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

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COPIES: North 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, financial and environmental benefit and impact evaluation of the North Davis Sewer District (NDSD) 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 the 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 NDSD fits in the Hybrid Process Category, as it is operating a TF/SC process.

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

This facility is designed for a maximum month flow of 41 million gallons per day (mgd) and currently receives an average annual influent flow of 21 mgd. The facility operates a TF/SC process with primary treatment. Residual primary and secondary solids are thickened and stabilized using conventional mesophilic anaerobic digestion, mechanically dewatered, and composted. The facility then disposes the composted material through a give-away program. Ferric chloride is added at the headworks for sulfide control. The TF/SC process is operated to achieve BOD and TSS effluent limits. A process flow diagram of the existing facility is presented in Figure 1 and an aerial photo of the WRF is shown in Figure 2. The major unit processes are listed in Table 2.

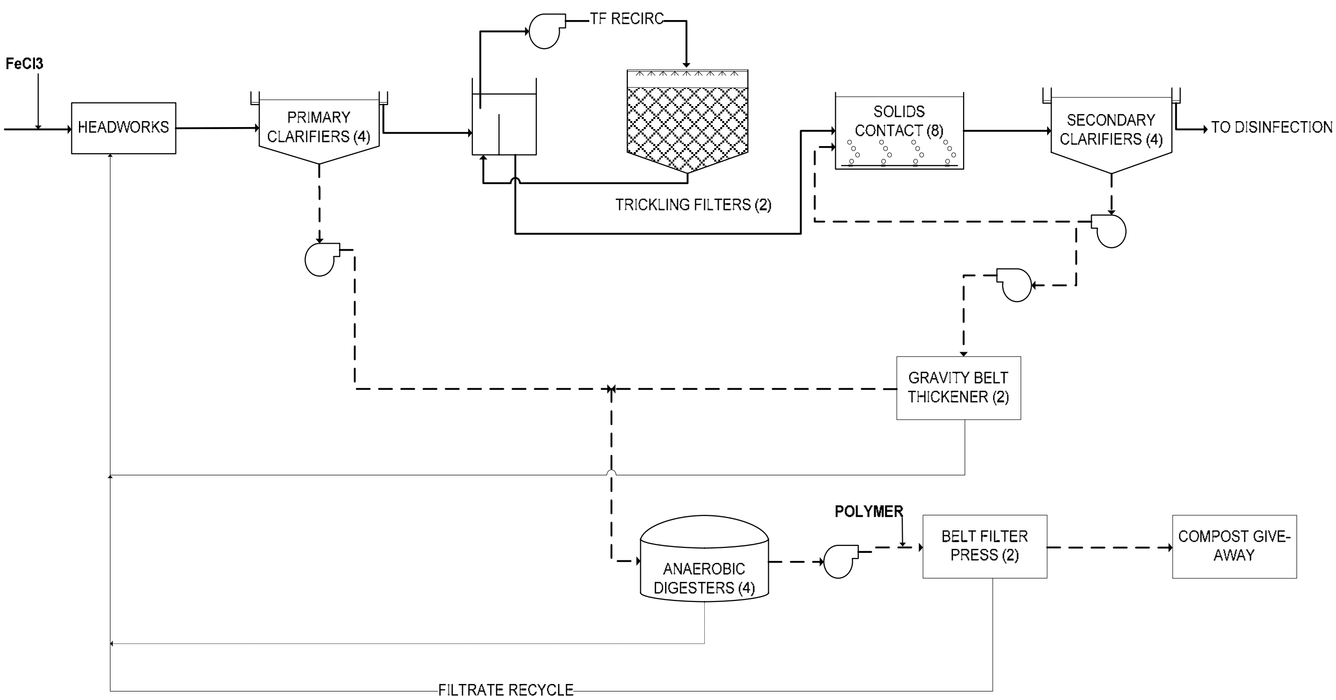

FIGURE 1
Process Flow Diagram

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 2	135-ft diameter, 7-ft SWD 160-ft diameter, 16-ft SWD	Metal-salt added for sulfide control
Trickling filters	2	120-ft diameter, 24-ft SWD	Plastic media with a natural draft system
Solids contact basins	8	0.37 MG each,15-ft SWD	100% diffused aeration
Secondary clarifiers	4	160-ft diameter, 15-ft SWD (3) 12-ft SWD (1)	Uni-tube suction header
WAS thickening	2	3 meter	Gravity Belt Thickener
Anaerobic digestion	4	1.2 MG each, conventional	Anaerobic Mesophilic
Sludge dewatering	2	2 meter	Belt Filter Press

