UDWQ POTW Nutrient Removal Cost Impact Study: Analysis of Provo City Water Reclamation Facility

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COPIES: Provo City Water Reclamation Facility

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In partial fulfillment of the Utah Division of Water Quality *Publicly Owned Treatment Works (POTW) Nutrient Removal Cost Impacts Study,* this Technical Memorandum (TM) summarizes the process, financial and environmental evaluation of the Provo City Water Reclamation Facility (PCWRF) to meet the four tiers of nutrient standards presented in Table 1.

The thirty mechanical POTWs in the State of Utah were categorized into five groups to simplify process alternatives development, evaluation, and cost estimation for a large number of facilities. Similar approaches to upgrading these facilities for nutrient removal were thus incorporated into the models developed for POTWs with related treatment processes. The five categories considered were as follows:

- Oxidation Ditch (OD)
- Activated Sludge (AS)
- Membrane Bioreactor (MBR)
- Trickling Filter (TF)
- Hybrid Process (Trickling Filter/Solids Contact (TF/SC) or Trickling Filter/Activated Sludge (TF/AS))

The PCWRF fits in the Hybrid Process Category.

TABLE 1
Nutrient Discharge Standards for Treated Effluent

Tier	Total Phosphorus, mg/L	Total Nitrogen, mg/L
1N	0.1	10
1	0.1	no limit
2N	1.0	20
2	1.0	no limit
3	Base condition (1)	Base condition (1)

Note: (1) Includes ammonia limits as per the current UPDES Permit

1. Facility Overview

This facility is designed for an average annual flow of 21 million gallons per day (mgd) and currently receives an average influent flow of 11.6 mgd and an industrial influent flow of approximately 0.07 mgd. The facility operates a TF/AS process with primary treatment. Though the flow splits after the primary clarification, the majority of it (80%) goes to the trickling filters followed by the aeration basins, and only a small portion (20%) goes to the aeration basins directly. The secondary effluent is filtered using gravity filters and disinfected using chlorination prior to its discharge. Waste solids from the trickling filters are co-settled with primary solids in the primary clarifiers. Secondary residual solids from the aeration basins are thickened using dissolved air floatation thickeners and stabilized along with the primary residual solids using conventional mesophilic anaerobic digestion. The digested solids are mechanically dewatered, air dried in sludge drying beds and either composted or land applied. Ferric chloride is added in two of the facility's interceptors for odor control. The TF/AS process is operated to achieve nitrification in order to meet the POTW's ammonia effluent limits. A process flow diagram is presented in Figure 1 and an aerial photo of the WRF is shown in Figure 2. The major unit processes are summarized in Table 2.

