

UDWQ POTW Nutrient Removal Cost Impact Study: Analysis of Snyderville Basin - Silver Creek 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 analysis of Silver Creek Water Reclamation Facility (SCWRF) 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 SCWRF fits in the Oxidation Ditch 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	Base condition

1. Facility Overview

SCWRF has a design flow of 2.4 million gallons per day (mgd) and currently receives an average influent flow of approximately 1.4 mgd annually. The facility operates an oxidation ditch with secondary clarification for solids separation. The secondary effluent is disinfected using a ultra-violet disinfection system prior to discharge. The facility has the option of filtering its secondary effluent using a traveling bridge filtration system. However, it is currently not being operated. The wasted secondary solids are mechanically dewatered using a belt filter press to obtain approximately 14.5% total solids and is utilized as a landfill top cover. A process flow diagram of the existing treatment plant is presented in Figure 1 and an aerial photo of the POTW is shown in Figure 2. The major existing unit processes are listed in Table 2.

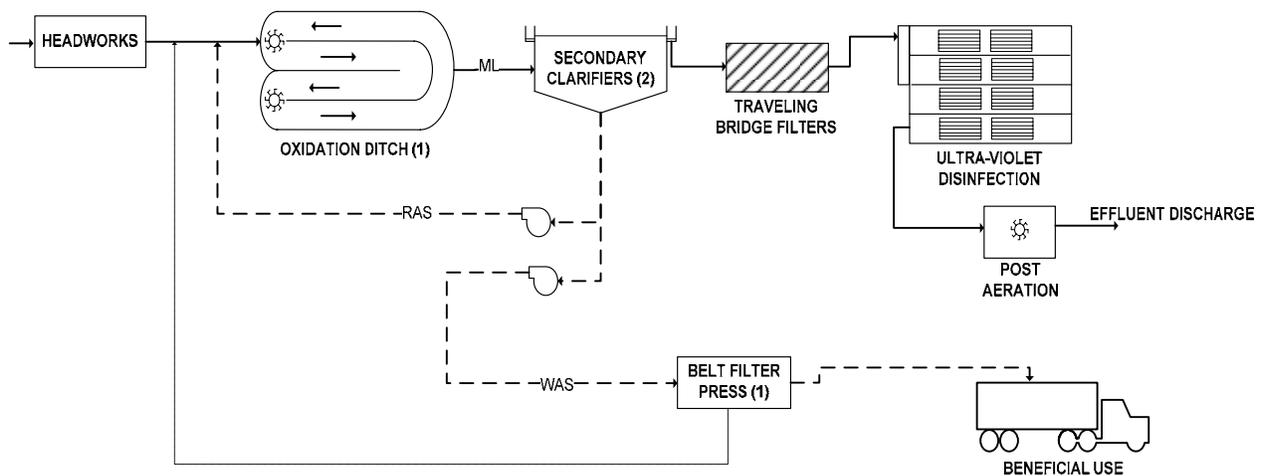


FIGURE 1
Process Flow Diagram



FIGURE 2
Aerial View of the Facility (Source: Google Earth)

TABLE 2
Summary of Major Unit Processes

Treatment step	Number of Units	Size, each	Details
Oxidation Ditch	1	1.5 MG	2 Aerators @ 100 HP each
Secondary Clarifiers	2	70-ft diameter, 14-ft SWD	Circular, covered
Traveling Bridge Filter	2	---	Not used
Belt Filter Press	1	1 m	----

2. Nutrient Removal Alternatives Development

A nutrient removal alternatives matrix was prepared to capture an array of viable approaches for OD 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 the 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.