2. Nutrient Removal Alternatives Development, Screening and Selection

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

The NDSD is a large POTW with a significant investment in the recently constructed TF/SC process. 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 as required to meet increasingly stringent discharge limits. Figure 3 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, multi-point metal-salt feed system was initiated at the headworks and secondary clarifiers.

B. To add total nitrogen control to Tier 2, a portion of the primary effluent was bypassed around the trickling filters and an anoxic zone and mixed liquor recirculation system were added ahead of the existing solids contact basin for total nitrogen removal.

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

D. To add total nitrogen control to Tier 1, the improvements proposed for Tier 2N (in B) were expanded, and deep bed granular media filters were installed for chemical phosphorus polishing.

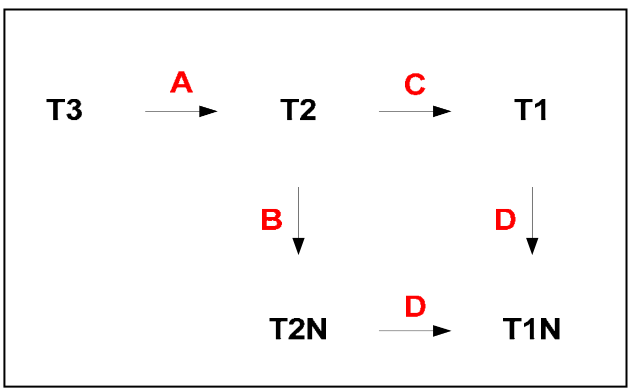

FIGURE 3
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

Data Evaluation and Modeling of Upgrades

The selected progression of upgrades conceived for meeting the different tiers of nutrient control for NDSD 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 NDSD 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	21	34	41
BOD, lb/day	41,780 (239 mg/L)	51,600 (182 mg/L)	77,390 (221 mg/L)
TSS, lb/day	54,980 (314 mg/L)	57,820 (204 mg/L)	86,740 (248 mg/L)
TKN, lb/day	4,590 (26 mg/L)	7,372 (26 mg/L)	9,180 (26 mg/L)
TP, lb/day	1,226 (7 mg/L)	1,726 (7 mg/L)	2,394 (7 mg/L)

(1) Historic average flow and load conditions for 2007-2009
(2) Projected 2029 conditions provided by the POTW
(3) Reported maximum month design capacity of POTW

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

TABLE 4
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 (All Tiers)	14 days
Portion of primary effluent bypassed around TFs (T2N and T1N)	50%
Mixed-Liquor return pumping ratio as a percent of influent flow (T2N and T1N)	100% to 150%
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 Tiers 1 and 1N only

(2) Hydraulic loading rate at peak hourly flow condition

3. Nutrient Upgrade Approaches

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

Tier 2 Phosphorus (A)

The NDSD can achieve the 1.0 mg/L total phosphorus goal by adding a metal-salt feed system to the existing unit process facilities. The process modeling effort simulated a dual-feed strategy with metal-salt addition at the headworks (existing point of addition) and at the secondary clarifiers (new point of addition). A process flow diagram for this treatment approach is presented in Figure 4.

