Treatment (SAT). SAT systems treat water by both physical-chemical and biological mechanisms including filtration, biological degradation, physical adsorption, ion exchange, and precipitation (Viswanathan et al., 1999). During the last 15 years, comprehensive pilot-scale and field studies conducted at different sites in the U.S. have shown that SAT can achieve low TOC concentrations in reclaimed water.

A research study at two field sites in Arizona demonstrated dissolved organic carbon (DOC) reductions from 5 to 15 mg/l down to ~ 1 mg/l, multiple-log reductions of bacteriophage, and effective nitrogen removal. Nitrogen removal was obtained through subsurface transformations including nitrification and denitrification. Jarusutthirak, et al. (2003) and Schoenheinz et al. (2001) conducted studies to compare product waters from SAT versus NF and RO membranes treating tertiary effluents. Findings indicated that SAT and NF or RO treated water achieved similar DOC concentrations with both containing less than 1.3 mg/l. Depending on the type of membrane, NF and RO can efficiently reject high-molecular weight organic matter (characterized as humic and fulvic acids) whereas low range molecular weight organics can still be present in membrane permeate. However, due to unavailability of land for SAT, this technology will not be considered for further evaluation.

4.10 Constructed Wetlands

Constructed wetlands are a form of natural treatment. OCU operates wetlands at the EWRF and Northwest Water Reclamation Facilities (NWRF). Recent evaluations of the EWRF and NWRF treatment wetlands show that these constructed wetlands remove both nitrogen and phosphorus in the reclaimed water to concentrations below the NNC limits. Between 2006 and 2010 at the EWRF, average wetland influent concentrations for TN and TP were 4.5

mg/l and 0.21 mg/l, respectively, while average effluent concentrations were 1.5 mg/l and 0.12 mg/l, respectively. The City of Orlando's Easterly Wetlands Reclamation project receives effluent from the City's Iron Bridge WRF and achieves nutrient levels below those proposed under the new NNC.

A combination of a BNR treatment process followed by wetlands is a feasible option for meeting low nitrogen and phosphorus limits. Based on a rule of thumb of about 30 – 35 acres per mgd, a total of 450 acres of land would be required to treat the anticipated build-out flows of 15 mgd for SWWRF. Due to the large land requirements for this treatment option, it will not be considered further in the analysis.

5.0 RECOMMENDATIONS - QUALITATIVE COMPARISON OF ADD-ON PROCESSES

A broad qualitative comparison can be made for the various processes described above. The comparison presented below is primarily based on three factors:

- Probability of success of the treatment technology to meet the anticipated effluent water quality for lake augmentation, and
- How widely the process technology has been implemented at full-scale.
- The perceived ease of implementing the technology at full-scale was also used in comparing the various processes.

The probability of success was subjectively determined based on full-scale data and studies as reported in the literature and as discussed above.

5.1 Add-On Processes to Meet Surface Water Discharge Requirements

In TM2, a combination of biological phosphorus removal with supplemental chemical polishing, as needed, was recommended to achieve the AWT limit of 1 mg/l TP. Achieving the NNC limits for TP in future phases will require tertiary treatment using chemical precipitation, IX, or reactive filtration. Consistently meeting the anticipated NNC for total phosphorus of 0.05 mg/l using any form of tertiary coagulation/sedimentation process alone will be challenging. Coagulation/sedimentation alone will not be able to remove other parameters sufficiently such as protozoan cysts or ESOC.

Reactive filtration is a new concept with few full-scale installations. A two-pass reactive filtration process or using reactive filtration downstream of a high-rate tertiary coagulation/sedimentation process has potential to achieve the anticipated NNC for total phosphorus of ≤0.05 mg/l. The presence of significant concentrations of soluble, non-reactive phosphorus in the reclaimed water will likely require additional measures beyond two-stage chemical precipitation and filtration.