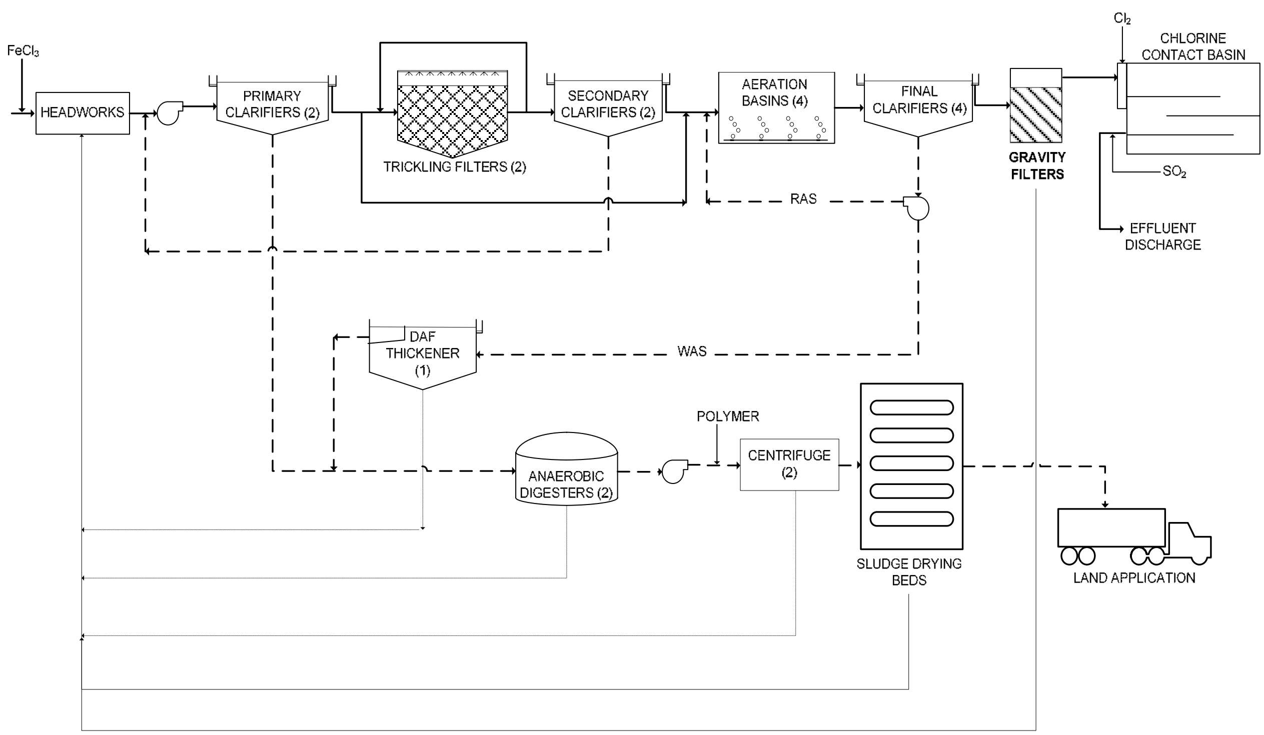

FIGURE 1
Process Flow Diagram

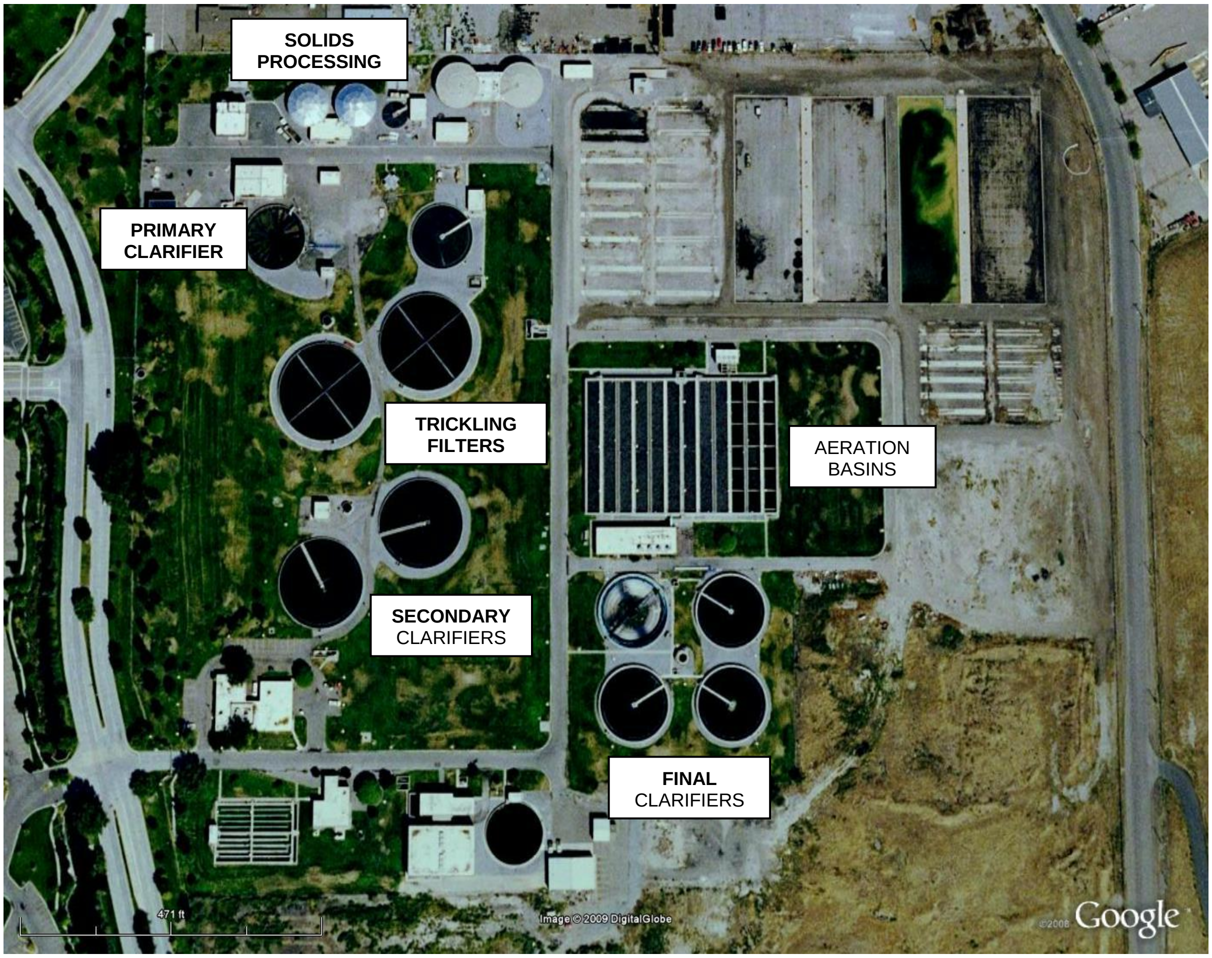

FIGURE 2
Aerial View of the Facility

TABLE 2
Summary of Major Unit Processes

Unit Process	Number of Units	Size, Each	Details
Primary clarifiers	2	100-ft diameter, 10-ft SWD	Metal-salt added for odor control
Trickling filters	2	150-ft diameter, 6-ft media depth	Rock media
Secondary clarifiers	2	135-ft diameter, 7-ft SWD	For trickling filter effluent
Aeration basins	4	1.683 MG, 15-ft SWD	100% diffused aeration
Final clarifiers	4	110-ft diameter, 10-ft SWD	Round clarifiers
Filters	6	666-ft^2	Gravity anthracite filters
WAS thickening	1	40-ft diameter	Dissolved air floatation
Anaerobic digestion	2	124,433-ft^3	Anaerobic Mesophilic
Solids dewatering	2	----	Centrifuge
Solids drying	----	----	Sludge drying beds

On October 28th, 2009, PCWRF, the Utah Division of Water Quality, and CH2M HILL met to review the proposed approach. In that meeting, it was indicated by PCWRF personnel that the best approach to address the nutrient limits and the best long-term plan for the WRF was to transition from TF/AS to activated sludge process only. Hence, it was decided that the modeling runs would include AS only. To accomplish this, CH2M HILL modeled the plant per design conditions described in Table 4. To accommodate the stated design capacity, the existing aeration basins and final clarifiers would be sufficient and no expansion would be required. Figure 3 illustrates the WRF with the suggested modifications and Table 3 includes the plant process units. For the purposes of estimating the impact of nutrient removal on the WRF, incremental differences in capital and O&M costs in addition to these modifications will be accounted for each of the four Tiers of nutrient removal.

