02380-10001-320

NORTH COAST BASIN ENGINEERING ANALYSIS TO IDENTIFY FACILITY COSTS TO ACHIEVE NITROGEN REMOVAL

July 2010

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1. INTRODUCTION

The North Coast Basin of the Regional Water Quality Control Board (Regional Water Board) is home to several municipalities, agencies, and districts responsible for wastewater treatment and disposal. The majority of these facilities do not currently include nutrient removal within their treatment process. The concentration of nitrate in effluent from some facilities exceeds the drinking water maximum concentration limit of 10 mg-N/L, and these facilities would be subject of imposition of a 10 mg-N/L limit on the concentration of nitrate in effluent. The Regional Water Board is considering a Basin Plan amendment that would conditionally allow a nitrate limit that is less stringent than 10 mg-N/L.

This analysis was conducted to evaluate the potential costs associated with updating existing treatment facilities with the necessary infrastructure to reliably achieve compliance with a 10 mg-N/L nitrate limit to support evaluation of the Basin Plan amendment by the Regional Water Board. For this analysis, reliable compliance with a nitrate limit of 10 mg-N/L would require complete ammonia conversion to nitrate (nitrification) and the reduction in the resulting nitrate levels (denitrification) consistently below 10 mg-N/L.

1.1 Scope of Analysis

Facility data were reviewed for approximately eighteen municipalities and/or dischargers struggling to achieve compliance with nitrates. A representative sample of six facilities was selected for use in the analysis. The Facilities were kept anonymous and are hereinafter referred to as Facility A - Facility F.

Preliminary opinions of probable capital, operation and maintenance, and 20-year lifecycle costs associated with providing the necessary improvements to achieve reliable nitrogen removal were developed for each of the six facilities. These are based on a Class 5 (planning-level) estimate of probable construction cost as defined by the Association for the Advancement of Cost Engineering, International (AACE). AACE defines the "Class 5" estimate as follows:

> *Generally prepared on very limited information, where little more than proposed plan type, its location, and the capacity are known, and for strategic planning purposes such as but not limited to market studies, assessment of viability, evaluation of alternate schemes, project screening, location and evaluation of resource needs and budgeting, long-range capital planning, etc. Some examples of estimating methods used would include cost/capacity curves and factors, scale-up factors, and parametric and modeling techniques. Typically, very little time is expended in the development of this estimate. The typical expected accuracy ranges for this class estimate are -20% to -50% on the low side and +30% to +100% on the high side.*

2. METHODOLOGY AND COST DATA ANALYSIS

2.1 Decision Criteria for Facility Selection

To obtain a representative sample of dischargers within the North Coast Basin, the six wastewater treatment facilities chosen to be included in this analysis vary according to size, type of treatment and location. Figure 1 below shows the general location of each facility.

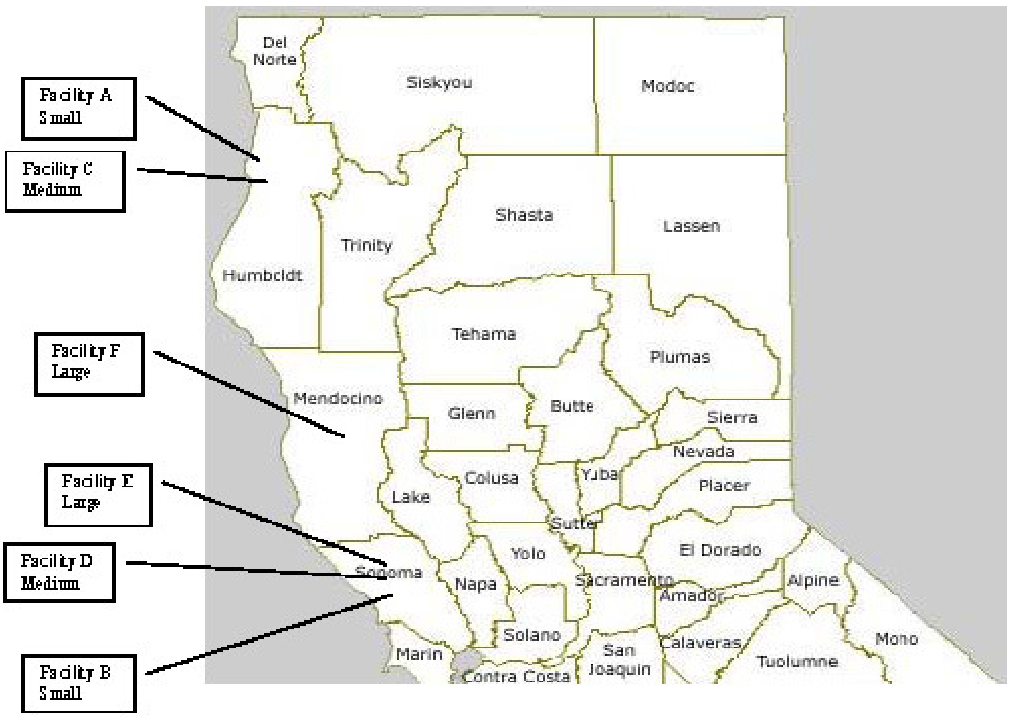

Figure 1. North Coast Basin Facility Locations

Facility size was categorized by average dry weather flow (ADWF) measured in million gallons per day (mgd). Small facilities were classified as having ADWF <0.5 mgd, medium facilities were classified as having ADWF between 0.5 and 1.0 mgd, and large facilities were classified as having ADWF >1.0 mgd. For the North Coast Basin, over 1 mgd is considered a larger facility when compared to the majority of the facilities being less than 1 mgd.

For treatment type diversity, each facility's secondary treatment system was considered the most relevant to nitrogen removal. The following existing types of systems are represented in the analysis:

1) Pond Systems (Aerated Lagoon Systems)
2) Activated Sludge Systems (Conventional and Extended Aeration)
3) Trickling Filter System (with solids contact)

The following section describes the methodology used for determining improvements that would be needed for the above types of existing systems to reliably achieve consistent nitrogen removal and achieve nitrate concentrations below 10 mg-N/L.