SCWRF currently operates an oxidation ditch without primary treatment. Process modeling efforts show that the existing plant would require a second oxidation ditch to achieve the current discharge requirements at design conditions provided by the utility. Because of this, the baseline condition (Tier 3) includes two oxidation ditches, of equal volume, in order to maintain capacity. Nutrient control approaches were then based on this Tier 3 system. As with all of the POTWs, the upgrade approaches for nutrient removal were developed with the goal of utilizing the existing infrastructure to the maximum extent possible. Figure 3 shows the selected 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 process) to Tier 2 phosphorus control, a metal-salt addition system was implemented at the secondary clarifiers for chemical phosphorus removal.
- B. To go from Tier 2 to Tier 2N, no additional upgrades were required.
- C. To go from Tier 2 to Tier 1 level of phosphorus control, a deep bed granular media filtration system replaced the existing traveling bridge filter downstream of the secondary clarifiers to remove particulate phosphorus from the liquid stream. Metal-salt was added upstream of the filters in addition to the secondary clarifiers to enhance chemical phosphorus removal.
- D. To go from Tier 1 to Tier 1N, an anoxic selector was installed upstream of the existing oxidation ditches, along with a mixed-liquor recirculation system to achieve denitrification. Metal-salt addition was implemented at the secondary clarifiers and upstream of the deep bed granular media filters to achieve chemical phosphorus removal.

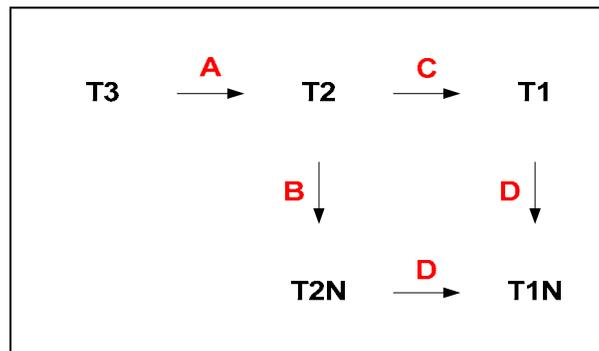


FIGURE 3
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

Data Evaluation, Initial Modeling, and Calibration

The selected progression of upgrades conceived for meeting the different tiers of nutrient control for SCWRF 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 SCWRF 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 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	1.4	2	2.5
BOD, lb/day	1,750 (150 mg/L)	3,600(215 mg/L)	5,630 (215 mg/L)
TSS, lb/day	2,070 (177 mg/L)	3,753 (225 mg/L)	6,255 (225 mg/L)
TKN, lb/day	374 (32 mg/L)	538 (32 mg/L)	898 (32mg/L)
TP, lb/day	53 (4 mg/L)	67 (4 mg/L)	120 (4 mg/L)

⁽¹⁾ Historic conditions 2007-2009

⁽²⁾ Projected by the POTW

⁽³⁾ Design maximum month capacity of POTW

The main sizing and operating design criteria that were associated with the system upgrade for SCWRF are summarized in Table 4.

TABLE 4
Main Unit Process Sizing and Operating Design Parameters

Design Parameter (Nutrient Tier)	Value
Influent design temperature (All Tiers)	10 deg C
Anoxic fraction of bioreactor (T1N)	15%
Target metal:PO ₄ -P molar Ratio (Tier 1 and 1N)	2:1, 7:1 ⁽¹⁾
Metal salt storage (All Tiers)	14 days
Fraction of mixed-liquor return flow to influent flow (T1N)	200%
Granular filter loading rate (T1 and T1N)	5 gpm/ft ² ⁽²⁾

⁽¹⁾ Target dosing ratio at the secondary clarifiers and upstream of polishing filter, respectively. Note that polishing filter included in T1 and T1N only. Filter doses were for Tiers 1 and 1N only

⁽²⁾ Hydraulic loading rate at peak hourly flow

3. Nutrient Upgrade Approaches

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

Tier 2 Phosphorus (A)

The effluent limit for this alternative is 1.0 mg/L total phosphorus. SCWRF can achieve this limit by implementing a metal-salt addition system at the secondary clarifiers. This approach would dose metal salt upstream of the clarifiers for chemical phosphorus removal. A chemical storage building was required to house both the storage tanks and the metering pumps. The process flow diagram for this approach is shown in Figure 4, with the upgrades indicated in red.