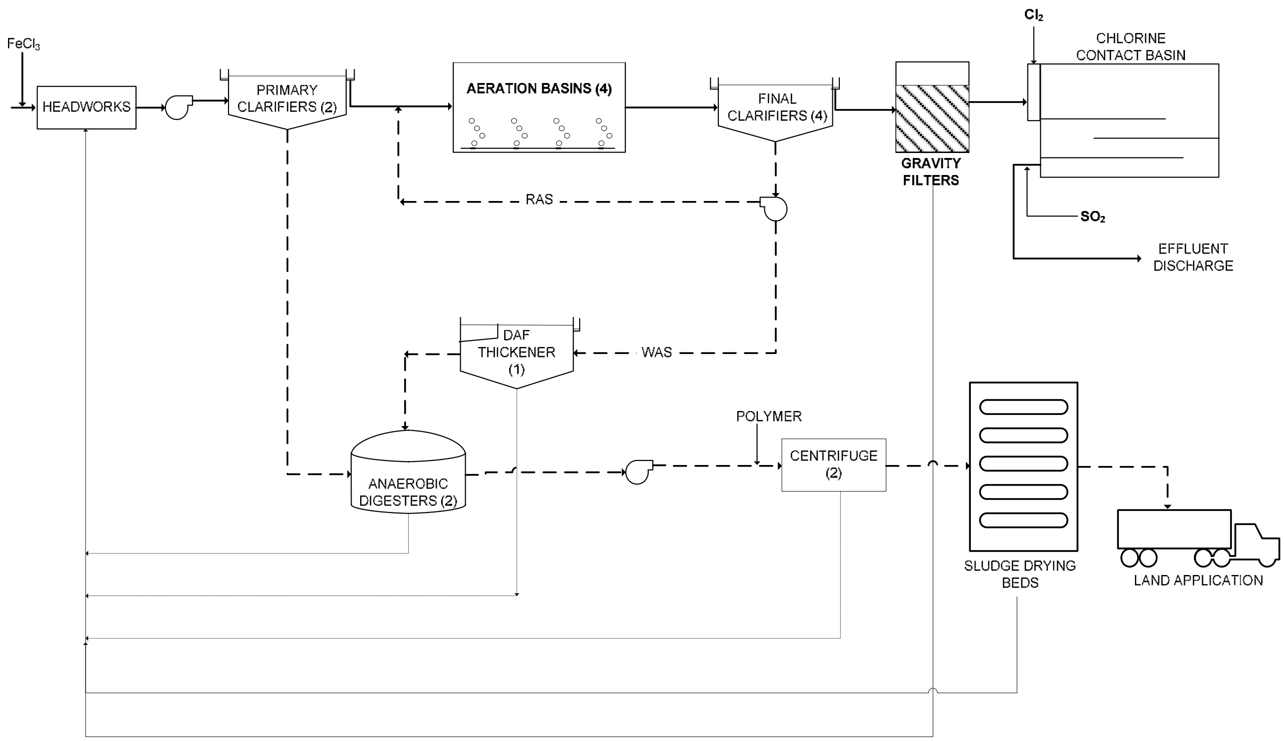

FIGURE 3
Process Flow Diagram

TABLE 3
Summary of Major Unit Processes

Unit Process	Number of Units	Size, Each	Details
Primary clarifiers	2	100-ft diameter, 10-ft SWD	Metal-salt added for odor control
Aeration basins	4	1.683 MG, 15-ft SWD	100% diffused aeration
Final clarifiers	4	110-ft diameter, 10-ft SWD	Round clarifiers
Filters	6	666-ft^2	Gravity anthracite filters
WAS thickening	1	40-ft diameter	Dissolved air floatation
Anaerobic digestion	2	124,433-ft^3	Anaerobic Mesophilic
Solids dewatering	2	----	Centrifuge
Solids drying	----	----	Sludge drying beds

2. Nutrient Removal Alternatives Development, Screening and Selection

A nutrient removal alternatives matrix was prepared in order to capture an array of viable approaches for TF/SC or TF/AS facilities (See Attachment A). This matrix considers biological and chemical phosphorus removal approaches as well as different activated sludge configurations for nitrogen control. The alternatives matrix illustrates that there are several strategies for controlling nutrient limits. The processes that were modeled and described in subsequent sections are considered proven methods for meeting the nutrient limits. There may be other ways to further optimize to reduce capital and operation and maintenance (O&M) costs that are beyond the scope of this project. This TM can form the basis for an optimization study in the future should that be desired by the POTW.

PCWRF has aeration basins and final clarifiers with sufficient capacity to accommodate the design flow of the plant. The basins can also be operated to meet the POTW's current ammonia limits. This being the case and as stated earlier it was proposed to model the POTW as an activated sludge plant only. In order to meet the different tiers of nutrient control, necessary modifications were made to the aeration basins and new process units were added as required. Figure 4 shows the selected upgrade approach used between each tier of nutrient control with the following bullet points A through D describing each upgrade step:

A. From Tier 3 (AS only) to Tier 2 phosphorus control, the aeration basins were modified to include an anaerobic zone prior to aerating the mixed liquor for enhanced biological phosphorus removal. The existing metal-salt addition system was used in addition to a new metal-salt feed point upstream of the secondary clarifiers as a backup for biological phosphorus removal.

B. From Tier 2 to Tier 2N, the existing aeration basins were modified to a step feed activated sludge system. The existing metal-salt addition system was used in addition to a new metal-salt feed point upstream of the secondary clarifiers as a backup for biological phosphorus removal.

C. To go from Tier 2 to Tier 1 phosphorus control, the existing gravity sand filters were expanded and an additional metal-salt feed point was added before them.

D. To add nitrogen removal to Tier 1, the step feed activated sludge system as described in Tier 2N was implemented along with metal-salt addition at the headworks, secondary clarifiers and ahead of the expanded gravity sand filters.

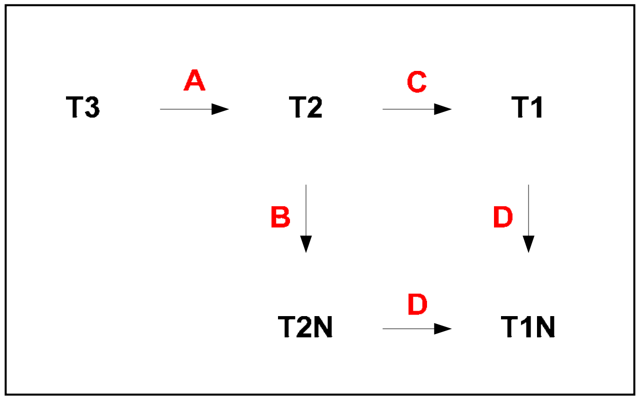

FIGURE 4
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

Data Evaluation and Modeling of Upgrades

The selected progression of upgrades conceived for meeting the different tiers of nutrient control for PCWRF was analyzed using the following four steps;

- Step 1. Review, compile, and summarize the process performance data submitted by the POTW;
- Step 2. Develop and calibrate a base model of the existing POTW using the summarized performance data;
- Step 3. Build upon the base model by sequentially modifying it to incorporate unit process additions or upgrades for the different tiers of nutrient control and use model outputs to establish unit process sizing and operating requirements;
- Step 4. Develop capital and O&M costs for each upgrade developed in Step 3.

The facility information and data received from PCWRF per the initial data request was evaluated to (a) develop and validate the base process model, and (b) size facilities to conserve the POTW's current rated capacity. Table 4 provides a summary of the reported information used as the model input conditions. See Process Modeling Protocol (Attachment B) for additional information.

TABLE 4
Summary of Input Conditions

Input Parameter	2009[1]	2029[2]	Design[3]
Flow, mgd	11.60	17.70	25
BOD, lb/day	15,777 (164 mg/L)	25,095 (170 mg/L)	34,402 (165 mg/L)
TSS, lb/day	17,746 (184 mg/L)	28,047 (190 mg/L)	38,573 (185 mg/L)
TKN, lb/day	2,903 (30 mg/L)	4,429 (30 mg/L)	6,255 (30 mg/L)
TP, lb/day	845 (8 mg/L)	1,181 (8 mg/L)	1,668 (8 mg/L)

(1) Historic conditions 2007-2008

(2) Projected based on increase in population

(3) Reported design maximum month capacity of POTW

The main sizing and operating design criteria that were important for capturing the costs associated with the system upgrade approach for PCWRF are summarized in Table 5.

TABLE 5
Main Unit Process Sizing and Operating Design Parameters

Design Parameter (Nutrient Tier)	Value
Target metal:PO_4-P molar Ratio (All Tiers)	1:1, 2:1, 7:1 [1]
Metal-salt storage (T2 and T2N)	5 days
Metal-salt storage (T1 and T1N)	14 days
Fraction of aeration basins converted to anaerobic volume (T2 and T1)	25%
Fraction of aerated zone in the step feed activated sludge basins (T2N and T1N)	50%
Fraction of non-aerated zone in the step feed activated sludge basins (T2N and T1N)	50%
Granular filter loading rate (T1 and T1N)	5 gpm/ft^2 [2]

(1) Target dosing ratio at the primary clarifiers, secondary clarifiers and upstream of polishing filter, respectively. Filter doses were for Tier 1 and 1N only

(2) Hydraulic loading rate at peak hourly flow

3. Nutrient Upgrade Approaches

The following paragraphs provide details of the upgrade approaches as presented previously in Figure 3.