Of the various high-rate processes, IX is widely used in potable water applications for removal of organics and nitrate nitrogen. Similarly, IX has also been used to remove ammonia to trace levels in other applications such as aquariums. Use of IX also provides the ability to recover the nitrogen for use in fertilizers. Several promising technologies based on adsorption and ion exchange are under development that may be capable of removing phosphorus sufficiently to meet very low concentration limits while allowing recovery of the phosphorus for recycling. Full-scale use of IX in wastewater, especially with synthetic resin, is limited. However, IX is a potential technology that should be considered to provide the additional removal of nitrate and phosphorus necessary to achieve the very low limits required by NNC.

Achieving TN levels as required by the NNC will be challenging if the dissolved organic nitrogen in the effluent is greater than 1.0 – 1.5 mg/l. While inorganic nitrogen can be reduced to very low levels by various tertiary denitrification technologies, other more expensive technologies such as AOPs or high-pressure membranes may be required. GAC adsorption also appears to be promising for removal of DON. Bench scale and pilot scale testing would be a first step in determining the effectiveness of these technologies in achieving low TN levels at the SWWRF.

Biological nitrogen removal, beyond the AWT, will require supplemental carbon addition. Technologies, which require use of supplemental carbon such as methanol, may pose certain operational and safety issues with respect to chemical handling. However, for denitrification filters, methanol has been shown to outperform other sources of supplemental carbon. On the other hand, use of safer forms of supplemental carbon such as Micro-C™ or acetic acid, even though more expensive than methanol, can be successfully used in tertiary denitrification processes such as MBBR, FBBR or tertiary MBR.

Use of the MBBR process has been limited on a full-scale basis. However, there are a few plants under construction of significant size (≥ 10 mgd) in the Chesapeake Bay area that will incorporate this process for nitrogen removal. BAFs such as deep-bed denitrification filters have numerous installations here in Florida and elsewhere in North America. Constructed wetlands have proven to offer excellent incremental removal of nitrogen and phosphorus, although wetlands may not be feasible for the SWWRF due to the large land required.

The anticipated effluent TN and TP concentrations that might be achieved using the add-on process technologies discussed above are provided in Table 5.1. This table was used to recommend the potential add-on treatment processes to be considered for further evaluation.

Table 5.1 Anticipated Effluent Water Quality Using Add-On Treatment Technologies for Lake Augmentation
SWWRF Conceptual Design and Facilities Plan Update
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Process	Anticipated Effluent TN (mg/l)	Anticipated Effluent TP (mg/l)	Anticipated Pathogen Removal[1]	Anticipated ESOC Removal
SWWRF Phase 1 AWT	≤ 3 TN (≤ 1 – 1.5 DON; ≤ 0.5 – 1.0 NO_3-N; ≤ 0.1 – 0.5 NH_3-N)	≤ 1 TP	< 0.5 log removal of protozoan cysts and < 0.6 log removal of virus	Function of activated sludge system SRT. Literature reports 22 – 94% and is compound specific[2]
High-rate clarification	≤ 2.5 TN (≤ 0.7 – 1.0 DON; ≤ 0.5 – 1.0 NO_3-N; ≤ 0.1 – 0.5 NH_3-N)	≤ 0.04 – 0.1 TP	Unknown, none reported	Unknown, none reported
Two-pass reactive filtration	Unknown TN removal	≤ 0.05 TP	6 log removal of protozoan cysts and < 1.3 log removal of virus	Unknown, none reported
GAC adsorption	≤ 2.0 TN (≤ 0.3 – 0.5 DON; ≤ 0.5 – 1.0 NO_3-N; ≤ 0.1 – 0.5 NH_3-N)	Unknown TP removal	0.4 – 1.5 log removal	Good removal
Tertiary denitrification filters	≤ 2.0 TN (≤ 1 DON; ≤ 0.5 NO_3-N; ≤ 0.1 – 0.5 NH_3-N)	Some TP removal	0.4 – 1.5 log removal	None reported
MF/UF membrane filtration	≤ 3 TN (≤ 1 – 1.5 DON; ≤ 0.5 – 1.0 NO_3-N; ≤ 0.1 – 0.5 NH_3-N)	< 0.1 TP	> 6 log removal of protozoan cysts and < 4 log removal of virus	None reported
RO membranes	≤ 1.2 TN	≤ 0.01 TP	> 9 log removal of protozoan cysts and < 6 log removal of virus	> 90% removal of all ESOC having molecular weights greater than 200 Da.