2.2 Decision Criteria for Improvements

Prior to developing costs, several decision criteria and assumptions were required. Firstly, pre-anoxic denitrification was established as the main mode to achieve nitrogen removal following nitrification. Secondly, certain organic loading assumptions were made to facilitate development of costs. Lastly, a detailed methodology was developed based on existing treatment technology to identify the improvements that would be required to achieve nitrogen removal. These assumptions and decision criteria are summarized in the following sections.

2.2.1 Secondary System Improvement Type

A series of guidelines were developed to identify the necessary infrastructure and treatment improvements required at each of the various facilities to achieve reliable and consistent nitrogen removal to achieve nitrate concentrations below 10 mg-N/L. For the purposes of developing planning-level cost estimates, these guidelines were used to determine the most logical improvement decision based on both the type of existing treatment system technology and available foot print at the facility.

The proposed technology for nitrification was considered on a case by case basis following the guidelines summarized below and presented in greater detail in Section 2.4.

1) **Pond System** – Convert to Extended Aeration Package Plant with Biological Nutrient Removal (BNR)
2) **Activated Sludge System** - Expand Aeration Tank to accommodate (BNR)
3) **Activated Sludge System (no room to expand) -** Convert to Membrane Bioreactor (MBR) System with BNR
4) **Trickling Filter with Solids Contact** – Add aeration tank capacity to perform BNR

The assumed mode of denitrification is the Modified Ludzack-Ettinger (MLE) system where nitrified mixed liquor is internally recycled and mixed with return activated sludge (RAS) and primary influent in a pre-anoxic environment. This is one of the most common and simplest forms of nutrient removal and offers many advantages over post-anoxic denitrification including reduced chemical requirements in the form of alkalinity and carbon sources. Reduced alkalinity requirements are needed in pre-anoxic systems such as the MLE system as the pre-anoxic basin contributes alkalinity through denitrification needed during nitrification, while the requirement for carbon addition is eliminated as primary influent provides the necessary electron donors to drive heterotrophic denitrification. In some instances, existing plant infrastructure may not be configured to readily facilitate the MLE process; in such cases, a typical post anoxic process is assumed.

The following nutrient removal technologies were not considered in this analysis as they were considered less than optimal and are not typically considered mainstream solutions:

1) Integrated Fixed Film Activated Sludge (IFAS)
2) Sequencing Batch Reactors (SBR)
3) Up-flow Denitrification Filters

2.3 Assumed Influent Flow Rates and Organic Loading

For the sake of consistency between facilities and in developing planning-level cost estimates, loadings were assumed as average, medium strength domestic loadings[1] of 210 mg/L total suspended solids (TSS), 190 mg/L biological oxygen demand (BOD), 25 mg/L ammonia, and 15 mg/L organic nitrogen (Metcalf and Eddy, 2003). ADWF rates used in the analysis were taken from the most recent facility NPDES permits and were used to predict the average organic loading for each facility and determine the required improvements needed based on the organic and nitrogen loadings.

2.4 Capital Improvements Required

Additional guidelines were used to identify the extent of capital improvements to the various facilities. It is assumed that the facilities considered herein are not reliably operating in nitrification as they are currently not required to per their NPDES permits. In order to reliably and consistently provide complete nitrification defined as complete removal of ammonia and nitrite, facilities are assumed to require additional aeration and alkalinity addition for pH control.

Construction costs are indexed to the Engineering News Record Construction Cost Index (ENR CCI) of 9910, which is for heavy construction in the San Francisco area in June 2010.

2.4.1 Existing Pond Systems

For each existing pond system, it is assumed that the ponds cannot easily be converted to full nutrient removal mode on a consistent basis. It is also assumed that given the relative size of the ponds, that there will be sufficient room to build a conventional extended aeration facility. The conversion to extended aeration will be in the form of a cast-in-place package treatment system. The system will have sufficient aeration tank capacity and diversity to perform simultaneous nitrification/denitrification (SND) and include secondary clarifiers and basic aerobic digestion for solids stabilization. For pond facilities converted to activated sludge over 0.5 mgd, additional solids handling facilities would have to be put in place to dewater solids onsite prior to disposal, in order to keep the cost of disposal reasonable.

2.4.2 Existing Activated Sludge Systems

For existing activated sludge systems, it is assumed that the existing aeration tankage is sufficient in size and sufficient diffusers are available to provide for both carbon and nitrogen removal. Additional aeration and chemical feed systems for buffering chemical (sodium hydroxide) are assumed to be required. Additional aeration needs were calculated based on the average oxygen uptake rate during BOD removal and nitrification and average oxygen transfer per horsepower. Additional blowers were added at the same assumed blower size at the existing facility. Depending on the size of the facility, sodium hydroxide feed system requirements range from a small heated building with small metering pump skid for small and medium facilities to a large heated storage tank and larger metering pumps for the larger facilities (>1.0 mgd).

The recycle rate for the MLE conversion is assumed at the current ADWF or 1xQ. The recycle rate is assumed to require the existing aeration tank size to be doubled to perform MLE. In addition to the increase in aeration tank size, the recycle pumps, and recycle lines are considered along with mechanical mixers in the anoxic zones. The minimal instrumentation to perform the denitrification is a nitrate probe, and some additional aeration automation to control dissolved oxygen.

2.4.3 Existing Activated Sludge Facilities Without Room to Expand

For existing activated sludge facilities without sufficient room for expansion, it is assumed that the facility is converted to a membrane bioreactor (MBR) facility. Because of higher mixed liquor concentrations and higher recirculation rates, MBR systems can treat wastewater and provide nutrient removal on a significantly reduced foot print when compared to activated sludge facilities.

A packaged MBR facility is assumed to have all the necessary pumps, tanks, and logic required to successfully operate the facility with BNR, including an automated screenings device required to protect the membranes. The packaged MBR systems are assumed to be sized to accommodate at least 2.5 times the ADWF for wet weather flows and daily peaks without assuming excessive flow equalization. Capital costs for MBR systems were substantiated by recent manufacturer quotes.

