UDWQ – POTW Nutrient Removal Cost Impact Study: Analysis of South Davis Sewer District – North

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COPIES: South Davis Sewer District

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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, economic and financial evaluation of South Davis Sewer District - North (SDSD-North) 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 Processes (Trickling Filter/Solids Contact (TF/SC) or Trickling Filter/Activated Sludge (TF/AS))

The SDSD-North fits in the TF 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

SDSD-North is permitted for an average design flow of 12 million gallons per day (mgd) and currently receives an average annual flow of approximately 7.3 mgd. The existing facility operates a single-stage trickling filter treatment process with primary treatment, chlorination and dechlorination. Tricking filter waste solids are co-settled with primary solids in the primary clarifier. Wastewater residuals are transferred from the primary clarifier to a gravity thickener, stabilized using conventional mesophilic anaerobic digestion, air dried in sludge drying beds, and the biosolids are beneficially used. The recycle stream from the sludge drying beds is periodic and occurs whenever stabilized sludge is conveyed to the beds. This recycle stream is not equalized and comes back to the main plant as a slug load. Ferric chloride is added at the primary clarifiers on an “as needed” basis to achieve an enhanced level of primary treatment. The POTW operates their secondary treatment in order to meet effluent ammonia limits. A process flow diagram for SDSD–North is presented in Figure 1 and an aerial photo of the existing facility is shown in Figure 2. The major unit processes are summarized in Table 2.

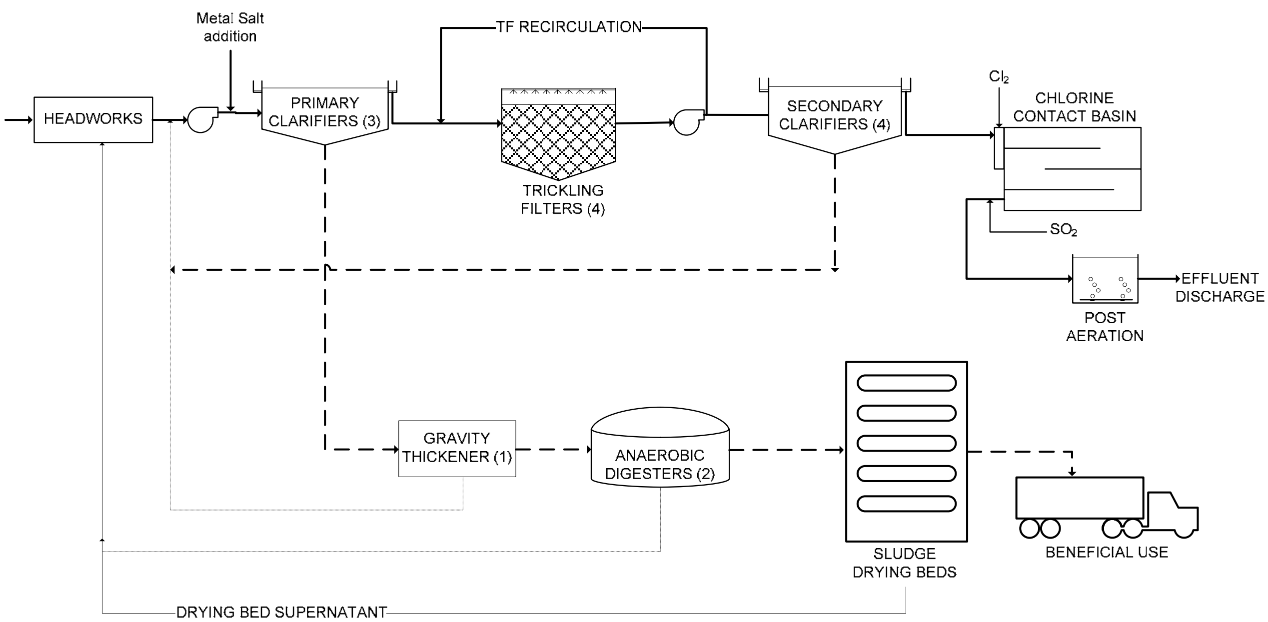

FIGURE 1
Process Flow Diagram of SDSD - North

FIGURE 2
Aerial View of SDSD - North

TABLE 2

Summary of Major Unit Processes

Unit Process	Number of Units	Size, each	Details
Primary Clarifiers	3	75-ft diameter, 10-ft SWD	Ferric chloride and polymer added to enhance treatment efficiency (as needed)
Trickling Filters	4	165 ft dia. x 7.5 ft media depth	Rock Media
Secondary Clarifiers	4	75-ft diameter, 2 w/8' SWD, 2 w/12' SWD	----
Primary Sludge Thickening	1	36-ft diameter, 10-ft SWD	Gravity Thickener
Anaerobic Digestion	2	0.365 MG	Anaerobic Mesophilic
Sludge Drying	---	115,200-ft^2 (total area)	Sludge drying beds