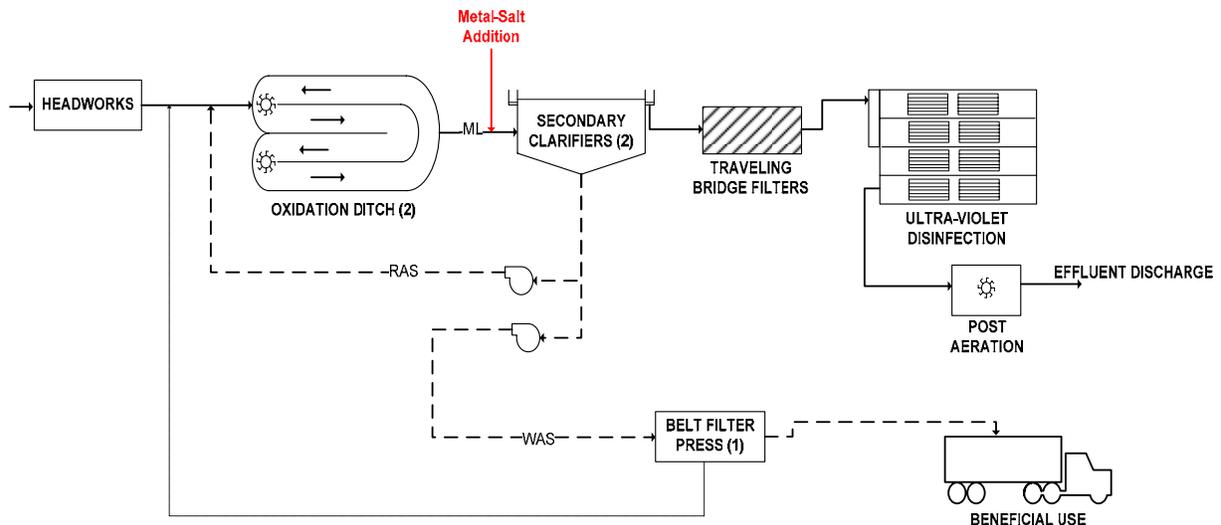


Figure 4
Modifications to POTW for Tier 2 Nutrient Control

Tier 2N – Phosphorus & Nitrogen (B)

The effluent limit for this alternative is 1.0 mg/L total phosphorus and 20 mg/L total nitrogen. The upgrades proposed for Tier 2 was sufficient for this nutrient removal alternative as the existing oxidation ditch process is already achieving enough nitrogen removal to meet the 20 mg/L total nitrogen limit. Thus, the process flow diagram would be the same as presented in Figure 4.

Tier 1 –Phosphorus (C)

This alternative builds upon the Tier 2 approach for phosphorus control to meet 0.1 mg/L total phosphorus limit. The settled effluent from the secondary clarifiers was pumped to a deep bed granular media filtration system, which replaced the existing traveling bridge filters. A second feed point for metal-salt addition was introduced upstream of the filters. The metal salt feed point at the secondary clarifiers was retained and operated. A process flow diagram of this approach is provided in Figure 5.