2.4.4 Existing Trickling Filter with Solids Contact

For existing facilities that utilize trickling filters with solids contact, it is assumed these facilities will upgrade in similar fashion as existing activated sludge facilities. The assumption is that the existing trickling filters will serve as roughing filters removing a majority of the BOD, and that the solids contact tank can be converted to provide complete nitrification. For post anoxic processes, sizing of the expansion is based on a hydraulic retention time (HRT) of 8 hrs minimum. Post anoxic processes will not require recirculation but will require additional chemical addition infrastructure for increased alkalinity requirements and the need for carbon source addition for denitrification.

2.4.5 Professional Services and Contingency Costs

In addition to infrastructure capital costs, other costs related to engineering, environmental, and administrative tasks are also included as capital costs. These additional costs are assumed at 30% of the capital construction costs and include design (8%), environmental documentation and permitting (5%), construction management (15%), and other administrative requirements (2%). Construction contingency costs are set at 20% and the contingency is not applied to the soft costs described above.

2.5 Lifecycle Cost Analysis & O&M Cost Assumptions

In order to develop 20-year lifecycle costs for the facilities, additional O&M requirements and associated costs were determined for each facility. Annual O&M costs are incorporated into present value calculations using a real Federal discount rate of 2.7%.

2.5.1 Additional Power Costs

For this analysis, average power costs are assumed to be $0.15 per kilowatt-hour (kWh).

For existing pond systems converted to extended aeration treatment, the additional power consumption is calculated at 0.163 hp per LB of ammonia converted per day and is a function of the plant influent loading and the stoichiometric relationship of oxygen needed for nitrification. The additional power required to operate an activated sludge plant strictly for BOD reduction from the power required to operate the existing pond is assumed at an additional 33% increase of the existing power cost.

In the MLE process, the additional facility power consumption is assumed to cover the recirculation of the nitrified mixed liquor and the additional costs of aeration for achieving nitrification. In the MBR process the additional power consists of the standard blower consumption for nitrification with an additional 60% increase over the cost to operate a conventional activated sludge plant to prevent membrane fouling.

All recycle pumps are assumed to be submersible pumps that operate at 20 ft total dynamic head and 70% efficiency. All aeration blowers are considered to operate at 80% efficiency.

2.5.2 Chemical Costs

For this analysis it is assumed that the treatment facilities lack sufficient alkalinity to perform nitrification without chemical addition. This is substantiated by the fact the majority of North Coast Basin facilities have soft water and low alkalinity.

Sodium hydroxide (NaOH) feed is based on the stoichiometric relationship of alkalinity consumed during nitrification at 7.1 parts of alkalinity (as CaCO3) per 1 part of ammonia converted. A recent cost quote from obtaining 50% hydroxide of approximately $7 per gallon is based on smaller sized deliveries in the North Coast locations. A 50% credit is given to the alkalinity required based on the denitrification reaction restoration of alkalinity if pre-anoxic MLE process is utilized, and a 60% alkalinity credit based on the equivalent relationship between CaCO3 and NaOH.

The trickling filter and solids contact conversion to post anoxic treatment will require carbon addition. Methanol is a standard carbon source used in the wastewater industry and is sold at $1.50 per LB for smaller tote quantities that would be representative of North Coast pricing, and $1.00 per LB at higher use (>1.0 mgd) facilities. Carbon consumption is assumed to be 1.9 lbs of carbon per lb of nitrate as N per day.

2.5.3 Additional Labor Costs

Additional labor costs were incorporated to account for increased operations and maintenance (O&M) needs to properly run the nutrient removal facility. Increased O&M needs were estimated at 1.25 hrs per day per facility mgd (ADWF). These costs are included to cover additional sampling, testing, monitoring and maintenance on additional equipment to properly maintain BNR processes.
For pond facility conversions to activated sludge, the daily solids processing labor costs are considered to cause an additional 50% increase in O&M labor to deal with additional testing, dewatering, and reporting.

2.5.4 Other Additional O&M Costs

For the MBR systems, it is assumed that the membranes would require replacement every 7 years. A recent manufacturer proposal was reviewed and contained a warranty for their membranes of 5 years. The replacement cost is estimated at $70,000 per mgd of average flux capacity.

For pond facility conversions to activated sludge, the solids disposal costs are considered to equal the cost of excavating pond sludge every 15-20 years.

3. FACILIITY DESCRIPTIONS AND REQUIRED IMPROVEMENTS

After selection of six representative treatment facilities, those facilities were analyzed using the established decision criteria for nitrate removal and methodology for estimating capital and O&M costs. Table 1 below summarizes existing facility information and illustrates the required nitrate removal method and resulting improvement based on the decision criteria. The individual facility itemized costs and design assumptions are located in Appendix A.

Table 1. Proposed Method of Nitrate Removal and Improvements for the Existing Facilities.

Facility	Facility Size	ADF (mgd)	Existing Secondary System	Available Land for Expansion (acres)	Method of Nitrate Removal	Improvement
A	Small	0.081	Activated Sludge	0.03	MLE	MBR Addition
B	Small	0.13	Ponds	N/A*	Simultaneous Nitrification /Denitrification	Extended Aeration Package Plant
C	Medium	0.57	Ponds	N/A*	Simultaneous Nitrification /Denitrification	Extended Aeration Package Plant
D	Medium	0.71	Extended Aeration Activated Sludge	1.1	MLE	Add Activated Sludge Capacity
E	Large	2.25	Activated Sludge	6.3	MLE	Add Activated Sludge Capacity
F	Large	2.8	Trickling Filter with Solids Contact	3.6	Post-Anoxic	Add Capacity to Solids Contact

**Facilities with an exciting pond system will convert to activated sludge. The footprint of the activated sludge facility will be much lower than the existing footprint and will not require additional land.*

3.1 Facility A Description and Required Capital Improvements

Facility A is a small activated sludge facility with an ADWF of 0.35 mgd. The facility is located on a limited foot print. Using the criteria established previously, this facility would be replaced by a packaged MBR facility due to lack of space for expansion of the activated sludge process. The MBR facility would completely replace the existing screening and secondary system and would be sized to process up to 2.5 times the ADWF, completely nitrify, and reduce nitrate consistently below 10 mg/l through the use of a pre-anoxic reactor. In addition to the package MBR system, a small hydroxide feed building is included and a nitrate analyzer from the permeate line would be connected to the MBR SCADA system.