2. Nutrient Removal Alternatives Development, Screening and Selection

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

SDSD-North is a POTW with four (4) rock media tricking filters that are well maintained and achieve significant nitrification along with BOD removal. A goal of this project was to make maximum use of existing infrastructure in the upgrade approaches selected for meeting the various tiers of nutrient limits. Upgrades were added to the system models added as required to meet increasingly stringent discharge limits. The decision flow diagram presented in Figure 3 shows the selected upgrade approach that was used to go from each tier of nutrient control to the next more stringent scenario, with the bullet points A-D (below) describing each upgrade step:

A. From Tier 3 (existing process) to Tier 2 phosphorus control, the existing metal-salt system at the primary clarifiers was used (and modified as needed) along with added feed points upstream of the secondary clarifiers and at the recycle stream from the sludge drying beds.

B. To add nitrogen removal to Tier 2, a denitrification moving bed biofilm reactor (MBBR) was installed after the trickling filters in order to achieve denitrification. Carbon required for the denitrification process was supplied by bringing the carbon-rich supernatant from the primary gravity thickeners to the bioreactors.

C. To go from Tier 2 to Tier 1 phosphorus control, deep bed granular media filters and an intermediate pump station was added to the facility with an additional metal-salt feed point before the filters.

D. To add nitrogen removal to Tier 1, the MBBR process described in Tier 2 was expanded with additional facilities for external carbon addition to the system.

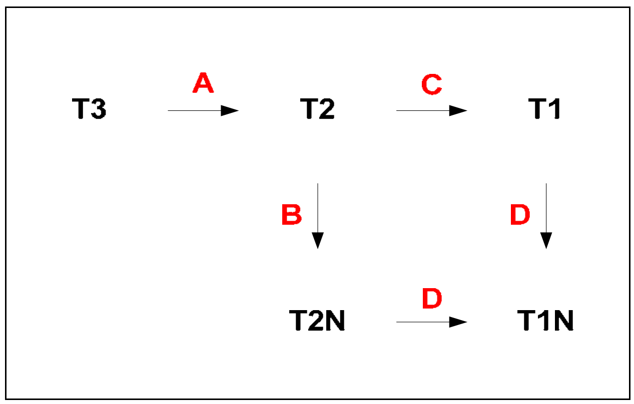

FIGURE 3
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

Data Evaluation, Modeling, and Upgrade Design

The selected progression of upgrades conceived for meeting the different tiers of nutrient control for SDSD-North 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 SDSD-North 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	7.34	9.50	14.40
BOD, lb/day	11,501 (188 mg/L)	15,084 (190 mg/L)(1)	19,220 (160 mg/L)
TSS, lb/day	13,766 (225 mg/L)	19,332 (225 mg/L)(1)	19,220 (160 mg/L)
TKN, lb/day	2,009 (33 mg/L)	2,616 (33 mg/L)(1)	3,966 (33 mg/L)
TP, lb/day	225 (4 mg/L)	317 (4 mg/L)(1)	481 (4 mg/L)

(1) Historic conditions 2007-2008

(2) Projected by the utility

(3) Design maximum month capacity of the POTW. Assumed 1.2 times (peaking factor) the design average flow.

The main sizing and operating design criteria that were associated with the selected upgrade approach for the SDSD-North facility are summarized in Table 4.

TABLE 4
Main Unit Process Sizing and Operating Design Parameters

Design Parameter (Nutrient Tier)	Value
Influent design temperature	14 deg C
Target metal:PO_4-P molar Ratio (All Tiers)	1:1, 2:1, 7:1 (1)
Metal salt storage (All Tiers)	14 days
Target methanol dose for post denitrification (T1N)	3.5 MeOH:NO3-Neq
Denitrification MBBR loading rate (T2N and T1N)	1.5 g-N_{-eq}/m^2/d
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 filters, 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)

The effluent limit for Tier 2 alternative is 1.0 mg/L total phosphorus. SDSD-North can achieve this goal by introducing additional metal-salt feed system to the existing unit process facility. The process modeling effort simulated a dual-feed strategy with metal-salt addition upstream of both the primary and the secondary clarifiers. The expanded chemical addition concept included metal-salt addition to the recycle stream from the sludge drying beds. This provided the utility an option to add metal-salt either upstream of the secondary clarifiers on at the recycle stream. A process flow diagram for this alternative is presented in Figure 4.

