UDWQ POTW Nutrient Removal Cost Impact Study: Analysis of Fairview City Wastewater Treatment Plant

PREPARED FOR: Utah Division of Water Quality

PREPARED BY: CH2M HILL

COPIES: Fairview City Wastewater Treatment Plant

DATE: September 2010

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 benefit and impact evaluation of Fairview City Wastewater Treatment Plant (FCWTP) 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 FCWTP fits in the MBR 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 flow of 0.375 million gallons per day (mgd) and currently receives an average annual influent flow of approximately 0.07 mgd. The facility operates an anoxic/aerobic activated sludge process ahead of the MBRs to treat its influent wastewater. The secondary effluent is discharged to the receiving water after disinfection. Currently FCWTP is regulated for BOD and TSS. Residual secondary solids generated from the process are mechanically dewatered using a belt press and disposed of in a landfill. A process flow diagram of the existing facility is presented in Figure 1 and the major existing unit processes are listed in Table 2.

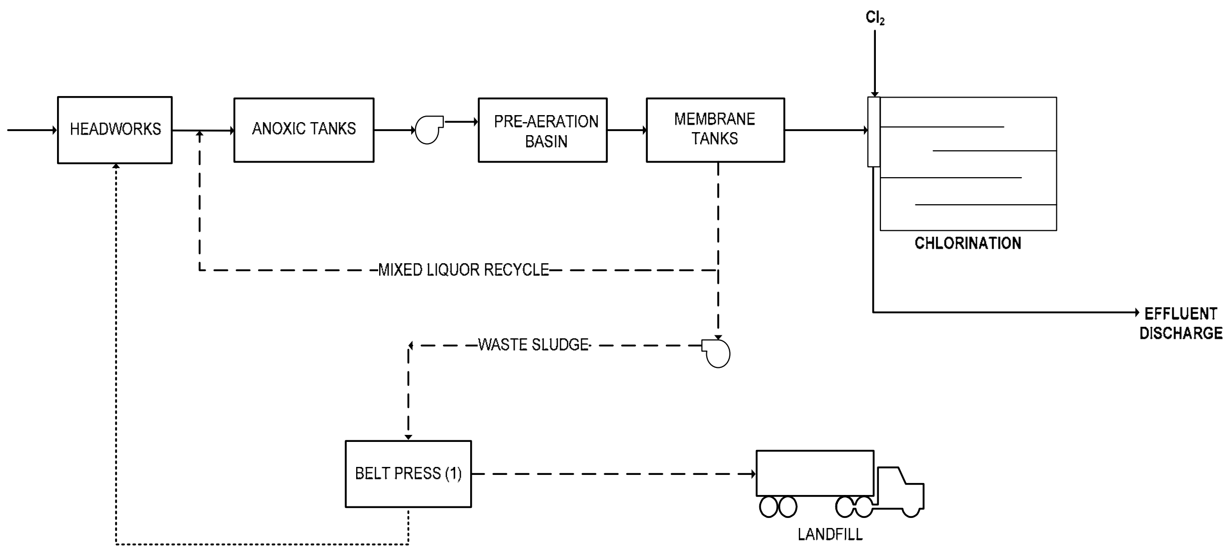

FIGURE 1
Process Flow Diagram

TABLE 2
Summary of Major Unit Processes

Unit Process	Number of Units	Size, Each	Details
Anoxic basins	2	14,000 gal. 7-ft SWD	Rectangular
Pre-aeration basin	2	28,500 gal	Fine bubble diffused aeration
Membrane basins	2	35,000 gal, 10-ft SWD	Flat plate-type membranes
Dewatering	1	0.75 meter	Belt filter press

2. Nutrient Removal Alternatives Development, Screening and Selection

For all the other treatment categories, a nutrient removal alternatives matrix was prepared to capture an array of viable approaches to meet the various Tiers of nutrient control. This was not done for the MBR category as they are inherently capable of achieving 1 mg/L total phosphorus and 10 mg/L total nitrogen limit. The most viable approach to upgrade the MBR facilities was to implement chemical phosphorus removal. 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 the process 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.

