To the Reader: An Introduction to Report

This report is part of the response to the Regional Watershed Permit requirements. This report presents the results of the plant assessment and opportunities for nutrient reductions due to optimization and upgrades as well as the associated costs for nutrient removal. It is based on the findings of the site visit and the site visit report completed in 2015. It is important to note that the technologies identified in this evaluation for sidestream treatment and plant upgrades are meant to serve as placeholders to understand potential site requirements and costs, should they be needed. It is anticipated that each agency would do additional planning to refine recommended projects prior to implementation.

Regional Watershed Permit Overview:

Nutrients in the San Francisco Bay (SF Bay) are a growing concern for the Bay Area water quality community. Historically, the SF Bay has not been adversely impacted by nutrient loading, although there are indications that its historic resilience to the effects of nutrient enrichment may be weakening.[1,2] While the definition of impairment has not been reached, there is concern that the SF Bay has reached a tipping point that might lead to impairment. Numerous scientific studies are being conducted to understand the impact of nutrients on the SF Bay. As a result, it may be necessary to limit the availability of essential nutrients, by implementing some form of nutrient removal to address three potential challenges:

1. Ammonia toxicity and/or inhibition of phytoplankton growth. Full or partial nitrification may be required.
2. Eutrophication. Denitrification may be required where total inorganic nitrogen is the limiting nutrient.
3. Undesirable phytoplankton assemblage changes due to the ratio of nitrogen to phosphorus. Phosphorus reduction may be required.

On April 9, 2014, the Water Board issued Order No. R2-2014-0014, *Waste Discharge Requirements for Nutrients from Municipal Wastewater Discharges to San Francisco Bay* (Watershed Permit). The Watershed Permit sets forth a regional framework to facilitate collaboration on studies that will inform future management decisions and regulatory strategies. The permit includes four key elements for evaluating nutrient load reduction opportunities at POTWs (if supported by sound science):

1. Plant optimization
2. Sidestream treatment
3. Plant upgrades
4. Nutrient reduction by other means (including source control, natural treatment systems, diversion of effluent to water recycling, and others)

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[1] Cloern, J.E. and Jassby, A.D. (2012) Drivers of change in estuarine-coastal ecosystems: Discoveries from four decades of study in San Francisco Bay. Reviews of Geophysics, 50, RG4001, page 21.

[2] San Francisco Estuary Institute (SFEI) (2013) Nutrient Conceptual Model Draft, May 1, 2013, page 14. San Francisco Estuary Institute, Richmond, CA.

In response to the Watershed Permit, the POTWs are working collectively under the joint powers agency, Bay Area Clean Water Agencies (BACWA), to submit one coordinated study.

This plant report is part of the coordinated study, which includes analyses for 37 POTWs that discharge to SF Bay. This report has been prepared using an approach and underlying assumptions accepted by the Water Board as documented in the Scoping and Evaluation Plan (2015).

Bay Area Clean Water Agencies
Nutrient Reduction Study

City of San Leandro

San Leandro, CA

May 24, 2018
Final Report

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Executive Summary

The City of San Leandro operates the City of San Leandro Water Pollution Control Plant (SLWPCP) which discharges to South San Francisco Bay. The plant has an average dry weather flow (ADWF) permitted capacity of 7.6 million gallons per day (mgd).

A summary of the flows and loads for the current conditions, optimization, sidestream and upgrade strategies are presented in Table ES-1. Capital costs, operation and maintenance (O&M) costs and unit costs were developed for each strategy.

Table ES-1. Summary of Costs and Load Reductions

Parameter[1]	Unit[1]	Current Dry Season	Current Year Round	Opt. Dry Season[3]	Opt. Year Round[3]	Level 2 Dry Season[3]	Level 2 Year Round[3]	Level 3 Dry Season[3]	Level 3 Year Round[3]	Side-stream
Design Flow	mgd	--	--	4.8	5.2	7.6	8.1	7.6	8.1	--
Flow to Bay[2]	mgd	5.0	5.0	5.0	5.0	6.5	6.5	6.5	6.5	--
Nutrients to Bay (Average)[2]										
Ammonia	lb N/d	1,240	1,240	200	190	120	110	120	110	1,270
TN	lb N/d	1,240	1,240	1,040	970	690	650	520	320	1,300
TP	lb P/d	114	114	122	114	60	50	40	20	122
Costs[4,5]										
Capital	$ Mil	--	--	10.9	11.9	63	64	87	91	10.0
O&M PV	$ Mil	--	--	3.4	4.3	31	35	39	44	9.8
Total PV	$ Mil	--	--	14.3	16.2	94	99	126	135	19.8
Unit Costs[6]										
Capital	$/gpd	--	--	2.2	2.3	8.3	7.9	11.4	11.2	--
Total PV	$/gpd	--	--	3.0	3.1	12.4	12.2	16.5	16.6	--

1. mgd = million gallons per day; TN = Total Nitrogen; TP = Total Phosphorus; O&M = Operations and Maintenance; PV = Present Value.
2. The current flows and loads to the Bay are the average annual 2015 BACWA Nutrient Reduction Study Group Annual Report (data from 7/2012-6/2015). The reported flows and loads for optimization, upgrades, and sidestream represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization and 30-yr for upgrades and sidestream).
3. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round. The sidestream facilities are sized for a year round loads and operated year round.
4. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
5. PV is calculated based on a 2 percent discount rate for 30 years.
6. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.

The recommended optimization strategy to reduce nutrient loads in the plant effluent includes:

1. Implement chemically enhanced primary treatment (CEPT) to the primary clarifiers by adding metal salt and polymer chemical feed facilities.
2. Add alkalinity to the aeration basins (required for nitrification).
3. Operate the aeration basins in series to control solids distribution issues and facilitate nitrification. Additionally, the basins in series will operate in step feed mode to reduce solids loading on the secondary clarifiers and facilitate total nitrogen removal.
4. Add a blower to meet the additional demand associated with nitrification.

The SLWPCP is considered a candidate for sidestream treatment to reduce nitrogen loads as the plant anaerobically digests biosolids and dewaters to produce a return sidestream laden with nitrogen. The recommended sidestream treatment strategy is deammonification for reducing ammonia/nitrogen loads. The plant is also a candidate for sidestream treatment to reduce phosphorus loads by adding a metal salt upstream of the mechanical dewatering.

The upgrade strategies to achieve Levels 2 and 3 for the entire plant flow include:

1. Level 2 (15 mg TN-N/L and 1 mg TP-P/L):
    a. Implement chemically enhanced primary treatment (CEPT) to the primary clarifiers by adding metal salt and polymer chemical feed facilities.
    b. Add a parallel MBR treatment train.
    c. Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor to remove ammonia/total nitrogen/total phosphorus.
2. Level 3 (6 mg TN-N/L and 0.3 mg TP-P/L)
    a. Same as Level 2, plus:
    b. Add filters for denitrification and phosphorus removal.
    c. Add chemical feed facilities for an external carbon source to trim nitrogen at the MBR and denite filters.
    d. Add chemical feed facilities for metal salt addition for phosphorus removal.

As shown in Table ES-1, and as might be expected, the costs generally increase from optimization to sidestream treatment, and again to Level 2 and Level 3 upgrades, respectively. The costs generally increase for both capital and O&M from the dry season to year round. Overall the present value costs range from $14 Mil for dry season optimization up to $135 Mil for Level 3 year round upgrades. In addition to costs, the relative increase in greenhouse (GHG) emissions was also evaluated. In general, the GHG emissions showed an increase as the level of treatment increases.

1 Introduction

The City of San Leandro Water Pollution Control Plant (SLWPCP) discharges to discharges to Lower San Francisco Bay. It is located at 3000 Davis Street San Leandro, CA 94577, and it serves about 15,300 service connections throughout northern two-thirds of the City of San Leandro. The plant has average dry weather flow (ADWF) permitted capacity of 7.6 million gallons per day (mgd).

2 Current Conditions

The following subsections provide information on current conditions, including existing permit requirements and process, flows and loads, and on-going efforts related to nutrient load reduction.