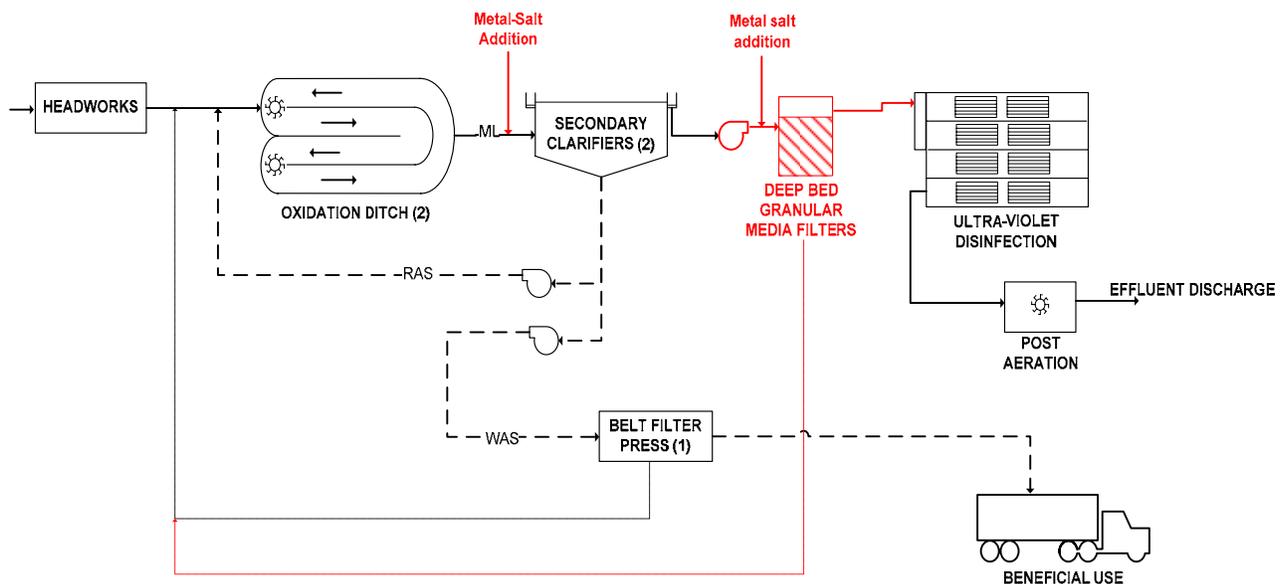


FIGURE 5
Modifications to POTW for Tier 1 Nutrient Control

Tier 1N – Phosphorus & Nitrogen (D)

The effluent limit for this alternative is 0.1 mg/L total phosphorus and 10 mg/L total nitrogen. Total nitrogen removal was achieved by installing an anoxic selector ahead of the oxidation ditches with a nitrate-rich mixed-liquor recirculation system. This allowed sufficient denitrification to occur in order to meet the 10 mg/L total nitrogen limit. For phosphorus removal, the multi-point metal salt feed systems at the secondary clarifiers and upstream of the granular filters as proposed for Tier 1 alternative was implemented. A process flow diagram is shown as Figure 6.