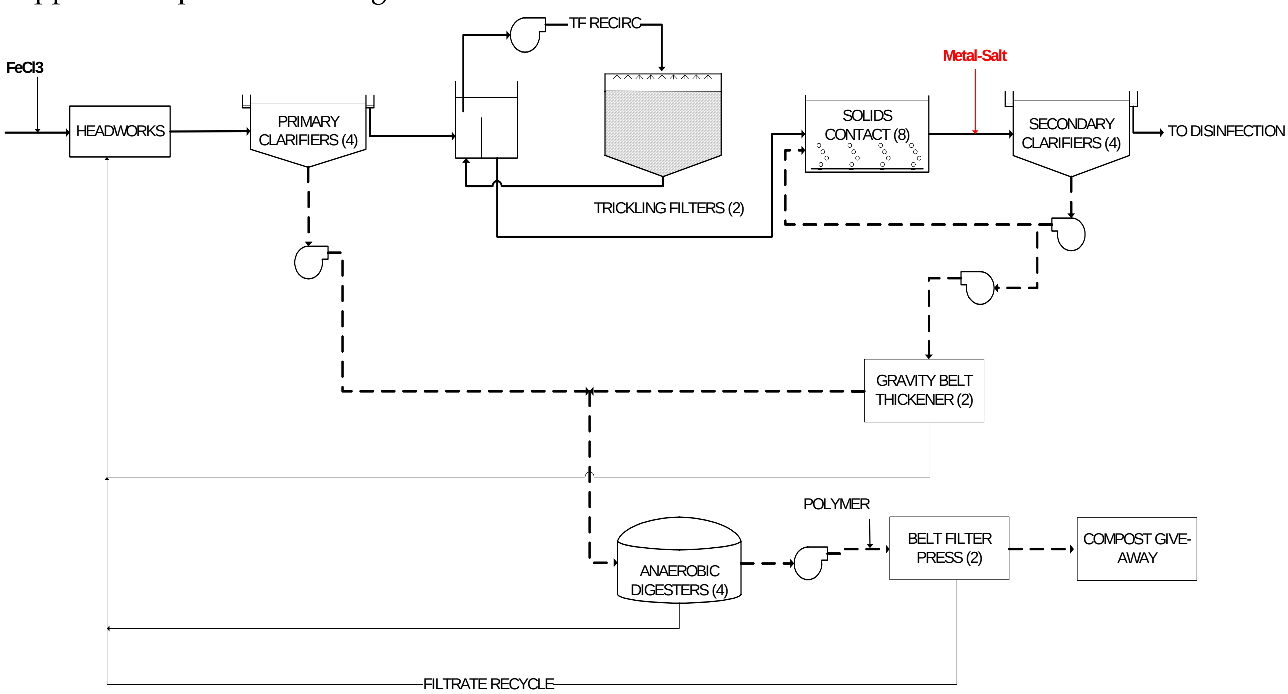

FIGURE 4
Modifications to POTW for Tier 2 Nutrient Control

Tier 2N – Phosphorus & Nitrogen (B)

The dual feed metal-salt addition for phosphorus control (described in Tier 2) would continue to be used for this alternative of nutrient removal. To provide a moderate level of nitrogen control (TN < 20 mg/L), an anoxic zone was added ahead of the existing solids contact basins and mixed-liquor recycle pumps were installed to recycle the nitrified mixed liquor from the end of the solids contact basin to the anoxic zones for denitrification. To provide the necessary carbon for denitrification, a portion of the primary effluent was bypassed around the trickling filters and then mixed with TF effluent prior to entering the new anoxic zones. Additional aeration capacity in the existing basins was required for sufficient nitrification to occur. In addition, covers and forced ventilation were installed on the TFs to eliminate heat loss from the units during winter season, thus preserving their "summertime" nitrification performance. A process flow diagram of this upgrade is provided in Figure 5.