2.1 Existing NPDES Permit

SLWPCP holds the National Pollutant Discharge Elimination System (NPDES) permit Order No. R2-2012-0004; CA0037869. SLWPCP shares the permit with other dischargers of the East Bay Dischargers Authority (EBDA). Table 2–1 provides a summary of the permit limitations for the San Leandro WPCP. Table 2–1 is not intended to provide a complete list of constituent limitations in the NPDES permit.

Table 2–1. NPDES Permit Limitations (Order No. R2-2012-0004; CA0037869)

Criteria[1]	Unit	Average Dry Weather	Average Monthly	Average Weekly	Maximum Daily
Flow	mgd	7.6	--	--	--
BOD	mg/L	--	25	40	--
TSS	mg/L	--	30	45	--
Total Ammonia, as N	mg/L	--	93	--	130

This table identifies relevant permit limitations only and does not include a complete list of permit limitations.

2.2 Process Flow Diagram

Figure 2-1 shows the process flow diagram for the SLWPCP. Both liquids processes and solids processes are shown. Treatment consists of a headworks, primary sedimentation, trickling filter, activated sludge, secondary clarification, and disinfection by sodium hypochlorite. Treated wastewater from the wastewater treatment facility is transported to EBDA's system for final dechlorination and discharge to the EBDA Common Outfall. The activated sludge process maintains a low SRT for secondary treatment. No major nutrient removal systems are currently in place. Sludge is anaerobically digested, dewatered using a belt filter press and further dried in open drying beds.

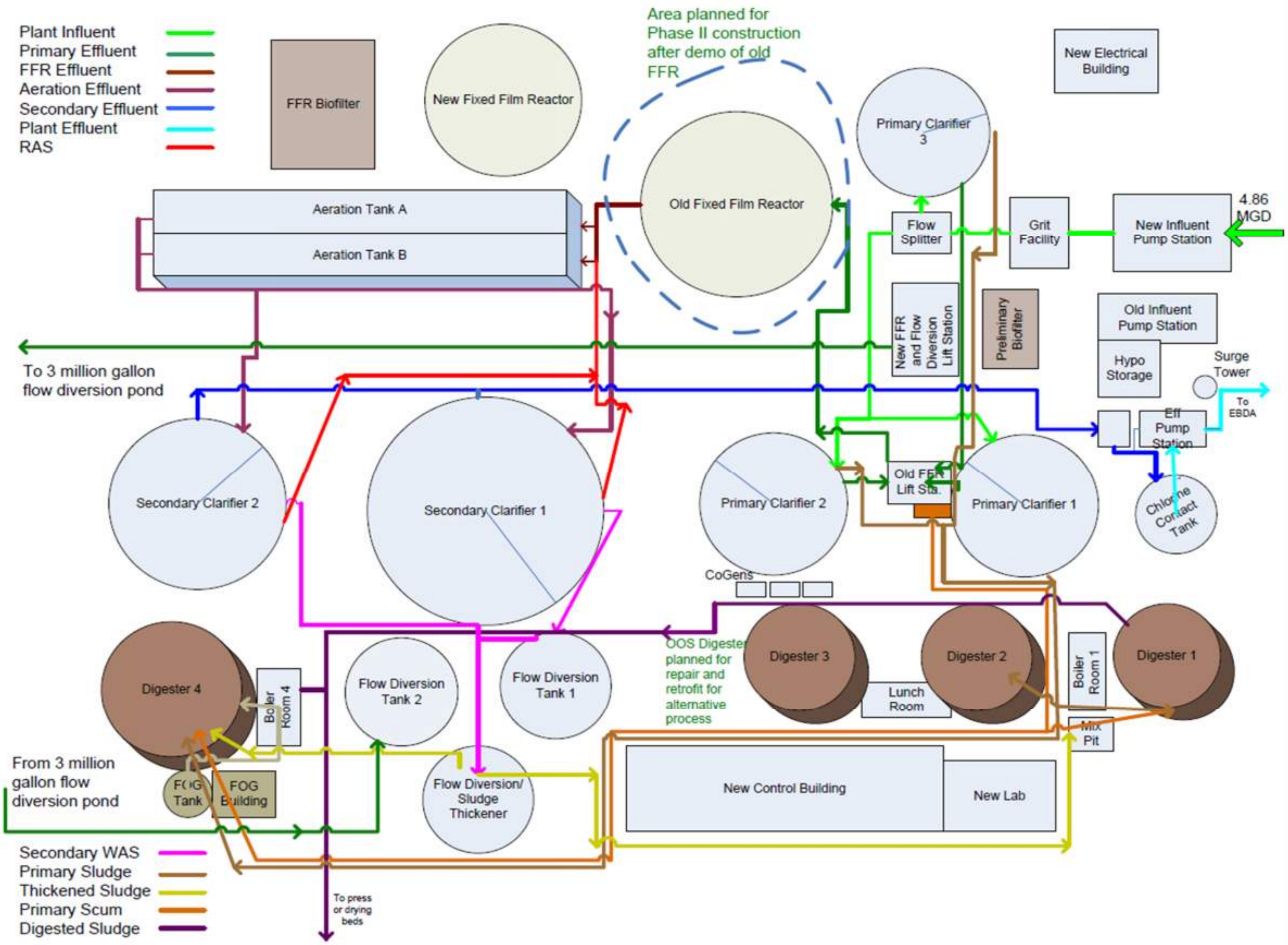

Figure 2-1. Process Flow Diagram for City of San Leandro Water Pollution Control Plant

2.3 Existing Flows and Loads

A data request was submitted to each POTW in December 2014 as a means to understand historical plant performance and identify plants that are candidates for sidestream treatment. A summary of the historical influent flows and loads for SLWPCP is shown in Table 2–2.

Table 2–2. Current Influent Flows and Loads (7/2011-6/2014)

Criteria	Unit	ADWF^{1,2}	Average Annual	Dry Season MM (May 1 – Sept 30)^{1,3}	Year Round MM^{1,3}
Flow	mgd	4.8	5.0	5.3	6.4
BOD	lb/d	22,200	21,900	25,000	29,100
TSS	lb/d	19,200	19,200	22,800	24,600
Ammonia	lb N/d	1,100	1,200	1,100	1,300
Total Kjeldahl Nitrogen (TKN)	lb N/d	2,100	2,300	2,100	2,500
Total Phosphorus (TP)	lb P/d	280	310	280	340
Alkalinity^4	lb $CaCO_3$/d	No Data	No Data	No Data	No Data
BOD	mg/L	549	521	570	549
TSS	mg/L	475	457	520	464
Ammonia	mg N/L	27	29	25	25
TKN	mg N/L	52	55	48	47
TP	mg P/L	6.9	7.4	6.4	6.4
Alkalinity^4	mg/L $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

2.4 Future Nutrient Removal Projects

The SLWPCP recently completed two projects that have the potential to impact nutrient removal:

1. In 2013, they installed a new high-efficiency turbo blower for the activated sludge aeration basin.
2. The flow equalization storage facility is in place and diurnal flow diversion tanks have started up which should support a more stable and reliable process.

2.5 Pilot Testing

The SLWPCP has not pilot tested any technologies to reduce nutrient discharge loads.

3 Basis of Analysis

The following subsections present the flow and loading conditions which were used as the basis for the optimization, sidestream treatment, and plant upgrades analyses, respectively. As described in the Scoping and Evaluation Plan[3], plant optimization strategies are based on each plant's documented plans for future growth through 2025, and where that information is unavailable, a 15 percent increase in loading was assumed as an allowance for growth for the 10 year horizon, with no increase in flows. Sidestream treatment and upgrades were developed based on permitted capacity.

3.1 Flow and Loading for Optimization Analysis

The flow and loading for optimizing the plant operation for nutrient removal is presented in Table 3–1 based on a nominal 15 percent increase in flow and loading by 2025. Any recommended modifications may impact the plant's future treatment capacity. Thus, any changes for optimization are considered an interim solution.