The total Class 5 estimate of probable capital costs including the infrastructure needed for BNR, professional costs, and 20% contingency is estimated at $1.7 million for the plant improvements.

3.1.1 Facility A - Lifecycle Cost

The additional yearly operation and maintenance (O&M) cost is estimated at approximately $30,000 per year. Included in the additional O&M cost is the replacement cost of the membranes spread over 20 years. The 20-year present worth of the annual O&M costs using a federal discount rate of 2.7% is approximately $386,000 for a total lifecycle cost of $2.1 million.

3.2 Facility B - Description and Required Capital Improvements

Facility B is a small aerated lagoon (pond) treatment facility with an ADWF of 0.13 mgd. The facility is located on a limited foot print. Using the criteria established previously, this facility would be replaced by a package CIP extended aeration facility. The package plant would have the ability to fully nitrify and denitrify consistently below 10 mg/l using simultaneous nitrification and denitrification. In addition, the package plant would include small aerobic digesters for waste activated sludge to be processed to Class B quality. A small hydroxide feed building is included and a nitrate analyzer from the secondary effluent line would be connected to the existing plant SCADA system. The total Class 5 estimate of probable capital costs including the infrastructure needed for BNR, professional costs, and 20% contingency is estimated at $2.9 million for the plant improvements.

3.2.1 Facility B - Lifecycle Cost

The additional operation and maintenance (O&M) cost is estimated at approximately $72,000 per year. The 20-year present worth of the annual O&M costs using a federal discount rate of 2.7% is approximately $1.1 million for a total lifecycle cost of $4.01 million.

3.3 Facility C - Description and Required Capital Improvements

Facility C is a medium-sized aerated lagoon (pond) treatment facility with an ADWF of 0.57 mgd. The facility is located on a limited foot print. Using the criteria established previously, this facility would be replaced by a package CIP extended aeration facility. The package plant would have the ability to fully nitrify and denitrify consistently below 10 mg-N/L nitrate using simultaneous nitrification and denitrification. In addition, the package plant would include small aerobic digesters for waste activated sludge to be processed to Class B quality. A small hydroxide feed building is included and a nitrate analyzer from the secondary effluent line would be connected to the existing plant SCADA system. The total Class 5 estimate of probable capital costs including the infrastructure needed for BNR, professional costs, and 20% contingency is estimated at $4.4 million for the plant improvements.

3.3.1 Facility C - Lifecycle Cost

The additional operation and maintenance (O&M) cost is estimated at approximately $193,000 per year. The 20-year present worth of the annual O&M costs using a federal discount rate of 2.7% is approximately $3.0 million for a total lifecycle cost of $7.39 million.

3.4 Facility D - Description and Required Capital Improvements

Facility D is a medium-sized conventional activated sludge facility with an ADWF of 0.71 mgd. The facility is located on a foot print with adequate room to expand. New aeration tank capacity would be doubled and constructed to allow pre-anoxic tanks to be established to perform the MLE process. Anoxic tanks would include mechanical mixers and a new recycle pump station would be established to recirculate nitrified mixed liquor back to the pre-anoxic basin. The upgraded facility would have the ability to fully nitrify and denitrify consistently below 10 mg-

N/L nitrate. A small hydroxide feed building is included and a nitrate analyzer from the secondary effluent line would be connected to the existing plant SCADA system. The total Class 5 estimate of probable capital costs including the infrastructure needed for BNR, professional costs, and 20% contingency is estimated at $2.8 million for the plant improvements.

3.4.1 Facility D - Lifecycle Cost

The additional operation and maintenance (O&M) cost is estimated at approximately $153,000 per year. The 20-year present worth of the annual O&M costs using a federal discount rate of 2.7% is approximately $2.4 million for a total lifecycle cost of $5.12 million.

3.5 Facility E - Description and Required Capital Improvements

Facility E is a large-sized extended aeration activated sludge facility with an ADWF of 2.25 mgd. The facility is located on a foot print with adequate room to expand. New aeration tank capacity would be doubled and constructed to allow pre-anoxic tanks to be established to perform the MLE process. Anoxic tanks would include mechanical mixers and a new recycle pump station would be established to recirculate the nitrified mixed liquor back to the pre-anoxic basin. The upgraded facility would have the ability to fully nitrify and denitrify consistently below 10 mg-N/L nitrate. A hydroxide tank and containment area would be required to be constructed with chemical feed pumps to supply alkalinity. A nitrate analyzer from the secondary effluent line would be connected to the existing plant SCADA system. The total Class 5 estimate of probable capital costs including the infrastructure needed for BNR, professional costs, and 20% contingency is estimated at $5.8 million for the plant improvements.

3.5.1 Facility E - Lifecycle Cost

The additional operation and maintenance (O&M) cost is estimated at approximately $296,000 per year. The 20-year present worth of the annual O&M costs using a federal discount rate of 2.7% is approximately $4.5 million for a total lifecycle cost of $10.33 million.

3.6 Facility F - Description and Required Capital Improvements

Facility F is a large-sized trickling filter with solids contact facility with an ADWF of 2.8 mgd. The facility is located on a foot print with adequate room to expand. The additional capacity would be added next to the existing solids contact basin. With the additional capacity, the solids contact basin would be redesigned to allow BNR to occur. The trickling filters would be kept in service to provide initial BOD reduction and allow the solids contact basin expansion to be minimized.

Based on the configuration of the trickling filters and the existing solids contact basin, post anoxic denitrification would be used due to the potential for insufficient carbon for heterotrophic denitrification to occur. Typically methanol is used and delivered in liquid form; this increases the facility O&M costs and also adds an additional capital cost for chemical feeding systems. In post anoxic processes, there is typically no need for recirculation. Post anoxic tanks would include mechanical mixers. The upgraded facility would have the ability to fully nitrify and denitrify consistently below 10 mg-N/L nitrate. A hydroxide tank and containment area would be required to be constructed with chemical feed pumps to supply alkalinity. A nitrate analyzer from the secondary effluent line would be connected to the existing plant SCADA system. The total Class 5 estimate of probable capital costs including the infrastructure needed for BNR, professional costs, and 20% contingency is estimated at $1.9 million for the plant improvements.