FCWTP operates all of the facilities listed in Table 2 and is able to achieve biological nutrient removal to a certain extent. A goal of this project was to make maximum use of the existing infrastructure in the upgrade approaches selected for meeting the various tiers of nutrient limits. Upgrades were added to the system models as required to meet increasingly stringent discharge limits. Figure 2 shows the basic upgrade approach used between each tier of nutrient control with the bullet points A through D below describing each upgrade step:

A. From Tier 3 (existing) to Tier 2 phosphorus control, a metal-salt addition system was initiated ahead of the MBR basins to be operated only as required to achieve chemical phosphorus removal.

B. From Tier 2 to Tier 2N, no additional process modifications were required.

C. To go from Tier 2 to Tier 1 level of phosphorus control, higher doses of metal-salt was added ahead of the membrane basins to bring down the effluent phosphorus concentration to 0.1 mg/L.

D. To add nitrogen removal to Tier 1, no additional process modifications were required.

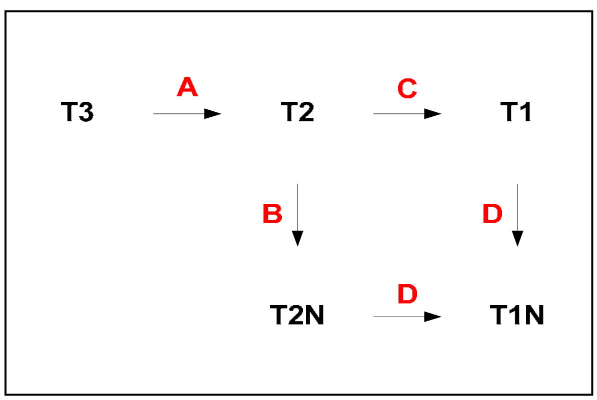

FIGURE 2
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

Data Evaluation and Modeling of Upgrades

The selected progression of the upgrades conceived for meeting the different tiers of nutrient control for FCWTP 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 David Nuttall of FCWTP during the October 2009 workshop and through follow-up emails was evaluated to (a) develop and validate the base process model, and (b) size facilities to conserve the POTW's current rated capacity. Table 3 provides a summary of the reported information used as the model input conditions. See Process Modeling Protocol (Attachment B) for additional information.

TABLE 3
Summary of Input Conditions

Input Parameter	2009[1]	2029[2]	Design[3]
Flow, mgd	0.07	0.20	0.45
BOD, lb/day	140 (240 mg/L)	400 (240 mg/L)	900 (240 mg/L)
TSS, lb/day	117 (200 mg/L)	335 (200 mg/L)	750 (200 mg/L)
TKN, lb/day	32 (50 mg/L)	85 (50 mg/L)	190 (50 mg/L)
TP, lb/day	4 (6 mg/L)	10 (6 mg/L)	23 (6 mg/L)

(1) Historic conditions 2007-2009

(2) Assumed based on increase in population from Census report

(3) Estimated design maximum month capacity of POTW. Assumed 1.2 times (peaking factor) the design annual average flow provided by the POTW

The main sizing and operating design criteria that were important for capturing the costs associated with the system upgrades for FCWTP are summarized in Table 4.

TABLE 4
Main Unit Process Sizing and Operating Design Parameters

Design Parameter (Nutrient Tier)	Value
Influent design temperature	10 deg C
Target metal:PO_4-P molar Ratio (All tiers)[1]	2:1
Metal salt storage capacity (Tier2 and Tier2N)	5 days
Metal salt storage (Tier1 and Tier1N)	14 days
Membrane flux rate	12 gpm/ft^2

(1)Target dosing ratio ahead of the MBR tanks

3. Nutrient Upgrade Approaches

The following paragraphs provide details of the upgrade approaches for the different Tiers of nutrient control as presented previously in Figure 3.

