

FINAL REPORT

Statewide Nutrient Removal Cost Impact Study

October 2010

PREPARED FOR

UTAH DIVISION OF WATER QUALITY

CH2MHILL

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Prepared for

Utah Division of Water Quality

Prepared by

CH2MHILL

215 S. State Street, Suite 1000
Salt Lake City, Utah 84111

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Executive Summary

The Utah Division of Water Quality (Division) conducted the Statewide Nutrient Removal Cost Impact Study to evaluate the economic impacts of potential nutrient removal requirements for Utah's publicly owned treatment works (POTWs). The study estimated economic, financial, and environmental impacts associated with a range of potential nutrient discharge standards for every discharging POTW in the state. The following were the principal objectives of this study:

1. Estimate the local and aggregate economic impacts that would result from implementation of statewide nutrient discharge standards for treated wastewater in Utah.
2. Quantify the potential environmental effects resulting from various statewide nutrient discharge standards. These evaluations were limited to estimates of receiving stream load reductions under simulated nutrient restricted conditions and to estimates of related power consumption, residuals disposal, and air pollutant emissions changes.
3. Quantify the financial impacts of various nutrient discharge standards on sewer user fees and their affordability.
4. Inform POTWs about how new effluent nutrient discharge limits might be addressed at their facilities, along with the associated capital and operation and maintenance (O&M) costs.

The Division worked in partnership with the POTWs from the early development phases of the project through planning, data collection, process upgrade evaluations, and technical review periods. The Division retained the services of the national engineering consulting firm CH2M HILL Inc. to conduct the study.

Results from the cumulative statewide impacts analysis are presented in this report. Summaries of the analyses conducted for each of the 30 mechanical POTWs, the City of Logan discharging lagoon POTW, and the "model" lagoon were prepared as individual technical memoranda (TMs) for each facility. The POTW TMs are provided in Appendix 2 of the report.

The study analyzed treatment plant upgrade requirements and the associated costs to meet four effluent nutrient discharge levels or tiers. The tiers were developed with increasingly stringent nutrient requirements so that a broad array of treatment technologies and upgrade approaches would be considered and a wide range of upgrade costs developed for each facility. The four tiers of effluent nutrient requirements used in this study are summarized in Table ES-1.

TABLE ES-1
Nutrient Removal Limits for Study

Tier	TP (mg/L)	TN (mg/L)
Tier 1N	0.1	10
Tier 1	0.1	no limit
Tier 2N	1.0	20
Tier 2	1.0	no limit

NOTES:
TN = total nitrogen
TP = total phosphorus

A variety of technical approaches were conceived to strategically upgrade the facilities, making full use of existing infrastructure to meet the treatment tiers and minimize costs. The approaches incorporated a variety of biological and chemical treatment technologies and combinations thereof. The approaches selected for each facility depended on the existing infrastructure, capacity, and treatment processes of each plant. Input from facility management and staff was also used in considering technical alternatives for upgrading their plants. For example, age and utility of existing infrastructure characterized by POTW personnel was a factor in how best to use existing infrastructure and incorporate new systems. The upgrade approaches studied for each facility are presented in detail in the TMs provided in Appendix 2. Capital and O&M cost estimates developed were intended to reflect the cost of upgrading Utah's POTWs to provide nutrient removal only. Costs for normal improvements needed to support service population growth, repairs, and replacement of existing infrastructure were not included.

Upgrade approaches were intended to be standard to the industry, which would be engineered for each plant. Upgrade alternatives that were selected for performance and cost analysis were proven and well-established technologies. Developmental and innovative technologies were avoided to constrain the scope of work and to ensure that robust solutions were used. Application of other technologies and more creative and cost-effective solutions to address nutrient problems are encouraged by the Division but were intentionally not included in the scope of this project. The TMs that were developed for each POTW are useful as a basis for further analysis but are not the only solutions.

Statewide Economic Impacts of Potential Nutrient Limits

The cost to upgrade the discharging wastewater treatment plants in Utah were evaluated in terms of the capital costs to implement the necessary improvements and the increased annual O&M costs. Capital and O&M costs were used to calculate the net present value (NPV) for a 20-year time-horizon, assuming a 3 percent inflation rate and a 5 percent discount rate. Facility costs were also converted to an annualized expense, which was then converted to a monthly utility rate increase that would be paid by utility customers. The total annual cost to the utilities, including debt service, were estimated assuming all capital improvements would be financed with a 5 percent loan/bond over a 20-year period. Costs and economic impacts of individual POTWs are presented in detail in the TMs provided in Appendix-2. All costs were estimated in 2009 U.S. dollars.

The capital costs to upgrade the 30 mechanical POTWs in Utah for each of the nutrient discharge tiers were estimated. Table ES-2 summarizes the mechanical POTW aggregated capital cost to meet the four tiers of nutrient limits. Major factors contributing to these costs were infrastructure expansion and equipment upgrades. In some cases, replacement of major existing treatment processes or treatment trains was required. Several of Utah's wastewater treatment facilities required little to no improvements to meet all but the most stringent of the nutrient standards considered in the study.

TABLE ES-2
Mechanical POTW Aggregated Capital Cost ($ Million)

Tier	Capital Cost
Tier 2	$24
Tier 2N	$142
Tier 1	$818
Tier 1N	$1,043

Table ES-3 summarizes the aggregate additional mechanical POTW annual O&M costs for operating the improved 30 mechanical POTWs in 2009.[1] In most cases for Utah POTWs, O&M costs increase throughout the planning period of the study as a result of growth in the service areas.[2] The principal components contributing to the O&M cost impacts were increased chemical usage and power consumption.

TABLE ES-3
Mechanical POTW Aggregated Annual O&M Cost in the Year 2009 ($ Million)

Tier	O&M
Tier 2	$4.4
Tier 2N	$4.4
Tier 1	$14.24
Tier 1N	$16.29

Table ES-4 summarizes the aggregated NPVs associated with implementing nutrient removal improvements to the 30 mechanical POTWs in Utah.

1 The amounts shown are for the first year of plant operations with nutrient treatment improvements in 2009 dollars.

TABLE ES-4
Mechanical POTW Aggregated Net Present Value ($ Million)

Tier	20-year NPV
Tier 2	$114
Tier 2N	$232
Tier 1	$1,090
Tier 1N	$1,352

The impacts that implementing nutrient controls would have on sewer use rates were estimated. The equivalent residential unit (ERU) weighted average monthly bill increases are summarized in Table ES-5. The range of monthly bill increases from POTWs across the state is also shown.

TABLE ES-5
Equivalent Residential Unit Weighted Average Monthly Bill Increases ($)

Tier	Monthly ERU Bill Increase	Monthly Rate Increase Range
Tier 2	$1.19	$0.00–$3.87
Tier 2N	$2.97	$0.00–$19.80
Tier 1	$12.41	$0.00–$41.44
Tier 1N	$15.30	$0.00–$41.44

The costs to upgrade discharging lagoon POTWs in Utah were estimated using a simplified approach. For the lagoon systems, a model lagoon designed to treat an average 0.55 million gallons per day (mgd) was evaluated. The design flow selected was the design average for discharging lagoons in Utah, excluding the large lagoon system in Logan, Utah. Because of its unusual size, the City of Logan lagoon system was evaluated separately from the other lagoon systems. The Logan cost results are provided in the facility-specific TM in Appendix 2.

The capital costs to upgrade all of the discharging lagoon systems in Utah were estimated based on analysis of a model 0.55-mgd discharging lagoon facility, the average capacity of such facilities in the state. The model lagoon upgrade approach included full replacement of the existing lagoon facilities for the two treatment tiers that included requirements for nitrogen removal (2N and 1N). The model lagoon costs were extended to the full design capacity of these systems in the state (excluding Logan), and the resulting statewide cost for each of the nutrient discharge tiers is summarized in Table ES-6.

TABLE ES-6
Discharging Lagoon Aggregated Capital Cost ($ Million)

Tier	Capital Cost
Tier 2	$30
Tier 2N	$239
Tier 1	$159
Tier 1N	$383

The aggregated O&M cost increase associated with the upgraded discharging lagoon facilities for each of the nutrient discharge tiers were estimated and summarized in Table ES-7. Again, these costs were estimated based on a model 0.55-mgd facility, extended proportionally to the full design capacity of all 22 small discharging lagoons in the state.

TABLE ES-7
Discharging Lagoon Aggregated Annual O&M Cost in the Year 2009 ($ Million)

Tier	O&M
Tier 2	$1.11
Tier 2N	$3.00
Tier 1	$1.79
Tier 1N	$4.02

Statewide Environmental Impacts of Potential Effluent Standards for Nutrients

The most immediate and direct environmental impact from implementation of nutrient discharge standards in Utah would be long-term reductions in nutrient loadings to many of Utah's significant rivers, lakes, and wetlands. The environmental significance of these load reductions depends on many characteristics of and in the receiving water bodies and watersheds as well as the relative magnitude of the nutrient loading from the POTWs versus those of all other nutrient sources. The value of implementing nutrient discharge controls depends on the environmental benefits gained from these load reductions in comparison with their costs. Judging the benefits of nutrient load reductions in terms of their ability to preserve or enhance the beneficial uses of the waters of the state is a complex cost-to-benefit "equation" that this study did not attempt to solve. Ongoing studies in Utah seek to address the environmental benefits that are achievable through nutrient load reductions in waters of the state. This study is intended to accompany these other studies as the Division addresses the issue of nutrient pollution.

Statewide nutrient load reductions were calculated. Table ES-8 summarizes the average annual reductions in nitrogen and phosphorus loadings to waters of the state in pounds per year (lb/yr) under the fours tiers of nutrient removal. Table ES-8 includes nutrient mass removal for the year 2009. As POTW influent nutrient mass loading rates increase due to growth, the mass of nutrients removed will increase commensurately.

TABLE ES-8
Estimated Mass of Nutrients Removed at Each Treatment Tier

Treatment Tier	Phosphorus Loading (lb/yr)	Nitrogen Loading (lb/yr)
Tier 2	1,465,000	--
Tier 2N	1,465,000	1,939,000
Tier 1	2,120,000	--
Tier 1N	2,120,000	6,168,000

The potential load reductions from implementing nutrient controls were examined in terms of the resulting impacts that they could have on in-stream loads of nitrogen and phosphorus. On a statewide basis, and using a mass balance of nutrients for all of the receiving waters in the state, nutrient loads would be reduced (presented in Table ES-9).

TABLE ES-9
Percentage Nutrients Load Reduction to Receiving Streams for Each Treatment Tier

Treatment Tier	% TP Load Reduction	% TN Load Reduction
Tier 2	50	----
Tier 2N	50	11
Tier 1	70	----
Tier 1N	70	33

Three major water systems of the state—Utah Lake, the Jordan River, and the Colorado River—were examined to illustrate how nutrient controls might be used to affect water quality in Utah. Table ES-10 summarizes the nutrient load reductions in these systems.

TABLE ES-10
Percentage Nutrients Load Reduction to Utah Lake, Jordan and Colorado River for Each Treatment Tier

Receiving Water	Tier 2	Tier 2N	Tier 1	Tier 1N
Jordan River				
TN		14		35
TP	36	36	55	55
Utah Lake				
TN		11		34
TP	53	53	80	80
Colorado River				
TN		0.32		0.51
TP	0.31	0.31	0.43	0.43

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Acronyms and Abbreviations

°C	degree(s) Celsius
AS	activated sludge
ASIWPCA	Association of State and Interstate Water Pollution Control Administrators
AU	assessment unit
bHp-hr	brake horsepower-hour
BMP	best management practice
BOD	biochemical oxygen demand
Btu	British thermal unit(s)
CO	carbon monoxide
CO_2	carbon dioxide
CPES	CH2M HILL Parametric Estimating System
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
ERU	equivalent residential unit
ft^2	square feet
g	gram(s)
gpm	gallon(s) per minute
HC	hydrocarbons
kWh	kilowatt-hour
L	liter(s)
lb	pound(s)
m^2	square meter
MAGI	median annual gross income
MBR	membrane bioreactor
mg/L	milligram(s) per liter
mgd	million gallon(s) per day
MLSS	mixed liquor suspended solids
MWh	megawatt-hour
NA	not applicable
NO_x	nitrogen oxide
NPV	net present value
NRC	National Research Council
O&M	operation and maintenance

OD	oxidation ditch
OIG	Office of Inspector General
PM	particulate matter
PM_{10}	particulate matter less than 10 micrometers in aerodynamic diameter
$PM_{2.5}$	particulate matter less than 2.5 micrometers in aerodynamic diameter
PMP	project management plan
POTW	publicly owned treatment works
SC	solids contact
SLCWRF	Salt Lake City Water Reclamation Facility
SRF	State Revolving Fund
STORET	Storage and Retrieval of Water-related Data
TF	trickling filter
TKN	total Kjeldahl nitrogen
TM	technical memorandum
TMDL	total maximum daily loads
TN	total nitrogen
TP	total phosphorus
U.S.	United States
VMT	vehicle miles traveled
WEAU	Water Environment Association of Utah

1.0 Introduction

The Utah Water Quality Board commissioned the Statewide Nutrient Removal Cost Impact Study to establish a baseline understanding of the economic and environmental impacts of potential new nutrient removal requirements for Utah's publicly owned treatment works (POTWs). The study estimated economic, financial, and environmental impacts for every discharging POTW in the state as well as the cumulative statewide impacts. This study describes the economic impacts to the state, its POTWs, and their customers should nutrient removal become necessary for the protection of waters of the state and their beneficial uses.

The results from the study will inform the State of Utah in determining nutrient management requirements; however, numerous other factors must be considered in establishing regulations for nutrient control. These other factors include a broad range of environmental, economic, legal, and administrative issues currently being reviewed by the Utah Division of Water Quality (Division) but not a part of this study. However, understanding the direct costs and impacts assessed in this study is an essential part of the regulatory process, providing critical information to stakeholders and decision-makers responsible for the protection of State resources, funds, and quality of life in Utah.

This study focused on determining the technical and economic requirements for upgrading 30 mechanical and 22 lagoon-based POTWs to achieve a range of increasingly stringent discharge standards for the nutrients nitrogen and phosphorus. A key goal of the study was to establish "good" cost estimates that take into account current capital infrastructure, community needs and requirements, local and future conditions, facility management, engineering, and operational inputs. This goal served two purposes. First, the facility-specific results were to be accurate and reasonably consistent with how plant upgrades might be developed and implemented within current management structures. Second, the facility-specific results were to be useful to the facilities (that is, to provide a functional starting point for facilities considering or needing to upgrade).

The scope of the study included evaluations of each POTW, beginning with an analysis of the historical treatment performance record, baseline assessment, process modeling, and alternatives development. Capital and operation and maintenance (O&M) costs were estimated for four treatment alternatives that were developed (with input from the POTWs) to provide increasing levels of nutrient removal. Then, based on these estimated costs, the financial impacts on the POTW and its customers were evaluated, establishing metrics for system affordability, treatment cost effectiveness, and sewer rate increases. The scope of work included a basic assessment of the environmental impacts that could result from implementation of treatment plant improvements for nutrient removal. Environmental impacts were measured in readily quantifiable terms, such as expected nutrient load reductions for the effluent receiving streams, changes in energy consumption, fuel use, landfill disposal requirements and air pollutant emissions. Other perceived benefits from nutrient load reduction in state waters—such as protection of stream designated beneficial uses (that is, for drinking water, recreation, and irrigation)—were not measured in this study. Measurement of these benefits is the subject of other ongoing studies by the Division.

Results from the studies of each discharging POTW were combined to establish estimates of the total cost and total environmental impact to the State should statewide discharge limits become necessary. These combinations were used to analyze the effects of treatment plant size, base configuration, and location on costs and environmental impacts.

The next section provides a brief background and a national perspective of the significance of nutrient removal from treated wastewater discharges and states the objectives of the study.

1.1 Background

Nutrients are essential for life, but an overabundance of nutrients in aquatic environments may result in negative environmental impacts. The presence of excess nutrients in water bodies—commonly known as nutrient pollution—has been reported to be a major source of water quality impairment worldwide (Vollenweider, 1981; National Research Council [NRC], 1992; United States [U.S.] Environmental Protection Agency [EPA], 1996; Carpenter et al., 1998; Smith, 2003; Selman et al., 2008). Nutrient pollution has well-documented adverse effects on surface water quality, causing excessive growth of harmful algae and phytoplankton, which can result in hypoxia or "dead zones" in large water bodies. The most common examples of nutrient impairment on a national level occur in the Great Lakes, Gulf of Mexico, Chesapeake Bay, Long Island Sound, and coastal Florida. Dissolved oxygen levels in hypoxic zones are so low that most aquatic life is unable to survive the condition. Human health may also be affected by nutrient-impaired drinking water sources due to proliferation of toxic microbes, such as certain forms of cyanobacteria.

In the U.S., the mass of nutrients entering waters has increased significantly over the past five decades, and nutrient pollution now poses a serious threat to the nation's water quality (Selman et al., 2008; EPA, 2009). Nutrient pollution has the potential to become one of the costliest and most difficult environmental problems we face in the 21st century (Boesch, 1999).

In its "National Water Quality Inventory: Report to Congress for the 2004 Reporting Cycle," the EPA reported that 16 percent of the nation's 3.5 million miles of rivers and streams were evaluated for water quality impairment. Of the stream miles assessed, 44 percent were reported as impaired or not clean enough to support their designated uses, such as fishing and swimming. Pathogens, habitat alternations, and organic enrichment/oxygen depletion were the leading causes of river and stream impairment, and the leading sources of impairment were agriculture, hydrologic modification, and other unknown or unspecified sources. Nutrients impaired about 39,000 miles of the assessed river and stream. Municipal discharges/sewage impaired about 35,000 miles of assessed miles, representing 15 percent of the total impairment.

Similarly, the EPA reported that 39 percent of the nation's 41.7 million acres of lakes, ponds, and reservoirs were assessed in the 2004 reporting cycle. Of these assessed water body acres, 64 percent were reported as impaired, and the remaining 36 percent were fully supporting their designated uses. Mercury, polychlorinated biphenyls, and nutrients were cited as the leading causes of lake impairment. Top sources of lake, pond, and reservoir pollution were atmospheric deposition, unknown or unspecified sources, and agriculture. Nutrients impaired about 2.0 million acres of the assessed lakes area. Municipal discharges/sewage impaired about 580,000 acres of assessed lakes, ponds, and reservoirs, representing 6 percent of the total impairment.

Utah has 86,000 miles of rivers and streams, only 14,000 miles of which are perennial. In its 2008 Integrated Report, Utah reported that 11,000 miles of rivers and streams were assessed during the 2-year reporting cycle. Overall, 72 percent of stream miles assessed were fully supporting and 28 percent were not supporting for at least one beneficial use. The major causes of stream water quality impairment were sediments, nutrients, thermal modification, total dissolved solids, and metals. The leading sources of stream impairment in Utah were agriculture, hydrologic modification, habitat modification, and unknown or unspecified sources. Nutrients impaired 850 miles of river and stream uses.

Utah has over 2,000 lakes and reservoirs, of which 132 were assessed during the 2008 reporting cycle. These 132 lakes and reservoirs represent 97 percent (468,000 acres) of the total lake acreage in the state. When accounting by lake acreage, 68 percent was supporting and 32 percent was not supporting of at least one designated beneficial use. The causes of impairment in Utah's lakes and reservoirs are nutrients, siltation, low dissolved oxygen, suspended solids, organic enrichment, and noxious aquatic plants. The major sources of these impairments are agricultural practices, point sources, and habitat modification.

Numerous laws, policies, and standards have been considered and implemented to address problems associated with excess nutrients in surface water in the U.S. With the enactment of the Canada Water Act in 1970 and the Great Lakes Water Quality Agreement in 1972, nutrient loading to the Great Lakes was controlled, leading to restoration of the lakes. The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (2001) is implementing its action plan to reduce the Gulf hypoxic zone area by significantly reducing nutrient loading (Rabalais et al., 2007). Since the early 1970s, the Chesapeake Bay has been the subject of many studies on cultural eutrophication, and extensive efforts have reduced nutrient inputs, particularly by regulation of point sources. In the Long Island Sound watershed, urbanization and population growth have also resulted in a significant increase in nutrient loadings, leading to water quality impairments and hypoxia in the sound. Current management efforts to reduce nutrient pollution by more than half focus on upgrading wastewater treatment plants with newer technologies and reducing polluted runoff with best management practices (BMPs) in agricultural and suburban areas (Long Island Sound Study, 2004). Connecticut has implemented an active nutrient trading program to comply with the Long Island Sound total maximum daily loads (TMDL). The success of these programs has and will depend on strong public support and political commitment.

Because of the broad geographic scope associated with nutrient problems, environmental groups have pressured the EPA to establish nutrient water quality standards in waters covered by the Clean Water Act (CWA). In recent years, stakeholders have urged action from the EPA against the adverse affects of nutrient pollution. The Florida Wildlife Federation sued the EPA to force the agency to adopt numeric nutrient criteria for the state of Florida. Midwest Environmental Advocates filed a petition to the EPA requesting numeric nitrogen and phosphorus standards and to develop cleanup plans for the Mississippi River watershed. The Natural Resources Defense Council, along with several other environmental interest groups, submitted a petition to the EPA seeking amendments to the secondary treatment requirements for wastewater treatment plants, suggesting that the EPA issue nitrogen and phosphorus secondary treatment limitations for wastewater facilities of 0.3 milligram per liter (mg/L) total phosphorus (TP) and 3.0 mg/L total nitrogen (TN). The Association of State and Interstate Water Pollution Control Administrators (ASIWPCA) also recently developed a "Call for Change" paper that invited the federal government to adopt a new course of action to protect and improve the water resources within the U.S. The paper urged the EPA to develop a comprehensive set of tools to equip states to achieve reliable, across-the-watershed nutrient reductions from both point and nonpoint sources in the shortest reasonable timeframe. The ASIWPCA recommended that the EPA develop a national strategy for nutrient reduction that would be cost effective, sustainable, and easy to implement.

A recent report by the Office of Inspector General (OIG) stated that the EPA has failed to encourage states to adopt nutrient standards for water bodies and should set and enforce criteria itself in key places (EPA OIG, 2009). It stated that the EPA's nutrient criteria strategy lacked control and did not seek commitment to specific actions or milestones from states. As a result, few states have made progress adopting numeric nutrient water quality standards. The report recommended that the EPA select waters of significant national value that need numeric nutrient water quality standards to meet the requirements of the CWA and set a standard for them. It also recommended that the EPA establish state accountability for meeting milestones for adopting numeric nutrient water quality standards.

These events have led the EPA, states, and the public to promote more public partnerships, collaboration, better science, and improved tools to reduce nutrient pollution. A State-EPA Nutrient Innovation Task Group was formed to review the existing and innovative approaches to nutrient management. In a recent report, the Task Group concluded that nutrient-related pollution significantly impacts drinking water supplies, aquatic life, and recreational water quality and needs urgent and effective action.

In Utah, numeric water quality criteria are established based on the designated beneficial uses (water classifications) of specific water bodies. Numeric criteria have been established for nitrate and ammonia in some cases, based on drinking water and aquatic wildlife beneficial uses, respectively. Utah also uses established pollution indicator levels for biochemical oxygen demand (BOD), nitrate, and TP for several water classifications. An exceedance of indicator levels triggers further detailed evaluation of watershed conditions.

The Division uses a basin rotation type monitoring for its rivers and streams and an odd/even year type monitoring for its lakes and reservoirs. The data collected provide essential river, stream, lake, and reservoir information that is used for water quality assessment to identify water quality problems. Where water quality standards and indicator levels are not met, these waters are added to the 303(d) list of impaired waters for a TMDL evaluation.

Utah's 303(d) list for streams includes 94 stream assessment units (AUs). About 1,400 miles of streams have approved TMDLs but are not meeting water quality standards or supporting beneficial uses (Category 4). Another 2,100 miles of stream are impaired and require TMDLs (Category 5). Only one Category 5 stream AU is listed for nutrients (phosphorus).

Utah's 303(d) list for lakes includes 28 lake AUs, representing about 117,000 acres of lake, including Utah Lake at 96,000 acres. Of these, 9 are listed for phosphorus, including Utah

Lake. There are 26 other lakes and reservoirs that have approved TMDLs but are not meeting water quality standards (Category 4). Among these, 18 are listed for phosphorus.

The Division works with stakeholders during the TMDL process to establish appropriate load applications within affected watersheds, where applicable. Completion of a TMDL frequently results in more stringent discharge standards for point source dischargers and implementation of BMPs for non-point source pollution control.

As demands for water continue to rise in Utah, more stream and reservoir impairments will likely occur, and greater regulation of nutrients in these waters will be needed. Recognizing the increasing concerns about nutrient pollution of state and federal waters, it is prudent that Utah undertake scientific and economic investigations to determine if more restrictive nutrient controls are needed and at what cost they be achieved. In conjunction with other important environmental studies, the Department conducted a comprehensive evaluation of the potential costs and economic impacts that could result from broad or statewide nutrient discharge requirements.

1.2 Project Objectives

The specific objectives of this study follow:

1. Estimate the local and aggregate economic impacts that would result from implementation of statewide nutrient discharge standards for treated wastewater in Utah.
2. Quantify the potential environmental effects resulting from various statewide nutrient discharge standards. These evaluations were limited to estimates of receiving stream load reductions under simulated nutrient restricted conditions and to establishing reactive impacts such as changes in power consumption, residuals disposal, and air pollutant emissions.
3. Quantify the financial impacts of various nutrient discharge standards on sewer customers to assess issues of affordability and equity.
4. Inform POTWs about how new effluent nutrient discharge limits might be addressed at their facilities, along with the associated capital and O&M costs.

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2.0 Methodology

The study was a comprehensive evaluation of 30 mechanical wastewater treatment plants, one large lagoon system, and one “model” discharging lagoon system. These facilities were evaluated to identify process alternatives for nutrient removal. This allowed the subsequent development of concept-level engineering cost estimates (capital and O&M) and the further determination of financial and environmental impacts. This section provides a detailed explanation of how the study was conducted.

Treatment facility upgrade requirements and associated costs were estimated for a range of prospective nutrient standards. The discharge standards scenarios or “tiers” considered in this study are outlined in Table 1. The nutrient concentrations shown in Table 1 were selected principally to ensure that a variety of treatment plant upgrade technologies were considered and to generate a broad range of upgrade costs. A 20-year planning period was selected for the study such that all process, financial, and environmental assessments were conducted for the planning period 2009 through 2029.

TABLE 1
Nutrient Discharge Standards for Treated Effluent*

Tier	TP (mg/L)	TN (mg/L)
Tier 1N	0.1	10
Tier 1	0.1	no limit
Tier 2N	1.0	20
Tier 2	1.0	no limit

NOTE:
* Monthly average values

Planning: There were 32 wastewater treatment plants evaluated by this study (30 mechanical and 2 lagoon plants). In the early planning stages, it was recognized that good study results depended on good input from the POTWs, both in terms of the body of technical information (data) needed for the analytical process of the treatment plant conditions. Further, it was recognized that strong buy-in to the work being done and the results being delivered was important for the study to have value to the State. The approach used to involve POTW stakeholders in the study development, implementation, and outcomes in described in the following paragraphs.

Framework for Stakeholder Involvement: Utah is fortunate to have strong leadership, participation, and interest from its POTW managers and staffs. The POTW managers communicate frequently among themselves and meet regularly, in both ad hoc and formal forums such as the Water Environment Association of Utah (WEAU) annual meetings. The POTWs are represented on the Utah Water Quality Board and through this representation are informed about state and local water pollution control activities.

In support of the Department's nutrient cost study, the POTW management group became involved more than 15 months prior to initiation of the study. General Manager Leland Myers (Central Davis Sewer District) supported the study concept with the Utah Water Quality Board and provided valuable input to the study. During development of the study work plan, the Department discussed the study scope with the POTW managers at the 2008 WEAU annual conference, and constructive input was provided along with offers of encouragement and support for the project.

Concurrent with the Department's preparation of the project scope of work and request for proposals, the Department notified the POTW managers that it intended to conduct a nutrient cost study for their plants and requested their support by beginning to collect supplementary influent and effluent wastewater quality data. Based on a review of each facility's discharge permits, parameters not routinely monitored but needed for the study (for example, total Kjeldahl nitrogen [TKN] and TP in the influent and effluent) were identified and were asked to be collected on a weekly composite sample basis. The POTWs were asked to collect these additional data for 8 months based on the estimated future starting time for the project. The Department estimated that this voluntary additional monitoring effort cost the POTWs between $350,000 to $450,000, collectively; 26 of the 32 plants studied contributed by collecting and furnishing additional data.

The POTW managers and staff were invited to attend two meetings with the project team that were scheduled during the course of the study. The first meeting, the "Nutrient Removal Seminar," was a 1-day session designed to be informational, covering nutrient removal and national trends and drivers in general, results from a recent nutrient cost study conducted by the Central Davis Sewer District, and an overview of the statewide study, its needs from the POTW community, work protocols, and the project timeline. This meeting informed the POTWs and provided a venue for formal and informal interaction between the study team and POTW managers and an opportunity to understand stakeholder expectations and constraints.

The second meeting, the "Nutrient Cost Study POTW Workshop," was conducted over a 5-day period. The first meeting was a 4-hour general session wherein all of the POTWs were represented. This meeting provided a status report for the project and outlined the basic approach used to model each facility. Discussions focused on modeling techniques that would be used most broadly to describe five main categories of secondary processes common in Utah: trickling filters (TFs), TF hybrids, oxidation ditches (ODs), activated sludge (AS), and membrane bioreactors (MBRs). On the following days, study team members met individually with managers and engineers from each facility. In these 2-hour "breakout sessions," the site-specific analyses used were reviewed and discussed. Assumptions and data limitations were checked, supplemental information was requested, and corrections were made.

The principal work products from the project consisted of two main components: (1) a statewide study report and (2) a series of technical memoranda (TMs) that summarized the study results on a broad statewide basis and on a facility-specific basis, respectively. The statewide study results were first presented to the public in the March 2010 Utah Water Quality Board meeting and 1 month later to the broader public at the 2010 WEAU annual meeting, which many POTW managers attended. The TMs were submitted to POTW managers between July and August 2010 in final draft forms. At that time, onsite presentations of the study results were scheduled with each of the 55 governing boards or city councils for the 30 mechanical and 25 discharging lagoon POTWs in the state. Onsite presentations are expected to be completed in October 2010.

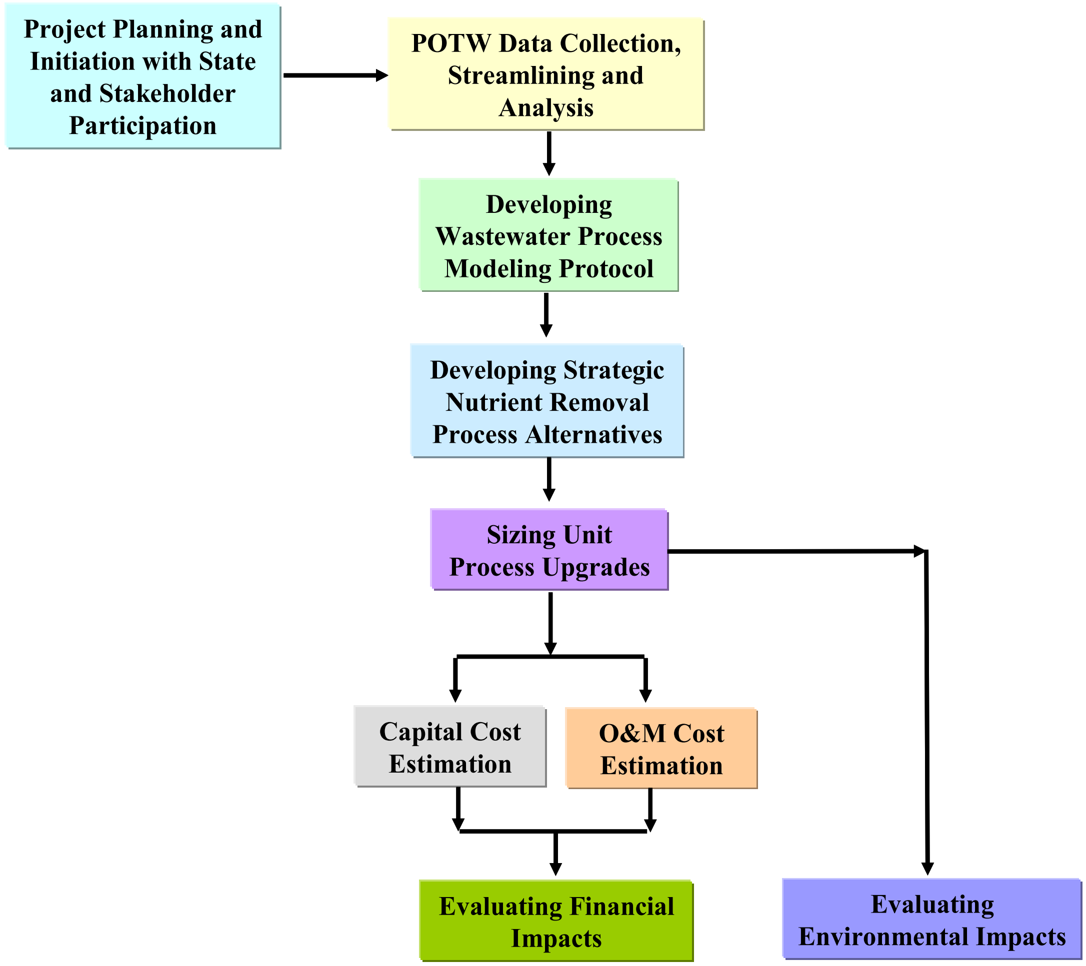
Project Organizational Framework: In the earliest planning stages, it was recognized that for a study of this magnitude to meet its objectives successfully, the work approach must be organized such that work elements (tasks) were systematized, work processes standardized, and information managed uniformly for efficient flow of data into and out of several analytical "machines." At the same time, it was important to maintain flexibility in the process to analyze, troubleshoot, and fine-tune results and to meet the quality and managerial objectives of the project.

The basic framework for organization was established in two planning documents: the contracted engineering services scope of work and the project management plan (PMP). The PMP was developed by CH2M HILL as the first task under contract with the Department for the project. The PMP allowed CH2M HILL to interpret the contract scope of work for its team into terms of executable work elements and to establish the technical and managerial methods and work processes that were to be used to meet the study requirements, budget, and schedule. The PMP served as a road map for execution of the work. As the work advanced and problems or special needs were encountered, the PMP was periodically updated.

Standardization: Data collection, management, and processing aspects of the project were critical elements in the study's success. For efficient execution of the planned analyses, standardized protocols were established for data and computational organization, processing, and reporting. Data collection systems were formatted for both direct and indirect (stepwise) integration with two primary computational tools that were used for process development and analysis (CH2M HILL's Pro2D wastewater simulator) and for facilities design and cost estimating (CH2M HILL's parametric estimating system). Figure 1 illustrates of the technical approach used to execute the study.

Standard protocols developed and used in systemization of the following project elements are presented in Figure 1.

FIGURE 1
Flow Diagram of the Methodology Used for the Statewide Nutrient Removal Study



2.1 Data Collection from POTWs

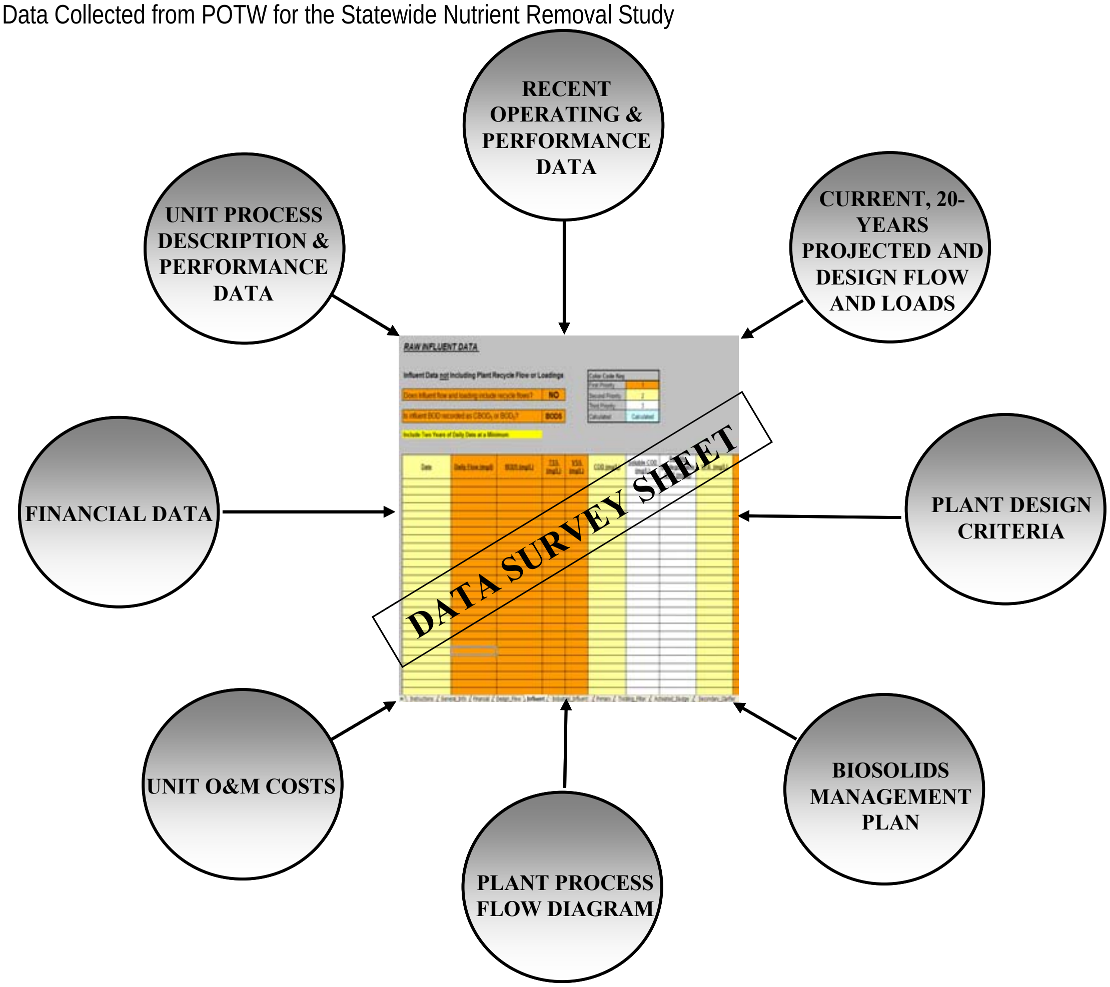
The first step of the study was to collect process and financial data from each POTW to define the existing treatment processes and performance, upon which nutrient removal strategic upgrades were conceived. To collect the data needed for this study, a standard data survey workbook was developed that could be used by every facility regardless of its unit processes and configuration. The data survey workbook was distributed to the POTWs, who then input all of the information applicable to their plants. The following data were collected.

- **Process data:** This included facility site plans, plant design criteria, process flow diagrams, unit process descriptions and dimensions, and recent (6 months to 2 years) operating and performance data.
- **Treatment plant service area information:** This included service connections information, current and projected 2029 population served, current and projected 2029 equivalent residential unit (ERU) served, and significant commercial and industrial inputs.

- **Projected 2029 and design data:** This included projected 2029 flow and loading rates, design average, and design maximum month criteria.
- **O&M information:** This included treatment plant operating budgets, unit operating costs for electricity, natural gas, chemicals used, sludge management, and end-use.
- Current National Pollutant Discharge Elimination System or Utah Pollutant Discharge Elimination System permit requirements.
- **Financial information:** This included debt financing information, current user charges, and new user connection charges.

The types of data collected and compiled from the POTWs are illustrated in Figure 2.

FIGURE 2
Data Collected from POTW for the Statewide Nutrient Removal Study



2.2 Data Reduction and Analysis

Process data collected from each POTW were screened for consistency, and any apparent outliers were removed before determining a statistical mean for each parameter. The statistical mean values of process data, along with other important operational and unit process information, were compiled and consolidated into a single-page data summary to be used for the engineering and financial computations for the follow-on tasks. The data summary sheet for each POTW was reviewed with POTW personnel during the POTW workshop. The data summary sheets from all POTWs were combined into a single database for later use.