3.6.1 Facility F - Lifecycle Cost

The additional operation and maintenance (O&M) cost is estimated at approximately $840,000 million per year. The 20-year present worth of the annual O&M costs using a federal discount rate of 2.7% is approximately $12.9 million for a total lifecycle cost of $14.71 million.

4. FACILITY COST SUMMARIZATION

Summarized in Table 2 are the Class 5 cost estimates for the capital, O&M, and 20-yr lifecycle costs required for the facilities in this analysis to remove nitrate consistently to levels less than 10 mg-N/L. The cost criteria for each facility improvement produced a large variety of capital costs and depended heavily on both the type of existing facility and the estimated additional aeration tank requirements. Figure 2 below presents estimates for capital costs to achieve nitrogen removal by facility and illustrates a large variation in capital costs. Traditional estimations show that capital costs per mgd tend to decrease as the facility sizes increase, showing an economy of scale. Given the relatively small range in size of the North Coast facilities, this economy of scale is not realized as in traditional "text book" estimates.

Table 2. Facility Upgrade Cost Estimates

Facility	Facility Size	ADWF (mgd)	Improvement	Estimated Improvement Capital Cost (million $)	Estimated Additional Annual O&M Cost	Additional 20-YR Lifecycle Cost (million $)
A	Small	0.081	MBR Package System	1.7	$26,000	2.1
B	Small	0.13	CIP -Activated Sludge Package Plant	2.9	$72,000	4.0
C	Medium	0.57	CIP -Activated Sludge Package Plant	4.4	$193,000	7.4
D	Medium	0.71	Add Activated Sludge Capacity	2.8	$153,000	5.1
E	Large	2.25	Add Activated Sludge Capacity	5.8	$296,000	10.3
F	Large	2.8	Add Capacity to EX. Solids Contact	1.9	$840,000	14.7

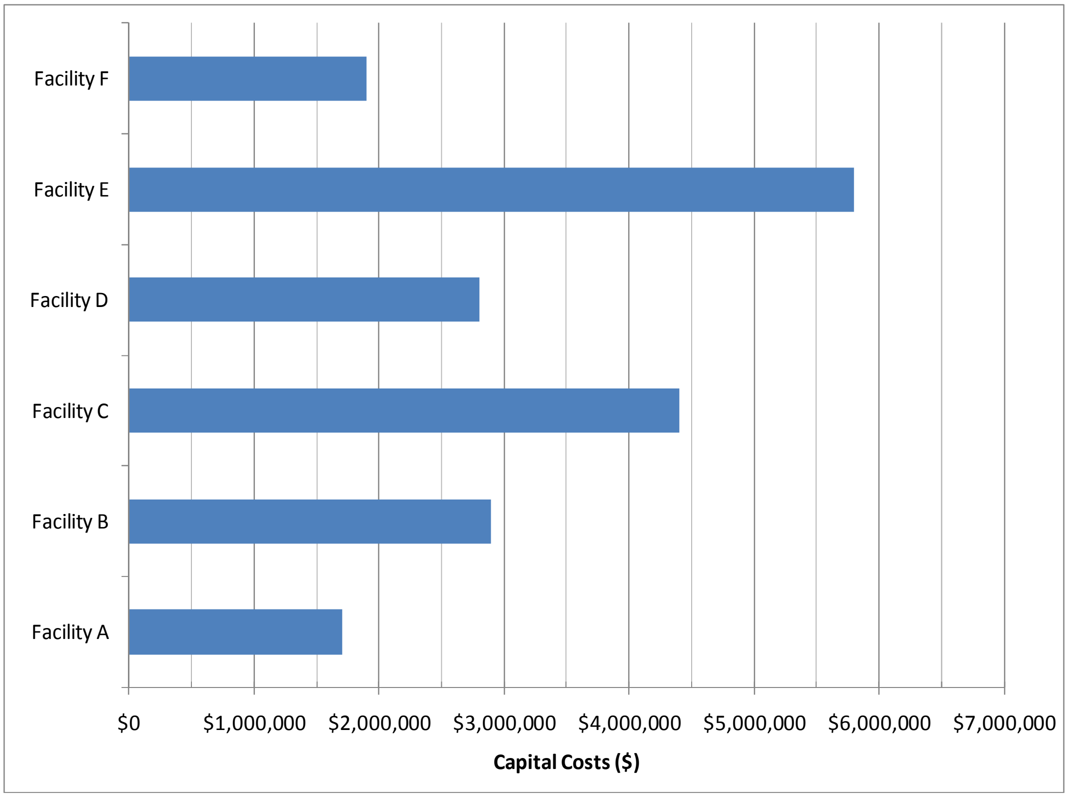

Figure 2. Capital Costs by Facility to Achieve Nitrogen Removal

A regression analysis of capital costs was also performed, and these results are shown below in Figure 3. Facility F (red square in figure below) was not included in the regression analysis as this facility represented an outlier in the analysis due to significant recent facility upgrades. The regression analysis indicates slightly over $3 million per million gallons of ADWF is the required capital investment to achieve reliable nitrogen removal.