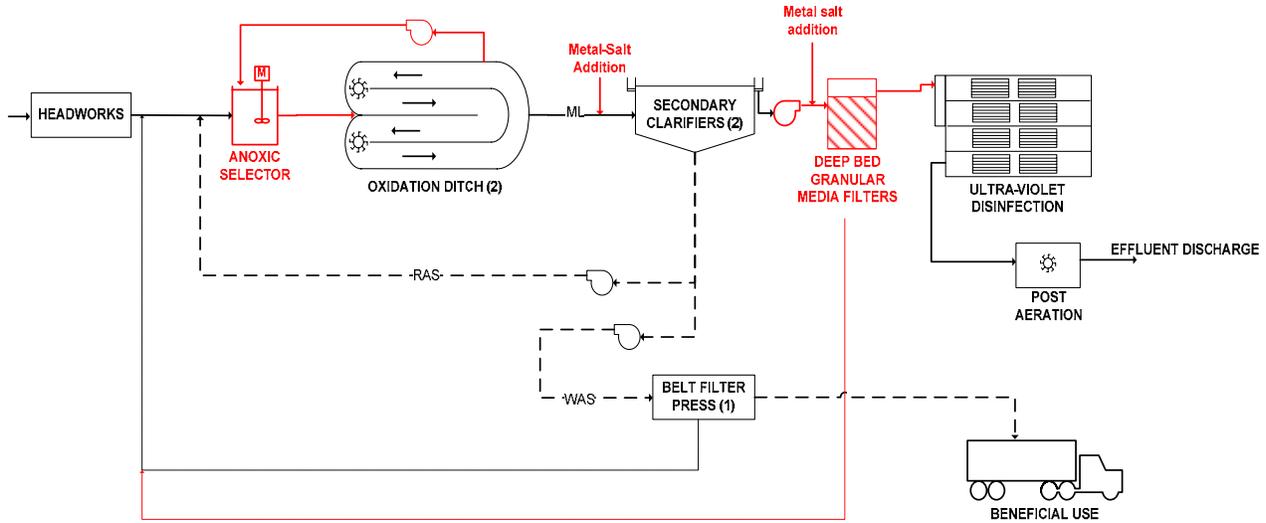


FIGURE 6
Modifications to POTW for Tier 1N Nutrient Control

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

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

Table 5 presents a summary of the major facility upgrade components identified for meeting each tier of nutrient control. For Tier 2 and Tier 2N, metal-salt storage facility and new feed pumps were required ahead of the secondary clarifiers. For Tier 1, a secondary effluent pump station was installed to lift the secondary effluent to the new deep bed granular media filters. A second metal-salt feed system was added upstream of the filters to provide chemical phosphorus polishing. For Tier 1N, in addition to the metal salt feed system at the secondary clarifiers and upstream of the new deep bed granular media filters, an anoxic selector along with mixed liquor recirculation system was installed.

TABLE 5
Major Facility Upgrade Summary

Processes	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed and storage facility	X	X	X	X
Anoxic selector				X
Mixed-liquor recirculation system				X
Secondary effluent pump station			X	X
Deep bed granular media filters			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 (\$ Million)

Unit Process Facility	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed pumps and storage facility	\$0.36	\$0.36	\$0.48	\$0.48
Anoxic selector	\$0	\$0	\$0	\$1.64
Mixed-liquor recirculation system	\$0	\$0	\$0	\$0.10
Secondary effluent pump station	\$0	\$0	\$1.62	\$1.62
Deep bed granular media filtration system	\$0	\$0	\$6.92	\$6.92
TOTAL TIER COST	\$0.36	\$0.36	\$9.02	\$10.76

December 2009 US Dollars

Incremental O&M costs associated with meeting each tier of nutrient standard were generated for the years 2009 and 2029. Unit costs provided by the POTW are presented in Table 7. If a unit cost was not provided, it was assumed based on the A round trip hauling distance was also assumed and is stated in Table 7. 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: secondary effluent pumps, backwash pumps and dewatering units

TABLE 7
Operating and Maintenance Unit Costs

Parameter	Value
Biosolids hauling	\$17/wet ton
Biosolids tipping fee	\$19/wet ton
Round trip hauling distance ⁽¹⁾	60 miles
Alum	\$480/ton
Polymer	\$1/lb
Power	\$0.06/kwh

⁽¹⁾ Roundtrip biosolids hauling distance was estimated between SCWRF and the Landfill site at Magna

Increased O&M relative to the current O&M cost (Tier 3) are presented in Table 8 and shown graphically in Figure 6.

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	\$0.005	\$0.007	\$0.005	\$0.007	\$0.009	\$0.012	\$0.008	\$0.011
Metal-salt	\$0.018	\$0.022	\$0.018	\$0.022	\$0.035	\$0.043	\$0.032	\$0.037
Polymer	\$0.000	\$0.001	\$0.000	\$0.001	\$0.001	\$0.001	\$0.001	\$0.001
Power	\$0.001	\$0.001	\$0.001	\$0.001	\$0.019	\$0.023	\$0.041	\$0.045
Total O&M	\$0.024	\$0.030	\$0.024	\$0.030	\$0.064	\$0.079	\$0.081	\$0.093

Note: \$ Million (US) in December 2009.