The summarized data were used as inputs for POTW process modeling. Three sets of process model input data were developed for each POTW. These included the current (2009) process and operational data, the projected 2029 (planning year) process and operational data, and the plant design maximum month data. For POTWs that would reach their design capacity within the 20-year planning period, intermediate plant expansions were not considered. Consequently, if projected plant influent flow and pollutant mass loadings were projected to exceed the design values before the year 2029, for the purpose of this analysis, the flows and loads were held constant after meeting design capacity. Hence, the incremental costs and environmental impacts of this intermediate expansion need were not included in this analysis. Only three communities, representing 10 million gallons per day (mgd) of combined capacity, were affected by this approach.

Where planning projection or design data gaps existed, the POTW was contacted to obtain additional information. If the needed information could not be obtained, one set of uniform, statewide, and specific assumptions was used. In some cases, discharge monitoring report data were used. Also, assumptions were made based on the standard wastewater design manual (Metcalf and Eddy, 2003). The assumptions that were made in case of data gaps are presented in Table 2.

TABLE 2
Process Data Assumptions in Case of Data Gaps

Parameters	Assumptions
Total suspended solids, mg/L	240
BOD, mg/L	250
TKN, mg/L	40
Ammonia nitrogen (NH_3-N), mg/L	65 percent of TKN
TP, mg/L	6
Peak month flow and loads peaking factor	1.2
Peak hourly flow and loads peaking factor	2.0
Secondary clarifier effluent concentration, mg/L	10
Sludge volume index	180
Influent average temperature	18°C
Influent design temperature	Minimum 7-day rolling average value, or 14°C

NOTE:
°C = degree(s) Celsius

2.3 POTW Process Modeling

This section summarizes the tool used for process modeling and the approach taken to model the wastewater treatment facilities.

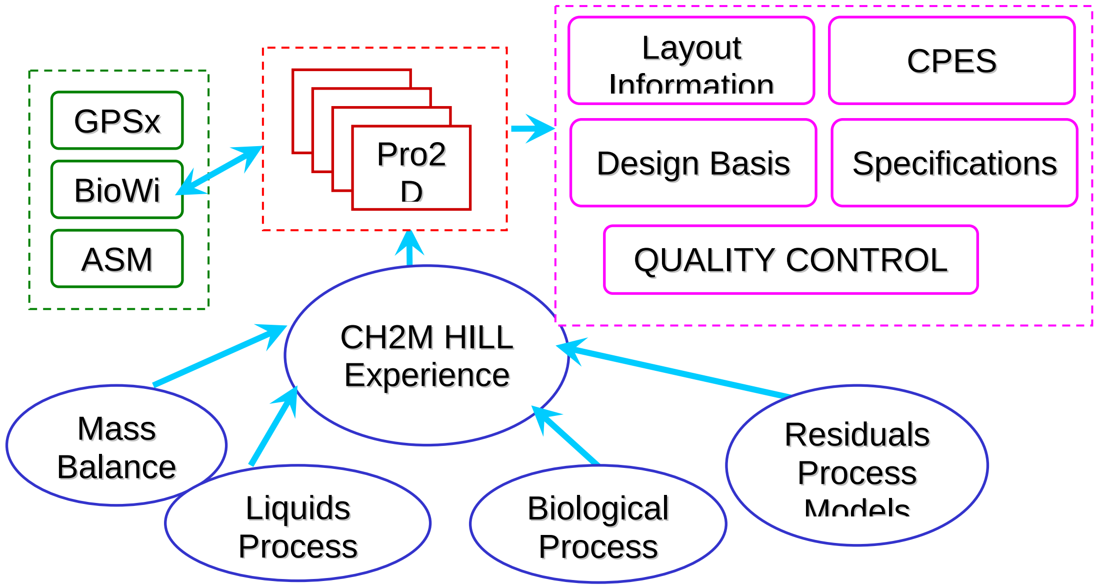
2.3.1 POTW Process Modeling

All process modeling was done using CH2M HILL's Pro2D tool. This tool provided a flexible and robust modeling approach to characterizing and predicting treatment plant performance. Use of this standardized tool allowed a wide range of potential design and operating scenarios to be assessed rapidly and reliably. Pro2D was used to calculate and document all process and sizing information related to the evaluation and design of strategic treatment plant upgrades, tracking up to 60 independent wastewater components through each unit process.

Pro2D was integrated with two other models: (1) PBNR, which provided detailed analysis of suspended growth biological nutrient removal processes, including processes for biological phosphorus removal using the International Water Association's ASM2d model, and (2) PClarifier, which provides detailed modeling of secondary clarifier performance and capacity using state-point analysis. Pro2D was also used to analyze TFs, including combined processes such as TF/solids contact (SC) and TF/AS.

Pro2D was interfaced directly with the cost estimating software package, CH2M HILL Parametric Estimating System (CPES). This approach enabled efficient evaluation of alternatives at each POTW with measured associated impacts (that is, the mass of nutrients removed, changes in biosolids quantity, and changes in chemical usage) and life-cycle costs. Figure 3 illustrates the modeling framework and how it can be linked to project data inputs and other computer-based tools.

FIGURE 3
Pro2D Framework

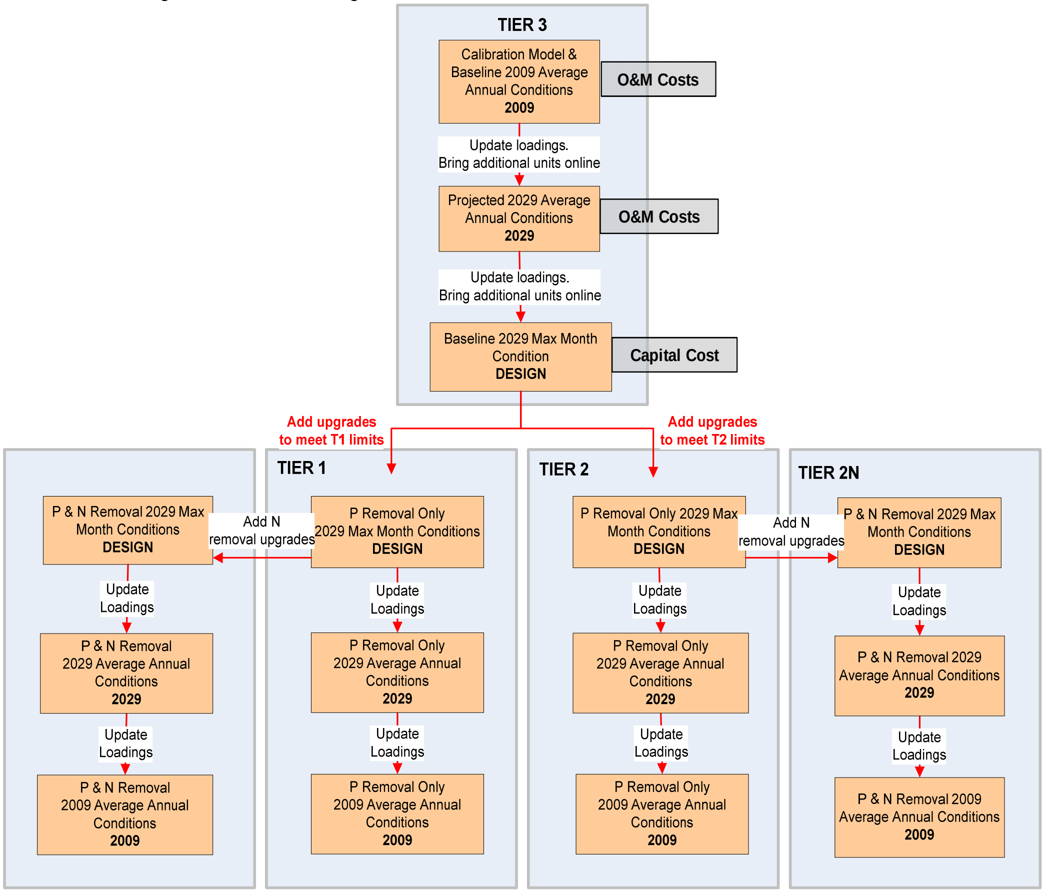


2.3.2 Process Model Calibration and Standardization

To model 30 mechanical and 2 discharging lagoon facilities for various tiers of nutrient standards over the 20-year planning period, a standardized approach was used to minimize redundant effort. Process models were initially developed and calibrated based on recent historical data obtained from each mechanical POTW and the City of Logan lagoon system. For the model lagoon, statewide averages were used. Calibration was accomplished by comparing specific model predictions with measured values. Modest adjustments in model parameters were made to obtain a reasonable fit between the simulated results and the POTW data. The number and type of adjustments to the model were limited to those necessary to obtain a reasonable and robust fit to the available data. They were further selected based on fundamental knowledge of the processes employed at the facility so that the changes made were consistent with known phenomena. The calibrated models were then updated to accommodate the flow and loads for the planned year (2029) and to preserve the design maximum month capacity of each POTW. This defined Tier 3 or the "base condition" for each POTW. The models for the planned year were used to estimate differential operating costs and nutrient load reductions, while the design models were used to generate capital costs for each tier of nutrient standards.

The process models for the various tiers of nutrient control were built up from Tier 3. The tiers with only phosphorus control (Tiers 1 and 2) were built first, followed by the tiers with both phosphorus and nitrogen controls (Tiers 1N and 2N). Figure 4 illustrates this approach, demonstrating that 15 process models were developed for each POTW to capture process upgrades and the incremental increase in capital and O&M costs from baseline conditions (Tier 3) for the four tiers of nutrient control.

FIGURE 4
Process Modeling Protocol Flow Diagram



2.3.3 Nutrient Removal Process Alternatives Evaluation

Categorization of the mechanical POTWs was feasible because of many similarities across these plants in Utah. Categorization into the following groups simplified the evaluation of upgrade alternatives and allowed several efficiencies in the work process.

- Oxidation ditch (OD)
- Activated sludge (AS)
- Membrane bioreactor (MBR)
- Trickling filter (TF)
- Hybrid processes, such as trickling filter/solids contact (TF/SC)

For each category, an alternative matrix was developed including four to five viable approaches to meet the limits for the various tiers of nutrient standards. This matrix considered biological and chemical phosphorus removal approaches, as well as different AS configurations for nitrogen control. The alternatives matrix illustrated that several strategies are available for achieving nutrient limits. For this study, the processes selected for evaluation are to be proven and conventional methods for meeting the nutrient limits. This was done to produce reasonable and robust estimates of the costs for facility upgrades with reliable performance. Further optimization of the system upgrades used is possible but was beyond the scope of this study. The project team identified viable upgrade processes for each POTW under each nutrient standard tier. The selected upgrade options for each POTW were reviewed with the POTW managers during the Nutrient Cost Study POTW Workshop to obtain agreement that these options were reasonable.

Figure 5 illustrates the general approach used to sequentially develop nutrient controls from tier to tier. Steps A through D (shown in Figure 5) describe each upgrade step:

A. Upgrades from Tier 3 (base conditions) to Tier 2-level of phosphorus control

B. Upgrades from Tiers 2 to 2N alternative, which included both phosphorus and nitrogen control

C. Upgrades from Tier 2-level of phosphorus control to Tier 1-level of phosphorus control

D. Upgrades from Tiers 1 to 1N alternative, which included both phosphorus and nitrogen control

FIGURE 5
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

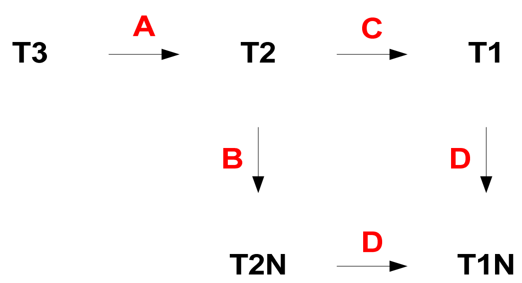


Table 3 presents the general design criteria used for sizing the various chemical and biological treatment alternatives. Site-specific design criteria are included in the TMs of individual POTWs. These design criteria were important for capturing the costs associated with the selected upgrade approach.

TABLE 3
Main Unit Process Sizing Design Criteria

Design Parameter (Nutrient Tier)	Value
Target metal: Phosphate molar ratio (Tiers 1 and 2)	1:1, 2:1, 7:1[(a)]
Metal-salt storage (All tiers)	14 days
Fraction of anaerobic volume in bioreactors (Tiers 2N and 1N)	15 percent
Fraction of anoxic volume in bioreactors (Tiers 2N and 1N)	30 percent
Mixed-liquor return pumping ratio as a percent of influent flow (Tiers 2N and 1N)	100 to 150 percent
Maximum MLSS concentration	3,500 mg/L[(b)]

TABLE 3
Main Unit Process Sizing Design Criteria

Design Parameter (Nutrient Tier)	Value
Maximum solids loading rate in secondary clarifiers	25 to 35 lb/day/ft^2
Target methanol dose for post denitrification (Tier 1N)	3.5 MeOH:NO3-Neq
Granular filter loading rate (Tiers 1 and 1N)	5 gpm/ft^2[(c)]

NOTES:
ft^2 = square feet
gpm = gallon(s) per minute
lb = pound(s)
MLSS = mixed liquor suspended solids
[(a)] Target dosing ratio at the primary clarifiers, secondary clarifiers, and upstream of polishing filter, respectively
[(b)] MBR plants can have maximum MLSS concentration of 10,000 mg/L
[(c)] Hydraulic loading rate at peak hourly flow

The progression of upgrades conceived for meeting the different tiers of nutrient control for each POTW was analyzed using the following steps:

- **Step 1:** Review and summarize the information submitted by the POTW; review with POTW as needed.
- **Step 2:** Develop and calibrate a base model of the existing POTW using the summarized data.
- **Step 3:** Modify the base model to include unit process modifications for the different tiers of nutrient control, and use model outputs to determine unit process sizing and operating requirements.

For each mechanical POTW, the concept-level design solutions for each tier of nutrient standard were summarized in a TM, with nutrient treatment process flow diagrams and new tankage and major equipment (mechanical, electrical, and instrumentation) requirements. The initial TMs were reviewed individually with managers from each facility during the POTW workshop. During the breakout meetings, the process alternatives were reviewed in detail, and any additional information necessary to perform accurate capital and operating cost estimates was obtained.

For the lagoon POTWs, design solutions were similarly developed and summarized. The process upgrades established to meet the various tiers of nutrient standards consisted of chemical phosphorus removal for Tiers 1 and 2 levels of phosphorus control and new mechanical treatment facilities with biological nutrient removal process and chemical phosphorus backup system for Tiers 1N and 2N.

2.4 Construction and O&M Cost Estimates for Implementing Nutrient Removal at Treatment Plants

This section discusses the approach and the tool used for estimating capital and O&M costs for the 30 mechanical POTWs and 2 lagoon POTWs.

2.4.1 Capital Cost Estimates

Budget-level present-worth cost estimates were developed for upgrading each of the facilities in the study at each nutrient standard tier. The following guidelines were used:

- Estimate major process equipment costs from recent Utah actual project costs and vendor quotes received within the last 2 years
- Estimate major equipment construction and installation costs from recent Utah (Intermountain West) actual project costs and builder/material supplier quotes received within the last 1 year
- Estimate site work, roads, support facilities, excavation, shoring, piping, wire and conduit, cable trays, field instruments, appurtenances, freight, taxes, and so forth from recent experience in Utah and current published cost estimation guidelines
- Escalate past costs using appropriate indices such as provided by *Engineering News-Record* or equal
- Estimate contractor overhead and profit as 20 percent of the construction cost
- Estimate engineering and construction management costs as 20 percent of the constructed value, including contractor overhead and profit
- Estimate legal and administrative costs as 10 percent of the constructed value
- Allow 30 percent contingency

All major process equipment was sized previously using Pro2D to accommodate the various tiers of nutrient standards. All estimates were prepared in accordance with the guidelines of the Association for the Advancement of Cost Engineering International and defined as Class 4 estimates. The expected accuracy range for cost estimates is +50/-30 percent.

2.4.2 Tool Used for Capital Cost Estimates—CPES

Conceptual-level cost estimates were prepared from each alternative using CH2M HILL's CPES. This is a Microsoft Excel workbook that allows the user to develop project-specific capital and annual costs for wastewater treatment facilities.

CPES Facilities Models: CPES contains models of various treatment processes, each located on a separate worksheet. Input cells for each process allow the user to specify detailed design criteria for the particular unit process. CPES was used to estimate the cost for each given unit process and to develop a cost breakdown for that unit. CPES links to Pro2D to allow rapid evaluation of a wide range of treatment options and develop capital and O&M costs.

CPES Life Cycle: This file imports data from CPES facilities for use in preparing O&M and life-cycle cost estimate for the facility. Specific life-cycle cost inputs (such as labor costs, power, sludge disposal, annual operating time, building power, and chemical cost) are provided from the facilities model for the development of life-cycle cost estimates.

2.4.3 O&M Cost Estimates

The incremental change in O&M costs for the base year (2009) and the planning year (2029) for implementing the identified improvements necessary for achieving the nutrient limits were estimated based on the process models outputs of Pro2D and unit O&M costs. The unit O&M costs were either provided by the POTW or, when site-specific unit costs were not available, based on the average costs in the state of Utah. Table 4 presents the average unit costs for the state of Utah used in this study.

TABLE 4
Utah-specific Operating and Maintenance Unit Costs

Parameter	Value
Biosolids hauling	$8/wet ton
Biosolids tipping fee	$6/wet ton
Ferric chloride	$1,000/ton
Alum	$480/ton
Methanol	$1.75/gallon
Polymer	$1.65/pound
Power	$0.05/kilowatt-hour

Annual O&M cost estimates included, but were not limited to, the following:

- Energy (electrical, natural gas, etc.) costs for the major mechanized process equipments, such as aeration systems, secondary effluent pump stations, backwash pumps, thickening, and dewatering units
- Chemical costs, such as metal-salts, polymer, and methanol
- Biosolids disposal and management, such as hauling, tipping, use, and disposal

The incremental changes in costs were calculated by estimating the O&M cost for each tier of nutrient standards and subtracting that from the O&M cost estimated for the "base conditions" (Tier 3) scenarios.

2.5 Financial Analysis

This section discusses the methodologies used for estimating the economic impacts of implementation of nutrient discharge standards for Utah. Financial and economic impacts were calculated for each of the 30 POTWs that were evaluated for this study. Financial impacts were summarized on a local and aggregate basis by three primary economic parameters—20-year life-cycle costs, user charge impacts, and community financial impacts. The basis for the financial impact analysis was the estimated capital and incremental O&M costs and other financial and POTW-specific data, such as number of ERUs and current (average) monthly bill that were either provided by the POTWs through the initial data request or developed from information available at the Division. This section also describes the economic model that was used to estimate the financial impacts of the nutrient removal requirements.

2.5.1 20-year 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 alternative prescribed, a multiyear life-cycle cost forecast was developed that included both capital and O&M costs.

Cost forecasts were 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. In other words, an inflation factor was not applied to projected O&M costs over the forecast period. This analysis further assumed that construction will be completed in the first year and O&M costs for all treatment alternatives will begin the following year. This assumption ensured that a fair cost comparison was created across recommended treatment alternatives by including 20 years of incremental O&M in each cost forecast.

Annual renewal and rehabilitation expenditures were not considered as part of the multiyear cost forecast. Although some outlay may be needed to maintain the assets over time, it was assumed that these expenditures would be minimal for new assets. Other costs, such as replacement of major mechanical components, for some treatment alternatives were examined but ultimately not included in the analysis because these costs did not fall within the forecast period.

The net present value (NPV) of each cost forecast was calculated to summarize the life-cycle costs of each treatment alternative. A real discount rate, rather than a nominal discount rate, was used to discount annual cost estimates across the forecast period because the forecasts are made in current (2009) dollars. The Division agreed to use an estimated real discount rate of 2.7 percent for the analysis, which is consistent with the most recent forecasts of real interest rates for treasury notes and bonds of the same maturity.[3]

To develop cost per pound estimates for the nutrient removal scenarios, the NPV of the cost forecast was divided by the total pounds of nutrient removed over the 20-year period. Incremental phosphorus and nitrogen load reductions were calculated by first establishing the expected nutrient load based on the effluent limit of the corresponding tier, and then subtracting that from the baseline load for the POTW (that is, without any treatment upgrades). Although it is understood that treatment alternatives will yield nutrient reductions well beyond 20 years (and continue to cause incremental O&M costs), this calculation represents an appropriate matching of costs with benefits over the same time period.

The recommended upgrades for each treatment alternative were designed to allow the POTW to consistently meet the nutrient limit for the existing design capacity of the treatment plant. The nutrient limit effluent concentration was therefore applied to the projected flows of the POTW to determine the annual phosphorus and nitrogen load (in

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3 From the U.S. Office of Management and Budget, Circular A-94 (Appendix C), *Real Interest Rates on Treasury Notes and Bonds of Specified Maturities*.

pounds) for each treatment alternative scenario. Based on direction from the Division, it was assumed that the effluent concentration limit remains constant over the 20-year forecast period even though the actual concentration may fluctuate slightly over time.[4]

The annual baseline load for each POTW was developed by determining a forecast of effluent concentration under the "base condition" scenario and applying that concentration to projected flows to develop annual loads for both phosphorus and nitrogen. The forecast uses effluent nutrient concentration limits for 2009 and 2029 from the calibrated "base condition" models for each POTW as described in the earlier sections. Annual effluent nutrient concentrations were extrapolated between the 2009 and 2029 estimates to yield a concentration forecast for the base-case scenario.

To calculate the load reduction for each treatment alternative, the nutrient load associated with each tiered concentration limit was subtracted from the baseline load for each year of the forecast period. The incremental load reduction for each tier was the total nutrient removal across the forecast period, from 2010 through 2029. The cost per pound metric was then calculated as the total NPV cost divided by the total pounds removed over the 20-year period, for Tiers 1 and 2, as shown in the following equation:

$$TP\ Cost\ per\ Pound_{\ Tier\ 2} = NPV_{\ Tier\ 2} \,/\, TP\ Pounds\ Removed_{\ Tier\ 2}$$

For Tiers 1N and 2N, the equation was adjusted slightly to account for the fact that the NPV includes costs for both phosphorus and nitrogen removal. To determine the allocation of costs to each nutrient, it was assumed that the incremental NPV costs across tiers with the same phosphorus limit (that is, Tiers 2 to 2N or Tiers 1 to 1N) will be attributed to nitrogen removal because phosphorus removal remains the same. Of course, this cost allocation procedure is an oversimplification of the actual cost allocation for both nutrients and should be used with caution; however, it does standardize the cost allocation procedure for comparing costs among POTWs of varying sizes within the study. The resulting equation for tiers that include nitrogen limits is therefore the following:

$$TN\ Cost\ per\ Pound_{\ Tier\ 2N} = (NPV_{\ Tier\ 2N} - NPV_{\ Tier\ 2}) \,/\, TN\ Pounds\ Removed_{\ Tier\ 2N}$$

It is important to note that cost per pound metrics for phosphorus removal are the same for Tiers 2 and 2N and for Tiers 1 and 1N, because the phosphorus effluent concentration limits remain the same. Again, this is an oversimplification because enhanced biological phosphorus removal or chemical phosphorus removal processes can be significantly different from biological nutrient removal. The "per pound unit costs" should be interpreted with caution.

2.5.2 Customer Financial Impacts

The second financial parameter measured the potential impact to user rates for those customers served by the POTW. The financial impact from nutrient standards was measured both in terms of potential rate increases and the resulting monthly bill impacts for the typical residential customer of the system. Rate increases were determined by estimating the potential increase in annual revenue requirements for the POTW. Implementation of each treatment alternative will cause an increase in annual revenue requirements associated with capital and incremental O&M costs.

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4 As flows increase, the target concentration may fluctuate at levels below the actual nutrient limit but will not exceed it.

In most cases, the POTW will secure financing from the municipal bond market, low-interest state loans, or other debt instruments to pay for the initial capital investment of the treatment alternative. This analysis assumed that money for the initial capital cost will be borrowed through loans at 5.0 percent interest over a 20-year term. Based on these assumed debt financing terms, the initial capital cost was converted to an annual debt service payment.[5] Incremental operating costs for the first year of the forecast period (2010) were also included in annual revenue requirements based on methods described previously in this section. Combined with the annual debt service payment amount, these costs represented the additional annual revenue requirement of the POTW if the treatment alternative is implemented.

While some POTWs may use tax and other revenues (from sources other than rates) to offset annual revenue requirements, this analysis assumed the POTW will fund recommended treatment alternatives by increasing rates. This assumption allowed a standardized comparison of user charge impacts for customers throughout the state. Ultimately, each POTW would choose the best combination of funding sources to meet the additional revenue requirements caused by statewide nutrient standards.[6]

To determine estimated rate increases for each treatment alternative, the analysis must establish the typical customer's current average monthly bill and the number of customers served by each POTW. Customers and customer units are often measured in ERUs, with a single ERU equal to the wastewater output of a single-family home or similar base unit. Large commercial or industrial customers are then measured in relation to this base unit and an ERU value assigned based on wastewater loading characteristics. In this way, an ERU estimate represents the total number of base units that may be charged for equivalent wastewater flows within the system.

Through the initial data collection survey, estimates of the current number of ERUs served by each POTW were requested. If an estimate was not provided by the POTW, data from the Division were used to develop an ERU estimate. For each POTW and nutrient limit, the total additional revenue requirement was divided by the number of ERUs to estimate the annual cost increase per ERU. The annual cost increase was then converted to a monthly cost increase for each customer.[7]

The bill increase metric estimated the monthly cost increase for a typical residential customer, but another metric was needed to measure the projected cost increase as a percentage of the current average monthly bill paid by the customer. The resulting metric identifies the rate increase percentage that would generate sufficient revenues to fund the implementation of each treatment alternative.

The current average monthly bill is difficult to estimate, since many POTWs (particularly regional facilities) offer wastewater service to multiple communities. CH2M HILL relied on input from the Division to link communities within the state to the POTWs that serve them.

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5 Debt financing terms will vary based on credit ratings and each service provider's access to capital funding sources. Debt financing terms are established as inputs within the framework of the economic model.

6 Depending on the chosen funding combination and access to credit markets, actual rate increases may vary from the estimated rate increases presented herein.

7 This analysis does not make an attempt to track the bill increase metric over time. Customer growth, higher incremental O&M costs, and the retirement of debt service can all lead to variations in customer financial impacts over time.

The Division provided current monthly bill estimates for all communities within the state, and a weighted average monthly bill statistic has been developed based on the number of residential connections served by the POTW in each community.

The monthly cost increase per ERU for each treatment alternative was then compared with the current average bill estimate, resulting in an estimate of the potential rate increase for the typical customer of each POTW. This calculation avoided the complexities often associated with rate studies. In particular, the analysis assumes that all costs for each treatment alternative will be funded through an increase in user rates, whereas some POTWs may choose to meet these revenue requirements from other sources (such as property taxes or connection fees). For POTWs that use funding sources beyond user fees, the potential rate increase will be overstated. However, the total estimated cost increase per ERU remains accurate. Despite its limitations, the metric does establish a common framework for establishing and comparing rate increase percentages across POTWs and nutrient limit scenarios.

2.5.3 Community Financial Impacts

The third and final parameter measured the financial impact of nutrient limits from a community perspective and accounts for the varied purchasing power of customers throughout the state. The metric was calculated as the ratio of the projected monthly bill (associated with each nutrient limit) to an affordable monthly bill, based on a metric used by the Division to determine project affordability.

This analysis referenced information developed for the second financial parameter, namely, the projected monthly bill increase metric and the current average monthly bill. By adding these two values together, an estimate of the projected monthly bill under each treatment alternative was calculated.

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 income (MAGI) for customers of the system. For this analysis, the Division provided 2008 data, which included MAGI information for each community within the state. Similar to the current monthly bill statistic, the MAGI was difficult to estimate because for many POTWs, service areas encompass more than one community or cut across multiple community boundaries. With guidance from the Division to link communities within the state to the POTWs that serve them, a weighted average MAGI statistic was developed based on the number of residential connections served in each community.

To calculate the affordability ratio, each MAGI statistic was escalated from 2008 dollars to 2009 dollars based on a conservative 1.5 percent annual rate for income escalation. Both the escalation rate and MAGI estimates are included as inputs within the economic model and can be updated as more accurate information becomes available.

The MAGI statistic for each POTW was multiplied by the affordability threshold parameter of 1.4 percent and converted to a monthly "affordable" wastewater bill amount for the typical customer. The projected monthly bill for each treatment alternative was then divided by the "affordable bill" amount, and the resulting ratio described the relative affordability of each treatment alternative and nutrient limit. Affordability ratios greater than 100 percent suggest that the projected monthly bill for that treatment alternative exceeds the State's affordability criterion.

As discussed, the existing monthly bill for each POTW may not represent the total cost of wastewater service per ERU because it does not consider costs that are funded through property taxes or other revenue sources (that is, the total existing cost per ERU is understated). In these cases, the affordability of treatment alternatives may be overstated (that is, they are less affordable than the metric suggests).

2.5.4 Economic Model

The financial impact parameters, statewide outputs, and other important POTW parameters were consolidated within an economic model provided to the Division. The Microsoft Excel based model contains a repository of electronic data, financial impact calculations, and interactive graphics that will be useful as the Division continues to study the potential impacts of nutrient effluent limits. As more accurate data become available and further studies are conducted, the model can be used to efficiently update the financial parameters for specific POTWs and other statewide metrics. Access to the electronic repository of data in Excel format will also allow the Division to easily create new summaries and analyses of the financial impact information for internal and external stakeholders and to address specific information needs.

2.6 Environmental Impacts Assessment

Potential direct environmental impacts that would result from implementing the process upgrades proposed for achieving the various tiers of nutrient control were assessed. The approach used for the assessment is summarized in this section.

The following environmental 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 air emissions from biosolids hauling and energy consumption

2.6.1 Reduction of Nutrient Loads from POTWs to Receiving Water Bodies

Reduction in nutrient loads from each POTW as a result of implementing process upgrades to meet the tiers of nutrient control was estimated for the current year (2009). This was done by first establishing the expected nutrient load based on the effluent limit of the corresponding tier and subtracting that from the baseline load for the POTW (that is, without any treatment upgrades). The baseline load for each POTW was determined either from the effluent nutrient data provided by the POTW or from the outputs of "base conditions" process modeling.

As an example, the following equation shows a nutrient load reduction calculation:

$$\textit{Nutrient removed, pounds/year} =$$

$$(\textit{Effluent Nutrient Load}_{\textit{Tier 3}} - \textit{Effluent Nutrient Load}_{\textit{Tier 2N}})$$

Similar calculations were done for all the tiers of nutrient control to determine corresponding reductions in phosphorus and nitrogen loads.

To summarize the nutrient content of POTWs and their receiving waters and 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 were then examined for the effects of future POTW nutrient removal alternatives.

Average effluent nutrient concentrations were provided for the discharges of each POTW. Upstream receiving water station water quality data were obtained from the Storage and Retrieval of Water-related Data (STORET) system but had to be summarized to yield average TN and TP concentrations that could then be paired with the appropriate POTW records. Nitrate and TKN were combined to calculate TN. If nitrate was not available, nitrate plus nitrite were added to TKN to calculate TN. The average TN was then calculated for each location. If no TKN measurements were available, TN was not estimated. Total phosphorus was calculated by averaging the total phosphate phosphorus concentration for each location.

The TN and TP and daily average flows were estimated by sample event, and these were averaged over the sample records available for the past 20 years, and nutrient loads were calculated. Nutrient loads for each POTW and corresponding receiving water were paired, and the two sets of nutrient loads were combined to yield an estimated average load and concentration in the receiving water immediately downstream from each discharge point. The combined loads were then used to estimate downstream concentrations, conservatively based on simple average combined flow rates without additional dispersion, dilution, or degradation modeling. Flows from the POTWs and streams were held constant, but nutrient loads were modified based on the potential effects of treatment tiers. Average daily concentrations were estimated as follows:

TN or TP (mg/L) = Combined daily TN or TP loads (mg)/Combined daily flows (L)

The upstream load was combined with a baseline or treatment-tier POTW load to provide comparative average downstream concentrations as might be expected with differing levels of treatment. The downstream concentrations for each treatment tier were then compared with baseline conditions to estimate the percent reduction in average concentrations as might be expected through the implementation of enhanced treatment.

2.6.2 Other Environmental Impacts

To determine the changes in chemicals used, biosolids produced, and energy consumed due to implementation of process upgrades for nutrient removal, a similar calculation as described for estimating reductions in nutrient load was performed. The amounts of chemicals required, biosolids generated, and energy used for the various tiers of nutrient standards were determined from the process models developed for each tier and were subtracted from the requirements of the base condition (Tier 3).

For estimating changes in emissions because of additional biosolids hauling and energy required, air emission factors for diesel truck hauling and additional electrical usage were determined.

It was assumed that the following two types of emissions would result from the truck hauling activities:

- Particulate emissions due to dust kicked up by trucks traveling on roads
- Tail pipe emissions resulting from diesel combustion

The trucks for biosolids hauling were assumed to be 22-ton diesels with compression ignition traveling on paved roads. The emission factors to estimate particulate emissions were derived using the equations from AP-42 (2006), which is represented as follows:

$$E_U \text{ (pounds of particulate emissions per vehicle mile traveled)}$$
$$= k\,(sL/2)^{0.65}(W/3)^{1.5} - C$$

where:

E_U = emission unit

k = 0.016 (Table 13.2.1-1, pounds per vehicle miles travelled [VMT] for particulate matter [PM] less than 10 micrometers in aerodynamic diameter [PM_{10}])

k = 0.004 (Table 13.2.1-1, pounds per VMT for PM less than 2.5 micrometers in aerodynamic diameter [$PM_{2.5}$])

sL = 0.1, silt loading (grams [g] per square meter [m^2]) (Table 13.2.1-3 high average daily traffic roads, at least 5,000 vehicles per day)

W = 22, mean vehicle weight (tons)

C = 0.00047, PM_{10} emission factor for 1980s vehicle fleet exhaust, brake wear, and tire wear

C = 0.00036, $PM_{2.5}$ emission factor for 1980s vehicle fleet exhaust, brake wear, and tire wear

Tailpipe emissions resulting from diesel combustion were based on EPA emission standards for heavy-duty and non-road engines (EPA, 1997). It was assumed that the diesel haul trucks would meet the emission standards for 1998 and newer. The emission standards provided by the EPA were in grams per brake horsepower-hour (bHp-hr) and were converted to grams per mile using a conversion factor obtained from the EPA (2002). The conversion factor was updated for truck models from 1987 through 1996 to 1997 through 2050. Trucks were assumed to be heavy-duty diesel vehicles (Class 8A and 33,001 to 60,000 pounds) from Table 1 of EPA, 2002. A diesel truck conversion factor projections for 1997 and later truck model years were used as 2.763 bHp-hr/mile from Table 28 of the same report. Table 5 provides the emission factors as derived for this study.

TABLE 5
Heavy-duty Highway Diesel-cycle Engines Federal Emission Factors in g/bHp-hr and g/mile

Year	CO (g/bHp-hr)	CO (g/mile)	HC (g/bHp-hr)	HC (g/mile)	NO_x (g/bHp-hr)	NO_x (g/mile)	PM (g/bHp-hr)	PM (g/mile)
1998+	15.5	42.8	1.3	3.6	4	11.1	0.1	0.28

NOTES:
CO = carbon monoxide
HC = hydrocarbons
NO_x = nitrogen oxide

Air emissions from additional electrical use are indirect since they occur at the source of electric generation; however, the emissions can be attributed to the additional consumption of electricity at the wastewater treatment plant. Emission factors for electricity were based on EPA Clean Energy Power Profiler (http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html), assuming PacifiCorp Utah region commercial customer and AP-42, 1998. The following assumptions were made for the emission factor selection from AP-42 and calculations:

- Dry bottom, wall-fired, pulverized coal boiler firing sub-bituminous coal, post New Source Performance Standard
- PM control with baghouse
- Heating value of sub-bituminous coal: 13,000 British thermal units (Btu) per pound
- 3,413 Btu per kilowatt-hour (kWh)
- Ash content = 7.5 percent

Table 6 provides a summary of the emission factors used for energy consumption.

TABLE 6
Emission Factors for Additional Electricity Use

Pollutant	Emission Factor (pound/ton coal burned)	Emission Factor (pounds/ MWh)	Source
NO_x	NA	1.40	EPA Clean Energy Power Profiler: PacifiCorp Utah region emission rates, assumed zip 84108, 1,000-ft^2 commercial customer (http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html)
Sulfur Oxide	NA	1.20	EPA Clean Energy Power Profiler: PacifiCorp Utah region emission rates, assumed zip 84108, 1,000-ft^2 commercial customer (http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html)
Carbon Monoxide	0.5	6.56E-02	AP-42, Table 1.1-3
Volatile Organic Compound	0.06	7.88E-03	AP-42, Table 1.1-19

TABLE 6
Emission Factors for Additional Electricity Use

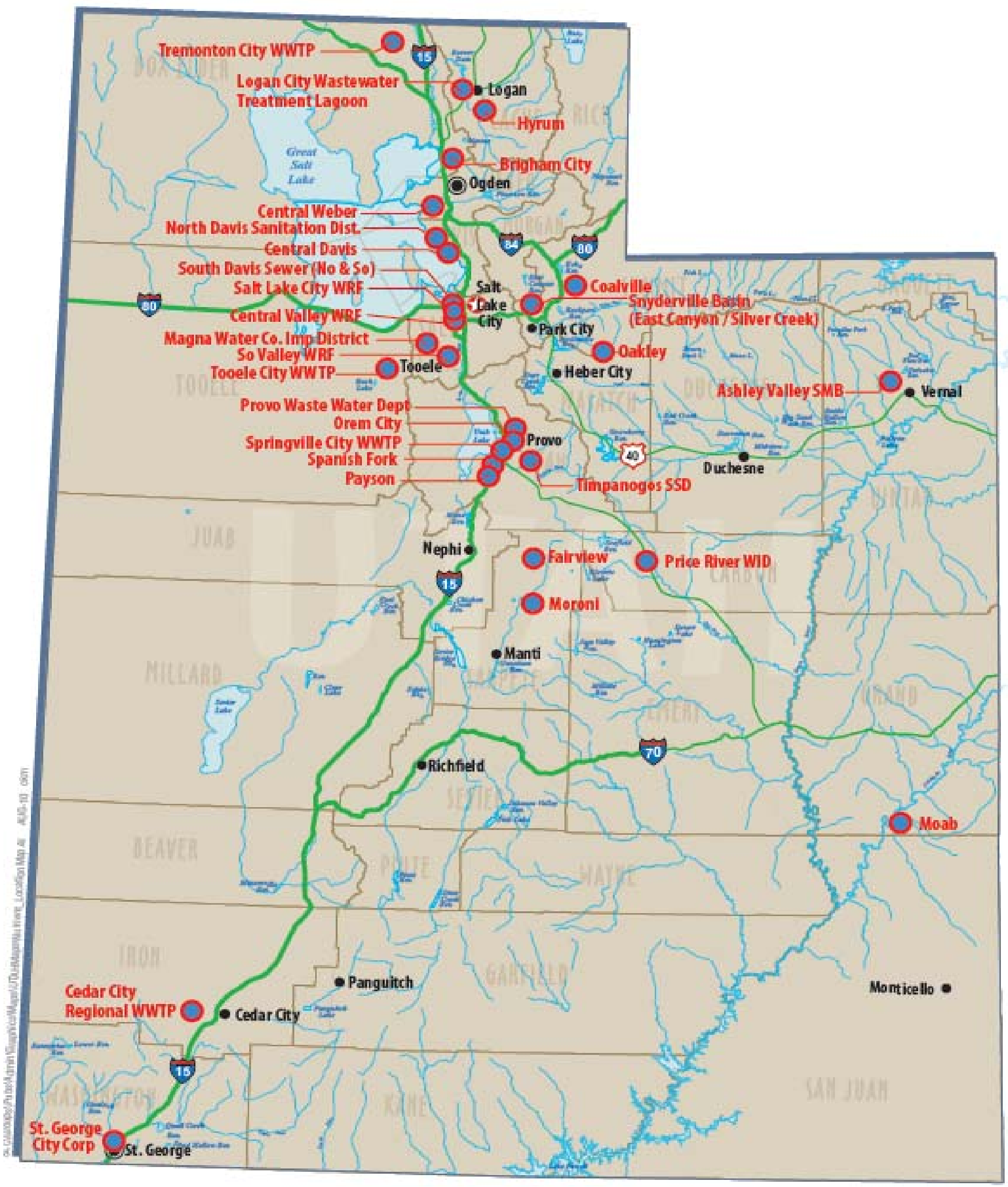
Pollutant	Emission Factor (pound/ton coal burned)	Emission Factor (pounds/ MWh)	Source
PM_{10}	0.15	1.97E-02	AP-42, Table 1.1-6
$PM_{2.5}$	0.075	9.85E-03	AP-42, Table 1.1-6
Carbon Dioxide	NA	902	EPA Clean Energy Power Profiler: PacifiCorp Utah region emission rates, assumed zip 84108, 1,000-ft^2 commercial customer (http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html)

NOTE:
ft^2 = square feet
MWh = megawatt-hour
NA = not applicable

3.0 Results

The results of the Statewide Nutrient Removal Study are summarized in this section. Figure 6 shows the locations of all 30 mechanical POTWs and the large lagoon system at Logan that were evaluated for nutrient removal. The model lagoon evaluated was a generic example for the small discharging lagoon treatment facilities in the state.

