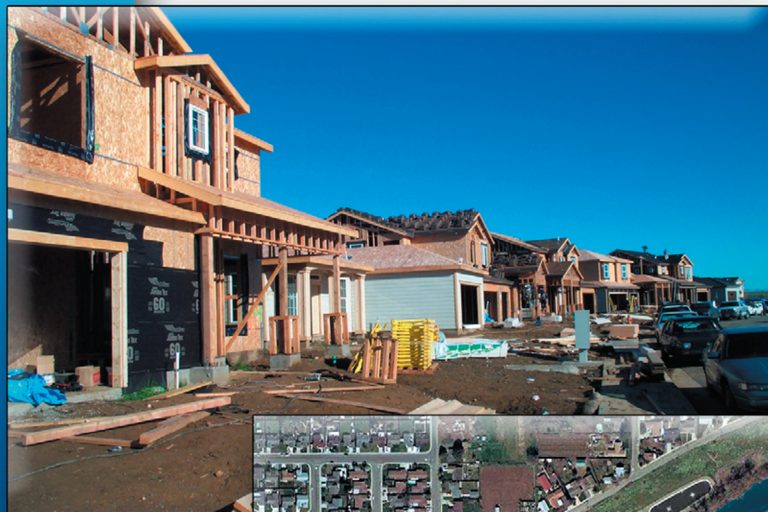

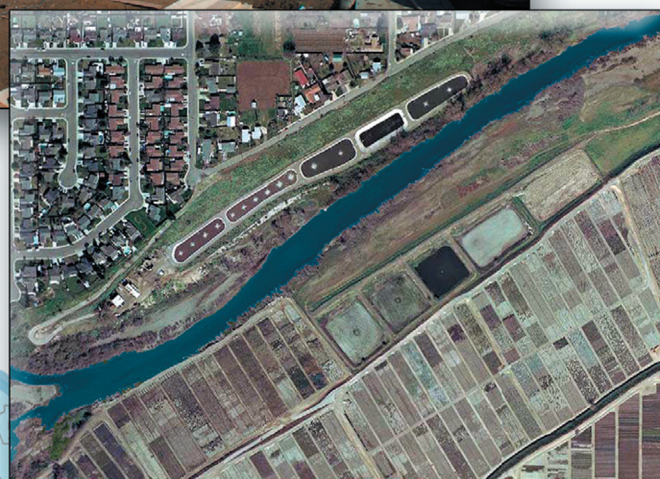

FINAL

Wastewater Treatment Plant Master Plan

March 2006

RMC Water and Environment

City of Waterford
Wastewater Treatment Plant Assessment Report

Final Report

Prepared by:

RMC Water and Environment

March 7, 2006

Table of Contents

List of Tables

List of Figures

Acknowledgements

The 2005 Wastewater Treatment Plant Assessment Report represents a collaborative effort between RMC and the City of Waterford. We would like to thank the following key personnel from the City whose invaluable knowledge, experience, and contributions were instrumental in the preparation of this Master Plan.

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Robert Borchard – Consulting City Planner, City of Waterford

Matt Ericson, City of Waterford

Jim Capps – WWTP Operator, City of Waterford

List of Abbreviations

BOD	Biological Oxygen Demand
CAS	Conventional Activated Sludge
DOC	Dissolved Oxygen Concentration
DU	Dwelling Unit
GIS	Geographic Information System
gpad	Gallons per acre per day
gpcd	Gallons per capita per day
mgd	Million Gallons per Day
LAFCO	Local Agency Formation Commission
MBR	Membrane Bioreactor
MID	Modesto Irrigation District
RMC	RMC Water and Environment
RWQCB	Regional Water Quality Control Board
TDS	Total Dissolved Solids
UWMP	Urban Water Management Plan
WDR	Waste Discharge Requirements
WMP	Wastewater Master Plan
WWTP	Wastewater Treatment Plant

Chapter 1 Introduction

This report presents a wastewater treatment plant assessment for the City of Waterford (City). The report was prepared by RMC Water and Environment (RMC) under a contract with the City dated March 20, 2005.

1.1 Background

The City is planning to add approximately 1,610 acres of agricultural land to the City's Sphere of Influence. This area is shown in Figure 1. To help plan for the development of the annexation area, the City contracted with RMC to develop the following planning documents:

- Water Distribution Master Plan
- Sewer System Master Plan
- Storm Drainage Master Plan
- Urban Water Management Plan
- Wastewater Treatment Plant Assessment Report

1.2 Purpose

The purpose of this Wastewater Treatment Plant Assessment Report is to identify near- and long-term improvements required for the City of Waterford Wastewater Treatment Plant (WWTP) to accommodate projected wastewater flows from both the present City limits and proposed annexation area, and to meet potential changes to wastewater discharge regulations. The planning horizon for near-term improvements is assumed to be the year 2015 and corresponds to the Local Agency Formation Commission's (LAFCO) timeframe for assessing the City's ability to extend services to proposed areas of annexation. The planning horizon for long-term improvements is 2040, consistent with the projected buildout of the City and proposed annexation area.

Chapter 2 Study Area and Wastewater Characteristics

This section provides a summary of the study area and wastewater characteristics including information on land use and population projections, wastewater flows, and wastewater quality.

2.1 Study Area

The City of Waterford is located in the eastern portion of Stanislaus County, approximately 13 miles east of Modesto and 11 miles northeast of Turlock. As shown in Figure 1, the City is bordered on the south by the Tuolumne River, on the north by the Modesto Irrigation District (MID) Modesto Main Canal, on the west by Eucalyptus Avenue.

The study area for this Assessment Report includes the present City and encompasses the proposed annexation area, which extends from the City's existing boundary to the north, east and west (see Figure 1). This area forms an arc around the existing City, and is bounded by the Tuolumne River on the south and Dry Creek on the north.

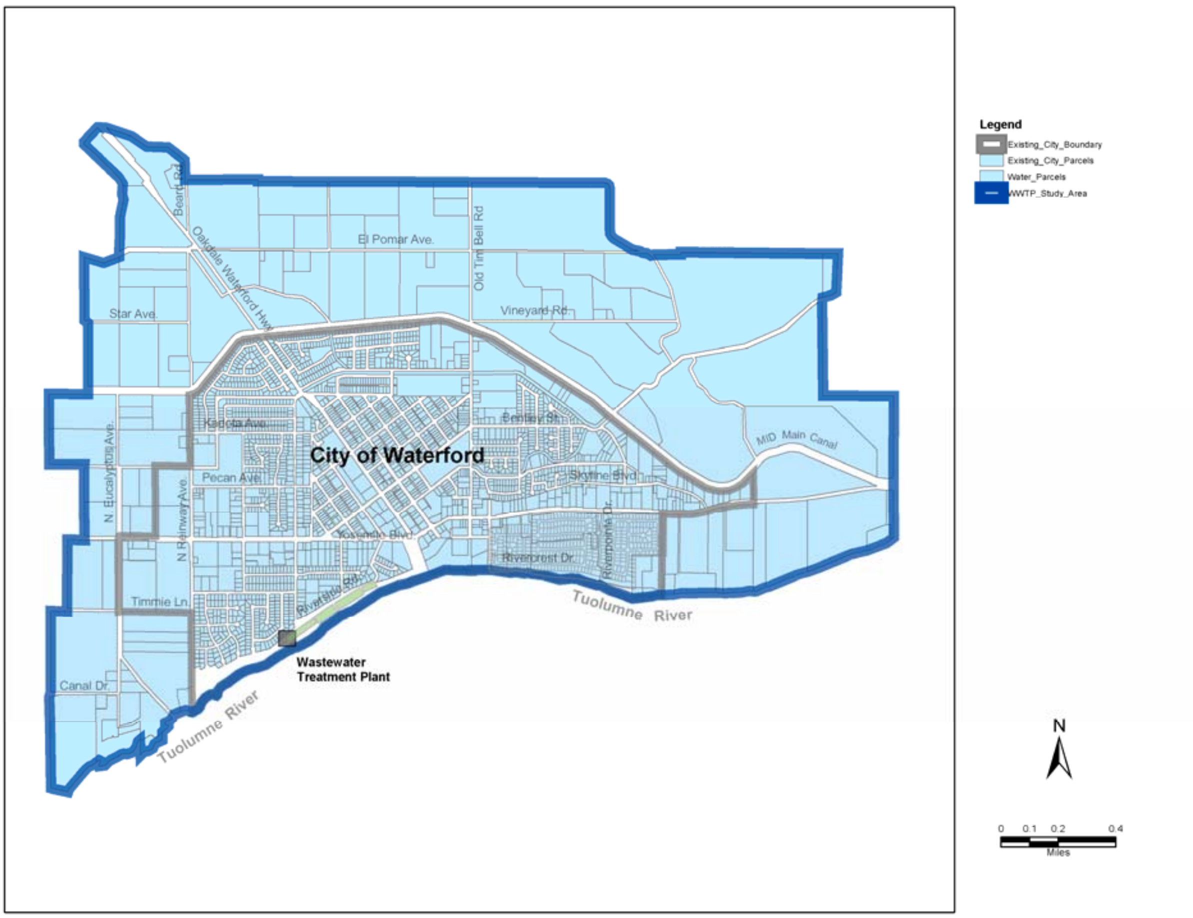


Figure 1 - Study Area and Projected Land Usage of Annexation Area

2.2 Population Projections

Population growth in the study area will come from a combination of buildout (maximum utilization of available space) within current City limits and growth in the annexation area. Current population within the present City limits is approximately 7,800 people[1]. The annexation area is currently undeveloped with no significant population; however, growth is anticipated to occur in the near future as new developments are constructed.

For the purposes of this assessment, two separate approaches were taken to determine population projections for the City:

- A "Low Growth" Scenario based on California Department of Finance forecasts for Stanislaus County; and
- A "High Growth" Scenario based on projected land use type and residential densities

Low Growth Scenario

The "Low Growth" population projection scenario, presented in Table 1, is based on the California Department of Finance population forecasts for Stanislaus County. Using a technique known as "shift-share analysis", City staff was able to forecast the City of Waterford's population through 2040 by assuming the population was a certain percentage of the total population for the County[2]. Using this method, the population for the City of Waterford is projected to be 11,800 by 2015 and 19,000 by 2040).

Table 1: Low Growth Population Estimates[3]

	2005	2010	2015	2020	2025	2030	2035	2040
Stanislaus County	522,300	585,500	647,200	709,000	778,000	847,000	923,000	998,900
City of Waterford	8,700	10,400	11,800	13,200	14,500	15,900	17,400	19,000
% of County	1.7%	1.8%	1.8%	1.9%	1.9%	1.9%	1.9%	1.9%

High Growth Scenario

The "High Growth" population projection scenario, presented in Table 2, is based on land use type and assumed residential densities for the undeveloped area. This scenario is consistent with the methodology used to develop population projections for the *2005 Urban Water Management Plan* and includes the following assumptions:

- Buildout within the present City limits will be 10,400 people, and is estimated to occur by 2040
- Development within the annexation area will have a residential density of 4.5 Dwelling Units (DUs) per acre at 3 persons per DU, which is consistent with the assumptions used in the other planning documents developed for the City. With 1,316 acres of low density residential land use type for the annexation area[4], this equates to a total population of approximately 17,800.
- Buildout within the annexation area will also occur by 2040, representing a total buildout population of the City (including annexed areas) of 28,200.
- Rate of growth will be linear.

[1] *City of Waterford Wastewater Master Plan.* DJH Engineering, February 2005.
[2] Adapted from Electronic communications with Robbert Borchard, City of Waterford, March 10, 2005.
[3] Adapted from population estimates developed by Robbert Borchard, City of Waterford.
[4] *Service Boundary and Land Use TM (Draft*). September 2005.

Table 2: High Growth Population Estimates

Year	Population Projections		
	Present City Limits	Annexation Area	Total
2005	7,800	0	7,800
2010	8,200	2,500	10,600
2015	8,600	5,000	13,300
2020	9,000	7,500	15,900
2025	9,400	10,000	18,600
2030	9,800	12,500	21,300
2035	10,200	15,000	25,200
2040	10,400	17,800	28,200

Population Projection

The "Low Growth" and "High Growth" population scenarios provide the range of population estimates used as of this WWTP Assessment report. A comparison of the Low Growth and High Growth scenarios is provided in Figure 2 and Table 3.

Figure 2 - Study Area and Projected Land Usage of Annexation Area

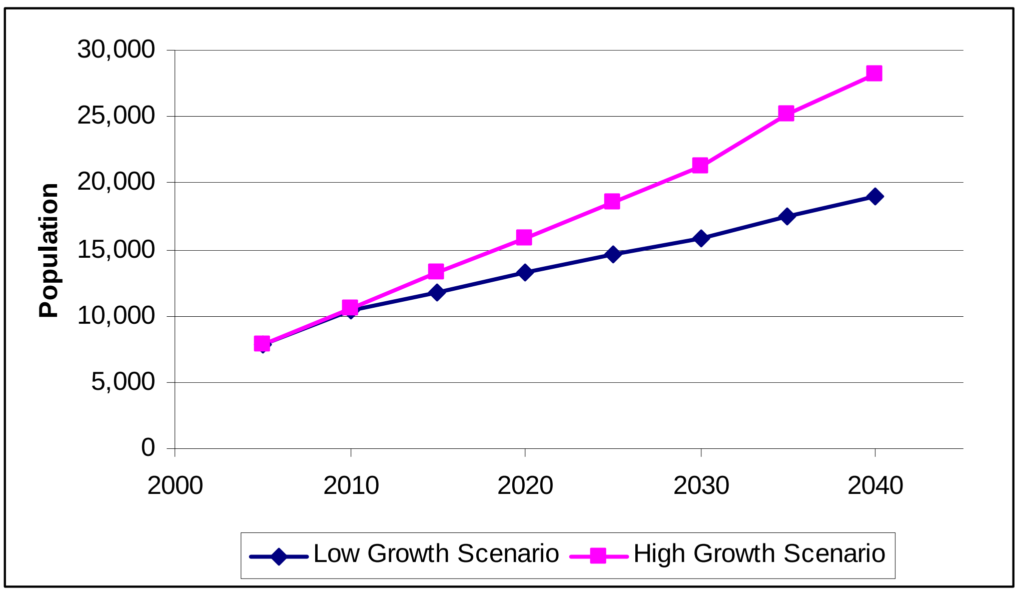


Table 3: Comparison of Population Projections

Year	"Low Growth" Population Projections	"High Growth" Population Projections
2005	7,800	7,800
2010	10,400	10,600
2015	**11,800**	**13,300**
2020	13,200	15,900
2025	14,600	18,600
2030	15,900	21,300
2035	17,500	25,200
2040	**19,000**	**28,100**

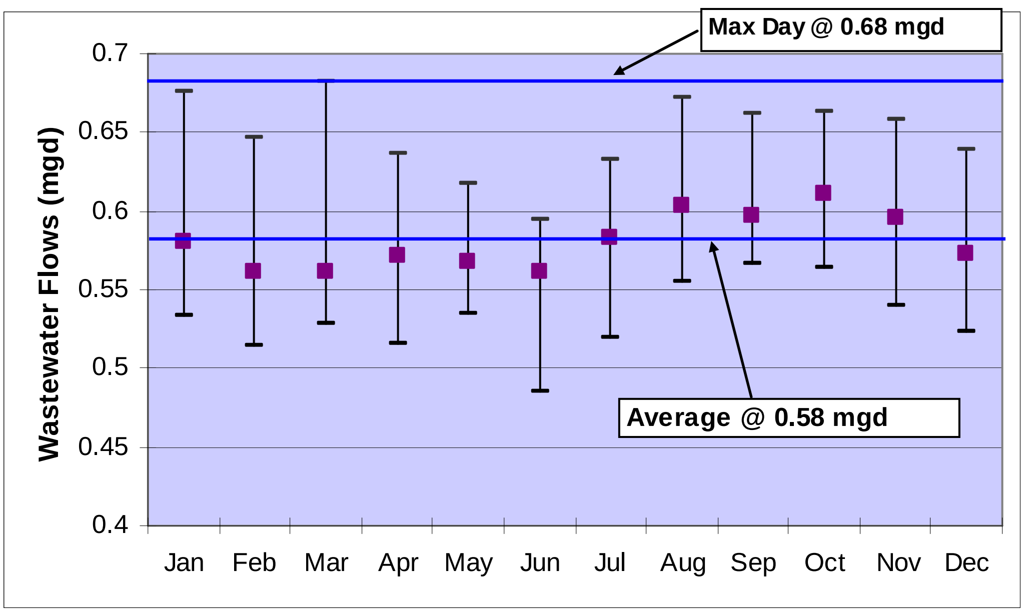
2.3 Wastewater Flows

The two major components of wastewater flows are residential and commercial/industrial. This section presents the current wastewater flows and projected wastewater flows based on the population estimates documented in the previous section.