Notes:
(1) Levine, et al. 2008.
(2) Reported by numerous studies.

Based on an assessment of the processes described above, the following two add-on configurations show promise should lake augmentation be selected for management of reclaimed water from the SWWRF in the future. The effective capacity of the lake augmentation option is expected to be very limited (< 1 mgd) as discussed in TM 4. Hence, only a small portion of the treated effluent from the SWWRF would need further treatment to remove nutrients prior to discharge to area lakes.

- <u>Alternative 1: GAC Followed by High-Rate Clarification or Reactive Filtration</u>

  A small portion of the treated effluent from the Phase 1 SWWRF will be filtered using GAC filters. The SWWRF Phase 1 effluent will have sufficient nutrients to support biological growth within the GAC filter media. Together with adsorption of DON on to the media, additional denitrification can be expected within the filter. Following the GAC filter and upstream of the high-rate coagulation/sedimentation process IX columns (with cation or anion resins or both) may be required to reduce the inorganic species of TN such as NH_3-N, NO_3-N and NO_2-N to trace levels depending on the efficacy of the GAC filters alone to reduce ammonia, nitrite, and nitrate to the concentrations needed to achieve a TN limit of less than 1.27 mg/l for lake augmentation. Following the GAC /IX, high rate coagulation/sedimentation process using iron salts (ferric chloride) will treat the filtered effluent to reduce the TP to the desired level of less than 0.05 mg/l. Alternatively, a two-stage reactive filtration system would be necessary downstream of the GAC/IX process for achieving the TP goal of 0.05 mg/l.

  If significant concentrations of refractory DON or DOP exist in the reclaimed water from Phase 1, and are not removed by GAC, an oxidation process may be required before GAC to transform the refractory organic materials into other compounds that could be removed by biological or physical/chemical methods.

  Finally, the effluent will be disinfected using UV light before being stored in a ground storage tank. UV disinfection will provide the necessary barrier against protozoan cysts and other pathogens. A new pump station will pump the highly treated effluent to nearby Lake Avalon as necessary to meet MFL goals.

  Bench-scale and pilot scale testing would be required to confirm the effectiveness of this process configuration before finalizing a decision to implement this process configuration. Prior to bench-scale testing, the AWT effluent from the SWWRF should be analyzed for DON and DOP concentrations. The concentrations of refractory DON and non-reactive DOP concentration would determine if additional pretreatment using advanced oxidation (prior to the high rate coagulation/sedimentation or the reactive filtration process) would be necessary. A process flow diagram for this process configuration is provided in Figure 4-4.