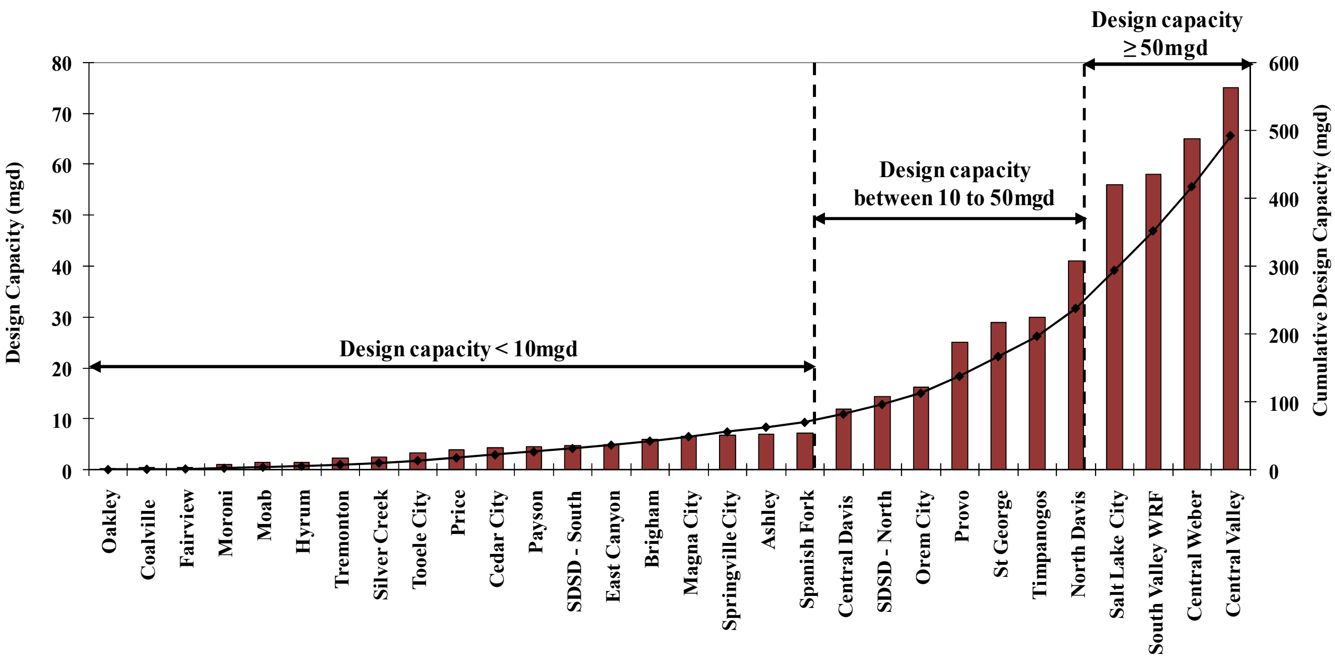
FIGURE 6
All POTWs in Utah That Were Evaluated as a Part of the Statewide Nutrient Removal Study



3.1 Results of POTW Data Collection and Analysis

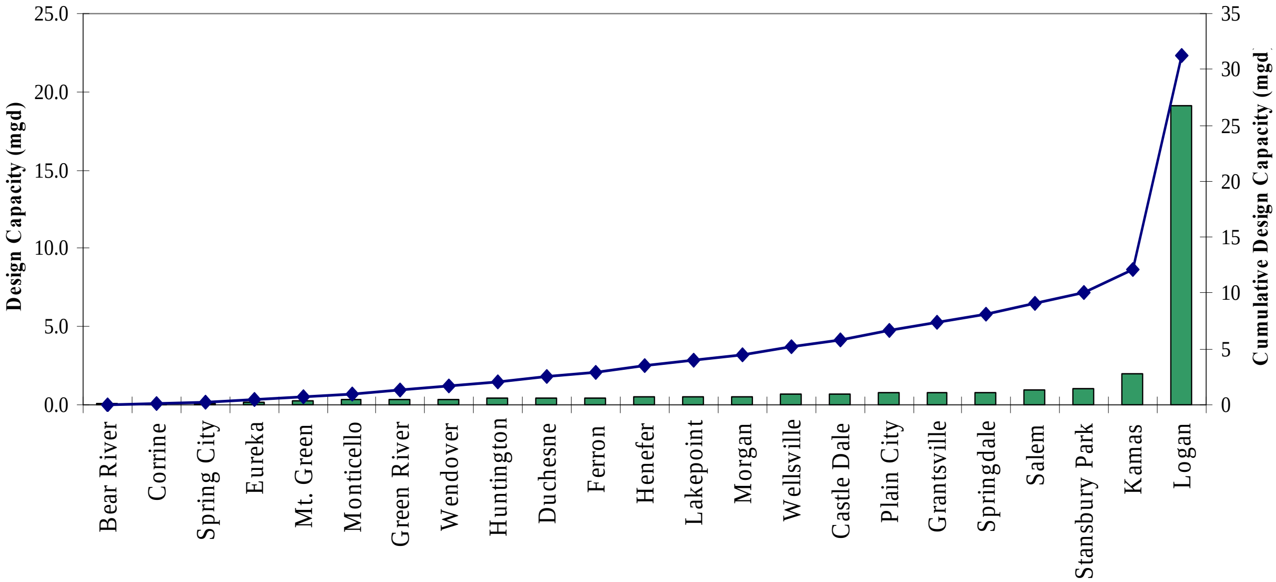
This section provides a brief summary of some of the data collected in this study from POTWs to provide an overview of the current situation. Figure 7 shows a statewide rollup of the design maximum month capacities of the mechanical POTWs in the state, ranked according to their design capacity. Approximately 500 mgd design capacity is currently available to mechanically treat wastewater in Utah. Eighteen mechanical treatment facilities are of less than 10-mgd design capacity. Although they represent more than half of the mechanical POTWs in the state, they contribute to only 13 percent of the total design capacity available. Seven facilities are between 10 and 50 mgd and contribute to 34 percent of the total design capacity available. Only four facilities are above 50-mgd design capacity; however, together they contribute to 52 percent of the total capacity available in the state.

FIGURE 7
Utah Statewide Rollup of Design Capacities of All Mechanical POTWs



The other major wastewater treatment facilities in Utah comprise discharging lagoons. There are 23 discharging lagoons in the state that treat wastewater using aerated or facultative lagoon systems. Together, these facilities have approximately 32-mgd design capacity, with 22 small facilities of less than or equal to 2-mgd capacity and one with 19.1-mgd design capacity. Figure 8 shows a statewide rollup of the design capacities of all the lagoons in Utah, ranked according to their design capacity.

FIGURE 8
Utah Statewide Rollup of Design Capacities of All Lagoons



Currently, three POTWs, including the discharging lagoon system at Wellsville, have TP limits and several have monitor only requirements in their permits. Most Utah POTWs have ammonia limits, and no facilities have TN limits. Many of these facilities do remove TP and TN as a result of the treatment process used and the operating mode selected. East Canyon Water Reclamation Facility (Snyderville Basin Water Reclamation District) and Hyrum City Water Reclamation Facility have discharge permits that limit effluent TP to 0.1 mg/L or less. East Canyon Water Reclamation Facility is operating a three-stage Bardenpho™ process to achieve this limit. As a result, they are already achieving the most stringent Tier 1N nutrient standard. For this reason, no process and cost evaluations were conducted for the East Canyon facility. Several mechanical POTWs that use MBRs or ODs are also achieving effluent phosphorus concentrations close to 1 mg/L and TN concentration of 10 mg/L.

The BOD:TP and BOD:TKN ratios in the POTW influents were examined as indicators for effective biological nutrient removal. The minimum acceptable ratios of BOD-to-nutrient were 20:1 to 25:1 for BOD:TP and 5:1 for BOD:TKN (Grady et al., 1999). Adequate presence of alkalinity in the influent was also important for nitrification. Deficiencies in the relative organic content or in alkalinity indicated the need to add supplemental external carbon (BOD) and/or alkalinity for effective nutrient removal by the deficient plant. Where applicable, the need to supplement organics or alkalinity had a direct impact on operating costs and overall process upgrade strategies.

The influent wastewater characteristics, especially the BOD:TP and BOD:TKN ratios and the presence of alkalinity were found to be favorable for biological nutrient removal process in almost all the mechanical POTWs. Figure 9 presents a summary of the BOD:TP ratio of the influent wastewater in all the mechanical POTWs in Utah, while Figure 10 shows a summary of the BOD:TKN ratio for the same. On an average, all the mechanical POTWs in Utah had a BOD:TP ratio of 35:1 and a BOD:TKN ratio of 5:1.

FIGURE 9
Utah Statewide Rollup of BOD:TP Ratios in Influent Wastewater

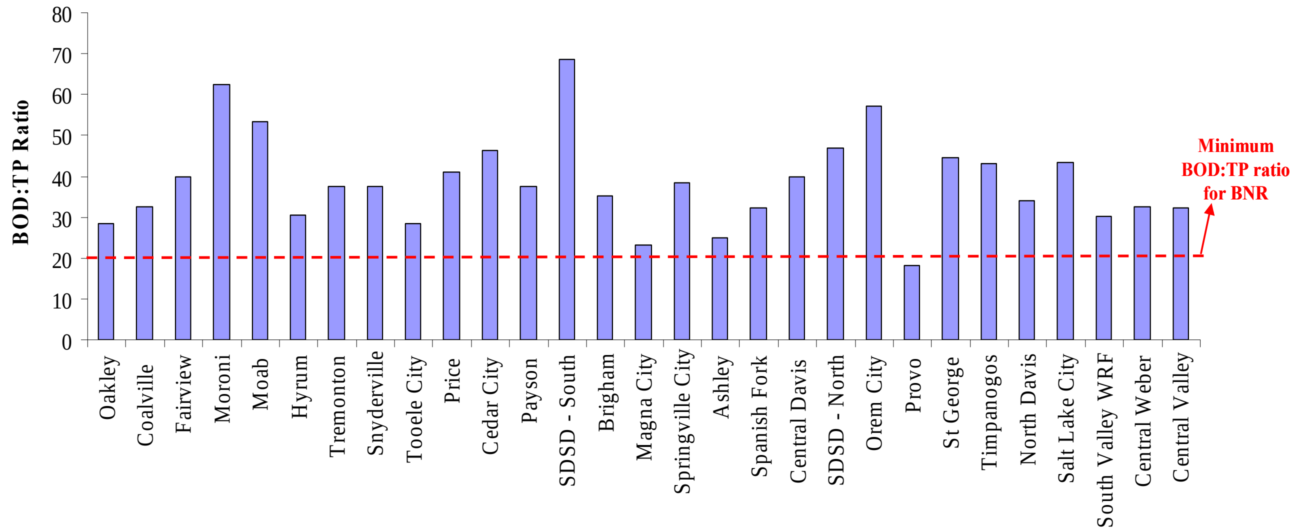
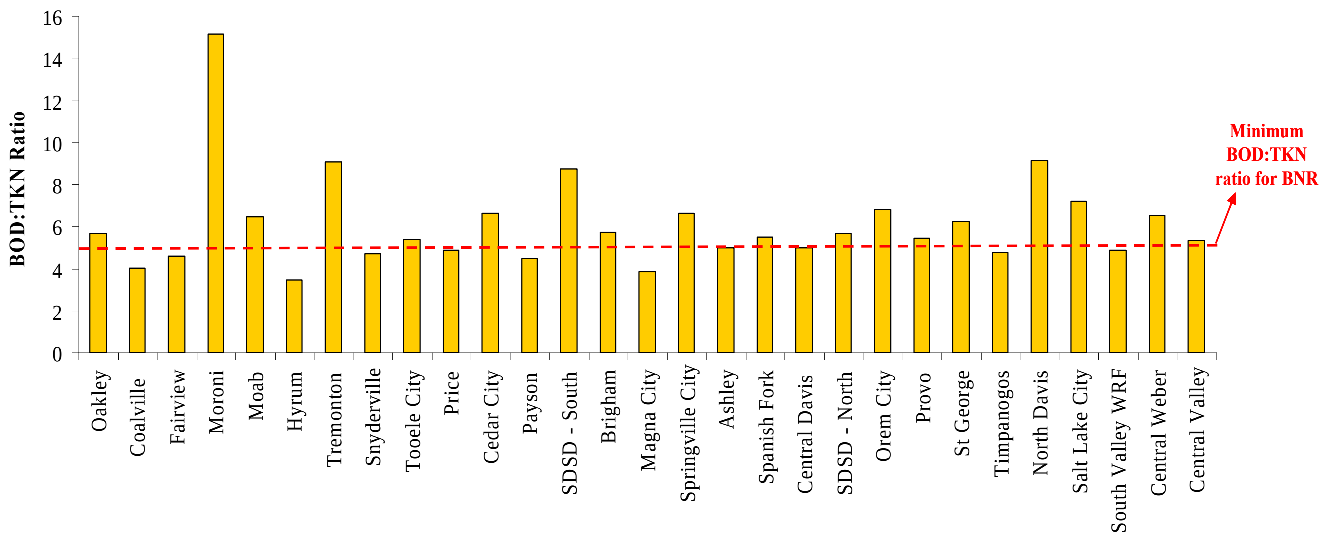


FIGURE 10
Utah Statewide Rollup of BOD:TKN Ratios in Influent Wastewater



All process, operational, and other data collected from the 30 mechanical POTWs were consolidated in a single-page data summary sheet for each POTW and are provided as a part of this report in Appendix 1.

3.2 POTW Process Modeling and Alternative Evaluation

As explained previously in the methodology section, to make the nutrient removal alternative evaluation and process modeling more efficient, it was decided to categorize all the mechanical POTWs in the state based on type of secondary treatment process, since similar upgrade approaches could then be implemented for POTWs with similar treatment processes. Table 7 shows the different categories of mechanical treatment processes and the POTWs within each category. Discharging lagoon systems is another category that was evaluated but is not shown in this table.

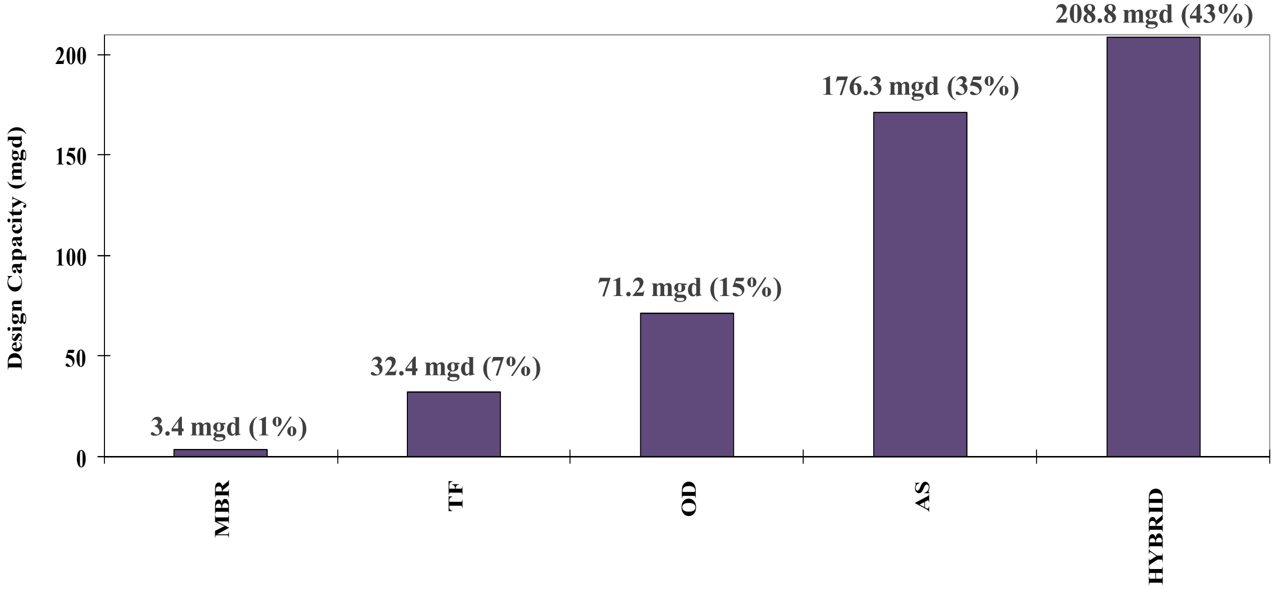
TABLE 7
State of Utah's Mechanical POTW Categories

Oxidation Ditch	Activated Sludge	Membrane Bioreactor	Trickling Filter	Hybrid Process
Ashley Valley	Timpanogos Special Service	Fairview City	Cedar City	Central Davis Sewer
Brigham City	South Valley Water	Hyrum City	Moab	Central Valley Water
Coalville City	Snyderville – East Canyon	Moroni City	South Davis Sewer District – North	Central Weber Sewer
Magna	Tremonton City	Oakley City	South Davis Sewer District – South	North Davis Sewer
Orem City	Salt Lake City*			Payson
Snyderville Basin – Silver Creek				Price River
St. George				Provo City
Toole City				Spanish Fork
				Springville City

NOTE:
* Based on discussions with Salt Lake City Water Reclamation Facility (SLCWRF) personnel, their preferred approach to long-term upgrade of the facility is to transition from TF/AS to AS process. For this reason, the SLCWRF is categorized under the AS category

Figure 11 shows the design capacity available within each POTW category, as well their percentage representation in the total design capacity available in Utah.

FIGURE 11
Utah Statewide Rollup of BOD:TKN Ratios in Influent Wastewater



Similar process upgrades were initially proposed for each treatment facility within a category. Facility-specific alternatives or refinements were then established during the POTW stakeholder workshop.

Process alternatives evaluation for the less stringent tier of phosphorus control (Tier 2), which limits the effluent phosphorus discharge to 1 mg/L, indicated that the POTWs operating MBRs, and some POTWs operating ODs, were able to achieve this limit with their existing infrastructure. For such facilities, a chemical addition backup system was proposed in case of biological phosphorus removal failure. For most POTWs in the TF category and some in the hybrid process category, chemical phosphorus removal was proposed with either dual metal-salt feed points at the primary and secondary clarifiers or a single-feed point at the secondary clarifiers. Precipitation of soluble phosphates can be achieved by the addition of metal-salts. The precipitates are then removed using solids separation processes, such as clarification or filtration. This process is easily integrated into most existing treatment facility without significant modifications. For AS POTWs and the remainder of the OD and hybrid plants, anaerobic zones were added ahead of existing aerated biological processes for enhanced biological phosphorus removal.

The upgrades proposed for the Tier 2N treatment alternative, which limits the effluent TP concentration to 1 mg/L and TN to 20 mg/L, were built up from the process modifications used for Tier 2. From this evaluation, all POTWs in the MBR category, as well as many in the OD category, were able to achieve Tier 2N limits without further modification beyond the Tier 2 upgrades. For the other POTWs, a variety upgrades incorporating biological nitrogen removal processes were incorporated for TN removal.

For Tier 1, the more stringent phosphorus control alternative, which limits the effluent phosphorus to 0.1 mg/L, built upon the phosphorus removal process upgrades used in Tier 2. Except for the MBR facilities, deep-bed granular media filters were added to post-secondary treatment for all POTWs. Another metal-salts addition was placed ahead of the filters to promote effective phosphorus capture and meet the Tier 1 standard of 0.1 mg/L.

The proposed upgrades for Tier 1N, which limits the effluent TN to 10 mg/L and TP to 0.1 mg/L, were typically a combination of the upgrades suggested for Tiers 1 and 2N. The POTWs in the MBR category and many in the OD category were already able to achieve the 10 mg/L TN limit without any process modifications. For several ODs, only chemical addition and an effluent filter were required to achieve this level of nutrient control.

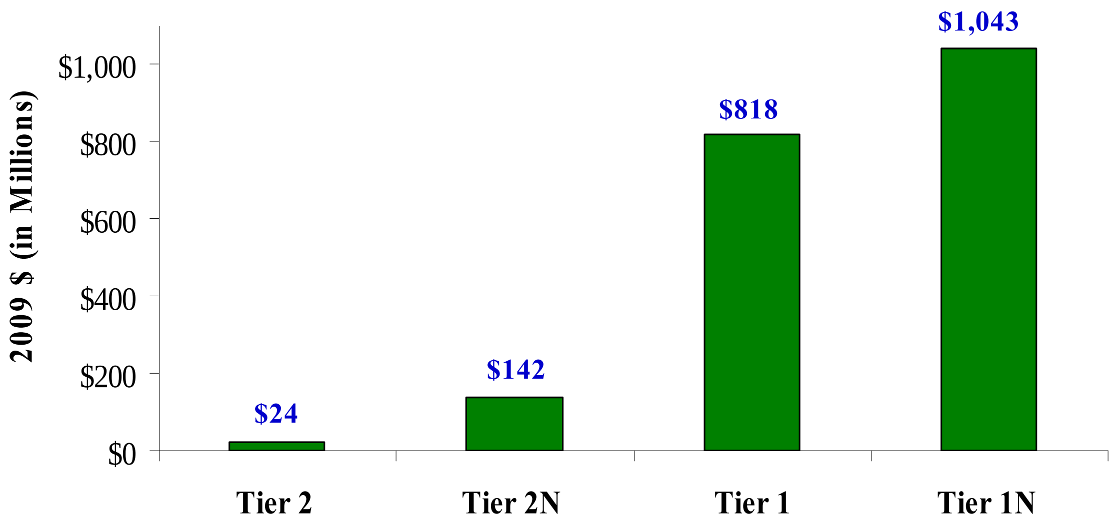
For the lagoon systems studied, phosphorus removal by metal-salts addition and sedimentation was used for Tier 2. These upgrades required chemical addition facilities and chemical "reactor-type" clarifiers. Chemical solids removed in the clarifiers would be transferred back to an existing lagoon cell. For Tier 1, the same modifications were made, followed by effluent filters with prefiltration metal-salts addition. To achieve the nitrogen removals established in Tiers 2N and 1N, a new mechanical wastewater treatment plant equipped with biological nutrient removal system and secondary clarifiers was used. Tier 1N also required effluent filters. Although other, lower cost approaches may be possible for lagoon-based removal of nitrogen, these were considered developmental and unproven, and as a result were not considered in this study.

Appendix 2 of this report provides individual TMs detailing the process upgrades selected for each mechanical POTW and a model lagoon to meet the various tiers of nutrient standards, as indicated in Table 1.

3.3 Capital Cost Estimates for Mechanical POTWs

Figure 12 presents a statewide rollup of the total capital cost for the proposed process upgrades for each tier of nutrient standard. These costs are for the mechanical POTWs only. To upgrade facilities statewide to achieve Tier 2 level of nutrient control, a capital cost of $24 million would be needed. For Tier 2N statewide process modifications, $142 million would be required. To achieve a statewide Tier 1 level of phosphorus control, a total capital cost of $818 million would be needed, and for Tier 1N level of nutrient control, $1.04 billion would be required.

FIGURE 12
Utah Statewide Rollup of Capital Cost for All Mechanical POTWs (All Costs in Millions)



Many POTWs were already achieving the less-stringent tiers of nutrient control (Tiers 2 and 2N). Thus, the statewide costs for these tiers were significantly less when compared with the more stringent tiers (Tiers 1 and 1N). The major element in the costs for Tiers 1 and 1N were the deep-bed granular media filtration systems. The cost of filters represented almost 78 percent of the total cost for Tier 1 and 62 percent of the total cost for Tier 1N. Figure 13 shows the statewide capital costs with the percentage of cost represented by the filters.

FIGURE 13
Utah Statewide Breakdown of Capital Cost to Show the Cost of Filtration Systems for Tiers 1 and 1N (All Costs in Millions)

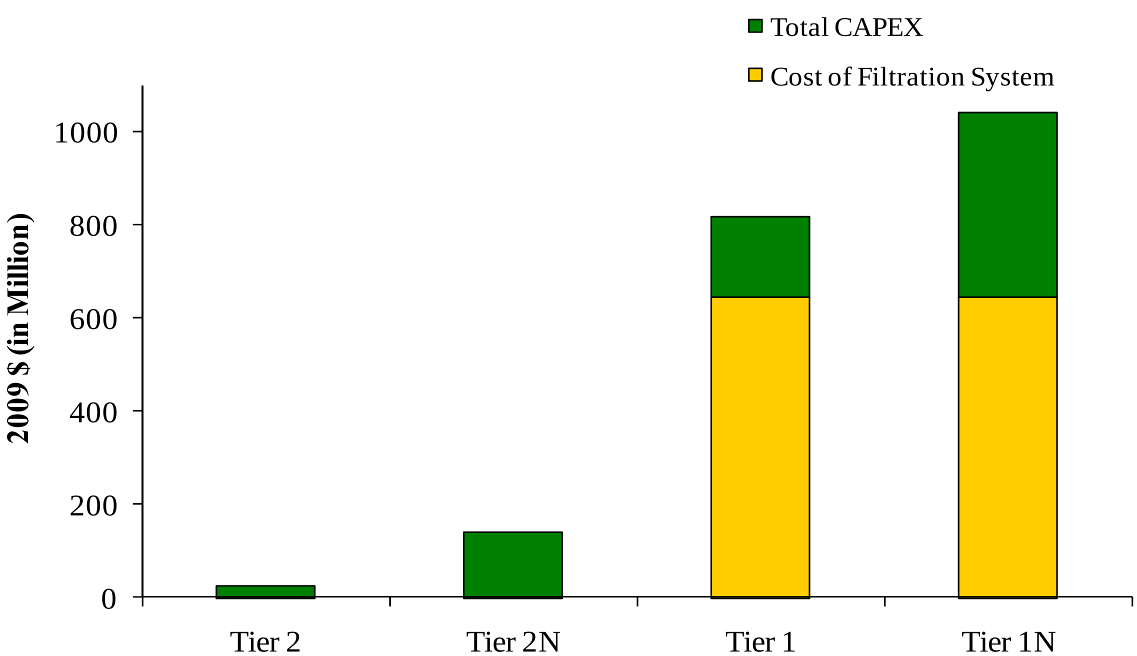
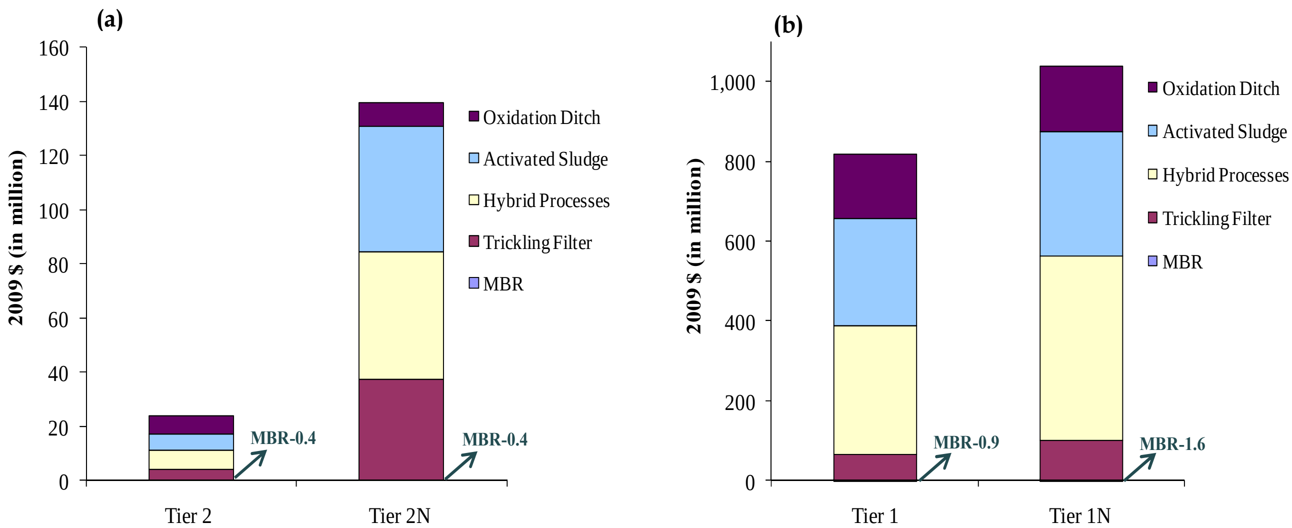


Figure 14 shows the breakdown of the capital cost for the various POTW categories. Figure 14a shows the capital cost breakdown for Tier 2 and Tier 2N, and Figure 14b shows the same for Tier 1 and Tier 1N.

FIGURE 14
Utah Statewide Breakdown of Capital Cost to Show the Cost Contribution of Various POTW Categories (all costs in Millions)



A breakdown of capital cost for each mechanical POTW is provided in Figures 15 through 18. The POTWs are ranked according to the capital cost required to meet each tier of nutrient control. Figures 15, 16, 17, and 18 present the capital cost of individual POTWs for Tier 2, Tier 2N, Tier 1, and Tier 1N, respectively. For more details on capital costs for individual POTWs, refer to TMs provided in Appendix 2.

FIGURE 15
Capital Cost of Individual POTWs to Achieve Tier 2 Level of Nutrient Control

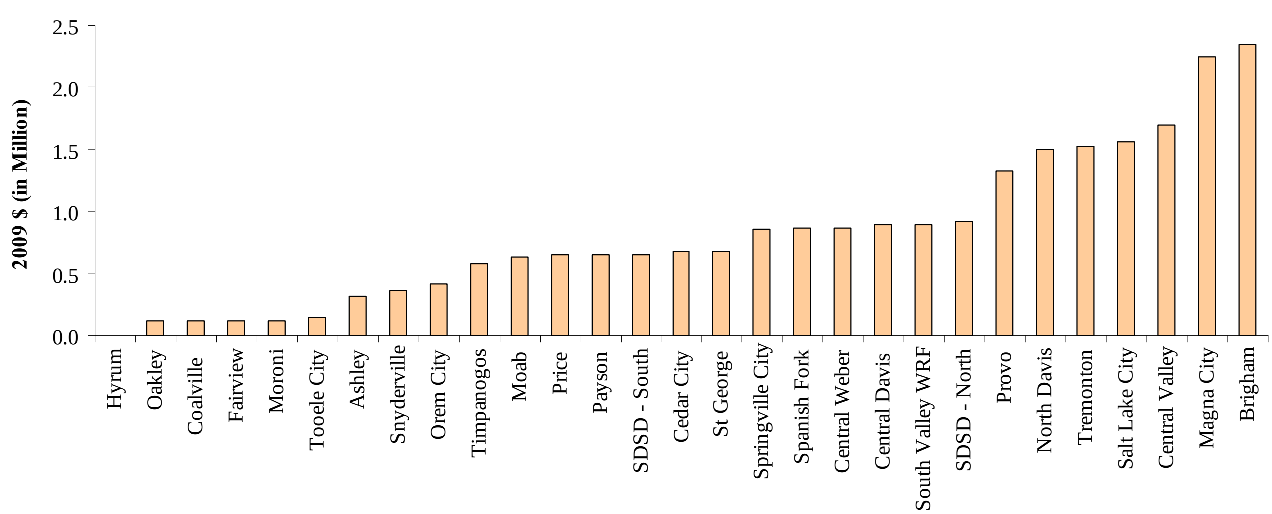


FIGURE 16
Capital Cost of Individual POTWs to Achieve Tier 2N Level of Nutrient Control
This figure is divided in two to show better y-axis resolution.

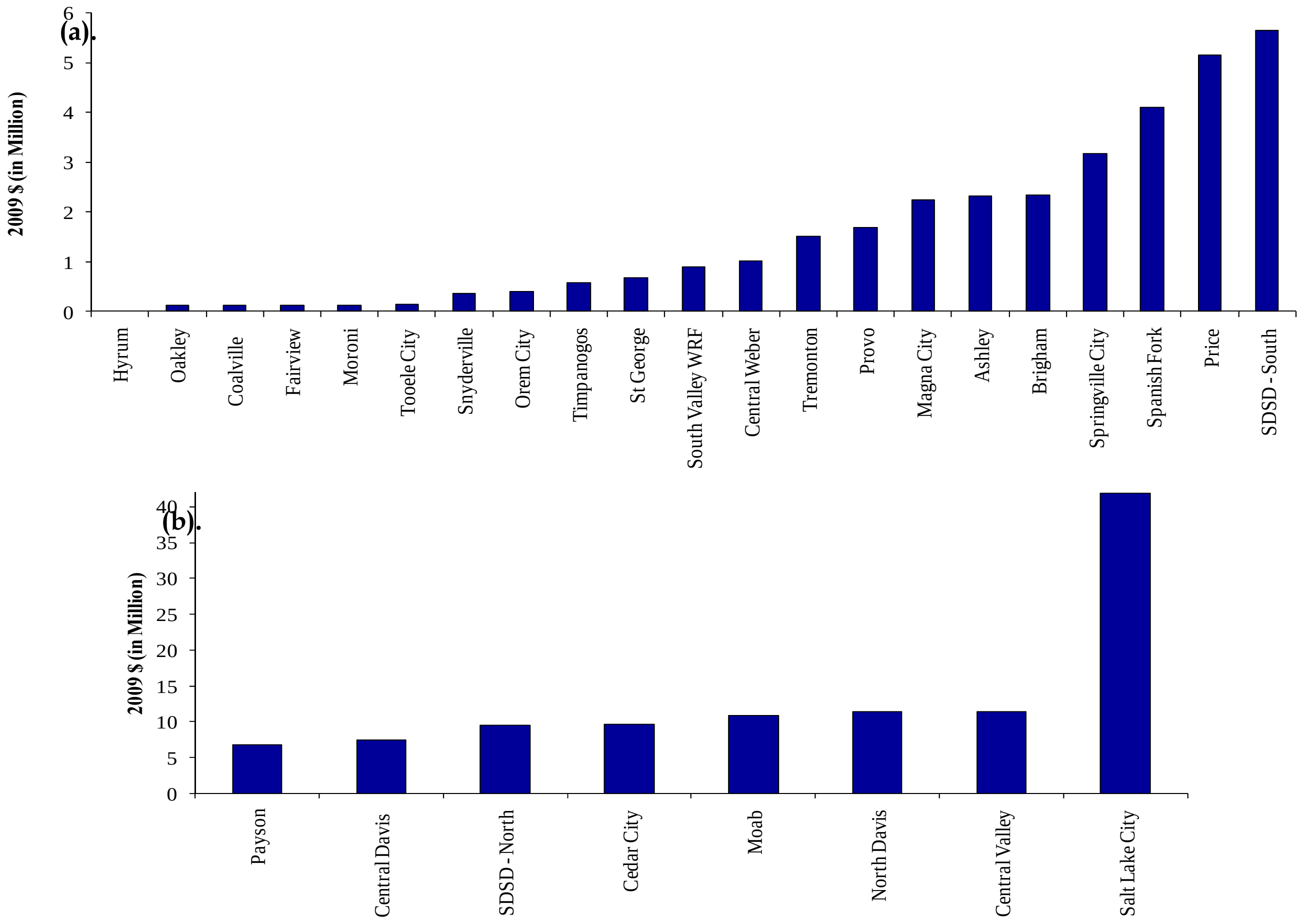
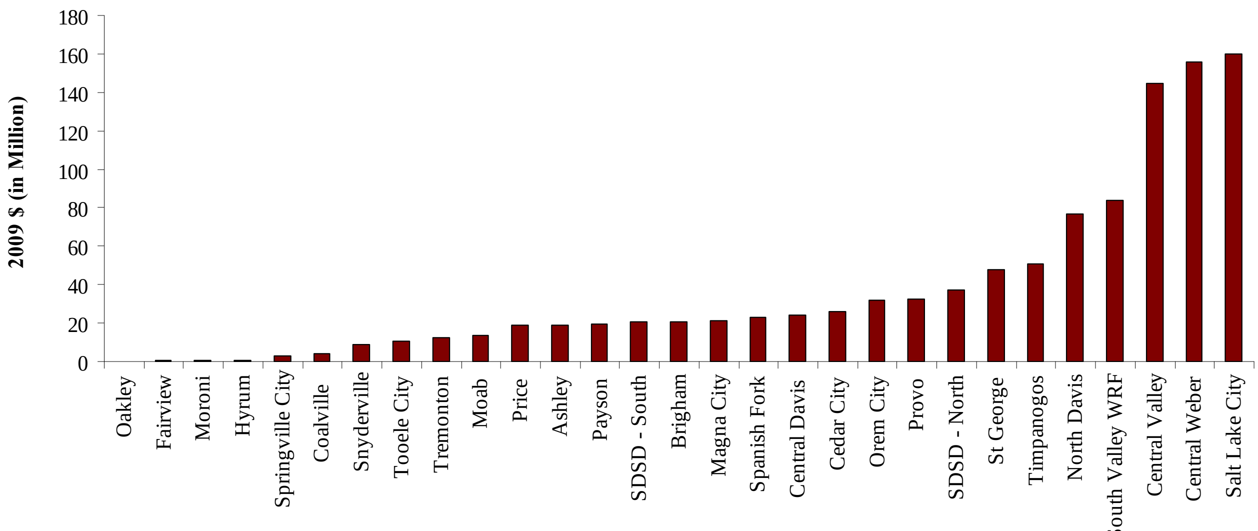


FIGURE 17
Capital Cost of Individual POTWs to Achieve Tier 1 Level of Nutrient Control

FIGURE 18
Capital Cost of Individual POTWs to Achieve Tier 1N Level of Nutrient Control



3.4 Upgrade Unit Cost Estimates for Mechanical POTWs

Unit costs to upgrade each POTW for the four tiers of nutrient standards were developed in dollars per gallon per day of design capacity. Figures 19, 20, 21, and 22 show the unit costs to upgrade each POTW as a function of its design capacity for Tiers 2, 2N, 1, and 1N, respectively. A similar pattern can be observed in each of these figures, where the unit costs to upgrade POTWs with capacities less than 10 mgd are much higher and varied than for POTWs with design capacities greater than 10 mgd. Typically, economies of scale do not apply to facilities less than 10 mgd; that is, the unit cost curves for facilities less than 10 mgd tend to be steep and erratic, while the unit cost curves for facilities 10 mgd and greater tend to be flatter and more predictable.