2.3.1 Current WWTP Influent Flows

The current annual average WWTP influent flow is approximately 0.58 million gallons per day (mgd)[5]. Figure 3 shows the monthly average influent wastewater flows, as well as the maximum and minimum flow rate observed within a given month based on actual daily wastewater flow data collected from November 2004 – October 2005. Based on this flow data, the max day flows (0.68 mgd) are roughly 1.17 times greater than the annual average flows (0.58 mgd). This is somewhat smaller than the peak day peaking factor of 1.5 that is typically expected for smaller wastewater systems. Hourly flow data was not available for use in this report.

Figure 3 – Average, Maximum and Minimum WW Influent Flows



[5] Based on monthly reports to RWQCB from November 2004 to October 2005.

2.3.2 Wastewater Flow Projections

This study involved the development of wastewater flow projections for both residential and commercial/industrial uses.

Residential Flow Projections

The residential flow projections are based on per capita flow rates and projected population estimates. The current per capita flow rate projection is estimated to be approximately 75 gallons per capita per day (gpcd) based on the current annual average flow rates observed at the WWTP (0.58 mgd) and the current population of 7,800.[6] This per capita flow rate is lower than what is typically observed for other systems (e.g., 90-100 gpcd) and may be due to the lack of infiltration and inflow to the system. Some high growth communities have experienced increases in per capita flows with new development because of the higher ratio of children. To allow for a range of possible per capita flow rates in the future, wastewater flow projections were developed using both 75 gpcd and 90 gpcd.[7]

Table 4 illustrates the expected wastewater flow rates using both the "Low Growth" and "High Growth" population estimates, and two per capita flow rates: 75 gpcd and 90 gpcd. As shown in this table, wastewater flows are projected to range from 0.9 mgd – 1.2 mgd in 2015, and 1.4 mgd to 2.5 mgd in 2040.

Table 4: Residential Flow Projections (Annual Average Flows)

Year	Residential Flow Projections (mgd)			
	Low Growth		High Growth	
	75 gpcd	90 gpcd	75 gpcd	90 gpcd
2005	0.59	0.70	0.59	0.70
2010	0.78	0.94	0.80	0.95
2015	**0.89**	**1.06**	**1.00**	**1.20**
2020	0.99	1.19	1.19	1.43
2025	1.10	1.31	1.40	1.67
2030	1.19	1.43	1.60	1.92
2035	1.31	1.58	1.89	2.27
2040	**1.43**	**1.71**	**2.12**	**2.54**

Industrial/Commercial Flow Projections

There is a small amount of land that is slated for industrial and commercial use in the annexation area. The wastewater contributions from these future uses were determined on the basis of unit factors (gallons per acre per day, (gpad)) applied to the estimated land use acreage. Since the majority of projected use for the annexation area is residential, the contributions to wastewater flow from the commercial and industrial sources are relatively small (Table 5).

[6] *City of Waterford Wastewater Master Plan.* DJH Engineering, February 2005.
[7] 90 gpcd is a typical assumption for wastewater flow rates for new development (e.g. City of Winters)

Table 5: Industrial and Commercial Wastewater Flows

Land Use Category	Gross Acreage	Unit Flow Factor (gpad)	Buildout ADWF (mgd)
Industrial	126	2,000	0.25
General Commercial	48	2,500	0.12
		TOTAL	**0.37**

Currently there are no commercial or industrial wastewater contributions from the annexation area. Buildout is assumed to occur in the same period as the residential projections and linear growth is assumed. Wastewater projections are shown in Table 6.

Table 6: Industrial and Commercial Wastewater Projections

Year	2005	2010	2015	2020	2025	2030	2035	2040
Flow (mgd)	0	0.05	**0.11**	0.16	0.21	0.26	0.32	**0.37**

Total Projected Wastewater Flows

The commercial/industrial flow projections shown in Table 6 were combined with the residential projections shown in Table 5 to determine the total projected flows that will enter the WWTP. These combined flow projections represent the total projected wastewater flows and define the future WWTP capacity requirements as well as the timing of critical expansions and upgrades. As shown in Table 7, wastewater flows are projected to range from 1.0 to 1.3 mgd in 2015, and from 1.8 to 2.9 mgd for buildout (2040).

Table 7: Total Wastewater Flow Projections

Year	Wastewater Flow Projections (mgd)			
	Low Growth		High Growth	
	75 gpcd	90 gpcd	75 gpcd	90 gpcd
2005	0.59	0.70	0.59	0.70
2010	0.83	0.99	0.85	1.00
2015	**1.00**	**1.17**	**1.11**	**1.31**
2020	1.15	1.35	1.35	1.59
2025	1.31	1.52	1.61	1.88
2030	1.45	1.69	1.86	2.18
2035	1.63	1.90	2.21	2.59
2040	**1.80**	**2.08**	**2.49**	**2.91**

2.4 Wastewater Characteristics

Wastewater influent entering the WWTP is from mainly residential sources. The known characteristics of the wastewater influent are shown in Table 8.

Table 8: Wastewater Characteristics[8]

Constituent	Measurement
Biological Oxygen Demand (BOD)	217-460 mg/l 275 mg/l (average)
Total Dissolved Solids (TDS)	483 mg/l
pH	6.8 - 8.4
Nitrate	No data

[8] *City of Waterford Wastewater Master Plan*. DJH Engineering. February 2005

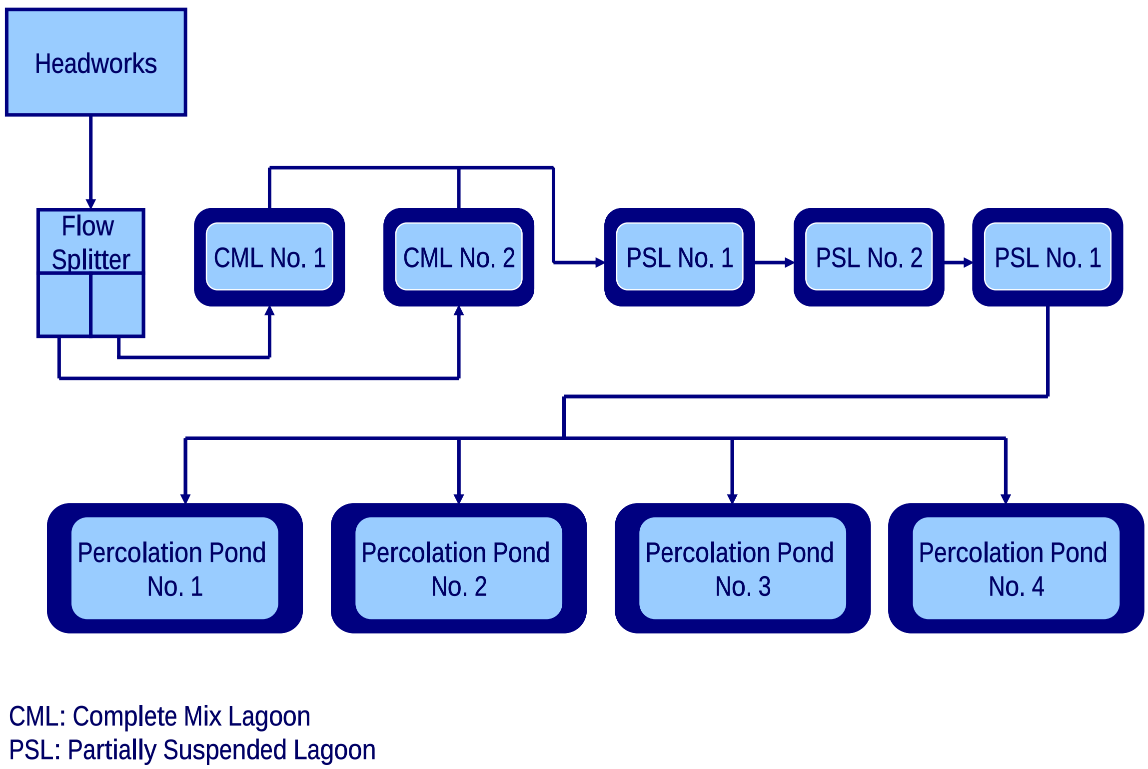
Chapter 3 Wastewater Treatment Plant Assessment

This section discusses the existing WWTP facilities operation and presents an assessment of the various drivers for near- and long-term WWTP improvements including: capacity constraints; regulatory requirements, and other considerations.

3.1 Existing Facilities and Operation

The existing wastewater treatment system is a "one pass" biological treatment system consisting of concrete lined aeration basins followed by percolation basins for effluent disposal. This system reduces the strength of the sewage, but does not meet typical secondary treatment standards[9]. A general process flow schematic is shown in Figure 4 and an aerial of the site is presented in Figure 5.

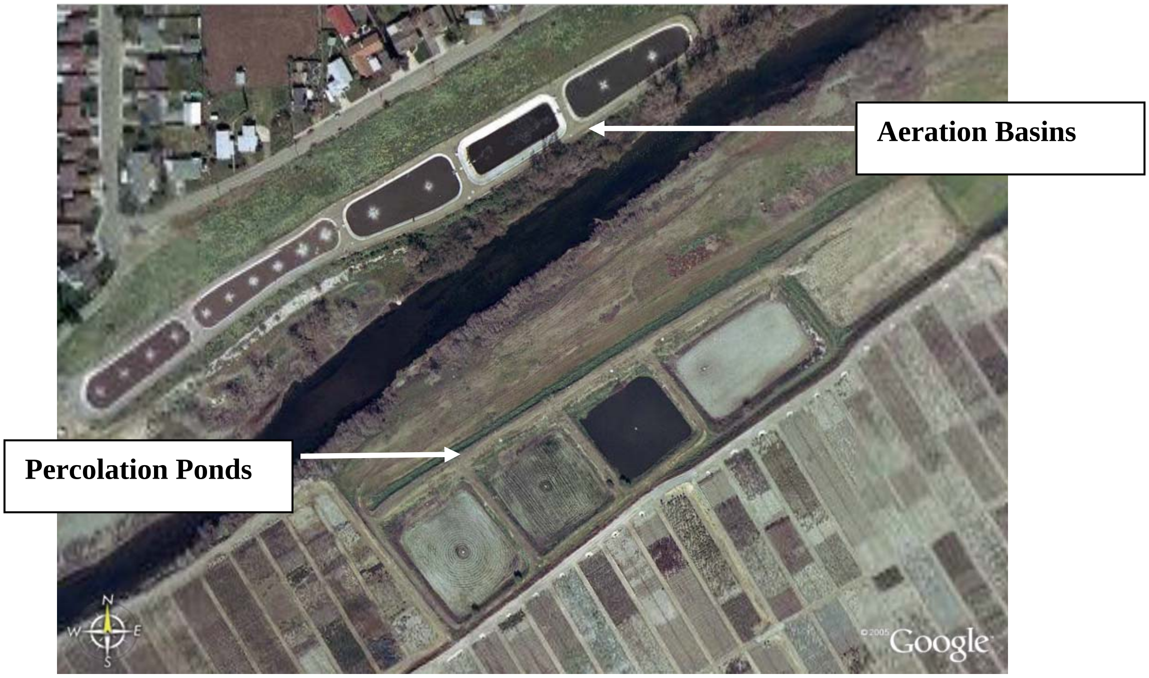
Figure 4 – Existing Process Flow Schematic



As shown in Figure 5, the Tuolumne River separates the treatment basins from the percolation ponds. Effluent from the aeration basins is conveyed to the percolation ponds for disposal via a gravity pipeline that is constructed below the river bed.

[9] *City of Waterford Wastewater Master Plan*. DJH Engineering. February 2005

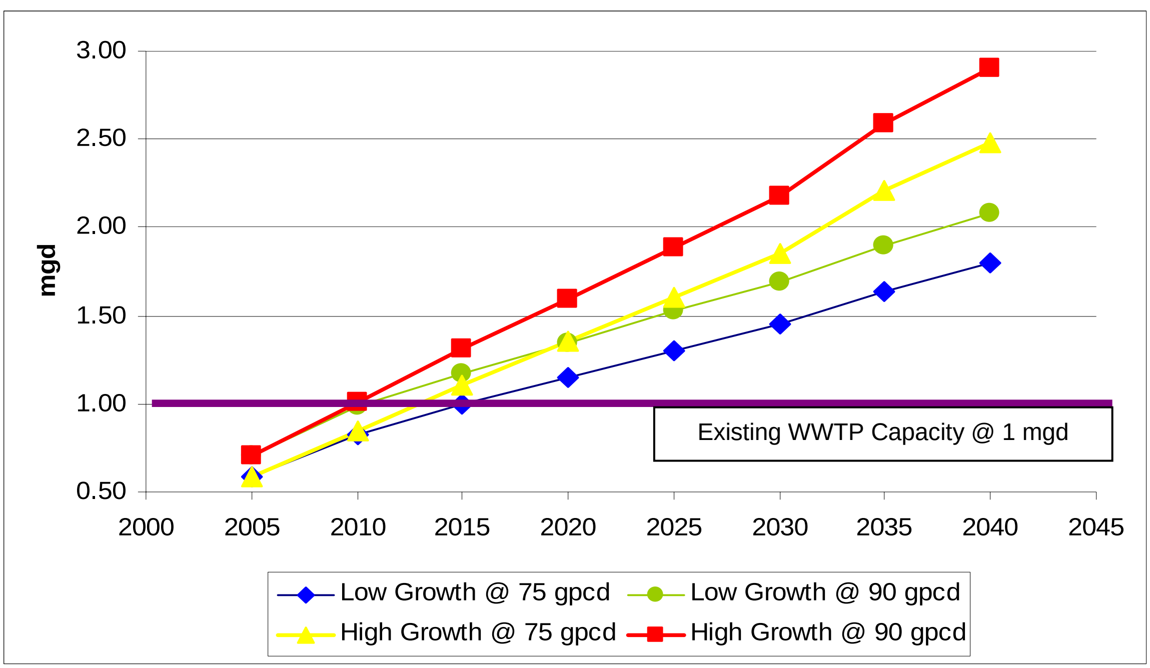
Figure 5 – Existing Waterford WWTP Site



3.2 Capacity Analysis

The current WWTP is rated to accommodate flows up to 1.0 mgd. As shown in Figure 6 and summarized in Table 9, it is anticipated that the existing treatment and disposal capacity will be exceeded between 2010 and 2015, depending on the growth rate and flow rate assumptions used.

Figure 6 – Wastewater Flow Projections vs. Capacity



While the both the aeration basins and percolation ponds currently have a capacity limited to 1.0 mgd, the previous WWTP Master Plan prepared by DJH Engineering indicated that the capacity of the percolations ponds could be increased to 1.5 mgd by constructing two new basins east of the existing ones. Table 9 presents the estimated year of occurrence for when these treatment and disposal thresholds are exceeded under the four wastewater flow projection scenarios.

Table 9: Timing for Exceeding Capacity Threshold

Milestone Event	Year of Occurrence			
	Low Growth @ 75 gpcd	Low Growth @ 90 gpcd	High Growth @ 75 gpcd	High Growth @ 90 gpcd
Exceed 1.0 mgd Treatment Capacity	2015	2011	2013	2010
Exceed 1.5 mgd Capacity of Expanded Percolation Ponds	2032	2025	2023	2019

As shown in this table, three of the four wastewater projection scenarios indicate that the existing treatment capacity will be exceeded prior to the LAFCO planning horizon (2015). The site cannot accommodate additional aeration basins, and the existing process will not achieve future discharge requirements, so a new treatment system will be required. The City can still use percolation ponds for effluent disposal, but will need to add two new ponds (as suggested by the DJH report) to increase the capacity to 1.5 mgd.

3.3 Regulatory Requirements

The WWTP currently operates under Waste Discharge Requirements (WDR) Order No. 94-273, which was issued in 1994. The provisions of this permit limit the monthly average dry weather discharge flows to 1.0 mgd - so a new WDR will be required to expand the capacity of the existing system. Based on more recent discharge permits issued in the Central Valley, the new permit will likely have more stringent water quality standards for Nitrate and BOD. Table 10 presents some of the monthly average effluent water quality limits included in recent permits issued in the Central Valley. The new treatment system to accommodate expanded capacity will also need to meet these water quality requirements.