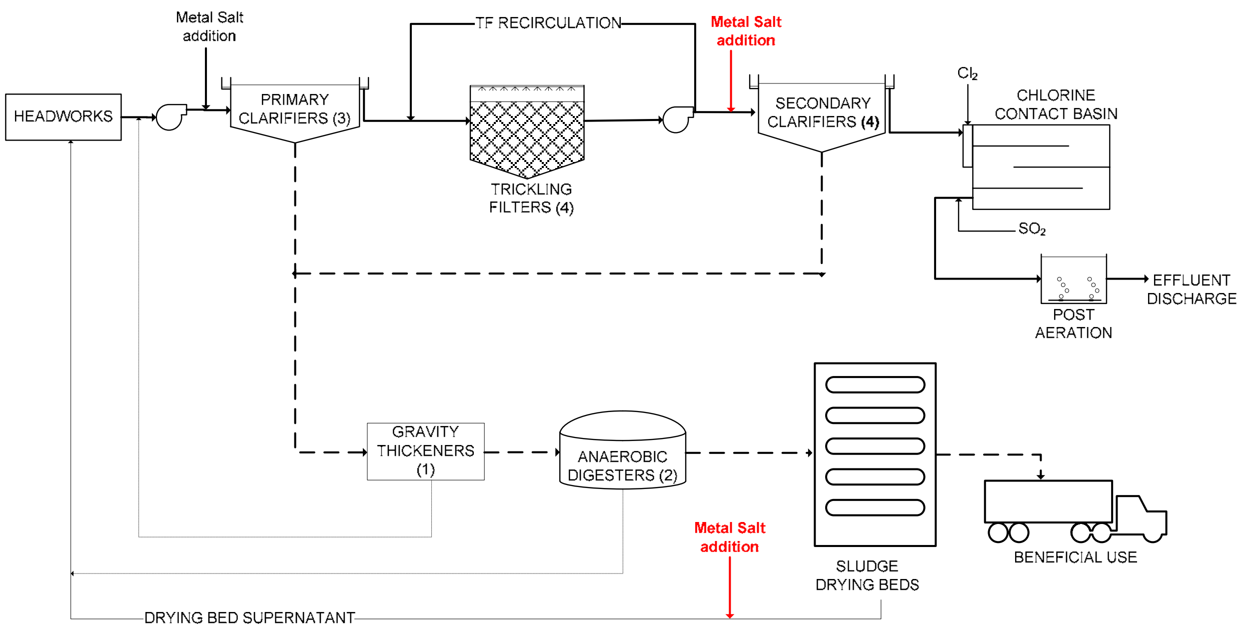

FIGURE 4
Modifications to POTW for Tier 2 Nutrient Control

Tier 2N - Phosphorus & Nitrogen (B)

The multiple metal-salt feed point approach for phosphorus control in Tier 2 was adjusted for this Tier to achieve moderate levels of nitrogen control (20 mg/L). A denitrification MBBR was installed after the trickling filters for denitrification in order to bring down the total nitrogen concentration in the effluent. The carbon source required for the denitrification process was provided by restructuring the supernatant line of the existing primary gravity thickener from going ahead of the primary clarifiers to the MBBR. A process flow diagram for this alternative is presented in Figure 5.