FIGURE 19
Upgrade Unit Capital Cost of Individual POTWs in Dollars per Gallon of Design Capacity to Achieve Tier 2 Level of Nutrient Control

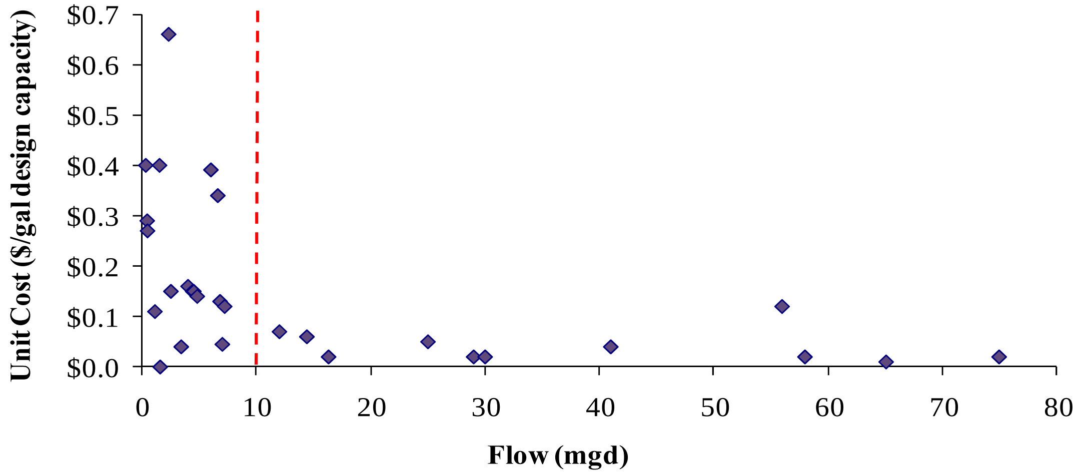


FIGURE 20
Upgrade Unit Capital Cost of Individual POTWs in Dollars per Gallon of Design Capacity to Achieve Tier 2N Level of Nutrient Control

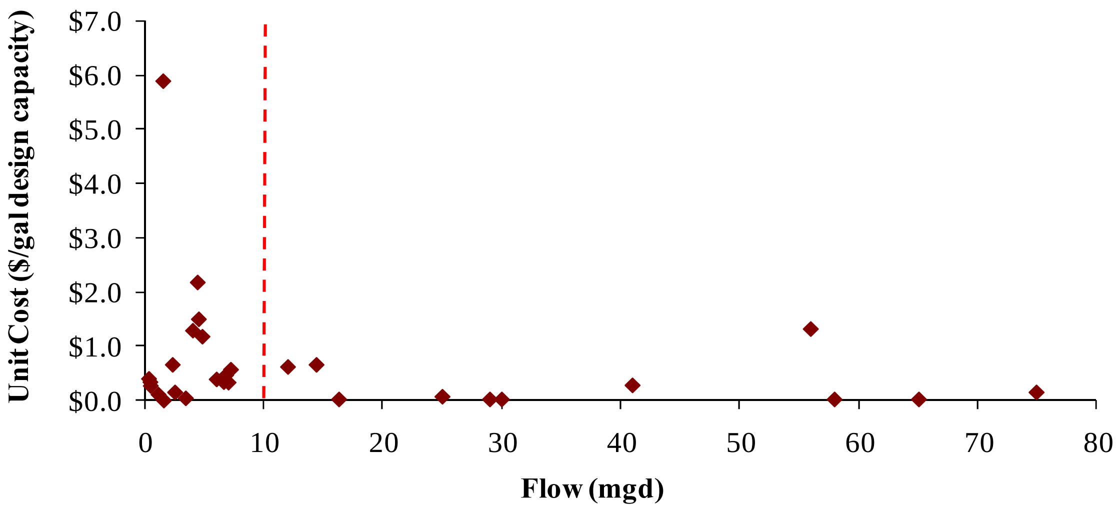


FIGURE 21
Upgrade Unit Capital Cost of Individual POTWs in Dollars per Gallon of Design Capacity to Achieve Tier 1 Level of Nutrient Control

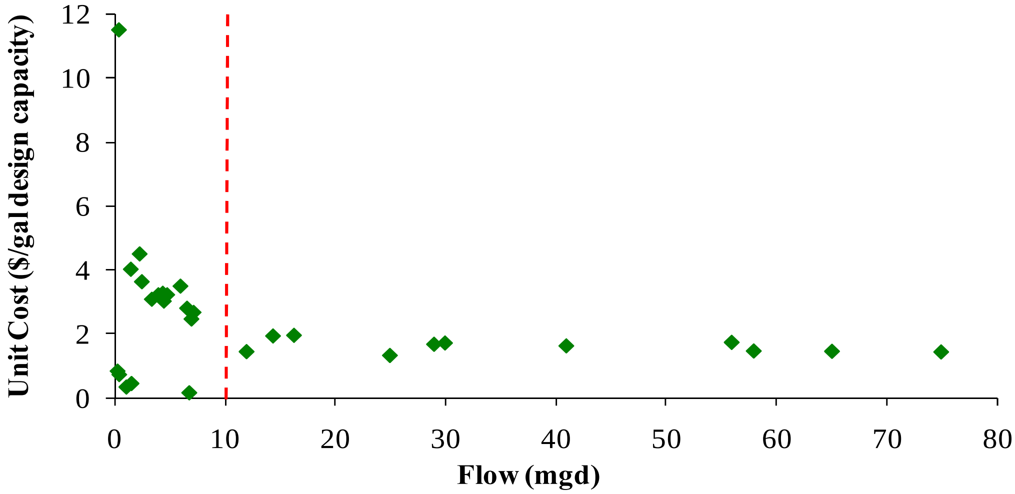


FIGURE 22
Upgrade Unit Capital Cost of Individual POTWs in Dollars per Gallon of Design Capacity to Achieve Tier 1N Level of Nutrient Control

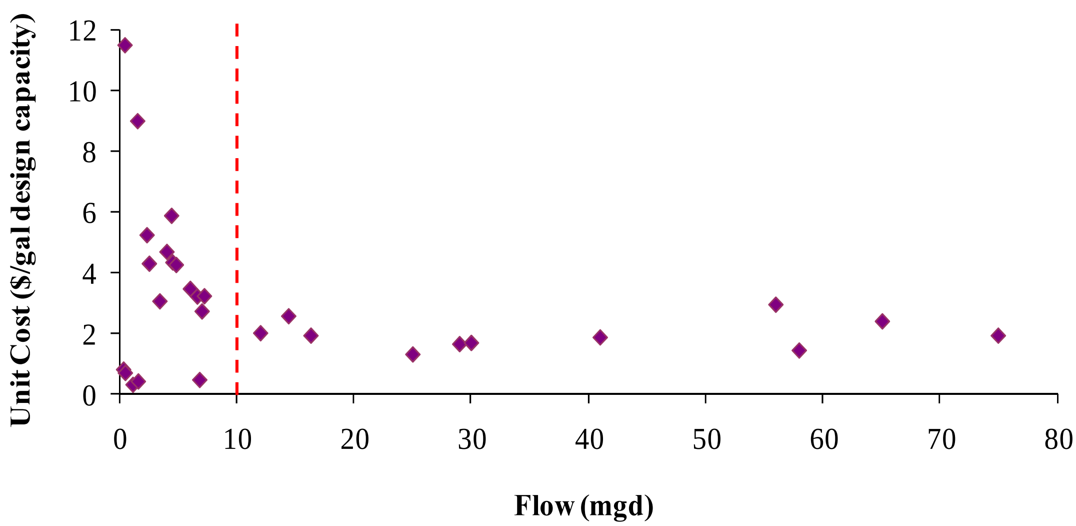


Figure 23 shows the weighted-average unit costs to upgrade for the four tiers of nutrient control, by process category. The unit costs for upgrading the MBR facilities were the lowest among all other categories as these POTWs were already close or meeting the limits specified in Table 1. On the other hand, unit costs for upgrading the TF facilities were high, especially for Tiers 1N and 2N, as significant modifications were required to accommodate biological nitrogen removal processes. The increase in unit costs for Tiers 1 and 1N when compared with Tiers 2 and 2N are mostly due to the implementation of deep-bed granular media filtration systems to meet the 0.1 mg/L TP limit. Note that when comparing Figures 19 through 22 with Figure 23, Figure 23 does not account for economies of scale.

FIGURE 23
Weighted Average Upgrade Unit Capital Cost of POTWs Categories in Dollars per Gallon of Design Capacity to Achieve Various Tiers of Nutrient Control

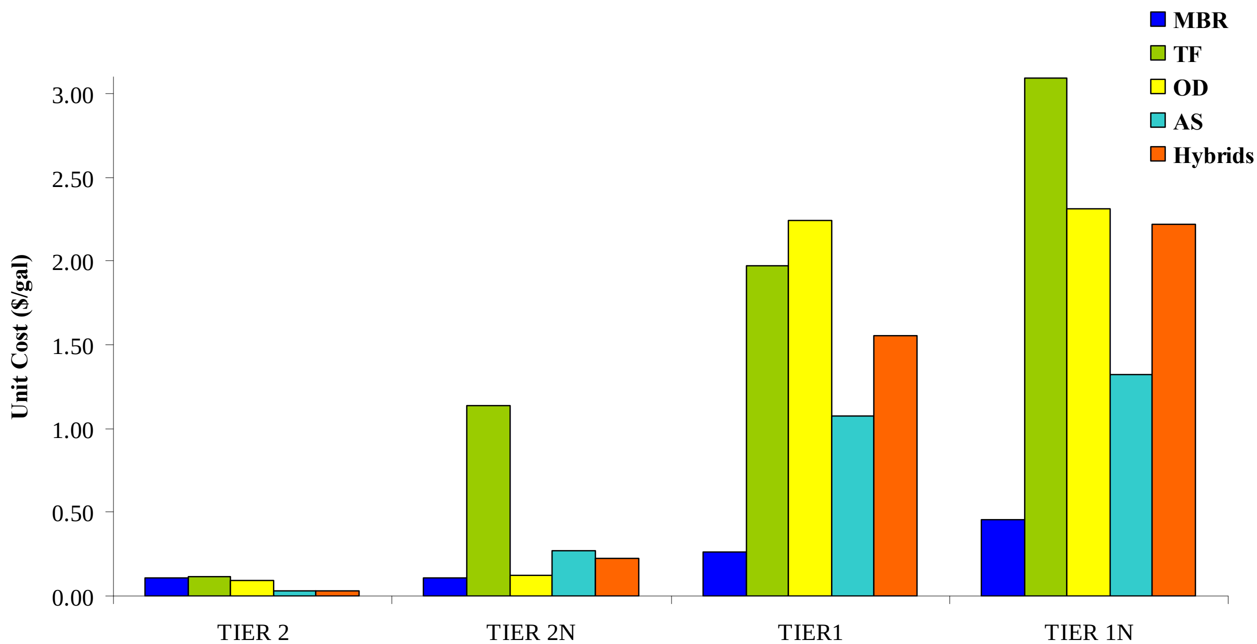


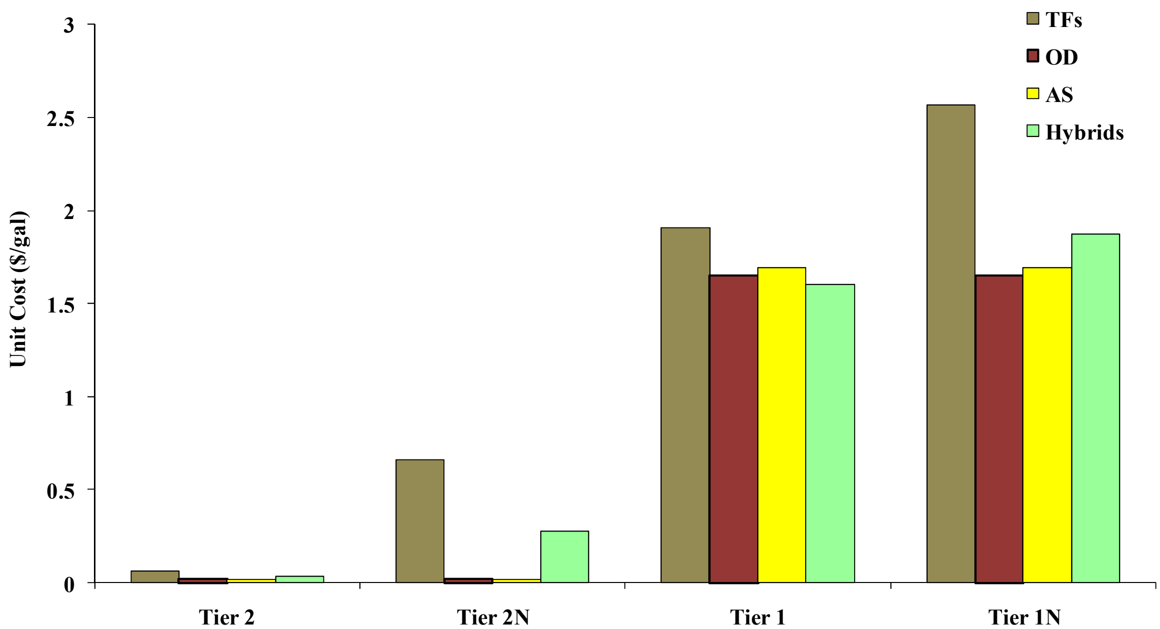
Table 8 shows the flow-weighted average values for the unit costs of each category of POTW.

TABLE 8
Flow-weighted Average Unit Costs for Different POTW Categories

POTW Category	Tier 2	Tier 2N	Tier 1	Tier 1N
MBR	0.11	0.11	0.46	0.46
TF	0.12	1.20	1.98	3.14
OD	0.10	0.13	2.44	2.53
AS	0.04	0.27	1.57	1.81
Hybrid Processes	0.03	0.24	1.63	2.31

Figure 23 includes the average unit cost for all plants in the defined POTW categories. To compare the relative unit costs of the process categories, Figure 24 shows the unit capital costs for Utah's POTWs that are greater than 10 mgd in capacity. (No MBR plants in the state were large enough to be included in this figure). For these (>10 mgd) POTWs, economies of scale are less of a factor, thus making direct comparison of unit costs more reliable.

FIGURE 24
Unit Capital Cost Comparison of Large POTWs (>10 mgd)

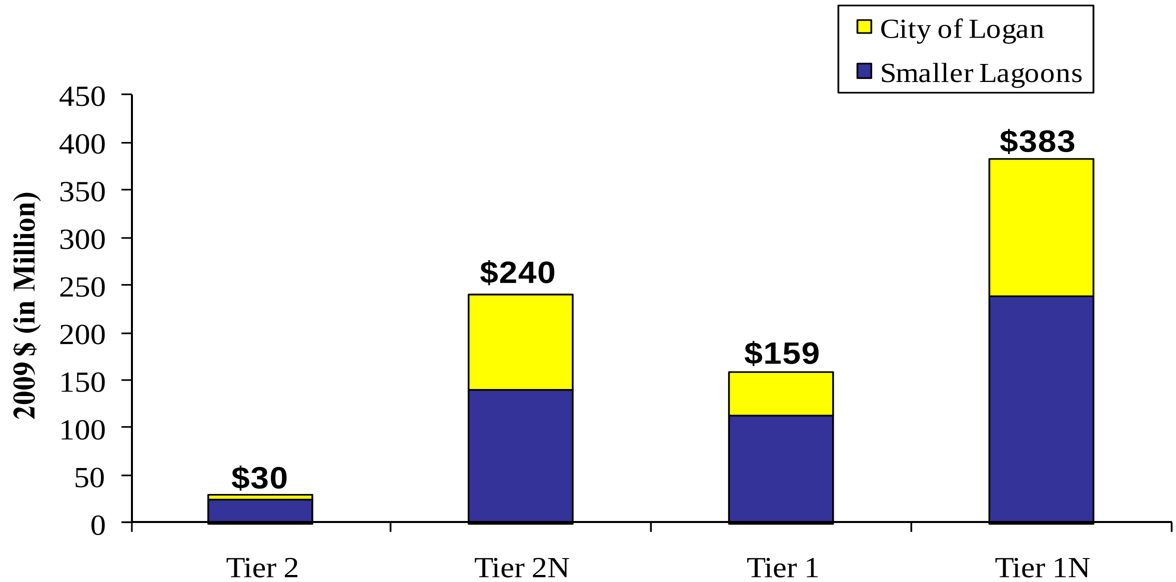


3.5 Capital Cost Estimates for Lagoon POTWs

Capital costs were also developed for upgrading a model lagoon to meet the specified tiers of nutrient control. The model lagoon was developed to represent the 22 small discharging lagoon facilities of Utah. Costs for each small lagoon system were developed by proportioning the model lagoon costs using the ratio of facility-to-model facility design capacities. Costs were developed separately for the City of Logan's lagoon system. Logan's facility has a design capacity of 19.1 mgd.

Figure 25 presents a statewide rollup of the total capital cost for the proposed process upgrades for each tier of nutrient standard for all the discharging lagoons in Utah. To upgrade facilities statewide to achieve Tier 2 level of nutrient control, a capital cost of $30 million would be needed. For Tier 2N statewide process modifications, $240 million would be required. To achieve a statewide Tier 1 level of phosphorus control, a total capital cost of $159 million would be needed. For Tier 1N level of nutrient control, $383 million would be required. The proportion of the total lagoon capital costs that result from upgrading Logan's plant is also shown in Figure 25.

FIGURE 25
Statewide Rollup of Capital Cost for Upgrading Utah Discharging Lagoons



3.6 O&M Cost Estimates for Mechanical POTWs

Incremental O&M costs were developed for each POTW based on the proposed process upgrades. Figure 26 shows a statewide rollup of the O&M costs for all mechanical POTWs in the state of Utah for the year 2009 and the planning year 2029. These costs represent the additional chemical, energy, and biosolids handling that would be required as a result of implementing the process upgrades to meet the various tiers of nutrient standards. Figure 27 shows a breakdown of the total O&M costs into chemicals used, energy consumed, and biosolids managed for the year 2009.

FIGURE 26
Statewide Rollup of Increased O&M Costs for Mechanical POTWs

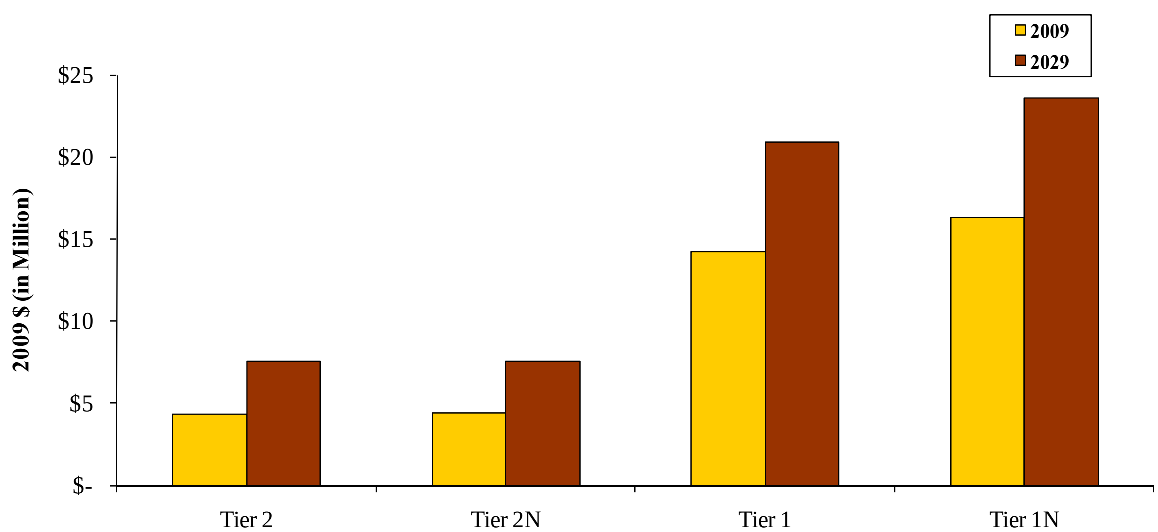
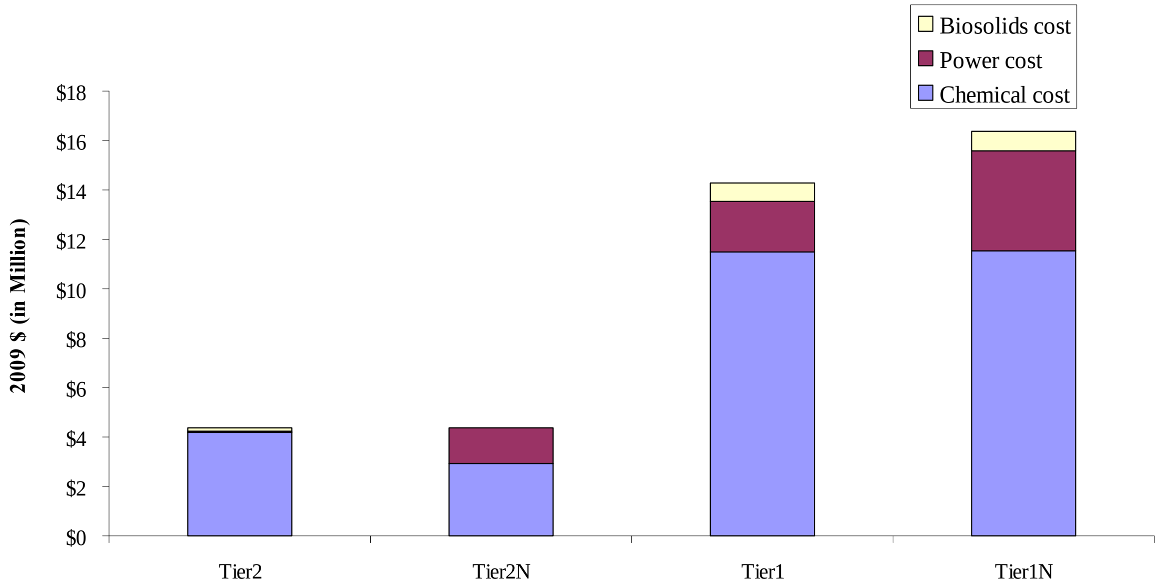


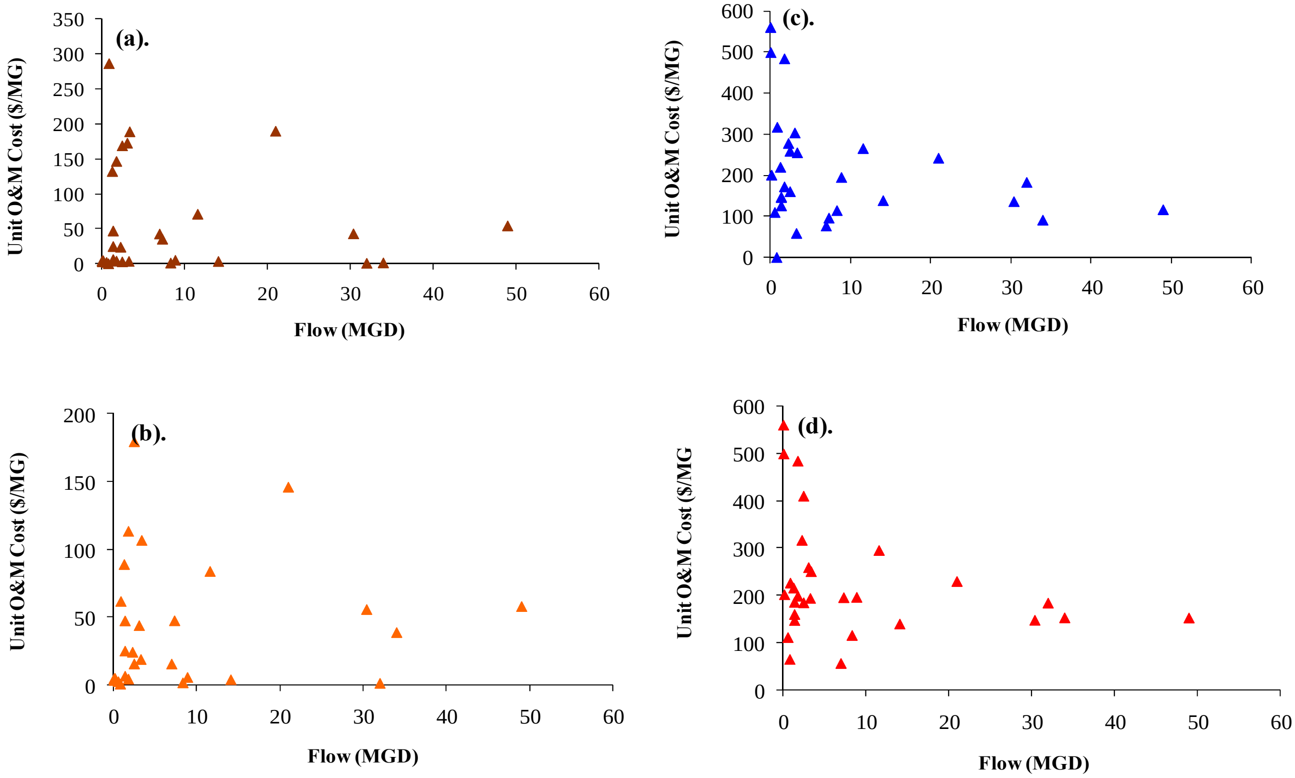
FIGURE 27
Breakdown of Increased O&M Costs for All Mechanical POTWs for the Year 2009



As indicated in Figure 27, the largest portion of the increased O&M costs was chemical costs, especially for Tiers 1 and 2 levels of nutrient control. The chemicals include the metal-salts for phosphorus removal, polymers for biosolids handling, and, in some cases, methanol, which is used as an external carbon source for denitrification. Tiers 1N and 2N have an increased cost for power when compared with the other tiers because of the additional aeration requirement for biological nitrogen removal.

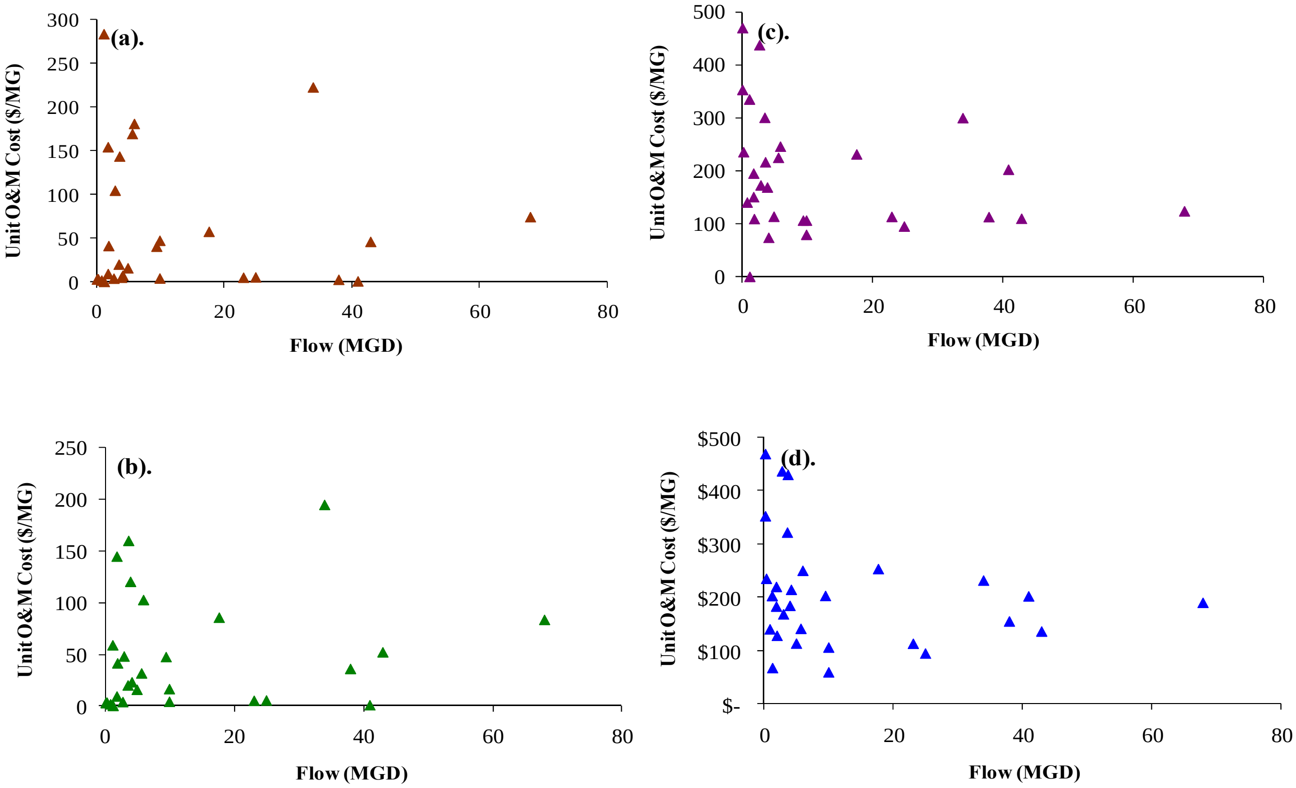
The increases in O&M unit costs were developed for each POTW in dollars per million gallon of 2009 and 2029 flows and were plotted against the design capacity of the POTW. Figure 28 shows the 2009 O&M unit cost of each POTW as a function of 2009 flows for each tier of nutrient control, and Figure 29 shows the 2029 O&M unit cost of each POTW as a function of 2029 flows for each tier of nutrient control. Economies of scale are less evident in the increased operating costs than for the capital costs, although some economy remains evident. This is the case because operating costs are more directly associated with flow rate and load.

FIGURE 28
2009 Unit O&M Costs of Individual POTWs in Dollars per Million Gallons to Achieve the Four Tiers of Nutrient Control



NOTES:
(a) Unit Costs for Tier 2
(b) Unit Costs for Tier 2N
(c) Unit Costs for Tier 1
(d) Unit Costs for Tier 1N

FIGURE 29
2029 Unit O&M Costs of Individual POTWs in Dollars per Gallon to Achieve the Four Tiers of Nutrient Control



NOTES:
(a) Unit Costs for Tier 2
(b) Unit Costs for Tier 2N
(c) Unit Costs for Tier 1
(d) Unit Costs for Tier 1N

Figure 30 shows the 2009 increased unit O&M costs for the four tiers of nutrient control in cost per year per gallon treatment capacity, by process category; Figure 31 shows the same results for year 2029. These figures show the effect of process categories on increased unit O&M costs. For example, MBR facilities are already close to meeting limits of the various nutrient control tiers. This results in smaller increases in O&M unit costs for these facilities. Similarly, the OD processes that are already capable of achieving the Tier 2 TP limit and the Tier 2N TN limit will require smaller increases in unit O&M costs to meet these limits. On the other hand, TF and the hybrid processes have to invest in purchasing more metal-salts for phosphorus removal. Thus, their increased unit costs are the highest in all tiers of nutrient control. The increase in unit costs for Tiers 1 and 1N when compared with Tiers 2 and 2N are mostly due to the implementation of chemical phosphorus removal to meet the 0.1 mg/L TP limit.

FIGURE 30
2009 Unit O&M Costs of POTWs Categories in Dollars per Million Gallons to Achieve the Various Tiers of Nutrient Control

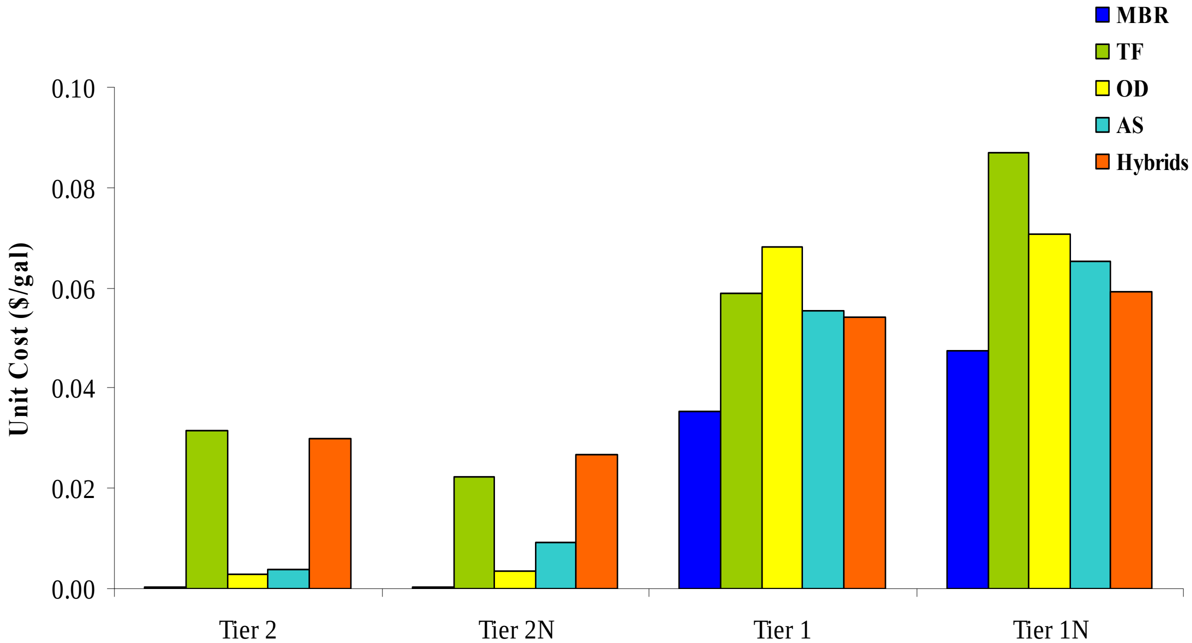
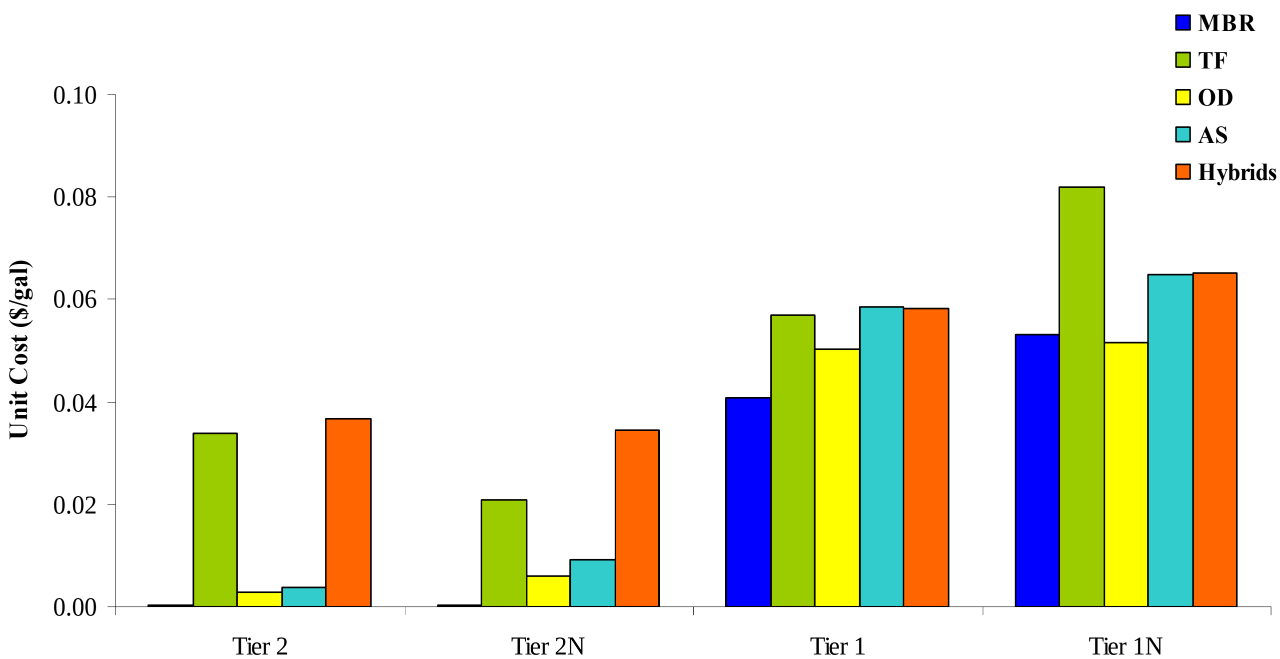


FIGURE 31
2029 Unit O&M Costs of POTWs Categories in Dollars per Gallon to Achieve the Various Tiers of Nutrient Control



3.7 O&M Cost Estimates for Lagoon POTWs

Operation and maintenance costs were developed for a model lagoon and for the City of Logan lagoon. The model lagoon was developed to represent the 22 small discharging lagoon facilities of Utah. Costs for each small lagoon system were developed by proportioning the model lagoon costs using ratio of facility-to-model facility capacities. Costs were developed separately for the City of Logan's lagoon system. Figure 32 presents the statewide rollup of the O&M cost for all discharging lagoons in Utah for the year 2009 and planning year 2029. These costs represent the additional chemical, energy, and biosolids handling required to operate the system upgrades under the various tiers of nutrient standards. Figure 33 shows a breakdown of the increased O&M costs into chemicals used, energy consumed, and biosolids managed for the year 2009.

FIGURE 32
Increased O&M Costs for Lagoon POTWs

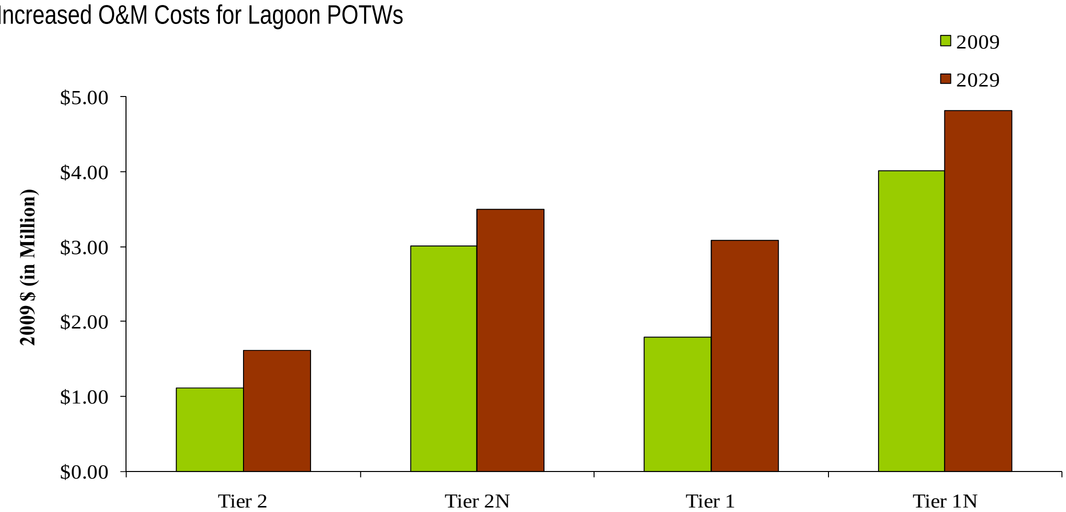
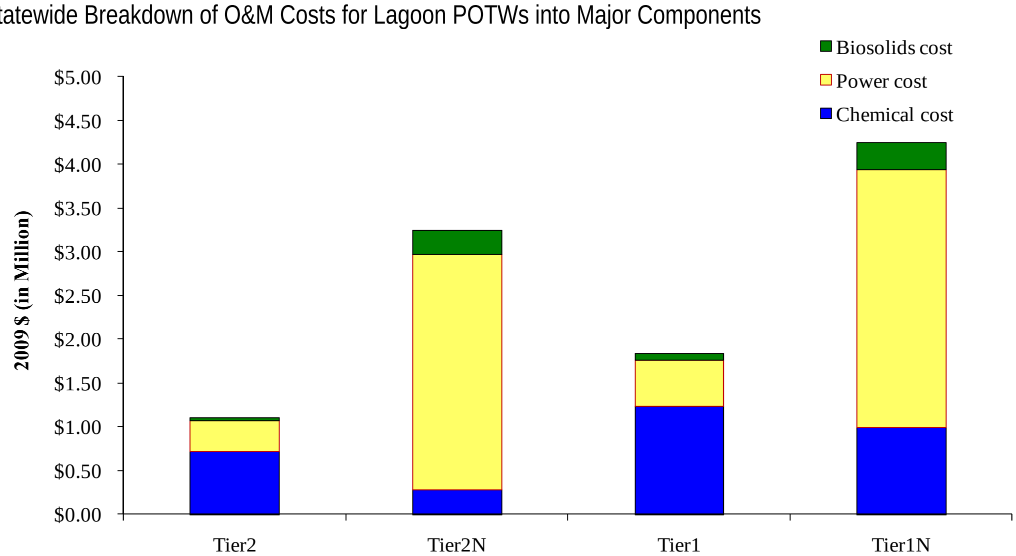


FIGURE 33
Statewide Breakdown of O&M Costs for Lagoon POTWs into Major Components



3.8 Financial Impacts

This section presents the estimated economic impacts that resulted from the implementation of nutrient discharge standards for the State of Utah. Financial and economic impacts were calculated for 30 mechanical POTWs, a model lagoon, and the City of Logan lagoon (referenced collectively hereafter as "facilities") based on the methodology described in Section 2.5 and also summarized and presented on a statewide basis.