Table 10: Monthly Average Water Quality Limits

Parameter[1]	Land Disposal		Surface Water Discharge	
	City of Lathrop[2]	City of Orange Cove[3]	City of Manteca[4]	City of Auburn[5,6]
BOD	< 10 mg/l	10 mg/l	20 mg/L	10 mg/l
Total N	< 10 mg/l	10 mg/l	10 mg/L	-
Nitrate (as N)	-	-	10 mg/L	10 mg/l-
TSS	< 10 mg/l	10 mg/l	20 mg/L	10 mg/L

Notes:
1. Does not include a complete list of the water quality parameter requirements typically included in discharge permits for surface water discharge.
2. Order No. R5-2005-0045 adopted March 17, 2005
3. Order No. R5-2004-0008 adopted January 20, 2004
4. Order No R5-2004-0028 adopted March 19, 2004 (amended August 5, 2005)
5. Order No. R5-2004-0030 adopted March 17, 2005.
6. Limits listed are for discharges when less than 20:1 dilution is available.

In addition to meeting these water quality parameters, the City will probably be required to increase the level of monitoring of its effluent upstream and downstream of the river water to demonstrate that the treatment plant is achieving the water quality required and that the percolation ponds are not impacting the river.

While there are some recent WDRs that require filtration and disinfection prior to land application of effluent, these permits are typically for wastewater discharges that also discharge to surface waters during a portion of the year. However, given that Waterford's percolation ponds are located adjacent to the Tuolumne River, there is a possibility that the Central Valley RWQCB will impose more stringent limitations for effluent disposal.

3.4 Site constraints

In addition to capacity limitations and water quality requirements there are other considerations that will impact future WWTP planning. The present site layout possesses a unique geometry. The aeration basins, which overlook the Tuolumne River are situated down a steep slope from the south edge of town and are contained in a long narrow site that is approximately 100 feet wide. Any significant expansion of the aeration basins is prohibited by presence of the slopes on either side – rising to the north towards the City and dropping to the south to meet the Tuolumne River (Figure 5). Since there is no room for expansion of the treatment ponds, any capacity expansion must be done within the current area occupied by the aeration basins (roughly 100 ft x 1300 ft).

As mentioned previously, there is some room to expand the percolation basins. The previous WWTP Master Plan prepared by DJH Engineering indicated that the capacity of the percolations ponds could be increased to 1.5 mgd by constructing two new basins east of the existing ones.

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Chapter 4 Development of Alternatives

As discussed in the previous section, the wastewater projections developed indicate the existing treatment and disposal capacity of Waterford's WWTP will be exceeded between 2010 and 2015, within the LAFCO planning horizon. An expansion of capacity will require a new WDR permit, which will likely require more stringent effluent standards that the current process will not be able to meet. This section presents the near-term and long-term alternatives evaluated to accommodate the City's needs.

4.1 Near-Term Improvement Alternatives

The planning horizon for near-term improvement alternatives is 2015, which corresponds to LAFCO's timeframe for assessing the City's ability to serve the proposed areas of annexation. Based on the flow projection scenarios evaluated as part of this study, it is anticipated that the capacity will need to be expanded to 1.1 - 1.3 mgd (see Table 7). The treatment and disposal improvements required to accommodate these increased flows are discussed in the following sections.

4.1.1 Treatment Improvement Alternatives

This expanded capacity will trigger a new permit, so the treatment system must also meet future anticipated standards for BOD, TDS and Nitrate. As discussed below, five potential treatment alternatives were evaluated for near-term improvements:

- Conventional Activated Sludge treatment
- Oxidation Ditch
- Biolac® Process
- Sequencing Batch Reactors (SBR)
- Membrane Bioreactor (MBR)

These alternatives will generally use an extended aeration activated sludge process with a similar biological nutrient removal (BNR) process approach to nitrogen removal. Nitrification of ammonia is achieved with longer retention times in the aeration cycle. Denitrification of the nitrate is achieved through anoxic zones with a recycle of activated sludge.

Conventional Activated Sludge (CAS)

Upgrading the existing treatment process to a conventional activated sludge system is one option for meeting the capacity and water quality requirements. This alternative involves modifying the current treatment process through the addition of primary sedimentation, additional mixing and anoxic tanks, -aeration tanks, and secondary clarifiers. However, the existing site is not large enough to accommodate the addition of these facilities, so this alternative would need to be located elsewhere.

Oxidation Ditch

Oxidation ditch treatment is a modified activated sludge biological treatment process that utilizes long retention times to remove biodegradable organics. They are typically complete mix systems consisting of an oval-shaped basin that circulates the activated sludge in a "race track" and secondary clarification. Nitrate removal can be accomplished through pre-anoxic cells. The main advantages of the oxidation ditch are simplicity of equipment and operation, high level of inherent mixing. Oxidation ditches require minimal operator maintenance. Given the constraints of the existing site, this alternative would be difficult to fit on the existing site.

Biolac® Process

Biolac® is an activated sludge process that uses extended retention of biological solids to achieve lower BOD and ammonia levels. Nitrate removal can be accomplished through a "wave oxidation process" whereby oxic/anoxic zones travel through the treatment system via coordinated cycles of oxygen delivery. This process is simple to operate and is reliable and stable with low energy requirements and low construction costs compared to other activated sludge systems. The main cost savings is that the system can be installed in earthen basins reducing the concrete costs... However, the existing site is too narrow for the Biolac® process to accommodate the projected flow rates, so this alternative would need to be located elsewhere.

Sequencing Batch Reactor (SBR)

A sequencing batch reactor (SBR) is another type of activated sludge system in which equalization, aeration and clarification all occur in a single reactor, by cycling through a series of steps: fill with anoxic mixing, aeration, settling, and decanting. Typically two or more batch reactors are used to optimize system performance. SBR systems are typically used for flow rates less than 5 mgd and have the advantages of operational flexibility and minimal footprint. A higher level of maintenance is typically required for these types of systems.

Membrane Bioreactors (MBRs)

MBRs utilize an activated sludge bioreactor for BOD removal and employ membranes to achieve biomass and solids separation. The primary advantages of MBR is the aeration basins can be reduced in size because the can be operated at mixed liquor concentrations of 10,000 mg/l compared to 2500 mg/l for the other systems that require secondary clarifiers, and do not need secondary clarifiers for solids settling. Very high quality effluent, including nitrate removal can be obtained through MBRs in a relatively small footprint. The costs of MBRs can be high due to both capital costs and operational costs including high energy, and the need to replace membranes every 5 to 7 years.

4.1.2 Comparison Near-Term Alternatives

All of the processes above have been proven effective and utilized in a wide variety of settings. To determine the suitability for meeting the City's needs, a number of features must be considered. The matrix below provides a quick comparison between the different treatment processes being considered.

Table 11: Comparison of Near-Term Treatment Alternatives

	Treatment Effectiveness	Size	Cost	Ease of operation	Ability to expand
CAS	+		+	+	
Oxidation Ditch	+		+	++	
Biolac	+		++	++	
SBR	+	+	+	+	
MBR	++	++			+

In general, the activated sludge options are simple systems that can achieve the water quality objectives with comparatively low costs – the primary constraint is that the existing WWTP site is not large enough to accommodate any of these treatment systems, with the exception of the SBR. The MBR, on the other hand, can produce excellent quality water within a very small footprint – but the capital and operation costs are much higher.

4.1.3 Disposal Improvements

The percolation pond capacity will need to be expanded to accommodate the additional effluent flows. This can be addressed by constructed two additional percolation ponds to the east of the existing ponds.

4.2 Long-Term Improvement Alternatives

The planning horizon for the long-term improvement alternatives is 2040, which corresponds to projected buildout. Based on the flow projection scenarios evaluated as part of this study, it is anticipated that the long-term WWTP improvements will need to accommodate projected wastewater flows ranging from 1.8 mgd – 2.9 mgd (see Table 7). Potential options for the long-term improvements are discussed below.

4.2.1 Remain at Existing Site

The existing site is small and the long narrow shape has significant limitations. The only potential alternative that would allow the City to remain at the existing WWTP site throughout buildout is to install an expanded MBR system. This option is only possible if an MBR system was selected for the near-term improvement option.

Although the existing treatment site could accommodate a 3.0 mgd MBR plant, the effluent disposal facilities (e.g. effluent pipeline crossing river, percolation ponds) do not have sufficient capacity to handle the additional flows. The City would either need to:

(1) Upsize the effluent pipeline and purchase additional land for more percolation ponds; or

(2) Secure an NPDES discharge permit for the balance of the flow beyond the capacity of the percolation ponds; or

(3) Purchase additional land for storage of effluent during the non irrigation season, and implement a recycled water system

Obtaining a NPDES permit for discharge to surface water is an expensive and time consuming process that will require that the City has explored all feasible disposal options, including recycled water or other land application methods. It is likely that some form of storage during the non irrigation system, and recycled water or land application will be required

4.2.2 Use Alternate Site

This scenario would involve phasing out the existing WWTP and utilizing a new site to meet the capacity and treatment requirements for a new WDR. This has the advantage of being able to design a WWTP that can accommodate flow well into the future. The disadvantage will be higher up front costs incurred to construct an entirely new facility including the high conveyance costs to the new site.

Another option once the current WWTP capacity is exceeded is to construct new facilities at a new treatment and disposal site. Three potential sites have been identified for a new WWTP (see Figure 7):

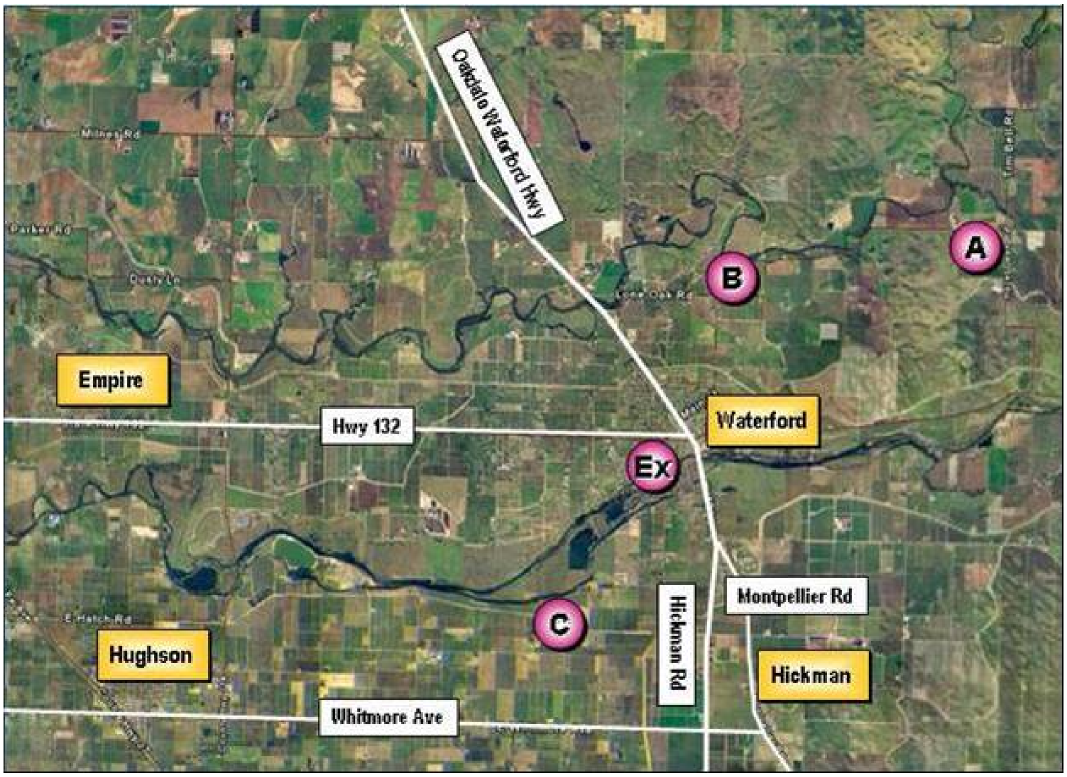
A. Northeast of the City near Tim Bell Road

B. North of the City near Lone Oak Road

C. South of the River

The site located South of the River (Site C) has a few advantages in that (1) it could serve as a joint facility treating wastewater from both Waterford and Hickman; (2) it may be possible to obtain less expensive land through negotiations with local nurseries.

Figure 7 – Alternative Sites



This option has the following advantages

- It allows the City to continue land application of effluent, thereby avoiding major regulatory hurdles associated with discharge to surface water.
- It keeps control of the wastewater system within the City of Waterford (avoiding potential institutional issues)
- Without the constraints of the existing site, it will be possible to implement a simple, cost effective treatment such as Bioloac®. The equipment cost for 3.0 mgd Biolac system is only $1.7 M (see Appendix B).

However, it also has a number of cost implementation constraints. The cost of legal, environmental, land and conveyance facilities may far outweigh the additional cost of an MBR.

4.2.3 Participate in a Regional Wastewater System

Another potential long-term option for the City is to become a regional partner with Modesto or Turlock, exporting wastewater for treatment and disposal. Both of these cities have considered turning their respective WWTPs into regional facilities.

Turlock Regional System

In order to partner with the City of Turlock, an 18-inch diameter sewer trunk line would need to be extended approximately 8 miles to the nearest connection in the vicinity of the City of Hughson[10]. Assuming a unit cost of $8 per inch diameter per linear foot, this would result in a capital cost of approximately $6.1M.

Modesto Regional System

In order to partner with the City of Modesto, the main sewer trunk line would need to be extended approximately 20 miles to the nearest connection that can accommodate the flow.[11] Assuming a unit cost of $8 per inch diameter per linear foot, this would result in a capital cost of approximately $15.2M

[10] Wastewater Planning Meeting Memo, prepared by Robbert Borchard, dated June 23, 2005.
[11] *City of Waterford Wastewater Master Plan*. DJH Engineering. February 2005

5 Recommended Projects

This section presents the recommendations for near-and long-term improvements for the Waterford wastewater treatment and disposal system.

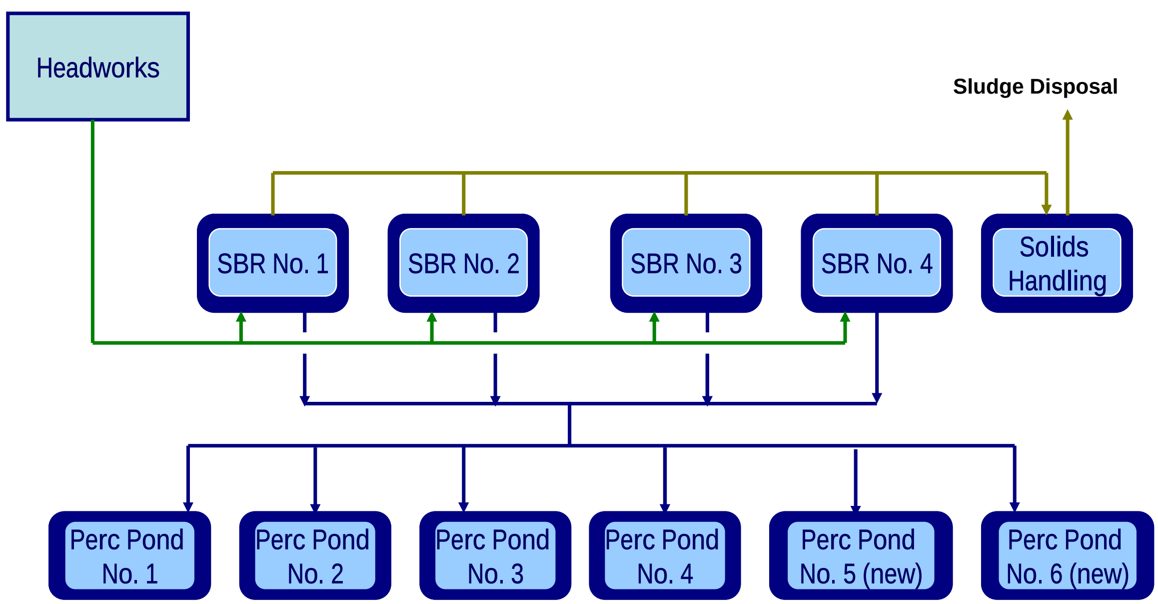
5.1 Near-Term Improvements

The City has expressed a preference for continuing to utilize the existing WWTP site for wastewater treatment and disposal through the 2015 LAFCO planning horizon. As such, there are two potential options for near term improvements (1) construct an SBR system; or (2) construct an MBR system. Additional detail regarding each option is provided below

5.1.1 Option 1: SBR System

This option involves construction of a 1.5 mgd SBR system for treatment and expansion of the existing percolation ponds for disposal. The SBR system, illustrated in Figure 8, should be able to serve the City of Waterford until about 2020, and may even last until 2030 if wastewater flow rates are on the lower end of the projections (see Table 9). Specific improvements are described below.