Tier 2 Phosphorus (A)

PCWRF can achieve the 1.0 mg/L total phosphorus goal specified for this Tier by modifying the existing volume of the aeration basins to include an anaerobic zone. The flow to the basins would pass through the anaerobic zone prior to aeration, for enhanced biological phosphorus removal. Metal-salts were added at the headworks, and an additional metal-salt addition system was implemented at the secondary clarifier as a backup to biological phosphorus uptake. A process flow diagram for this treatment approach is presented in Figure 5.

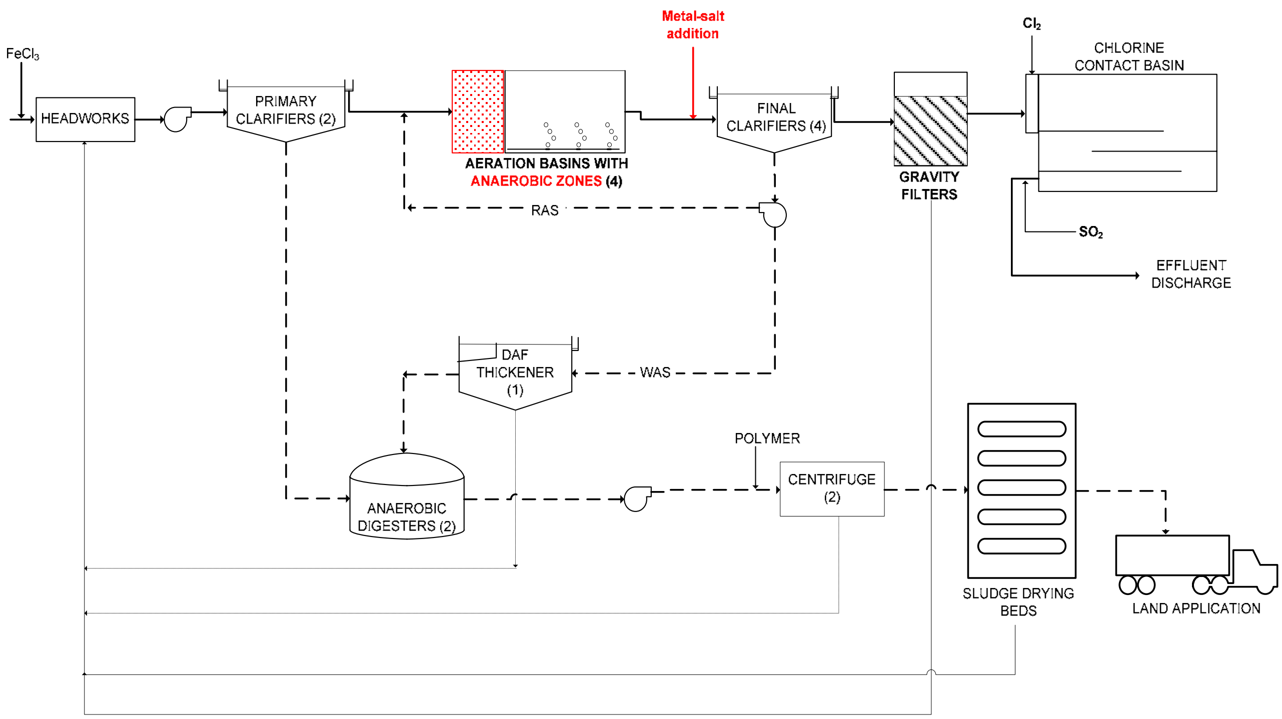

FIGURE 5
Modifications to POTW for Tier 2 Nutrient Control

Tier 2N – Phosphorus & Nitrogen (B)

The dual-feed metal-salt addition for phosphorus control (described in Tier 2) would be continued to be used to meet the nutrient limits specified for this Tier. However, to achieve nitrogen control (TN < 20 mg/L) along with phosphorus, the aeration basins were modified to a step feed activated sludge system. With this system, each pass in the existing basins was modified to include alternate non-aerated and aerated zones with the primary effluent fed to each of the non-aerated zones. Metal-salts were added at the headworks, and an additional metal-salt addition system was implemented at the secondary clarifier for phosphorus removal, as a back-up. A process flow diagram of this approach is provided in Figure 6.

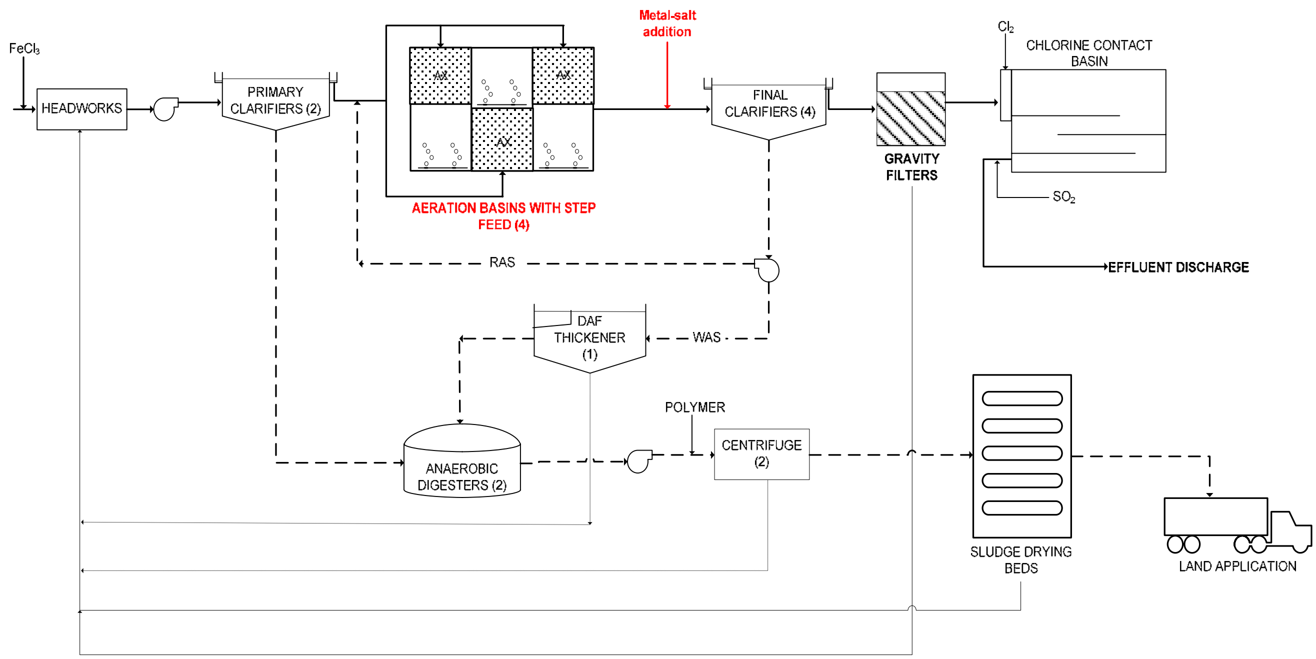

FIGURE 6
Modifications to POTW for Tier 2N Nutrient Control

Tier 1 Phosphorus (C)