3.8.1 Life-cycle Cost Results

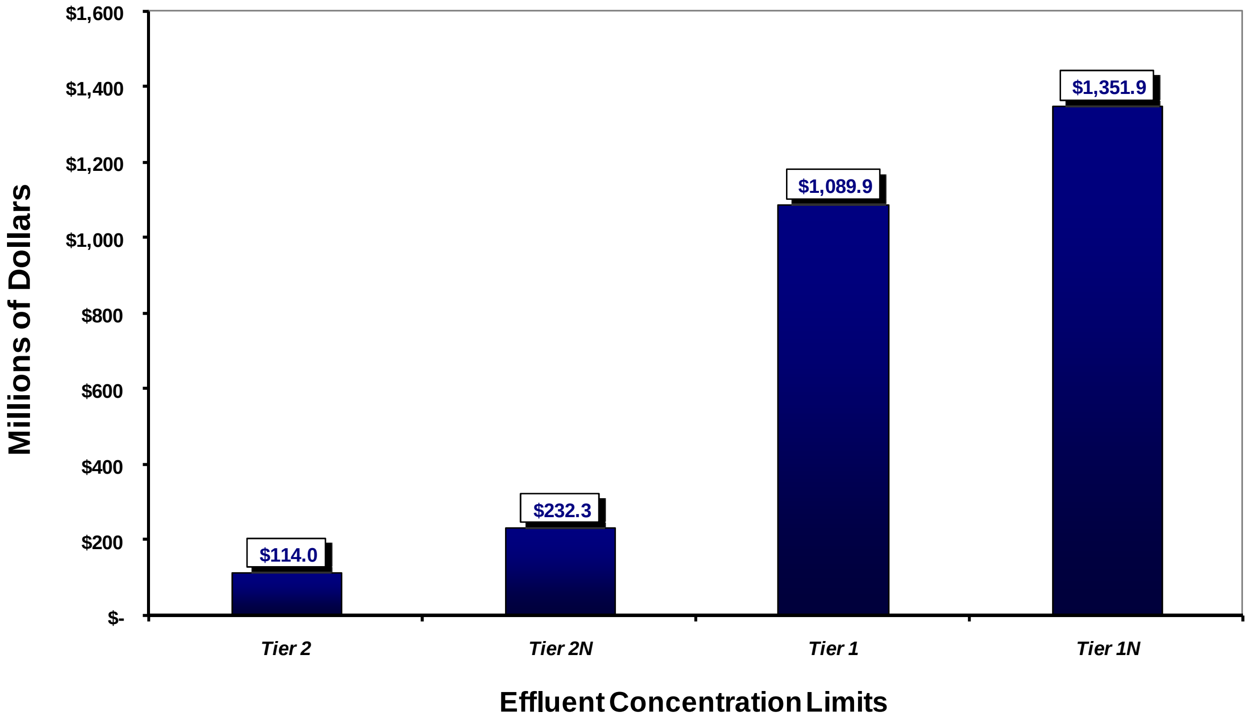
Table 9 presents the results of the life-cycle cost analysis for each facility and nutrient limit. Net present value estimates range from $0.1 million to $200.5 million. For facilities already meeting limits, the NPV estimate may be zero (for example, Snyderville East Canyon plant). For other facilities meeting the nutrient limits, the NPV estimate may include costs for redundant facilities or backup processes to ensure that the facility continues to meet the nutrient limit across the 20-year forecast period.

TABLE 9
Net Present Value Costs by Facility and Tier (in Millions)

	Tier 2	Tier 2N	Tier 1	Tier 1N
ASHLEY VALLEY	$ 0.38	$ 2.56	$ 20.07	$ 22.41
BRIGHAM CITY	2.65	2.65	22.98	22.98
CEDAR CITY	3.33	12.62	18.31	33.15
CENTRAL DAVIS	3.02	8.23	25.50	31.58
CENTRAL VALLEY	22.92	34.73	142.28	200.53
CENTRAL WEBER	9.93	11.85	117.93	184.28
COALVILLE	0.13	0.13	4.73	4.73
FAIRVIEW	0.12	0.12	0.68	0.68
HYRUM	-	-	-	1.04
MAGNA	2.60	2.60	23.10	26.47
MOAB	2.33	11.26	7.95	17.52
MORONI	0.13	0.13	0.87	0.87
NORTH DAVIS	33.36	37.99	107.77	111.78
OAKLEY	0.12	0.12	0.58	0.58
OREM	0.54	0.54	37.69	37.69
PAYSON	1.99	7.47	15.71	21.70
PRICE	2.20	6.48	14.71	20.89
PROVO	6.44	8.55	52.14	54.54
SALT LAKE CITY	1.92	49.29	111.55	162.17
SNYDERVILLE - EAST CANYON	-	-	-	-
SNYDERVILLE - SILVER CREEK	0.77	0.77	10.12	12.09
SOUTH DAVIS - NORTH	2.70	12.32	32.22	46.25
SOUTH DAVIS - SOUTH	0.77	6.09	16.75	24.72
SOUTH VALLEY	1.02	1.02	122.91	122.91
SPANISH FORK	5.65	6.81	25.52	29.77
SPRINGVILLE	5.00	4.04	7.02	7.64
ST. GEORGE	1.15	1.15	59.17	59.17
TIMPANOGOS	1.02	1.02	63.40	63.40
TOOELE CITY	0.19	0.19	16.20	16.20
TREMONTON	1.59	1.59	12.10	14.16
TOTAL	**$ 113.97**	**$ 232.33**	**$ 1,089.94**	**$ 1,351.92**
LOGAN	14.14	112.77	59.23	166.25
MODEL LAGOON	1.65	8.03	6.30	12.89

Figure 34 graphically summarizes the total life-cycle costs (NPV) for each of the tiered nutrient limits on a statewide basis. For a phosphorus limit of 1.0 mg/L (Tier 2), the total NPV for all POTWs in the state is $114.0 million. When that phosphorus limit is combined with a nitrogen limit of 20 mg/L (Tier 2N), the total NPV is $232.3 million. If a phosphorus limit of 0.1 mg/L is implemented (Tier 1), the estimated NPV of nutrient removal is $1,089.9 million. The NPV is $1,351.9 million if a nitrogen limit of 10 mg/L is combined with the more stringent phosphorus standard (Tier 1N).

FIGURE 34
Net Present Value (Cost) of Nutrient Removal across Tiered Limits for Mechanical POTWs



3.8.2 Cost per Pound Nutrients Removed

Table 10 presents the cost per pound metrics by facility and nutrient limit and shows the median cost per pound for each tier for the mechanical POTWs. Some POTWs are already meeting one or more of the tiered limits. For these POTWs, the cost per pound metric is shown as not applicable (NA) because there is no corresponding nutrient reduction. It is important to note that some POTWs may still show costs associated with a limit that is already being met. As described in previous sections, these NPV estimates represent the cost of redundant facilities that were considered necessary for the POTW to continue meeting nutrient limits as flows increase over the forecast period.

For the mechanical POTWs, the median cost per pound of phosphorus removal at the less stringent limit (1.0 mg/L) is $4.49; for nitrogen removal at 20 mg/L, the median cost per pound is $3.41. Removing phosphorus at the more stringent limit (0.1 mg/L) is by far the most expensive nutrient limit, with a median cost per pound of $31.76. Nitrogen removal at 10 mg/L shows a median cost per pound of $1.96.

TABLE 10
Nutrient Removal: Cost per Pound by Facility and Tier
Ratio of NPV Costs to 20-year Nutrient Removal (pounds)

	Tier 2	Tier 2N	Tier 1	Tier 1N
	phosphorus	nitrogen	phosphorus	nitrogen
ASHLEY VALLEY	$ 0.60	$ 3.62	$ 24.36	$ 0.90
BRIGHAM CITY	5.06	NA	32.61	-
CEDAR CITY	5.32	4.43	22.98	3.71
CENTRAL DAVIS	2.89	NA	16.83	5.83
CENTRAL VALLEY	2.68	0.39	12.07	0.88
CENTRAL WEBER	2.14	NA	17.70	2.94
COALVILLE	NA	NA	315.11	NA
FAIRVIEW	NA	NA	89.62	NA
HYRUM	NA	NA	NA	6.20
MAGNA	6.25	NA	39.89	1.85
MOAB	14.00	7.96	35.21	5.37
MORONI	NA	NA	20.90	NA
NORTH DAVIS	5.06	0.82	13.28	0.18
OAKLEY	NA	NA	68.85	NA
OREM	NA	NA	74.63	NA
PAYSON	4.63	3.20	28.56	1.97
PRICE	8.77	3.65	41.70	2.69
PROVO	2.13	0.66	13.60	0.20
SALT LAKE CITY	0.42	NA	16.87	2.30
SNYDERVILLE - EAST CANYON	NA	NA	NA	NA
SNYDERVILLE - SILVER CREEK	4.03	NA	35.40	1.89
SOUTH DAVIS - NORTH	3.36	4.68	25.43	1.94
SOUTH DAVIS - SOUTH	2.29	6.98	30.91	2.60
SOUTH VALLEY	NA	NA	61.05	NA
SPANISH FORK	5.85	1.04	20.80	1.06
SPRINGVILLE	4.34	-	5.03	0.17
ST. GEORGE	17.56	NA	58.19	NA
TIMPANOGOS	NA	NA	61.44	NA
TOOELE CITY	NA	NA	127.11	NA
TREMONTON	6.17	NA	34.62	2.03
Median Cost per Pound	**$ 4.49**	**$ 3.41**	**$ 31.76**	**$ 1.96**
LOGAN	3.72	10.36	12.70	5.62
MODEL LAGOON	20.39	15.75	63.53	10.83

Cost per pound metrics were organized and graphed according to the design capacity of each mechanical POTW. Figures 35, 36, 37, and 38 present cost per pound metrics by size category for each tiered nutrient limit. The POTWs were divided into four size categories based on their existing design capacity. There are six very small POTWs (less than 2 mgd), 13 small POTWs (2 to 9 mgd), six medium POTWs (10 to 30 mgd), and five large POTWs (greater than 30 mgd) among the four size categories. Facilities that already meet a nutrient limit are not shown on the corresponding graph.

The figures demonstrate that there is some correlation between design capacity (size) and the cost per pound of nutrient removal across the same tiered nutrient limit. In general, the cost per pound removed decreases with increasing treatment capacity. Economies of scale are evident from the graphs as well.

FIGURE 35
Mechanical POTW Cost per Pound of Phosphorus Removal by Size Category, Tier 2 Limit

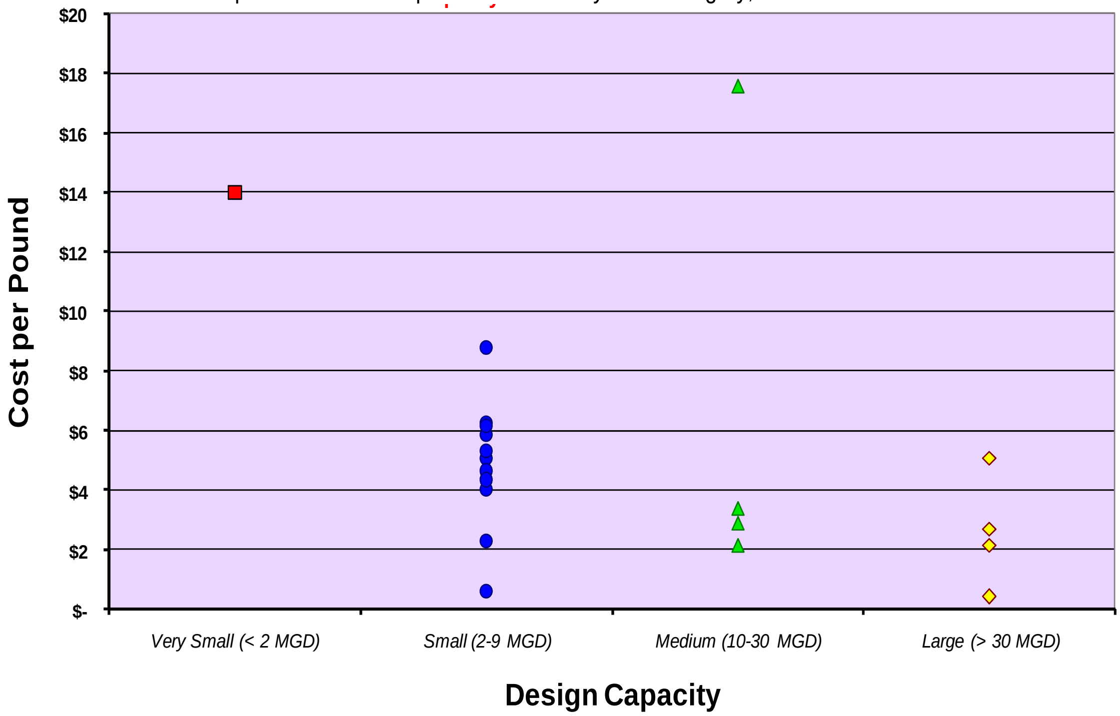


FIGURE 36
Mechanical POTW Cost per Pound of Nitrogen Removal by Size Category, Tier 2N Limit

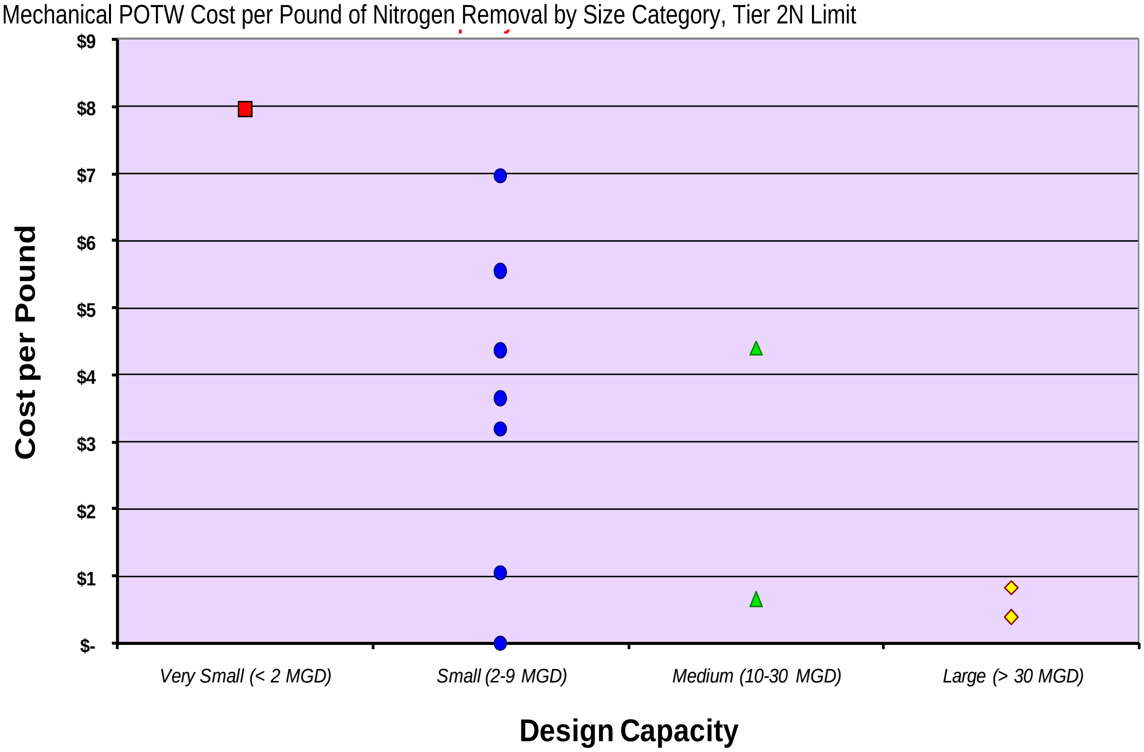


FIGURE 37
Mechanical POTW Cost per Pound of Phosphorus Removal by Size Category, Tier 1 Limit

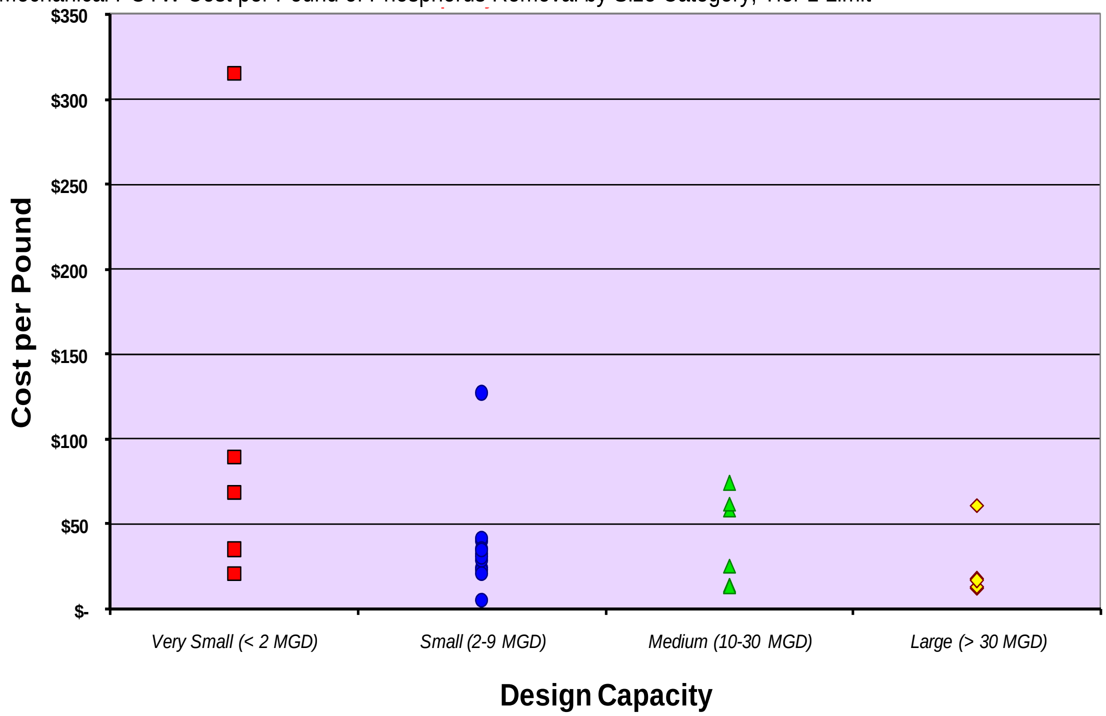
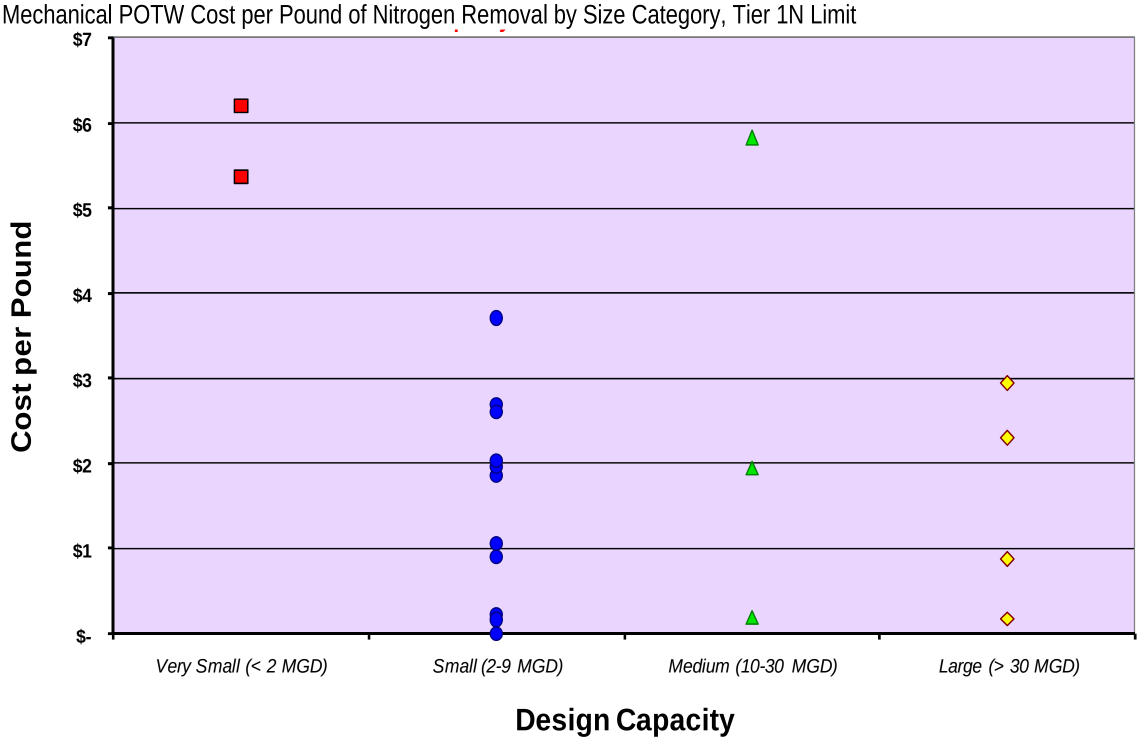


FIGURE 38
Mechanical POTW Cost per Pound of Nitrogen Removal by Size Category, Tier 1N Limit



Cost per pound nutrient removed metrics were also organized and graphed by process category: OD (10 facilities), TF (4 facilities), hybrid process (8 facilities), MBR (4 facilities), and AS (4 facilities). Figures 39, 40, 41, and 42 present cost per pound metrics for the four treatment tiers by process category. Facilities that already meet a nutrient limit are not shown on the corresponding graph.

FIGURE 39
Mechanical POTW Cost per Pound of Phosphorus Removal by Process Category, Tier 2 Limit

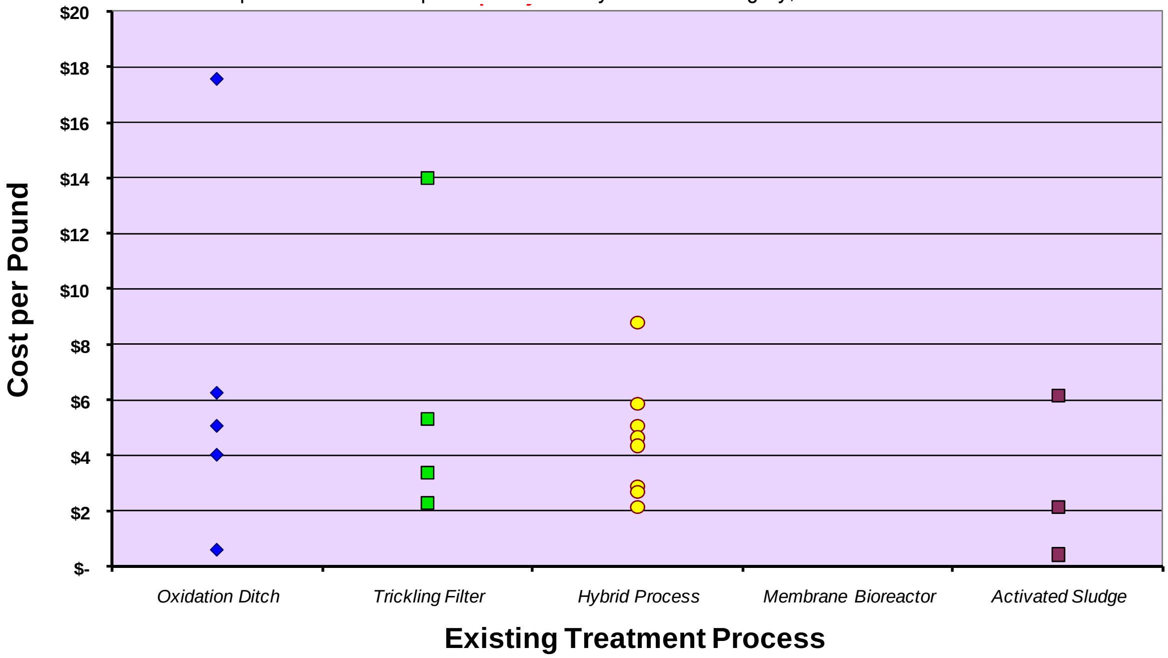


FIGURE 40
Mechanical POTW Cost per Pound of Nitrogen Removal by Process Category, Tier 2N Limit

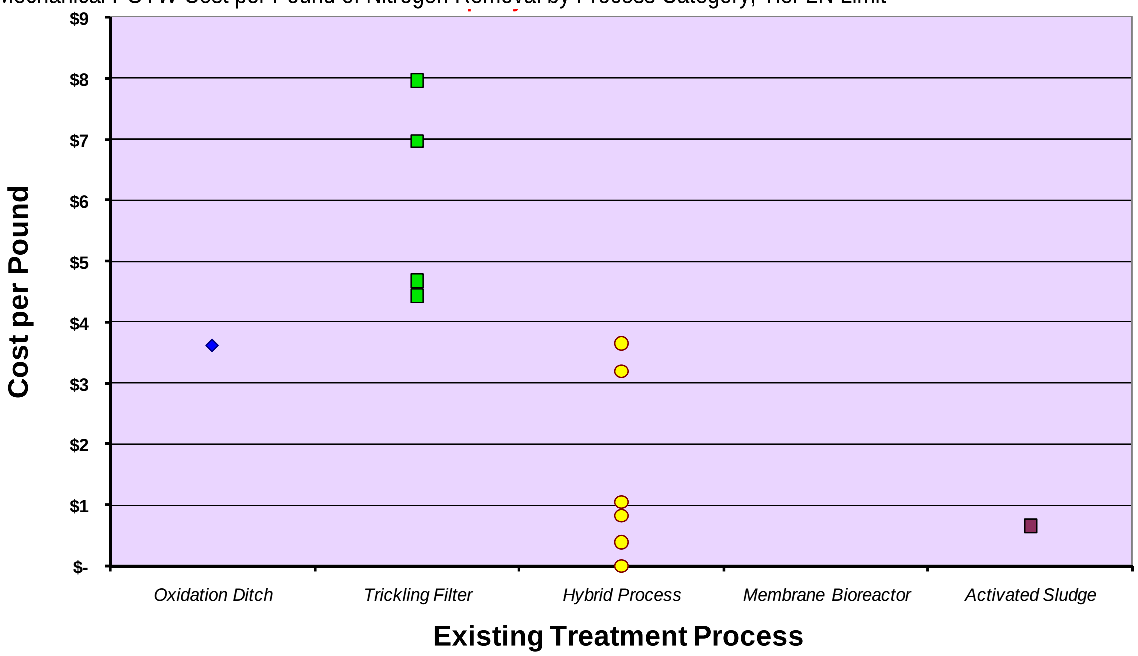


FIGURE 41
Mechanical POTW Cost per Pound of Phosphorus Removal by Process Category, Tier 1 Limit

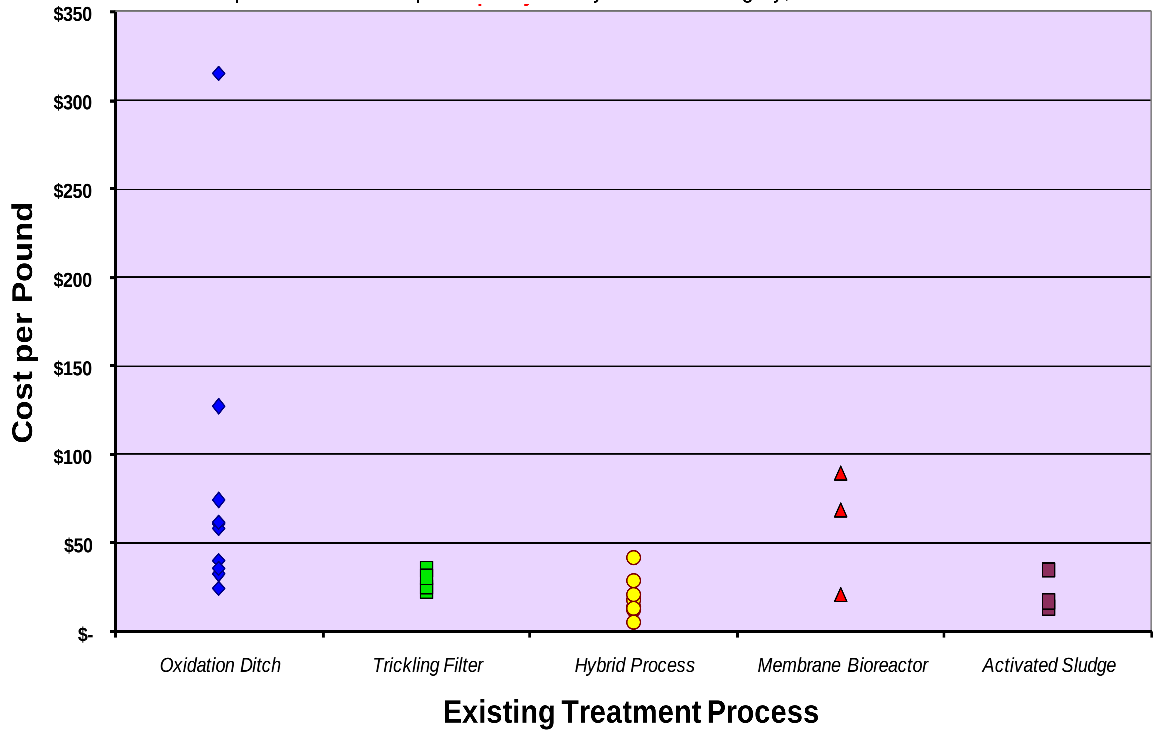
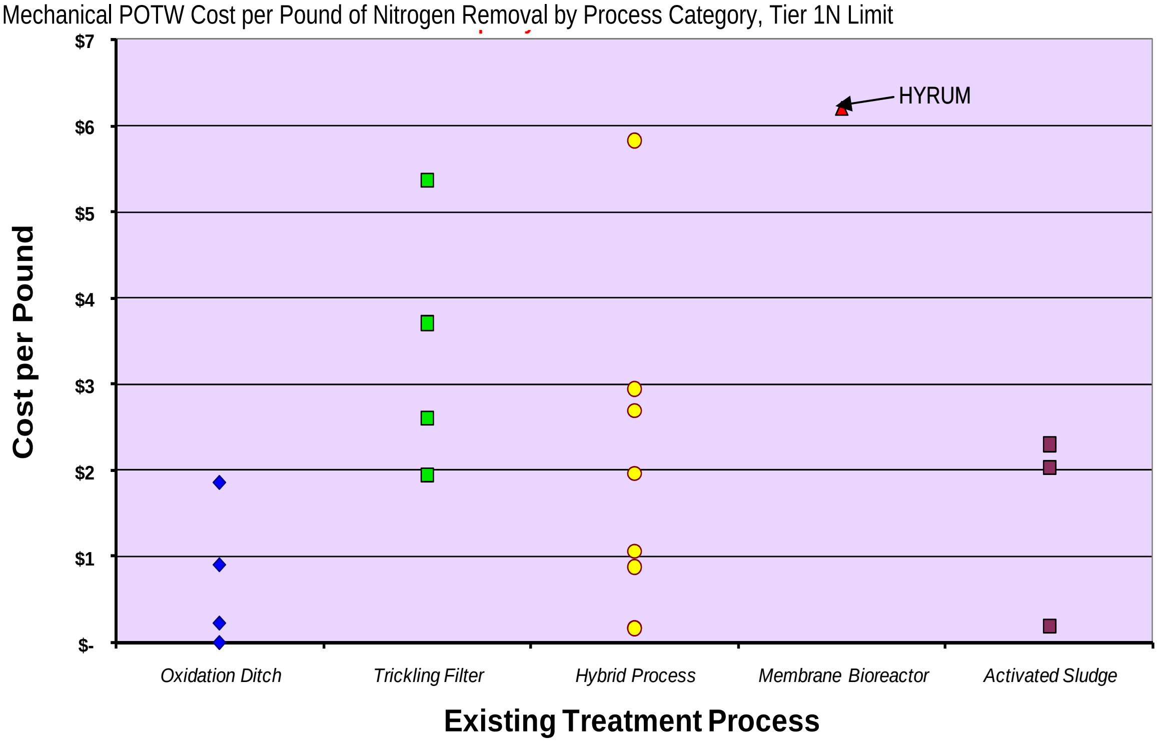
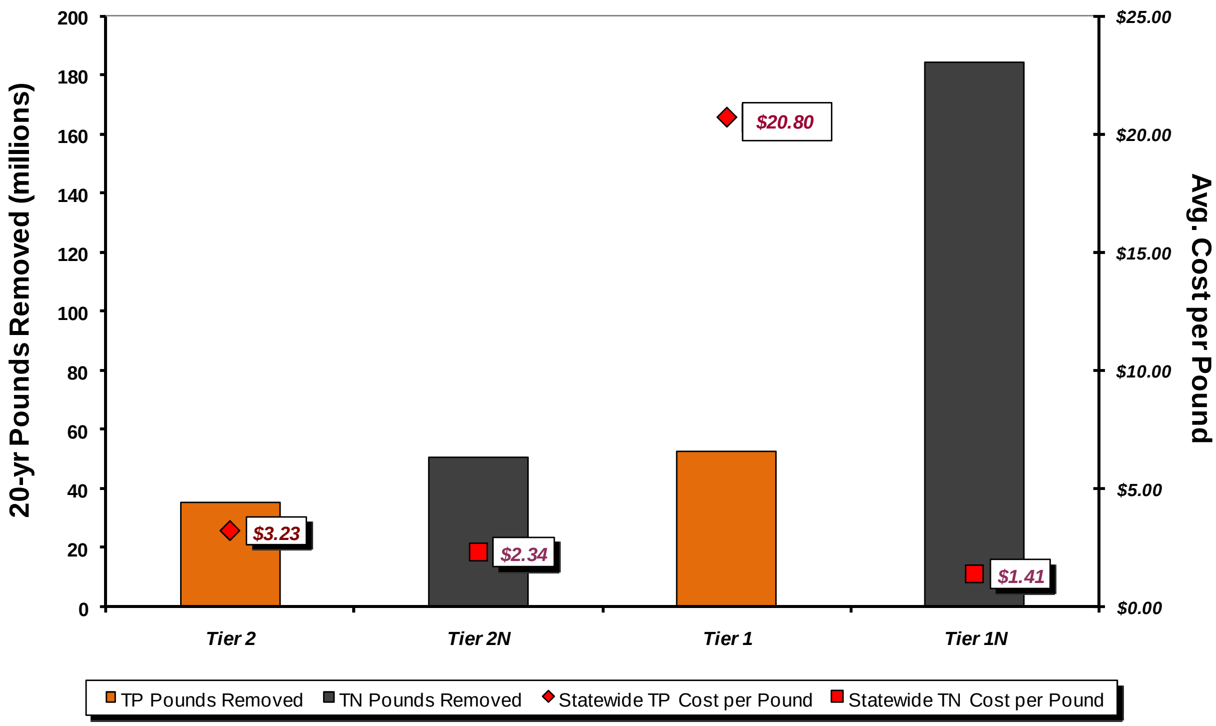


FIGURE 42
Mechanical POTW Cost per Pound of Nitrogen Removal by Process Category, Tier 1N Limit



A statewide cost per pound metric was developed by taking the total (statewide) NPV for each nutrient limit and dividing by the total pounds of nitrogen or phosphorus removal under each scenario. Again, this is an oversimplification because enhanced biological phosphorus removal or chemical phosphorus removal processes can be significantly different from biological nutrient removal. The "per pound unit costs" should be interpreted carefully and not used for planning purposes. Figure 43 presents the results of this analysis.

FIGURE 43
Statewide Cost per Pound of Nutrient Removal for Tiered Effluent Limits for Mechanical POTW



From Figure 43, the unit cost for removal of a pound of phosphorus is the highest unit cost at $20.80 per pound for the Tier 1 limit. The less stringent phosphorus limit (Tier 2) resulted in a statewide cost of $3.23 per pound. Nitrogen removal unit costs ranged from $2.34 for Tier 2N and decreases to $1.41 for Tier 1N.

Phosphorus unit removal costs were generally more than those for nitrogen removal for the following reasons:

- Chemical removal technologies are generally more expensive that biological ones.
- The initial concentrations of phosphorus are lower than those for nitrogen, which results in a lower reaction (rate) driving gradient, making it harder and more expensive to treat.
- Treatment standards for phosphorus were lower, requiring more intensive (aggressive) treatment.
- The higher cost to remove less mass results in a higher unit removal cost.

3.8.3 Nutrient Removal Efficiency Curves

Figures 44, 45, 46, and 47 rank and organize the NPV estimates by POTW to produce an efficiency curve for each nutrient limit. The graphs illustrate the necessary levels of investment in treatment versus the corresponding total (20-year) nutrient removal. Because the data points are ranked from most efficient to least efficient in terms of nutrient removal, the chart was expected to help identify a point or points of diminishing returns.[8]

FIGURE 44
Statewide Cumulative NPV Cost Comparison to 20-year Phosphorus Removal for Mechanical POTWs for Tier 2

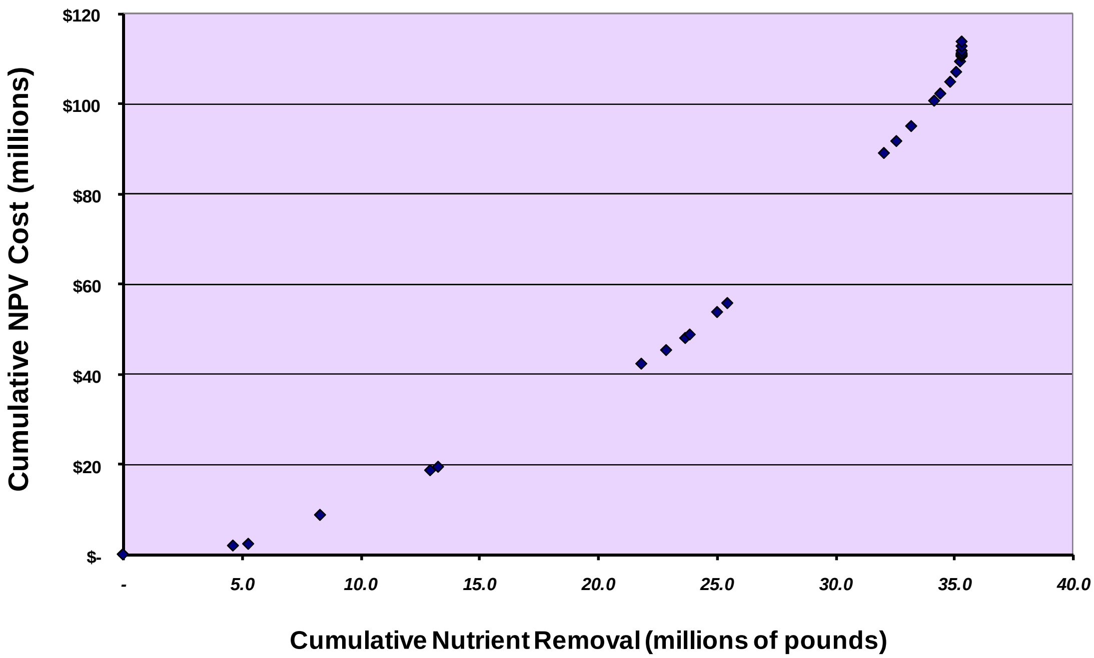
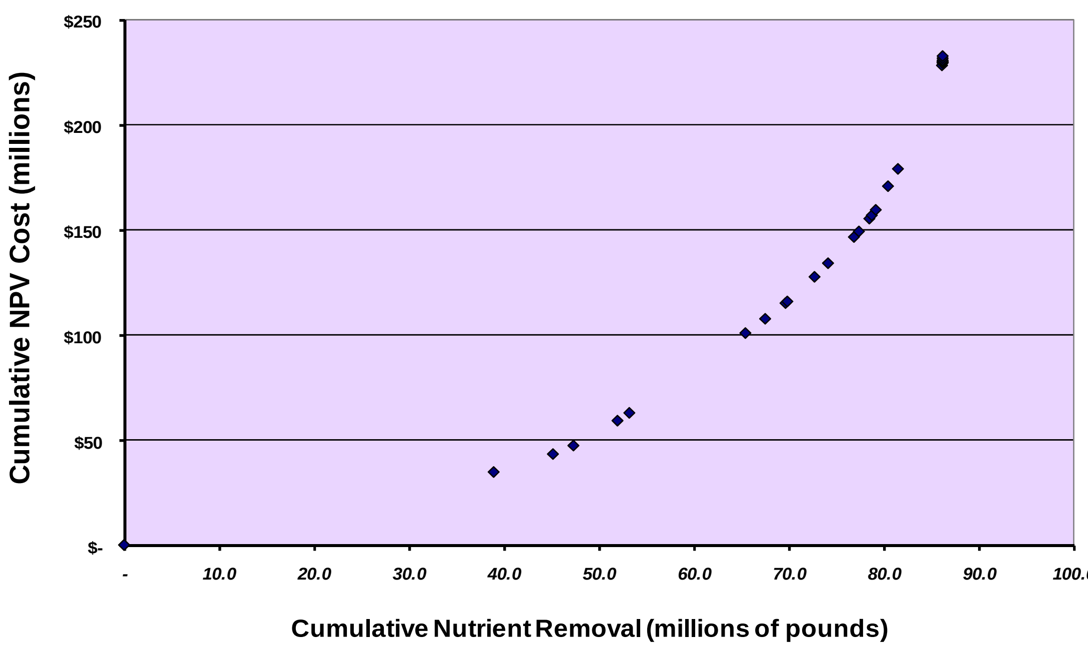


FIGURE 45
Statewide Cumulative NPV Cost Comparison to 20-year Phosphorus and Nitrogen Removal for Mechanical POTWs for Tier 2N



8 POTW data points near the origin may represent facilities that require redundant facilities to continue to meet nutrient limits into the future, and therefore represent a level of investment without an associated reduction in nutrient loads.