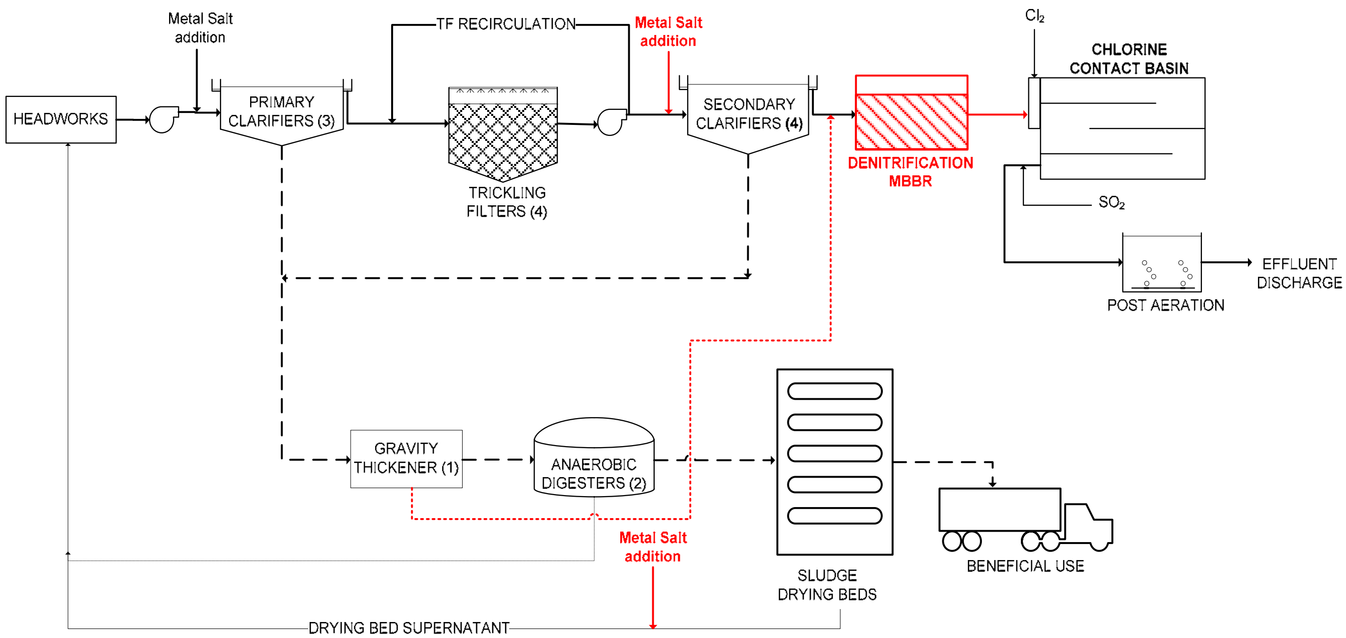

FIGURE 5
Modifications to POTW for Tier 2N Nutrient Control

Tier 1 Phosphorus (C)

This alternative builds upon the Tier 2 approach for phosphorus control. Effluent from the trickling filter was sent to a secondary rapid mix tank after receiving a dose of metal-salt and polymer before entering the secondary clarifiers. Settled effluent from the clarifiers was then pumped to the deep bed granular media filters. A process flow diagram for this alternative is presented in Figure 6.