This alternative builds upon the Tier 2 approach for phosphorus control. Settled effluent from the final clarifiers passed through a third feed point for metal-salt addition upstream of the existing gravity filters for chemical phosphorus polishing. The existing filters required expansion in order to maintain a hydraulic loading rate of 5gpm/ft^2 at peak hourly flow conditions. A process flow diagram of this approach is provided in Figure 7.

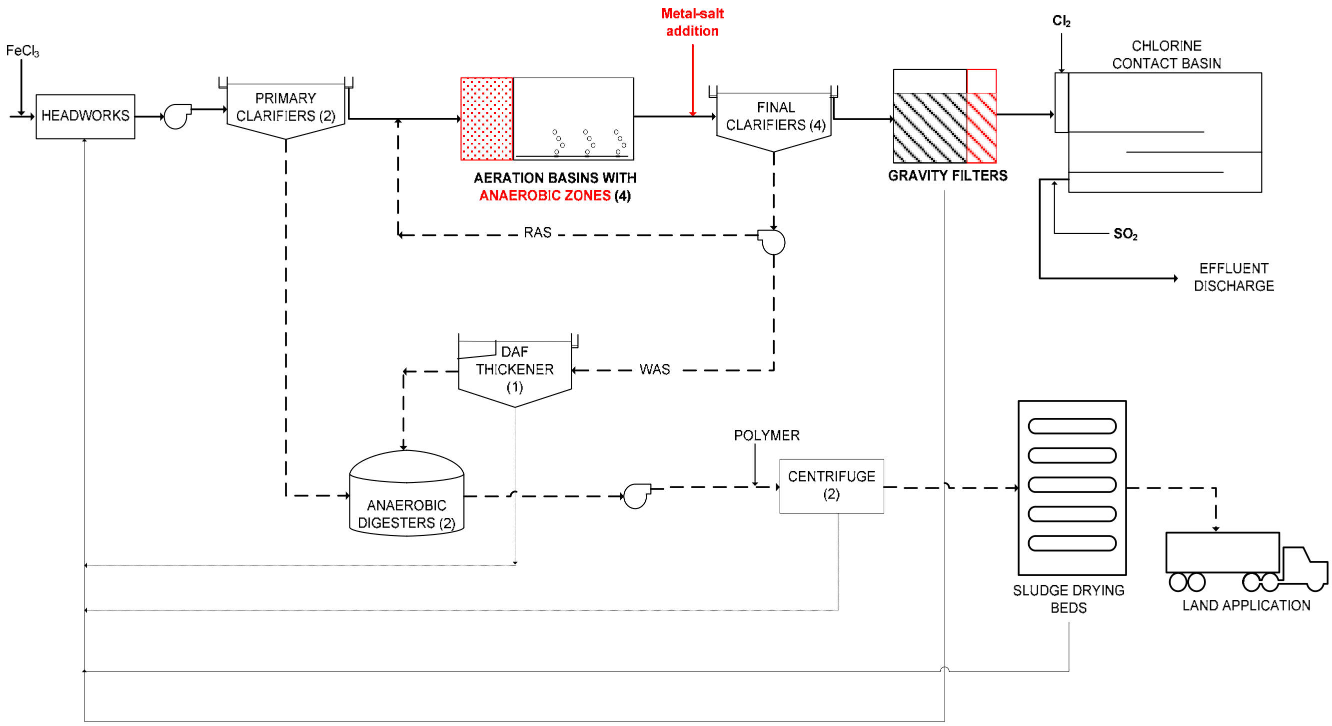

FIGURE 7
Modifications to POTW for Tier 1 Nutrient Control

Tier 1N Phosphorus & Nitrogen (D)

This Tier of nutrient removal combined the approaches adapted for Tier 2N and Tier 1. The step feed activated sludge process designed for Tier 2N required no additional modification to meet the total nitrogen limit of this Tier along with some biological phosphorus removal. Metal-salts were added at the headworks, secondary clarifiers and ahead of the expanded filters as required to chemically polish the phosphorus in the effluent. A process flow diagram for this alternative is presented in Figure 8.