FIGURE 46
Statewide Cumulative NPV Cost Comparison to 20-year Phosphorus Removal for Tier 1

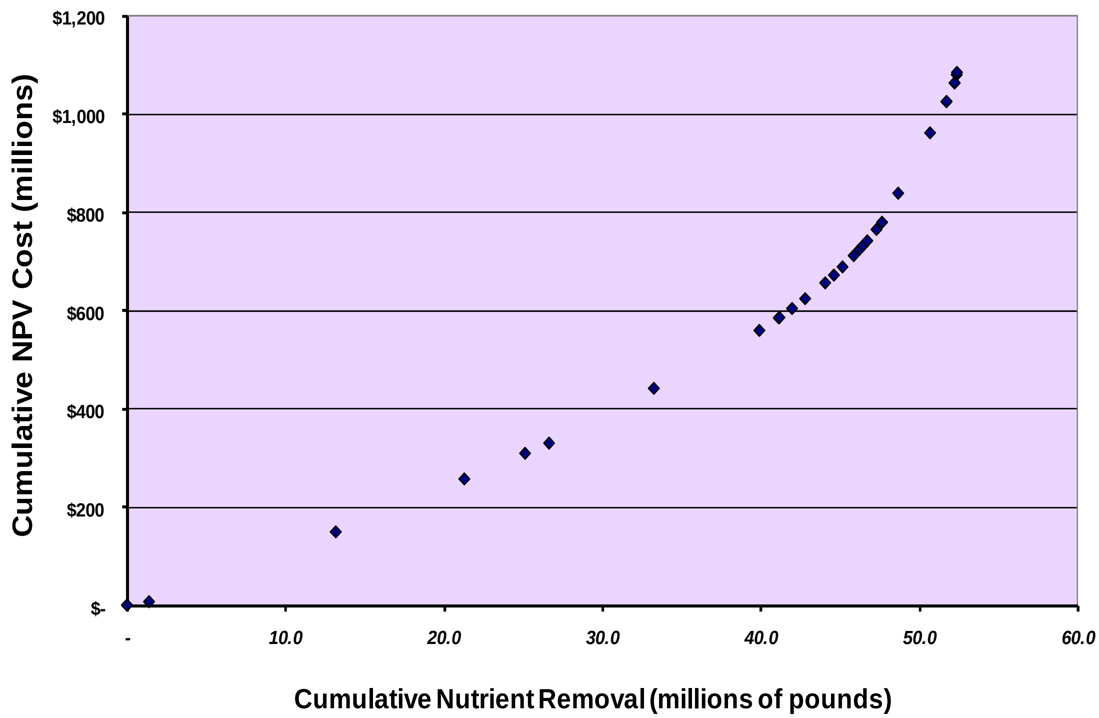
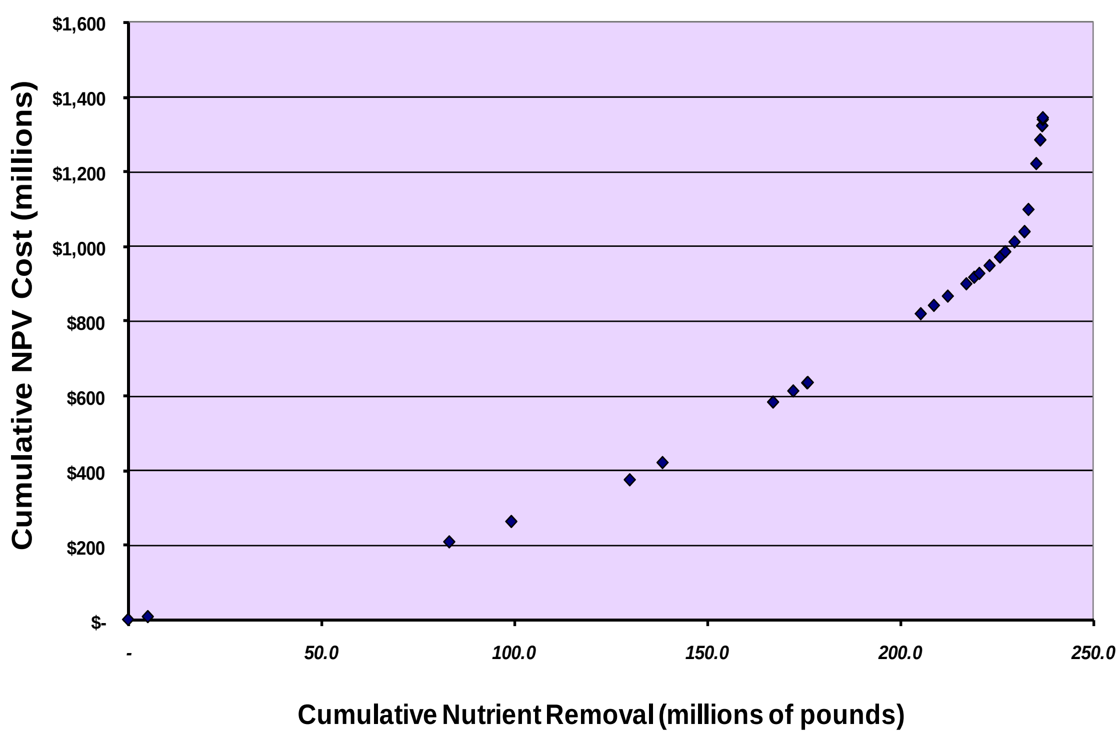


FIGURE 47
Statewide Cumulative NPV Cost Comparison to 20-year Phosphorus and Nitrogen Removal for Tier 1N



3.8.4 Monthly Bill Increase Results

Table 11 presents the estimated monthly increase to a typical residential customer's bill for each facility at each nutrient limit tier. The estimated monthly bill increase for each customer is based on the methodology described in Section 2.5.

TABLE 11
Monthly Bill Increase per Residential Customer (ERU)

	Tier 2	Tier 2N	Tier 1	Tier 1N
ASHLEY VALLEY	$0.43	$3.10	***$23.59***	***$26.42***
BRIGHAM CITY	$2.90	$2.90	***$25.22***	***$25.22***
CEDAR CITY	$1.75	**$7.82**	***$11.56***	***$20.55***
CENTRAL DAVIS	$1.21	$4.22	***$12.84***	***$16.20***
CENTRAL VALLEY	$0.62	$1.07	$5.60	**$7.74**
CENTRAL WEBER	$0.98	$1.23	***$15.80***	***$24.81***
COALVILLE	$1.14	$1.14	***$41.44***	***$41.44***
FAIRVIEW	$1.31	$1.31	$5.36	$5.36
HYRUM	$0.00	$0.00	$0.00	$2.87
MAGNA	$1.99	$1.99	***$17.00***	***$19.63***
MOAB	$3.23	***$19.80***	***$13.00***	***$30.48***
MORONI	$0.18	$0.18	$0.93	$0.93
NORTH DAVIS	$2.10	$2.69	**$9.26**	***$10.21***
OAKLEY	$1.92	$1.92	$7.36	$7.36
OREM	$0.15	$0.15	***$11.56***	***$11.56***
PAYSON	$1.89	**$9.40**	***$19.17***	***$26.93***
PRICE	$1.53	$5.02	***$11.73***	***$16.78***
PROVO	$1.53	$1.86	***$13.93***	***$14.50***
SALT LAKE CITY	$0.17	$4.64	***$10.23***	***$15.04***
SNYDERVILLE - EAST CANYON	$0.00	$0.00	$0.00	$0.00
SNYDERVILLE - SILVER CREEK	$0.80	$0.80	***$11.87***	***$14.22***
SOUTH DAVIS - NORTH	$0.63	$3.40	**$9.10**	***$12.89***
SOUTH DAVIS - SOUTH	$0.39	$3.26	**$8.94**	***$12.86***
SOUTH VALLEY	$0.06	$0.06	$6.69	$6.69
SPANISH FORK	$3.87	$5.78	***$23.02***	***$27.16***
SPRINGVILLE	$1.97	$2.20	$3.04	$3.96
ST. GEORGE	$0.16	$0.16	***$10.09***	***$10.09***
TIMPANOGOS	$0.13	$0.13	$9.99	$9.99
TOOELE CITY	$0.17	$0.17	***$14.28***	***$14.28***
TREMONTON	$2.62	$2.62	***$19.59***	***$22.92***
Average Bill Increase	**$1.19**	**$2.97**	**$12.41**	**$15.30**
LOGAN	$2.54	***$24.76***	***$12.45***	***$36.31***
MODEL LAGOON	$5.65	***$29.06***	***$22.51***	***$47.09***

NOTE:
Monthly bill increases greater than $10.00 are highlighted in red, while increases between $7.50 and $10.00 are highlighted in orange. Increases between $5.00 and $7.50 are highlighted in light yellow.

The average bill increase ranges from $1.19 for Tier 2 to $15.30 for Tier 1N, the most stringent nutrient limit.

3.8.5 Rate Increase Results

Projected rate increase percentages for each tiered nutrient limit are presented by facility in Table 12. Projected rate increases were estimated based on the methodology described in Section 2.5.

TABLE 12
Estimated Rate Increase (percent) per ERU

	Tier 2	Tier 2N	Tier 1	Tier 1N
ASHLEY VALLEY	2%	14%	106%	119%
BRIGHAM CITY	11%	11%	100%	100%
CEDAR CITY	7%	33%	49%	87%
CENTRAL DAVIS	7%	24%	73%	92%
CENTRAL VALLEY	4%	7%	35%	49%
CENTRAL WEBER	6%	8%	102%	160%
COALVILLE	4%	4%	148%	148%
FAIRVIEW	3%	3%	14%	14%
HYRUM	0%	0%	0%	16%
MAGNA	12%	12%	100%	115%
MOAB	17%	106%	70%	163%
MORONI	1%	1%	7%	7%
NORTH DAVIS	15%	19%	64%	71%
OAKLEY	7%	7%	27%	27%
OREM	1%	1%	46%	46%
PAYSON	8%	42%	85%	120%
PRICE	8%	26%	62%	88%
PROVO	36%	44%	327%	340%
SALT LAKE CITY	2%	44%	97%	142%
SNYDERVILLE - EAST CANYON	0%	0%	0%	0%
SNYDERVILLE - SILVER CREEK	3%	3%	42%	50%
SOUTH DAVIS - NORTH	8%	46%	123%	174%
SOUTH DAVIS - SOUTH	5%	44%	120%	173%
SOUTH VALLEY	0%	0%	44%	44%
SPANISH FORK	19%	28%	112%	132%
SPRINGVILLE	10%	12%	16%	21%
ST. GEORGE	1%	1%	53%	53%
TIMPANOGOS	1%	1%	48%	48%
TOOELE CITY	1%	1%	60%	60%
TREMONTON	12%	12%	87%	102%
Average Rate Increase	**7.1%**	**18.4%**	**73.9%**	**92.1%**
LOGAN	17%	168%	84%	246%
MODEL LAGOON	31%	158%	123%	256%

NOTE:
The average rate increase for the Tier 2 nutrient limit is 7.1 percent, while the average rate increase for Tier 1N is 90.5 percent. Rate increases greater than 50.0 percent are highlighted in red, with rate increases between 25.0 and 50.0 percent highlighted in orange. Rate increases between 10.0 and 24.9 percent are highlighted in light yellow.

Rate increase results are also organized graphically based on the size of the mechanical POTW in Figures 48, 49, 50, and 51.

FIGURE 48
Estimated Rate Increase by Mechanical POTW Size Category, Tier 2 Limit

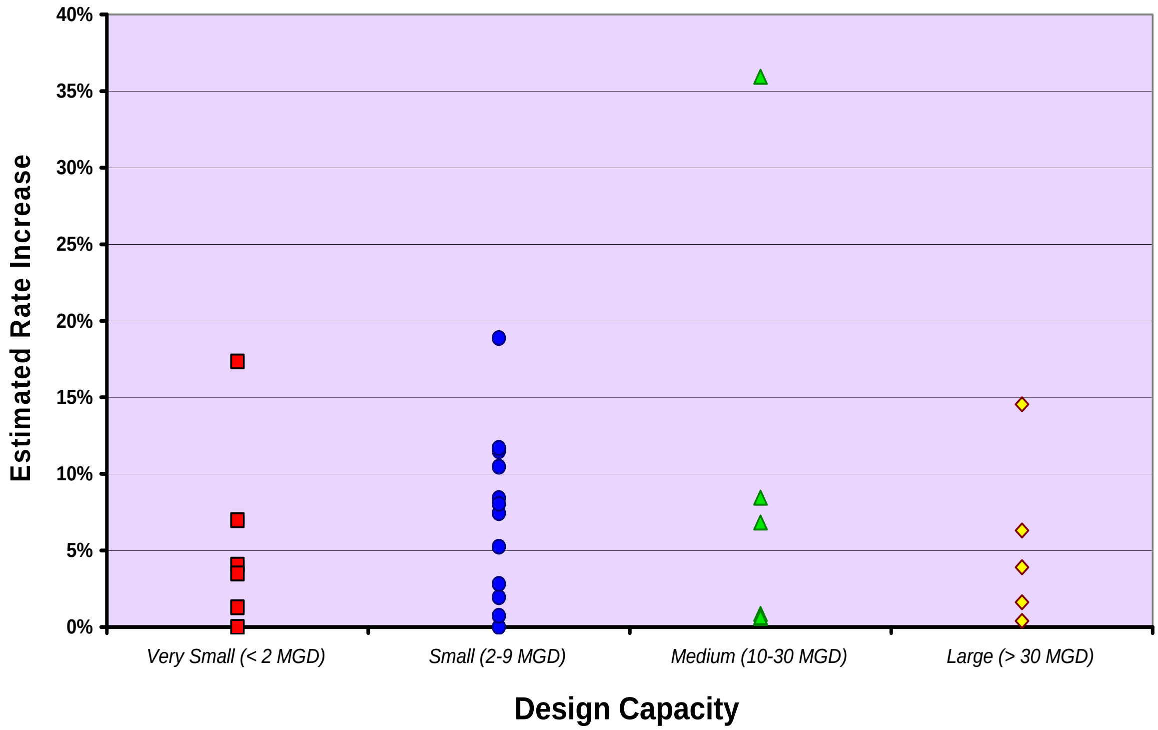


FIGURE 49
Estimated Rate Increase by Mechanical POTW Size Category, Tier 2N Limit

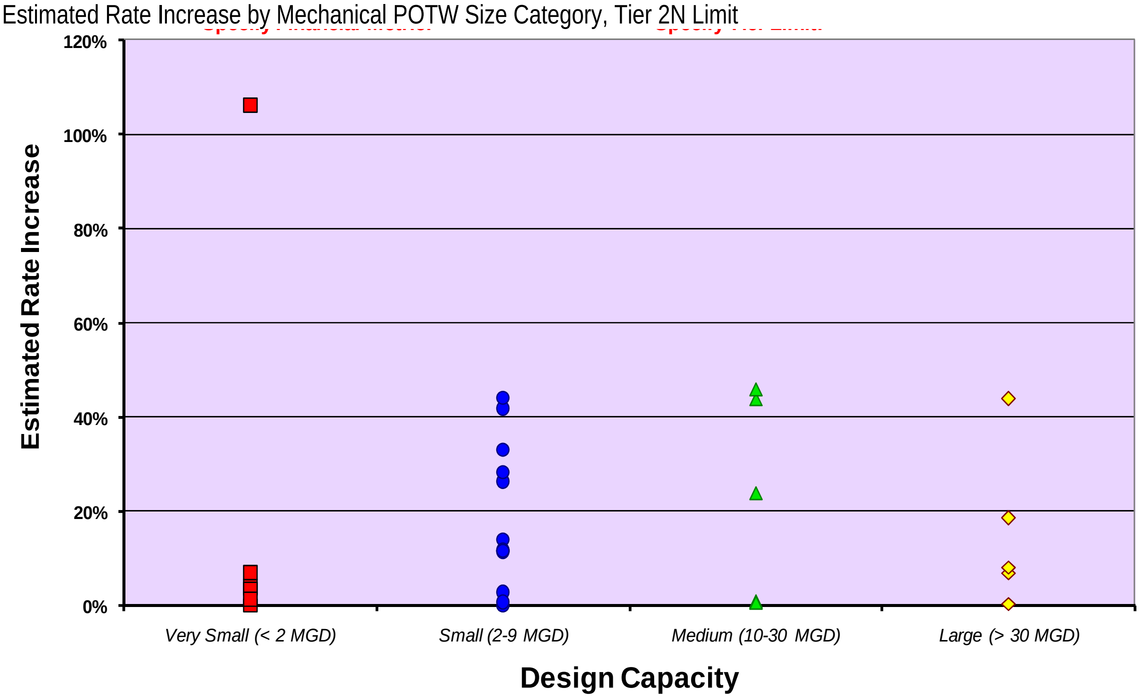


FIGURE 50
Estimated Rate Increase by Mechanical POTW Size Category, Tier 1 Limit

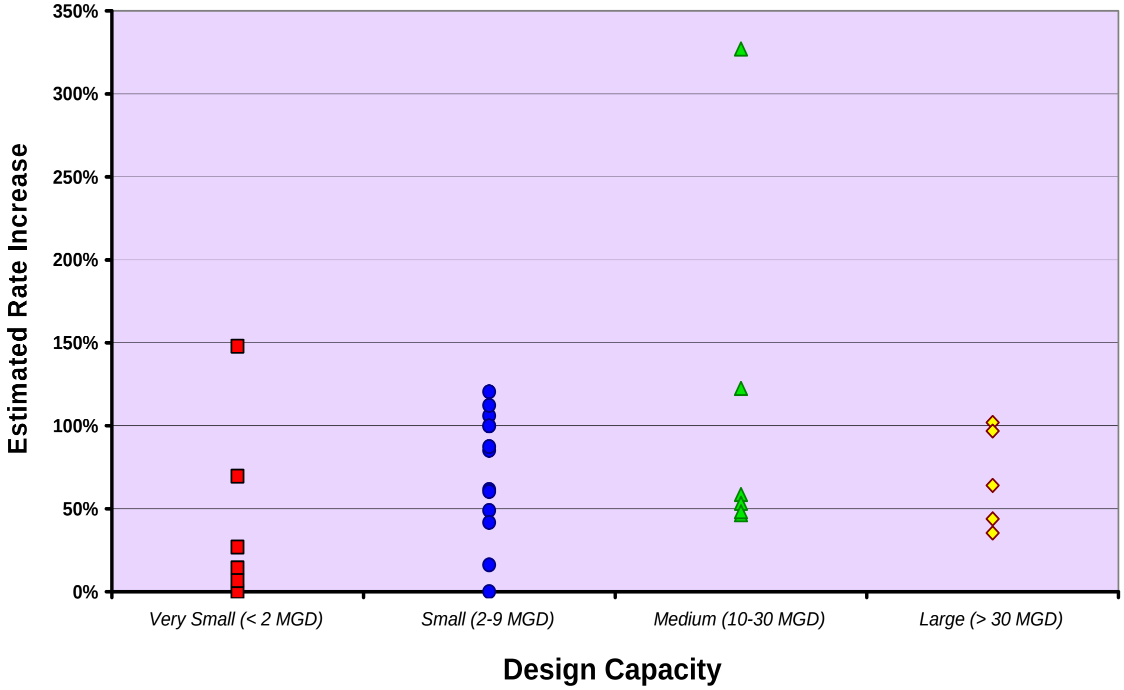
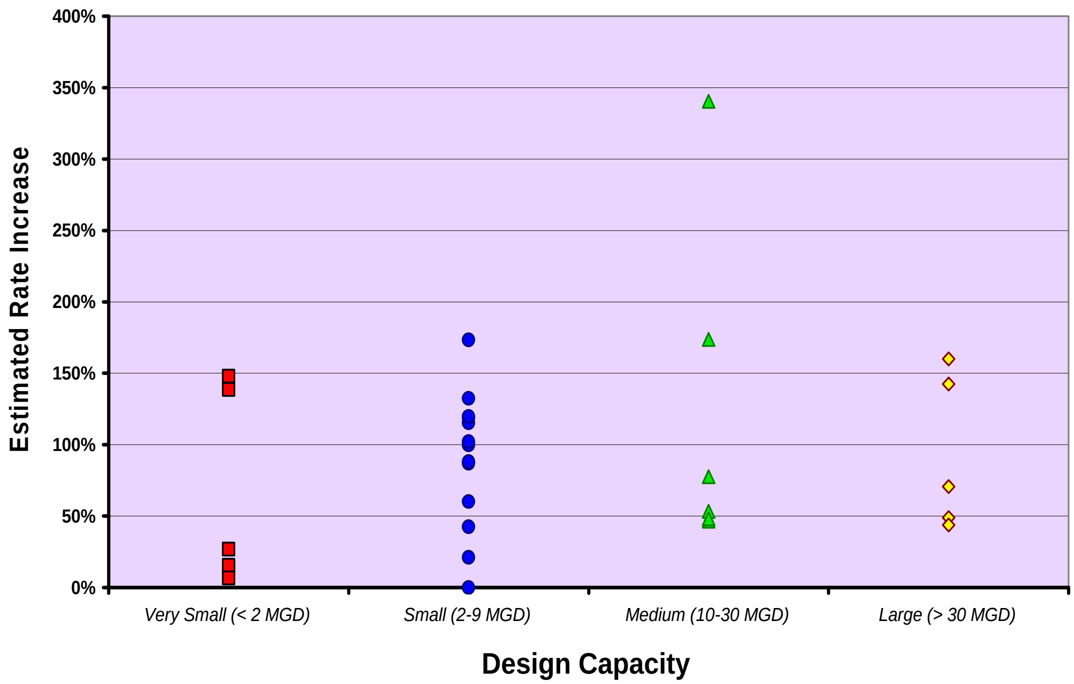


FIGURE 51
Estimated Rate Increase by Mechanical POTW Size Category, Tier 1N Limit



Rate increase results are also organized graphically based on the existing treatment process for each POTW. Figures 52, 53, 54, and 55 present the results of this analysis for each nutrient limit and process category.

FIGURE 52

Estimated Rate Increase by POTW Process, Tier 2 Limit

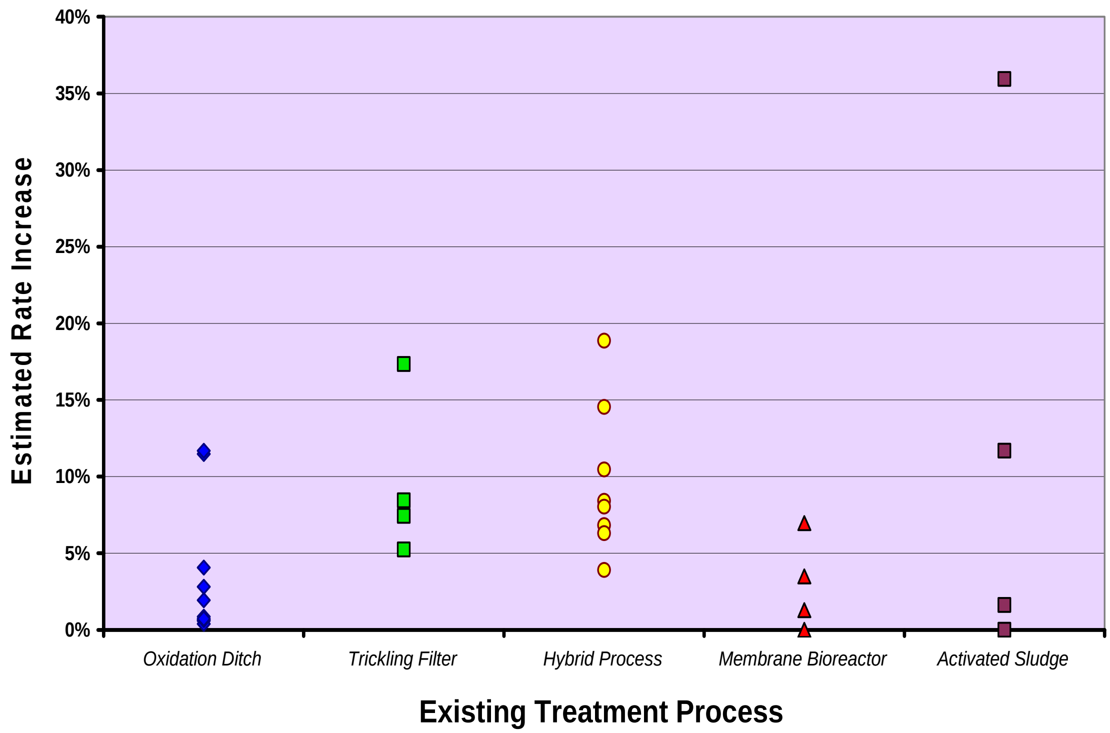


FIGURE 53
Estimated Rate Increase by POTW Process, Tier 2N Limit

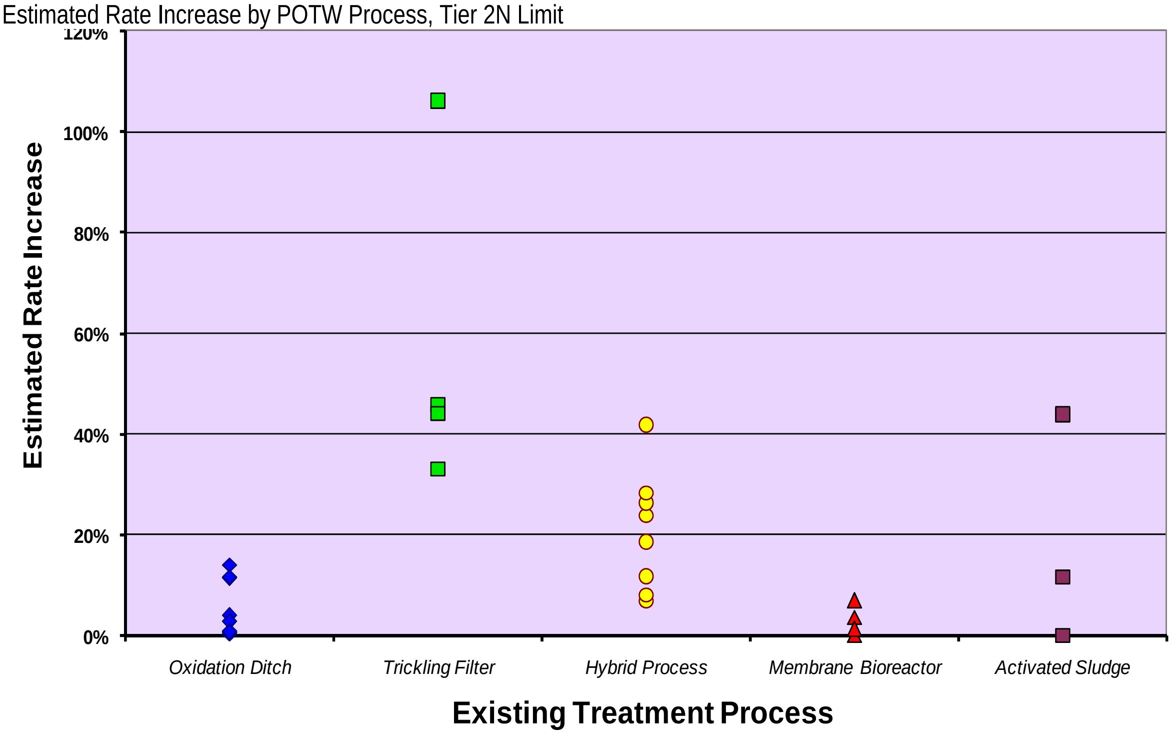


FIGURE 54
Estimated Rate Increase by POTW Process, Tier 1 Limit

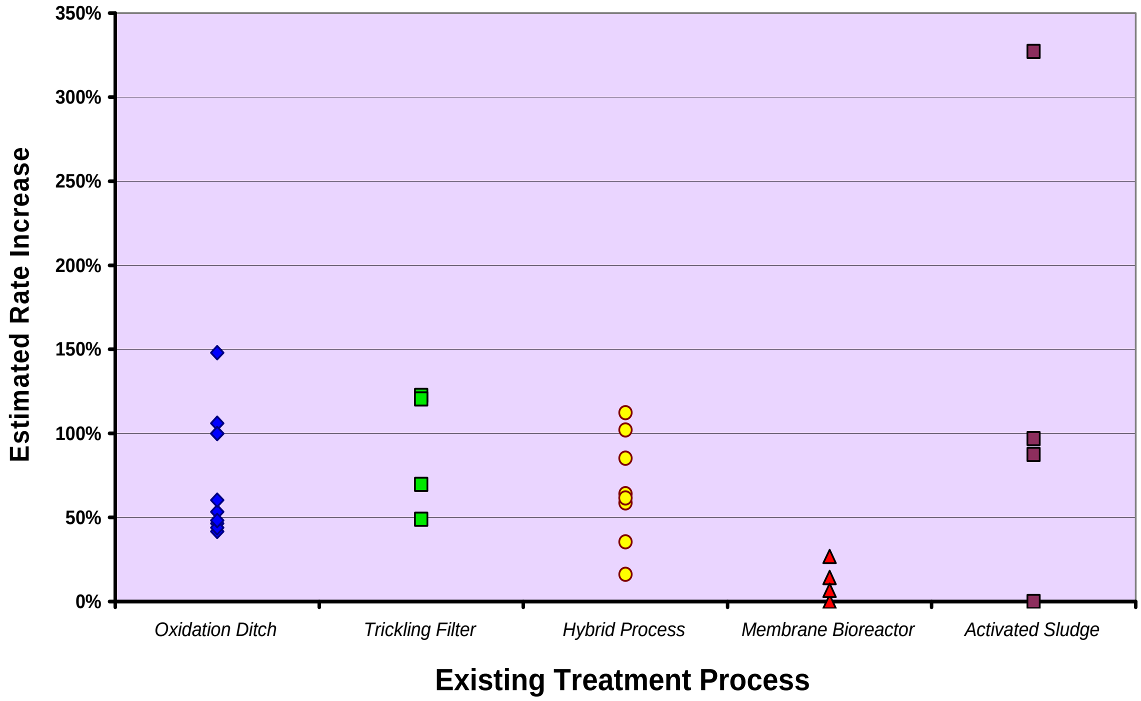
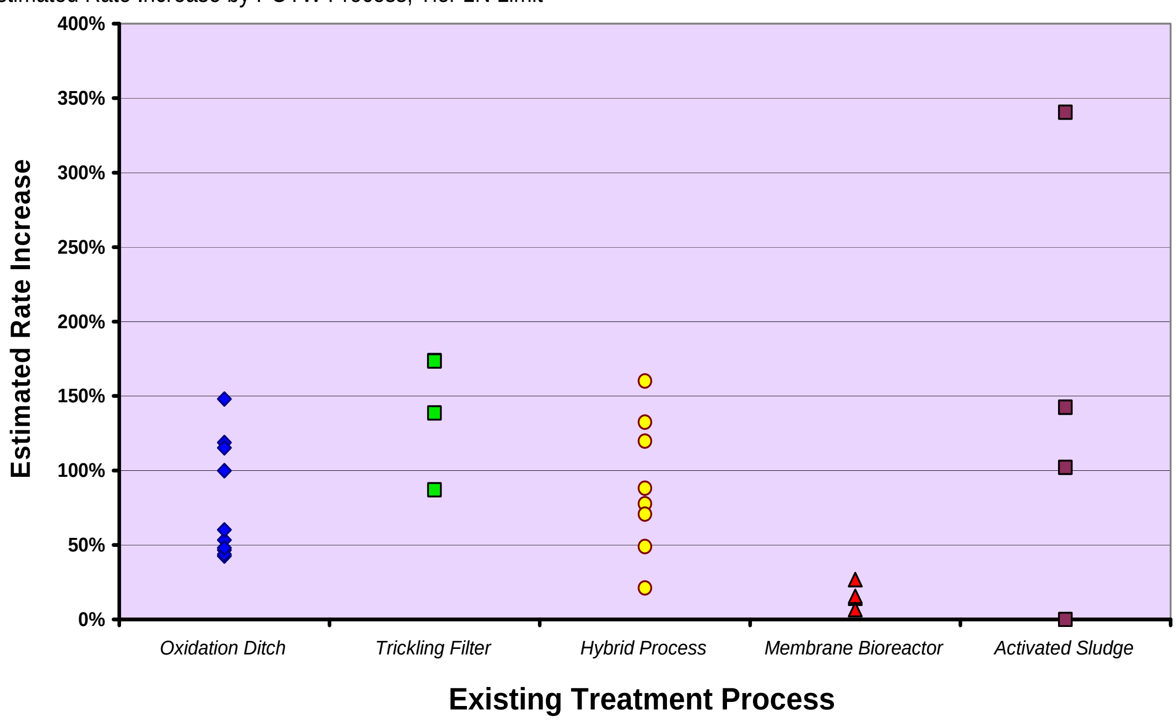


FIGURE 55
Estimated Rate Increase by POTW Process, Tier 1N Limit



3.8.6 Affordability Ratio Results

Table 13 presents the affordability ratios for each facility and nutrient limit tier, based on the calculation methodology described in Section 2.5. Affordability ratios that are greater than

100 percent indicate that the projected monthly bill for that treatment alternative is greater than the State's SRF loan affordability criterion. The average affordability ratios are 45 and 49 percent for Tiers 2 and 2N, respectively. The average ratio for Tier 1 is 69 percent, and the average ratio for Tier 1N is 76 percent.

TABLE 13
Estimated Bill as Percentage of State Affordability Criterion

	Tier 2	Tier 2N	Tier 1	Tier 1N
ASHLEY VALLEY	36%	40%	72%	**76%**
BRIGHAM CITY	63%	63%	***113%***	***113%***
CEDAR CITY	68%	**85%**	**95%**	***119%***
CENTRAL DAVIS	26%	31%	43%	47%
CENTRAL VALLEY	41%	42%	53%	59%
CENTRAL WEBER	36%	36%	68%	**88%**
COALVILLE	55%	55%	***131%***	***131%***
FAIRVIEW	**95%**	**95%**	***105%***	***105%***
HYRUM	41%	41%	41%	47%
MAGNA	48%	48%	**85%**	**92%**
MOAB	65%	***115%***	**95%**	***147%***
MORONI	41%	41%	44%	44%
NORTH DAVIS	32%	33%	46%	48%
OAKLEY	51%	51%	60%	60%
OREM	63%	63%	**92%**	**92%**
PAYSON	51%	66%	**87%**	***103%***
PRICE	45%	52%	67%	**78%**
PROVO	19%	21%	61%	63%
SALT LAKE CITY	28%	40%	55%	67%
SNYDERVILLE - EAST CANYON	59%	59%	59%	59%
SNYDERVILLE - SILVER CREEK	60%	60%	**83%**	**88%**
SOUTH DAVIS - NORTH	14%	19%	29%	35%
SOUTH DAVIS - SOUTH	14%	19%	28%	35%
SOUTH VALLEY	31%	31%	44%	44%
SPANISH FORK	45%	49%	**81%**	**88%**
SPRINGVILLE	45%	45%	47%	49%
ST. GEORGE	48%	48%	73%	73%
TIMPANOGOS	34%	34%	50%	50%
TOOELE CITY	48%	48%	**76%**	**76%**
TREMONTON	51%	51%	**86%**	**93%**
Average Affordability Ratio	**45%**	**49%**	**69%**	**76%**
LOGAN	41%	**94%**	65%	***122%***
MODEL LAGOON	55%	***108%***	**93%**	***149%***

NOTE:
Ratios greater than 100 percent are highlighted in red. Ratios that are between 75 and 99 percent are highlighted in orange, while ratios that range from 50 to 74 percent are highlighted in light yellow.

Additional outputs related to the estimated affordability of treatment alternatives are presented in the following figures. As with other financial impact metrics, the calculated affordability ratios for each mechanical POTW are organized graphically based on the size of the treatment plant and the existing treatment process of the mechanical POTW. Figures 56, 57, 58, and 59 present affordability ratios by design capacity, while Figures 60, 61, 62, and 63 organize affordability ratios by existing treatment process. A separate graph is presented for each nutrient limit and category.