Tier 2 Phosphorus (A)

The effluent limit for Tier 2 alternative is 1.0 mg/L total phosphorus. According to process modeling, FCWTP is able to achieve this limit with their existing infrastructure and mode of operation. However, a metal-salt feed point was added to the existing facilities ahead of the MBR basins as a backup to biological phosphorus removal. This feed point would be operated as required for chemical phosphorus removal if and when the existing process fails to achieve the phosphorus limit. A process flow diagram for this treatment approach is presented in Figure 3. The upgrades are indicated in red.

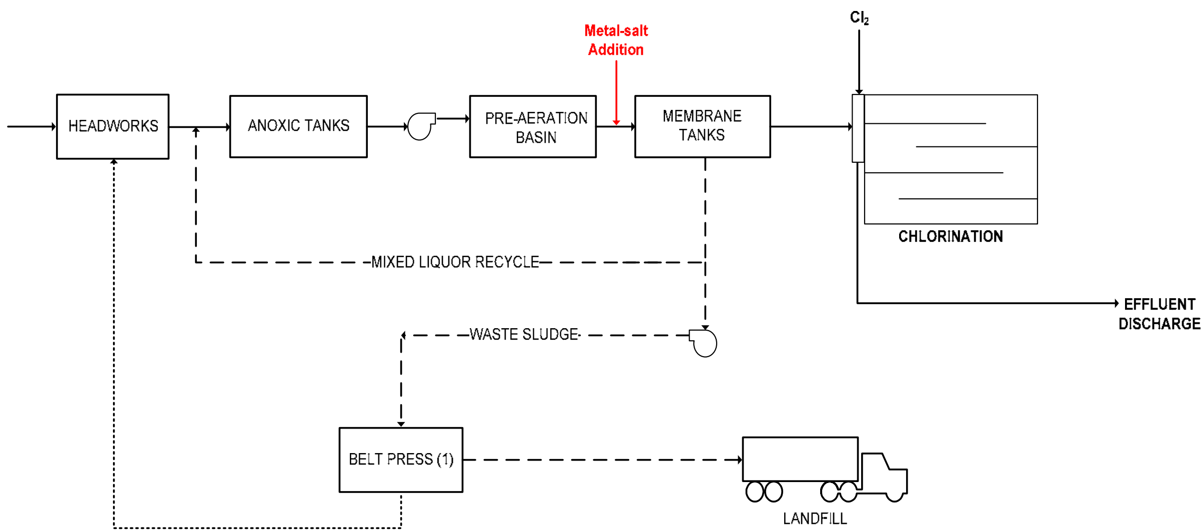

FIGURE 3
Modifications to POTW for Tier 2 Nutrient Control

Tier 2N – Phosphorus & Nitrogen (B)

The metal-salt feed point ahead of the MBR basins added in Tier 2 would not require any adjustments or modification to achieve moderate levels of nitrogen control for this Tier along with phosphorus control. The existing process is already exhibiting sufficient biological nitrogen removal to meet this limit; therefore, the process flow diagram for this approach would be the same as presented in Figure 3.

Tier 1 Phosphorus (C)

Upgrades to this alternative would essentially be the same as the Tier 2 approach for phosphorus control, thus the process flow diagram would be the same as presented in Figure 3. However, greater and regular application rate of metal-salt would be required to bring down the effluent phosphorus concentration to 0.1 mg/L, thus requiring an expansion of the feed facility proposed for Tier 2 and 2N.

Tier 1N Phosphorus & Nitrogen (D)

The approach and process flow diagram for this approach would be the same as presented for Tier 1 level of phosphorus control. The existing process is already exhibiting sufficient biological nitrogen removal to meet the limits of this alternative.

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

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

Table 5 presents a summary of the major components identified for facility upgrades in order to meet the various Tiers of nutrient standards. For all the Tiers, a metal-salt storage facility and new metal-salt feed pumps were installed ahead of the MBR basins. It was assumed that the building that houses the existing anoxic, aerobic and MBR basins has sufficient space to house the metal-salt storage and pump systems.