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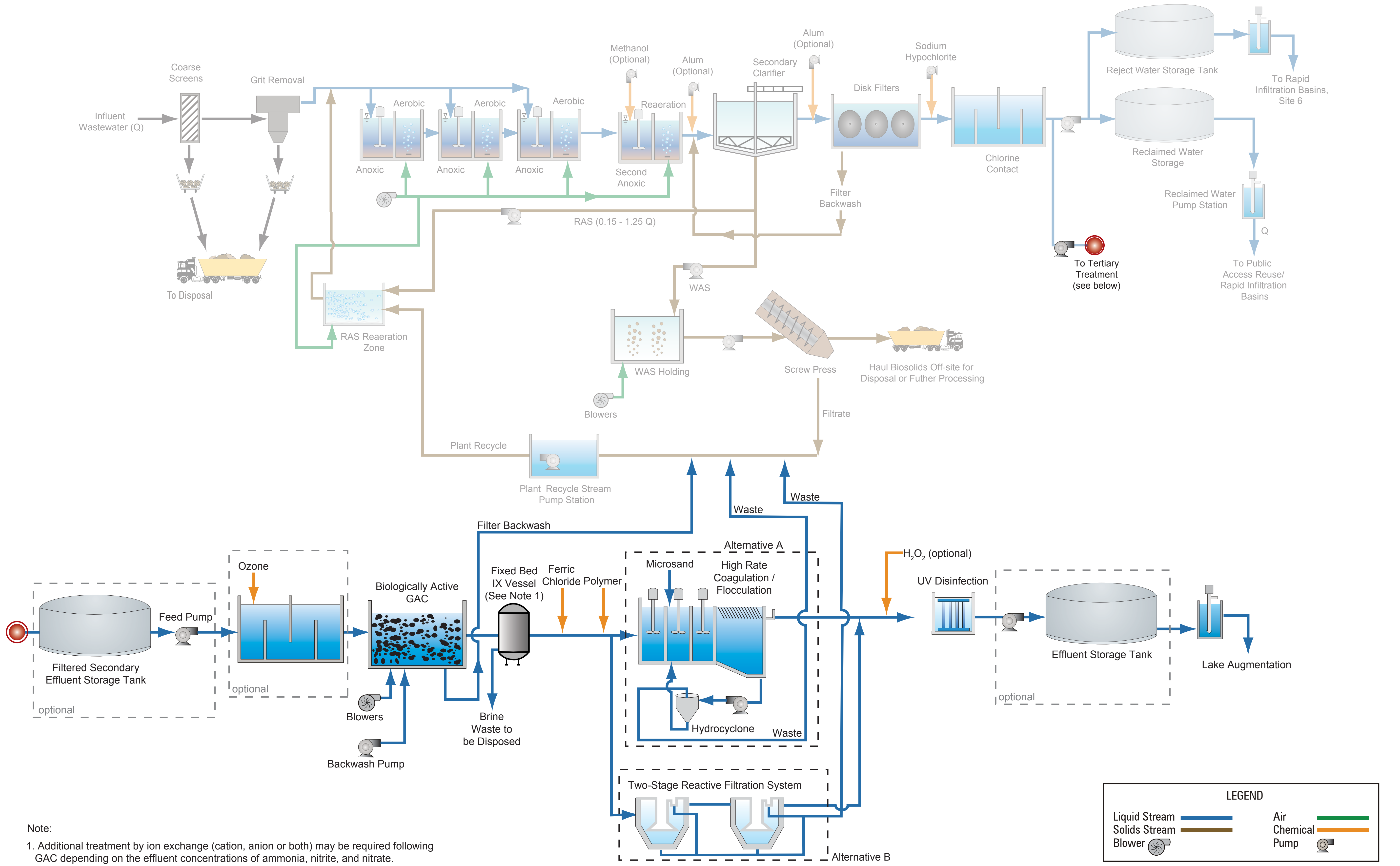

Note:

1. Additional treatment by ion exchange (cation, anion or both) may be required following GAC depending on the effluent concentrations of ammonia, nitrite, and nitrate.