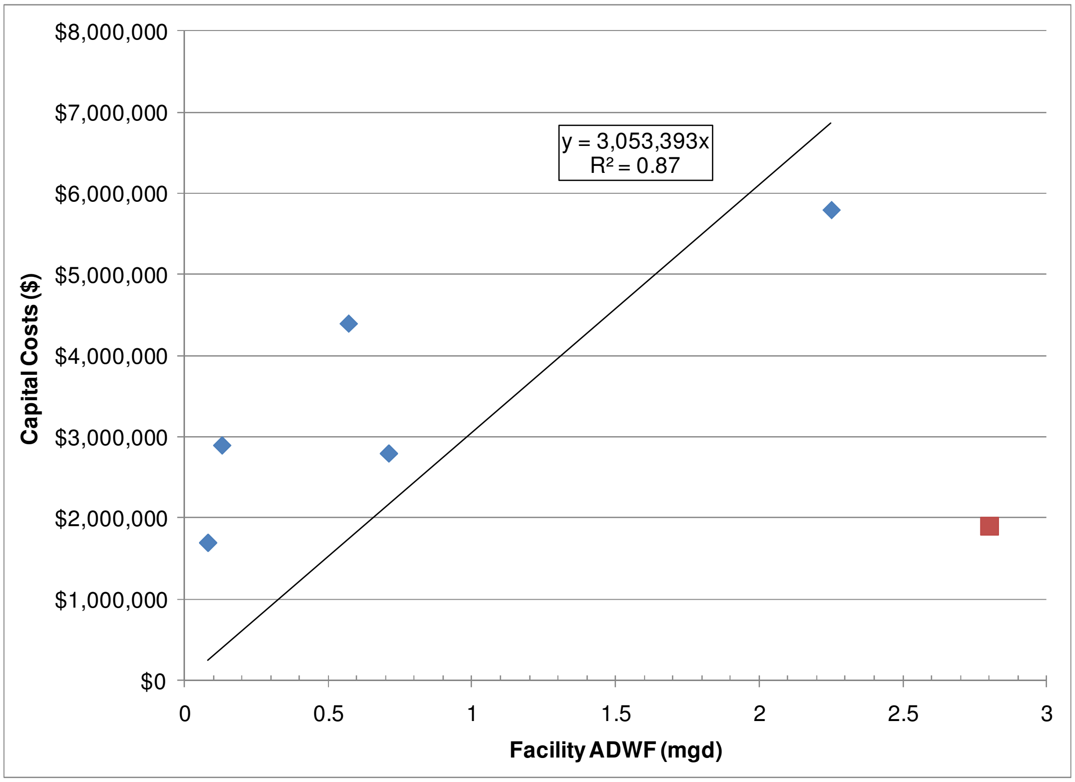

Figure 3. Regression Analysis of Capital Costs to Achieve Nitrogen Removal.

A regression analysis for annual increases in operation and maintenance costs for a given facility size was also developed and is shown below in Figure 4. The O&M trend shows a linear increase in costs. The average increase in O&M cost was $160,000 per mgd (ADWF). A majority of these costs are associated with additional energy, chemical, and labor requirements to consistently achieve nitrification.

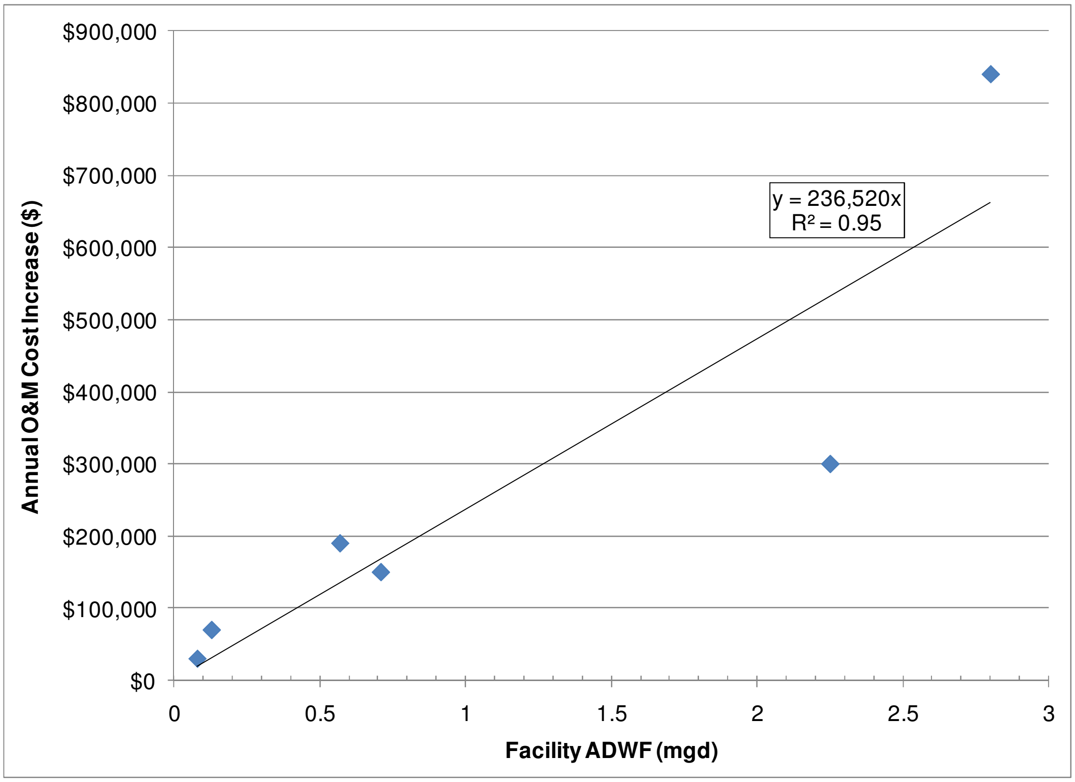

Figure 4. Regression Analysis of Annual O&M Cost Increases to Achieve Nitrogen Removal

The 20-yr lifecycle costs for the facility conversions are shown in Figure 5 below. Lifecycle costs are heavily influenced by the increase in O&M and show a linear trend similar to the O&M cost curve. The average 20-yr lifecycle costs per mgd to provide nitrogen removal are estimated at approximately $15.3 million per mgd.