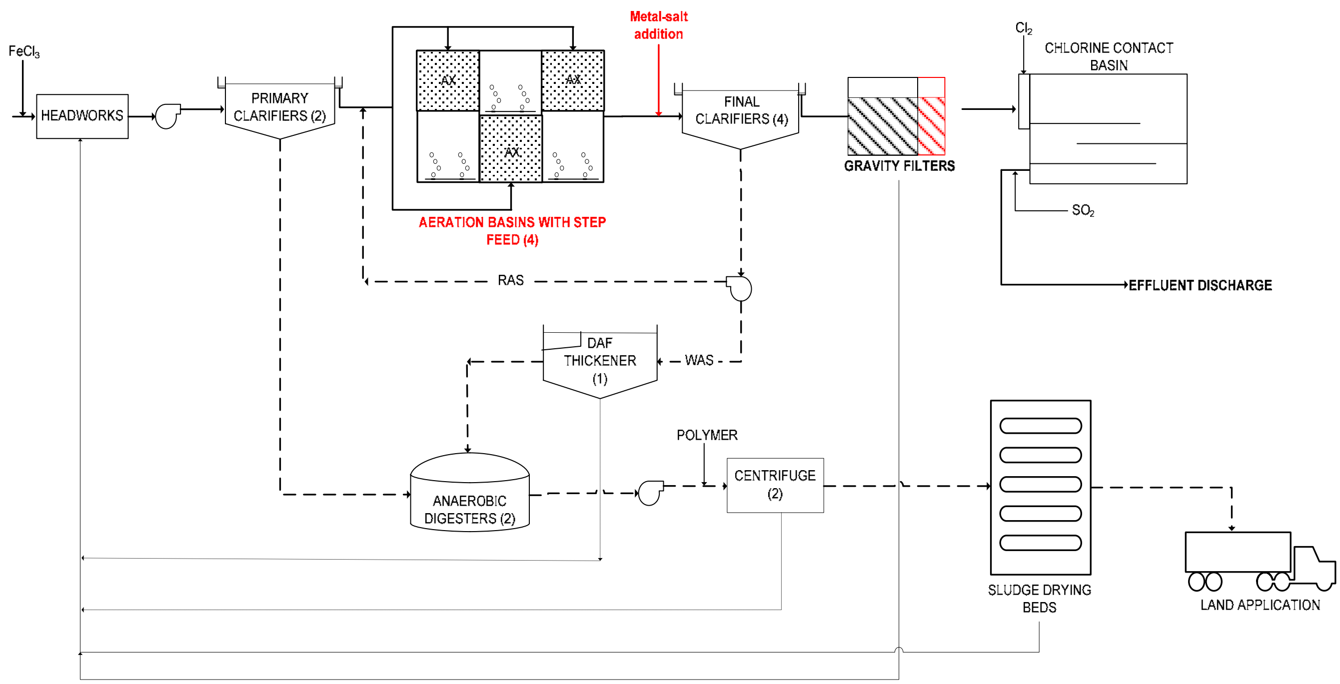

FIGURE 8
Modifications to POTW for Tier 1N Nutrient Control

4. Capital and O&M Cost Estimates for Nutrient Control

This section summarizes the cost-impact results from this nutrient control analysis. These outputs were used in the financial cost model and subsequent financial analyses.

Table 6 presents a summary of the major components identified for facility upgrade for meeting each tier of nutrient control. For Tier 2, the aeration basins were modified to include an anaerobic zone and the existing metal-salt storage facility was augmented with additional storage and new feed pumps ahead of the final clarifiers. To go to Tier 2N, the modifications to the aeration tanks included accommodating a step feed activated sludge system with alternating non-aerated and aerated zones. Tier 1 level of phosphorus control required expansion of the existing gravity sand filters and an additional metal-salt storage and feed pumps upstream of them gravity filters, in addition to the components identified for Tier 2. With Tier 1N, all the components identified for Tier 2N and Tier 1 were required.

TABLE 6

Major Facility Upgrade Summary

Processes	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed and storage facility	X	X	X	X
Aeration basin modifications to include anaerobic zone	X		X	
Aeration basin modifications to include step feed activated sludge process		X		X
Secondary Effluent Pump Station			X	X
Expansion of the existing gravity sand filter system			X	X

The capital cost estimates shown in Table 6 were generated for the facility upgrades summarized in Table 5. These estimates were prepared in accordance with the guidelines of the Association for the Advancement of Cost Engineering (AACE) International and defined as a Class 4 estimate. The expected accuracy range for the estimates shown in Table 7 is -30%/+50%.

TABLE 7
Capital Cost Estimates ($ Million)

Unit Process Facility	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed and storage facility	$0.70	$0.70	$2.08	$2.08
Aeration basin modifications to include anaerobic zone	$0.60	$0.00	$0.60	$0.00
Aeration basin modifications to include step feed activated sludge process	$0.00	$0.97	$0.00	$0.97
Secondary Effluent Pump Station	$0.00	$0.00	$9.24	$9.24
Expansion of the existing gravity sand filter system	$0.00	$0.00	$20.34	$20.34
TOTAL TIER COST	**$1.31**	**$1.69**	**$32.26**	**$32.63**

December 2009 US Dollars

Incremental O&M costs associated with meeting each tier of nutrient standard were generated for the years 2009 and 2029. The unit costs were either provided by the POTW or assumed based on the average costs in the State of Utah, and are presented in Table 8. A straight line interpolation was used to estimate the differential cost for the two years. O&M costs for each upgrade included the following components:

- Biosolids management: hauling , use, and disposal
- Chemical consumption costs: metal-salt, and, polymer
- Power costs for the major mechanized process equipment: aeration, secondary effluent pumps, backwash pumps and dewatering units

TABLE 8
Operating and Maintenance Unit Costs

Parameter	Value
Biosolids hauling	\$6.02/wet ton
Biosolids tipping fee	\$0/wet ton
Biosolids roundtrip hauling distance (1)	70 miles
Ferric Chloride	\$480/ton
Polymer	\$1/lb
Power	\$0.04/kwh

(1) Provided by the POTW

Increased O&M relative to the current O&M cost (Tier 3) are presented in Table 9 and shown graphically in Figure 9.

TABLE 9
Estimated Impact of Nutrient Control on O&M Costs

	Tier 2		Tier 2N		Tier 1		Tier 1N	
	2009	**2029**	**2009**	**2029**	**2009**	**2029**	**2009**	**2029**
Biosolids	\$0.01	\$0.01	\$0.00	\$0.01	\$0.09	\$0.13	\$0.09	\$0.13
Metal-salt	\$0.28	\$0.35	\$0.32	\$0.50	\$0.94	\$1.23	\$1.04	\$1.33
Polymer	\$0.01	\$0.01	\$0.01	\$0.01	\$0.03	\$0.03	\$0.03	\$0.04
Power	(\$0.01)	(\$0.00)	\$0.02	\$0.04	\$0.06	\$0.10	\$0.09	\$0.14
Total O&M	**\$0.30**	**\$0.37**	**\$0.35**	**\$0.55**	**\$1.12**	**\$1.49**	**\$1.25**	**\$1.63**

Note: \$ Million (US) in December 2009

Costs shown are the annual differential costs relative to the base line O&M cost of the POTW

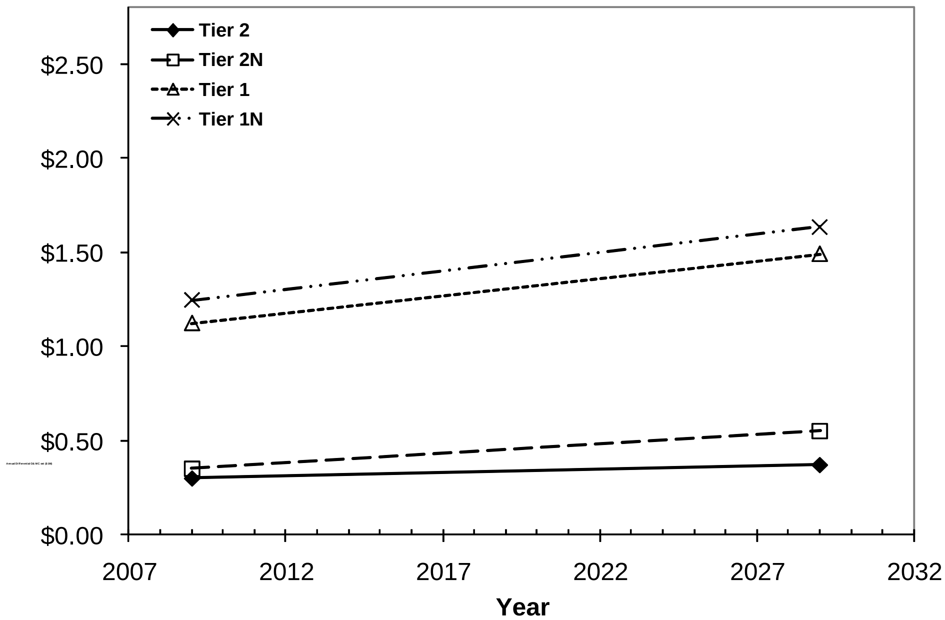

FIGURE 9
Impact of Nutrient Control on O&M Costs over 20 year evaluation period

5. Financial Impacts

This section presents the estimated financial impacts that will result from the implementation of nutrient discharge standards for the PCWRF. Financial impacts were summarized for each POTW on the basis of three primary economic parameters: 20-year life cycle costs, user charge impacts, and community financial impacts. The basis for the financial impact analysis is the estimated capital and incremental O&M costs established in the previous sections.