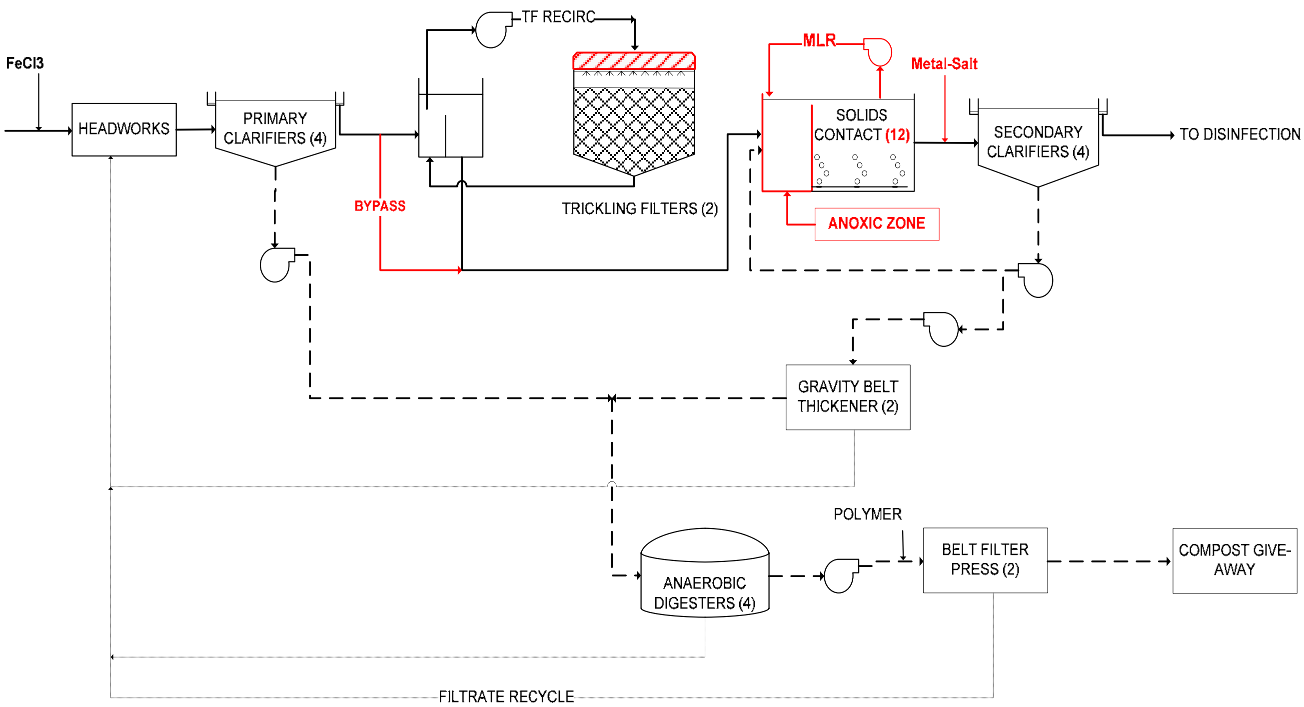

FIGURE 5
Modifications to POTW for Tier 2N Nutrient Control

Tier 1 Phosphorus (C)

This alternative builds upon the Tier 2 approach for phosphorus control. To achieve more stringent levels of phosphorus control, the settled secondary effluent was pumped to a deep bed granular media filtration system. A third feed point for metal-salt addition was added upstream of the filters for chemical phosphorus polishing. A process flow diagram of this approach is provided in Figure 6.