Table 3–1. Raw Influent Flow and Load for Optimization (Projected to Year 2025)

Criteria	Unit	ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30) [1,3]	Year Round MM[1,3]
Flow	mgd	4.8	5.0	5.3	6.4
BOD	lb/d	25,500	24,500	28,800	29,400
TSS	lb/d	22,100	22,100	26,200	28,300
Ammonia	lb N/d	1,300	1,400	1,300	1,500
TKN	lb N/d	2,400	2,600	2,400	2,900
TP	lb P/d	320	360	320	390
Alkalinity[4]	lb/d as $CaCO_3$	No Data	No Data	No Data	No Data
BOD	mg/L	631	583	656	555
TSS	mg/L	547	526	597	534
Ammonia	mg N/L	32	33	30	28
TKN	mg N/L	59	62	55	55
TP	mg P/L	7.9	8.6	7.3	7.4
Alkalinity[4]	mg/L as $CaCO_3$	No Data	No Data	No Data	No Data

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

3.2 Flow and Loading for Sidestream Treatment

Based on the data provided by SLWPCP, it was determined that the SLWPCP may be a candidate for sidestream treatment.

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[3] BACWA (2015). Potential Nutrient Reduction by Treatment Optimization and Treatment Upgrades, Scoping and Evaluation Plan. Submitted to the San Francisco Regional Water Quality Control Board, Oakland, CA.

Additional sampling for the sidestream was performed in July, 2015. The sampling results were projected forward to the permitted capacity for use in the sidestream treatment evaluation. The sidestream flows and loads for the permitted capacity are provided in Table 3–2. The permitted capacity flows and loads were used in the facility sizing.

Table 3–2. Flow and Load for Sidestream Treatment

Criteria	Unit	Current	Projected to Permitted Flow Capacity
Sidestream Flow	mgd	0.03	0.05
Ammonia	lb N/d	280	450
TKN	lb N/d	570	890
TN[1]	lb N/d	570	890
TP	lb P/d	90	140
OrthoP	lb P/d	20	30
Alkalinity	lb $CaCO_3$/d	1,400	2,200
Ammonia	mg N/L	1,150	1,150
TKN	mg N/L	2,300	2,300
TN[1]	mg N/L	2,300	2,300
TP	mg P/L	370	370
OrthoP	mg P/L	80	80
Alkalinity	mg/L as CaCO3	5,800	5,800

1. It was assumed that TKN = TN.

3.3 Flow and Loading for Facility Upgrades

The flow and loading for facility upgrades to meet Level 2 and Level 3 nutrient targets are based on the plant permitted capacity as ADWF. The other averaging period values were determined by applying the current flow and load peaking factors (PFs) to the plant permitted capacity. The flows and loading for facility upgrades are given in Table 3–3.

Table 3–3. Flow and Load for Facility Upgrades (Projected to Permitted Capacity)

Criteria	Unit	Permitted Flow Capacity, ADWF[1,2]	Annual Average	Dry Season MM (May 1 – Sept 30)[1,3]	Year Round MM[1,3]
Flow	mgd	7.6	7.9	8.2	10.0
BOD	lb/d	34,800	34,300	39,200	45,600
TSS	lb/d	30,100	30,100	35,800	38,600
Ammonia	lb N/d	1,700	1,900	1,700	2,100
TKN	lb N/d	3,300	3,600	3,300	3,900
TP	lb P/d	440	490	440	530
Alkalinity[4]	lb/d as $CaCO_3$	-	-	-	-
BOD	mg/L	549	521	570	549
TSS	mg/L	475	457	520	464
Ammonia	mg N/L	27	29	25	25
TKN	mg N/L	52	55	48	47
TP	mg P/L	6.9	7.4	6.4	6.4
Alkalinity[4]	mg/L as $CaCO_3$	-	-	-	-

1. ADWF = Average Dry Weather Flow and MM = Maximum Month.
2. ADWF is calculated as the average flow for the months of July, August, and September.
3. The dry season maximum month values are used to size facilities to treat dry season loads that operate year round; the year round maximum month values are used to treat year round loads that operate year round.
4. Alkalinity data not available.

3.4 Basis for Cost Analysis

The approach to developing the estimated capital and O&M costs for the optimization strategies and facilities upgrades was consistent for each of the 37 POTWs included in the study.

First, treatment options were analyzed to determine their feasibility and facility needs and the major process facilities were identified on a site plan to show their respective footprint and location. The need for additional major facilities such as pumping stations, significant transfer piping, chemical feed facilities, and blowers were identified and the footprint for these facilities was located on the site plan. Once the major facilities were defined, a parametric cost analysis was used to estimate the construction costs for each facility. Allowances were included for undefined facilities, site conditions, and contractor's costs and profit. An allowance for engineering, construction management, legal and other administrative costs was then applied to develop a total estimated capital cost. Appendix A presents the various allowances that were included to estimate the capital cost.

The O&M costs for power, chemicals, and labor were also estimated using a parametric cost analysis. Unit chemical costs were developed using information from the Bay Area Chemical Consortium (BACC). The same unit costs were used for all the BACWA treatment plants to simplify the analysis. See Appendix A for the unit costs used in the cost opinions.

The capital and O&M costs are presented in current dollars, referenced to the ENR SF CCI for November 2017 at 12,015. In order to understand the relative costs for each of the 37 POTWs included in the watershed permit, the capital and O&M costs were also expressed as unit costs:

- Unit capital cost per gallon ($/gpd) includes the capital cost for the treatment strategy to remove ammonia, nitrogen and phosphorus.

- Unit total present value cost per gallon ($/gpd) includes the present value capital and O&M costs for the treatment strategy to remove ammonia, nitrogen and phosphorus.
- Unit cost for TN and TP reductions ($ per pound nutrient removed) include both capital and O&M costs for the life of the project.
    - Unit costs for TN reduction were estimated based only on the cost elements that contribute to TN removal.
    - Unit costs for phosphorus reduction were estimated based on the cost elements needed to remove phosphorus.

The nutrient reduction is calculated based on the average removal over the life cycle period. The unit cost calculation is then based on the total present value (capital and O&M average over the project duration) divided by the average nutrient load reduction over the period. Table 3-4 shows the discount rate and period used for the different scenarios.

Table 3-4. Assumptions for Life Cycle Analysis

Scenario	Discount Rate	Period (yr)
Optimization	2%	10
Side Stream Treatment	2%	30
Level 2	2%	30
Level 3	2%	30

4 Nutrient Load Reduction by Optimization

This section describes the optimization strategies that were considered, and presents the effluent nutrient load and estimated costs for the recommended strategy.

Five optimization strategies were identified during the SLWPCP site visit. These were analyzed following the site visit to screen and select the most attractive strategy. In some cases, strategies were combined into one overall strategy to reduce both nitrogen and phosphorus effluent loads. The five optimization strategies were screened down to four strategies as follows.

- **Optimization Strategy 1:** Modify the primary clarifiers to operate as chemically enhanced primary treatment (CEPT) by adding ferric chloride and polymer.
    - ***Is it feasible?*** Yes
    - ***Potential impact on ability to reduce nutrient discharge loads?*** Remove phosphorus in the primaries and reduce overall loadings to downstream biological processes.
    - ***Result from analysis:*** It will remove phosphorus at the primaries and increase downstream capacity. The phosphorus load reduction is limited to the wet season as the facility is already removing phosphorus during the dry. It has the potential to remove more carbon than desired for future total nitrogen removal (if required in the future).
    - ***Recommendation:*** Carry forward.

- **Optimization Strategy 2:** Baseload flows to the fixed film reactors (FFRs) for nitrification
    - ***Is it feasible?*** Yes

  - ***Potential impact on ability to reduce nutrient discharge loads?*** Remove more nutrients in the process by keeping flows to the FFRs consistent.
  - ***Result from analysis:*** The nutrient removal benefits were marginal as the FFRs are heavily loaded.
  - ***Recommendation:*** Do not carry forward.

- **Optimization Strategy 3:** Operate the aeration basins in series to control solids distribution issues between the two basins and to facilitate ammonia and total nitrogen removal. The first train would be retrofitted to operate as an anoxic zone.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy could successfully reduce the year round ammonia/total nitrogen discharge load.
  - ***Result from analysis:*** This strategy will address solids distribution between the two trains and assist with ammonia/total nitrogen load reduction. An extra blower is required to meet the additional demand associated with nitrification. The extent of total nitrogen load reduction will depend on the return activated sludge pumping rate. There are concerns with the secondary clarifiers to handle additional solids loading.
  - ***Recommendation:*** Carry forward.