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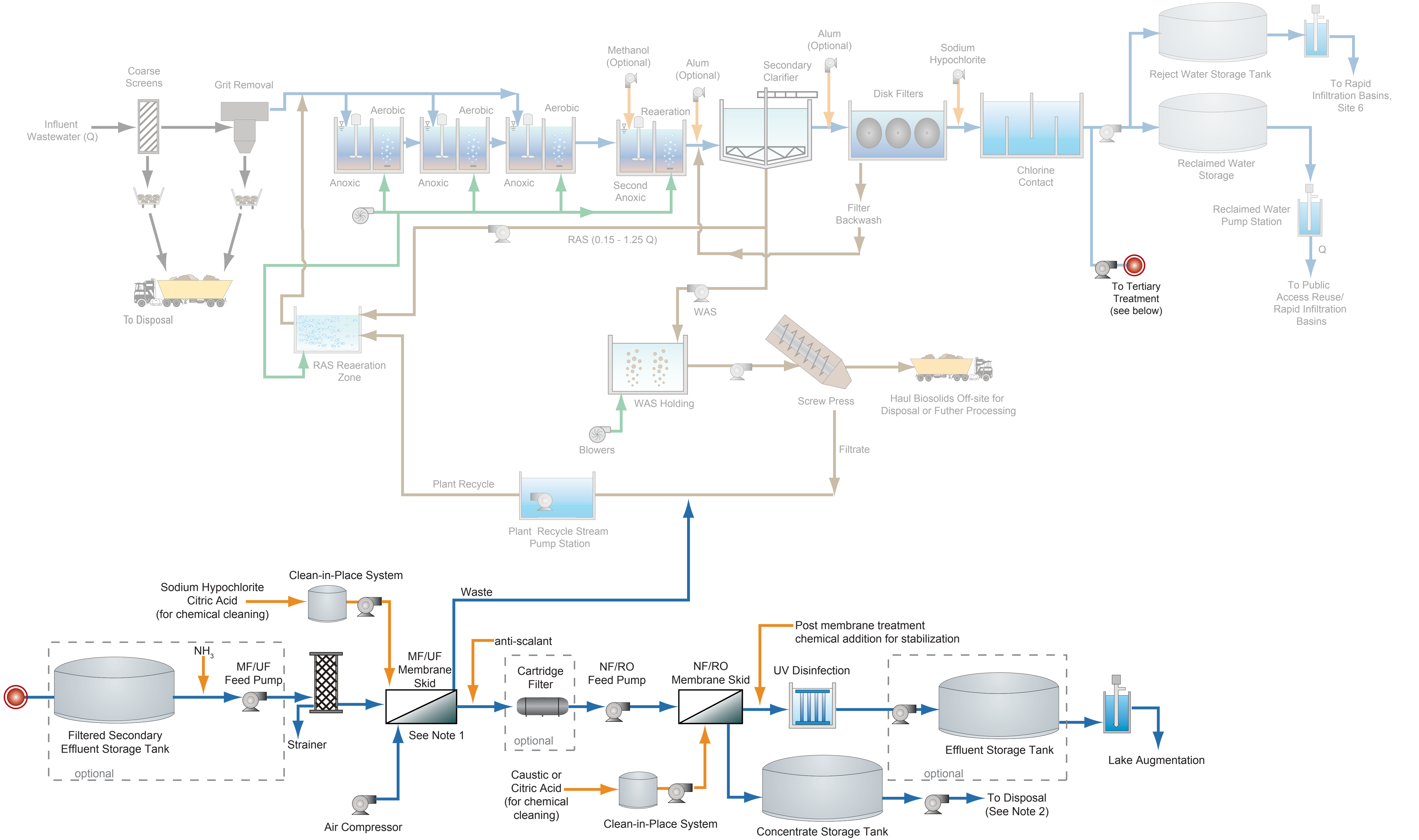
ADD-ON TREATMENT TRAIN FOR FUTURE PHASES - LAKE AUGMENTATION - ALTERNATIVE 1

FIGURE 4-4

- Alternative 2 - UF Membranes followed by RO Membranes.

    A small portion of the effluent from Phase 1 of the SWWRF will be initially filtered with low-pressure UF membranes. The UF membrane could be either an immersed membrane system or an in-vessel pressurized membrane system. The UF membrane will act as a pretreatment for the subsequent RO membranes. The RO membranes will reduce the TP to less than 0.05 mg/l and TN to less than 1.27 mg/l. As described in Alternative 1, the effluent will be disinfected using UV light before being stored in a ground storage tank. UV disinfection will provide the necessary barrier against protozoan cysts and other pathogens. A new pump station will pump the highly treated effluent to nearby Lake Avalon as necessary to meet MFL goals. Similar to Alternative 1, bench-scale and pilot scale testing would be required to confirm the effectiveness of this process configuration before proceeding with implementation, and to measure its relative performance and cost against Alternative 1.

    A process flow diagram for this process configuration is provided in Figure 4.5.



Notes: 1. Schematic shows a pressurized MF/UF membrane. MF/UF membranes can also be submerged type. Final determination to be made at later time.
2. Depending on concentrate total dissolved solids (TDS), chloride concentration and other ion concentrations, concentrate could be disinfected, blended with reclaimed water for disposal to PAR. Detailed analysis should be conducted to confirm suitability. Alternatively, other means of concentrate disposal such as crystallization/evaporation or deep well injection may be required.