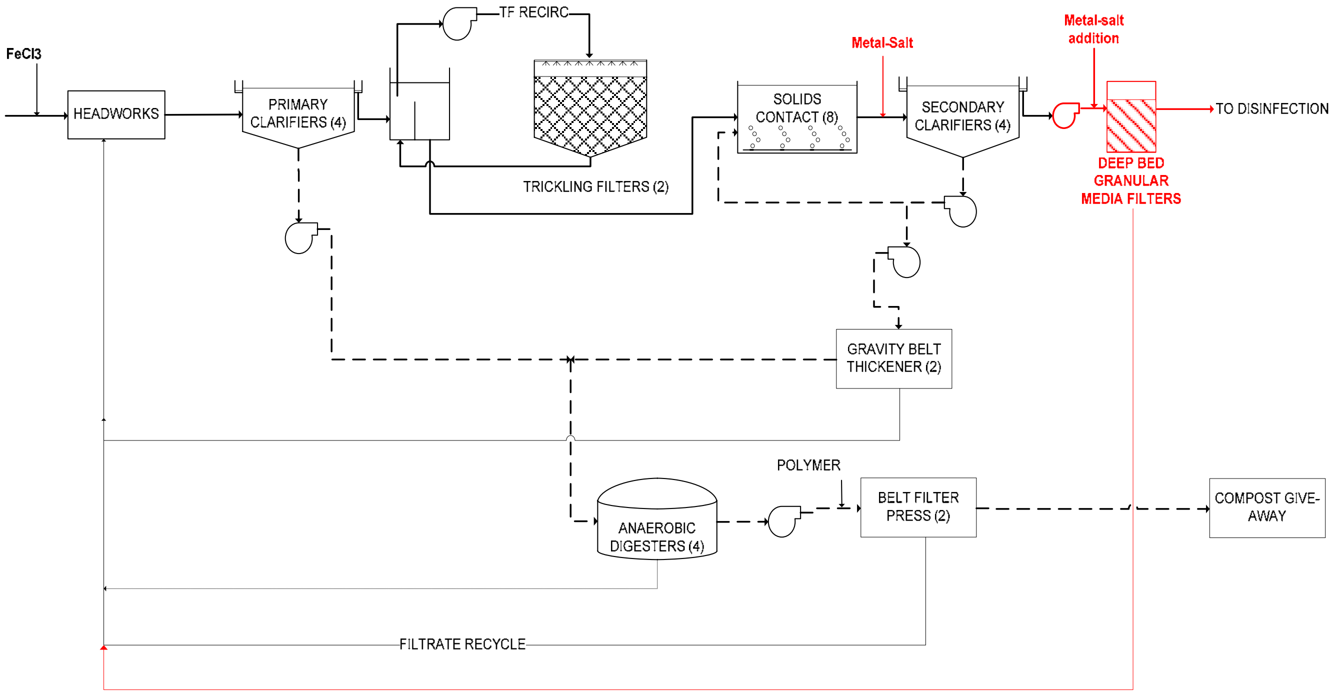

FIGURE 6
Modifications to POTW for Tier 1 Nutrient Control

Tier 1N Phosphorus & Nitrogen (D)

This alternative builds on a combination of the proposed Tier 1 and Tier 2N schemes. The anoxic zone proposed for Tier 2N was expanded to meet the more stringent total nitrogen limits of 10 mg/L. Total phosphorus was removed by addition of metal-salts at the headworks, ahead of the secondary clarifiers, and upstream of the deep bed granular media filters. A process schematic of this upgrade is presented in Figure 7.