- **Optimization Strategy 4:** Operate the aeration basins in step feed mode to reduce solids loading on the secondary clarifiers and enhance total nitrogen load reduction. This strategy is predicated on implementation of Optimization Strategy 3.
  - ***Is it feasible?*** Yes
  - ***Potential impact on ability to reduce nutrient discharge loads?*** This strategy could successfully reduce the year round total nitrogen discharge load.
  - ***Result from analysis:*** This strategy would reduce solids loading on the secondary clarifiers to a level that would not require additional secondaries. Additionally, this strategy builds upon the total nitrogen load reduction in Strategy 3. The extent of total nitrogen load reduction beyond Strategy 3 will depend upon the step feed distribution and would require additional analysis.
  - ***Recommendation:*** Carry forward.

Strategies 1, 3, and 4 could reduce ammonia, total nitrogen, and total phosphorus loads. The recommended strategies are shown with the process flow diagram presented in Figure 4-1. A description of each strategy and the evaluation results are presented thereafter. It is noted, however, that recommended modifications for optimization may impact the plant’s treatment capacity. Thus, any changes for optimization should be considered an interim solution.

The capital and operational elements of the recommended optimization strategies are shown in Table 4-1.

Table 4-1. Optimization Strategy Project Elements

Capital Elements	Operating Elements
Implement chemically enhanced primary treatment (CEPT) • Add metal salt chemical feed facilities • Add polymer chemical feed facilities	• Operate the chemical feed facilities
Operate the aeration basins in series • Replace the existing aeration basin overflow pipes layout. The pipes would most likely require replacement due to corrosion • Modify a portion of the first train to operate as an anoxic zone • Add a blower to meet the additional demand associated with nitrification	• Operate in a new mode that the operations staff will need to get accustomed to • Maintain the additional blower
Operate the aeration basins in step feed mode • Add additional piping to facilitate feeding the aeration basins along the length	• Operate in a new mode that the operations staff will need to get accustomed to

Table 4-2 presents the estimated effluent nutrient loads for the optimization strategy as previously described. The values presented for the current discharge loads and the discharge loads after optimization represent the average for the period between 2016 and 2025.

Table 4-2. Projected Discharge Nitrogen and Phosphorus Loads for Optimization

Parameter	Units	NH4-N Dry Season	NH4-N Year Round	TN Dry Season	TN Year Round	TP Dry Season	TP Year Round
Current Discharge[1]	lb N or P/d	1,340	1,340	1,340	1,340	122	122
Discharge with Opt. Strategy[1]	lb N or P/d	200	190	1,040	970	122	114
Load Reduction[2]	lb N or P/d	1,140	1,150	300	370	0	8
Load Reduction[2]	%	85%	86%	23%	28%	0%	7%
Annual Load Reduction	lb N or P/yr	416,000	420,000	110,000	134,000	0	2,900

1. The loads represent average projected loads discharged to the Bay for the period of analysis (10-yr for optimization).
2. As compared to Current Discharge (Note 1).
3. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.

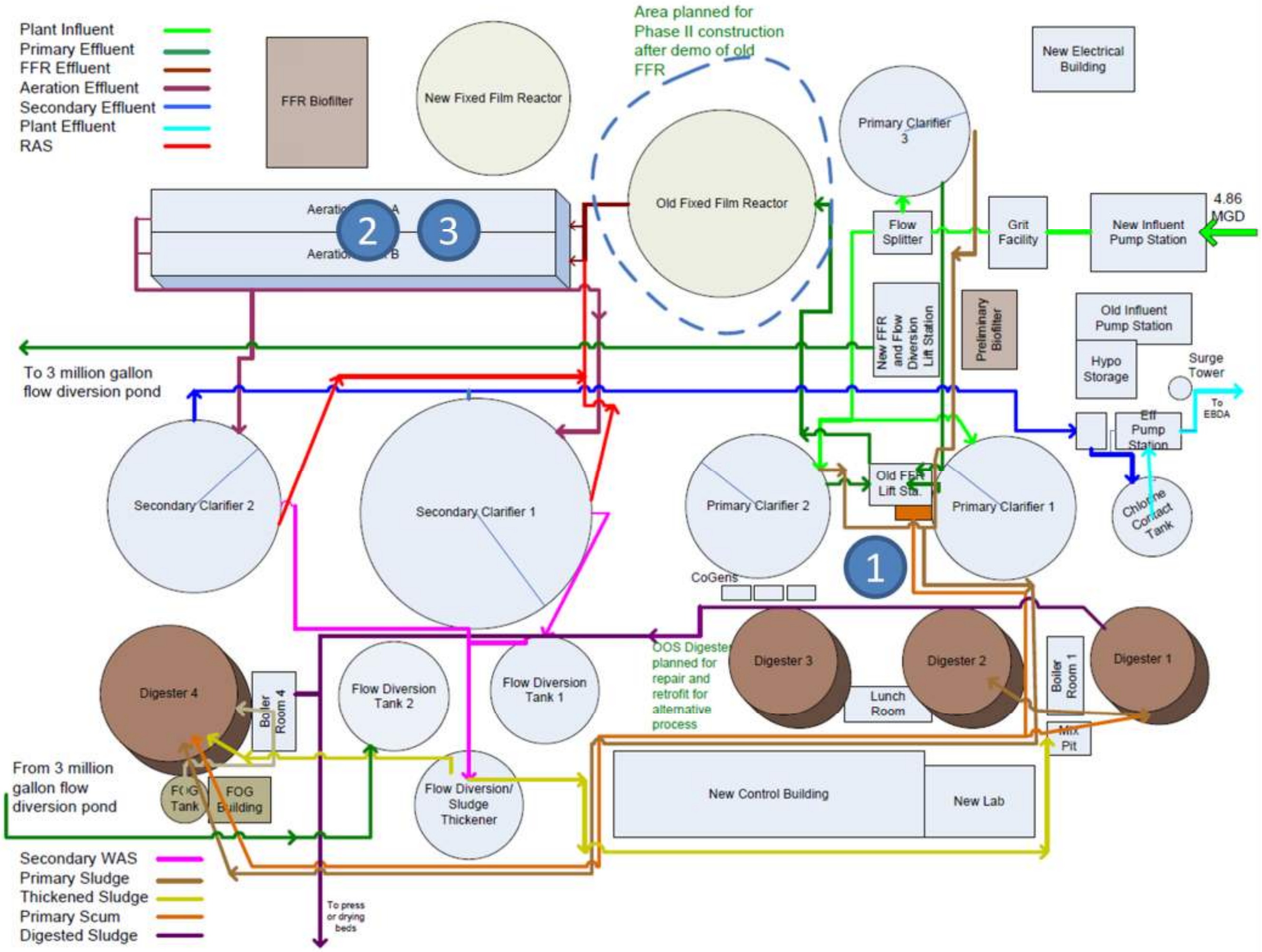

Figure 4-1. Optimization Concepts Considered for SLWPCP

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) operate the aeration basins in series and add an anoxic zone and blower, and (3) provide piping/pumping to operate in step feed mode (requires implementation of concept (2))

The estimated capital and O&M costs for the recommended optimization strategy are presented in Table 4-3 for the average flows during 2016-2025. In addition, the estimated costs per pound of nutrient removed are presented in Table 4-3. These unit costs are estimated based on the cost of the elements needed to reduce nitrogen or phosphorus, respectively.

Table 4-3. Projected Costs and Nutrient Unit Costs for Optimization Strategy

Parameter	Units	Dry Season[1]	Year Round[1]
Design Flow	mgd	4.8	5.2
Ammonia, TN and TP Removal			
Capital[2]	$ Mil	10.9	11.9
Annual O&M	$ Mil/yr	0.3	0.4
Present Value O&M[3]	$ Mil	3.4	4.3
Present Value Total[3]	$ Mil	14.3	16.2
Unit Capital Cost[8]	$/gpd	2.2	2.3
Unit Total PV Cost[8]	$/gpd	2.9	3.1
TN Removal			
Capital[2,4]	$ Mil	10.0	10.9
Annual O&M[4]	$ Mil/yr	0.2	0.3
O&M PV[3,4]	$ Mil	2.4	3.3
Total PV[3,4]	$ Mil	12.4	14.2
TN Removed (Ave.)[6]	lb N/d	300	370
Annual TN Removed (Ave.)[7]	lb N/yr	110,000	134,000
TN Cost[4,9]	$/lb N	11	11
TP Removal			
Capital[2,5]	$ Mil	2.0	2.0
Annual O&M[5]	$ Mil/yr	0.2	0.2
O&M PV[3,5]	$ Mil	1.6	1.8
Total PV[3,5]	$ Mil	3.6	3.8
TP Removed (Ave.)[6]	lb P/d	--**	8
Annual TP Removed (Ave.)[7]	lb P/yr	--**	2,900
TP Cost[5,9]	$/lb P	--**	130

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for nitrogen removal only.
5. Based on cost for phosphorus removal only.
6. The average daily nutrient load reduction over the 10-year project duration.
7. The average annual load reduction over the 10-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost was calculated by dividing the capital or total present value by the design flow.
9. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 10-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 10-years)).