FIGURE 56
Estimated Affordability Ratio by POTW Size, Tier 2 Limit

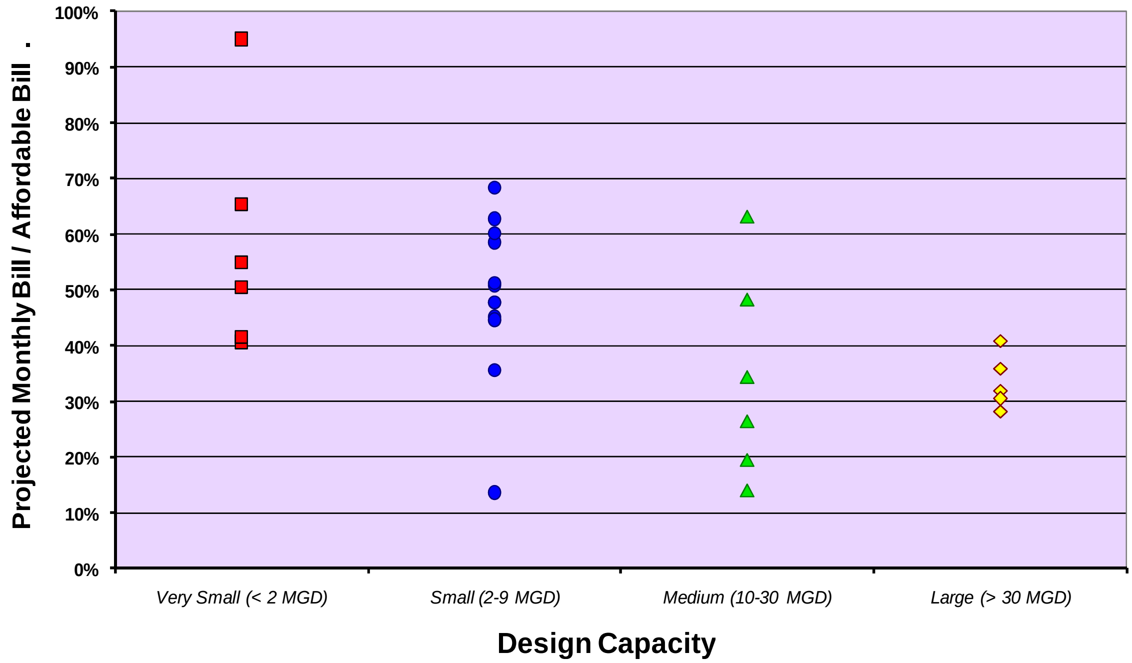


FIGURE 57
Estimated Affordability Ratio by POTW Size, Tier 2N Limit

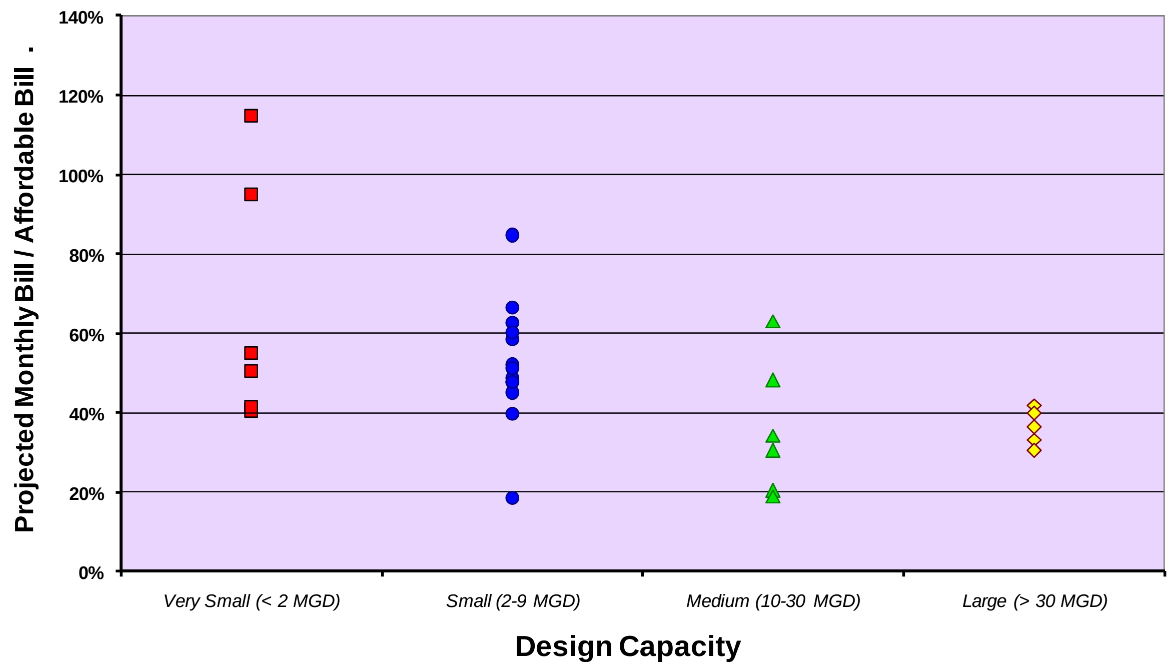


FIGURE 58
Estimated Affordability Ratio by POTW Size, Tier 1 Limit

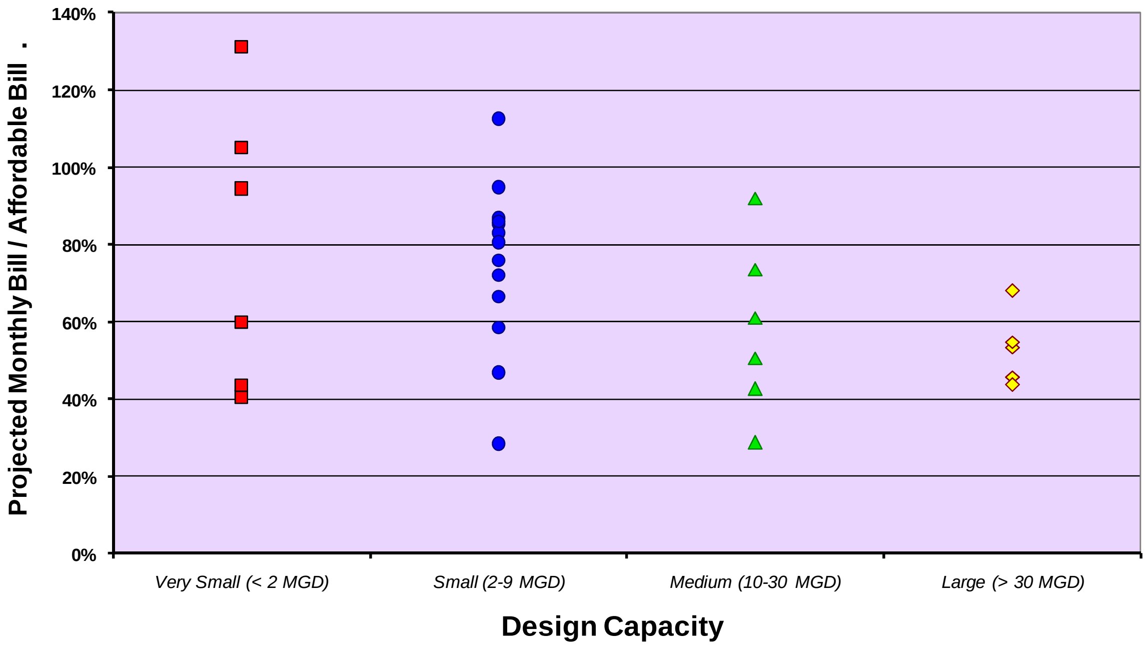


FIGURE 59
Estimated Affordability Ratio by POTW Size, Tier 1N Limit

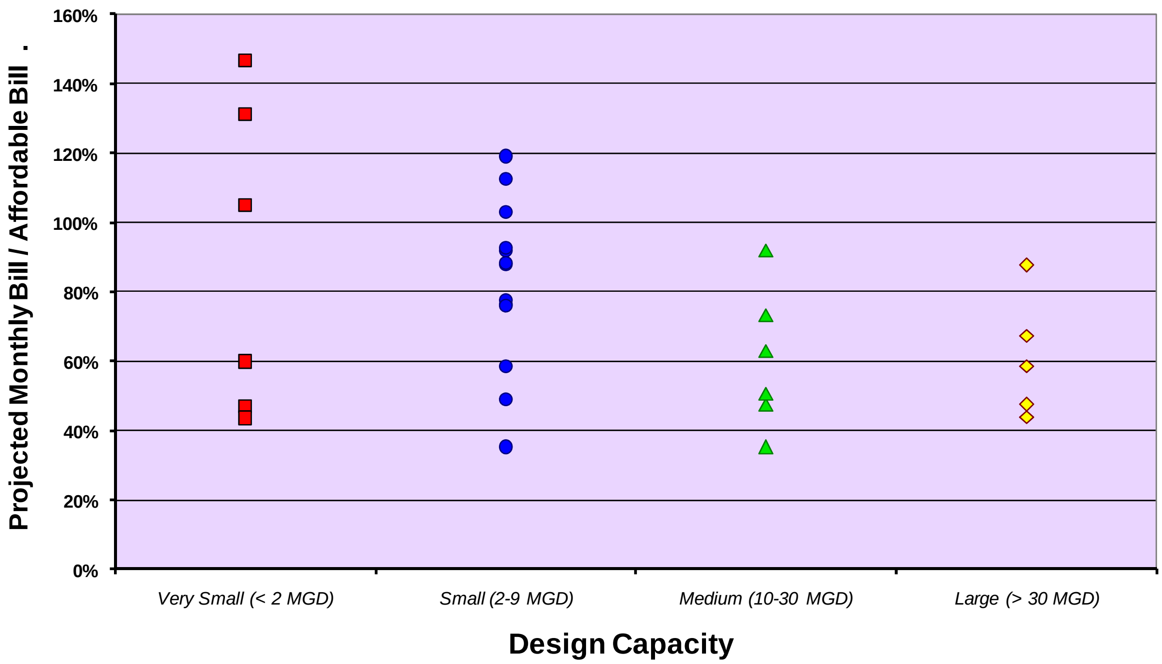


FIGURE 60
Estimated Affordability Ratio by POTW Process, Tier 2 Limit

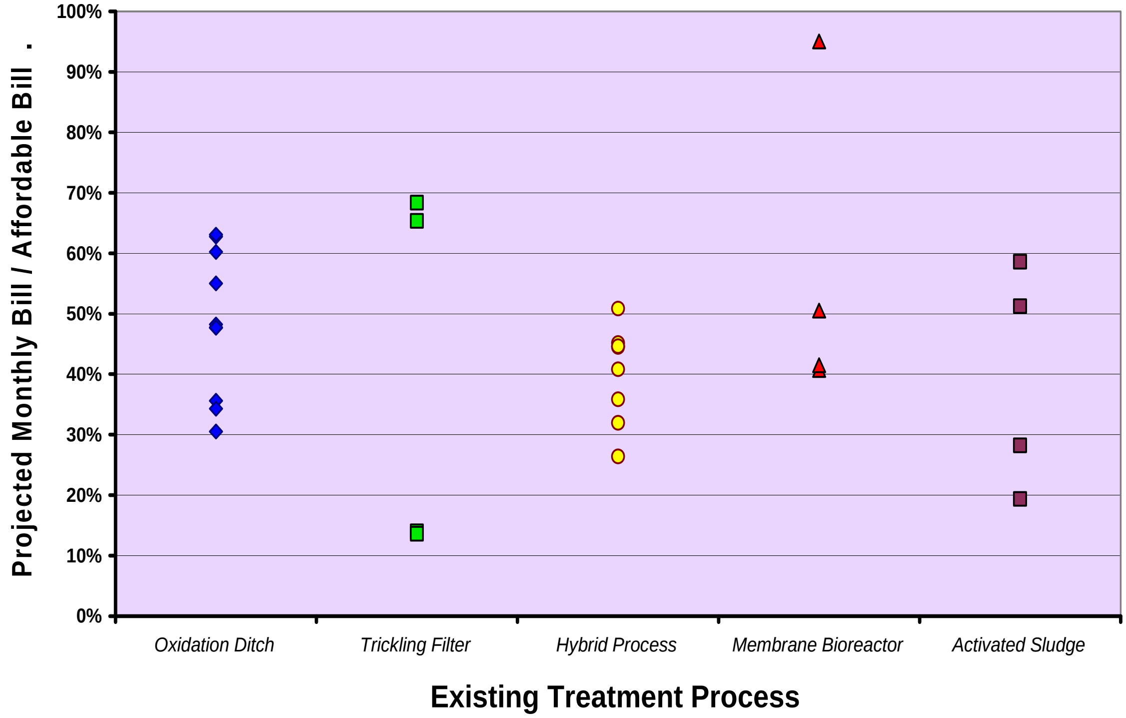


FIGURE 61
Estimated Affordability Ratio by POTW Process, Tier 2N Limit

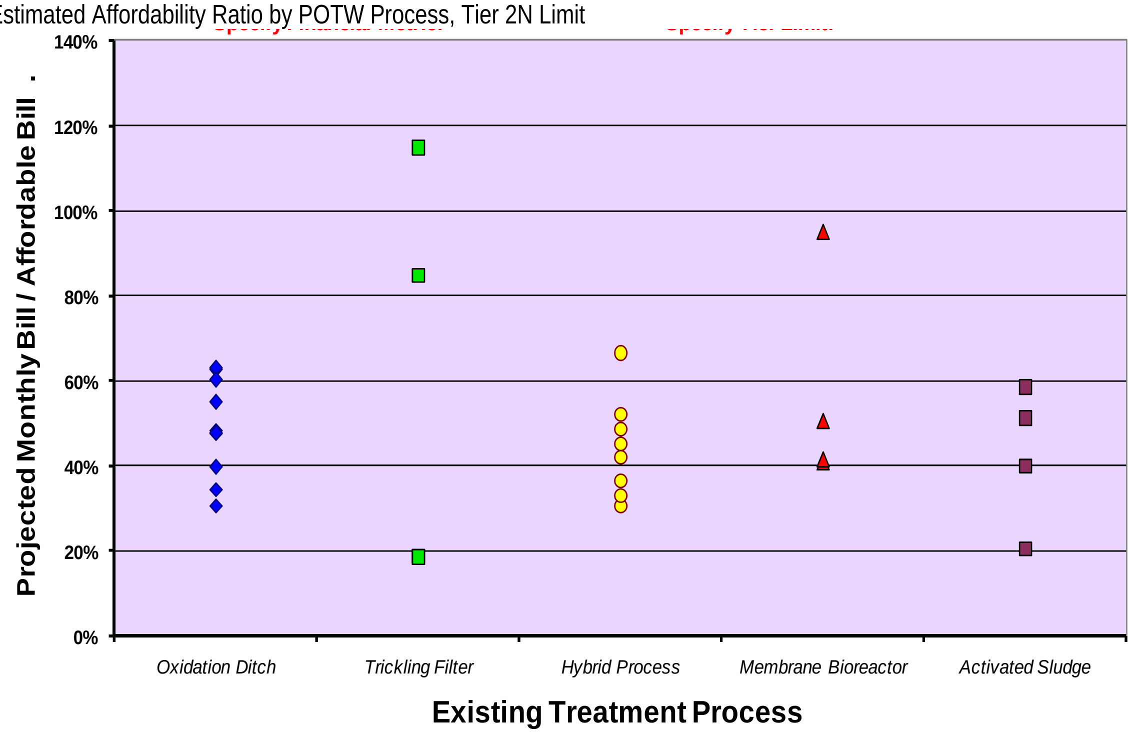


FIGURE 62
Estimated Affordability Ratio by POTW Process, Tier 1 Limit

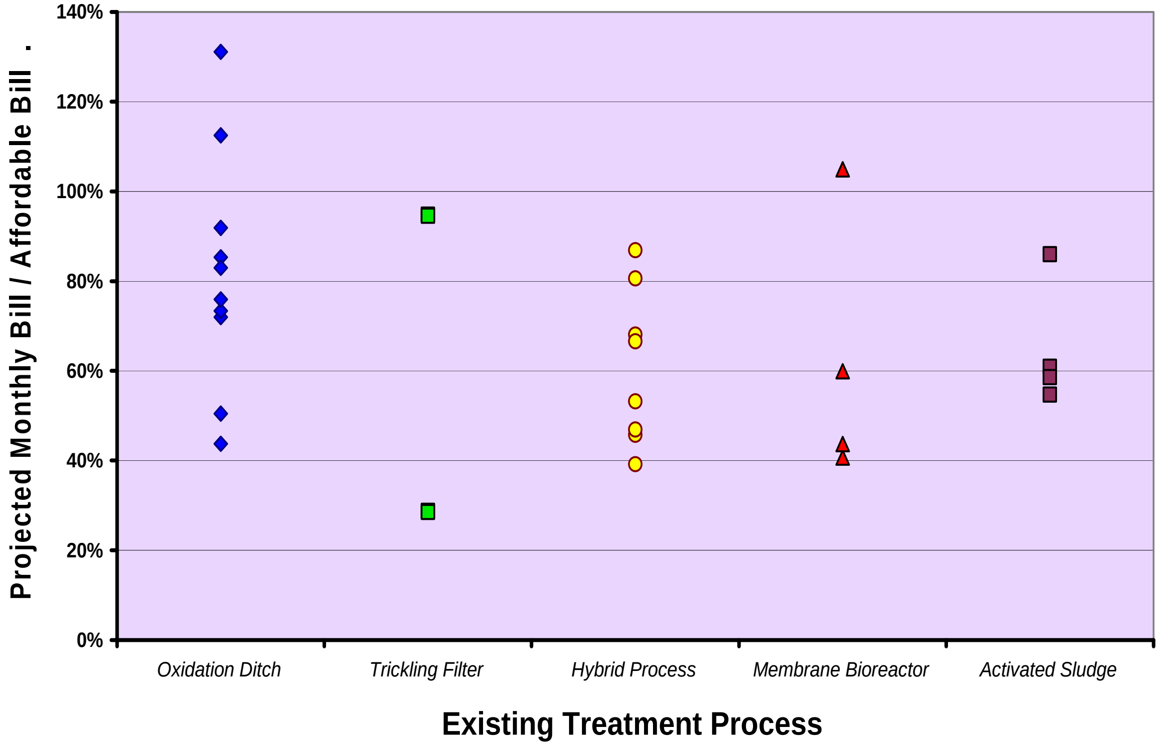
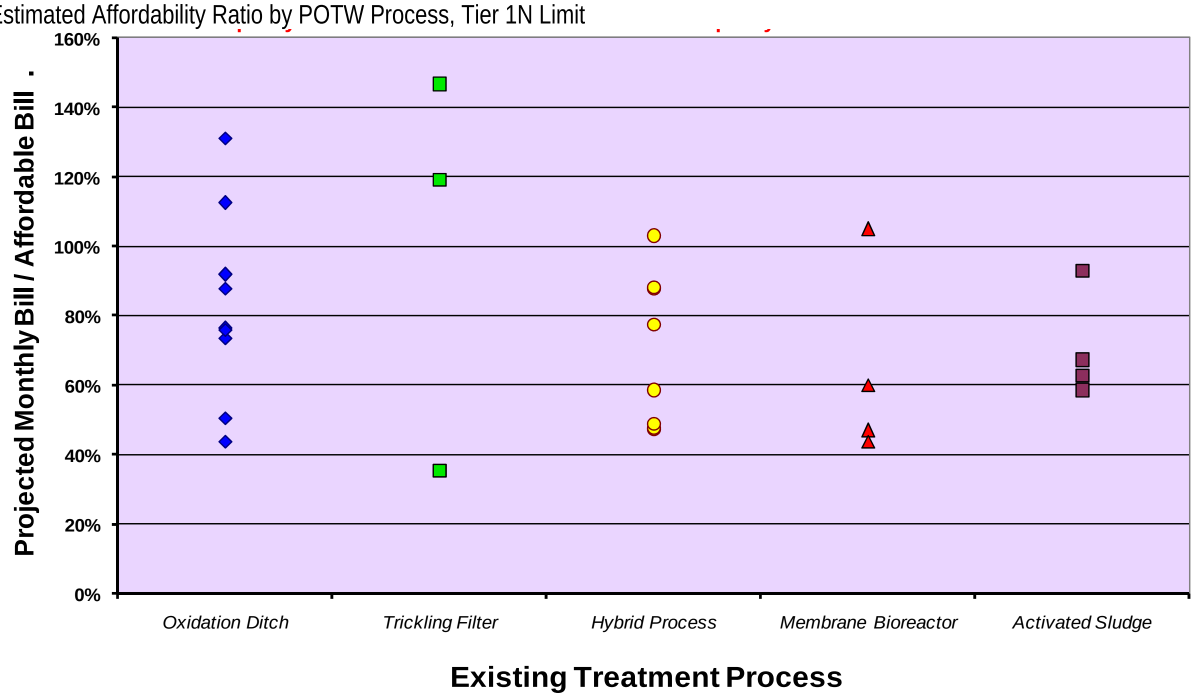


FIGURE 63
Estimated Affordability Ratio by POTW Process, Tier 1N Limit



3.8.7 Economic Model

The financial impact parameters, statewide outputs, and other important POTW parameters are contained within an economic model that is provided in Appendix 4. This model was provided to the Division. The economic model uses a Microsoft Excel format that is enhanced with Visual Basic® code to generate interactive outputs. Tabular data may be used to create new outputs and existing formats may be modified to meet the needs of the Division. The following paragraphs briefly describe the primary components of the economic model.

The first three worksheets of the model allow the Division to modify assumptions related to the analysis. As a general rule, the color of the text throughout the model indicates whether data can be updated or revised. Blue text identifies inputs or other assumptions that may be changed, while black text signals a formulaic cell that cannot be modified.

The INPUTS worksheet contains general assumptions associated with the financial calculations, including the real discount rate, debt financing terms, and the Division's affordability criterion. These inputs have all been discussed and verified with the Division but may be changed to test the sensitivity of the financial parameters to changes in assumptions.

The MAGI worksheet displays raw census data and other information provided by the Division and is used to develop the weighted average current monthly bill and MAGI estimates for each POTW.

The DATA worksheet is the primary repository for capital and O&M cost estimates, as well as other important variables such as existing and projected flow and effluent concentration. The data are organized in a tabular format, with POTWs listed alphabetically on the left side followed by the model lagoon and City of Logan lagoon at the bottom.[9]

A series of worksheets (identified by light yellow tabs) is used to extrapolate forecasts of flows and effluent concentrations across the forecast period. Nutrient load forecasts are calculated for the baseline and nutrient limit scenarios. Incremental load reduction by tiered limit is established for each year and summed across the forecast period to develop a 20-year reduction estimate. The final worksheet in this series develops a forecast of incremental O&M based on the 2009 and 2029 estimates that are recorded on the DATA worksheet.

Two worksheets perform the basic financial computations for all tabular and graphical outputs. The first worksheet, T-NPV, presents the cost forecast for each facility and tiered nutrient limit and calculates the corresponding NPV. The T-Results worksheet is a tabular summary of both intermediate outputs and all financial parameters. For example, the worksheet presents the incremental nitrogen and phosphorus load reductions by facility and tier, as well as the resulting cost per pound estimates that rely on them. The T-Results worksheet serves as a repository of results and acts as a data engine that drives many of the graphical and tabular outputs that are presented in this section.

The three worksheets labeled Table 1, Table 2, and Table 3 represent the framework that is used to present financial parameters within the TMs for each POTW. By selecting the POTW name on Table 1, a drop-down menu can be used to select a different POTW. The financial computations *for all three tables* are automatically changed to reflect the data for the chosen

9 Some of the interactive financial graphs rely on an alphabetical listing of POTWs on the DATA worksheet to function properly.

POTW. Table 1 presents life-cycle costs and cost per pound metrics. Customer financial impacts are presented in Table 2, including the projected monthly bill increase and estimated rate increase percentage. Finally, Table 3 shows the methodology and results for the affordability ratio, the metric used to estimate community financial impacts. These tables are described in greater detail in the POTW TMs.

Worksheets labeled T1-Lag, T2-Lag, and T3-Lag are the lagoon counterparts that present the financial parameters for the City of Logan and model lagoon. As with the POTW worksheets, the name of the lagoon may be changed on the T1-Lag worksheet, and financial computations for all three tables in this series are automatically changed to reflect the data for the chosen lagoon.

The remainder of the worksheets within the economic model consists of the financial parameter outputs presented as tables and figures in this report. Changes to inputs and other intermediate parameters such as cost estimates, MAGI data, ERUs, the discount rate, and other information will automatically be reflected in all tabular and graphical outputs in the economic model.

In addition, most of the outputs are interactive. For example, the highlighting associated with many of the tabular outputs can be modified by changing the limits within small tables labeled “Impact Level” at the right of the table. The appendices include interactive graphics that allow the Division to toggle between financial summaries of different tiers by using drop-down menus embedded in each chart. For Appendices B, C, and D, the Division may also specify the financial parameter and the nutrient limit that is displayed. One of the graphics, Appendix A, includes a button called “Re-Sort Costs.” If changes to costs are made, the Division can use this button to automatically update the nutrient removal efficiency curves for all tiered limits

3.9 Environmental Impacts

Potential direct environmental impacts that would result from implementing process upgrades for nutrient control were assessed, and the results from these analyses are presented in this section.

3.9.1 Reduction of Nutrient Loads/Receiving Water Concentrations

Most of the mechanical POTWs were achieving some nutrient removal with their existing infrastructure (Tier 3) but not enough to meet the four tiers of nutrient standards considered in this study. Figures 64 and 65 present the statewide total annual load reductions of phosphorus and nitrogen, respectively, under the four tiers of treatment considered in this study. Load reductions calculated for the individual mechanical POTWs are presented in the TMs.

Figures 66 and 67 present the total annual load reductions of phosphorus and nitrogen, respectively for the discharging lagoons under the four tiers of treatment. Load reductions for the “model lagoon” and the City of Logan are also presented in individual TMs.

FIGURE 64
Utah Statewide Rollup of TP Removed from All Mechanical POTWs

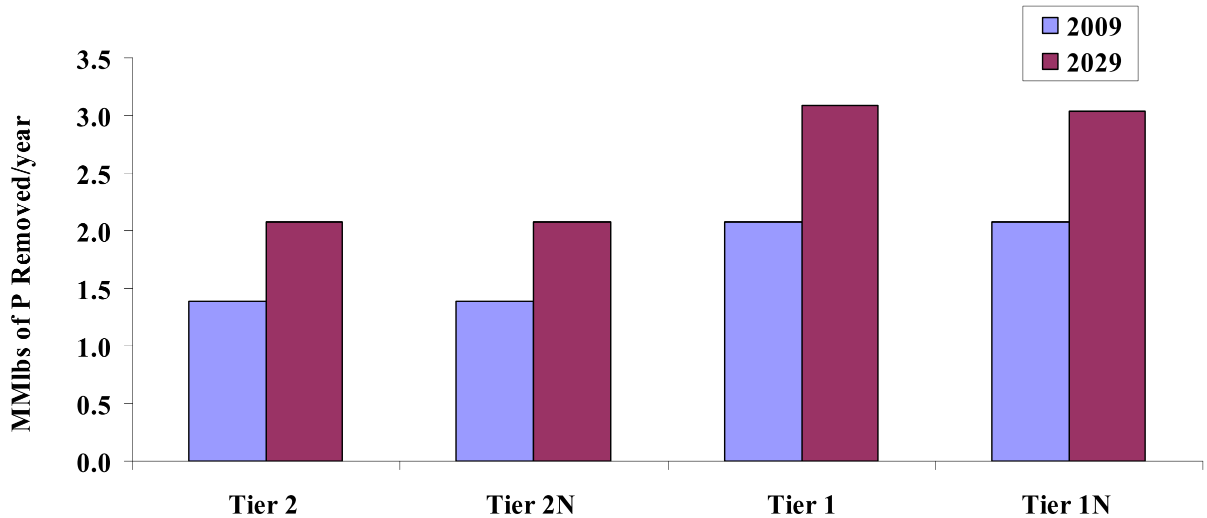


FIGURE 65
Utah Statewide Rollup of TN Removed from All Mechanical POTWs

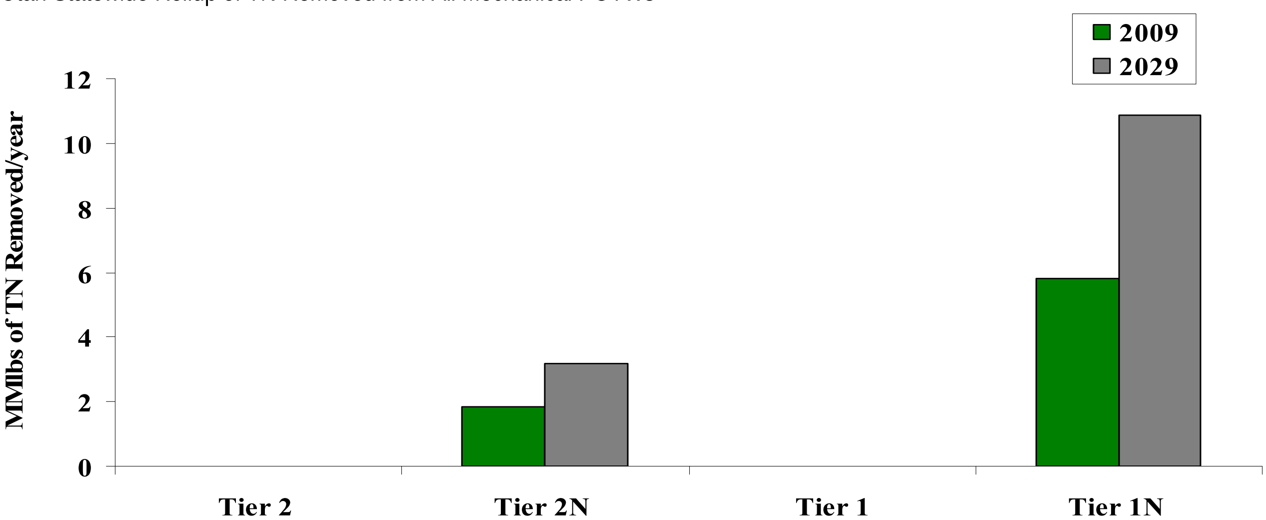


FIGURE 66
Utah Statewide Rollup of TP Removed from Discharging Lagoons

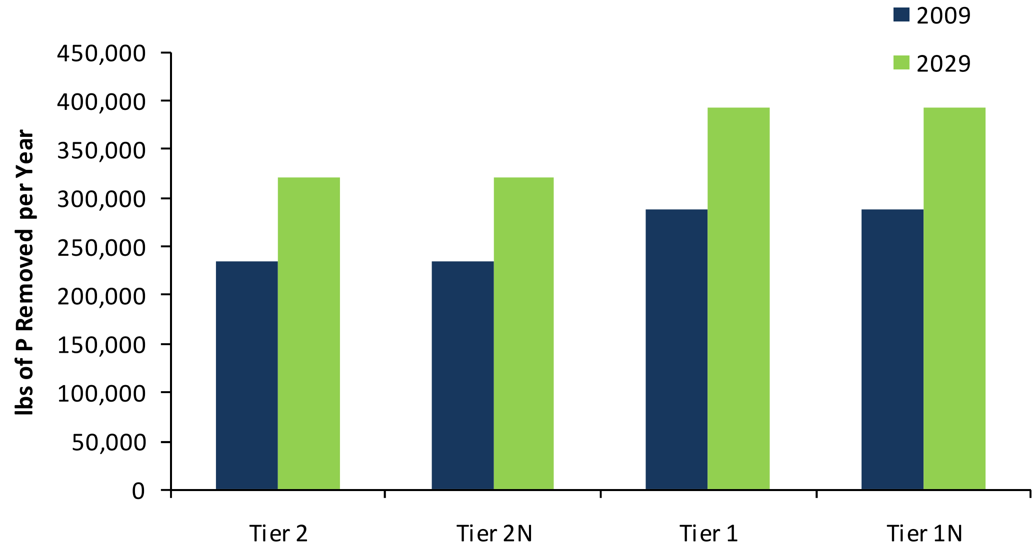
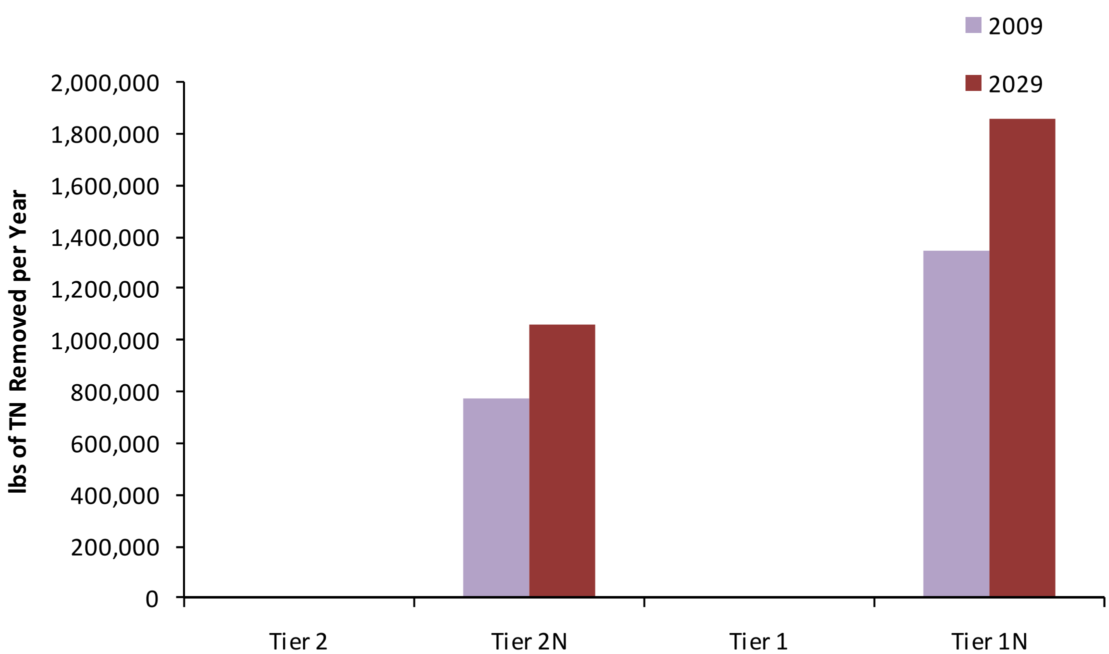


FIGURE 67
Utah Statewide Rollup of TN Removed from Discharging Lagoons



The water quality impacts expected from effluent load reductions by the POTWs were estimated using simple mass balances that were based on POTW effluent load reductions and average receiving stream loads, near the points of discharge. Table 14 summarizes the average upstream and downstream receiving water flow rates and concentrations of TN and TP from the POTW points of discharge. These stream data were paired with their corresponding POTW nutrient discharge loadings under current (baseline) and nutrient removal (tier) conditions to evaluate the stream load reductions for each tier of system upgrades. The current (2009) POTW nutrient discharge loadings were obtained from the data provided by each POTW during the survey, while the nutrient loadings for the tiers were established based on concentrations specified in Table 1 and 2009 flows. Figure 68 shows the statewide baseline in-stream nutrient concentration and the in-stream reduction in nutrient concentration for the fours tiers of nutrient standards. The individual stream loads, load reductions, and in-stream nutrient concentrations that would occur under the four tiers of nutrient standards are specified in the TM for the individual POTWs.

TABLE 14
Daily Flows and TN and TP Average Concentrations by Stream or POTW

STORET Number	Location Name/Description	Average Flow (L/day)	TN (mg/L)	TP (mg/L)
4905080	Receiving stream above City of Logan lagoons	16,272,539	0.96	0.24
4901980	Bear River below Cutler Reservoir at upper left bridge	3,060,438,029	1.21	0.14
4995250	Orem POTW*	31,570,336	10.00	1.00
4995260	Powell Slough above Orem POTW	11,098,272	2.65	1.69
4995240	Powell Slough to Utah Lake	45,154,234	–	–
4995410	Payson POTW*	4,921,036	34.00	4.10
4995420	Beer Creek above Payson POTW at U-115 crossing	45,596,320	2.79	0.46
4996560	Provo POTW*	43,910,779	23.68	4.23
4996570	Millrace Creek above Provo POTW	92,311,966	1.98	0.14
4996540	Mill Race Creek at Interstate 15 Crossing (2 miles south of Provo courthouse)	85,249,986	5.03	1.07
4996020	Spanish Fork POTW*	12,870,401	24.39	4.47
4996030	Dry Creek above Spanish Fork POTW	48,691,375	3.33	0.24
4996280	Springville POTW*	11,734,777	24.20	5.13
4996290	Spring Creek above Springville POTW	24,122,758	–	0.04
4995040	Timpanogos POTW*	53,374,309	10.00	1.00
4932370	Price POTW*	6,813,742	29.79	3.30
4932390	Price River above Price POTW at Wellington Bridge	192,691,335	1.08	0.23
4990070	North Davis POTW*	79,493,652	22.30	4.86
4990050	Unnamed ditch 1,000 feet below North Davis POTW	67,814,064	17.10	4.20
4990270	Central Davis POTW*	26,497,884	10.00	3.00
4990290	Baer Creek above Central Davis POTW	9,152,987	2.34	0.20
4991250	Salt Lake City POTW*	128,704,008	20.00	3.00
4991200	Sewage canal below Salt Lake City POTW at	–	12.17	3.49

TABLE 14
Daily Flows and TN and TP Average Concentrations by Stream or POTW

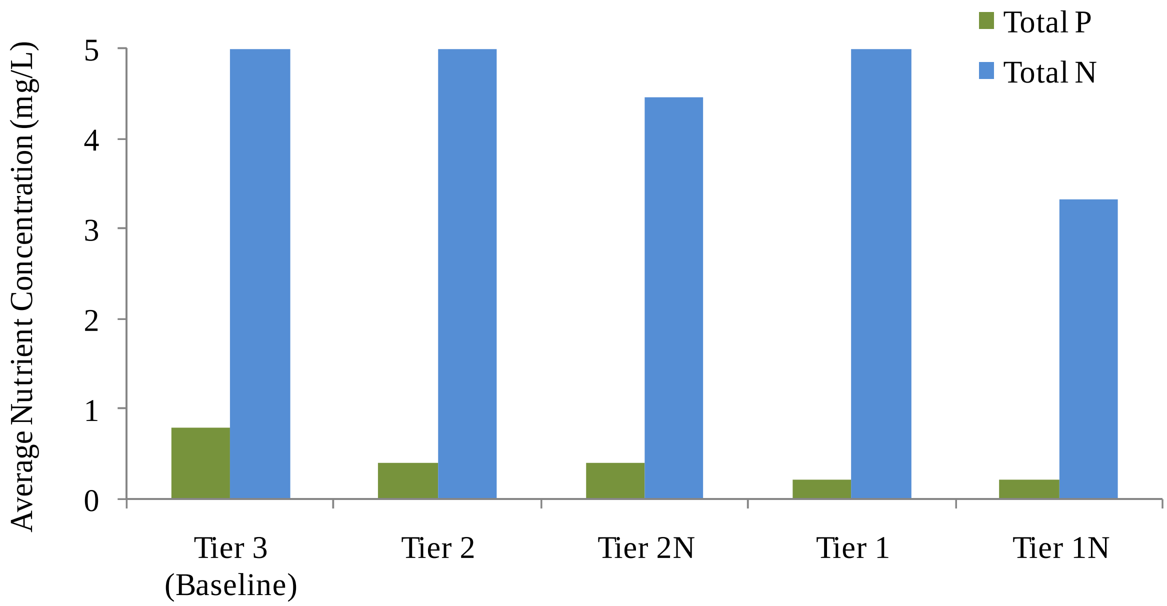
STORET Number	Location Name/Description	Average Flow (L/day)	TN (mg/L)	TP (mg/L)
	Redwood Road crossing			
4991050	Sewage canal at Cudahy Lane crossing	157,832,014	9.64	2.91
4902710	Tremonton POTW*	5,299,577	20.00	3.20
4902720	Malad River above Tremonton POTW	258,699,466	2.00	0.18
4920110	Central Weber POTW 002 above canal*	115,076,525	20.00	3.00
4920120	Weber River above Central Weber POTW	959,201,090	0.98	0.20
4990780	South Davis North POTW*	27,784,924	24.20	2.50
4990790	State Canal 100 feet above South Davis North POTW	137,350,768	2.80	0.65
4991810	South Davis South POTW*	12,491,860	23.10	2.40
4991820	Jordan River at Cudahy Lane above South Davis South POTW	444,605,183	4.38	0.88
4991800	Jordan River 1,000 feet below South Davis POTW	152,421,675	4.34	0.66
4926770	Silver Creek at Ranch Exit	24,287,001	1.17	0.36
4926800	Silver Creek above Silver Creek POTW east of Triumph Gear Co.	13,130,666	0.63	0.23
4994160	South Valley POTW*	121,133,184	10.00	1.00
4994170	Jordan River at 7800 South crossing above South Valley POTW	589,037,157	1.69	0.08
4950060	St. George POTW*	33,690,167	10.00	1.05
4950020	Virgin River below first narrows and new St. George POTW	510,440,409	1.97	0.49
4950120	Virgin River at Bloomington crossing above St. George POTW	645,329,562	1.15	0.21
4960300	Tooele POTW outfall*	6,813,742	10.00	1.00
4901200	Brigham City POTW*	5,299,577	20.00	3.00
4901190	Box Elder Creek above Brigham City POTW	55,282,014	1.02	0.08
4901180	Box Elder Creek below Brigham City POTW at Forest Road Crossing	54,099,820	2.61	0.76
4940420	Cedar City POTW*	9,463,530	31.00	4.23
4992500	Central Valley POTW*	185,485,188	27.50	3.37
4992540	Mill Creek above Central Valley POTW at 300 West	92,045,675	1.48	0.10
4926320	Coalville POTW*	719,228	10.00	1.00

TABLE 14
Daily Flows and TN and TP Average Concentrations by Stream or POTW

STORET Number	Location Name/Description	Average Flow (L/day)	TN (mg/L)	TP (mg/L)
4925960	Weber River above the confluence of Lost Creek	387,523,423	0.33	0.05
4926330	Chalk Creek above Coalville POTW	–	0.59	0.12
4925260	East Canyon Creek above East Canyon POTW	80,817,761	0.47	0.12
4925240	East Canyon Creek below East Canyon POTW	105,075,573	1.44	0.39
4946830	Fairview POTW*	264,979	10.00	1.00
4946840	San Pitch River above Fairview POTW at restoration project	25,622,485	0.98	0.02
4905520	Hyrum POTW*	3,141,892	12.00	0.10
4905510	Curtis Creek above Hardware Ranch at road crossing	23,424,944	0.16	0.03
4991640	Magna POTW*	8,706,448	20.00	3.40
4991650	Kersey Creek above Magna POTW	5,639,751	3.00	0.22
4956550	Moab POTW*	3,406,871	37.00	3.37
4956540	Colorado River below Moab POTW	16,277,194,529	1.11	0.16
4946970	Moroni POTW*	2,271,247	10.00	1.00
4946960	San Pitch River above Moroni POTW	79,520,735	1.41	0.15
4928010	Oakley POTW 002 new plant*	378,541	10.00	1.00
4928030	Weber River above Oakley Lagoons	330,287,738	0.68	0.11

NOTES:
L = liter(s)
*POTW data are taken from the 2009 survey forms submitted by each POTW during data collection.

FIGURE 68
Utah Statewide Rollup of TP and TN Removed from All Mechanical POTWs Based on Year 2009



Nutrient load reductions were also evaluated on a "regional" basis for three major water systems in the state, listed below. The nutrient load reduction estimates were computed from cumulative loads and tier-based load reductions based on 2009 flows, then converted to in-stream concentrations. The percent in nutrient load reductions from the baseline conditions are shown in the following figures:

- **Jordan River:** South Valley, Central Valley, and South Davis POTWs (Figure 69)
- **Utah Lake:** Provo, Orem, Springville, Spanish Fork, Payson, and Timpanogos POTWs (Figure 70)
- **Colorado River:** Moab POTW (Figure 71)

Table 15 presents the resulting nutrient concentrations expected in the above receiving waters after treatment upgrades are implemented at each tier.

Note that Tier 1 treatments provide higher nutrient removals for TN and TP than the Tier 2 treatments. Also note that the tremendous dilution of the Colorado River results in little change in concentrations among treatment tiers from the Moab plant; all values are within 1 percent of the baseline condition (Figure 3).