Figure 8 – SBR Process Flow Schematic



Headworks

The existing headworks consists of a comminutor which cuts up debris (rags, sticks, etc.) but does not remove them from the waste stream. A self-cleaning traveling bar screen is recommended to replace the comminutor to remove the debris prior to the biological treatment system. Most of these materials removed by the screen are not degradable in the treatment process, take up volume in the process tankage, and require increased maintenance of process equipment. . The screenings material thus removed are hauled to a landfill for disposal.

SBR

The five existing aeration basins will need to be replaced with four (4) sequencing batch reactors and (1) aerated sludge holding basin to accommodate the increased flow. It is assumed that each batch reactor will be constructed out of concrete and will have a footprint of approximately 60 ft long by 50 feet wide, with a depth of 20 ft. This will provide sufficient capacity to accommodate peak day flows[12]. Refer to Appendix A for facility sizing calculations.

Filtration and Disinfection

RMC is not aware of any recent WDRs that include a requirement for filtration and disinfection of effluent prior to disposal when land application (e.g., percolation ponds) is the sole means of disposal. However, given the proximity of the percolation ponds to the Tuolumne River, there is a possibility that the Central Valley RWQCB may impose such a limitation. If filtration and Ultraviolet (UV) disinfection is required, the facilities would need to be located at the percolation pond site due to limited size of existing treatment site. In addition, power would need to be brought to the percolation pond site in order to operate the facilities.

Solids Handling

One of the existing basins would be converted to an aerated sludge holding basin where the sludge would aerobically digest. With an average BOD of 275 mg/l, it is estimated that approximately 47,100 gallons of sludge will be produced per day (see Appendix A for calculation). The sludge basin would be decanted regularly to concentrate the sludge and periodically the sludge would be removed for disposal. Sludge removal would require a specialty contractor mobilize to the site to dredge and dewater biosolids, suitable for hauling to a landfill. Additional drying of the dewatered biosolids could be accomplished at the site during the summer to further reduce the weight, reducing the disposal costs. The sludge at this point should be suitable for landfill disposal or land application sites. Another option for consideration is to construct dewatering facilities and composting facilities for beneficial reuse or for reduced transportation costs of disposal. Our experience however indicates that these options are significantly more expensive for smaller facilities.

Percolation Ponds

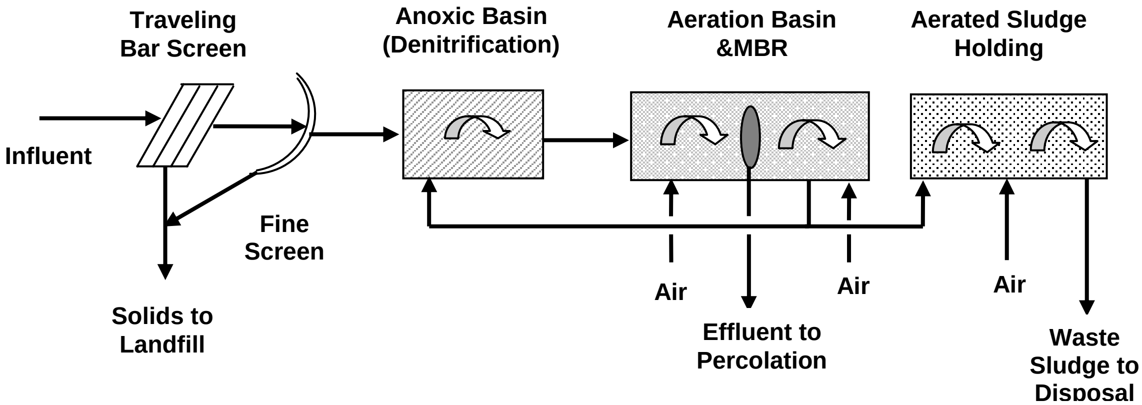
Two new percolation ponds would need to be constructed east of the existing ponds to expand the capacity up to 1.5 mgd.

5.1.2 Option 2: MBR

This option involves construction of a 1.5 mgd MBR system for treatment and expansion of the existing percolation ponds for disposal. The MBR system, illustrated in Figure 9, should be able to serve the City of Waterford until about 2020, and may even last until 2030 if wastewater flow rates are on the lower end of the projections (see Table 9). Specific improvements are described below.

[12] Peak day flows are currently estimated to be 1.17 times the annual average day flows (see Section 2.3.1).

Figure 9 – MBR Process Flow Schematic



Headworks

The improvements to the headworks would be the same improvements described for the SBR alternative. In addition for the MBR process, this traveling bar screen would be followed by a fine screen between 2-3 mm to capture smaller particles which foul the MBR membranes

MBR System

The MBR system would involve conversion of one of the basins into an anoxic (denitrication) basin, replacing several basins with the MBR system, and conversion of a basin into an aerated sludge holding basin. A 42,000-gal equalization basin would also be required.

Disinfection

RMC is not aware of any recent WDRs that include a requirement for disinfection of effluent prior to disposal when land application (e.g., percolation ponds) is the sole means of disposal. However, given the proximity of the percolation ponds to the Tuolumne River, there is a possibility that the Central Valley RWQCB may impose such a limitation. If Ultraviolet (UV) disinfection is required, the disinfection facilities could be located at the existing treatment site.

Solids Handling

Similar to the SBA option, one of the existing basins would be converted to an aerated sludge holding tank where the sludge would aerobically digest. The Zenon vendor estimates that the system will produce approximately 36,100 gallons of sludge per day (see Appendix B). This basin would be decanted regularly to concentrate the sludge and periodically the sludge would be removed for disposal.

Percolation Ponds

Two new percolation ponds would need to be constructed east of the existing ponds to expand the capacity up to 1.5 mgd.

5.1.3 Comparison of Near-Term Alternatives

The matrix below provides a summary comparison between the SBR and MBR alternatives. A more detailed discussion of these comparisons is provided in the following paragraphs.

Table 12: Comparison of SBR vs. MBR

	Water Quality	Ease of Operation	Ease of Expansion	Ease of Implementation	Cost
SBR		+			+
MBR	+		+	+	

Water Quality

As shown in Table 13, the effluent produced by the MBR system will be of higher quality than the SBR system and would be suitable for recycled water applications should that market be developed..

Table 13: Comparison of SBR vs. MBR Water Quality

Parameter	SBR Effluent	MBR Effluent
BOD	10 mg/L	<5 mg/L
Nitrate	<10 mg/L	<10 mg/L
NH3	1 mg/L	< 1 mg/L
TSS	10 mg/L	<5 mg/L

Ease of Operation

Although the SBR system will require an increased level of maintenance compared to the existing treatment system, the MBR system is even more complex than the SBR system. The sophistication of the technology will require additional training for the operators, additional level of effort to maintain the membranes, and close monitoring of the system performance so that operations can be modified as needed if evidence of membrane fouling is observed.

Ease of Expansion

Due to the constraints of the existing site, the SBR system cannot be expanded to accommodate flows beyond 1.5 mgd. In contrast, the small footprint of the MBR system would allow for expansion up to 3.0 mgd at the current site, providing more flexibility for long-term options.

Ease of Implementation

Ease of implementation is an important consideration when comparing these two options. Because the City would like to utilize the existing WWTP site for the new treatment system, there will be a period of time when the current treatment system will still need to be in operation while the new treatment system is being constructed. Due to the smaller footprint size, construction of the MBR system will have less of an impact to existing operations (and less risk) than construction of the SBR system.

To construct the SBR system, the existing aeration basins will need to be taken out of service, one at a time, to convert it to an SBR. Since each one of the five existing aeration basins will require modification

(4 will be converted to SBR basin and 1 will be converted to a solids handling basin), this will result in decreased treatment capacity for the entire length of the time it takes to complete the conversion to SBR.

Construction of the MBR will impact three of five existing basins: one will need to be converted to an anoxic (denitrification) basin; one will need to be taken out of service to install the membrane units, and a third basin will need to be converted to a solids handling basin.

Cost

A comparison of capital and operation and maintenance (O&M) costs for the SBR and MBR system is presented in Table 14, with more detailed estimates provided in Tables 15 and 16, respectively. As shown in this table, the MBR system is more expensive to construct and operate than the SBR system.

Table 14: Comparison of SBR vs. MBR Preliminary Costs

Cost	SBR	MBR
Capital Costs	$7.7 M	$9.2 M
O&M Costs	$400,000/ yr	$800,000/yr

However, it should be noted that the cost presented in Table 14 assume that the RWQCB will not require filtration and disinfection of the effluent prior to disposal to the percolation ponds. If the RWQCB does impose this requirement, the capital costs for the SBR will be comparable to the MBR (based on a unit cost of $350,000/mgd for UV disinfection and $900,000/mgd for filtration).

Table 15: Preliminary Cost Estimate for SBR Alternative

Item	Unit	Unit Cost	Quantity	Total
Capital Costs				
Demolition	LS	$50,000	1	$ 50,000
Site Work	LS	$150,000	1	$ 150,000
Yard Piping	LS	$250,000	1	$ 250,000
Concrete	gal	$1.5	1,795,200	$ 2,693,000
Headworks Improvements	LS	$350,000	1	$ 350,000
SBR Equipment	LS	$582,000	1	$ 582,000
Electrical/Instrumentation/Controls	LS	$300,000	1	$ 300,000
Power (allowance)	LS	$50,000	1	$ 50,000
Pond Development	acre	$50,000	3	$ 150,000
Subtotal				**$ 4,575,000**
Construction Contingency	%	25%		$ 1,143,800
Subtotal				**$ 5,718,800**
Contractor Overhead & Profit	%	10%		$ 571,900
Subtotal				**$ 6,290,700**
Engineering/Legal/Admin	%	25%		$ 1,429,700
Total Capital Cost				**$ 7,720,400**
O&M Costs				
Annual O&M	$/yr	$400,000	1	$ 400,000
Total O&M Cost				**$ 400,000**

Notes:
1. SBR equipment costs extrapolated from a 2000 Aqua Aerobics quote for a 1.46 mgd system using ENR construction cost indices.
2. Costs for headwork improvements based on the previous DJH WWTP Master Plan report.
3. Costs do not include filtration or disinfection, which may be required by the RWQCB.

Table 16: Preliminary Cost Estimate for MBR Alternative

Item	Unit	Unit Cost	Quantity	Total
Demolition	LS	$50,000	1	$ 50,000
Site Work	LS	$75,000	1	$ 75,000
Yard Piping	LS	$250,000	1	$ 250,000
Concrete	gal	$1.5	750,000	$ 1,125,000
Headworks Improvements	LS	$350,000	1	$ 350,000
MBR Equipment	LS	$3,000,000	1	$ 3,000,000
Electrical/Instrumentation/Controls	LS	$400,000	1	$ 400,000
Power (allowance)	LS	$50,000	1	$ 50,000
Pond Development	acre	$50,000	3	$ 150,000
Subtotal				**$ 5,450,000**
Construction Contingency	%	25%		$ 1,362,500
Subtotal				**$ 6,812,500**
Contractor Overhead & Profit	%	10%		$ 681,300
Subtotal				**$ 7,493,800**
Engineering/Legal/Admin	%	25%		$ 1,703,100
Total Capital Cost				**$ 9,196,900**
O&M Costs				
Annual O&M	$/yr	$800,000	1	$ 800,000
Total O&M Cost				**$ 800,000**

Notes:
1. Concrete costs include costs for an equalization basin.
2. MBR equipment costs from Zenon quote dated 12/14/05 (see Appendix B)
3. Costs for headwork improvements based on the previous DJH WWTP Master Plan report.
4. O&M costs include annual allowance for membrane replacement.

5.2 Long-Term Improvements

For the long-term planning horizon, there are two key considerations:

1. The existing site is limited in size and therefore restricts the treatment capacity and options available
2. The existing percolation disposal capacity is limited to 1.5 mgd.

For the long term planning horizon, the ultimate limiting factor is the maximum capacity available for the percolation ponds at the current WWTP site. As discussed in Section 4.2, three options exist for the long term:

1. Construct MBR system at existing site and develop additional methods of effluent disposal beyond 1.5 mgd such as:
    a. Upsize the effluent pipeline and purchase additional land for more percolation ponds; or
    b. Secure an NPDES discharge permit for the balance of the flow beyond the capacity of the percolation ponds; or
    c. Purchase additional land for storage of effluent during the non irrigation season, and implement a recycled water system
2. Construct wastewater treatment and disposal system at new another site, or
3. Become a partner in a regional wastewater system.

As shown in **Table 17**, there are various advantages and disadvantages associated with each of these options. Additional analysis and discussions with the City will be required to identify a recommended long-term solution:

Table 17: Advantages and Disadvantages of Long-Term Options

Option	Advantages	Disadvantages
1a. MBR at Existing Site w/ More Perc Ponds	- Can continue to use existing site - Avoids legal, environmental, land and conveyance costs of using a new treatment site	- Sophisticated MBR technology will require increased maintenance - Need to purchase additional land for percolation ponds - Depending on location of the Percolation ponds, will either need to upsize existing effluent discharge pipe or construct new effluent conveyance facilities to the ponds
1b. MBR at Existing Site w/ NPDES permit for flows exceeding 1.5 mgd	- Can continue to use existing site - Avoids legal, environmental, land and conveyance costs of using a new treatment site - Avoids cost of land for new percolation ponds	- Sophisticated MBR technology will require increased maintenance - Securing an NPDES permit is an expensive and time consuming process - More effluent water quality monitoring will be required
1c. MBR at Existing Site w/ seasonal storage and recycling	- Can continue to use existing site - Avoids legal, environmental, land and conveyance costs of using a new treatment site - Provides opportunity to use recycled water	- Sophisticated MBR technology will require increased maintenance - Need to purchase additional land for effluent storage - Depending on location of the effluent disposal site, will either need to upsize existing effluent discharge pipe or construct new effluent conveyance facilities to the site
2. Relocate WWTP operations to site south of Tuolumne River	- Allows the City to continue land application of effluent (avoiding NPDES permit issues) - Allows for the construction of a lower cost treatment system that is simple to operate (e.g. Biolac) - Provides an opportunity to serve the community of Hickman	- Costs of legal, environmental, land and design/construction of conveyance and treatment facilities could outweigh costs of other options. -

Option	Advantages	Disadvantages
3. Become a Partner in a Regional Wastewater System	- Avoids land costs for effluent storage/disposal - Avoids legal, environmental, land and conveyance costs of using a new treatment site	- Potential for institutional hurdles - Need to construct conveyance facilities to connect with a regional system

6 Next Steps

The wastewater flow projections developed as part of this report indicate that the existing treatment and disposal capacity will be exceeded at some point between 2010 and 2015, within the LAFCO planning horizon. Table 18 summarizes some of the next steps that need to occur under the worst case (plant capacity exceed in 2010) and best case (plan capacity exceed in 2020) scenarios.