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

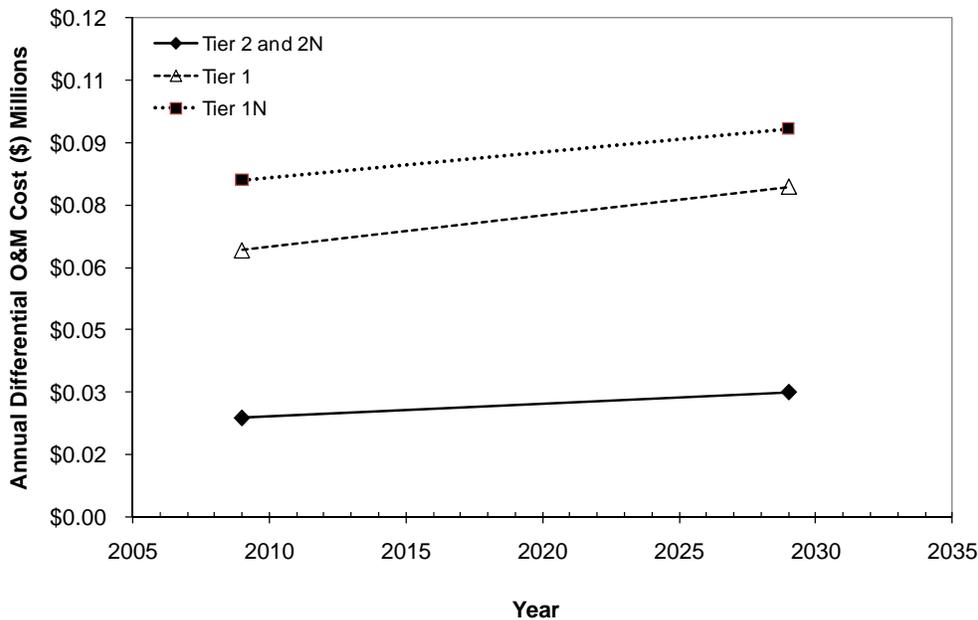


FIGURE 6
Impact of Nutrient Control on O&M Costs over 20 year evaluation period

5. Financial Impacts

This section presents the estimated financial impacts that will result from the implementation of nutrient discharge standards for the State of Utah. 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 SCWRF.

TABLE 9

<i>Nutrient Removal: 20-Year Life Cycle Cost per Pound¹</i>				
	Tier 2	Tier 2N	Tier 1	Tier 1N
Phosphorus Removal (pounds) ²	191,732	191,732	285,748	285,748
Nitrogen Removal (pounds) ²	-	meets limit	-	1,044,627
Net Present Value of Removal Costs³	\$ 773,518	\$ 773,518	\$ 10,115,005	\$ 10,351,422
NPV: Phosphorus Allocation	773,518	773,518	10,115,005	10,115,005
NPV: Nitrogen Allocation ⁴		-		236,417
TP Cost per Pound⁵	\$ 4.03	\$ 4.03	\$ 35.40	\$ 35.40
TN Cost per Pound⁵		NA		\$ 0.23
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 SCWRF are presented in Table 10.

TABLE 10

<i>Projected Monthly Bill Impact per Equivalent Residential Unit (ERU) for Treatment Alternatives</i>				
	Tier 2	Tier 2N	Tier 1	Tier 1N
Initial Capital Expenditure	\$ 363,000	\$ 363,000	\$ 9,021,000	\$ 10,762,000
Estimated Annual Debt Service ¹	\$ 29,100	\$ 29,100	\$ 723,900	\$ 863,600
Incremental Operating Cost ²	24,300	24,300	65,000	81,700
Total Annual Cost Increase	\$ 53,400	\$ 53,400	\$ 788,900	\$ 945,300
Number of ERUs	5,540	5,540	5,540	5,540
Annual Cost Increase per ERU	\$9.64	\$9.64	\$142.40	\$170.63
Monthly Cost Increase per ERU³	\$0.80	\$0.80	\$11.87	\$14.22
Current Average Monthly Bill ⁴	\$28.50	\$28.50	\$28.50	\$28.50
Projected Average Monthly Bill⁵	\$29.30	\$29.30	\$40.37	\$42.72
Percent Increase	2.8%	2.8%	41.6%	49.9%
1 - Assumes a financing term of 20 years and an interest rate of 3.0 percent				
2 - Incremental annual increase in O&M based on chosen treatment technology, estimated for first operational year				
3 - Projected monthly bill impact per ERU for each alternative, based on estimated increase in facility's annual operating budget				
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 alternatives are 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 SCWRF is shown in Table 11.