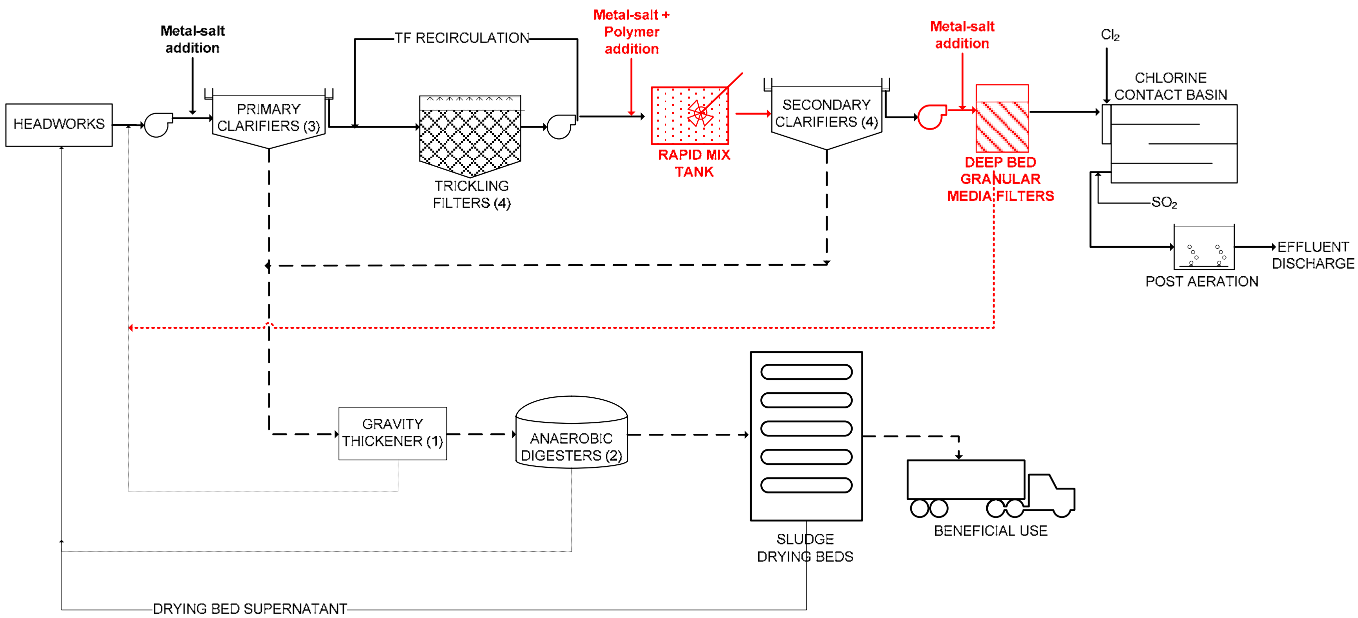

FIGURE 6
Modifications to POTW for Tier 1 Nutrient Control

Tier 1N - Phosphorus & Nitrogen (D)

This approach builds on Tier 2N and Tier 1 levels of nutrient control by implementing a MBBR system after the trickling filters for denitrification, and metal-salt addition and granular media filtration for chemical phosphorus removal. However, for this Tier, a supplemental carbon source was required to meet the 10 mg/L total nitrogen limit. A process flow diagram for this alternative is presented in Figure 7.

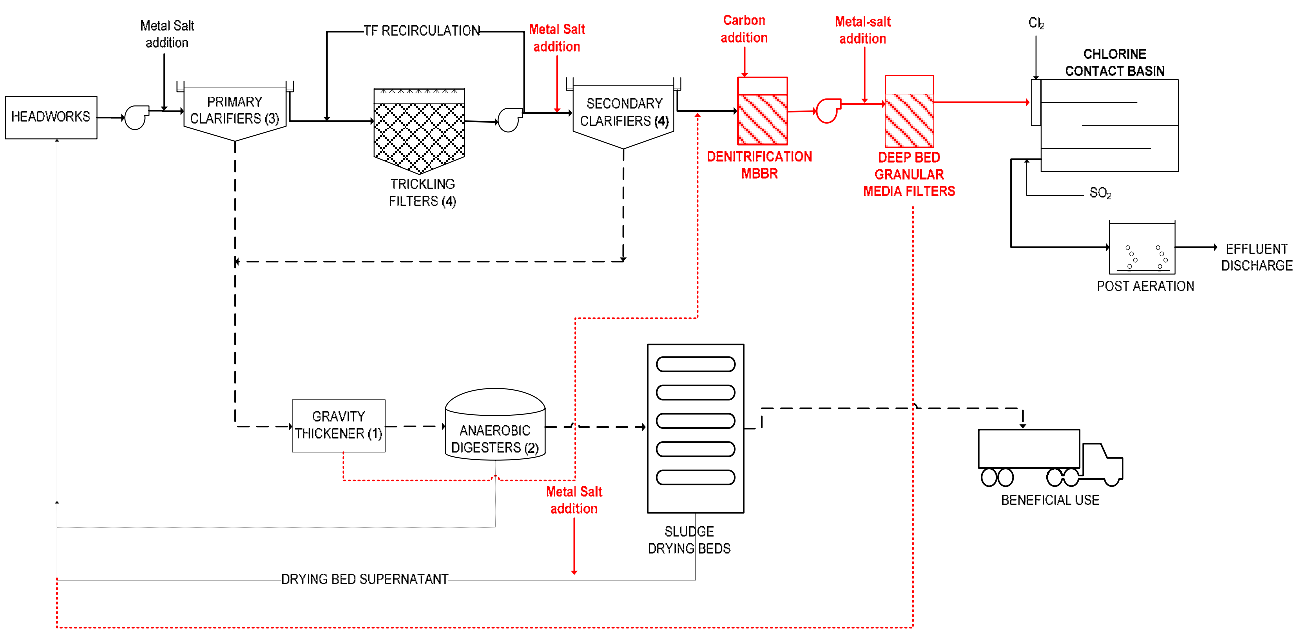

FIGURE 7
Modifications to POTW for Tier 1N Nutrient Control

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 5 presents a summary of the major facility upgrade components identified for meeting each tier of nutrient control. For Tier 2, the existing metal-salt storage facility was augmented with additional storage and new feed pumps. To go to Tier 2N, a MBBR was installed after the trickling filters and the primary gravity thickener supernatant flow line was restructured to bring it to the new MBBR. For Tier 1 phosphorus control, a rapid mix tank with new metal-salt feed pumps and a secondary effluent pump station was needed, along with new deep bed granular media filters. For Tier 1N the MBBR system was expanded by the addition of a supplemental carbon feed system.