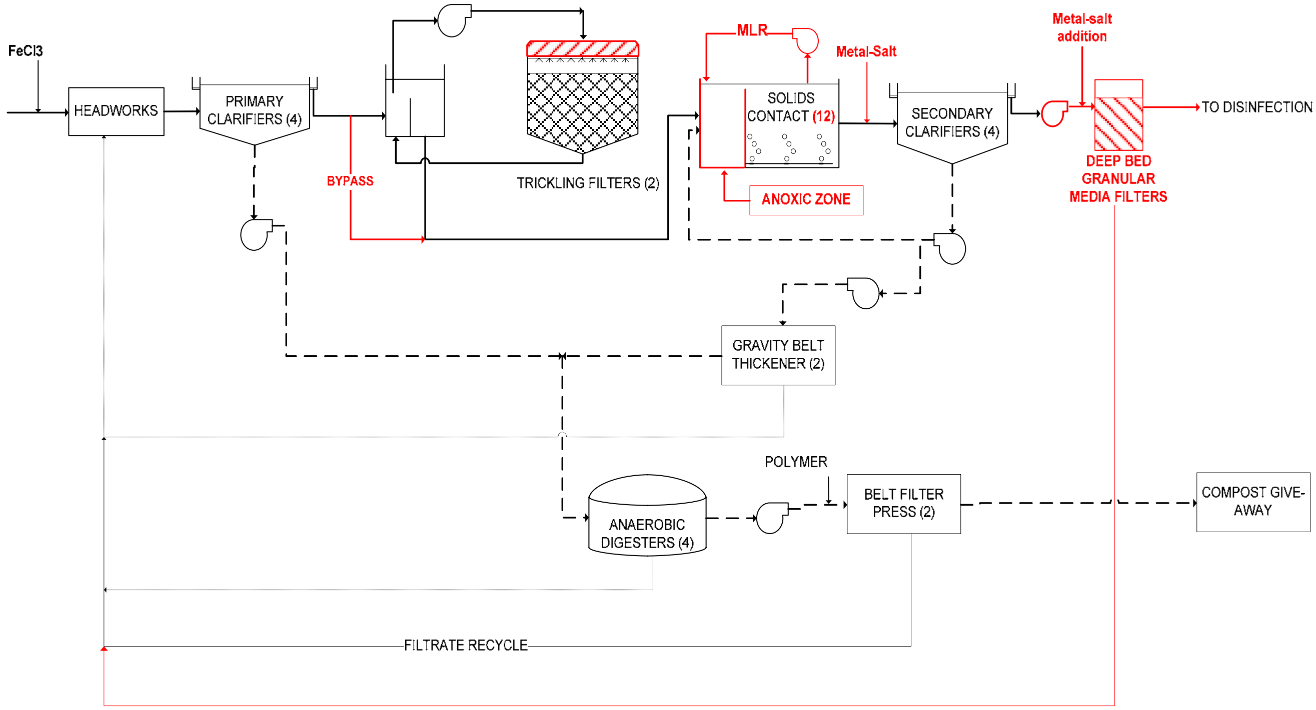

FIGURE 7
Modifications to POTW for Tier 1N Nutrient Control

4. Capital and O&M Cost Estimates of 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 facility upgrade components identified for meeting each tier of nutrient standards. For Tier 2, the existing metal-salt storage facility were augmented with additional storage capacity and new feed pumps for the secondary clarifiers chemical addition. For Tier 2N, a bypass structure was required to bring 50% of the primary effluent flow around the TFs, along with the addition of an anoxic zone with mixed liquor recirculation system. The existing blower building capacity was expanded to achieve sufficient nitrification. The TFs would require covers and forced ventilation systems to enhance winter-time nitrification. For Tier 1 phosphorus control, a secondary effluent pump station was added to lift the flow to the new granular media filters, and a third metal-salt feed system was added ahead of the filters. With Tier 1N, all the facilities identified for Tier 2N and Tier 1 were required, and the Tier 2N anoxic zone was expanded.

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
TF bypass piping and flow distribution structure modifications		X		X
Covers and forced ventilation for TFs		X		X
Anoxic basins and mixed liquor recirculation system		X		X
Blowers and blower building expansion		X		X
Secondary effluent pump station			X	X
Granular media filtration 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 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	$1.50	$1.50	$2.47	$2.47
Modification to TF effluent piping and flow distribution structure	$0.00	$0.94	$0.00	$0.94
Covers and forced ventilation for TFs	$0.00	$2.90	$0.00	$2.90
Anoxic basin with mixers	$0.00	$2.73	$0.00	$3.82
Mixed liquor recycle system	$0.00	$0.56	$0.00	$0.56
Blowers and blower building expansion	$0.00	$2.76	$0.00	$2.76
Secondary effluent pump station	$0.00	$0.00	$9.46	$9.46
Deep bed granular media filtration system	$0.00	$0.00	$53.84	$53.84
TOTAL TIER COST	**$1.50**	**$11.39**	**$65.77**	**$76.74**

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 cost estimates 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, dewatering units and recycle pumps

TABLE 7
Operating and Maintenance Unit Costs

Parameter	Value
Biosolids hauling (1)	$0/wet ton
Biosolids tipping fee (1)	$0/wet ton
Ferric chloride	$1000/ton
Polymer	$1.65/lb
Power	$0.05/kwh

(1) NDSD composts all biosolids on site and disposes its compost through a give-away program. Thus biosolids hauling costs or disposal tipping fees were zero.