LEGEND

Liquid Stream		Air	
Solids Stream		Chemical	
Blower		Pump	

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ADD-ON TREATMENT TRAIN FOR FUTURE PHASES - LAKE AUGMENTATION - ALTERNATIVE 2

FIGURE 4-5

5.2 Add-On Processes to Meet Direct Aquifer Recharge

Based on the above discussions, the following two add-on process configurations show excellent potential for treatment of the effluent from Phase 1 of the SWWRF to meet the water quality limits for direct aquifer recharge.

- Alternative 1 - Ozonation followed by Biological Active Filters followed by UV Disinfection.

  Under this alternative, the effluent from the Phase 1 SWWRF will be subjected to oxidation and disinfection using an appropriate dose of ozone. The ozonated effluent will then be filtered using biologically active filters (BAF) with GAC media. Recent studies have shown that this combination has been able to reduce the TOC of a secondary treated effluent to below the 3 mg/l, the regulatory limit in Florida for direct aquifer injection (Rule 62-610.560 F.A.C.). Alternatively, a sand mono-medium filter such as a deep-bed filter could be investigated in lieu of a GAC media filter. The ozone-BAF process has also shown to significantly reduce or completely remove a host of ESOCs from wastewater effluent. Similarly, an intermediate MF/UF low-pressure membrane after the BAFs may be necessary to provide a final barrier to particulate matter. Following filtration, the effluent will be further disinfected using UV light as an additional barrier to pathogens and other ESOCs. Bench-scale and pilot scale testing should be performed to confirm the effectiveness of this process configuration prior to implementation, and to evaluate the economics of this configuration in comparison to UF/RO.

  A process flow diagram for this process configuration is provided in Figure 4.6

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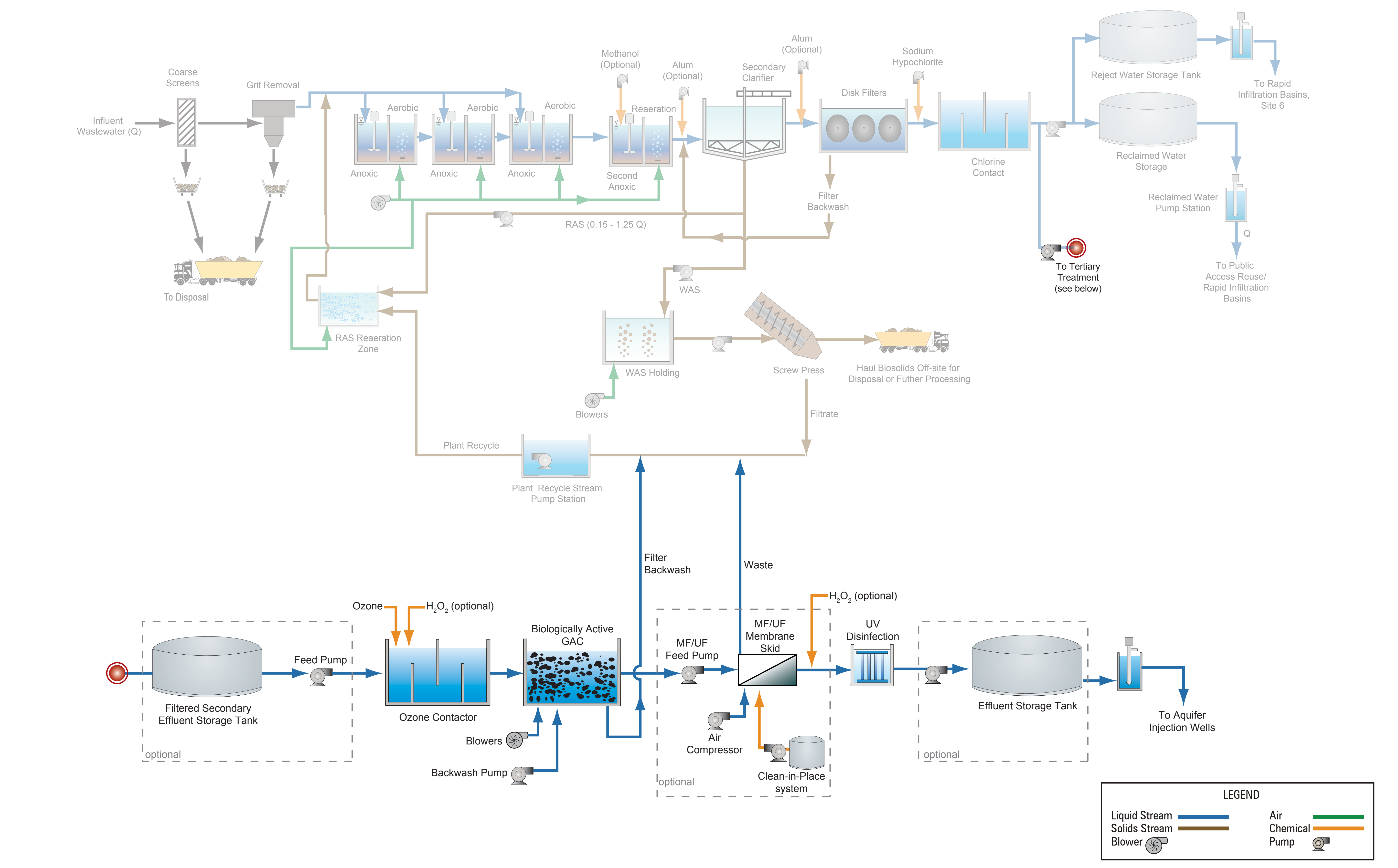