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
Rapid mix tank			X	
Denitrification MBBRs		X		X
Piping modifications		X		X
Supplemental carbon feed facility				X
Secondary effluent pump station			X	X
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 and storage facility	$0.92	$0.92	$1.19	1.19
Rapid mix tank	$0.00	$0.00	$1.31	0.00
Denitrification MBBRs	$0.00	$8.25	$0.00	9.07
Piping modifications	$0.00	$0.36	$0.00	0.36
Supplemental carbon feed facility	$0.00	$0.00	$0.00	1.31
Secondary effluent pump station	$0.00	$0.00	4.60	4.60
Granular media filters	$0.00	$0.00	20.39	20.39
TOTAL TIER COST	**$0.92**	**$9.53**	**27.49**	**36.92**

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 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: aeration, secondary effluent pumps and backwash pumps

TABLE 7
Operating and Maintenance Unit Costs

Parameter	Value
Biosolids handling cost	$14/wet ton
Roundtrip hauling distance[(1)]	10 miles
Ferric chloride	$1000/ton
Polymer	$2.73/lb
Power	$0.048/kwh

(1) Provided by the POTW

The estimated net impact of nutrient control on O&M relative to the current O&M cost (Tier 3) are presented in Table 8 and shown graphically in Figure 8.

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	$0.00	$0.00	$0.00	$0.00	$0.00	$0.01	$0.00	$0.00
Metal-salt	$0.07	$0.10	$0.10	$0.13	$0.14	$0.22	$0.15	$0.23
Carbon	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.19	$0.26
Polymer	$0.02	$0.03	$0.02	$0.03	$0.04	$0.05	$0.02	$0.01
Power	$0.00	$0.00	$0.03	$0.05	$0.07	$0.09	$0.16	$0.20
Total O&M	**$0.09**	**$0.14**	**$0.16**	**$0.21**	**$0.26**	**$0.37**	**$0.52**	**$0.70**

Note: $ Million (US) in December 2009

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

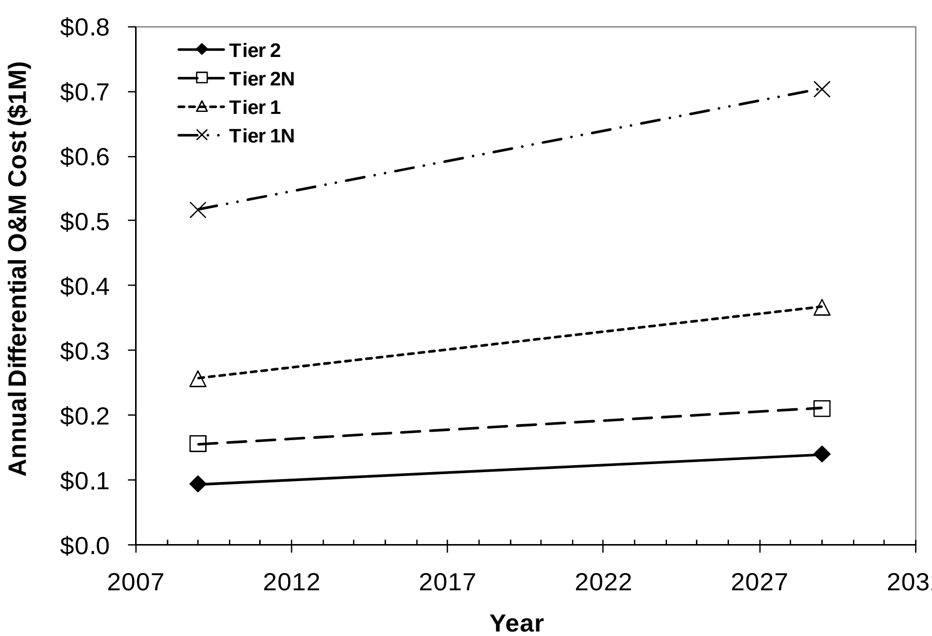

Figure 8

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 SDSD - North. 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 SDSD-North.