Increased O&M costs 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	$0.00	$0.00	$0.00
Metal-salt	$1.37	$2.60	$0.87	$2.08	$1.44	$3.08	$1.22	$2.14
Polymer	$0.08	$0.16	$0.06	$0.15	$0.19	$0.30	$0.11	$0.20
Power	$0.01	$0.00	$0.20	$0.19	$0.21	$0.33	$0.42	$0.53
Total O&M	**$1.45**	**$2.76**	**$1.12**	**$2.43**	**$1.85**	**$3.71**	**$1.75**	**$2.87**

Note: $ Million (US) in December 2009

Costs shown are the annual differential costs relative to the base line (Tier 3) O&M cost of the POTW

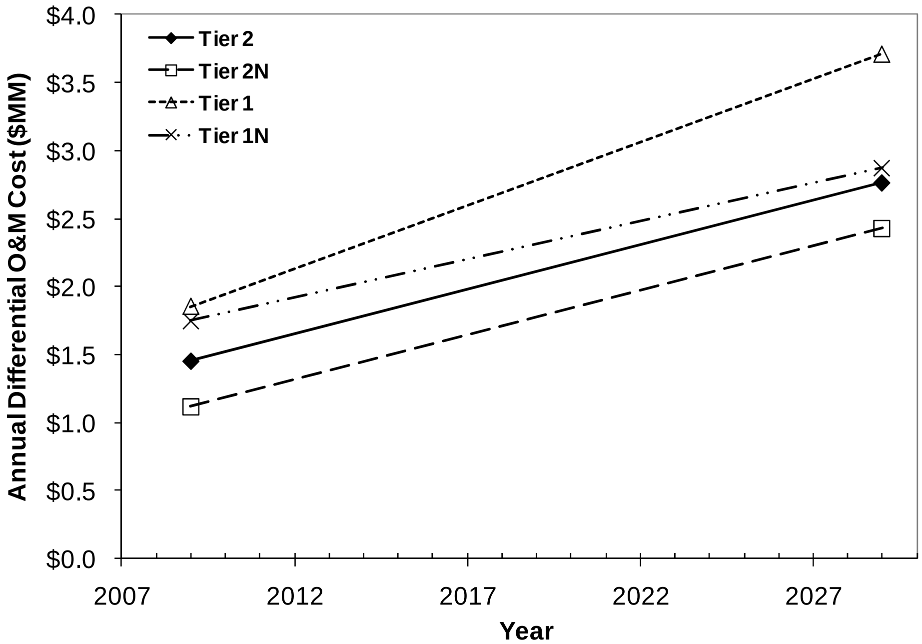

FIGURE 8
Impact of Nutrient Control on O&M Costs over 20 year evaluation period

5. Financial Impacts

This section presents the estimated financial impacts that would result from the implementation of nutrient discharge standards for NDSD. Financial impacts are 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 section.

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 the NDSD.

TABLE 9

Nutrient Removal: 20-Year Life Cycle Cost per Pound [1]				
	Tier 2	**Tier 2N**	**Tier 1**	**Tier 1N**
Phosphorus Removal (pounds)[2]	6,589,918	6,589,918	8,115,287	8,115,287
Nitrogen Removal (pounds)[2]	-	5,618,282	-	22,566,823
Net Present Value of Removal Costs[3]	**$ 33,361,444**	**$ 37,990,141**	**$ 107,772,596**	**$ 111,777,934**
NPV: Phosphorus Allocation	33,361,444	33,361,444	107,772,596	107,772,596
NPV: Nitrogen Allocation[4]		4,628,697		4,005,338
TP Cost per Pound[5]	**$ 5.06**	**$ 5.06**	**$ 13.28**	**$ 13.28**
TN Cost per Pound[5]		**$ 0.82**		**$ 0.18**