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ADD-ON TREATMENT TRAIN FOR FUTURE PHASES - DIRECT AQUIFER INJECTION - ALTERNATIVE 1

FIGURE 4-6

- Alternative 2 - Low-Pressure (UF) Membranes followed by RO Membranes followed by UV/H_2O_2

  The process configuration is identical to the one described above as Alternative 2 for lake augmentation. OCU has already conducted a comprehensive pilot study using this process configuration to produce an effluent amenable for direct aquifer injection. The results of the pilot study confirmed that this process configuration would work well and meet all requirements of Rule 62-610.560 F.A.C. The results of the pilot study have also been accepted by the Florida Department of Environmental Protection.

  A process flow diagram for this process configuration is provided in Figure 4.7.

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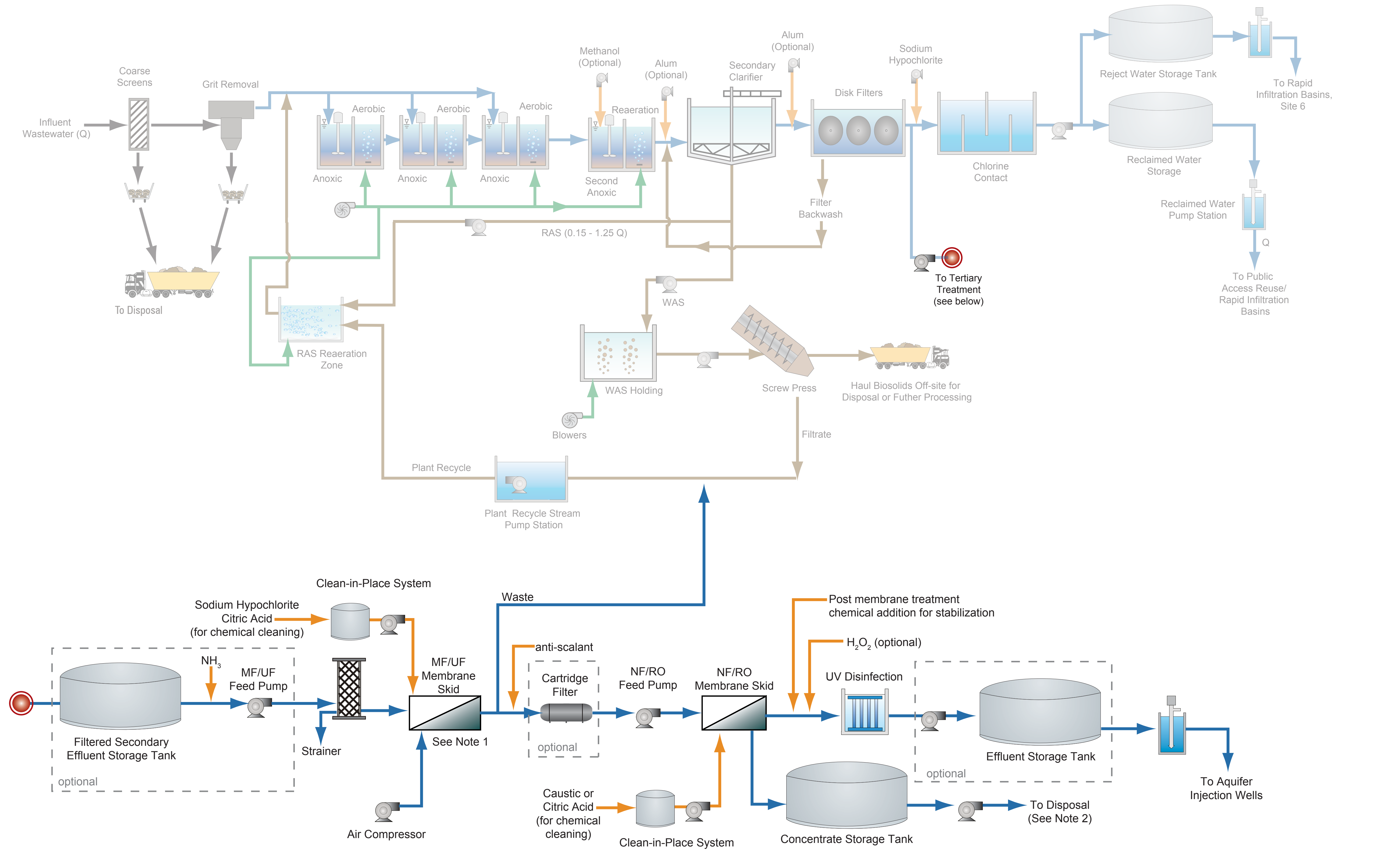

LEGEND

Liquid Stream	▬ (blue)	Air	▬ (green)
Solids Stream	▬ (brown)	Chemical	▬ (orange)
Blower		Pump	

Notes: 1. Schematic shows a pressurized MF/UF membrane. MF/UF membranes can also be submerged type. Final determination to be made at later time.
2. Depending on concentrate total dissolved solids (TDS), chloride concentration and other ion concentrations, concentrate could be disinfected, blended with reclaimed water for disposal to PAR. Detailed analysis should be conducted to confirm suitability. Alternatively, other means of concentrate disposal such as crystallization/evaporation or deep well injection may be required.

ADD-ON TREATMENT TRAIN FOR FUTURE PHASES - DIRECT AQUIFER INJECTION - ALTERNATIVE 2

FIGURE 4-7

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6.0 CONCLUSIONS

Several technologies have been evaluated for reduction of nutrients to trace levels to meet the NNC for discharge to lakes. Similarly, several technologies were evaluated for removal of TOC and TOX to meet the “full treatment and disinfection” requirements of Rule 62-610.563(3), F.A.C. for direct aquifer injection. Several of the technologies identified are applicable to both reclaimed water management options.

Four add-on treatment trains have been identified for further treatment of the AWT effluent from Phase I of the SWWRF, if necessary in the future, to produce a higher quality effluent amenable either to discharge to lakes for augmentation or to inject into the aquifer to augment potable water supplies. Two of the four identified treatment trains (low-pressure membranes followed by RO membranes) are common to both options. OCU has successfully pilot tested an integrated membrane treatment process to produce an effluent amenable to direct aquifer recharge. Further bench scale and pilot-scale testing should be conducted for the other two add-on treatment process trains (Alternative 1 for both options) to confirm performance of the process schemes to meet the desired water quality and provide sufficient data to determine design parameters and estimate capital and life cycle costs. Ultimately, the most cost effective add-on process train should be selected for implementation at full-scale to produce the desired water quality pursuant to the reclaimed water management option deemed necessary in the future.

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