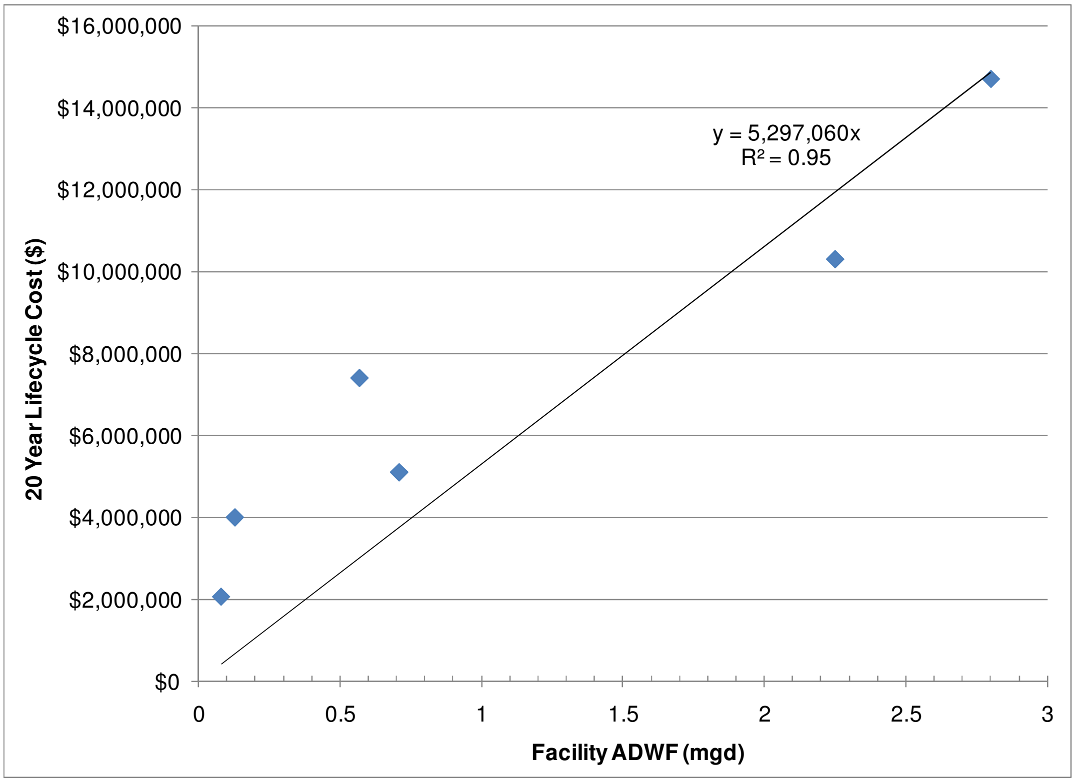

Figure 5. Regression Analysis of 20-Year Lifecycle Costs to Achieve Nitrogen Removal

5. SUMMARY

In summary, this analysis was conducted to evaluate the potential costs associated with updating existing treatment facilities within the North Coast Basin of the Regional Water Board with the necessary infrastructure to reliably achieve compliance with a 10 mg-N/L nitrate limit. Currently, the majority of these facilities do not include nutrient removal within their treatment process, and the concentration of nitrate in effluent from some facilities exceeds the drinking water maximum concentration limit of 10 mg-N/L. The Regional Water Board is considering a Basin Plan amendment that would conditionally allow a nitrate limit that is less stringent than 10 mg-N/L.

Facility data were reviewed for approximately eighteen municipalities and/or dischargers struggling to achieve compliance with nitrates within the North Coast Basin. A total of six facilities were randomly selected and included in this analysis that represented a variety of design flows and technologies. Class 5 planning level cost estimates were developed for capital, operation and maintenance, and 20-year lifecycle costs associated with providing the necessary improvements to achieve reliable nitrogen removal were developed for each of the six facilities. Capital costs are estimated at approximately $3.1 million per million gallons ADWF, annual O&M cost increases are estimated at approximately $240,000 per million gallons ADWF, and 20-year lifecycle costs are estimated at approximately $5.3 million per million gallons ADWF.

6. REFERENCES AND MANUFACTURERS

Wastewater Engineering Treatment and Reuse, 2003, 4th Edition. Metcalf and Eddy
Building Construction Cost Data, 2009, 67th Edition, RSMeans
Various Completed Wastewater Projects, 2005-Present. Winzler and Kelly
Aeromod - Sequox – Cast-in-place Activated Sludge Package Plant System – 2009-2010
Seimans – Xpress - Package MBR Systems – 2007

Appendix A
Facility Cost Estimating Spreadsheets

Facility A - Existing Conventional Activated Sludge

	Item	*Cost*
Capital Costs	New Membrane Bioreactor - Package System	$1,083,250
	Chemical Dosing	$25,000
	Instrumentation	$25,000
	30% Professional and 20% Contingency	$541,625
	Total Capital	**$1,674,875**
O&M Costs	Additonal Aeration	$6,357
	Chemical	$11,267
	Membrane Replacement (every 7 years)	$6,000
	Labor	$1,774
	Total Additonal Annual O&M	**$25,398**
	20 YR Present Value of Additional O&M	**$388,594**
	Total Additional Lifecycle Cost	**$2,063,469**

Cost Criteria

Est BOD, LB/day	128.4
Est Blower Size, HP	5.1
ADWF MGD	0.081
Est Ammonia LBS/day	27.0
Additional Blower HP for Nitr.	4.05
Additional Blower kWh	72.57
Alkalinity Req., LBS/day	96.5
Gallons of 50% Naoh reqd/day	6.17

Facility B - Existing Oxidation Pond

	Item	*Cost*
Capital Costs	New Secondary System - Package Activated Sludge	$1,910,000
	Chemical Dosing	$25,000
	Instrumentation and Control	$25,000
	30% Professional and 20% Contingency	$955,000
	Total Capital	**$2,915,000**
O&M Costs	Additonal Aeration	$9,042
	Chemical	$18,083
	Labor	$44,447
	Total Additonal Annual O&M	**$71,573**
	20 YR Present Value of Additional O&M	**$1,095,060**
	Total Additional Lifecycle Cost	**$4,010,060**

Cost Criteria	
Est BOD, LB/day	206.0
Est Blower Size, HP	8.2
ADWF MGD	0.13
Est Ammonia LBS/day	43.4
Additional Blower HP for Nitr.	6.51
Additional Blower kWh	116.47
Alkalinity Req., LBS/day	154.8
Gallons of 50% Naoh reqd/day	9.91

Facility C - Existing Oxidation Pond

	Item	*Cost*
Capital Costs	New Secondary System - Package Activated Sludge System	$2,760,000
	Dewatering System	$250,000
	Chemical Dosing	$25,000
	Instrumentation and Control	$25,000
	30% Professional and 20% Contingency	$1,380,000
	Total Capital	**$4,440,000**
O&M Costs	Additonal Aeration	$39,646
	Chemical	$79,289
	Labor	$73,845
	Total Additonal Annual O&M	**$192,780**
	20 YR Present Value of Additional O&M	**$2,949,540**
	Total Additional Lifecycle Cost	**$7,389,540**