Life Cycle Costs

Life cycle cost analysis refers to an assessment of the costs over the life of a project or asset, emphasizing the identification of cost requirements beyond the initial investment or capital expenditure.

For each treatment upgrade established to meet the studied nutrient limits (Tier 2, Tier 2N, Tier 1, and Tier 1N), a multi-year life cycle cost forecast was developed that is comprised of both capital and O&M costs. Cost forecasts are organized with initial capital expenditures in year 0 (2009), and incremental O&M forecasts from year 1 (2010) through year 20 (2029). The cost forecast for each treatment alternative was developed in current (2009) dollars, and discounted to yield the net present value (NPV).

The NPV was divided by the estimated 20-year nutrient discharge mass reduction for each tier, resulting in a cost per pound estimate for nutrient removal. This calculation represents an appropriate matching of costs with receiving stream load reduction over the same time period. Table 10 presents the results of the life cycle cost analysis for PCWRF.

TABLE 10

Nutrient Removal: 20-Year Life Cycle Cost per Pound [1]

	Tier 2	Tier 2N	Tier 1	Tier 1N
Phosphorus Removal (pounds)[2]	3,023,225	3,023,225	3,834,699	3,834,699
Nitrogen Removal (pounds)[2]	-	3,212,136	-	12,228,517
Net Present Value of Removal Costs[3]	**$ 6,438,733**	**$ 8,548,033**	**$ 52,139,185**	**$ 54,538,482**
NPV: Phosphorus Allocation	6,438,733	6,438,733	52,139,185	52,139,185
NPV: Nitrogen Allocation[4]		2,109,301		2,399,297
TP Cost per Pound[5]	**$ 2.13**	**$ 2.13**	**$ 13.60**	**$ 13.60**
TN Cost per Pound[5]		**$ 0.66**		**$ 0.20**

1 - For facilities that are already meeting one or more nutrient limits, "meets limit" is displayed for nutrient removal mass and "NA" is displayed for cost per pound metrics

2 - Total nutrient removal over a 20-year period, from 2010 through 2029

3 - Net present value of removal costs, including capital expenditures and incremental O&M over a 20-year period

4 - For simplicity, it was assumed that the nitrogen cost allocation was the incremental difference between net present value costs across Tiers for the same phosphorus limit (i.e. Tier 2 to Tier 2N); differences in technology recommendations may result in different cost allocations for some facilities

5 - Cost per pound metrics measured over a 20-year period are used to compare relative nutrient removal efficiencies among treatment alternatives and different facilities

Customer Financial Impacts

The second financial parameter measures the potential impact to user rates for those customers served by the POTW. The financial impact was measured both in terms of potential rate increases for the POTW's associated service provider, and the resulting monthly bill impacts for the typical residential customer of the system.

Customer impacts were estimated by calculating annual increased revenue requirements for the POTW. Implementation of each treatment upgrade will increase the annual revenue requirements for debt service payments (related to initial capital cost) and incremental O&M costs.

The annual cost increase was then divided by the number of customers served by the POTW, as measured by equivalent residential units (ERUs), to establish a monthly rate increase per ERU. The monthly rate increase associated with each treatment alternative was estimated by adding the projected monthly rate increase to the customer's current average monthly bill. Estimated financial impacts for customers of the PCWRF are presented in Table 11.

TABLE 11

Projected Monthly Bill Impact per Equivalent Residential Unit (ERU) for Treatment Alternatives

	Tier 2	Tier 2N	Tier 1	Tier 1N
Initial Capital Expenditure	$ 1,330,000	$ 1,693,000	$ 32,262,000	$ 32,625,000
Estimated Annual Debt Service[1]	$ 106,700	$ 135,900	$ 2,588,800	$ 2,617,900
Incremental Operating Cost[2]	303,100	363,000	1,140,700	1,264,900
Total Annual Cost Increase	$ 409,800	$ 498,900	$ 3,729,500	$ 3,882,800
Number of ERUs	22,310	22,310	22,310	22,310
Annual Cost Increase per ERU	$18.37	$22.36	$167.17	$174.04
Monthly Cost Increase per ERU[3]	**$1.53**	**$1.86**	**$13.93**	**$14.50**
Current Average Monthly Bill[4]	$4.26	$4.26	$4.26	$4.26
Projected Average Monthly Bill[5]	**$5.79**	**$6.12**	**$18.19**	**$18.76**
Percent Increase	**35.9%**	**43.7%**	**327.0%**	**340.5%**

1 - Assumes a financing term of 20 years and an interest rate of 5.0 percent

2 - Incremental annual increase in O&M for each upgrade, based on chosen treatment technology, estimated for first operational year

3 - Projected monthly bill impact per ERU for each upgrade, based on estimated increase in annual operating costs

4 - Estimated 2009 average monthly bill for a typical residential customer (ERU) within the service area of the facility

5 - Projected average monthly bill for a typical residential customer (ERU) if treatment upgrade is implemented

Community Financial Impacts

The third and final parameter measures the financial impact of nutrient limits from a community perspective, and accounts for the varied purchasing power of customers throughout the state. The metric is the ratio of the projected monthly bill that would result from each treatment alternative to an affordable monthly bill, based on a parameter established by the State Water Quality Board to determine project affordability.

The Division employs an affordability criterion that is widely used to assess the affordability of projects. The affordability threshold is equal to 1.4 percent of the median annual gross household income (MAGI) for customers served by a POTW. The MAGI estimate for customers of each POTW is multiplied by the affordability threshold parameter, then divided by 12 (months) to determine the monthly 'affordable' wastewater bill for the typical customer.

The projected monthly bill for each nutrient limit was then expressed as a percentage of the monthly affordable bill. The resulting affordability ratio for each nutrient limit for the PCWRF is shown in Table 12.