TABLE 9

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

	Tier 2	Tier 2N	Tier 1	Tier 1N
Phosphorus Removal (pounds)[2]	802,434	802,434	1,266,980	1,266,980
Nitrogen Removal (pounds)[2]	-	2,055,110	-	7,216,725
Net Present Value of Removal Costs[3]	**$ 2,695,512**	**$ 11,729,355**	**$ 32,218,742**	**$ 46,252,017**
NPV: Phosphorus Allocation	2,695,512	2,695,512	32,218,742	32,218,742
NPV: Nitrogen Allocation[4]		9,033,843		14,033,275
TP Cost per Pound[5]	**$ 3.36**	**$ 3.36**	**$ 25.43**	**$ 25.43**
TN Cost per Pound[5]		**$ 4.40**		**$ 1.94**

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 SDSD-North 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	$ 919,000	$ 9,529,000	$ 27,474,000	$ 36,954,000
Estimated Annual Debt Service[1]	$ 73,700	$ 764,600	$ 2,204,600	$ 2,965,300
Incremental Operating Cost[2]	96,300	127,500	262,600	529,200
Total Annual Cost Increase	$ 170,000	$ 892,100	$ 2,467,200	$ 3,494,500
Number of ERUs	22,600	22,600	22,600	22,600
Annual Cost Increase per ERU	$7.52	$39.47	$109.17	$154.62
Monthly Cost Increase per ERU[3]	**$0.63**	**$3.29**	**$9.10**	**$12.89**
Current Average Monthly Bill[4]	$7.42	$7.42	$7.42	$7.42
Projected Average Monthly Bill[5]	**$8.05**	**$10.71**	**$16.52**	**$20.31**
Percent Increase	**8.4%**	**44.3%**	**122.6%**	**173.7%**

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 CVWRF 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]	$ 49,200	$ 49,200	$ 49,200	$ 49,200
Affordability Threshold (% of MAGI)[3]	1.4%	1.4%	1.4%	1.4%
Monthly Affordability Criterion	**$57.40**	**$57.40**	**$57.40**	**$57.40**
Projected Average Monthly Bill	$8.05	$10.71	$16.52	$20.31
Meets State's Affordability Criterion?	Yes	Yes	Yes	Yes
Estimated Bill as % of State Criterion	**14%**	**19%**	**29%**	**35%**

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 SDSD-North and per process modeling of the base condition (Tier 3), SDSD-North 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 12 summarizes the annual reduction in nutrient loads in SDSD-North 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	32,450	32,450	52,275	52,275
Total nitrogen removed, lb/year	----	94,570	----	318,000

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 SDSD-North 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)

			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**
SDSD-North	----	11.36	2.50	24.20	1.0	N/A	1.0	20	0.1	N/A	0.1	10
State Canal above POTW	4990790	56.14	0.65	2.80	----	----	----	----	----	----	----	----
Combined Concentrations			**0.96**	**6.40**	**0.71**	**N/A**	**0.71**	**5.70**	**0.56**	**N/A**	**0.56**	**4.01**

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 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 a differential value 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		134,655	135,840	287,500	294,360
Polymers, lb/year		8,545	8545	14,765	6,750
Biosolids Management:					
Biosolids produced, ton/year		214	214	269	169
Average yearly hauling distance[1]		97	97	168	77
Particulate emissions from hauling trucks, lb/year [2]		5	5	9	4
Tailpipe emissions from hauling trucks, lb/year[3]		12	12	21	10
CO_2 emissions from hauling trucks lb/year[4]		1,235	1,235	2,135	975
Energy Consumption:					
Annual energy consumption, kwh		8,765	448,460	975,660	2,256,515
Air pollutant emissions, lb/year [5]					
	CO_2	7,908	404,512	880,047	2,035,376
	NOx	12	628	1,366	3,159
	SOx	11	538	1,171	2,708
	CO	1	29	64	148
	VOC	0	4	8	18
	PM_{10}	0	9	19	44
	$PM_{2.5}$	0	4	10	22

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 10 miles round trip hauling distance and, on the assumption that the facility uses 22 ton trucks for hauling biosolids to land application.

[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)*.