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 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 North Davis Sewer District 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	$ 1,499,000	$ 11,390,000	$ 65,758,000	$ 76,736,000
Estimated Annual Debt Service[1]	$ 120,300	$ 914,000	$ 5,276,600	$ 6,157,500
Incremental Operating Cost[2]	1,518,200	1,181,600	1,945,700	1,806,800
Total Annual Cost Increase	$ 1,638,500	$ 2,095,600	$ 7,222,300	$ 7,964,300
Number of ERUs	65,000	65,000	65,000	65,000
Annual Cost Increase per ERU	$25.21	$32.24	$111.11	$122.53
Monthly Cost Increase per ERU[3]	**$2.10**	**$2.69**	**$9.26**	**$10.21**
Current Average Monthly Bill[4]	$14.45	$14.45	$14.45	$14.45
Projected Average Monthly Bill[5]	**$16.55**	**$17.13**	**$23.71**	**$24.66**
Percent Increase	**14.5%**	**18.6%**	**64.1%**	**70.7%**

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 NDSD 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]	$ 44,400	$ 44,400	$ 44,400	$ 44,400
Affordability Threshold (% of MAGI)[3]	1.4%	1.4%	1.4%	1.4%
Monthly Affordability Criterion	**$51.80**	**$51.80**	**$51.80**	**$51.80**
Projected Average Monthly Bill	$16.55	$17.13	$23.71	$24.66
Meets State's Affordability Criterion?	Yes	Yes	Yes	Yes
Estimated Bill as % of State Criterion	**32%**	**33%**	**46%**	**48%**

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 usage
- Changes in biosolids production
- Changes in energy consumption
- Changes in emissions from biosolids hauling, disposal, and energy consumption

As per the data received from NDSD and per process modeling of the base condition (Tier 3), NDSD is able to achieve some nutrient removal with its existing infrastructure, but not enough to meet the four tiers of nutrient standards. Table 12 summarizes the annual reduction in nutrient loads in NDSD 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	191,800	197,300	242,500	242,900
Total nitrogen removed, lb/year	----	585,550	----	638,250

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

Attempts were also made to summarize the impact of effluent load reductions on receiving streams or 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 requirements. 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.

For NDSD, no STORET data was found upstream to the POTW discharge point. A STORET ID 4990050 was found to be located below the POTW discharge point, which provided data similar to the POTW effluent data. A receiving stream load reduction calculation was not applicable to the NDSD plant because this facility discharges directly to the Great Salt Lake.

The process upgrades established to meet the four tiers of nutrient standards require increased chemical usage, biosolids production and energy consumption. Additional metal-salt would be needed to meet the phosphorus limits. This would result in increased chemical sludge production and consequently increased biosolids production. Process modifications to meet the total nitrogen limits would also result in increased energy consumption and biosolids productions. Table 13 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 and are for the current (2009) flow and load conditions.

TABLE 13
Estimated Environmental Impacts of Nutrient Control

	Tier 2	Tier 2N	Tier 1	Tier 1N
Chemical Use:				
Metal-salt use, lb/year	2,730,808	1,730,622	2,888,857	2,436,260
Polymers, lb/year	50,399	34,208	117,501	68,726
Biosolids Management:				
Biosolids produced, ton/year	1,260	873	2,950	1,720
Average annual hauling distance	0	0	0	0
Particulate emissions from hauling trucks, lb/VMT-year (1)	0	0	0	0
Tailpipe emissions from hauling trucks, lb/VMT-year(2)	0	0	0	0
CO_2 emissions from hauling trucks lb/VMT-year(3)	0	0	0	0
Energy Consumption:				
Annual energy consumption, kwh	56,940	2,787,505	3,034,610	5,985,635
Air pollutant emissions, lb/year (4)				
CO_2	51,360	2,514,330	2,737,218	5,399,043
NOx	80	3,903	4,248	8,380
SOx	68	3,345	3,642	7,183
CO	4	183	199	393
VOC	0	22	24	47
PM_{10}	1	55	60	118
$PM_{2.5}$	1	27	30	59

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 vehicle miles traveled (lb/VMT). 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 vehicle miles traveled (lb/VMT) 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 vehicle miles traveled (lb/VMT) for hauling trucks were derived from *Rosso and Chau, 2009, WEF Residuals and Biosolids Conference Proceedings.*

(4) 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)*.