TABLE 5
Major Facility Upgrade Summary

Processes	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed pumps and storage facility	X	X	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 6 is -30%/+50%.

TABLE 6
Capital Cost Estimates

Unit Process Facility	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed pumps and storage facility	$120,923	$120,923	$314,401	$314,401
TOTAL TIER COST	**$120,923**	**$120,923**	**$314,401**	**$314,401**

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 O&M costs were either provided by the POTW or assumed based on the average costs in the State of Utah, and are presented in Table 7. A straight line interpolation was used to estimate the differential cost for the two years. O&M estimates for each upgrade included the following components:

- Biosolids management: hauling, and disposal

- Chemical consumption costs: metal-salt, and polymer.

No energy costs were included because the energy required to operate the metal-salt feed pumps would be insignificant when compared to the total energy of the facility.

TABLE 7
Operating and Maintenance Unit Costs

Parameter	Value
Biosolids hauling	$8/wet ton
Biosolids tipping fee(1)	$30/wet ton
Round trip hauling distance(2)	96 miles
Ferric chloride	$1000/ton
Polymer	$1/lb

(1) Tipping/disposal fee provided by the POTW

(2) Round trip hauling distance to the landfill provided by the POTW

Increased O&M relative to the current O&M cost (Tier 3) are presented in Table 8 and shown graphically in Figure 4.

TABLE 8
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(1)	$0	$0	$0	$0	$1,293	$2,596	$1,293	$2,596
Metal-salt	$64	$150	$64	$150	$12,775	$31,025	$12,775	$31,025
Polymer	$36	$50	$36	$50	$232	$579	$232	$579
Total O&M	**$100**	**$200**	**$100**	**$200**	**$14,300**	**$34,200**	**$14,300**	**$34,200**

Note: $ (US) in December 2009.

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

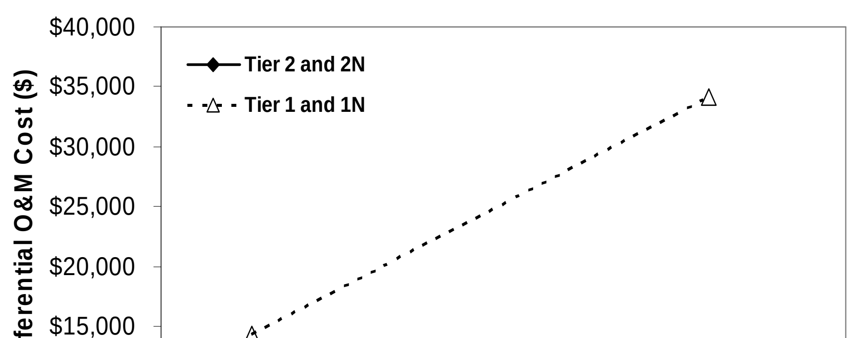

FIGURE 4
Impact of Nutrient Control on O&M Costs over 20 year evaluation period

5. Financial Impacts

This section presents the estimated financial impacts that would result from the implementation of nutrient discharge standards for the FCWTP. 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 9 presents the results of the life cycle cost analysis for FCWTP.

TABLE 9

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

	Tier 2	Tier 2N	Tier 1	Tier 1N
Phosphorus Removal (pounds)[2]	meets limit	meets limit	7,579	7,579
Nitrogen Removal (pounds)[2]	-	meets limit	-	meets limit
Net Present Value of Removal Costs[3]	**$ 123,266**	**$ 123,266**	**$ 679,182**	**$ 679,182**
NPV: Phosphorus Allocation	123,266	123,266	679,182	679,182
NPV: Nitrogen Allocation[4]		-		-
TP Cost per Pound[5]	**NA**	**NA**	**$ 89.62**	**$ 89.62**
TN Cost per Pound[5]		**NA**		**NA**

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 w as assumed that the nitrogen cost allocation w as the incremental difference betw een 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 customers served by the POTW. The financial impact is 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 FCWTP are presented in Table 10.