Table 18: Next Steps

Activity	Duration	Year of Occurrence	
		Low Growth @ 75 gpcd	High Growth @ 90 gpcd
Near Term Improvements			
Notify Regional Board of Need to Increase Capacity to 1.5 mgd[1]	*	2011	2006
Start Design of New Treatment System at Existing Site	2 years	2011	2006
Start Construction of New Treatment Plant at Existing Site	2 years	2013	2008
Begin Operation of New Treatment System at Existing Site	*	2015	2010
Long Term Improvements			
Start design for Selected Long-Term Option	2 years	2029	2016
Start Construction of facilities for Selected Long-Term Option	1 year	2031	2018
Start up Operation of Long-Term Option	*	2032	2019

Notes:
1. Requirement of current WDR (Provision E.4 of the Standard Provisions and Reporting Requirements, pg 8)

References

1. Borchard, Robert, electronic communication, 2005
2. Central Valley Regional Water Quality Control Board, Order No. 94-273: Waste Discharge Requirements for City of Waterford Wastewater Treatment Facility
3. City of Waterford, Draft 2005 Urban Water Management Plan
4. DJH Engineering, "Wastewater Master Plan," February 2005.
5. MCR Engineering, Waterford Land Use Map
6. MCR Engineering, Waterford Annexation Area Map

Appendix A: Calculations

WATERFORD WWTP ASSESSMENT

SBR SIZING CALCULATIONS

AVERAGE ANNUAL DESIGN FLOW: 1.5 mgd

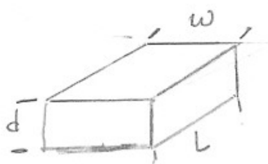
MAX DAY PEAKING FACTOR: 1.17 (based on 2005 ww flow data)

MAX DAY DESIGN FLOW: 1.755 mgd

MAX DAY VOLUME: $\underline{1.755 \text{ MG}}$

SBR BASINS: 4

VOLUME PER BASIN (cf): $\dfrac{1.755 \text{ MG}}{4 \text{ BASIN}} \times \dfrac{10^6 \text{ gal}}{\text{MG}} \times \dfrac{\text{cf}}{7.48 \text{ gal}} \approx 58{,}700 \text{ cf/basin}$



SIZING CONSIDERATIONS:

- basin should be roughly square
- depth should be 16-20'
- width cannot exceed 50' (narrow site)

Assume $\left.\begin{array}{l} w = 50' \\ d = 20' \end{array}\right\} \forall = L \times w \times d \rightarrow L = \dfrac{\forall}{w \times d}$

$L = \dfrac{58{,}700 \text{ cf}}{50' \times 20'} \approx 59' \rightarrow 60'$

$\boxed{4 \text{ BASINS @ } 60' \times 50' \times 20'}$

(L x w x d)

WATERFORD WWTP ASSESSMENT

SLUDGE VOLUME / STORAGE CALCULATIONS

BOD = 275 mg/L (DJH Report)

Q = 1.5 mgd

% solids = 0.7 %

lbs sludge per lb BOD = .8

$$\text{BOD loading } (\text{lbs/day}) = 275 \frac{mg}{L} \times 1.5 \frac{MG}{day} \times \frac{8.34 \text{ lb}}{MG \cdot (mg/L)} = 3440 \text{ lb BOD/day}$$

$$\text{sludge load rate} = 3440 \frac{\text{lb BOD}}{\text{day}} \times \frac{.8 \text{ lb sludge}}{\text{lb BOD}} = 2750 \text{ lb sludge/day}$$

$$\text{sludge volume} = 2750 \frac{\text{lb sludge}}{\text{day}} \times \frac{100 \text{ lbs } H_2O}{0.7 \text{ lbs sludge}} \times \frac{cf}{62.4 \text{ lbs } H_2O} \times \frac{7.48 \text{ gal}}{cf} = 47,100 \text{ gal sludge/day}$$

$$\boxed{\text{sludge volume} = 47,100 \frac{gal}{day}}$$

Appendix B: Vendor Quotes and Materials

2727 Northwest 62nd Street
Fort Lauderdale, FL 33309-1721

Preliminary Budget Proposal

To:	Matt Rebmann	**Date:**	December 15, 2005
Company:	Coombs-Hopkins Co.	**From:**	Mark Rasor
Tel.:	760-931-0555	**Tel.:**	954-974-6610
cc:	Steve Young		

Subject: Waterford, CA
Biolac®-R Treatment System

As per your request, the following is a budget proposal for a Biolac®-SS Treatment System for the subject project. This preliminary proposal is divided into the following sections:

I. Facility Background and Design Basis
   1. General Information
   2. Data Supplied
   3. Other Design Data and Assumptions

II. Process Design
   1. Basin Design
   2. Aeration Design
   3. Clarifier Design

III. Equipment and Services Provided
IV. Summary of Biolac Process
V. Cost Estimate and Terms
VI. Supplemental Information

Thank you for your interest in Parkson's Biolac Treatment System. We look forward to working with you on this project and should you have any questions or need clarifications, please feel free to contact me at 954-917-1892.

Sincerely,
PARKSON CORPORATION
An Axel Johnson, Inc. Company

Mark Rasor
Product Manager, Biolac System
mrasor@parkson.com

I. FACILITY DESIGN BASIS

1. General Information

The Biolac System recommended below will consist of two parallel treatment systems, each consisting of an earthen-basin activated sludge reactor and two isolatable integral clarification units. The two systems will share a common blower and control system located adjacent to the earthen basins. The system provides complete secondary treatment of the wastewater with both nitrification and denitrification in the most hydraulically efficient package available.

2. Data Supplied

Preliminary design work is based on the following parameters supplied by RMC Water and Environment:

Influent (Average)

Flow	3.0	MGD
BOD_5	275	mg/L
TSS	205	mg/L
TKN	55	mg/L
NH_3	40	mg/L

Desired Effluent (based upon monthly averages)

BOD_5	30	mg/L
TSS	20	mg/L
TN	10	mg/L

3. Other Design Data and Assumptions

In order to offer this proposal, Parkson Corporation makes the following assumptions:

A. The wastewater will be pretreated to remove debris and grit using a screen. Comminution is not recommended pretreatment.

B. Sufficient alkalinity is present or will be added to the system to allow nitrification to proceed uninhibited.

C. Incoming oil, grease, chemical, and metals concentrations are within aerobically treatable levels.

D. Sufficient nutrients (P and N) are present for treatment or will be added by the plant operator.

E. A qualified operator will supervise plant activities.

II. PROCESS DESIGN

The following sections describe the components summarized in Table 1.

1. Basin Design

Based on the information listed above, the proposed Biolac System is proposed as follows:

The design criteria for the extended aeration/activated sludge basin with an integral clarifier for sludge separation and recycle are:

F/M Ratio	0.06	
MLSS	3,000	mg/L
HRT	1.53	days
SRT	40-60	days

This process design results in reliable BOD removal, nitrification and denitrification. The long SRT provides process stability and due to the large quantity of biological solids present, wide swings in organic and hydraulic loads can easily be handled without equipment or process adjustments. The excess biomass produced is well digested and stabilized.

The integral clarifier shares wall with the aeration basin. The design criteria for the clarifier are discussed in Section 3.

2. Aeration Design

A. The aeration requirements for the Biolac System are detailed in the attached print out “Oxygen Requirements” and are summarized in Table 1.

B. The estimated air and energy requirements and the number of BioFlex© moving aeration headers and BioFuser™ units estimated are given in Table 1.

C. The required air will be supplied by two 175 HP centrifugal blowers. One (1) additional blower is provided as an installed spare. Only one (1) blower is necessary for mixing. Therefore, it is possible to operate one (1) blower and cut energy usage significantly during periods of low load. The blowers will be located on a concrete pad next to the aeration basins or a blower building can be provided by others.

3. Clarifier Design

A. The biomass is separated from the mixed liquor in two rectangular clarifiers attached to the end walls of the aeration basins. Sludge removal is accomplished using Parkson's SuperScraper system to transport the settled solids on one end of the clarifier where an airlift pump discharges to a sludge sump and return pipe. Sludge is typically returned by gravity to the influent end of the basins. Sludge is recycled and wasted using an automated control valve system to a location determined by the facility design. The effluent exits the clarifiers through fixed overflow weirs. Floating materials are removed using automatically operated rotating scum pipes.

Table 1
Biolac Treatment System Preliminary Design Information

Approximate dimensions at grade (ft)	184 x 154	
Approximate bottom dimensions (ft)	160 x 106	
Side slope	1.5:1	
Side water depth (ft)	14	
Basin volume (MG)	2.3	
Clarifier design rise rate at design flow (gpd/ft^2)	330	
# clarifiers	1 per basin	
Size/Integral clarifier (ft)	144 x 32	
Estimated SOR (lbs/hr)	641 each basin	
Estimated SCFM (excl. airlift requirements)	3090 each basin	
# diffusers	560 each basin	
# BioFuser assemblies	140 each basin	
# BioFlex headers	10 each basin	

III. EQUIPMENT AND SERVICES SUPPLIED

Parkson supplies the following equipment and services for the treatment system described above:

A. Complete BioFlex moving chains including BioFuser units, high temperature flexible connecting hose and all required hardware.

B. Motorized butterfly valves for individual control of the air flow to each BioFlex aeration chain.

C. Quantity three complete 175 blower assemblies (Centrifugal blowers) including motor and required accessories (includes one installed spare blower for redundancy).

D. Remote-mounted control system for operation of the aeration system and clarifiers including control panel, starters and switches for all motors except blowers, and timers for controlling the aeration system. Dissolved oxygen measurement/recording is optional.

E. Project development and design drawings on AutoCAD disk, submittal package for approval and operation and maintenance manuals.

F. Final installation inspection, start-up supervision and operator training; extended training and plant operation supervision is also available.

G. All Integral clarifier equipment required including SuperScraper sludge removal system, airlift sludge removal pumps, automatic rotating scum pipe and overflow weirs.

IV. SUMMARY OF BIOLAC PROCESS

A. The Biolac System is a unique extended aeration process characterized by excellent BOD removal, complete nitrification, denitrification and biosolids stabilization and is specifically designed to be compatible with earthen basin applications (lined or unlined) or concrete construction:

B. It uses fine bubble membrane diffusers attached to floating aeration chains, which are moved across the basin by the air released from the diffusers.

C. The moving BioFusers provide efficient mixing of the basin contents as well as high oxygen transfer at low energy usage.

D. There is no submerged aeration piping to be installed, leveled or secured.

E. Each BioFlex chain can be individually controlled by an air valve, providing great flexibility in fine-tuning the system to the oxygen demand of the waste.

F. The BioFlex chains with BioFusers do not contact or harm a basin liner or erode an unlined basin bottom.

G. A turndown capability of 50-70% is typical without sacrificing mixing due to the mixing capabilities of the moving BioFlex aeration chains.

H. Inspection and service of the BioFusers is done quickly and easily without dewatering the basin, keeping maintenance costs low and eliminating the need for redundant aeration basins.

I. Winter operation presents no difficulty as fine bubble diffusion beneath the water surface eliminates icing and minimizes wastewater cooling.

J. Energy efficiency is high, reducing operating costs. The moving aeration chain design is not mixing limited so the horsepower required for mixing is typically 1/2 to 1/3 that required for aeration.

K. An integral clarifier is installed inside Basin 1 opposite the wastewater influent to settle and recycle the stable extended aeration type sludge.

V. COST ESTIMATE AND TERM

A. The budget price for the equipment and services supplied is **$1,700,000.00**, FOB Factory, freight allowed.

B. Terms are net 30 days.

C. Approval drawings: Typically 6-8 weeks after receipt of written order.

D. Equipment shipment: Typically 16-20 weeks after complete release for manufacture.

E. **Excluded Items**: Installation, concrete structures, electric wiring and main air header.

VI. SUPPLEMENTAL INFORMATION AND REFERENCES

A. Biolac System Oxygen Requirements

THE BIOLAC SYSTEM OXYGEN REQUIREMENTS

Waterford, CA

Basin Data (at mid-depth) FOR BASIN ONE

LENGTH	*	WIDTH	*	DEPTH	=	BASIN CAPACITY (CU. FT.)
181		121		14	=	306376

BASIN CAPACITY * NUMBER OF BASINS = TOTAL BASIN CAPACITY
306376 * 1 = 306376

TOTAL BASIN CAPACITY * 7.48 = MILLION GALLON BASIN CAPACITY (MGBC
306376 * 7.48/1000000 = 2.29

Oxygen Requirements for the Biolac Aeration System

ACTUAL OXYGEN REQUIREMENTS (AOR)

M G D * BOD (mg./l.) * 8.34 LBS./(mg./l.) = TOTAL LBS. BOD/DAY
1.5 275 * 8.34 = 3440

1.5 LBS. O2/LB. OF BOD REMOVED

37 HOURS RETENTION TIME

96 % REMOVAL OF BOD

LBS. BOD REMOVED/DAY * LBS.O2/LB. BOD REMOVED= AOR FOR BOD REMOVAL
3303 * 1.5 = 4954

M G D * TKN(mg./l.) * 8.34 = TOTAL LBS. TKN / DAY
1.5 55 * 8.34 = 688

4.6 LBS.O2/LB. OF TKN REMOVED (STANDARD)

98 % REMOVAL OF TKN

LBS. TKN REMOVED/DAY * LBS. O2/LB. TKN REMOVED = AOR FOR TKN REMOVA
674 * 4.6 = 3102

COMBINED AOR = **8056** /24 HRS. = **336** LBS. O2/HR. AOR

THE ACTUAL OXYGEN REQUIREMENT MUST BE CONVERTED TO A STANDARD OXYGE
REQUIREMENT. THIS CONVERSION TAKES INTO CONSIDERATION SUCH FACTORS
TEMPERATURE, ELEVATION, DIFFUSER DEPTH, ALPHA FACTOR, BETA FACTOR,
DISSOLVED OXYGEN LEVEL DESIRED.

TEMPERATURE=(T)	20
SATURATION=(CSM)	9.092
SITE BAROMETRIC PRESSURE=(BP)	14.649
DIFFUSER WATER DEPTH=(DWD)	13
EQUIVILENT DEPTH FACTOR=(F)	0.25
ALPHA=(A)	0.7
BETA=(B)	0.95
THETA=(O)	1.024
DISSOLVED OXYGEN LEVEL=(C-L)	2

C-ST = CSM * (BP+(.433*DWD* F)) / 14.7 = 9.9315

C-S20= 9.07 *((14.7+(.433*DWD* F)) / 14.= 9.9383

C-SW = BETA * C-ST = 9.4349

LBS.O2/HR. AOR 336
SOR = -- = 641
ALPHA*(C-SW - C-L / C-S20) * (THETA^T - 20)

SOR = <u>641</u>

AERATION SYSTEM DESIGN

AIR RATE PER FT OF DIFFUSER AS DETERMINED **1.38** **SCFM**
SOR = 641
DIFFUSER 02 TRANSFER RATE **0.2861**
SCFM REQ =(SOR/FT OF DIFF O2 TRANS RATE*AIR FLOW RATE/FT DI

SCFM = **3090** FOR DESIGN OXYGEN REQ
SCFM = **3465** INCLUDING RAS AIRLIFT PUMP
DELTA P=(((swd - 1)/34)*14.7)+1.5 **7.12**
AIR LIFT AIR FLOW **375** AIR LIFT BHP= **17**
BHP.= (SCFM*0.3775)((ATM.P+DEL.P/ATM.P)^.283-1)
BHP. = **138** FOR DESIGN OXYGEN REQ
BHP. = **155** INCLUDING CLARIFIER AIRLIFT
MIN SCFM FOR MIXING BASED ON SIDE SLOPE = 4 /1000 FT3
MIN SCFM = BASIN VOLUME 1000 FT3 * 4.0 **1225** SCFM
MIN BHP FOR MIXING = **55**

TOTAL FT OF DIFFUSERS SUGGESTED AT TARGET FLOW RATE 2240
TOTAL FT OF DIFFUSERS BASED ON ACTUAL FINAL LAYOUT 2240
TUBES PER BIOFUSER ASSEM = **4** TOTAL BIOFUSERS = **140**
SERIES BIOFUSER SELECTED = **2000** FT/DIFF ASSEMBLY = **4**
NUMBER OF BIOFLEX CHAINS ON PROJECT = **10**
NUMBER OF BIOFUSER ASSEMBLIES PER BIOFLEX CHAIN = **14**

NOTE AIR FLOW TARGET = 50 fps VELOCITY
AIR FLOW PER CHAIN (SCFM) = **309**
FEED DIAMETER = **6** VELOCITY AT CONDITION = **21**
CHAIN SPACING = **16.00** DIFFUSER ASSEM SPACING = **7.57**

SOR = **641** LBS O2/HR

PARKSON CORPORATION

BIOLAC® WASTEWATER TREATMENT SYSTEM

Biolac® Wastewater Treatment System
Extended sludge age biological technology

This innovative process features

- **Low-loaded activated sludge technology**
- **High oxygen transfer efficiency delivery system**
- **Exceptional mixing energy from controlled aeration chain movement**
- **Simple system construction**

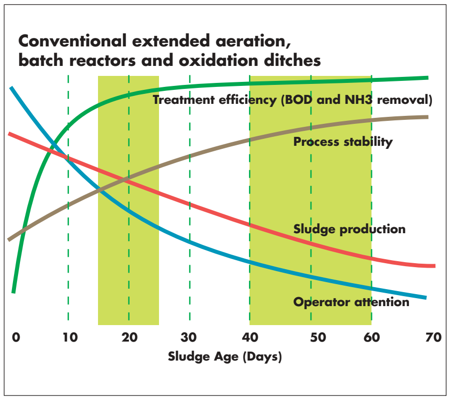
The Biolac System is an innovative activated sludge process using extended retention of biological solids to create an extremely stable, easily operated system.