FIGURE 69
Percentage Reductions from Baseline Jordan River Loads of TN or TP as Are Likely by Implementing Tiers of Alternatives

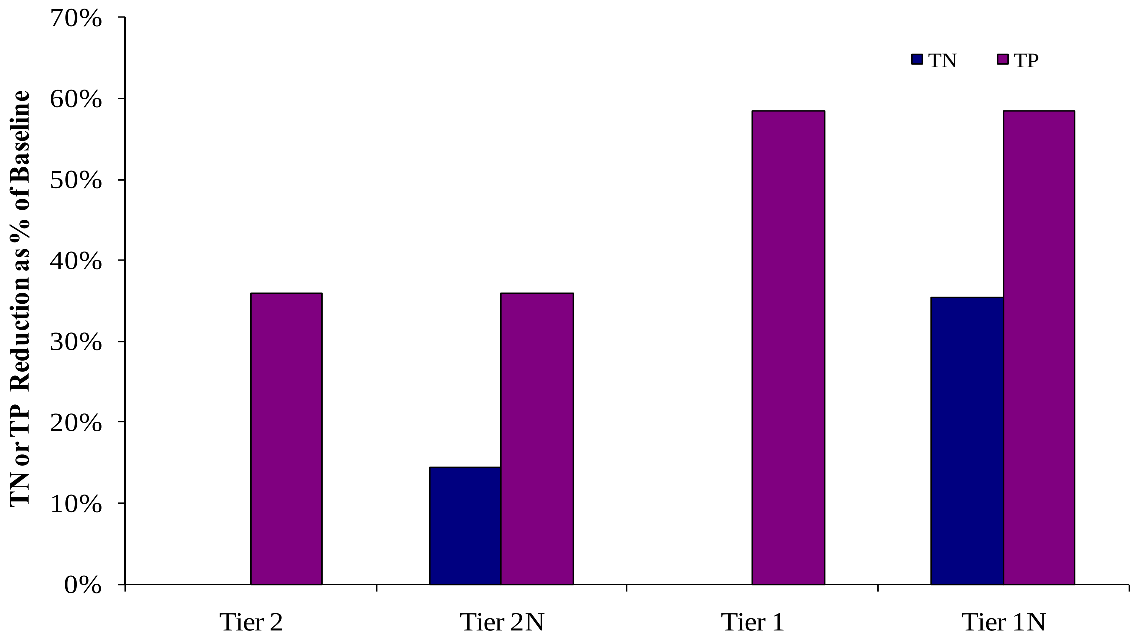


FIGURE 70
Percentage Reductions from Baseline Utah Lake Loads of TN or TP as Are Likely by Implementing Tiers of Alternatives

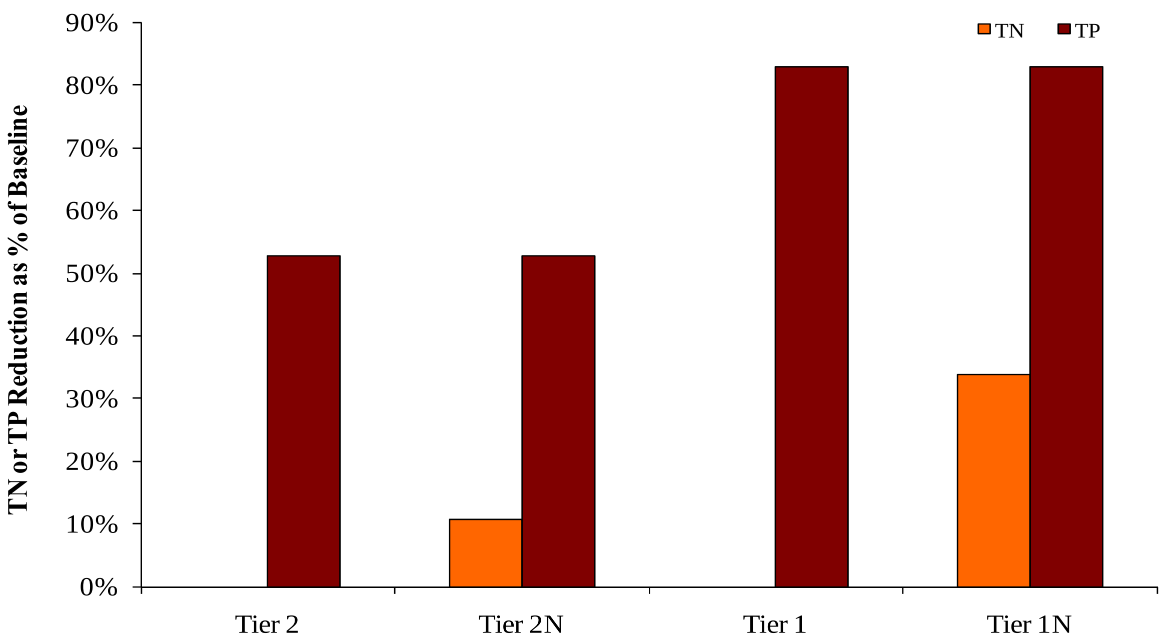


FIGURE 71
Percentage Reductions from Baseline Colorado River at Moab Loads of TN or TP as Are Likely by Implementing Tiers of Alternatives

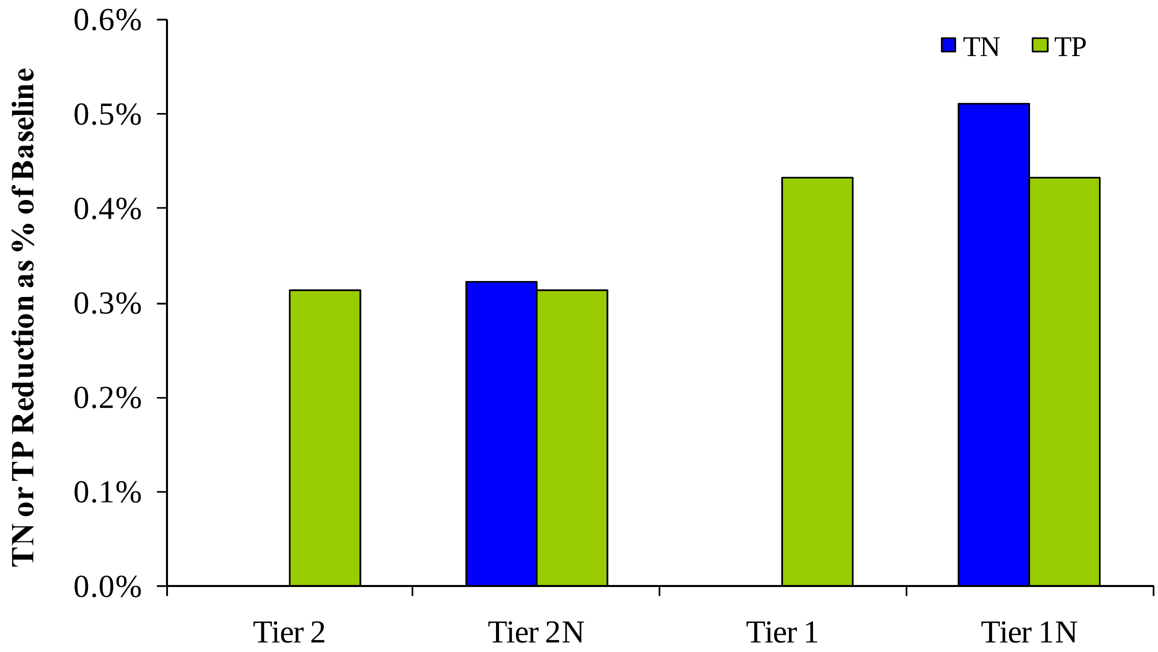


TABLE 15
Estimates of Average TN and TP Concentrations for Baseline and Cumulative Treatments to Receiving Waters (mg/L)

Receiving Water	Baseline	Tier 2	Tier 2N	Tier 1	Tier 1N
Jordan River					
TN	6.670		5.710		4.317
TP	0.861	0.551	0.551	0.357	0.357
Utah Lake					
TN	8.308		7.424		5.492
TP	1.247	0.589	0.589	0.214	0.214
Colorado River at Moab					
TN	1.105		1.101		1.099
TP	0.159	0.158	0.158	0.158	0.158

NOTE: Concentrations shown for Utah Lake represent the average concentration in the aggregate of inputs from six POTWs and their respective receiving streams. Lake and lake output concentrations are affected by physical, chemical, and biological reactions and interactions. As a result input values shown are not directly comparable with the lake concentrations.

The process upgrades identified in this report to meet the four tiers of nutrient standards would result in increased chemical and energy consumption and increased biosolids production. These environmental impacts are summarized in the following sections. The individual TMs provided in Appendix 2 summarize the environmental impacts of implementing the process upgrades to achieve the various tiers of nutrient control for each facility.

3.9.2 Energy Consumption

The process upgrades established for each mechanical and lagoon POTW to meet the four tiers of nutrient standards require increased energy consumptions. Additional energy is required to meet the increased aeration demands for nitrification and for the operation of mixers, mixed liquor recirculation pumps, secondary effluent pumps, and the deep-bed gravity filtration system. A statewide rollup of the additional energy required by the mechanical POTWs is shown in Figure 72 based on 2009 flows and loads, and the rollup of the discharging lagoons is shown in Figure 73. The individual TMs in Appendix 2 present additional energy consumptions calculated for the individual mechanical POTWs and model and Logan lagoons.

FIGURE 72
Utah Statewide Rollup for Additional Energy Required for Meeting the Four Tiers of Nutrient Standards for Mechanical POTWs

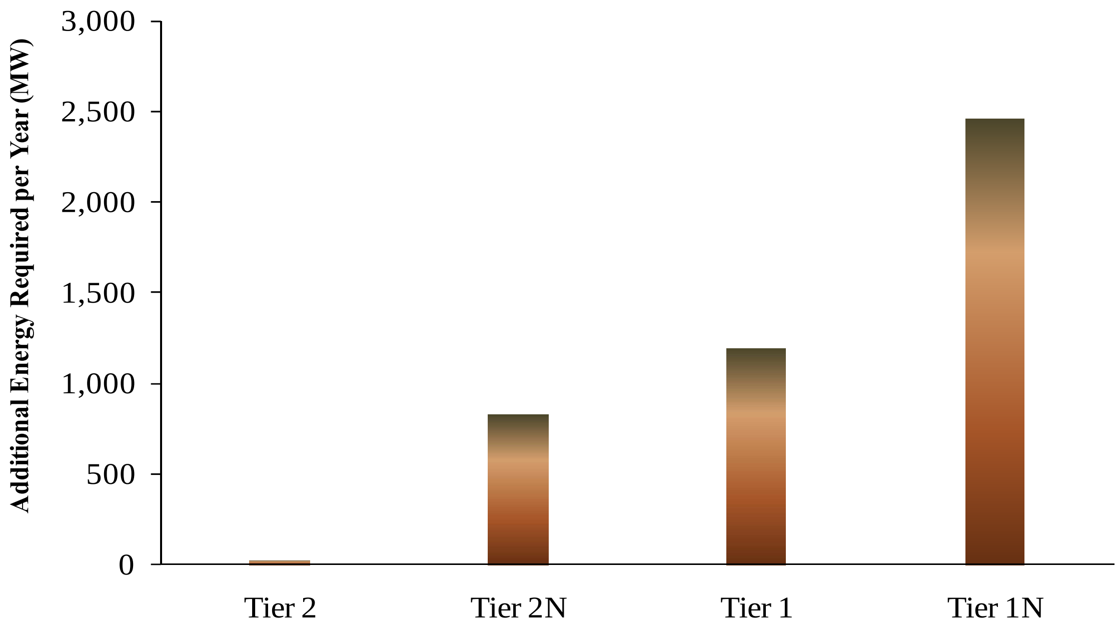
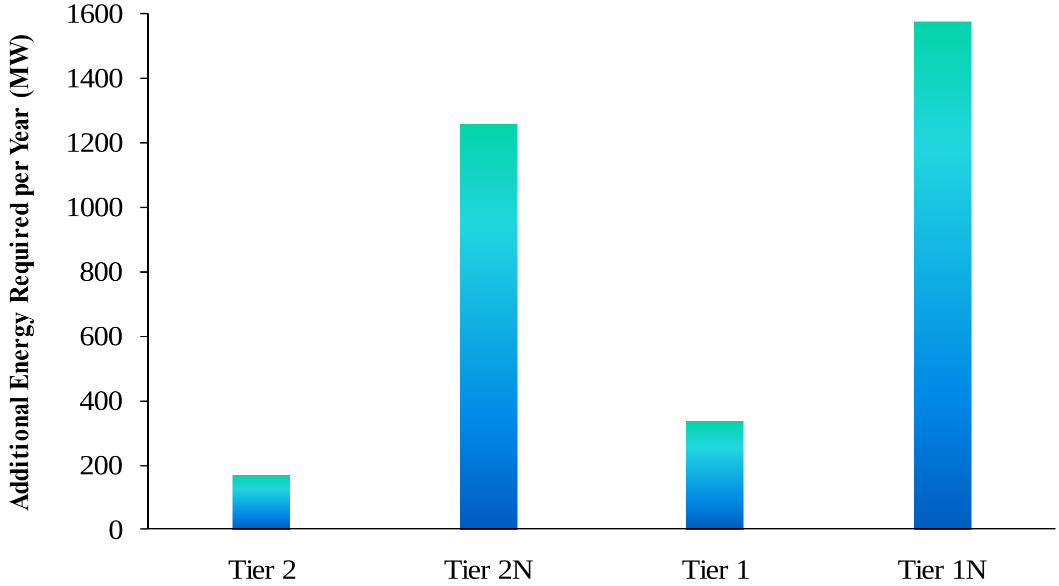


FIGURE 73
Rollup for Additional Energy Required for Meeting the Four Tiers of Nutrient Standards for Discharging Lagoon



3.9.3 Increased Air Emissions

Increased energy consumption due to process upgrades will require more offsite electricity generation. This will result in additional air emissions of carbon dioxide (CO_2), nitrogen oxide (NO_x), and particulate matters (PM). Additional air emissions will also result from increased biosolids hauling, as process upgrades will require metal-salt addition for chemical phosphorus removal, thus generating increased chemical sludge. Figures 74, 75, and 76 show the statewide rollup of additional CO_2, NO_x, and PM emissions respectively, for the mechanical POTWs, based on 2009 flows and loads. Figures 77, 78, and 79 show the air emissions from the discharging lagoons. Air emissions calculated for the individual mechanical POTWs and the model and Logan lagoons are presented in the individual TMs in Appendix 2.

FIGURE 74
Utah Statewide Rollup for Additional CO_2 Emissions from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Mechanical POTW

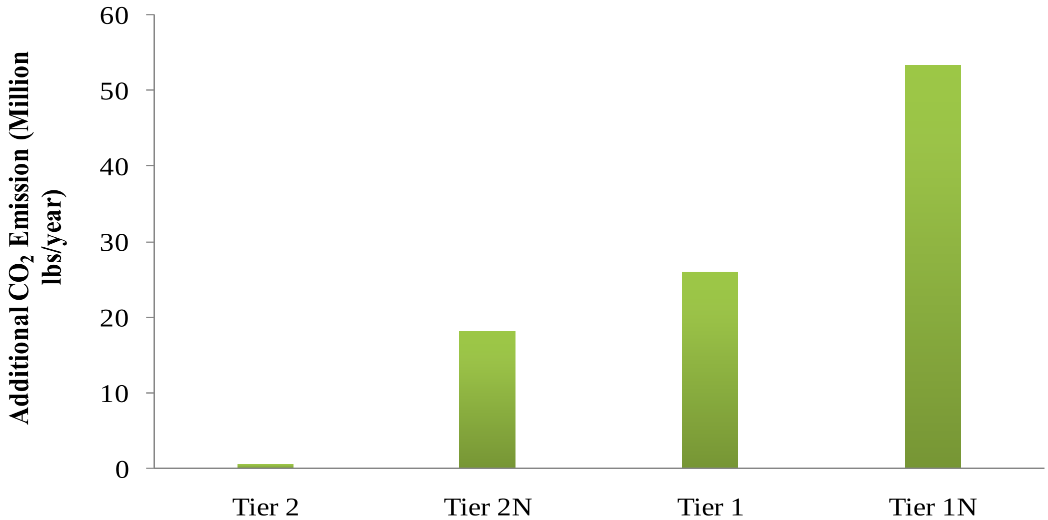


FIGURE 75
Utah Statewide Rollup for Additional NO_x Emissions from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Mechanical POTW

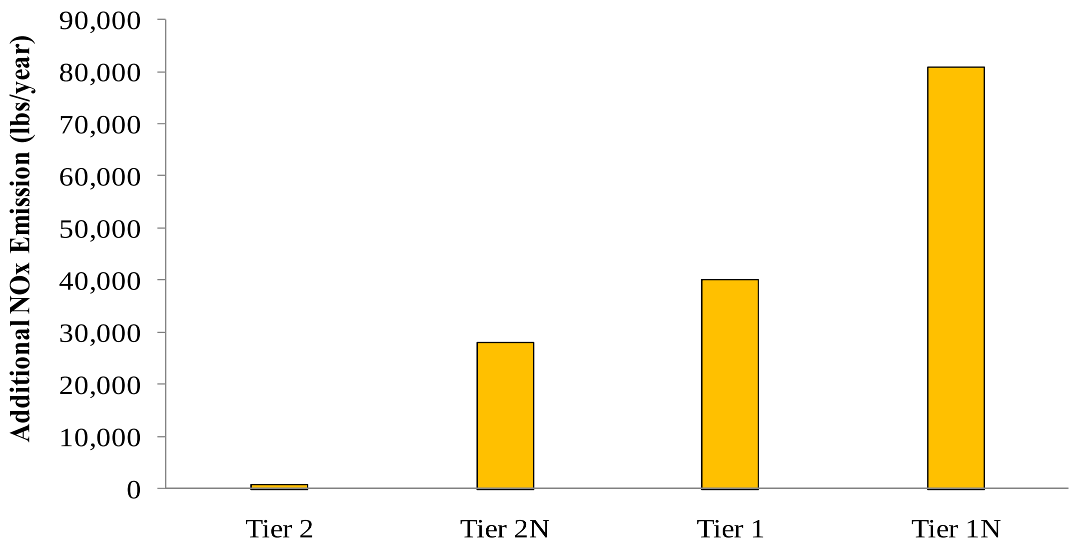


FIGURE 76
Utah Statewide Rollup for Additional PM Emissions from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Mechanical POTW

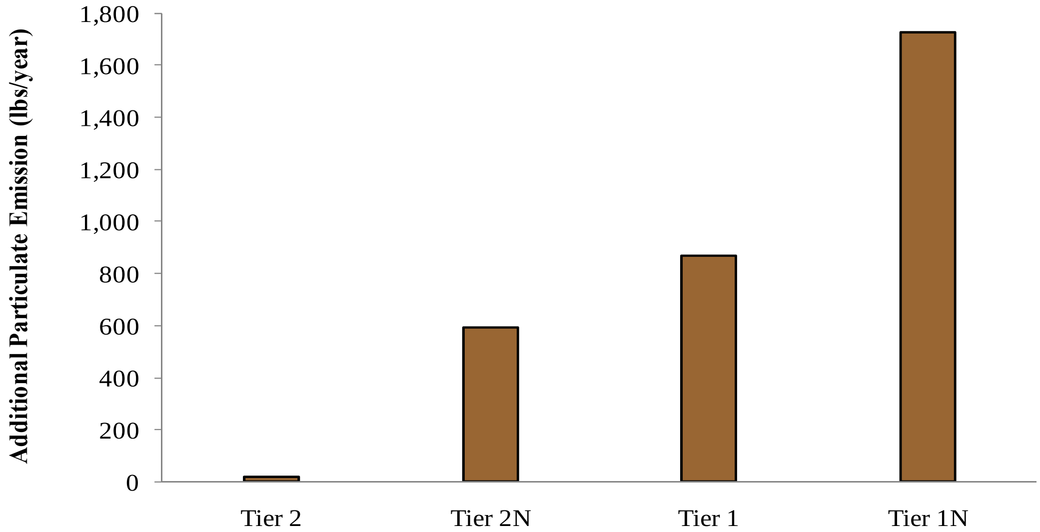


FIGURE 77
Rollup for Additional CO_2 Emissions from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Discharging Lagoons

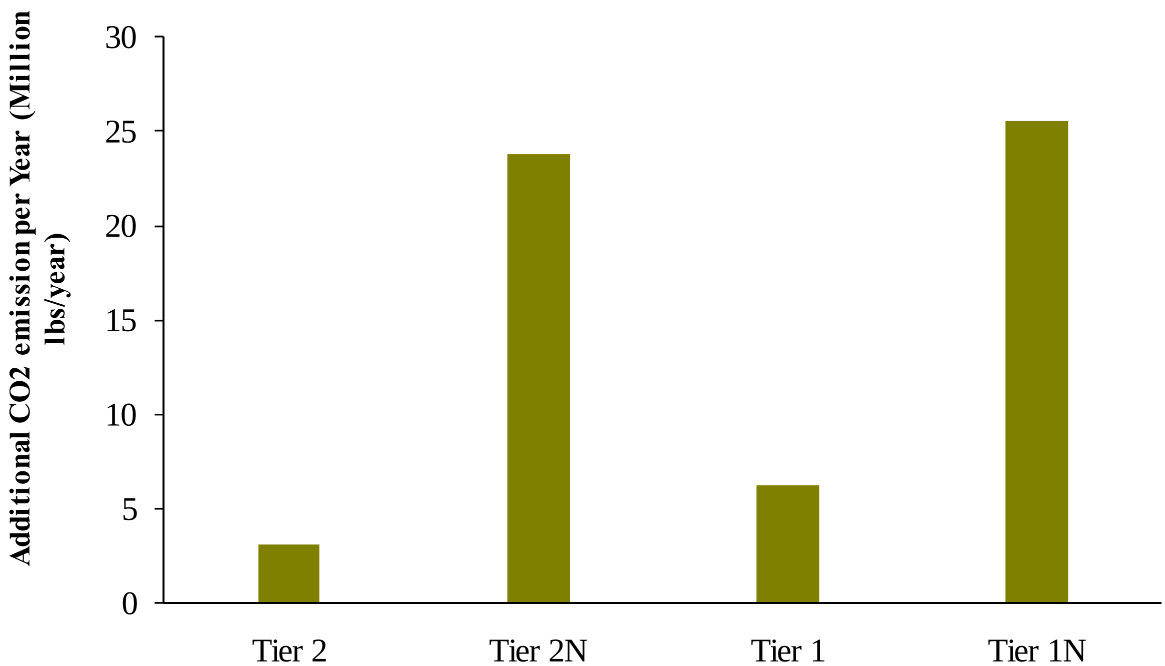


FIGURE 78
Rollup for Additional NO_x Emissions from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Discharging Lagoons

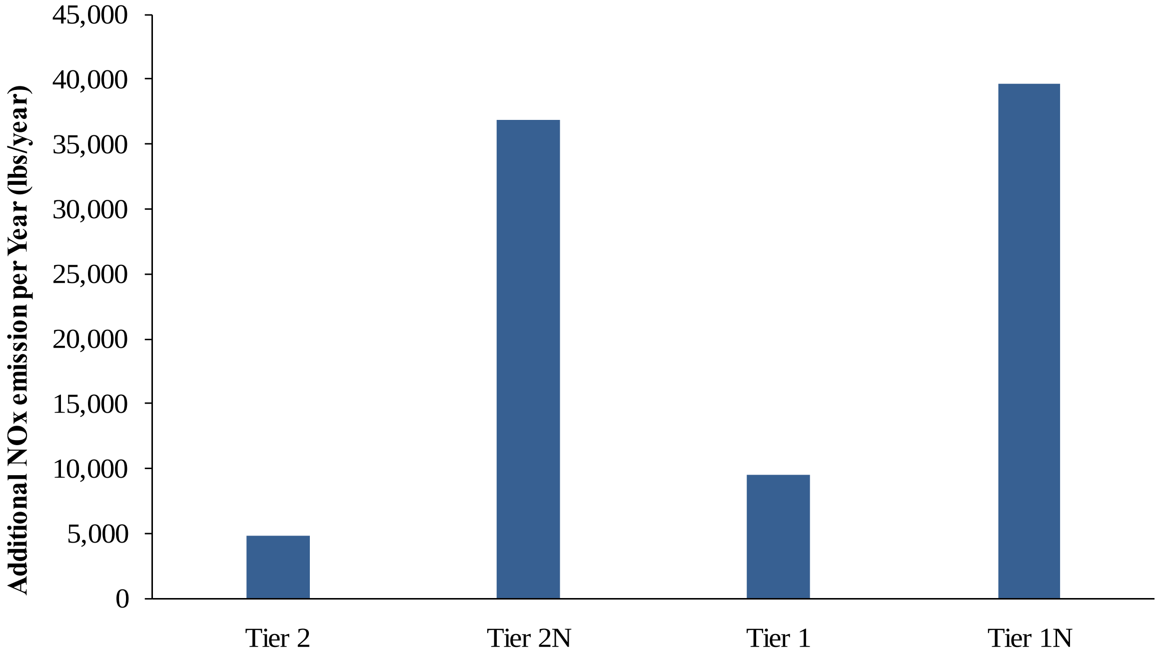
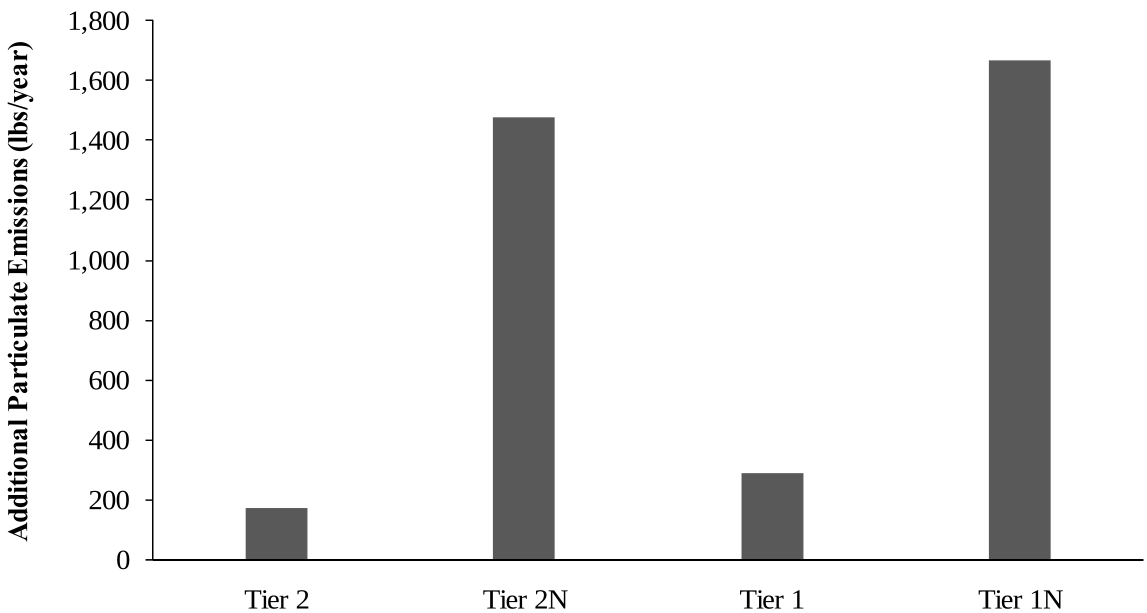


FIGURE 79
Rollup for Additional PM Emissions from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Discharging Lagoons



3.9.4 Increased Biosolids Production

Additional metal-salts will be used in the future to meet the phosphorus limits specified in Table 1. This will result in an overall increase in chemical sludge and, consequently, more biosolids production. Figure 80 shows the statewide rollup of additional biosolids generated for the mechanical POTWs, based on 2009 flows and loads. Figure 81 shows the same for the discharging lagoons. Increase in biosolids generation calculated for the individual mechanical POTWs and for the model and Logan lagoons are presented in the individual TMs provided in Appendix 2.

FIGURE 80
Utah Statewide Rollup for Additional Biosolids from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Mechanical POTW

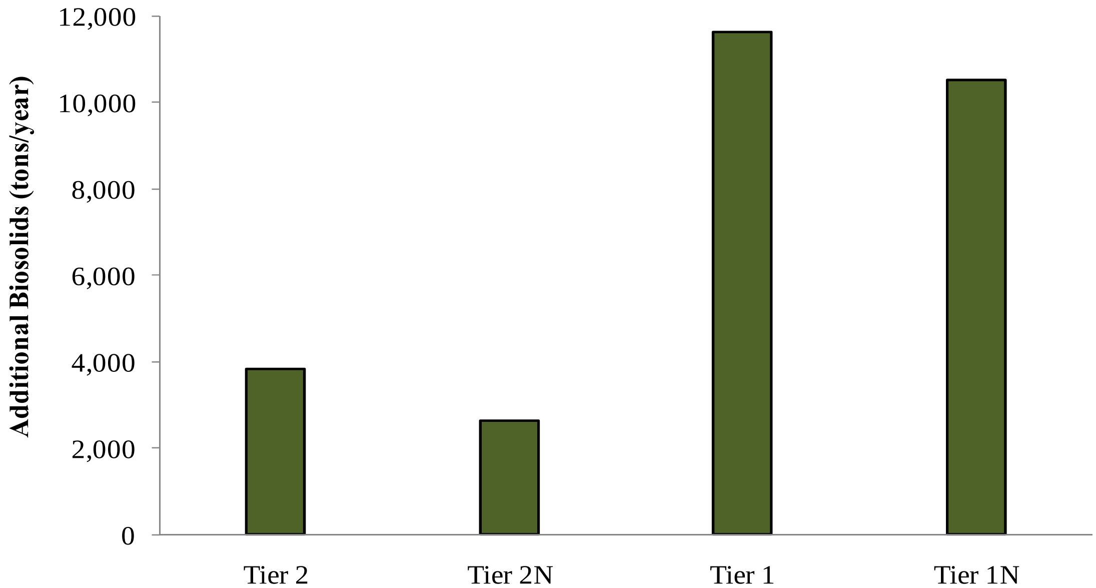
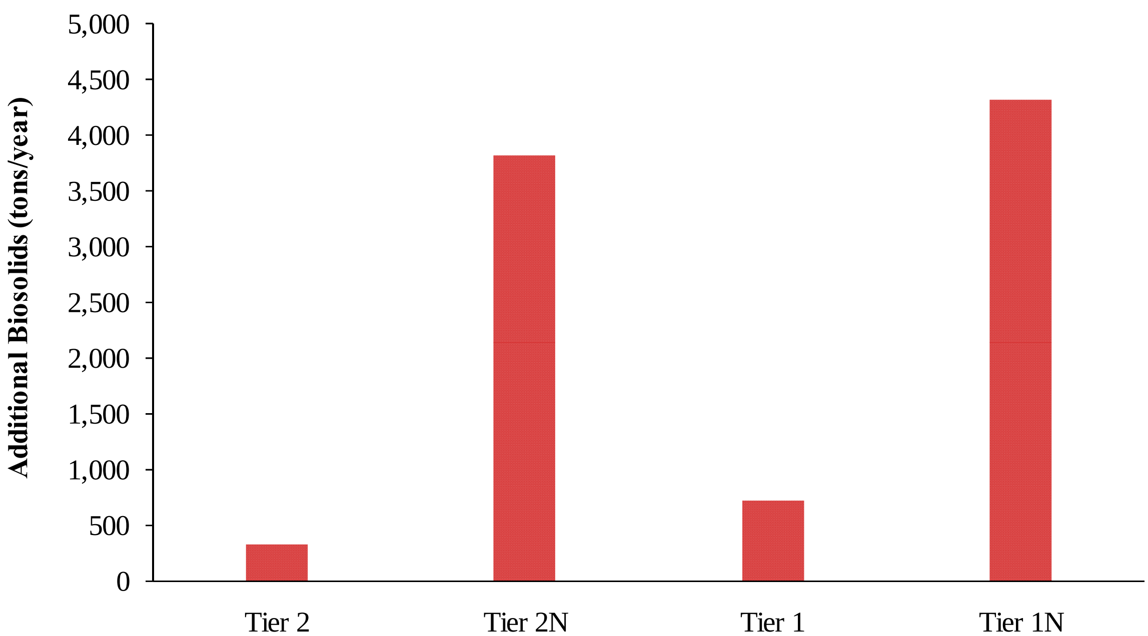


FIGURE 81
Rollup for Additional Biosolids from Process Upgrades for Meeting the Four Tiers of Nutrient Standards for Discharging Lagoons



3.9.5 Other Potential Impacts

In addition to the environmental impacts reviewed, other effects from nutrient discharge standards could impact the operations and costs of wastewater treatment. Other potential impacts to POTWs could include the following:

- Higher phosphorus content in treatment plant sludge could cause or exacerbate struvite problems in plant. Struvite, or magnesium ammonium phosphate hexahydrate, is a mineral that often precipitates from wastewater during anaerobic digestion where high concentrations of dissolved orthophosphates, ammonia, and magnesium ions are encountered. Typically, struvite formation is detrimental since it clogs pipes, reduces efficiency in heat exchangers, and restricts flow in surface aerators. This could cause increased operational problems; however, its evaluation is beyond the scope of the study.
- Higher phosphorus in biosolids could lead to additional land requirements for POTWs that apply residuals on land. This could occur where land application processes are limited to agronomic loading rates for phosphorus. North Davis Sewer District raised this concern in one of the stakeholder meetings.
- With chemical precipitation of phosphorus, heavy metals may co-precipitate. Metals co-precipitation would lead to higher loading of heavy metals in the biosolids; however, the mass of metal salt would be greater than the increased amount of heavy metals precipitated. The increased metal-salt load would probably attenuate the increase in heavy metals, so it is unlikely that the POTW would exceed specific heavy metal concentrations in biosolids. An increase in land may be required to account for the overall increase in sludge production due to the presence of metal-salts.
- With increased biosolids hauling, more criteria air pollutants will be emitted from this activity. See Appendix 2 for more detail on criteria air pollutants.

4.0 Conclusions

This study was commissioned by the Utah Water Quality Board to develop an understanding of the potential economic impacts that could result from promulgation of wastewater discharge standards for nitrogen and phosphorus in Utah, to support the state's POTWs with technical and economic information about nutrient treatment in their facilities, and to develop management tools for analysis. The study was successful in meeting each of these goals.

A management tool was developed by the project containing a repository of electronic data, financial impact calculations, and interactive graphics that will be useful as the Division continues to study the potential impacts of nutrient effluent limits. As more accurate data become available, and further studies are conducted, the tool can be used to efficiently update the financial parameters for specific POTWs and other statewide metrics.

The study analyzed the wastewater treatment requirements that would need to be implemented in Utah if statewide nutrient standards were established for wastewater discharges to waters of the state. The study encompassed a broad range of nutrient standards aimed at establishing an understanding of the system upgrade costs, the types of technologies that would be needed, and the manner in which technologies might be integrated in the state's POTWs to achieve measured and effective nutrient control. The study also examined the potential direct effects of nutrient standards on the state's environmental resources. It estimated the mass of nutrients that could be removed from waters of the state and the resulting nutrient concentrations in the corresponding receiving waters. Further, the study examined the potential increase in biosolids disposal requirements, chemicals usage, energy consumption, and air pollution emissions. It will be important for the State of Utah to consider these other environmental impacts when assessing the need for nutrient pollution controls.

Specific conclusions from the project, based on the study results presented previously, are as follows.

1. The following total statewide capital costs for mechanical POTWs process upgrades were needed to meet the nutrient standards established for this study:

    a. Tier 2 nutrient control $24 million
    b. Tier 2N nutrient control $142 million
    c. Tier 1 nutrient control $818 million
    d. Tier 1N nutrient control $1.04 billion

2. The following total statewide capital costs for lagoon POTWs process upgrades were needed to meet the nutrient standards established for this study:

    a. Tier 2 nutrient control $30 million
    b. Tier 2N nutrient control $239 million
    c. Tier 1 nutrient control $159 million
    d. Tier 1N nutrient control $383 million

3. The capital costs, along with the O&M costs and a performance period of 20 years, were used to estimate the NPV of each mechanical plant upgrade at each tier of nutrient control. The following were the statewide NPVs for all of the process upgrades:
    a. Tier 2 total NPV for all mechanical POTWs $114 million
    b. Tier 2N total NPV for all mechanical POTWs $233 million
    c. Tier 1 total NPV for all mechanical POTWs $1,089 million
    d. Tier 1N total NPV for all mechanical POTWs $1,352 million
4. The statewide NPVs for all of the process upgrades for the discharging lagoons are as follows:
    a. Tier 2 total NPV for all discharging lagoons $51 million
    b. Tier 2N total NPV for all discharging lagoons $289 million
    c. Tier 1 total NPV for all discharging lagoons $198 million
    d. Tier 1N total NPV for all discharging lagoons $450 million
5. The costs for process upgrades would increase the monthly bill for the typical Utah residential customer. The average monthly user rate increases for nutrient control in mechanical POTWs would be as follows:
    a. Tier 2 average monthly bill increase $1.19/month
    b. Tier 2N average monthly bill increase $2.97/month
    c. Tier 1 average monthly bill increase $12.41/month
    d. Tier 1N average monthly bill increase $15.30/month
6. The average monthly user rate increases for nutrient control in the small discharging lagoons would be as follows (does not include City of Logan):
    a. Tier 2 average monthly bill increase $5.65/month
    b. Tier 2N average monthly bill increase $29.06/month
    c. Tier 1 average monthly bill increase $22.51/month
    d. Tier 1N average monthly bill increase $47.09/month
7. The estimated monthly bill increases translate into the following average expected rate increases for the mechanical POTWs: 7.1 percent for Tier 2, 18.4 percent for Tier 2N, 73.9 percent for Tier 1, and 92.1 percent for Tier 1N. These percentages neglect user costs through property tax collections, where applicable. In these cases, the percentage shown is an overestimate of the actual rate increase.
8. The estimated average expected rate increases for the small discharging lagoons will be as follows: 31 percent for Tier 2, 158 percent for Tier 2N, 123 percent for Tier 1, and 256 percent for Tier 1N.
9. The affordability criterion from Utah's State Revolving Fund (SRF) was used to evaluate the relative affordability of each POTW upgrade and for each tier of nutrient standard. This analysis found that, for the mechanical POTWs, on average, the projected monthly bill would be 45 percent of the affordable bill for Tier 2; 49 percent of the affordable bill for Tier 2N; 69 percent of the affordable bill for Tier 1; and 76 percent of the affordable bill for Tier 1N. These percentages neglect user costs through property tax collections,

where applicable. In these cases, the percentage shown overstates the affordability of the system upgrades.

10. The relative affordability of the small discharge lagoons were also evaluated, and on an average the projected monthly bill would be 55 percent of the affordable bill for Tier 2; 108 percent of the affordable bill for Tier 2N; 93 percent of the affordable bill for Tier 1; and 149 percent of the affordable bill for Tier 1N.
11. The capital cost for meeting Tier 2 and Tier 2N are relatively inexpensive for most mechanical POTWs in Utah. At these levels, the rate impacts were also reasonable and affordable. Many of Utah's mechanical POTWs can meet the Tier 2 level TP limits of 1 mg/L simply by adding metal-salts to a mixing zone ahead of the existing secondary clarifiers.
12. The capital costs to meet Tier 1 and Tier 1N levels for mechanical POTWs were much higher, driven primarily by the addition of deep-bed filters to all POTWs that did not have an existing tertiary filtration system. At these levels, the rate impacts were mixed, and, in several cases, new user rates exceeded the State's affordability criterion for plants. These plants were typically ones that that serve small populations or have relatively low median annual gross household incomes.
13. The capital cost for meeting Tier 2 for all the discharging lagoons in Utah were relatively inexpensive. At this level, the rate impacts were also reasonable and affordable. For Tier 1, the cost was much higher primarily because of the addition of deep-bed filters. However the new user rates were within the State's affordability criterion for the plants.
14. The capital costs for meeting Tier 2N, Tier 1 and Tier 1N for discharging lagoons were significantly higher. This was because, for these Tiers, new mechanical plants and/or filters were proposed in place of the existing lagoons. At these levels, the new user rates exceeded State's affordability criterion for the small discharging lagoons. For the City of Logan's lagoon facility, cost for Tier 2N was just within the State's affordability criterion, while for Tier 1N this was exceeded.

5.0 References

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APPENDIX 1

POTW Data Summary Sheets

APPENDIX 2

POTW Technical Memoranda

APPENDIX 3

POTW Cost Summary Tables

APPENDIX 4

Economic Models