Cost Criteria

Est BOD, LB/day	903.2
Est Blower Size, HP	36.1
Est Blower Round up, HP	50.0
ADWF MGD	0.57
Est Ammonia LBS/day	190.2
Additional Blower HP for Nitr.	28.52
Additional Blower kWh	510.67
Alkalinity Req., LBS/day	678.8
Gallons of 50% Naoh reqd/day	43.45

Facility D - Existing Conventional Activated Sludge

	Item	*Cost*
Capital Costs	Aeration Tank Addition	$1,355,156
	Anoxic Tank Addition	$338,789
	Recirculation Piping	$5,175
	Recriculation Pumps	$40,000
	Chemical Dosing	$25,000
	Additonal Blower	$30,000
	Mechanical Mixing	$29,531
	Instrumentation and Control	$65,000
	30% Professional and 20% Contingency	$897,060.2
	Total Capital	**$2,785,712**
O&M Costs	Additonal Aeration	$34,827
	Chemical	$98,763
	Labor	$15,549
	Power (pumping)	$3,487
	Total Additonal Annual O&M	**$152,626**
	20 YR Present Value of Additional O&M	**$2,335,176**
	Total Additional Lifecycle Cost	**$5,120,888**

Cost Criteria

Est BOD, LB/day	1125.1
Est Blower Size, HP	45.0
Est Blower Round up, HP	10.0
ADWF MGD	0.71
Est Ammonia LBS/day	236.9
Additional Blower HP for Nitr.	35.53
Additional Blower kWh	636.10
Alkalinity Req., LBS/day	845.6
Gallons of 50% Naoh reqd/day	54.12
N. Anoxic Basin EQ. Length	315
N. Anoxic Basin Width, ft	45
N. Anoxic Basin Depth, ft	16
Ex. Basin Length	116
Ex.Basin Width, ft	163
Ex. Basin Depth	12

Facility E - Existing Extended Aeration

	Item	*Cost*
Capital Costs	Aeration Tank Addition	$2,727,521
	Anoxic Tank Addition	$681,880
	Recirculation Piping	$10,313
	Recriculation Pumps	$84,000
	Chemical Dosing	$80,000
	Additonal Blower	$160,000
	Mechanical Mixing	$59,438
	Instrumentation and Control	$125,000
	30% Professional and 20% Contingency	$1,871,857
	Total Capital	**$5,800,009**
O&M Costs	Additonal Aeration	$110,366
	Chemical	$125,193
	Labor	$49,275
	Power (pumping)	$11,051
	Total Additonal Annual O&M	**$295,884**
	20 YR Present Value of Additional O&M	**$4,527,029**
	Total Additional Lifecycle Cost	**$10,327,038**

Cost Criteria

Est BOD, LB/day	3565.4
Est Blower Size, HP	142.6
Est Blower Round up, HP	100.0
ADWF MGD	2.25
Est Ammonia LBS/day	750.6
Additional Blower HP for Nitr.	112.59
Additional Blower kWh	2015.81
Alkalinity Req., LBS/day	2679.6
Gallons of 50% Naoh reqd/day	171.50
Ex. Basin Length	205
Ex.Basin Width, ft	365
EX. Basin Depth, ft	6
N Anoxic Basin EQ Length	634
N. Anoxic Basin Width, ft	45
N. Anoxic Basin Depth, ft	16

Facility F - Existing Trickling Filter and Solids Contact

	Item	*Cost*
Capital Costs	Post Anoxic Tank Addition	$793,495
	Chemical Dosing	$160,000
	Additonal Blower	$160,000
	Mechanical Mixing	$62,250
	Instrumentation and Control	$125,000
	30% Professional and 20% Contingency	$556,748
	Total Capital	**$1,857,493**
O&M Costs	Additonal Aeration	$137,344
	Chemical (NaOH)	$155,796
	Chemical (Methanol)	$485,838
	Labor	$61,320
	Total Additonal Annual O&M	**$840,298**
	20 YR Present Value of Additional O&M	**$12,856,558**
	Total Additional Lifecycle Cost	**$14,714,051**

Cost Criteria	
Est BOD, LB/day	4436.9
Est Blower Size, HP	177.5
Est Blower Round up, HP	200.0
ADWF MGD	2.8
Est Ammonia LBS/day	934.1
Additional Blower HP for Nitr.	140.11
Additional Blower kWh	2508.57
Alkalinity Req., LBS/day	3334.7
Gallons of 50% Naoh reqd/day	213.42
New Basin Volume, mgal	0.93
New Basin Length	166
New Basin Width, ft	50

Capital Cost - Operation and Maintenance Cost Assumptions

Aeration tank Construction

per CY	slab	$800	
	wall	$900	111% of slab
	grout	$700	38% of Wall Material

Recirculation Piping, LF	< 1mgd	$150
	> 1 mgd	$300

Mech Mixing, EA	$10,000
Nitrate Probe and SCADA integration	$25,000

Recriculation Pumps (EA) w/ VFDs

5 HP	$20,000
10 HP	$31,000
15 HP	$42,000
20 HP	$53,000

Chemical Dosing

>1mgd	Tank (heat trace) and Containment	$60,000
<1mgd	Heated Enclosure/Tote	$15,000
>1mgd	Pump Skid	$20,000
<1mgd	Pump Skid	$10,000

Blowers		**Blower Control ans SCADA integration**	
5hp	$25,000	>1mgd	$100,000
10hp	$30,000	<1mgd	$40,000
20hp	$35,000		
50hp	$50,000		
100hp	$80,000		

O&M

	Aeration			
			0.439	LB O2/min/hp
	Hydroxide			
<1mgd	5	$/gallon	7.14	LB alk/LB N
>1mgd	2	$/gallon		
	Carbon Req (Post Anaoxic)			
	1.9	LB C / LB NO3-N	1	$/LB C
	Labor			
	40	$/hr	1.5	additonal hr/day/mgd
	Power			
	0.15	$/kWh		

Blower Use	0.150	hp/LB NH3 day
	0.040	hp/LB BOD day