TABLE 12

Community Financial Impacts: Affordability of Treatment Alternatives

	Tier 2	Tier 2N	Tier 1	Tier 1N
Median Annual Gross Income (MAGI)[1,2]	$ 25,600	$ 25,600	$ 25,600	$ 25,600
Affordability Threshold (% of MAGI)[3]	1.4%	1.4%	1.4%	1.4%
Monthly Affordability Criterion	**$29.87**	**$29.87**	**$29.87**	**$29.87**
Projected Average Monthly Bill	$5.79	$6.12	$18.19	$18.76
Meets State's Affordability Criterion?	Yes	Yes	Yes	Yes
Estimated Bill as % of State Criterion	**19%**	**21%**	**61%**	**63%**

1 - Based on the average MAGI of customers within the service area of the facility

2 - MAGI statistics compiled from 2008 census data

3 - Parameter established by the State Water Quality Board to determine project affordability for POTWs

6. Environmental Impacts of Nutrient Control Analysis

This section summarizes the potential environmental benefits and impacts that would result from implementing the process upgrades established for the various tiers of nutrient control detailed in Section 3. The following aspects were considered for this evaluation:

- Reduction of nutrient loads from POTW to receiving water bodies
- Changes in chemical consumption
- Changes in biosolids production
- Changes in energy consumption
- Changes in emissions from biosolids hauling, disposal and energy consumption

As per the data received from PCWRF and per process modeling of the base condition (Tier 3), PCWRF is able to achieve some nutrient removal with its existing infrastructure, but not enough to meet the effluent limits of the specified Tiers of nutrient standards. Table 13 summarizes the annual reduction in nutrient loads in PCWRF effluent discharge if the process upgrades were implemented. The values shown are for the current (2009) flow and load conditions. It should be noted that any increase in flow or load will result in higher reductions.

TABLE 13

Estimated Environmental Benefits of Nutrient Control

	Tier 2	Tier 2N	Tier 1	Tier 1N
Total phosphorus removed, lb/year	114,130	114,130	145,910	145,910
Total nitrogen removed, lb/year	----	130,055	----	483,170

Note: Nutrient loads shown are the annual differential loads relative to the baseline (Tier 3) condition of the POTW for the year 2009.

The nutrient content of POTWs' discharges and their receiving waters were also summarized to examine the potential of various treatment alternatives for reducing nutrient loads to those water bodies. The POTW loads were paired with estimated loads in the upstream receiving waters to create estimated downstream combined loads. Those combined stream and POTW loads could then be examined for the potential effects of future POTW nutrient removal alternatives. The average total nitrogen and phosphorus concentrations discharged by each POTW were either provided by the POTW during the data collection process or obtained from process modeling efforts. Upstream receiving historical water quality data was obtained from STORET. Data from STORET was summarized in order to yield average total nitrogen and total phosphorus concentrations that could then be paired with the appropriate POTW records. It should be noted that the data obtained from STORET were not verified by sampling and possible anomalies and outliers could exist in historical data sets due to certain events or errors in measurement.

Table 14 shows the total phosphorus and total nitrogen concentration discharged by PCWRF to its receiving waters for baseline condition (Tier 3) and for each Tier of nutrient standard. The STORET ID from where historical water quality data were obtained is also presented in the Table.

TABLE 14
Estimates of Average TN and TP Concentrations for Baseline and Cumulative Treatments to Receiving Waters (mg/L)

			Tier 3		Tier 2		Tier 2N		Tier 1		Tier 1N	
STORET LOCATION	**STORET ID**	**FLOW (cfs)**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**
PCWRF	----	17.95	4.23	23.68	1.0	N/A	1.0	20	0.1	N/A	0.1	10
Millrace Creek above POTW	4996570	37.73	0.14	1.98	----	----	----	----	----	----	----	----
Combined Concentrations			**1.46**	**8.98**	**0.42**	**N/A**	**0.42**	**7.79**	**0.13**	**N/A**	**0.13**	**4.57**

The process upgrades established to meet the four tiers of nutrient standards require increased energy consumptions, chemical usage and biosolids production. Regular metal-salt addition would be required to meet the more stringent phosphorus limits. This would result in increased chemical sludge generation and consequently increased biosolids production. Process modifications to meet the total nitrogen limits would also result in increased energy consumption and biosolids productions. Table 15 summarizes these environmental impacts of implementing the process upgrades to achieve the various tiers of nutrient control. The values shown are on an annual basis, for the current (2009) flow and load conditions and indicate a differential value relative to the base line condition.

TABLE 15
Estimated Environmental Impacts of Nutrient Control

		Tier 2	Tier 2N	Tier 1	Tier 1N
Chemical Use:					
Metal-salt use, lb/year		15,600	637,470	1,887,220	2,072,525
Polymers, lb/year		320	6,800	28,100	27,500
Biosolids Management:					
Biosolids produced, ton/year		7	170	700	685
Average yearly hauling distance(1)		0	540	2,235	2,185
Particulate emissions from hauling trucks, lb/year (2)		0	30	125	122
Tailpipe emissions from hauling trucks, lb/year(3)		0	70	285	280
CO_2 emissions from hauling trucks lb/year(4)		0	6,895	28,415	27,760
Energy Consumption:					
Annual energy consumption, kwh		0	552,422	1,395,931	2,155,947
Air pollutant emissions, lb/year (5)					
	CO_2	0	498,285	1,259,130	1,944,664
	NOx	0	773	1,954	3,018
	SOx	0	663	1,675	2,587
	CO	0	36	92	141
	VOC	0	4	11	17
	PM_{10}	0	11	27	42
	$PM_{2.5}$	0	5	14	21

Note: Values shown are the annual differential values relative to the base line condition (Tier 3) of the POTW for the year 2009

(1) Based on the assumption of a 70 miles round trip hauling distance and, on the assumption that the facility uses 22 ton trucks for hauling biosolids to the land application and composting.

(2) Includes PM_{10} and $PM_{2.5}$ emissions in pounds per year. The emission factors to estimate particulate emissions were derived using the equations from *AP-42, Fifth Edition, Vol. I, Section 13.2.1.: Paved Roads (11/2006)*.

(3) Tailpipe emissions in pounds per year resulting from diesel combustion of hauling trucks were based on *Emission standards Reference guide for Heavy-Duty and Nonroad Engines, EPA420-F-97-014 September 1997.* It was assumed that the trucks would meet the emission standards for 1998+.

(4) CO_2 emission factor in pounds per year for hauling trucks were derived from *Rosso and Chau, 2009, WEF Residuals and Biosolids Conference Proceedings.*

(5) Emission factors for electricity are based on EPA Clean Energy Power Profiler (http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html) assuming PacifiCorp UT region commercial customer and *AP-42, Fifth Edition, Vol. I, Chapter 1, Section 1.1.: Bituminous and Sub bituminous coal Combustion (09/1998)*.