** The optimization strategy will not reduce total phosphorus loads during the dry. Rather, it will improve the load reduction reliability.

Table 4-4 presents a list of the ancillary benefits and impacts associated with the optimization strategies at SLWPCP.

Table 4-4. Ancillary Benefits and Impacts for the Optimization Strategies

Benefits	Adverse Impacts
Add CEPT • Ability to reduce total phosphorus discharge loads • Increased capacity in the FFRs and activated sludge process • Increased solids/organics diverted to the digesters, which translates to increased biogas production	• Additional chemicals to handle • Carbon management issues for meeting low level total nitrogen discharge limits (if required in the future)
Operate Aeration Basins in Series • Ability to reduce ammonia/total nitrogen loads	• Changed mode of operation • Most likely requires alkalinity • Additional loading on the secondary clarifiers • Additional energy demand associated with extra blower
Operate Aeration Basins in Step Feed Mode • Ability to further reduce total nitrogen loads (predicated on implementation of operating aeration basins in series) • Alkalinity recovery • Reduce solids loading on the secondaries compared to operating in non-step feed mode	• Changed mode of operation that requires operator input on step feed distribution • Occasionally bleed ammonia if step feed is not appropriately distributed between the in series trains

5 Sidestream Treatment

As previously described, the SLWPCP was identified as a potential candidate for sidestream treatment. The plant currently uses belt filter presses followed by drying beds.

A questionnaire was included with the July 2015 sidestream sampling to better understand the biosolids operations (e.g., days of week that dewatering is operated). Based on the questionnaire and sampling results, a deammonification sidestream treatment technology is recommended for ammonia and total nitrogen load reduction and metal salts/solids separation facilities for total phosphorus load reduction.

Deammonification is an innovative technology that is well suited for treating wastewater with a typical sidestream composition of high ammonia, alkalinity to allow 50 percent nitrification, and warm temperature. It also offers several benefits over conventional nitrogen removal (i.e., nitrification/denitrification) including requiring 60 percent less oxygen than conventional nitrification, elimination of organic carbon demand for nitrogen removal, and requires 50 percent less alkalinity than conventional nitrification. Based on these benefits, deammonification is recommended for the SLWPCP.

The removal of total phosphorus from the sidestream relies upon metal salt and subsequent solids separation. The most common metal salts are alum and ferric chloride. Ferric chloride offers the advantage over alum in that it also assists with odor control and dewaterability. Given that most sidestreams are returned to the potentially odorous headworks the use of ferric chloride is recommended. The solids separation can occur in a stand-alone sidestream tank, simultaneous with dewatering solids separation, or in a main stream sedimentation tank (e.g., primary clarifier if sidestream returned to the headworks). In the case of the SLWPCP, ferric chloride addition ahead of the dewatering is recommended where the precipitated phosphorus will be captured with the cake.

Recovery of the total phosphorus sidestream load via struvite precipitation is another option to eliminate the phosphorus recycle stream loads. This process produces a useful byproduct (struvite crystals) that can be sold economically. Chemical addition is typically simpler and easier for plants to implement. Plants are encouraged to evaluate the technical and economic feasibility to implement phosphorus recovery by struvite formation at their plant as an alternative to chemical phosphorus recycle load control.

A list of the facility needs for sidestream treatment is provided in Table 5-1.

Table 5-1. Sidestream Treatment Facility Needs for Ammonia/TN or TP Load Reduction

Ammonia/TN Load Reduction Elements	TP Load Reduction Elements
Feed Pumping (if necessary)	Metal Salt Chemical Feed Facility
Feed Flow Equalization	--
Pre-Treatment Screens	--
Biological Reactor	--
Aeration Supply Equipment	--
Effluent Pumping (if necessary)	--

Table 5-2 presents the estimated nutrient load reductions based on the sidestream treatment described in Table 5-1. The current and permitted capacity with sidestream treatment uses the additional sampling from July 2015 to determine the effluent levels.

Table 5-2. Projected Effluent Annual Average Nutrient Discharge

Parameter	Units	NH4-N (lb N/d)	TN (lb N/d)	TP (lb P/d)
Current Discharge[1]	lb/d	1,600	1,600	146
Discharge with Sidestream Treatment[2]	lb/d	1,270	1,300	122
Load Reduction[3]	lb/d	330	300	24
Load Reduction	%	21%	18%	17%
Annual Load Reduction	lb/yr	119,700	106,400	8,800

1. The loads represent average projected loads discharged to the Bay for the period of analysis (30-yr for sidestream).
2. As compared to Current Discharge (Note 1).
3. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.

The estimated capital and O&M costs for the recommended sidestream treatment upgrade are presented in Table 5-3. In addition, the estimated cost per pound of nutrient removed is presented in Table 5-3. These unit costs are estimated based on the cost of the elements needed to reduce ammonia, nitrogen, or phosphorus, respectively.

Table 5-3. Projected Costs and Nutrient Unit Costs for Sidestream Treatment

Parameter	Units	Ammonia/TN	TP
Capital[1]	$ Mil	9.9	0.10
Annual O&M	$ Mil/yr	0.42	0.02
Total Present Value[2]	$ Mil	19.3	0.48
NH4-N Load Reduction[3,5]	lb N/yr	119,700	--
TN Load Reduction[3,5]	lb N/yr	106,400	--
TP Load Reduction[4,5]	lb P/yr	--	8,800
NH4-N Cost [3,5,6]	$/lb N	5.4	--
TN Cost [3,5,6]	$/lb N	6.0	--
TP Cost [4,5,6]	$/lb P	--	1.8

1. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes.
2. PV is calculated based on a 2 percent discount rate for 30 years.
3. Based on cost for ammonia/nitrogen removal only.
4. Based on cost for phosphorus removal only.
5. Based on the average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
6. The unit load reduction cost was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

6 Nutrient Reduction Upgrades

There are several technologies that could be applied at the SLWPCP to meet the Level 2 and Level 3 nutrient removal targets. The general approach taken was to consider Level 3 nutrient removal as a potential endpoint for all facilities. The intent is to avoid situations where the recommended facilities to meet Level 2 would require the construction of facilities that would be stranded in a future upgrade to meet Level 3.

The technologies selected for this evaluation represent established technologies that are appropriate for determining planning level costs and space requirements. SLWPCP should evaluate other available technologies that may be available and applicable if nutrient reduction becomes a requirement in the future.

6.1 Plant Upgrades to Meet Level 2

The technology upgrades considered to meet the Level 2 discharge requirements build on those presented under the Optimization Section. The process flow diagram for Level 2 upgrades is presented in Figure 6-1. As shown, metal salt and polymer chemical feed facilities would be added at the primaries to operate in CEPT for reducing the downstream facility needs (similar to Optimization Concept). A parallel MBR would be constructed in the area where the current old fixed film reactor is located. The existing aeration basins would be modified to operate as a biological nutrient removal (BNR) reactor. In order to do this, the reactors would be operated in series (similar to the optimization concept) plus there would be anaerobic/anoxic zones fully outfitted with the appropriate mixed liquor return pumping between the zones. Other process improvement technologies to consider include IFAS (integrated fixed film activated sludge) and moving bed bioreactor (MBBR).

6.2 Plant Upgrades to Meet Level 3

The technology upgrades considered to meet the Level 3 discharge requirements are shown with the process flow diagram presented in Figure 6-2. Level 3 upgrades would expand upon those listed for Level 2.