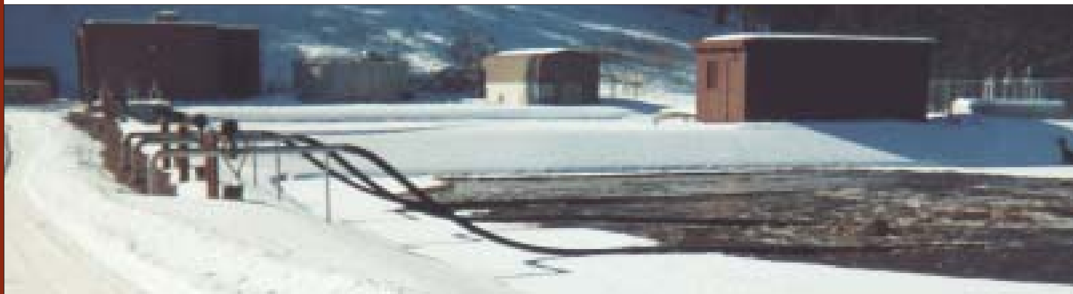
The capabilities of this unique technology far exceed ordinary extended aeration treatment. The Biolac process maximizes the stability of the operating environment and provides high efficiency treatment. The design ensures the lowest-cost construction and guarantees operational simplicity. Over 500 Biolac Systems are installed throughout North America treating municipal wastewater and many types of industrial wastewater.

The Biolac system utilizes a longer sludge age than other aerobic systems. Sludge age, also known as SRT (solids retention time) or MCRT (mean cell residence time), defines the operating characteristics of any aerobic biological treatment system. A longer sludge age dramatically lowers effluent BOD and ammonia levels. The Biolac long sludge age process produces BOD levels of less than 10 mg/l and complete nitrification (less than 1 mg/l ammonia). Minor modifications to the system will extend its capabilities to denitrification and biological phosphorous removal.

While most extended aeration systems reach their maximum mixing capability at sludge ages of approximately 15-25 days, the Biolac System efficiently and uniformly mixes the aeration volumes associated with 30-70 day sludge age treatment.

The large quantity of biomass treats widely fluctuating loads with very few operational changes. Extreme sludge stability allows sludge wasting to non-aerated sludge ponds or basins and long storage times.





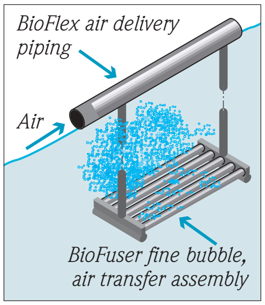
Aeration Components

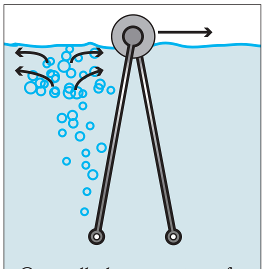
SIMPLE PROCESS CONTROL AND OPERATION

The control and operation of the Biolac® process is similar to that of conventional extended aeration. Parkson provides a very basic system to control both the process and aeration. Additional controls required for denitrification, phosphorous removal, dissolved oxygen control and SCADA communications are also available.

AERATION SYSTEM COMPONENTS

The ability to mix large basin volumes using minimal energy is a function of the unique BioFlex® moving aeration chains and the attached BioFuser® fine bubble diffuser assemblies. The gentle, controlled back and forth motion of the chains and diffusers distributes the oxygen transfer and mixing energy evenly throughout the basin area.





Controlled oxygen transfer and mixing energy

No additional airflow is required to maintain mixing.

Stationary fine-bubble aeration systems require 8-10 CFM of air per 1000 cu. ft. of aeration basin volume. The Biolac System maintains the required mixing of the activated sludge and suspension of the solids at only 4 CFM per 1000 cu.ft. of aeration basin volume. Mixing of a Biolac basin typically requires 35-50 percent of the energy of the design oxygen requirement. Therefore, air delivery to the basin can be reduced during periods of low loading without the risk of solids settling out of the wastewater.

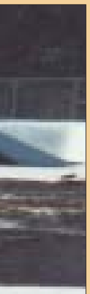
SYSTEM CONSTRUCTION

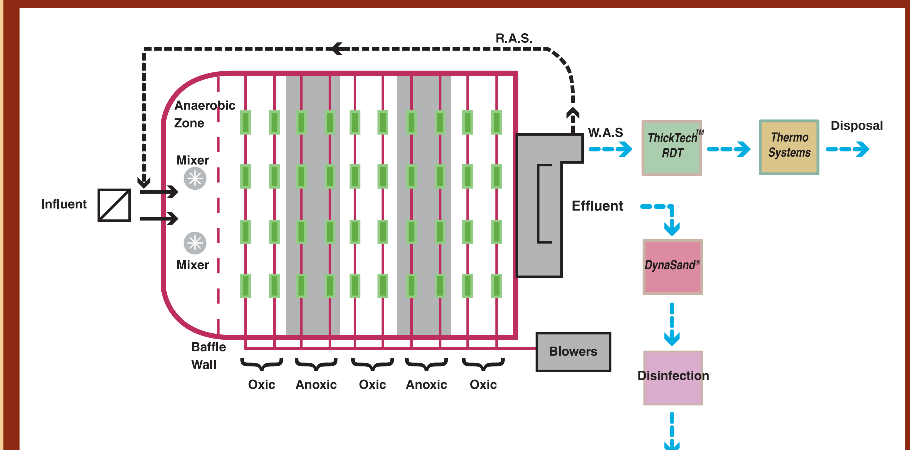
A major advantage of the Biolac system is its low installed cost. Most systems require costly in-ground concrete basins for the activated sludge portion of the process. A Biolac system can be installed in earthen basins, either lined or unlined. The BioFuser fine bubble diffusers require no mounting to basin floors or associated anchors and leveling. These diffusers are suspended from the BioFlex aeration chains above the basin floor. The only concrete structural work required is for the simple internal clarifier(s) and blower/control buildings.

Biological Nutrient Removal

Simple control of the air distribution to the BioFlex chains creates moving waves of oxic and anoxic zones within the basin. This repeated cycling of environments nitrifies and denitrifies the wastewater without recycle pumping or additional external basins. This mode of Biolac operation is known as the Wave Oxidation© process. No additional in-basin equipment is required and simple timer-operated actuator valves regulate manipulation of the air distribution.

Biological phosphorous removal can also be accomplished by incorporating an anaerobic zone.

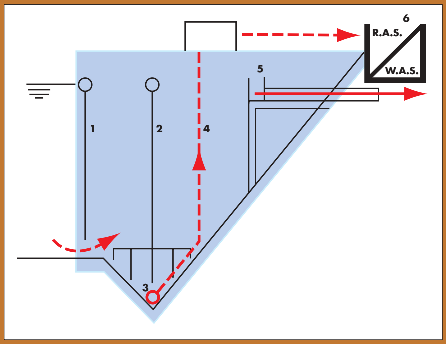




Wave Oxidation Process

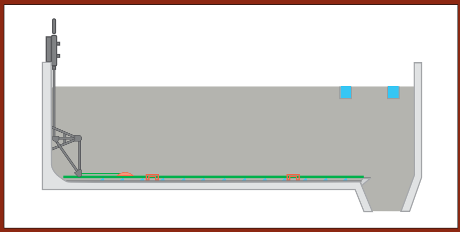
Type "R" Clarifier

Land space and hydraulic efficiencies are maximized using the type "R" clarifier. The clarifier design incorporates a common wall between the clarifier and aeration basin. The inlet ports in the bottom of the wall create negligible hydraulic headloss and promote efficient solids removal by filtering the flow through the upper layer of the sludge blanket. The hopper-style bottom simplifies sludge concentration and removal, and minimizes clarifier HRT. The sludge return airlift pump provides important flexibility in RAS flows with no moving parts. All maintenance is performed from the surface without dewatering the clarifier.



Type "SS" Clarifier

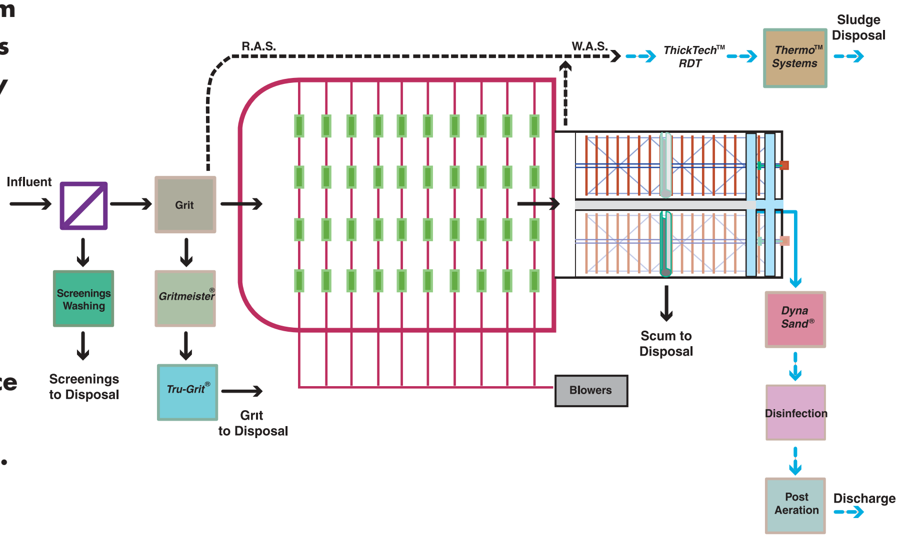
Higher flow systems incorporate a flat-bottom internal clarifier utilizing the Parkson SuperScraper™ sludge removal system. This clarifier design maintains the efficiencies of the common wall layout while providing ample clarification surface area within the footprint of the aeration basin width. The SuperScraper system moves settled solids along the bottom of the clarifier to an integral collection trough. The unique design of the scraper blades and gentle forward movement of the SuperScraper system concentrates the biological solids as they are moved along the bottom of the clarifier without disturbing the sludge blanket.



A Parkson *Complete* Wastewater Treatment System

The Parkson "Complete" system featured here utilizes the Biolac® process with two flat-bottom internal Type SS clarifiers. SuperScraper™ units are installed in the clarifier bottoms to simplify sludge removal. Influent screening with grit removal and appropriate residuals management such as washing, dewatering and conveying are included.

Sludge from the clarifiers is sent to the ThickTech™ rotary drum thickener and on to a THERMO-SYSTEM™ solar sludge dryer to reduce the volume of sludge by 50% and produce a Class "A" product suitable for beneficial reuse. Clarifier effluent is polished by a DynaSand® filter followed by disinfection and post-aeration as the final steps prior to discharge.



PARKSON CORPORATION

www.parkson.com

AN AXEL JOHNSON INC. COMPANY

Parkson Florida Corporate
2727 NW 62nd St.
Fort Lauderdale FL
33309-1721
P.O. Box 408399
Fort Lauderdale FL
33340-8399
P 954.974.6610
F 954.974.6182

Parkson Illinois
29850 N. Skokie Hwy.
(U.S. 41)
Lake Bluff IL
60044-1110
P 847.473.3700
F 847.473.0477

Parkson Michigan
2001 Waldorf St. NW
Suite 300
Grand Rapids MI
49544-1437
P 616.791.9100
F 616.453.1832

Parkson Canada
9045 Cote-de-Liesse
Suite 201
Dorval QC H9P 2M9
Canada
P 514.636.4618
F 514.636.9718

Parkson México
Callejón Catita No.10
San Diego Churubusco
Delegacion Coyoacán
04120 México D.F.
P 52.55.5688.4368
F 52.55.5601.0963

Parkson do Brasil Ltda.
Calçada dos Mirtilos 15
Barueri Sao Paulo
CEP 06453-000
Brazil
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United States Environmental Protection Agency
Office of Water Washington, D.C.
EPA 832-F-99-073
September 1999

Wastewater Technology Fact Sheet
Sequencing Batch Reactors

DESCRIPTION

The sequencing batch reactor (SBR) is a fill-and-draw activated sludge system for wastewater treatment. In this system, wastewater is added to a single "batch" reactor, treated to remove undesirable components, and then discharged. Equalization, aeration, and clarification can all be achieved using a single batch reactor. To optimize the performance of the system, two or more batch reactors are used in a predetermined sequence of operations. SBR systems have been successfully used to treat both municipal and industrial wastewater. They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions.

Fill-and-draw batch processes similar to the SBR are not a recent development as commonly thought. Between 1914 and 1920, several full-scale fill-and-draw systems were in operation. Interest in SBRs was revived in the late 1950s and early 1960s, with the development of new equipment and technology. Improvements in aeration devices and controls have allowed SBRs to successfully compete with conventional activated sludge systems.

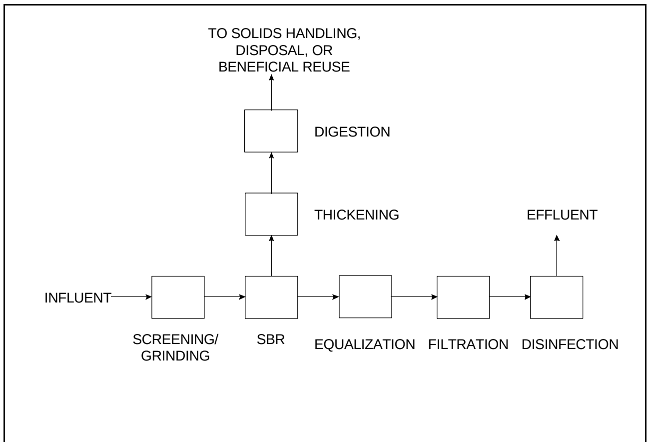
The unit processes of the SBR and conventional activated sludge systems are the same. A 1983 U.S. EPA report, summarized this by stating that "the SBR is no more than an activated sludge system which operates in time rather than in space." The difference between the two technologies is that the SBR performs equalization, biological treatment, and secondary clarification in a single tank using a timed control sequence. This type of reactor does, in some cases, also perform primary clarification. In a conventional activated sludge system, these unit processes would be accomplished by using separate tanks.

A modified version of the SBR is the Intermittent Cycle Extended Aeration System (ICEAS). In the ICEAS system, influent wastewater flows into the reactor on a continuous basis. As such, this is not a true batch reactor, as is the conventional SBR. A baffle wall may be used in the ICEAS to buffer this continuous inflow. The design configurations of the ICEAS and the SBR are otherwise very similar.

Description of a Wastewater Treatment Plant Using an SBR

A typical process flow schematic for a municipal wastewater treatment plant using an SBR is shown in Figure 1. Influent wastewater generally passes through screens and grit removal prior to the SBR. The wastewater then enters a partially filled reactor, containing biomass, which is acclimated to the wastewater constituents during preceding cycles. Once the reactor is full, it behaves like a conventional activated sludge system, but without a continuous influent or effluent flow. The aeration and mixing is discontinued after the biological reactions are complete, the biomass settles, and the treated supernatant is removed. Excess biomass is wasted at any time during the cycle. Frequent wasting results in holding the mass ratio of influent substrate to biomass nearly constant from cycle to cycle. Continuous flow systems hold the mass ratio of influent substrate to biomass constant by adjusting return activated sludge flowrates continually as influent flowrates, characteristics, and settling tank underflow concentrations vary. After the SBR, the "batch" of wastewater may flow to an equalization basin where the wastewater flowrate to additional unit processed can be is controlled at a determined rate. In some cases the wastewater is filtered to remove additional solids and then disinfected.

As illustrated in Figure 1, the solids handling system may consist of a thickener and an aerobic digester. With SBRs there is no need for return activated sludge (RAS) pumps and primary sludge (PS) pumps like those associated with conventional activated sludge systems. With the SBR, there is typically only one sludge to handle. The need for gravity thickeners prior to digestion is determined



Source: Parsons Engineering Science, 1999.

FIGURE 1 PROCESS FLOW DIAGRAM FOR A TYPICAL SBR

on a case by case basis depending on the characteristics of the sludge.

An SBR serves as an equalization basin when the vessel is filling with wastewater, enabling the system to tolerate peak flows or peak loads in the influent and to equalize them in the batch reactor. In many conventional activated sludge systems, separate equalization is needed to protects the biological system from peak flows, which may wash out the biomass, or peak loads, which may upset the treatment process.

It should also be noted that primary clarifiers are typically not required for municipal wastewater applications prior to an SBR. In most conventional activated sludge wastewater treatment plants, primary clarifiers are used prior to the biological system. However, primary clarifiers may be recommended by the SBR manufacturer if the total suspended solids (TSS) or biochemical oxygen demand (BOD) are greater than 400 to 500 mg/L. Historic data should be evaluated and the SBR manufacturer consulted to determine whether primary clarifiers or equalization are recommended prior to an SBR for municipal and industrial applications.