TABLE 10

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

	Tier 2	Tier 2N	Tier 1	Tier 1N
Initial Capital Expenditure	$ 121,000	$ 121,000	$ 314,000	$ 314,000
Estimated Annual Debt Service[1]	$ 9,700	$ 9,700	$ 25,200	$ 25,200
Incremental Operating Cost[2]	200	200	15,300	15,300
Total Annual Cost Increase	$ 9,900	$ 9,900	$ 40,500	$ 40,500
Number of ERUs	630	630	630	630
Annual Cost Increase per ERU	$15.71	$15.71	$64.29	$64.29
Monthly Cost Increase per ERU[3]	**$1.31**	**$1.31**	**$5.36**	**$5.36**
Current Average Monthly Bill[4]	$37.50	$37.50	$37.50	$37.50
Projected Average Monthly Bill[5]	**$38.81**	**$38.81**	**$42.86**	**$42.86**
Percent Increase	**3.5%**	**3.5%**	**14.3%**	**14.3%**

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 FCWTP is shown in Table 11.

TABLE 11

Community Financial Impacts: Affordability of Treatment Alternatives

	Tier 2	Tier 2N	Tier 1	Tier 1N
Median Annual Gross Income (MAGI)[1,2]	$ 35,000	$ 35,000	$ 35,000	$ 35,000
Affordability Threshold (% of MAGI)[3]	1.4%	1.4%	1.4%	1.4%
Monthly Affordability Criterion	**$40.83**	**$40.83**	**$40.83**	**$40.83**
Projected Average Monthly Bill	$38.81	$38.81	$42.86	$42.86
Meets State's Affordability Criterion?	Yes	Yes	No	No
Estimated Bill as % of State Criterion	**95%**	**95%**	**105%**	**105%**

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 emissions from biosolids hauling.

Changes in energy consumption from the proposed upgrades were insignificant and thus were not considered.

As per the data received from FCWTP and per process modeling of the base condition (Tier 3), FCWTP is able to meet an effluent total nitrogen concentration of 10 mg/L and Tier 2 level of phosphorus control with its existing infrastructure. Table 12 summarizes the annual reduction in nutrient loads in FCWTP 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 to the POTW will result in higher reductions.

TABLE 12
Estimated Environmental Benefits of Nutrient Control

	Tier 2	Tier 2N	Tier 1	Tier 1N
Total phosphorus removed, lb/year	0	0	192	192
Total nitrogen removed, lb/year	----	0	----	0

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.

Currently FCWTP discharges to the San Pitch River. Table 13 shows the total phosphorus and total nitrogen concentration discharged by FCWTP to the San Pitch River 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 13
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**
FCWTP	----	0.108	1.0	10	1.0	N/A	1.0	20	0.1	N/A	0.1	10
San Pitch River	4946840	10.472	0.024	0.98	----	----	----	----	----	----	----	----
Combined Concentration			**0.034**	**1.072**	**0.034**	**N/A**	**0.034**	**1.072**	**0.025**	**N/A**	**0.025**	**1.072**

The process upgrades established to meet the four tiers of nutrient standards require increased chemical consumption and biosolids production. Metal-salt would need to be added to meet the more stringent phosphorus limits. This would generate more chemical sludge and consequently result to increased biosolids production. Table 14 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 the differential relative to the base line condition.

TABLE 14
Estimated Environmental Impacts of Nutrient Control

	Tier 2	Tier 2N	Tier 1	Tier 1N
Chemical Use:				
Metal-salt use, lb/year	100	100	29,200	29,200
Biosolids Management:				
Biosolids to disposal, ton/year	0	0	6	6
Additional hauling distance, miles/year	0	0	96	96
Particulate emissions from hauling trucks, lb/year[(1)]	0	0	5	5
Tailpipe emissions from hauling trucks, lb/year[(2)]	0	0	12	12
CO_2 emissions from hauling trucks lb/year[(3)]	0	0	1,200	1,200

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

[(1)] 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)*.

[(2)] 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+.

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