In addition to those listed for Level 2, Level 3 upgrades requires an external carbon source chemical feed facility, alum/polymer chemical feed facilities at newly constructed filters, a rapid mix/flocculation tank upstream of the filters, and new filters for nitrogen and phosphorus removal. The external carbon source is provided to meet the carbon requirements for meeting the TN discharge target. The chemical feed facilities and the rapid mix/flocculation step prior to the filters is in place to remove solids loading associated with chemical precipitation upstream of the filters. The additional chemical feed facilities would operate on a daily basis to meet the TP discharge target.

6.3 Facility Needs to Meet Level 2 and 3

A list of the facility needs to meet the Level 2 and 3 effluent limits are provided in Table 6-1. Aerial layouts for the key Level 2 and 3 facilities during both dry season and year round are shown in Figure 6-1 and Figure 6-2, respectively.

Table 6-1. Facility Needs Overview for Level 2 and 3 Plant Upgrades

Treatment	Level 2	Level 3
Primary	Implement chemically enhanced primary treatment (CEPT): • Add metal salt chemical feed facilities • Add polymer chemical feed facilities	Same as Level 2
Biological	• Parallel MBR • Retrofit the aeration basins to operate as a BNR reactor to achieve ammonia/total nitrogen/total phosphorus load reduction	Same as Level 2, plus: • External Carbon Source Chemical Feed Facility for MBR
Tertiary	--	• Denitrification and phosphorus removal filters to reduce load from the parallel MBR facilities • Add an external carbon source chemical feed facilities • Add a metal salt chemical feed facilities

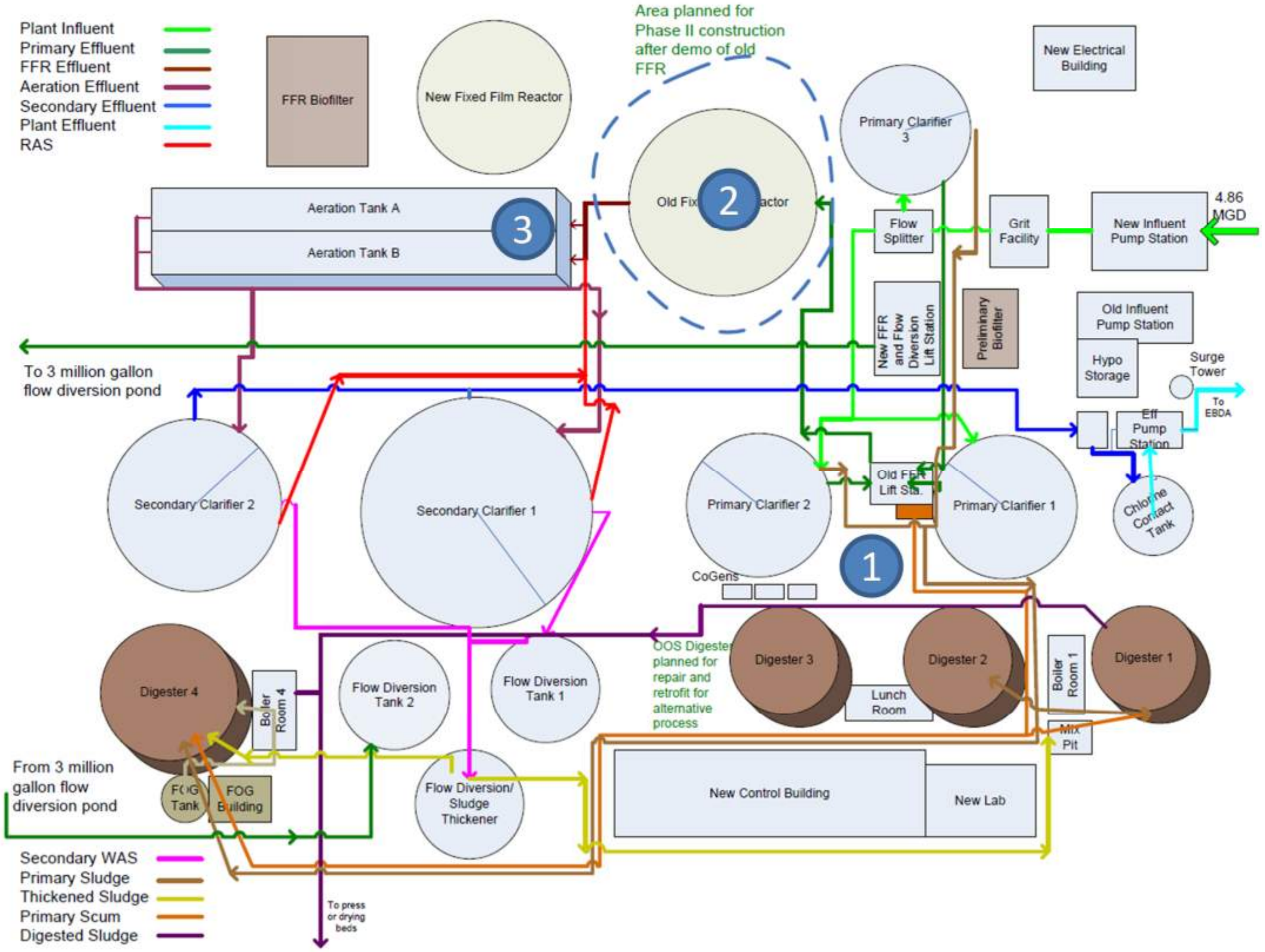

Figure 6-1. Level 2 Upgrade Concepts for SLWPCP

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor

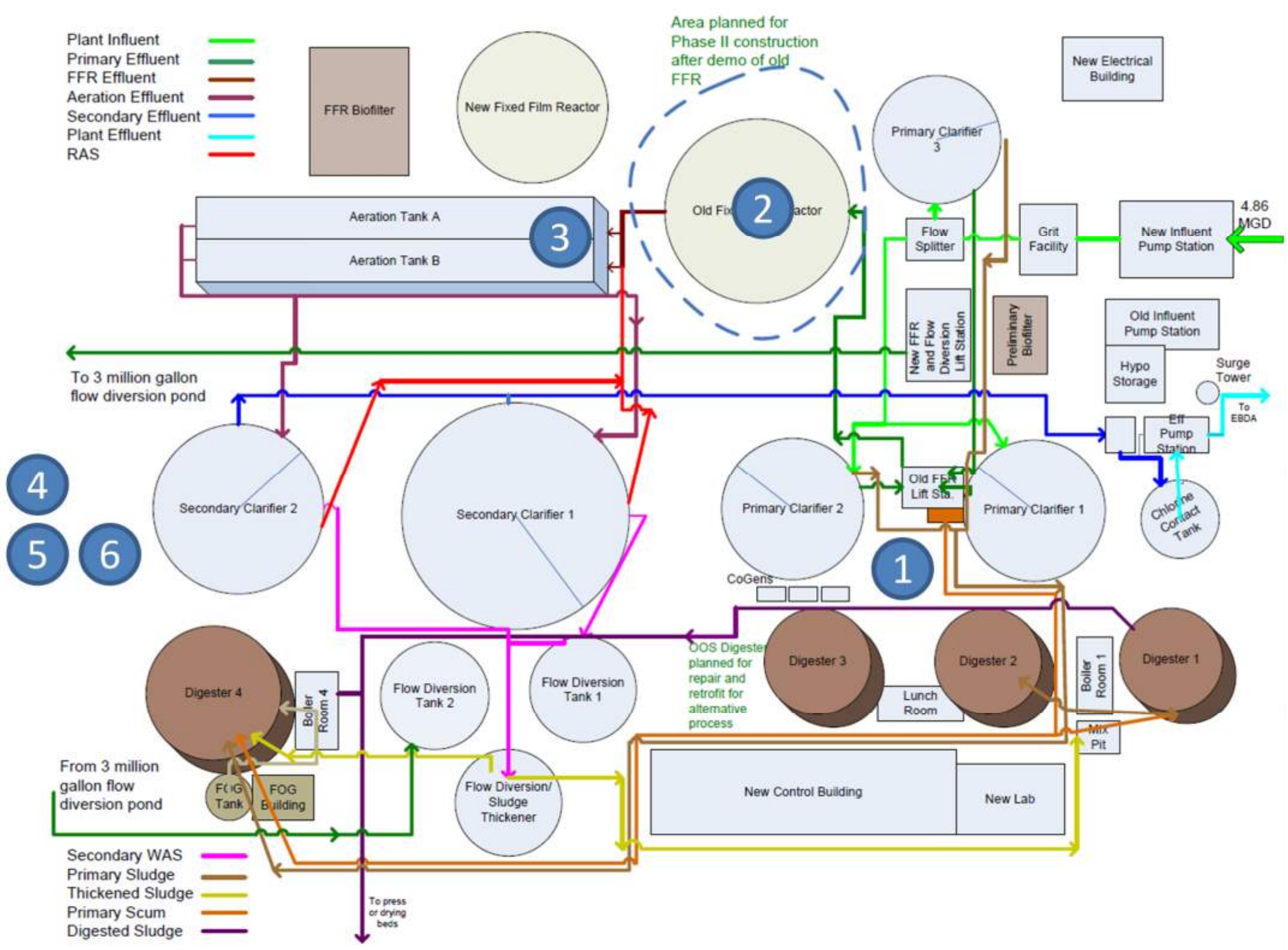

Figure 6-2. Level 3 Upgrade Concepts for SLWPCP

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor (4), add filters for denitrification and P removal (5) metal salt facilities for P removal (6) add external carbon source chemical feed facilities for MBR and denite filters