Equalization may be required after the SBR, depending on the downstream process. If equalization is *not* used prior to filtration, the filters need to be sized in order to receive the batch of wastewater from the SBR, resulting in a large surface area required for filtration. Sizing filters to accept these “batch” flows is usually not feasible, which is why equalization is used between an SBR and downstream filtration. Separate equalization following the biological system is generally not required for most conventional activated sludge systems, because the flow is on a continuous and more constant basis.

APPLICABILITY

SBRs are typically used at flowrates of 5 MGD or less. The more sophisticated operation required at larger SBR plants tends to discourage the use of these plants for large flowrates.

As these systems have a relatively small footprint, they are useful for areas where the available land is limited. In addition, cycles within the system can be easily modified for nutrient removal in the future, if it becomes necessary. This makes SBRs extremely flexible to adapt to regulatory changes for effluent parameters such as nutrient removal. SBRs are also very cost effective if treatment beyond biological treatment is required, such as filtration.

ADVANTAGES AND DISADVANTAGES

Some advantages and disadvantages of SBRs are listed below:

Advantages

- Equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved in a single reactor vessel.

- Operating flexibility and control.

- Minimal footprint.

- Potential capital cost savings by eliminating clarifiers and other equipment.

Disadvantages

- A higher level of sophistication is required (compared to conventional systems), especially for larger systems, of timing units and controls.

- Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches, and automated valves.

- Potential of discharging floating or settled sludge during the DRAW or decant phase with some SBR configurations.

- Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.

- Potential requirement for equalization after the SBR, depending on the downstream processes.

DESIGN CRITERIA

For any wastewater treatment plant design, the first step is to determine the anticipated influent characteristics of the wastewater and the effluent requirements for the proposed system. These influent parameters typically include design flow, maximum daily flow BOD_5, TSS, pH, alkalinity, wastewater temperature, total Kjeldahl nitrogen (TKN), ammonia-nitrogen (NH_3-N), and total phosphorus (TP). For industrial and domestic wastewater, other site specific parameters may also be required.

The state regulatory agency should be contacted to determine the effluent requirements of the proposed plant. These effluent discharge parameters will be dictated by the state in the National Pollutant Discharge Elimination System (NPDES) permit. The parameters typically permitted for municipal systems are flowrate, BOD_5, TSS, and Fecal Coliform. In addition, many states are moving toward requiring nutrient removal. Therefore, total nitrogen (TN), TKN, NH_3-N, or TP may also be required. It is imperative to establish effluent requirements because they will impact the operating sequence of the SBR. For example, if there is a nutrient requirement and NH_3-N or TKN is required, then nitrification will be necessary. If there is a TN limit, then nitrification and denitrification will be necessary.

Once the influent and effluent characteristics of the system are determined, the engineer will typically consult SBR manufacturers for a recommended design. Based on these parameters, and other site specific parameters such as temperature, key design parameters are selected for the system. An example of these parameters for a wastewater system loading is listed in Table 1.

TABLE 1 KEY DESIGN PARAMETERS FOR A CONVENTIONAL LOAD

	Municipal	Industrial
Food to Mass (F:M)	0.15 - 0.4/day	0.15 - 0.6/day
Treatment Cycle Duration	4.0 hours	4.0 - 24 hours
Typically Low Water Level Mixed Liquor Suspended Solids	2,000-2,500 mg/L	2,000 - 4,000 mg/L
Hydraulic Retention Time	6 - 14 hours	varies

Source: AquaSBR Design Manual, 1995.

Once the key design parameters are determined, the number of cycles per day, number of basins, decant volume, reactor size, and detention times can be calculated. Additionally, the aeration equipment, decanter, and associated piping can then be sized.

Other site specific information is needed to size the aeration equipment, such as site elevation above mean sea level, wastewater temperature, and total dissolved solids concentration.

The operation of an SBR is based on the fill-and-draw principle, which consists of the following five basic steps: Idle, Fill, React, Settle, and Draw. More than one operating strategy is possible during most of these steps. For industrial wastewater applications, treatability studies are typically required to determine the optimum operating sequence. For most municipal wastewater treatment plants, treatability studies are not required to determine the operating sequence because municipal wastewater flowrates and characteristic variations are usually predictable and most municipal designers will follow conservative design approaches.

The Idle step occurs between the Draw and the Fill steps, during which treated effluent is removed and influent wastewater is added. The length of the Idle step varies depending on the influent flowrate and the operating strategy. Equalization is achieved during this step if variable idle times are used. Mixing to condition the biomass and sludge wasting can also be performed during the Idle step, depending on the operating strategy.

Influent wastewater is added to the reactor during the Fill step. The following three variations are used for the Fill step and any or all of them may be used depending on the operating strategy: static fill, mixed fill, and aerated fill. During static fill, influent wastewater is added to the biomass already present in the SBR. Static fill is characterized by no mixing or aeration, meaning that there will be a high substrate (food) concentration when mixing begins. A high food to microorganisms (F:M) ratio creates an environment favorable to floc forming organisms versus filamentous organisms, which provides good settling characteristics for the sludge. Additionally, static fill conditions favor organisms that produce internal storage products during high substrate conditions, a requirement for biological phosphorus removal. Static fill may be compared to using “selector” compartments in a conventional activated sludge system to control the F:M ratio.

Mixed fill is classified by mixing influent organics with the biomass, which initiates biological reactions. During mixed fill, bacteria biologically degrade the organics and use residual oxygen or alternative electron acceptors, such as nitrate-nitrogen. In this environment, denitrification may occur under these anoxic conditions. Denitrification is the biological conversion of nitrate-nitrogen to nitrogen gas. An anoxic condition is defined as an environment in which oxygen is not present and nitrate-nitrogen is used by the microorganisms as the electron acceptor. In a conventional biological nutrient removal (BNR) activated sludge system, mixed fill is comparable to the anoxic zone which is used for denitrification. Anaerobic conditions can also be achieved during the mixed fill phase. After the microorganisms use the nitrate-nitrogen, sulfate becomes the electron acceptor. Anaerobic conditions are characterized by the lack of oxygen and sulfate as the electron acceptor.

Aerated Fill is classified by aerating the contents of the reactor to begin the aerobic reactions completed in the React step. Aerated Fill can reduce the aeration time required in the React step.

The biological reactions are completed in the React step, in which mixed react and aerated react modes are available. During aerated react, the aerobic reactions initialized during aerated fill are completed and nitrification can be achieved. Nitrification is the conversion of ammonia-nitrogen to nitrite-nitrogen and ultimately to nitrate-nitrogen. If the mixed react mode is selected, anoxic conditions can be attained to achieve denitrification. Anaerobic conditions can also be achieved in the mixed react mode for phosphorus removal.

Settle is typically provided under quiescent conditions in the SBR. In some cases, gentle mixing during the initial stages of settling may result in a clearer effluent and a more concentrated settled sludge. In an SBR, there are no influent or effluent currents to interfere with the settling process as in a conventional activated sludge system.

The Draw step uses a decanter to remove the treated effluent, which is the primary distinguishing factor between different SBR manufacturers. In general, there are floating decanters and fixed decanters. Floating decanters offer several advantages over fixed decanters as described in the Tank and Equipment Description Section.

Construction

Construction of SBR systems can typically require a smaller footprint than conventional activated sludge systems because the SBR often eliminates the need for primary clarifiers. The SBR never requires secondary clarifiers. The size of the SBR tanks themselves will be site specific, however the SBR system is advantageous if space is limited at the proposed site. A few case studies are presented in Table 2 to provide general sizing estimates at different flowrates. Sizing of these systems is site specific and these case studies do not reflect every system at that size.

TABLE 2 CASE STUDIES FOR SEVERAL SBR INSTALLATIONS

Flow	Reactors			Blowers	
(MGD)	No.	Size (feet)	Volume (MG)	No.	Size (HP)
0.012	1	18 x 12	0.021	1	15
0.10	2	24 x 24	0.069	3	7.5
1.2	2	80 x 80	0.908	3	125
1.0	2	58 x 58	0.479	3	40
1.4	2	69 x 69	0.678	3	60
1.46	2	78 x 78	0.910	4	40
2.0	2	82 x 82	0.958	3	75
4.25	4	104 x 80	1.556	5	200
5.2	4	87 x 87	1.359	5	125

Note: These case studies and sizing estimates were provided by Aqua-Aerobic Systems, Inc. and are site specific to individual treatment systems.

The actual construction of the SBR tank and equipment may be comparable or simpler than a conventional activated sludge system. For Biological Nutrient Removal (BNR) plants, an SBR eliminates the need for return activated sludge (RAS) pumps and pipes. It may also eliminate the need for internal Mixed Liquor Suspended Solid (MLSS) recirculation, if this is being used in a conventional BNR system to return nitrate-nitrogen.

The control system of an SBR operation is more complex than a conventional activated sludge system and includes automatic switches, automatic valves, and instrumentation. These controls are very sophisticated in larger systems. The SBR manufacturers indicate that most SBR installations in the United States are used for smaller wastewater systems of less than two million gallons per day (MGD) and some references recommend SBRs only for small communities where land is limited. This is not always the case, however, as the largest SBR in the world is currently a 10 MGD system in the United Arab Emirates.

Tank and Equipment Description

The SBR system consists of a tank, aeration and mixing equipment, a decanter, and a control system. The central features of the SBR system include the control unit and the automatic switches and valves that sequence and time the different operations. SBR manufacturers should be consulted for recommendations on tanks and equipment. It is typical to use a complete SBR system recommended and supplied by a single SBR manufacturer. It is possible, however, for an engineer to design an SBR system, as all required tanks, equipment, and controls are available through different manufacturers. This is not typical of SBR installation because of the level of sophistication of the instrumentation and controls associated with these systems.

The SBR tank is typically constructed with steel or concrete. For industrial applications, steel tanks coated for corrosion control are most common while concrete tanks are the most common for municipal treatment of domestic wastewater. For mixing and aeration, jet aeration systems are typical as they allow mixing either with or without aeration, but other aeration and mixing systems are also used. Positive displacement blowers are typically used for SBR design to handle wastewater level variations in the reactor.

As previously mentioned, the decanter is the primary piece of equipment that distinguishes different SBR manufacturers. Types of decanters include floating and fixed. Floating decanters offer the advantage of maintaining the inlet orifice slightly below the water surface to minimize the removal of solids in the effluent removed during the DRAW step. Floating decanters also offer the operating flexibility to vary fill-and-draw volumes. Fixed decanters are built into the side of the basin and can be used if the Settle step is extended. Extending the Settle step minimizes the chance that solids in the wastewater will float over the fixed decanter. In some cases, fixed decanters are less expensive and can be designed to allow the operator to lower or raise the level of the decanter. Fixed decanters do not offer the operating flexibility of the floating decanters.

Health and Safety

Safety should be the primary concern in every design and system operation. A properly designed and operated system will minimize potential health and safety concerns. Manuals such as the Manual of Practice (MOP) No. 8, Design of Municipal Wastewater Treatment Plants, and MOP No. 11, Operation of Municipal Wastewater Treatment Plants should be consulted to minimize these risks. Other appropriate industrial wastewater treatment manuals, federal regulations, and state regulations should also be consulted for the design and operation of wastewater treatment systems.

PERFORMANCE

The performance of SBRs is typically comparable to conventional activated sludge systems and depends on system design and site specific criteria. Depending on their mode of operation, SBRs can achieve good BOD and nutrient removal. For SBRs, the BOD removal efficiency is generally 85 to 95 percent.

SBR manufacturers will typically provide a process guarantee to produce an effluent of less than:

- 10 mg/L BOD
- 10 mg/L TSS
- 5 - 8 mg/L TN
- 1 - 2 mg/L TP

OPERATION AND MAINTENANCE

The SBR typically eliminates the need for separate primary and secondary clarifiers in most municipal systems, which reduces operations and maintenance requirements. In addition, RAS pumps are not required. In conventional biological nutrient removal systems, anoxic basins, anoxic zone mixers, toxic basins, toxic basin aeration equipment, and internal MLSS nitrate-nitrogen recirculation pumps may be necessary. With the SBR, this can be accomplished in one reactor using aeration/mixing equipment, which will minimize operation and maintenance requirements otherwise be needed for clarifiers and pumps.

Since the heart of the SBR system is the controls, automatic valves, and automatic switches, these systems may require more maintenance than a conventional activated sludge system. An increased level of sophistication usually equates to more items that can fail or require maintenance. The level of sophistication may be very advanced in larger SBR wastewater treatment plants requiring a higher level of maintenance on the automatic valves and switches.

Significant operating flexibility is associated with SBR systems. An SBR can be set up to simulate any conventional activated sludge process, including BNR systems. For example, holding times in the Aerated React mode of an SBR can be varied to achieve simulation of a contact stabilization system with a typical hydraulic retention time (HRT) of 3.5 to 7 hours or, on the other end of the spectrum, an extended aeration treatment system with a typical HRT of 18 to 36 hours. For a BNR plant, the aerated react mode (oxic conditions) and the mixed react modes (anoxic conditions) can be alternated to achieve nitrification and denitrification. The mixed fill mode and mixed react mode can be used to achieve denitrification using anoxic conditions. In addition, these modes can ultimately be used to achieve an anaerobic condition where phosphorus removal can occur. Conventional activated sludge systems typically require additional tank volume to achieve such flexibility. SBRs operate in time rather than in space and the number of cycles per day can be varied to control desired effluent limits, offering additional flexibility with an SBR.

COSTS

This section includes some general guidelines as well as some general cost estimates for planning purposes. It should be remembered that capital and construction cost estimates are site-specific.

Budget level cost estimates presented in Table 3 are based on projects that occurred from 1995 to 1998. Budget level costs include such as the blowers, diffusers, electrically operated valves, mixers, sludge pumps, decanters, and the control panel. All costs have been updated to March 1998 costs, using an ENR construction cost index of 5875 from the March 1998 Engineering News Record, rounded off to the nearest thousand dollars.

TABLE 3 SBR EQUIPMENT COSTS BASED ON DIFFERENT PROJECTS

Design Flowrate (MGD)	Budget Level Equipment Costs ($)
0.012	94,000
0.015	137,000
1.0	339,000
1.4	405,000
1.46	405,000
2.0	564,000
4.25	1,170,000

Source: Aqua Aerobics Manufacturer Information, 1998.

In Table 4, provided a range of equipment costs for different design flowrates is provided.

TABLE 4 BUDGET LEVEL EQUIPMENT COSTS BASED ON DIFFERENT FLOW RATES

Design Flowrate (MGD)	Budget Level Equipment Costs ($)
1	150,000 - 350,000
5	459,000 - 730,000
10	1,089,000 - 1,370,000
15	2,200,000
20	2,100,000 - 3,000,000

Note: Budget level cost estimates provided by Babcock King - Wilkinson, L.P., August 1998.

Again the equipment cost items provided do not include the cost for the tanks, sitework, excavation/backfill, installation, contractor's overhead and profit, or legal, administrative, contingency, and engineering services. These items must be included to calculate the overall construction costs of an SBR system. Costs for other treatment processes, such as screening, equalization, filtration, disinfection, or aerobic digestion, may be included if required.

The ranges of construction costs for a complete, installed SBR wastewater treatment system are presented in Table 5. The variances in the estimates are due to the type of sludge handling facilities and the differences in newly constructed plants versus systems that use existing plant facilities. As such, in some cases these estimates include other processes required in an SBR wastewater treatment plant.

TABLE 5 INSTALLED COST PER GALLON OF WASTEWATER TREATED

Design Flowrate (MGD)	Budget Level Equipment Cost ($/gallon)
0.5 - 1.0	1.96 - 5.00
1.1 - 1.5	1.83 - 2.69
1.5 - 2.0	1.65 - 3.29

Note: Installed cost estimates obtained from Aqua-Aerobics Systems, Inc., August 1998.

There is typically an economy of scale associated with construction costs for wastewater treatment, meaning that larger treatment plants can usually be constructed at a lower cost per gallon than smaller systems. The use of common wall construction for larger treatment systems, which can be used for square or rectangular SBR reactors, results in this economy of scale.

Operations and Maintenance (O&M) costs associated with an SBR system may be similar to a conventional activated sludge system. Typical cost items associated with wastewater treatment systems include labor, overhead, supplies, maintenance, operating administration, utilities, chemicals, safety and training, laboratory testing, and solids handling. Labor and maintenance requirements may be reduced in SBRs because clarifiers, clarification equipment, and RAS pumps may not be necessary. On the other hand, the maintenance requirements for the automatic valves and switches that control the sequencing may be more intensive than for a conventional activated sludge system. O&M costs are site specific and may range from $800 to $2,000 dollars per million gallons treated.