TABLE 11

<i>Community Financial Impacts: Affordability of Treatment Alternatives</i>				
	Tier 2	Tier 2N	Tier 1	Tier 1N
Median Annual Gross Income (MAGI) ^{1,2}	\$ 41,700	\$ 41,700	\$ 41,700	\$ 41,700
Affordability Threshold (% of MAGI) ³	1.4%	1.4%	1.4%	1.4%
Monthly Affordability Criterion	\$48.65	\$48.65	\$48.65	\$48.65
Projected Average Monthly Bill	\$29.30	\$29.30	\$40.37	\$42.72
Meets State's Affordability Criterion?	Yes	Yes	Yes	Yes
Estimated Bill as % of State Criterion	60%	60%	83%	88%
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 and disposal and energy consumption

As per the data received from SCWRF and per process modeling of the base condition (Tier 3), SCWRF is able to meet an effluent total nitrogen concentration of 20 mg/L with its existing infrastructure. Table 12 summarizes the annual reduction in nutrient loads in SCWRF 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	7,600	7,600	11,500	11,500
Total nitrogen removed, lb/year	----	0	----	42,615

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 13 shows the total phosphorus and total nitrogen concentration discharged by SCWRF 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 13
Estimates of Average TN and TP Concentrations for Baseline and Cumulative Treatments to Receiving Waters (mg/L)

STORET LOCATION	STORET ID	FLOW (cfs)	Tier 3		Tier 2		Tier 2N		Tier 1		Tier 1N	
			TP	TN	TP	TN	TP	TN	TP	TN	TP	TN
SCWRF	----	2.166	2.78	20.0	1.0	N/A	1.0	20	0.1	N/A	0.1	10
Silver Creek above POTW	4926800	5.367	0.23	0.63	----	----	----	----	----	----	----	----
Combined Concentrations			0.96	6.20	0.45	N/A	0.45	6.19	0.19	N/A	0.19	3.70

The process upgrades established to meet the four tiers of nutrient standards require increased energy consumptions, chemical usage and biosolids production. Metal-salt addition would be required to meet the phosphorus limits. This would result in increased chemical sludge generation and consequently 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	73,000	73,000	146,000	131,500
Polymers, lb/year	730	730	1,100	730
Biosolids Management:				
Biosolids produced, ton/year	20	20	40	35
Average yearly hauling distance ⁽¹⁾	60	60	120	90
Particulate emissions from hauling trucks, lb/year ⁽²⁾	3	3	7	5
Tailpipe emissions from hauling trucks, lb/year ⁽³⁾	8	8	15	11
CO ₂ emissions from hauling trucks lb/year ⁽⁴⁾	760	760	1,525	1,145
Energy Consumption:				
Annual energy consumption, kwh	11,300	11,300	318,300	677,450
Air pollutant emissions, lb/year ⁽⁵⁾				
CO ₂	10,206	10,206	287,089	611,051
NOx	16	16	446	948
SOx	14	14	382	813
CO	1	1	21	44
VOC	0	0	3	5
PM ₁₀	0	0	6	13
PM _{2.5}	0	0	3	7

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 assumptions that the round trip hauling distance to the landfill is 60 miles and, that the facility uses 22 ton trucks for hauling biosolids.

⁽²⁾ Includes PM₁₀ 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⁾ CO₂ 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)*.