Figure 6-3. Level 2 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor

Figure 6-4. Level 3 Upgrade Aerial Layouts for Dry Season and Year Round

(1) Add metal salt and polymer chemical feed facilities to primaries for operating in CEPT mode, (2) add a parallel treatment MBR, (3) Retrofit the aeration basins to operate as a biological nutrient removal (BNR) reactor, (4) add filters for denitrification and P removal (5) ferric facilities for P removal (6) add external carbon source chemical feed facilities for MBR and denite filters

6.4 Project Costs for Levels 2 and 3 Upgrades

The estimated capital and O&M costs for the upgrades to meet the Level 2 and Level 3 effluent limits are summarized in Table 6-2. Operating costs represent the average cost for the 30-year period.

Table 6-2. Estimated Capital and O&M Costs for Nitrogen and Phosphorus Plant Upgrades

Parameter	Unit	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]
Design Flow	mgd	7.6	8.1	7.6	8.1
Cost for Ammonia, TN, and TP Removal					
Capital[2]	$ Mil	63	64	87	91
Annual O&M	$Mil/yr	1.4	1.6	1.7	2.0
O&M PV[3]	$ Mil	31	35	39	44
Total PV[3]	$ Mil	94	99	126	135
Unit Capital Cost	$/gpd	8.3	7.9	11.4	11.2
Unit Total PV	$/gpd	12.4	12.2	16.5	16.6
TN Removal					
Capital[2,4]	$ Mil	62	63	86	90
Annual O&M[4]	$ Mil/yr	1.3	1.5	1.6	1.9
O&M PV[3,4]	$ Mil	30	34	37	42
Total PV[3,4]	$ Mil	92	97	123	131
TN Removed (Ave.)[6]	lb N/d	910	950	1,080	1,270
Annual TN Removed (Ave.)[7]	lb N/yr	331,000	347,000	395,000	465,000
TN Cost[4,8]	$/lb N	9.2	9.3	10.4	9.4
TP Removal					
Capital[2,5]	$ Mil	43	43	65	69
Annual O&M[5]	$ Mil/yr	1.3	1.4	1.4	1.5
O&M PV[3,5]	$ Mil	29	31	32	34
Total PV[3,5]	$ Mil	71	74	98	103
TP Removed (Ave.)[6]	lb P/d	88	92	107	130
Annual TP Removed (Ave.)[7]	lb P/yr	32,000	33,000	39,000	47,000
TP Cost[5,8]	$/lb P	74	73	83	73

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. Costs are referenced to the ENR SF CCI for November 2017 at 12,015. Costs do not include changes in solids handling or changes in energy requirements in other unit processes. Level 3 costs are inclusive of facilities needed to meet Level 2.
3. PV is calculated based on a 2 percent discount rate for 30 years.
4. Based on cost for ammonia/nitrogen removal only
5. Based on cost for phosphorus removal only
6. The average daily nutrient load reduction over the 30-year project duration.
7. The average annual load reduction over the 30-year project duration. The calculation considers days with no discharge.
8. The unit load reduction cost ($/lb) was calculated by dividing the total present value for the nutrient of interest by the nutrient load reduction over the 30-year projection duration (e.g., Total PV for TN Removal divided by (Annual TN Removed times 30-years)).

Nutrient reduction is also calculated as the average of the 30 year life cycle analysis, based on projected nutrient discharge loads under current operation versus the nutrient discharge when meeting Levels 2 and 3. Unit costs (e.g., $/gpd) are also provided to present a normalized estimate of the cost for comparison to other facilities. The unit costs include only the respective facilities and costs needed to address ammonia, TN or TP reductions.

6.5 Ancillary Benefits and Impacts for the Plant Upgrades

Table 6-3 lists the ancillary benefits and impacts associated with the recommended plant upgrades to meet the Level 2 and Level 3 nutrient targets.

Table 6-3. Ancillary Impacts for the Upgrades to Meet Levels 2 and 3

Strategy	Benefits	Adverse Impacts
Level 2	• Additional primary clarifiers capacity • Enhanced phosphorus and nitrogen load reduction • MBR produces higher quality product water than current facilities	• Increased energy demand from MBR • Additional process to operate • Operate in a new mode that will require the operators to get accustomed to
Level 3	Same as Level 2 plus the following additional benefits: • Further alkalinity recovery due to more denitrification than the other Levels • Further improved product water due to filtration step	Same as Level 2 plus the following additional adverse impacts: • More chemicals required than Level 2 • Additional solids • Safety from external carbon source (if methanol) • Additional aeration basin volume to operate • Operating an additional biological process (i.e., sidestream treatment)

7 Nutrient Load Reduction by Other Means

The SLWPCP has an existing recycled water program that is employed year-round. This existing program has the effect of reducing nutrients discharged to the Bay. The plant recycles approximately 570 acre-feet per year (185 million gallons per year). There are plans to further expand the recycled water program up to approximately 710 acre-feet per year (230 million gallons per year).

8 Greenhouse Gas Emissions

The impact of any proposed unit processes on greenhouse gas (GHG) emissions is a requirement under the Regional Watershed Permit. The permit GHG emissions requirements are not intended to be a plantwide GHG emissions with indirect and direct emissions reporting. Rather, the intent is to identify potential changes in potential energy and chemical demands if plants transitioned from secondary treatment to nutrient removal. It is well documented that transitioning from secondary treatment to advanced treatment with nutrient removal will most likely increase the plant wide GHG emissions. The increase is attributed to a combination of additional energy required to oxidize and reduce the various nitrogen species, filtration requirements, chemical demands for alkalinity and phosphorus precipitation, and others.

The increase in energy, chemicals, and GHG emissions while transitioning from secondary treatment to nutrient targets is plant specific due to varying water characteristics, technology selection, chemical type, fuel type (e.g., coal versus natural gas), location, and others. Research by Falk et al. (2013) is presented in Figure 8-1 that illustrates the potential plant wide increase in GHG emissions at variable nutrient targets for a nominal 10 mgd plant. Target 1 represents secondary treatment and Targets 2 through 5 represent variable nutrient targets with Target 5 being the most stringent. The BACWA Level 2 targets lie somewhere between Targets 1 and 2, and the BACWA Level 3 is comparable to Target 3. The gradual increase in GHG emissions in Falk et al. (2013) from Target 1 to the higher levels is attributed to additional biological treatment facilities, increased energy and chemical use, and additional tertiary nitrogen and phosphorus removal processes. The study findings revealed that a point of diminishing return is reached as nutrient removal objectives approach the technology-best achievable performance where GHG emissions increase rapidly, cost of treatment increase rapidly, while the potential for algal growth reduce marginally. Note, the point of diminishing returns is watershed specific.