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13. Manual of Practice (MOP) No. 8, Design of Municipal Wastewater Treatment Plants,

14. Manual of Practice (MOP) No. 11, Operation of Municipal Wastewater Treatment Plants.

ADDITIONAL INFORMATION

Brad Holtsinger, Chief Operator
City of Stockbridge WWTP
4545 North Henry Boulevard
Stockbridge, GA 30281

Gary Hooder, Operator
Martinsburg WWTP
133 East Allegheny
Martinsburg, PA 16662-1112

Mitchell Meadows, Lead Operator
1300 Recker Highway
Auburndale, FL 33823

Teresa Schnoor, Administrator
Antrim TWP
P.O. Box 130
Greencastle, PA 17225

Charles Sherrod, Chief Operator
Blountstown WWTP
125 West Central Avenue
Blountstown, FL 32424

For more information contact:

Municipal Technology Branch
U.S. EPA
Mail Code 4204
401 M St., S.W.
Washington, D.C., 20460

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Water for the World

ZEEWEED® MEMBRANE BIOREACTOR WASTEWATER TREATMENT SYSTEM FOR WATERFORD, CA

1.5 MGD & 3.0 MGD (ADF) Design Capacity

Budgetary Proposal Number: 05-Rev1

Submitted to:

RMC Water and Environment

Attn: Brett T. Kawakami

Submitted by:

Zenon Environmental Corporation

3236 Dundas Street West
Oakville, ON
L6M 4B2

Ms. Jodi Smart
Regional Manager
Cell phone: 619-990-7987
Office phone: 760-547-2165
Email: jodic@zenon.com

Local Representation by:

Coombs-Hopkins Company

5411 Avenida Encinas, Suite 250
Carlsbad, CA
92008, USA

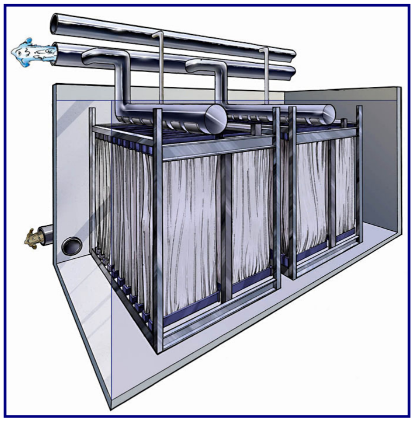
Mr. Mathew Rebmann

Cell Phone: 760-579-9411
Office Phone: 760-931-0555
Email: bruce@coombshopkins.com

December 14, 2005

1.0 THE ZEEWEED® MEMBRANE BIOREACTOR (MBR) SYSTEM

The ZeeWeed® MBR process is a ZENON technology that consists of a suspended growth biological reactor integrated with an ultrafiltration membrane system, using the ZeeWeed® hollow fiber membrane. Essentially, the ultrafiltration system replaces the solids separation function of secondary clarifiers and sand filters in a conventional activated sludge system.



ZeeWeed® ultrafiltration membranes are immersed in an aeration tank, in direct contact with mixed liquor. Through the use of a permeate pump, a vacuum is applied to a header connected to the membranes. The vacuum draws the treated water through the hollow fiber ultrafiltration membranes. Permeate is then directed to disinfection or discharge facilities. Intermittent airflow is introduced to the bottom of the membrane module, producing turbulence that scours the external surface of the hollow fibers. This scouring action transfers rejected solids away from the membrane surface.

ZeeWeed® MBR technology effectively overcomes the problems associated with poor settling of sludge in conventional activated sludge processes. ZeeWeed® MBR technology permits bioreactor operation with considerably higher mixed liquor solids concentrations than conventional activated sludge systems that are limited by sludge settling. The ZeeWeed® MBR process is typically operated at a mixed liquor suspended solids (MLSS) concentration in the range of 8,000 to 10,000 mg/L. Elevated biomass concentrations allow for highly effective removal of both soluble and particulate biodegradable material in the waste stream. The ZeeWeed® MBR process combines the unit operations of aeration, secondary clarification and filtration into a single process, producing a high quality effluent, simplifying operation and greatly reducing space requirements.

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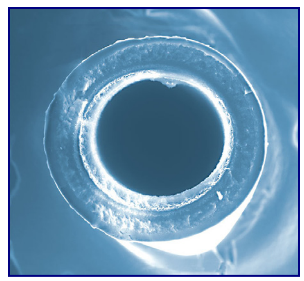
2.0 FEATURES & BENEFITS OF THE ZEEWEED® MBR SYSTEM

Experience

ZENON has over 20 years of MBR experience and has immersed ZeeWeed® MBR systems operating since 1993 ranging in size from a few thousand gallons per day to over 10 MGD of average day flow. ZENON's immersed membrane technology was originally developed for wastewater bioreactors and is ideally suited to such high solids applications. With over 220 wastewater installations globally, including numerous large scale installations and over ten years of operating experience of immersed MBR's, ZENON provides the security and assurance to our Clients of a proven and reliable membrane system.

Effluent Quality and Reuse Potential



Depending on the specific application and design requirements, a ZeeWeed® MBR plant can achieve either high quality nitrified effluent or, with the addition of an anoxic zone, high quality denitrified effluent. Phosphorus removal is readily achieved through biological means and/or the addition of metal salts to the feed wastewater or mixed liquor. High quality effluent from the ZeeWeed® MBR system meets California Title 22 and similar regulatory requirements and is ideally suited for reuse applications such as golf course and park land irrigation, aquifer recharge and urban reuse. ZeeWeed® MBR systems are capable of achieving the following effluent qualities.

BOD	< 5 mg/L
TSS	< 5 mg/L
TN	< 3 mg/L *Warm Climates* < 10 mg/L *Cool Climates*
TP	< 0.1 mg/L
Turbidity	< 1 NTU

The information provided in this section of the proposal is general and intended only to indicate what the ZeeWeed® MBR Membrane Wastewater Treatment Technology is capable of achieving. For the specific design treated wastewater qualities, based on the consideration of specific raw wastewater characteristics and the required discharge criteria for the treated effluent, refer to Section 3.0.

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Compact Plant

The ZeeWeed® MBR process typically operates at mixed liquor suspended solids (MLSS) concentrations in the range of 8,000 to 10,000 mg/L, which is substantially greater than conventional activated sludge processes. The increased MLSS concentration allows for conventional organic loading rates to be achieved with much lower hydraulic residence times. Compression of the wastewater treatment process into a single stage process results in an overall plant footprint substantially smaller than that of conventional tertiary wastewater treatment plants. Additionally, the compact footprint allows for the expansion of plant capacity within existing conventional plant basins in many instances.

Expandability

The ZeeWeed® MBR equipment is modular in nature and therefore allows for plant construction or expansion that can be completed in phases over the life of the facility. Civil works can be designed for ultimate flow while membranes are added in phases as plant operating capacity dictates.

ZeeWeed® is modular in nature; ideal for phased plant expansion.

Simple Operation

The ZeeWeed® MBR process uses membranes to perform solid/liquid separation, and therefore there is no requirement for sludge to settle. Thus there is no need for a secondary clarifier or polishing filters. Sludge is wasted directly from the aeration tank at a solids concentration in the range of 0.8 – 1.0 percent solids. The result is a single system, that is simple to operate.

Process Reliability

Since the ZeeWeed® MBR plant is typically operated at low organic loading rates, and the membrane provides a barrier to particulate discharge, ZeeWeed® MBR effluent quality is not susceptible to hydraulic or organic surges which can negatively affect effluent quality in conventional activated sludge and fixed film plants. At periods of low flow (and organic load), the sludge within the reactor basin simply digests itself without affecting the effluent quality.

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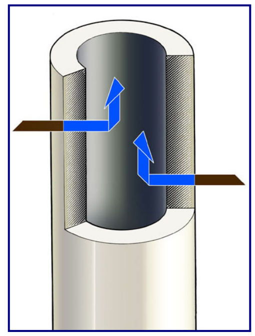
Resistance to Fouling



The ZeeWeed® membrane is an "Outside-In" membrane where the flow of water is from the outside of the membrane to the inside of the hollow fiber, meaning that the inside only sees clean, membrane-filtered water. The bacteria and inert solids removed from the wastewater remain outside the membrane and never enter the membrane to cause fouling.

Exceptional Membrane Durability

The ZeeWeed® membrane has been designed for exceptional durability and resistance to breakage. To achieve this high level of membrane durability ZENON utilizes a patented internal support to which the membrane is bonded. This support strengthens the membrane and protects it against tearing and breakage without reducing its flux capacity.

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3.0 PROPOSED SYSTEM DESIGN PARAMETERS

3.1 Design Flow

Design Flow	Option 1	Option 2
Average Daily Flow	1.5 MGD	3.0 MGD
Maximum Daily Flow	3.0 MGD	6.0 MGD
Peak Hourly Flow(See Note*)	4.5 MGD*	9.0 MGD*

Note: * The MBR membrane plant is designed with the membrane capacity for 4.0 MGD for option 1 and 7.2 MGD for option 2. The hydraulic capacity for the peak hourly flow is approximately 2 hours. The total equalization volumes are 42,000 and 150,000 US gallon for option 1 and option 2, respectively. These volumes will be accommodated in the bioreactor/separate tank by others.

3.2 Physical Parameters

Design Flow	Raw Water	Treated Water
Wastewater Temperature	15 – 25 °C	
BOD	275 mg/L	≤ 5 mg/L
TSS	205 mg/L	≤ 5 mg/L
NH_3-N	39 mg/L	≤ 1 mg/L
TKN	55 mg/L	n/a
Nitrate	n/a	≤ 10 mg/L
TP	10 mg/L	≤ 0.2 mg/L
Alkalinity (as $CaCO_3$)**	250 mg/L*	n/a
Turbidity	N/A	≤ 1.0 NTU

* Assumed values.
** Sufficient influent alkalinity is required to ensure proper pH level and performance of a biological treatment system to meet the treatment objectives. If the available feed water alkalinity is insufficient to meet the design requirements, alkalinity addition by others, may be required.

***Sufficient carbon source is required to ensure proper denitrification/nitrification performance of the biological treatment system. Insufficient carbon source in feed water may require methanol addition (by others) to ensure proper denitrification/nitrification treatment to meet TN effluent requirement.

3.3 Preliminary Process Design

Parameters	Option 1	Option 2	Unit
Total Anoxic Tank Volume*	248,200	485,400	US gallons
Total Aerobic Tank Volume*	375,200	779,400	US gallons
Total Membrane Tank Volume	76,700	140,800	US gallons
Total Volume	700,100	1,405,600	US gallons
HRT	9	9	Hours
SRT	16	16	Days
MLSS Concentration	8,000 - 10,000	8,000 - 10,000	mg/L
Estimated Sludge Production	36,100	72,100	US gal/day
Estimate Overall Bioreactors Footprint	115' x 45'	156' x 67'	ft L x W
Estimate Overall Membrane Trains Footprint	31' x 45'	38' x 67'	ft L x W
Estimate Overall Plant Footprint including Tanks, Equipments, and Facilities	195' x 50'	245' x 72'	ft L x W

* Equalization volumes stated in the design flow table are not included in the bioreactor volumes.

**Tank dimensions are preliminary only and may change slightly once final detail design commences. The system is designed for installation within concrete tanks (by others).

3.4 ZW-500D Ultrafiltration Membrane Cassettes

Design Flow	Option 1	Option 2
Membrane Design Flux	7.7 gfd at ADF 15.3 gfd at MDF 20.4 gfd at MDF @ N-1 20.4 gfd at PHF	8.4 gfd at ADF 16.7 gfd at MDF 20.1 gfd at MDF @ N-1 20.1 gfd at PHF
Number of Trains	4	6
Number of Cassettes Installed Per Train	3	4
Number of Cassettes Spaces Per Train	4	5
Number of Modules Per Cassette	48 in a 48-module cassette	44 in a 48-module cassette
Total Membrane Cassettes Installed	12	24
Total Spare Space	25 %	27 %

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4.0 COMMERCIAL

4.1 Scope of Supply

Membranes and Tankage Equipment

- Membrane Cassette Support Frames and Support Beams
- ZeeWeed® 500d Membrane Cassettes
- Permeate Collection Header Pipes – 316 SS
- Air Scour Distribution Header Pipes – 304 SS
- Process Tank Level Transmitters
- Process Tank Level Switches

Permeate Pump System Equipment

- Permeate Pumps, supplied loose, complete with required Isolation Valves
- Trans-Membrane Pressure Transmitters
- Permeate Pump Pressure Gauges
- Permeate Flowmeters
- Turbidimeters

Membrane Air Scour Blower Equipment

- Membrane Air Scour Blower Packages, supplied loose, complete with required Isolation Valves
- Membrane Air Scour Blower Flow Switches
- Membrane Air Scour Blower Pressure Gauges

Recirculation Pumping System

- Sludge Recirculation Pumps, supplied loose

Backpulse System

- Permeate Pumps also serve as Backpulse Pumps
- Backpulse Water Storage Tank(s)
- Backpulse Water Storage Tank Level Transmitter(s)
- Backpulse Tank Inlet Fill Valve(s)
- Backpulse Tanks Discharge Isolation Valve(s)

Membrane Cleaning Systems

- Sodium Hypochlorite Chemical Feed System, including
  Chemical Feed Pumps and Chemical Storage Tank
- Citric Acid Chemical Feed System, including
  Chemical Feed Pumps and Chemical Storage Tank

Electrical and Control Equipment

- PLC (Allen Bradley) with Touchscreen HMI

Miscellaneous

- Air Compressors for pneumatic valve operation
- Refrigerated Air Drier(s)

General

- General Arrangement and Layout Drawings
- Operator Training
- Operating & Maintenance Manuals
- Field Service and Process Start-up Assistance
- Equipment Delivery FCA Project Site
- Pro-Rated Membrane Warranty

4.2 Budgetary System Price

Design Flow	Option 1	Option 2
Average Daily Flow	1.5 MGD	3.0 MGD
Maximum Daily Flow	3.0 MGD	6.0 MGD
Peak Hourly Flow (See Note*)	4.5 MGD*	9.0 MGD*

Note: * The MBR membrane plant is designed with the membrane capacity for 4.0 MGD for option 1 and 7.2 MGD for option 2. The hydraulic capacity for the peak hourly flow is approximately 2 hours. The total equalization volumes for option 1 and 2 are 42,000 and 150,000 US gallon, respectively. These volumes will be accommodated in the bioreactor/separate tank by others.

Budgetary System Price:

Option 1	**$ 3,062,000.00 USD**
Option 2	**$ 4,760,000.00 USD**

The pricing herein is for budgetary purposes only and does not constitute an offer of sale. No sales, consumer use or other similar taxes or duties are included in the above pricing. Any such taxes and duties shall be for the account of the Purchaser. No Performance or Maintenance Bonds are included in the above pricing. Bonds can be provided on request but will be at additional cost.

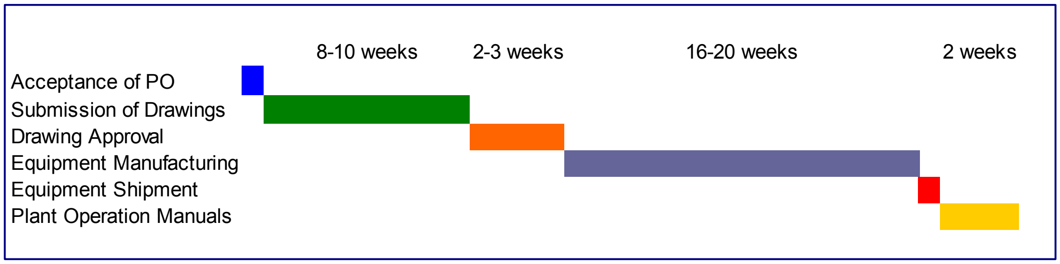
4.3 Payment Terms

The pricing quoted in this proposal is based on the following payment terms (all payments are net 30 days):

- 15% with Purchase Order;
- 25% on Submission of Shop Drawings;
- 50% on Shipment of Equipment (partial shipments permitted);
- 10% on Completion of Commissioning.

4.4 Equipment Shipment and Delivery

Typical Drawing Submission and Equipment Shipment Schedule



Operator training will occur when preferred by the Customer, but no later than 2 weeks prior to the scheduled plant start-up.

4.5 Standard Terms and Conditions

ZENON's Standard Terms and Conditions apply.

RMC Water and Environment

2868 Prospect Park Drive ▪ Suite 130 ▪ Rancho Cordova, CA, 95670 ▪ Phone: 916-273-1500 ▪ Fax: 916-273-1505