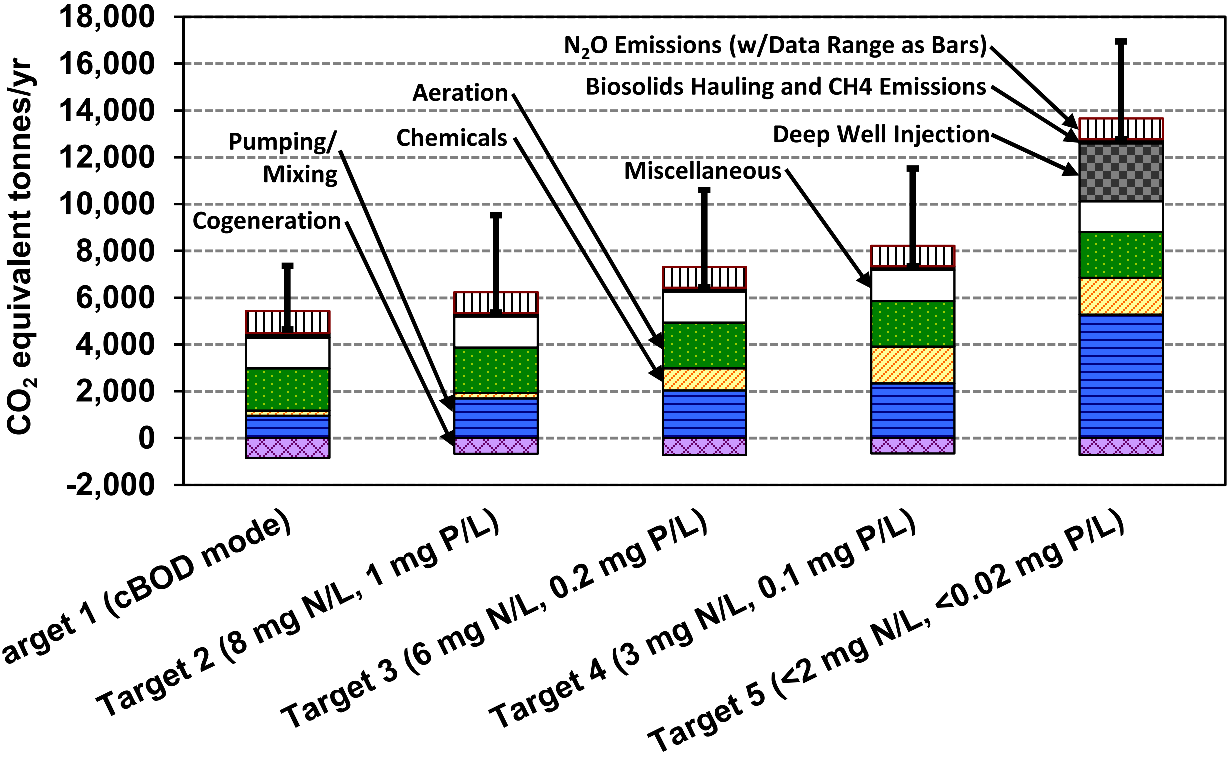

Figure 8-1. GHG Emissions Distribution for a Nominal 10 mgd Plant at Various Treatment Targets (Adapted from Falk et al., 2013)

The GHG emissions evaluation for the Regional Watershed Permit is not intended to be plant-wide study. Rather, the evaluation focuses on the relative increase in GHG emissions associated with any recommended plant optimization and/or upgrade strategies (e.g., additional oxygen demand associated with nitrification).

The GHG emissions accounting focuses on the operating energy and chemical demand for the recommended plant optimization and/or upgrade strategies. The approach relies on the USEPA eGRID values[4] for the regional energy production and the GHG emissions associated with chemical

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[4] http://www.epa.gov/cleanenergy/energy-resources/egrid/

mining/fabrication. For example, converting energy demand to GHG emissions is based on additional energy demand (kWh/yr) associated with plant optimization and/or upgrade strategies, followed by a conversion from energy to GHG emissions. The process and fugitive emissions associated with nitrous oxide emissions were not quantified. It is anticipated that nitrous oxide emissions would increase as a plant transitions from secondary treatment to nitrogen removal due to cycling between oxic and anoxic conditions.

A summary of the relative change in GHG emissions with respect to current emissions is provided in Table 8-1. In general, the GHG emissions increase with more advanced treatment which is in-line with the trends presented in Figure 8-1. Energy is the predominant contributor to GHG emissions, regardless of treatment level. The increase in GHG emissions associated with the most stringent Level 3 targets is primarily due to additional energy required to reduce both TN and TP, compounded with additional chemicals.

Table 8-1. Projected Greenhouse Gas Emissions

Parameter	Unit	Optimization Dry Season[1]	Optimization Year Round[1]	Level 2 Dry Season[1]	Level 2 Year Round[1]	Level 3 Dry Season[1]	Level 3 Year Round[1]	Sidestream Year Round
GHG Emissions Increase from Energy	MT CO_2/yr	570	610	1,650	1,760	1,680	1,800	44
GHG Emissions Increase from Chemicals	MT CO_2/yr	50	50	20	30	340	360	1
GHG Emissions Increase Total	MT CO_2/yr	620	660	1,680	1,790	2,020	2,150	45
Unit GHG Emissions[2]	lb CO_2/MG	700	800	1,300	1,400	1,500	1,600	54
Unit GHGs for Ammonia Removal[2,3,5]	lb GHG/lb N	3	3	7	7	6	7	0.9
Unit GHGs for Total N Removal[2,3]	lb GHG/lb N	12	10	11	11	11	10	0.9
Unit GHGs for Total P Removal[2,4]	lb GHG/lb P	--*	50	70	70	60	60	0.3

1. Dry Season = facilities sized for May 1 through September 30 loads but operate year round; year round = facilities sized for year round loads and operated year round.
2. The GHG Emissions are based on the flow and load reduction average over the project. The average flow and nutrient load reduction over the 10-year project duration for optimization and 30-year project duration for sidestream and upgrades.
3. Based on ammonia/nitrogen removal only.
4. Based on phosphorus removal only.

* The plant is not removing additional phosphorus load during for the dry season optimization.

9 Emerging Technologies

The recommendations presented in the prior sections are generally based on established technologies that can utilize process automation and process control to meet nutrient discharge limitations. These established technologies were used because there is a wealth of information related to facilities costs and sizing which are important for planning purposes. Nevertheless, there are many innovative technologies that could also be considered.

Innovative technologies offer the potential to provide nutrient removal at a reduced footprint and/or a lower cost. However, many of these technologies are too early in their development for full-scale consideration. Rather, bench-scale, pilot-scale and/or demonstration-scale testing would be prudent to confirm process benefits and further explore potential cost and footprint savings. For planning purposes, pilot studies can commonly represent approximately 1 percent of project costs.

The following two innovative technologies were specifically identified for future consideration at the SLWPCP:

- Granular Activated Sludge – this could be used to phase out the biotower/activated sludge. The application of granular sludge means process tankage requirements are reduced which reduces overall costs. One supplier, Nereda, has large full-scale installations overseas in the Netherlands and South Africa; however, there are currently no full-scale installations in North America.
    - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
    - Disadvantages: No installations in North America.
    - Potential Next Steps: Determine footprint requirements and estimated cost of full-scale system and consider pilot or demonstration testing.
- Membrane Aerated Biofilm Reactor (MABR) – this aeration technology could replace the aeration system within the existing aeration basins. The membrane is used to deliver air (inside-out) and the activated sludge biology resides as a biofilm on the membrane. The biology takes up the air as it is delivered through the membrane. This configuration has been shown to use more or less all the provided air and thus results in a compact footprint. The benefit to the SLWPCP is it has the potential to not require basin expansion for Levels 2 or 3. There are a few suppliers with several on-going piloting studies. However, there are currently no full-scale installations in North America.
    - Advantages: Low footprint requirements, energy efficient, ability to remove ammonia, TN, and TP.
    - Disadvantages: No installations in North America.
    - Potential Next Steps: Determine footprint requirements and cost of full-scale system and consider pilot or demonstration testing.

Appendix A. Basis of Cost Estimates

Allowances for additional construction costs were included using a markup. These allowances are added to the major facility costs to determine the capital cost (see Table 1).

The unit costs for power, chemicals, and labor are shown in Table 2. A common unit cost basis for all plants in the study was selected for this analysis.

Table 1. Allowanced used in developing the Opinion of Probably Cost.

Undefined Items	Value
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor’s Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%
Contingency to Reflect Current Bidding Climate in the Bay Area	15%

Table 2. Unit Costs

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb