Lake Champlain TMDL: 2014 Cost Estimate Analysis for Vermont Wastewater Treatment Facilities

Prepared by:

Vermont Department of Environmental Conservation

Facilities Engineering Division, Water Infrastructure Financing Programs, Clean Water State Revolving Fund

Authors:

Lynnette Claudon, PE

Winslow Ladue

Robert Pelosi, EI

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Executive Summary

The Lake Champlain Phosphorus TMDL has a convoluted history. On November 4, 2002, the US Environmental Protection Agency (US EPA) approved the Vermont portion of the Total Maximum Daily Load (TMDL) for the Lake Champlain Basin. Thereafter, the VT Agency of Natural Resources (VT ANR) began implementing strategies outlined in the 2002 TMDL. In 2007, the Vermont Legislature passed Act 43 and requested VT ANR to assess the implementation progress and estimate future implementation costs. On October 28, 2008, the Conservation Law Foundation filed a lawsuit to set US EPA's November 4, 2002 approval aside. In response, US EPA reconsidered the 2002 TMDL, withdrew the prior approval, and began collaborating to develop a new TMDL.

At each stage of the TMDL progression, VT ANR has estimated the cost of upgrading wastewater treatment facilities (WWTFs) to meet policy goals.[1] A new TMDL is anticipated from US EPA in 2015 and specific proposals for WWTFs are not known at this time. With this report, VT ANR has updated the evaluation to cover costs for 4 potential implementation scenarios, as they apply to WWTFs. The scenarios may be distinguished by effluent limits, facility size, permitted phosphorus capacity, and watershed.

The scenarios are summarized in Table 1 below.

Table 1 -- TMDL Implementation Scenarios

Scenario	Approach	Effluent Limits
1	Total Phosphorus Upgrades; Applicable to all Watersheds	0.8 mg/L TP or 0.2 mg/L TP depending on WWTF size
2	Total Phosphorus Upgrades; Applicable to all Watersheds	0.2 mg/L TP at all WWTFs
3	Total Phosphorus Upgrades; Applicable to all Watersheds; ***Applicable to WWTFs Exceeding 80% of Phosphorus Capacity***	0.8 mg/L TP or 0.2 mg/L TP depending on size of affected WWTF
4	Total Phosphorus Upgrades; ***Applicable to WWTFs Exceeding 80% of Phosphorus Capacity and Situated in Targeted Watersheds***	0.8 mg/L TP or 0.2 mg/L TP depending on size of affected WWTF

Historically, for each cost estimate, VT ANR always assumed that (1) chemical addition is the appropriate phosphorus removal technology for achieving effluent concentrations as low as 0.8 mg/L TP and (2) cloth disk filtration preceded by chemical addition is the appropriate phosphorus removal technology for achieving effluent concentrations as low as 0.2 mg/L TP.

[1] Progress in Establishing and Implementing the Total Maximum Daily Load (TMDL) Plan for Lake Champlain, Prepared by Vermont Agency of Natural Resources, Vermont Agency of Agriculture, Food, and Markets, January 15, 2008.

Recent findings, however, suggest that a broad-based technological assumption is inappropriate. First, pilot testing and operating data indicate that cloth disk filters do not perform well at lagoon facilities. Second, since many small facilities lack solids handling processes, the capital investment for cloth disk filtration is not cost effective; rather, chemical addition in the existing treatment train is preferred with any additional maintenance cost absorbed by the operating budget. Finally, VT ANR also recognizes that several major facilities receive considerable high-strength wastewater and any phosphorus upgrade must also address organic assimilation.

In addition, VT ANR has further refined its analysis based on other mitigating factors. Most importantly, the Agency has excluded facilities that have recently been upgraded with technology generally capable of meeting effluent concentrations as low as 0.2 mg/L TP from consideration. Also, the Agency has excluded facilities with design flow less than 0.1 MGD from consideration as any upgrade would not be cost effective. For the remaining facilities, the Agency has applied basic, consistent assumptions regarding building footprint (with accommodation for accessibility, maintenance, and storage), concrete work, structural steel work, environmental systems (e.g. HVAC and electrical), and yard piping. Further, where appropriate, the Agency allows for permitting and green infrastructure costs, OSHA requirements, and site-specific needs. In all cases, the Agency has utilized RS Means, current bid tabs, and peer review to formulate prices.

All costs presented account for inflation. Table 2 below lists cost estimates for all scenarios in 2014 dollars, as calculated by linearly interpolating the appropriate Engineering News Record Construction Cost Indices[2].

Recently, the US EPA contracted an independent assessment of implementation costs. The report only analyzed two scenarios: (1) effluent limits of 1.0 or 0.2 mg/L TP, depending on WWTF size, as applied to all watersheds (essentially Scenario No. 1, as discussed above) and (2) a new ultra-low limit of 0.1 mg/L TP applied to all large WWTFs across all watersheds.

VT ANR's cost estimate for Scenario No. 1 is in stark contrast to the one provided by US EPA. Specifically, VT ANR's estimate is 5 times higher. This is primarily due to the mitigating factors discussed above. Additional factors include equipment redundancy requirements, delivery fees, and testing charges.

VT ANR has not performed an in-depth cost analysis for achieving ultra-low effluent concentrations of 0.1 mg/L TP. Based on one available data point, preliminary estimates indicate a project cost range of $300 – 600M. These figures exclude operation and maintenance costs. Further, if required, phosphorus offset costs add an unspecified amount.

Based on literature review, the Agency believes the assumption that simple operational changes adequately improve performance of cloth disk filters to consistently meet an effluent limit of 0.1 mg/L TP is unreliable. Further, regulators must recognize the limit of technology for cloth disk filtration and the significance of phosphorus speciation on removal efficiency.

[2] The Engineering News Record Construction Cost Index is an industry tool used to adjust construction costs for inflation based on data collected since 1968.

Table 2 -- Cost Estimates for Each Implementation Scenario

Scenario	**Approach**	**Effluent Concentrations[3]**	**Cost Estimate**	**Number of Facilities Affected**
1	Total Phosphorus Upgrades; Applicable to all Watersheds	0.8 mg/L TP or 0.2 mg/L TP depending on WWTF size	$172.1M	33
2	Total Phosphorus Upgrades; Applicable to all Watersheds	0.2 mg/L TP at all WWTFs	$182.0M	33
3	Total Phosphorus Upgrades; Applicable to all Watersheds; ***Applicable to WWTFs Exceeding 80% of Phosphorus Capacity***	0.8 mg/L TP or 0.2 mg/L TP depending on size of affected WWTF	$103.0M	18
4	Total Phosphorus Upgrades; **Applicable to *Targeted* Watersheds for *WWTFs Exceeding 80% of Phosphorus Capacity***	0.8 mg/L TP or 0.2 mg/L TP depending on size of affected WWTF	$66.8M	10

[3] Note that the phrase "effluent concentration" is used as a general descriptor in this report. For regulatory purposes, the actual permit limits are likely to be expressed as mass-based annual average loads, calculated based on a 0.2 or 0.8 mg/L TP effluent concentration, at design flow.

Introduction

On January 24, 2011, the US EPA withdrew its November 4, 2002 approval of the Vermont portion of the Lake Champlain Phosphorus TMDL. Upon reconsideration, the US EPA concluded that, by not requiring additional phosphorus reductions at WWTFs, the 2002 TMDL provided an insufficient margin of safety for all lake segments. Further, the US EPA found that the 2002 TMDL did not outline reasonable assurances that non-wastewater controls would achieve expected phosphorus load reductions. With these findings, US EPA commenced to develop a new TMDL with collaboration from VT ANR.

In on-going discussions, US EPA has indicated that new TMDL waste load allocations (WLAs) must be based on annual limits for WWTFs. For large facilities, US EPA prefers a mass discharge limit that is calculated on an average effluent concentration of 0.2 mg/L TP. For small facilities, US EPA assumes an average effluent concentration of 0.8 mg/L TP. Further, US EPA suggests that, in the event that non-wastewater load reductions are not reasonably assured, large facilities can upgrade to meet an ultra-low limit of 0.1 mg/L TP. To justify this approach, US EPA relies on a contracted cost assessment released on January 13, 2014 that assumes a combination of operational changes and cost-effective capital improvements are sufficient to achieve ultra-low effluent concentrations.[4]

In response, VT ANR proposed a revised Lake Champlain TMDL Phase I Implementation Plan on May 29, 2014. The revised implementation plan did not include additional phosphorus reductions at WWTFs, principally based on concerns over cost effectiveness. Instead, VT ANR once again focused on non-wastewater load.

Subsequently, US EPA reiterated their expectation that the new TMDL would require WWTFs to improve phosphorus treatment.

VT ANR has prepared this report to illustrate the cost implications of achieving additional phosphorus reductions at WWTFs. VT ANR has reviewed archived bid tabulations, referenced professionally accepted cost estimation tools, and sought peer review to account for common construction impediments. Further, VT ANR has adjusted all costs for inflation, conducted literature review on technology and phosphorus speciation, and developed alternative implementation strategies. In summary, VT ANR estimates that point source controls are far more expensive than suggested by US EPA and offers implementation scenarios to both defray cost and provide substantive margins of safety.

In total, VT ANR has evaluated a total of four upgrade scenarios. The scenarios encompass two effluent limits: (1) either 0.8 or 0.2 mg/L TP depending on facility size and (2) a flat 0.2 mg/L TP applicable to all facilities. Further, VT ANR examined two implementation strategies: (1) mandating upgrades only where facilities exceed 80% of their permitted phosphorus load and (2) requiring upgrades only for facilities situated in targeted watersheds.

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[4] Lake Champlain Phosphorus Removal: Technologies and Cost for Point Source Phosphorus Removal, Final Report, January 13, 2014, by Tetra Tech, Inc. of Denver, CO. http://www.epa.gov/region1/eco/tmdl/pdfs/vt/WWTFFeasibilityStudy.pdf

For purposes of this report, simple definitions govern facility size. Large facilities are permitted to receive more than 200,000 gallons of wastewater per day. Small facilities are permitted to receive between 100,000 and 200,000 gallons of wastewater per day.

Note that this report excludes the thirteen micro facilities that are permitted to receive less than 100,000 gallons of wastewater per day.

In total, thirteen large and small WWTFs are excluded from evaluation. In many cases, these facilities have been upgraded and use phosphorus removal technology that should allow them to meet proposed TP limits. Five facilities have existing permit limits lower than proposed limits. These facilities are described below in Table 3.

Table 3 – Large and Small WWTFs Excluded from Consideration

WWTF Name	Lake Segment	Facility Type	Phosphorus Removal Technology
Alburgh	13 Isle LaMotte	Aerated Lagoon	Spray Field Disposal
Burlington Electric	05 Main Lake	Aeration	Sand Filter
Pittsford Fish Hatchery	04 Otter Creek	Fish Hatchery	Information Unavailable
Salisbury Fish Hatchery[5]	04 Otter Creek	Fish Hatchery	Settling Pond
Shelburne #1	06 Shelburne Bay	Sequential Batch Reactor (SBR)	Chemical Addition Followed by Cloth Disk Filtration (CDF)
Shelburne #2	06 Shelburne Bay	SBR	Chemical Addition & CDF
So. Burlington Airport Parkway	05 Main Lake	Waste Activated Sludge	Chemical Addition & CDF
So. Burlington Bartlett Bay	06 Shelburne Bay	Extended Aeration	Chemical Addition & CDF
Stowe	05 Main Lake	SBR	Chemical Addition & CDF
Troy/Jay	12 Missisquoi Bay	SBR	Chemical Addition & CDF
Vergennes	04 Otter Creek	Lagoon	Chemical Addition & CDF
Waterbury	05 Main Lake	Aerated Lagoon	Ballasted Flocculation

[5] Salisbury Fish Hatchery requires an $11.4M phosphorus upgrade to meet the phosphorus standards derived from the 2014 Vermont Water Quality Standards, however, this is not related to the Lake Champlain TMDL and therefore no cost is shown in this report. There may be other Vermont wastewater treatment facilities that will require phosphorus or other nutrient upgrades in order to comply with the 2014 Vermont Water Quality Standards, independent of the Lake Champlain TMDL requirements. Potential costs for these other projects are not included in this report.

Weed Fish Culture Station	05 Main Lake	Fish Hatchery	Chemical Addition & IDR

<u>Effect of Effluent Limits on Cost</u>

As mentioned above, VT ANR evaluated the effect of effluent concentrations on upgrade cost. The base scenario assumes that small facilities must produce effluent at 0.8 mg/L TP and large facilities must meet a stringent effluent concentration of 0.2 mg/L TP. The enhanced scenario applies 0.2 mg/L TP to all facilities, excluding micro facilities.

VT ANR has looked beyond theory and has attempted to account for various situations that limit the application of technology or exacerbate construction costs. All assumptions are based on literature review, peer review, and actual Vermont project bid tabulations.

Base Effluent Limit Scenario – Large Facilities

VT ANR developed the base effluent limit scenario by first examining technology. After reviewing historical cost estimates, the Agency assumed that chemical addition followed by cloth disk filtration would typically allow large facilities to meet an effluent concentration of 0.2 mg/L TP. The Agency then contacted a vendor with extensive experience in Vermont. After providing flow parameters for various WWTFs, the Agency requested quotes grouped by equipment size.

Next, the Agency considered redundancy. Based on regulatory standards, the Agency specified that any process would be installed with redundant equipment to assure that permit limits are met – even with a unit out of service during peak flow. The vendor made redundancy recommendations. For all but one facility, two units were sufficient. For the remaining facility (the Middlebury WWTF), the vendor recommended a third unit.

Based on bid tabulations and industry estimating standards, the Agency recognized that equipment procurement involves more than simply purchasing equipment. In practice, procurement includes various fees for: base equipment, engineering submittals, delivery, installation, overhead and profit, factory representation during start-up, and testing. In the Agency's experience, a multiplier of 2 is appropriate.

As another consideration, the Agency assumes that all processes will be housed in either a new or expanded building. From a design perspective, filter footprint establishes the initial building size. The manufacturers suggest a minimum clearance of 4 feet around the perimeter of the units. The Agency has supplemented this recommendation by assuming 4'6" of clearance around each unit and allowing additional space to meet electrical code requirements, and providing storage space for parts, maintenance equipment, and safety apparatus.

With the building dimensions established, the Agency then selected a construction method. For economy, the Agency decided to calculate costs for insulated, pre-engineered steel-framed buildings that meet Vermont Commercial Building Energy Code Standards. Based on our experience with the facilities in the Town of Shelburne and interviews with the Operator, the Agency specified each building would be constructed to a standard 24-foot height and would include a mezzanine for access to the top of process equipment, roof structural components capable of snow load resistance, and HVAC ducts. Further, the Agency presumed each building has concrete floors and frost walls. In addition, the Agency used general assumptions regarding ancillary systems and components--heating and ventilation, electrical and controls, plumbing, yard piping, site improvements, and other factors.

To estimate construction cost, the Agency first referenced RS Means[6]. The Agency selected values from either the minimum or maximum range – as determined by cross-referencing current bid tabulations and on-going construction projects. The Agency also considered applying the suggested cost adjustment factor that appears in the latest edition but did not feel that it was appropriate for planning level cost estimates.

After compiling the preliminary cost estimates, the Agency solicited the engineering consultant that handles the largest quantity of Vermont CWSRF projects for peer review. Per the suggestions, the Agency adjusted RS Means values upwards and made the following additional revisions:

1. Revised several cost factors;
    a. Increased building square foot costs
    b. Reduced HVAC and other multipliers
2. Modified site-specific costs based on recent bids ; and
3. Added costs for blasting and dewatering.

Our peers offered additional insight. First, for facilities greater than 1 MGD, designers typically specify concrete tanks in lieu of the steel tanks principally due to the caustic chemical environment and municipal preference. Additionally, steel buildings require greater insulation to meet the Vermont Commercial Building Energy Code.

To validate the cost estimates, the Agency compared the above method to a recently proposed project. In 2014, consultants provided a site-specific estimate of $6M for the Rutland WWTF. This compared favorably to the Agency's estimate of $6.5M. Therefore, FED concluded that the method is appropriate for TMDL planning level efforts.

For one large facility, the Agency relied on cost information that the municipality supplied. The Essex Junction WWTF is a large waste activated sludge plant equipped with cloth disk filters. As currently configured, the existing filters are not capable of meeting 0.2 mg/L effluent limits at design flow. The Owner estimates that it will cost $1M to install additional filters to meet demand at peak flow. This $1M figure is used in lieu of the cost estimates described above and is unique to the facility.

Other Considerations – Waterbury WWTF

One pilot test in particular challenged VT ANR's design assumptions. Beginning in 2005, the Village of Waterbury started plans to upgrade the existing WWTF in order to meet an effluent concentration of 0.8 mg/L TP limit. Subsequently, after US EPA rescinded its approval of the 2002 TMDL, the Village decided to evaluate options for achieving an effluent concentration of 0.2 mg/L TP. Pilot testing conducted in 2009 demonstrated that chemical addition and cloth disk filtration was capable of achieving the former effluent limit. The testing also showed that

[6] **RS Means** is an annual series of publications (typically used by engineers and architects) that summarizes national databases of material and construction costs.

lower limits would be problematic due to seasonal operational variables (high lagoon effluent solids/algae concentration) and excessive chemical usage. Thus, the Village explored alternative technologies.

Beginning in late winter 2011, the Village pilot tested two ballasted flocculation technologies -- CoMag and Actiflo. Both technologies were capable of consistently meeting 0.2 mg/L TP. Further, jar testing proved that high concentrations of algae improved phosphorus removal.

After pilot testing, the Village selected the CoMag ballasted flocculation technology and proceeded with design. VT ANR approved the facilities plan and final design in the summer of 2013. Construction commenced in the fall of 2013.

The *actual* construction cost for the Waterbury upgrade far exceeded prior cost estimates. The lowest responsive bid for the CoMag project was $5,779,400, excluding change orders, contingency, administrative cost, and legal work. As of the most recent change order, the overall project cost was $7.8M.

The Waterbury experience affects specific plants under the base scenario. As suggested by the pilot study, cloth disk filters are unable to meet stringent effluent limits at lagoon facilities. Accordingly, the Agency, has referenced the bid price, made adjustments for inflation, and estimated engineering fees based on the VT ANR, Department of Environmental Conservation, Facilities Engineering Division protocols (the engineering fee curve). The results are equivalent to the $7.8M cost for the Waterbury facility and the Agency has applied that flat cost to the four large lagoon facilities situated in the Champlain Basin.[7]

The cost estimates are provided in Table 4 below.

Table 4 -- Ballasted Flocculation for Large Lagoon Facilities

WWTF Name	Lake Segment	Treatment Technology	Cost to Upgrade to 0.2 mg/L
Hardwick	09 Malletts Bay	Aerated Lagoon	$7.8 M
Hinesburg	06 Shelburne Bay	Aerated Lagoon	$7.8 M
Proctor	04 Otter Creek	Aerated Lagoon	$7.8 M
Richford	12 Missisquoi Bay	Aerated Lagoon	$7.8 M
Total			**$31.2M**

Note that the Waterbury cost estimate is relevant to other scenarios and is discussed in subsequent sections.

[7] FED believes that there is little economy of scale with this technology and that scaling down costs proportionally to flow for smaller plants is not appropriate. While smaller units may exist, this technology is not sold as a package unit and has higher associated labor and installation costs. Examination of the schedule of values provided by the Contractor for Waterbury's upgrade suggests that there are few items that are "scalable" and based on change order information that $7.8M may underrun actual costs depending on the sludge drying bed construction requirements and other ancillary equipment.

Other Considerations -- Montpelier WWTF

Another report[8] suggested that high organic loading may interfere with phosphorus removal. In May of 2014, the City of Montpelier commissioned a report to determine what upgrades are needed to achieve a total P effluent concentration as low as 0.1 mg/L TP. The City's consultants modeled treatment processes with BioWin, the industry standard modeling software, and determined that the existing WWTF has reached its organic load capacity – as indicated by high mixed liquor suspended solids (MLSS) concentration – even though actual flows are less than half the permitted flow. Further, since there is a relationship between MLSS and effluent TP, the WWTF would also need additional bioreactors, clarifiers, and sludge digesters to accommodate the high MLSS concentration[9].

Prior to this study, VT ANR did not consider wastewater strength relevant to nutrient removal. Subsequently, VT ANR decided to determine how many facilities slated for phosphorus upgrade may be in a situation similar to Montpelier. Staff met to review historical and institutional knowledge of the various facilities in the Champlain basin, discuss the origin of high strength wastewater (e.g. septage receiving facilities, leachate receiving practices, breweries, etc.) and review performance history.

Using these findings, VT ANR has identified facilities where phosphorus removal projects may require concurrent upgrades for organic capacity. In total, five large facilities may be affected with a significant resulting cost adjustment.[10]

A summary of the findings is presented in Table 5 below.

Table 5 -- Large WWTFs with Organic Loading Challenges

WWTF Name	**Lake Segment**	**Treatment Technology**	**Cost to Upgrade to 0.2 mg/L**
Barre City	05 Main Lake	Oxidation Ditch	$ 20.2M
Brandon	04 Otter Creek	Oxidation Ditch	$ 3.5M
Burlington Main	07 Burlington Bay	Waste Activated Sludge	$24.0M
Montpelier	05 Main Lake	Waste Activated Sludge	$20.0M
Winooski	05 Main Lake	Extended Aeration	$7.0M

[8] Draft Report, City of Montpelier, Wastewater Treatment Facility, Modernization and Phosphorus Removal Study, February, 2014, by Aldrich + Elliot and Stantec and Final Report, City of Montpelier, Wastewater Treatment Facility, Modernization and Phosphorus Removal Study, February, 2014, by Aldrich + Elliot and Stantec.

[9] MLSS is comprised of active microorganisms (which consume the waste) and non-biodegradable matter that form in the bioreactors. MLSS exits the bioreactors and enters the secondary clarifiers for settling. Any solids not removed by the clarifiers exit the WWTF as total suspended solids (TSS) in the effluent. Since phosphorus removal is highly dependent on TSS control, there is a direct relationship between MLSS and effluent TP.

[10] Initially there were 15 facilities identified, but this was reduced to 5 facilities after additional investigations. Notably, Barre and Brandon are already operating consistently at 0.2 mg/L so an upgrade would be required only if mandated by the Agency.

Total			**$74.7M**

The cost estimates above are simply pro-rated values from the Montpelier report. For each facility, the Agency divided the permitted flow by Montpelier's permitted flow and then multiplied the quotient by $20M (the low range cost for a 0.2 mg/L TP upgrade from the draft Montpelier report).

Base Effluent Scenario – Small Facilities

For small facilities, the Agency relied on past projects to develop cost estimates. After the 2002 Lake Champlain Phosphorus TMDL was adopted, the Agency eliminated the exemption for large lagoons. Thereafter, lagoon facilities in the Towns of Richford, Hardwick, and Proctor implemented chemical addition to meet the new permitted effluent limits of 0.8 mg/L. Though, the large lagoons are not necessarily comparable to other facilities, the Agency believed that capital investment at small plants would be similar (i.e. chemical addition alone does not require building improvements, significant systems modification, or procurement of proprietary equipment). Further, chemical addition (without disk filtration) is generally assumed to be capable of meeting an effluent concentration of 0.8 mg/L TP. Therefore, the Agency gathered cost records from these three facilities, adjusted them for inflation, and applied the resulting figure -- $875,000 -- to each of the five small facilities.

The cost estimates for the five small facilities are presented in Table 6 below.

Table 6 -- Small WWTFs Upgraded with Chemical Addition

WWTF Name	Lake Segment	Treatment Technology	New Cost to Upgrade to 0.8 mg/L
North Troy	12 Missisquoi Bay	Extended Aeration	$0.88M
Plainfield	05 Main Lake	Sequential Batch Reactor	$0.88M
Poultney	01 South Lake B	Sequential Batch Reactor	$0.88M
Wallingford	04 Otter Creek	Oxidation Ditch	$0.88M
Williamstown	05 Main Lake	Aerated Lagoon	$0.88M
Total			**$4.4M**

The base effluent limit scenario, with all considerations discussed above, is summarized in Table 7.

Table 7 -- Base Effluent Limit Scenario

Facility Type	Number of Facilities Affected	Phosphorus Upgrade	Effluent Concentration	Upgrade Cost
Large WWTF	18	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$60.8M
Large WWTF	1 (Essex Junction)	Additional Disk Filtration	0.2 mg/L TP	$1.0M
Large Lagoon WWTF	4	Ballasted Flocculation	0.2 mg/L TP	$31.2M
Large WWTF with High Organic Loading	5	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$74.7M
Small WWTF	5	Chemical Addition	0.8 mg/L TP	$4.4M
Total	**33**			**$172.1M**

Enhanced Effluent Scenario – All Facilities

Under the enhanced effluent limit scenario, all facilities in the Basin meet an effluent concentration of 0.2 mg/L TP. As shown in Table 7, the design assumptions for small WWTFs must change to meet the lower limit. Small lagoons require ballasted flocculation while the remaining small facilities (with secondary clarification) may use cloth disk filtration.

With such discrete changes, calculating the respective cost estimate is straightforward. The Agency has applied the project cost from the Waterbury WWTF upgrade to each of small lagoons. For the other small facilities, the Agency applied a flat $1.6M cost for cloth disk filtration. The results are shown in Tables 8 and 9 below.

Table 8 -- Small WWTFs Upgraded with Advanced Technology

WWTF Name	Lake Segment	Treatment Technology	New Cost to Upgrade to 0.2 mg/L
North Troy	12 Missisquoi Bay	Extended Aeration	$1.6M
Plainfield	05 Main Lake	Sequential Batch Reactor	$1.6M
Poultney	01 South Lake B	Sequential Batch Reactor	$1.6M
Wallingford	04 Otter Creek	Oxidation Ditch	$1.6M
Williamstown	05 Main Lake	Aerated Lagoon	$7.8M
Total			**$14.2M**

Table 9 -- Enhanced Effluent Limit Scenario

Facility Type	Number of Facilities Affected	Phosphorus Upgrade	Effluent Concentration	Upgrade Cost
Large WWTF	18	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$60.8M
Large WWTF	1 (Essex Junction)	Additional Disk Filtration	0.2 mg/L TP	$1.0M
Large Lagoon WWTF	4	Ballasted Flocculation	0.2 mg/L TP	$31.2M
Large WWTF with High Organic Loading	5	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$74.7M
Small WWTF	5	Ballasted Flocculation or Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$14.2M
Total	**33**			**$181.9M**

Effect of Implementation on Cost

Given the magnitude of the construction cost estimates for a general effluent-based approach, the Agency sought an implementation alternative that would reduce financial burden while providing the margin of safety US EPA has mandated. The first alternative is temporal – requiring upgrades only when population growth increases influent flow and the resulting annual phosphorus load reaches a threshold percentage of permitted capacity. The second alternative is spatial – requiring upgrades at facilities located in specific watersheds.

Implementation Based on Phosphorus Capacity

For the first implementation option, the Agency assumes facilities are required to perform phosphorus upgrades *only when* the respective phosphorus waste load meets or exceeds 80% of the current permitted value. This approach essentially defers an upgrade until a community's commercial and population growth result in total wastewater flows that approach original design criteria. Further, during the intervening years, the CWSRF can accrue capital for future investment and the Vermont Legislature can reasonably allocate annual funds to the Phosphorus Grant program.

To identify facilities that currently meet or exceed the proposed phosphorus threshold, staff compiled and analyzed available data. First, staff recorded annual average flows and annual average effluent concentrations by facility. Since flow data can vary greatly annually and to mitigate wet years (like 2011) and dry years, staff compiled data for the 5-year period 2009 – 2013 and applied a geometric mean to calculate average phosphorus load. Finally, staff compared these values with permitted flow and proposed effluent limits.

The 14 affected facilities are listed in Table 10 below. Facilities that upgraded with appropriate technology during the 5-year period are omitted (refer to the facilities listed in Table 3).

Table 10 – WWTFs Approaching Permitted Phosphorus Capacity

WWTF Name	Facility Size	Lake Segment	Treatment Technology
Burlington East	Large	05 Main Lake	Waste Activated Sludge
Burlington Main	Large	07 Burlington Bay	Waste Activated Sludge
Burlington North	Large	05 Main Lake	Waste Activated Sludge
Essex Jct	Large	05 Main Lake	Waste Activated Sludge
Hardwick	Large	09 Malletts Bay	Aerated Lagoon
Johnson	Large	09 Malletts Bay	Sequential Batch Reactor
Montpelier	Large	05 Main Lake	Waste Activated Sludge
North Troy	Small	12 Missisquoi Bay	Extended Aeration
Northfield	Large	05 Main Lake	Sequential Batch Reactor
Plainfield	Small	05 Main Lake	Sequential Batch Reactor
Proctor	Large	04 Otter Creek	Aerated Lagoon
Richford	Large	12 Missisquoi	Aerated Lagoon
Rutland City	Large	04 Otter Creek	Extended Aeration
St. Albans	Large	11 St. Albans Bay	RBC, Sand Filtration
Swanton	Large	12 Missisquoi Bay	Facultative Lagoon
Wallingford	Small	04 Otter Creek	Oxidation Ditch
Williamstown	Small	05 Main Lake	Aerated Lagoon
Winooski	Large	05 Main Lake	Extended Aeration

With the WWTFs identified by phosphorus capacity, the Agency then simply applied the base effluent limit scenario to the affected facilities. In the case of St. Albans, the facility is under, but very near 80%, and the sand filter components are nearing the end of their useful life. The resulting cost estimates are presented below in Table 11.

Table 11 -- Base Effluent Limit Implemented by Phosphorus Capacity

WWTF Name	Lake Segment	Phosphorus Upgrade	Effluent Annual Avg Concentration	Upgrade Cost
Burlington East	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$3.5M
Burlington Main	07 Burlington Bay	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$24.0M
Burlington North	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$3.5M
Essex Jct	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$1.0M
Hardwick	09 Malletts Bay	Ballasted Flocculation	0.2 mg/L TP	$7.8M
Johnson	09 Malletts Bay	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$2.1M
Montpelier	05 Main Lake	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$20.0M
North Troy	12 Missisquoi Bay	Chemical Addition	0.8 mg/L TP	$0.88M
Northfield	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$3.0M
Plainfield	05 Main Lake	Chemical Addition	0.8 mg/L TP	$0.88M
Proctor	04 Otter Creek	Ballasted Flocculation	0.2 mg/L TP	$7.8M
Richford	12 Missisquoi	Ballasted Flocculation	0.2 mg/L TP	$7.8M
Rutland City	04 Otter Creek	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$6.0M
St. Albans	11 St. Albans Bay	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$2.9M
Swanton	12 Missisquoi Bay	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$3.0M
Wallingford	04 Otter Creek	Chemical Addition	0.8 mg/L TP	$0.88M
Williamstown	05 Main Lake	Chemical Addition	0.8 mg/L TP	$0.88M
Winooski	05 Main Lake	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$7.1 M
Total				$103.0M

Implementation Based on Targeted Watersheds

US EPA has proposed a TMDL wastewater policy that would apply new, reduced annual phosphorus loading limits based on effluent concentrations of 0.2 mg/L or 0.8 mg/L, depending on the permitted flows at the facilities. Under EPA's proposal, these new waste load allocations would apply to facilities in four "targeted" watersheds (Main Lake, Burlington Bay, Shelburne Bay, St. Albans Bay) where the currently permitted wastewater loads are a larger proportion (>15%) of the total base load from all sources.

In order to further analyze the implications of stricter wastewater loading limits in the targeted watersheds, DEC used the TMDL lake model to calculate the benefits in terms of the corresponding reductions in the burden placed on non-wastewater sources in order to achieve the TMDL. The results presented in Table 12 below show that applying 0.2/0.8 mg/L based waste load allocations to facilities in the four targeted watersheds would have significant benefits in terms of mitigating the percent load reduction required from non-wastewater sources contributing to the Main Lake and St. Albans Bay lake segments.

Table 12 -- Relationship between Non-Wastewater and Wastewater Load Reductions, by Watershed

Lake Segment	Effluent Limits	Required Non-wastewater Load Reduction
05 Main Lake, 06 Shelburne Bay, 07 Burlington Bay	Current, Permitted Limits	45%
	0.2 or 0.8 mg/L, Depending on Facility Size	32%
11 St. Albans	Current, Permitted Limits	41%
	0.2 or 0.8 mg/L, Depending on Facility Size	28%

Implementing phosphorus upgrades to facilities that (1) are situated in the targeted watersheds and (2) exceed 80% of phosphorus capacity refine applicability to a discrete number of WWTFs. Of the 59 facilities in the Basin, only 17 are situated in the targeted watersheds. Of those, 10 exceed 80% of phosphorus capacity. The facilities are described below.

With the WWTFs situated in targeted watersheds identified, the Agency then simply restricted the base effluent limit scenario and enhanced effluent scenario to the affected facilities. The resulting cost estimates are presented below in Table 13.

Table 13 -- Base Effluent Scenario Implemented by Phosphorus Capacity and Targeted Watersheds

WWTF Name	Lake Segment	Phosphorus Upgrade	Effluent Limit	Upgrade Cost
Burlington East	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$3.5M
Burlington Main	07 Burlington Bay	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$24.0M
Burlington North	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$3.5M
Essex Junction*	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$1.0M
Montpelier	05 Main Lake	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$20M
Northfield	05 Main Lake	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$3M
Plainfield	05 Main Lake	Chemical Addition	0.8 mg/L TP	$0.88M
St. Albans	11 St. Albans	Chemical Addition Followed by Disk Filtration	0.2 mg/L TP	$2.9M
Williamstown	05 Main Lake	Chemical Addition	0.8 mg/L TP	$0.88M
Winooski	05 Main Lake	Chemical Addition Followed by Disk Filtration; Increased Clarification, Solids Handling, and Reaction Tank Capacity	0.2 mg/L TP	$7.1M
Total				$66.8M

*An upgrade at Essex Jct would only be required to meet design flow, an upgrade was recently completed and better TP removal performance is anticipated.

Ultra-low Phosphorus Limits

Recently, US EPA has suggested that an evaluative approach could be applied to phosphorus reduction strategies. Under this approach, implementation would first begin with effluent concentrations of either 0.8 or 0.2 mg/L TP (dependent on WWTF size) with concurrent non-wastewater load reductions. EPA would then evaluate Vermont's progress in implementing the Vermont Phase 1 Lake Champlain TMDL Implementation Plan under an Accountability Framework. If progress is inadequate, US EPA may limit WWTF phosphorus discharges to lower levels such as 0.1 mg/L TP.

In its January 2014 report, US EPA predicated cost estimates for achieving the 0.1 mg/L TP on what appear to be basic assumptions. These include:

1. Fixed capital costs for achieving either 0.2 or 0.1 mg/L TP;
2. Additional chemical addition costs absorbed by the operation and maintenance (O/M) budget; and
3. Any resulting residual management costs absorbed by the O/M budget.

VT ANR believes these assumptions ignore specific technological and capital impediments. Specifically, any attempt to achieve ultra-low phosphorus limits must account for phosphorus speciation, the practical limit of technology described by available empirical data and literature, and vendor guarantees.

Phosphorus Speciation

Various phosphorus species exist in wastewater. As reported by WERF[11], "(p)hosphorus compounds are not isolated and identified directly; rather, phosphorus compounds are grouped into fractions and defined by the analytical method used to measure them." The fractions include soluble (a.k.a. dissolved) phosphorus and particulate (a.k.a insoluble or suspended) phosphorus, where insoluble phosphorus is the particulate that is not removed by a 0.45 µm filter under EPA Method 365.2 and Standard Methods 4500-P. Within each fraction, the following species of phosphorus compounds exist: (1) reactive phosphorus, (2) acid-hydrolyzable phosphorus, and (3) organic phosphorus. The compounds are distinguished by direct colorimetry, sulfuric acid digestion/colorimetry, and persulfate digestion/colorimetry, respectively. In total, there are six species of phosphorus present in wastewater, as summarized in Table 14[12].

[11] Neethling, JB et al. *Tertiary Phosphorus Removal* [PDF Document]. Retrieved from http://www.werf.org/c/KnowledgeAreas/NutrientRemoval/HDRContributions/NutrientCompendium/Tertiary_Phosphorus_.aspx

[12] Stensel, H. David. (2012). *BAP Workshop* [PowerPoint Slides]. Retrieved from http://www.spokaneriver.net/wp-content/uploads/2012/05/3StenselSession1Pspeciationin-wastewatertreatment1.pdf

Table 14 – Phosphorus Species Present in Wastewater

Total Phosphorus (TP)					
Soluble Phosphorus			Particulate Phosphorus		
Reactive	Non-reactive		Reactive	Non-reactive	
Soluble Reactive **(sRP)**	Acid –Hydrolyzable **(sAHP)**	Organic **(dOP)**	Particulate Reactive **(pRP)**	Acid –Hydrolyzable **(pAHP)**	Organic **(pOP)**

It is important to note that acid-hydrolyzable and organic phosphorus species are referred to as non-reactive phosphorus.

As reported by Gu et al.[13], wastewater treatment processes assimilate the six phosphorus species to varying degrees. Biological phosphorus removal (BPR) effectively removes reactive phosphorus and pAHP, is slightly less effective removing organic phosphorus, but is relatively ineffective at removing sAHP. Chemical addition removes considerable sRP, removes modest levels of sAHP, pAHP, and pOP, ***increases*** the concentration of pRP, and ***does not remove any*** dOP. Tertiary polishing (either clarification or filtration) achieves modest removal of most phosphorus species, but is relatively ineffective removing sRP and pOP.

Limit of Technology

When considering ultra-low effluent limits, the above findings are significant. Chemical phosphorus removal *depends highly on solids separation* since considerable amounts of pRP form through precipitation and co-adsorption[14]. Further, as increasing amounts of phosphorus are removed, the recalcitrant[15] dOP comprises an increasing proportion of remaining phosphorus. For this reason, the practical limit of technology (LOT) for cloth disk filtration is considered to be 0.1 mg/L TP[16]. *Even more importantly, the available literature suggests that a suite of technologies (e.g. primary phosphorus removal by biological means, secondary phosphorus removal by chemical addition and clarification, tertiary phosphorus removal by cloth disk filtration,* ***and even supplemental, serial ultra-filtration****) must be employed to reliably meet such stringent effluent limits.*

Vendor Guarantee

Staff have discussed the 0.1 mg/L limit with vendors. Many do not guarantee performance without pilot testing and laboratory analysis to speciate phosphorus. Finally, since the Agency currently does not request monitoring of

[13] Gu, A.Z. et al. (2011). Treatability and Fate of Various Phosphorus Fractions in Different Wastewater Treatment Processes [PDF Document]. Retrieved from http://www1.coe.neu.edu/~april/documents/publications/Gu-2011-Treatability.pdf

[14] Gu, A.Z. et al. (2011). Treatability and Fate of Various Phosphorus Fractions in Different Wastewater Treatment Processes [PDF Document]. Retrieved from http://www1.coe.neu.edu/~april/documents/publications/Gu-2011-Treatability.pdf

[15] Recalcitrant: not responsive to treatment

[16] deBarbadillo, Christine et al. (2013). Sustainable Operating Practices for Achieving Low Phosphorus Effluents [PDF Document}. Retrieved from http://assets.conferencespot.org/fileserver/file/258541/filename/a942_1.pdf

phosphorus species, VT ANR has little ability to estimate the potential impact of phosphorus speciation on technology selection and design cost due to lack of available data.

Applicability to the Lake Champlain TMDL

Regarding the 0.1 mg/L TP limit currently being considered for the Lake Champlain TMDL, the above threshold is relevant for several reasons. Each reason is dependent on facility type.

As mentioned above, available literature indicates that, in order to achieve high levels of phosphorus removal, cloth disk filtration must be incorporated as a true tertiary process. Specifically, many authors assume that phosphorus removal begins with the biological process, continues with secondary clarification, and finishes with filtration. Of the 46 facilities evaluated in this report, only 5 are currently configured with biological nutrient removal and secondary clarification. Thirteen facilities are sequential batch reactors and, with operational changes, are capable of phosphorus removal through biological and chemical means. The remaining 28 facilities, therefore, lack the additive benefit of biological nutrient removal. And, of those, some do not have secondary clarifiers.

At these remaining 28 facilities, the LOT is not indicative of reliability. Cloth disk filtration can be expected to periodically violate stringent effluent limits[17]. Additional chemical dosing may not be sufficient to increase performance; rather, the facilities may need to supplement solids separation by installing advanced technologies such as ballasted flocculation, low-pressure membrane filtration, or two-stage granular filtration. Accordingly, the Agency recognizes that cloth disk filtration may be inappropriate for select facilities and alternative technologies may involve additional capital investment.

In its 2014 report, EPA has promoted the idea that a WWTF with disk filters capable of achieving 0.2 mg/L TP can retrofit high-performance filter media and adjust chemical feed to meet an effluent concentration of 0.1 mg/L TP. The information presented in that report suggests that these changes are simple, cost-effective solutions that require minimal capital investment. As discussed above, this is implausible as actual upgrades may require advanced technology, pumping installations to overcome associated head loss, higher operation and maintenance costs for said equipment, and, finally, greater chemical cost.

Preliminary Cost Estimate

Only two facilities have performed a cost analysis for achieving ultra-low phosphorus limits: Montpelier WWTF and Rutland WWTF. In the 2014 reports discussed earlier, Montpelier's consulting engineers give a cost range of $25 – 30M, while Rutland's report gave a cost of $18M. As previously mentioned, the Montpelier cost estimate does assume that process changes are required to increase organic assimilation; however, these are the only analyses currently available.

Using this preliminary data, the Agency developed a basin-wide estimate. As before, the cost figures are derived by pro-rating according to design flow. With this approach, the estimate for the basin is between $300 – 600M. These figures exclude operation and maintenance costs. Further, if required, phosphorus offset costs add an unspecified amount.

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[17] Neethling, JB et al. *Tertiary Phosphorus Removal* [PDF Document]. Retrieved from http://www.werf.org/c/KnowledgeAreas/NutrientRemoval/HDRContributions/NutrientCompendium/Tertiary_Phosphorus_.aspx

The Agency is currently funding a study to better evaluate advanced phosphorus removal technologies. Piloting of up to three advanced phosphorus removal technologies is to be conducted at an existing plant. As part of the project, the Agency is also requiring that phosphorus be speciated at several points in the treatment train. Finally, the consultant is to provide cost estimates for the technologies capable of meeting performance goals. At that time, the Agency can prepare a realistic cost estimate.

Funding Discussion

Any discussion of phosphorus upgrades must also account for project funding. Depending on the scope and timing of improvements, funding is available through the Vermont Environmental Protection Agency Pollution Control Revolving Fund -- also known as the Vermont Clean Water State Revolving Fund (CWSRF). The CWSRF is annually appropriated by the US Congress, directed to US EPA, and administered by the state. The state is required to match $1 for every $5 of federal money.

Historically, Vermont has also administered state grant programs, including a phosphorus grant. Each state grant is appropriated by the Vermont legislature and may be directed either to specific projects or as a batch funding mechanism.

USDA Rural Development also funds Vermont clean water projects, including WWTF upgrades.

Clean Water State Revolving Fund (CWSRF)

The clean water state revolving fund (CWSRF) is a low interest loan program enacted by the federal government to provide funding for municipal water pollution control projects. The program is funded by a combination of federal capitalization grants, state capitalization match, and payments returning from municipal borrowers. Each year the state solicits project applications, prioritizes the applications, and develops funding plans. The state must seek public comments before adopting a priority list and developing an intended use plan for CWSRF funding.

CWSRF loans are governed by a number of provisions. The state sets interest rates, but CWSRF loans are intended to be an affordable alternative to market rate financing. In Vermont, CWSRF loans have a zero percent interest, a two percent administrative fee, and may be prepaid or refinanced without penalty. CWSRF loans may be used for a broad range of clean water projects, including new facilities and renovations of existing facilities.

CWSRF funding may vary over time depending on federal appropriations. Currently, CWSRF remains consistent with federal capitalization, Vermont capitalization, and municipal loan payments totaling about $18M per year. Future CWSRF funding is subject to a decreasing share of federal appropriations over a 20-year phase-out. The Agency conservatively estimates that future funding availability will range from $11 to $18M per year.

Historically, there have been extraordinary funding appropriations. In 2009, ARRA (the American Recovery and Reinvestment Act) allocated a one-time sum of $19.2M towards the state’s clean water programs. Further, in 2014 the City of Burlington made a $14M balloon payment. Events such as these offset capitalization grant variability.

Recent legislation provides loan term flexibility. The Water Resource Reform and Development Act (WRRDA) of 2014 extends the CWSRF loan term from the current 20 years to 30 years – however loan terms cannot exceed the service life of the project. This change is consistent with Vermont law which limits municipal bond financing for wastewater projects to a 30-year term. Additionally, changes to the Vermont law governing the term of CWSRF loans consistent with the new federal provisions is currently pending.

Specific facility infrastructure is subject to eligibility requirements. Site and process equipment, such as concrete tanks and buried piping, could be eligible for a 30-year CWSRF loan. Mechanical and electrical equipment are limited to a maximum loan term of 20 years. To accommodate these differences, the loan terms can be based on a weighted average indexed to the component service life.

Under Vermont law, 10 VSA section 1625(e), specifically has stated that municipalities are not required to remove phosphorus unless 100 percent Vermont grant funding is available. As a result, most municipalities have not used CWSRF funding for phosphorus removal projects; rather, municipalities have primarily utilized the under-capitalized state grant program.

Given the range of costs described by this report, funding options for TMDL needs may require the use of government and private funds. As discussed above, the CWSRF is capable of absorbing up to $18M, annually. The remaining funding needs may require use of USDA-RD grants, USDA-RD loans, and Vermont Municipal Bond Bank bond funds. The overall capitalization needs are dictated by implementation schedule, the number of affected facilities, local bond capacity, and the effectiveness of non-wastewater reduction efforts.

Notably, the same funding sources are also required for age related refurbishment projects, other TMDL upgrades in the State, and any other clean water project. Only a portion of each capitalization is likely to go towards a Lake Champlain basin project.

Potential Cost Savings

The Facilities Engineering Division offers one possible cost mitigation strategy. The Division believes that if the Agency consistently recognized plant optimization, where appropriate, in lieu of upgrades, there would be potential for savings.

Plant Optimization

One option that is gaining national momentum is WWTF optimization. Optimization improves facility performance through energy efficiency and process control measures. Examples include updating instrumentation, replacing large pumps and blowers with multiple, smaller equivalents (which operate at higher efficiency), and incorporating selector zones to effect biological nutrient removal by using recirculation or feed forward controls. Optimization studies may include in-situ performance evaluations and/or computer modeling with industry recognized software. Optimization projects would be a departure from the classic SRF protocol of adding processes through capital improvement.

Optimization through adaptive management may also achieve efficiency gains. To afford flexibility, plant design could deviate from hydraulic control (flow) as the governing design parameter; rather, design could favor process-specific parameters --such as nutrient removal or organic assimilation – and specify equipment which can adapt to changing performance conditions. Further, initial design and construction could be structured around current flows with set asides (either physical or process-related) for future growth – all without relinquishing future hydraulic capacity.

Initial projections suggest that, at the watershed level, optimization may yield up to 60% cost savings. These projections are predicated on existing treatment technology and comparison to similar intrastate facilities (based on performance and flow data).

Conclusions

As shown, the cost of implementing the Lake Champlain Phosphorus TMDL varies widely depending on effluent limits and implementation approach. VT ANR has estimated these costs by accounting for selected (1) regulatory scenarios, (2) recent bid tabulations, (3) peer review, (4) pilot testing results, (5) and facility-specific considerations such as size and organic capacity.

The cost estimates provided herein vary greatly from the figures compiled by US EPA. For the base effluent scenario, VT ANR's figures are 5 times higher, despite similar technological assumptions. The Agency believes that US EPA has used assumptions that do not adequately reflect redundancy principles, space requirements, the limits of technology for cloth disk filtration, the significance of phosphorus speciation on removal efficiency.

US EPA has indicated that, if the State of Vermont's proposed implementation plan for reducing phosphorus into Lake Champlain is not approved, EPA may impose the most stringent phosphorus controls technologically available and require facility owners to also obtain offsets of phosphorus not removed through treatment. The level of removal would be at least down to a concentration of 0.1 mg/L TP, after treatment – a level commonly known as "ultra-low" phosphorus limits.

The Agency has estimated that the cost of achieving ultra-low phosphorus limits for all large facilities across the entire Lake Champlain Basin would be at least $300 million. Due, however, to the practical limits of technology, potential for phosphorus speciation, lack of facility-specific data pertaining to speciation, and unique facility conditions, this analysis is unreliable and likely understates the true costs. Further, these figures exclude operation and maintenance costs. And, if required, phosphorus offset costs add an unspecified amount.

Additional References Consulted

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http://www.nhm.ac.uk/research-curation/research/projects/phosphate-recovery/pk213.html

Phosphorus Recovery From Wastewater: Needs, Technologies, and Costs, by P. Cornel and C. Schaum, Water Science & Technology, 2009.

APPENDIX A: WWTF TECHNOLOGY

Technology at Existing Facilities

The table below documents the various technologies used in Vermont WWTFs and discusses cost assumptions. Plants that already have installed advanced treatment technologies are denoted with an asterisk.

Existing Treatment Type: WWTF Locations	**Discussion of Cost Estimate Assumptions and Plant Technologies**
Soil Based Disposal Processes: Alburgh*, Newport Center	Alburgh can achieve very low phosphorus concentrations through hayfield spray irrigation and hay harvesting, and we concur that this plant would not need to be upgraded for phosphorus removal. The current Newport Center plant uses subsurface sand filtration, with wick discharge and no filter backwash. It is not meeting its current phosphorus mass loading limit, based on <0.1 mg/L total phosphorus at permitted flow capacity. For the purposes of this report, both are considered micro facilities and no costs are carried.
Oxidation Ditches with Clarifiers: Barre City, Brandon, Wallingford	Two of these plants exceed the design organic load. FED estimates required treatment upgrades to range from $600,000 (Wallingford, chemical feed only) to $20.1M (Barre updated primary and secondary process plus cloth disk filters). Alternatively, Barre or Brandon may be good candidates for studies to determine if their plants' SOPs and BMPs can be documented in a manner that would allow them to permit their processes as EBNR without a costly upgrade.
Enhanced Biological Phosphorus Removal (EBPR): Enosburg Falls, Fair Haven, Pittsford, Richmond*, South Burlington Airport Parkway*	Richmond already upgraded, with cloth disk filters. The updated FED cost estimate for this plant is zero. Upgrades are assumed for Enosburg Falls and Fair Haven. Pittsford can be exempted to its micro size under 100,000 gpd. FED estimates treatment upgrades for large facilities based on addition of cloth disk filters.
Membrane Biological Reactor (MBR): Cabot*	Cabot as a micro sized plant is not anticipated to need an upgrade under several scenarios. However, Cabot uses membrane microfiltration to achieve high nutrient removal.
Sequenced Batch Reactor (SBR): Castleton, Johnson, Middlebury, Milton, Morrisville, Northfield, Plainfield, Poultney, Shelburne 1*, Shelburne 2*, Stowe*, Troy/Jay*, West Rutland	Four of these plants are already upgraded with cloth disk filters. Addition of filters is assumed for most, but not all unfiltered SBR plants. Chemical feed is only assumed for Plainfield (< 0.2 MGD. The combined cost estimate carries filtration costs for those plants. FED estimates range from chemical addition to cloth disk filtration projects. Some plants may be good candidates for optimization projects if the 80% phosphorus measure is adopted.
Large Lagoons: Hardwick, Hinesburg, Proctor, Richford, Swanton, Vergennes, Waterbury*	The Waterbury lagoon plant is currently upgrading to a ballasted flocculation process, at a total project cost of $7.8 M. Ballasted flocculation is considered a best available technology (BAT) for this application and is expected to be able to consistently achieve a 0.2 mg/L TP concentration. We are assuming that similar phosphorus removal upgrades, including sludge management facilities, would be required at all other large lagoon plants. Based on the Waterbury project history, we are assuming a project cost of $7.8M per lagoon project.

Small Lagoons: Benson, Fairfax, Jeffersonville, Marshfield, NW State Correctional*****, Orwell, Williamstown	FED estimates assume that the micro lagoons (≤0.1 MGD) would be exempt. Chemical feed is assumed for Williamstown to reach a 0.8 mg/L limit as a WWTF that is smaller than 0.2 MGD. FED estimates a project cost for Williamstown of $875,000.
Small Package Plants: North Troy, Otter Valley Union High School, Sheldon Springs	FED estimates assume that the micro lagoons (≤0.1 MGD) would be exempt. Some of the small package plants house processes comprised of a single unit. Adding a tertiary process may require replacement of the disinfection system, if required.
Rotating Biological Contactor (RBC): St Albans, West Pawlet	St Albans already has post-RBC granular media filters, and a permitted total phosphorus concentration limit of 0.5 mg/L. St Albans is now planning to rehabilitate the existing granular media filters or upgrade to an alternative advanced phosphorus removal technology. FED estimates a project cost for St Albans of $2.9M, based on cloth disk filters and no pump station. West Pawlet is assumed to be exempt due to size under 0.1 MGD.
Conventional Waste Activated Sludge (WAS): Burlington East, Burlington Main, Burlington North, Essex Junction*****, Montpelier, Rutland City,	Essex Junction recently upgraded with cloth disk filters that can theoretically achieve the proposed limits. One additional filter is needed to meet limits under design flows at a cost of $1M. CDF upgrades are assumed for the five other conventional activated sludge plants.
Extended Aeration: South Burlington Bartlett Bay Road*****, Winooski	South Burlington Bartlett Bay Road is already upgraded, with cloth disk filters, so no additional upgrades are required. Winooski is assumed to upgrade with CDF.
Boiler Blowdown: Burlington Electric	Boiler blowdown water discharge permit for McNeil power plant. Phosphorus project not likely to be needed based on the type of wastewater treated.
Industrial Treatment: IBM, PBM Nutritionals (Wyeth)*****, RockTenn	The IBM semiconductor industry wastewater plant has chemical feed. Operating well below permitted discharge flow capacity. The PBM Nutritionals food industry wastewater plant already has chemical feed and filtration. It is operating well below permitted discharge flow capacity. The RockTenn paper industry wastewater plant has chemical feed. RockTenn recycles treated effluent for process water needs. It is discharging far below permitted discharge flow capacity. Any projects at these privately-owned facilities would not be eligible for Vermont pollution control or CWSRF federal funding.
Fish Hatcheries: Pittsford Fish Hatchery, Salisbury Fish Hatchery, (Ed) Weed,	Effluent phosphorus concentrations from the state fish hatcheries are already extremely low, lower than the proposed limits. Therefore, no changes are proposed for these facilities based on the LC TMDL.
Offsite Mitigation: Shoreham	This facility uses offsite phosphorus mitigation, Shoreham is considered exempt for the purposes of this report due to its size under 0.1 MGD.

Appendix B – Cost Estimates

FED 2014 CLOTH DISK FITLER ESTIMATE															
	Unit Cost		0.02 MGD	0.11 MGD	0.25 MGD	0.4 MGD	0.45 MGD	0.5 MGD	1.0 MGD	2.0 MGD	4.0 MGD	4.0 MGD	5.3 MGD	8.1 MGD	Notes & Assumptions
WWTF Flow	50%	Qd	0.01	0.055	0.125	0.2	0.225	0.25	0.6	1.0	2	2	2.7	4.05	
WWTF Design Flow (Qd)	100%	Qd	0.02	0.11	0.25	0.4	0.45	0.5	1.2	2.0	4.0	4.0	5.3	8.1	
Max Hourly Flow	500%	Qd	0.1	0.55	1.3	2.0	2.3	2.5	6.0	10.0	20.0	20.0	26.5	40.5	
Cloth Disk Filter Cost	per vendor		$145,448	$145,448	$145,448	$ 170,785	$ 200,274	$ 242,099	$ 294,654	$ 350,435	$ 551,966	$ 655,477	$ 695,481	$ 636,875	
Redundancy			2	2	2	2	2	2	2	2	3	2	2	2	2 or 3 Fully Redundant Units
Subtotal Equipment Cost			**$ 581,792**	**$ 581,792**	**$ 581,792**	**$ 683,140**	**$ 801,096**	**$ 968,396**	**$ 1,178,616**	**$1,401,740**	**$ 3,311,796**	**$ 2,621,908**	**$ 2,781,924**	**$2,547,500**	Assume Factor of Two for Install/Deliver, Testing, etc
Equipment Width	per vendor		6.5	6.5	6.5	8.5	8.5	8.5	8.5	8.5	10	22.5	24	23	Dimensions by Supplier, will vary by Supplier
Equipment Length	per vendor		10.5	10.5	10.5	10	10.5	13	14.5	16	16	26	27.5	53	
Equipment Height	per vendor		6	6	6	12	12	12	12	12	15	15	15	20	
Required Bldg Footprint			1604.5	1604.5	1604.5	1665	1682.5	1770	1822.5	1875	2446.375	3205	3409	4968	Includes 1000 SF for Storage & Electrical Panels
Building Cost	$58	/SF	$93,061	$93,061	$93,061	$96,570	$97,585	$102,660	$ 105,705	$108,750	$141,890	$ 185,890	$197,722	$288,144	RS Means Steel Structure 24' Ceilings, Prefab with adjustment for snow
Mezzanine	$26	/SF	$38,168	$38,168	$ 38,168	$ 38,870	$39,104	$40,274	$40,976	$41,678	$50,833	$ 52,910	$ 54,314	$65,780	RS Means, metal decking & steel frames, with $4 add'l for bracing & stairs
Footing Cost	$50	/LF	$3,050	$3,050	$3,050	$3,200	$3,250	$3,500	$ 3,650	$3,800	$ 5,756	$6,200	$6,500	$8,950	RS Means, Strip Footings, Poor Soils
Floor Cost	$ 16	/SF	$ 25,672	$ 25,672	$ 25,672	$ 26,640	$ 26,920	$ 28,320	$29,160	$ 30,000	$39,142	$ 51,280	$54,544	$ 79,488	Concrete floor
Subtotal Shell Cost			**$ 159,951**	**$ 159,951**	**$ 159,951**	**$ 165,280**	**$ 166,859**	**$174,754**	**$ 179,491**	**$ 184,228**	**$237,621**	**$296,280**	**$ 313,080**	**$ 442,362**	
HVAC Cost	8.00%	cost	$ 59,339	$ 59,339	$ 59,339	$67,874	$77,436	$91,452	$108,649	$ 126,877	$283,953	$233,455	$ 247,600	$239,189	Based on recent projects
Electrical Cost	9.00%	cost	$ 66,757	$66,757	$66,757	$76,358	$ 87,116	$ 102,884	$ 122,230	$ 142,737	$ 319,448	$262,637	$ 278,550	$269,088	Based on recent projects
Instrumentation	9.00%	cost	$ 66,757	$ 66,757	$66,757	$ 76,358	$87,116	$102,884	$122,230	$142,737	$319,448	$262,637	$ 278,550	$ 269,088	Based on recent projects
Yard Piping Cost	12.00%	cost	$89,009	$ 89,009	$89,009	$101,810	$116,155	$137,178	$162,973	$190,316	$ 425,930	$350,183	$ 371,400	$358,783	Based on recent projects
Access/Walks	4.00%	cost	$ 29,670	$29,670	$29,670	$33,937	$ 38,718	$45,726	$54,324	$ 50,000	$50,000	$50,000	$50,000	$50,000	Allowance Capped at $50,000
Chemical Addition	Allowance		$38,000	$38,000	$38,000	$38,000	$38,000	$38,000	$ 76,000	$ 152,000	$304,000	$304,000	$304,000	$ 304,000	Allowance Capped at $304,000
Stormwater Cost	Allowance		$2,000	$2,000	$2,000	$ 2,000	$2,000	$ 2,000	$3,000	$3,500	$4,000	$4,000	$ 5,000	$ 6,000	Assumes small footprint GI BMP
Safety Equipment	Allowance		$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	Allowance
Construction	subtotal		$1,094,275	$ 1,094,275	$1,094,275	$1,245,756	$1,415,496	$1,664,273	$2,008,512	$2,395,136	$5,257,196	$4,386,099	$4,631,106	$4,487,010	
Mobilization & Demob	10%	cost	$218,855	$218,855	$218,855	$249,151	$283,099	$332,855	$401,702	$479,027	$1,051,439	$ 877,220	$926,221	$897,402	Typical for industry/ region
Construction Cost Total			**$1,313,130**	**$ 1,313,130**	**$ 1,313,130**	**$1,494,908**	**$ 1,698,595**	**$1,997,128**	**$ 2,410,214**	**$ 2,874,163**	**$6,308,635**	**$5,263,319**	**$ 5,557,327**	**$ 5,384,411**	
Engineering Costs	Cost Curve	cost	$ 302,020	$ 302,020	$ 302,020	$343,829	$ 390,677	$459,339	$554,349	$ 661,057	$ 1,450,986	$1,210,563	$1,278,185	$1,238,415	FED Cost Curve
Base Project Cost		**cost**	**$1,620,150**	**$1,620,150**	**$1,620,150**	**$1,843,736**	**$ 2,094,272**	**$ 2,461,467**	**$2,969,564**	**$3,540,220**	**$7,764,621**	**$ 6,478,883**	**$ 6,840,512**	**$6,627,826**	**Used in Cost Report for CDF Upgrades**
+Pumping Costs	$124,306	/Qd	$2,486	$13,674	$31,077	$49,722	$55,938	$ 62,153	$149,167	$248,612	$497,224	$497,224	$658,822	$1,006,879	Assumes space can be repurposed for pump station, based on Waterbury Bid
+ Flocculation Tank	$1,000,000	/10 min Q	$4,138	$4,759	$ 5,725	$6,760	$7,105	$7,450	$12,280	$17,800	$31,600	$ 31,600	$40,570	$59,890	Assumes $1M/1MGD + $4k base cost
+ Blasting for Ledge	$175	/CY	$10,400	$10,400	$ 10,400	$10,792	$10,905	$11,472	$11,813	$ 12,153	$ 15,856	$ 20,773	$22,095	$32,200	Assumes average 1ft ledge depth
+ Piloting	$35,000	cost	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	Assumes only selected technology
+ Dewatering	$ 125,000	each	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	Based on Fixed cost for recent project
+ H Piles	$ 600	/50SF	$ 19,254	$ 19,254	$19,254	$19,980	$20,190	$ 21,240	$21,870	$ 22,500	$29,357	$38,460	$40,908	$59,616	RS Means, Steel Pile, 30' Deep
Grand Total Less Sludge			**$1,816,428**	**$1,828,236**	**$1,846,605**	**$2,090,991**	**$2,348,410**	**$2,723,782**	**$3,324,693**	**$4,001,285**	**$8,498,658**	**$ 7,226,940**	**$7,762,907**	**$7,946,411**	
+ Sludge Drying Beds	$4,241,368	/Qd	$84,827	$466,550	$1,060,342	$1,696,547	$ 1,908,616								Prorated based on Waterbury bid price
Grand Total With Sludge			**$1,901,255**	**$2,294,787**	**$2,906,947**	**$3,787,538**	**$4,257,026**								

Facilities that are Not Excluded by Size or Upgrade

Facility	Lake Segment	Permitted Flow (mgd)	2012 Flow (mgd)	Percent Hydraulic Capacity Used	Percent P	1.0 or 0.2 TetraTech Reported Costs All WWTFs($)	1.0 or 0.1 TetraTech Reported Costs All WWTFs($)	Combined Scenario	0.2 All Upgrade Scenario	0.2 or 0.8 Combined Cost Estimate	Total Cost for Plants that "immediately" need TMDL upgrades.
Barre City	05 Main Lake	4.000	2.630	66%	60%	$0	*$2,140,000*	High Organics	$20,151,133	$20,151,133	$0
Brandon	04 Otter Creek	0.700	0.350	50%	56%	$0	*$ 780,000*	High Organics	$3,526,448	$3,526,448	$0
Burlington East	05 Main Lake	1.200	0.497	41%	**102%**	$1,095,000	$1,095,000	Cloth Disk Filter	$3,540,220	$3,540,220.0	$3,540,220
Burlington Main	07 Burlington Bay	5.300	3.751	71%	**170%**	$2,921,000	$2,921,000	High Organics	$ 24,030,226.7	$24,030,227	$24,030,227
Burlington North	05 Main Lake	2.000	0.961	48%	**106%**	$217,000	$217,000	Cloth Disk Filter	$3,540,220	$3,540,220	$3,540,220
Castleton	01 South Lake B	0.480	0.265	55%	73%	$0	*$740,000*	Cloth Disk Filter	$2,461,467	$2,461,467	$0
Enosburg Falls	12 Missisquoi Bay	0.450	0.242	54%	58%	$840,744	$840,744	Cloth Disk Filter	$2,267,002.5	$2,267,002	$0
Essex Junction	05 Main Lake	3.300	1.710	52%	145%	$ 153,000	$ 153,000	Upgraded	$1,000,000	$1,000,000	$1,000,000*
Fair Haven	01 South Lake B	0.500	0.132	26%	46%	$840,744	$840,744	Cloth Disk Filter	$2,461,467	$2,461,467	$0
Hardwick	09 Malletts Bay	0.371	0.191	51%	**146%**	$1,275,000	$1,275,000	Waterbury	$7,800,000	$7,800,000	$7,800,000
Hinesburg	06 Shelburne Bay	0.250	0.135	54%	78%	$850,744	$850,744	Waterbury	$7,800,000	$7,800,000	$0
IBM	05 Main Lake	8.000	2.936	37%	30%	$4,110,000	$4,110,000	Cloth Disk Filter	$4,110,000	$4,110,000	$0
Johnson	09 Malletts Bay	0.270	0.135	50%	**84%**	$700,744	$700,744	Cloth Disk Filter	$2,094,272	$2,094,272	$2,094,272
Middlebury	04 Otter Creek	2.200	0.894	41%	64%	$1,355,000	$1,355,000	Cloth Disk Filter	$7,764,621	$7,764,621	$0
Milton	09 Malletts Bay	1.000	0.235	24%	61%	$880,744	$880,744	Cloth Disk Filter	$2,969,564	$2,969,564	$0
Montpelier	05 Main Lake	3.970	1.653	42%	**83%**	$2,268,000	$2,268,000	High Organics, Owner Supplied Cost	$ 20,000,000	$20,000,000	$20,000,000
Morrisville	09 Malletts Bay	0.550	0.222	40%	72%	$840,744	$840,744	Cloth Disk Filter	$2,461,467	$2,461,467	$0
North Troy	12 Missisquoi Bay	0.110	0.063	58%	101%	$600,744	$600,744	Chem Addition of CDF	$1,600,000	$875,000	$875,000
Northfield	05 Main Lake	1.000	0.605	61%	**101%**	$885,000	$885,000	Cloth Disk Filter	$2,969,564	$2,969,564	$2,969,564
Plainfield	05 Main Lake	0.125	0.047	37%	126%	$100,744	$100,744	Chem Addition or CDF	$1,620,150	$ 875,000	$875,000
Poultney	01 South Lake B	0.500	0.179	36%	20%	$0	$96,444	Chem Addition	$1,620,150	$ 875,000	$0
Proctor	04 Otter Creek	0.325	0.165	51%	**220%**	$1,298,000	$1,298,000	Waterbury	$7,800,000	$7,800,000	$7,800,000
Richford	12 Missisquoi Bay	0.380	0.219	58%	**128%**	$1,270,744	$1,270,744	Waterbury	$7,800,000	$7,800,000	$7,800,000
Richmond	05 Main Lake	0.222	0.060	27%	17%	$0	$96,444	Cloth Disk Filter	$1,620,150	$1,620,150	$0
Rock Tenn	12 Missisquoi Bay	2.500	0.204	8%	19%	$1,350,744	$1,350,744	Cloth Disk Filter	$6,478,883	$6,478,883	$0
Rutland City	04 Otter Creek	8.100	4.586	57%	**83%**	$3,913,000	$3,913,000	Cloth Disk Filter, Owner Supplied Cost	$6,000,000	$6,000,000	$6,000,000
St. Albans City	11 St. Albans Bay	4.000	2.264	57%	**77%**	$115,000	$115,000	Owner Supplied Cost	$2,900,000	$2,900,000	$0
Swanton	12 Missisquoi Bay	0.900	0.374	42%	**122%**	$885,000	$885,000	Cloth Disk Filter	$2,969,564	$2,969,564	$2,969,564
Wallingford	04 Otter Creek	0.120	0.045	38%	85%	$100,744	$100,744	Chem Addition	$1,620,150	$875,000	$875,000
West Rutland	04 Otter Creek	0.450	0.157	35%	45%	$840,744	$840,744	Cloth Disk Filter	$2,094,272	$2,094,272	$0
Williamstown	05 Main Lake	0.150	0.054	36%	147%	$100,744	$100,744	Chem Addition	$7,800,000	$ 875,000	$875,000
Winooski	05 Main Lake	1.400	0.645	46%	**130%**	$1,095,000	$1,095,000	High Organics	$7,052,897	$7,052,897	$7,052,897
Wyeth (PBM Nutritionals)	09 Malletts Bay	0.425	0.124	29%	18%	$0	$0	Cloth Disk Filter	$ 2,094,272.0	$ 2,094,272.0	$0

*Essex Jct upgrade costs would be for design flow.

Facilities Not Included in Cost Estimate Based on Design Flows under 0.1 MGD											
Facility	Lake Segment	Permitted Flow (mgd)	2012 Flow (mgd)	Percent Hydraulic Capacity Used	Percent P	1.0 or 0.2 TetraTech Reported Costs All WWTFs($)	1.0 or 0.1 TetraTech Reported Costs All WWTFs($)	Combined Scenario	0.2 All Upgrade Scenario	0.2 or 0.8 Combined Cost Estimate	Total Cost for Plants that "immediately" need TMDL upgrades.
Benson	01 South Lake B	0.018	0.014	78%	45%	$ 96,444	$ 96,444	Micro	$0	$0	$0
Cabot	05 Main Lake	0.050	0.021	41%	13%	$0	$ 96,444	Micro	$0	$0	$0
Fairfax	09 Malletts Bay	0.078	0.041	52%	42%	$ 100,744	$ 100,744	Micro	$0	$0	$0
Marshfield	05 Main Lake	0.045	0.016	36%	17%	$ 100,744	$ 100,744	Micro	$0	$0	$0
Northwest State Correctional	11 St. Albans Bay	0.040	0.020	50%	15%	$0	$0	Micro	$0	$0	$0
Newport Center	12 Missisquoi Bay	0.042	0.039	94%	801%	$ 596,444	$ 596,444	Micro	$0	$0	$0
Orwell	02 South Lake A	0.033	0.012	36%	31%	$ 100,744	$ 100,744	Micro	$0	$0	$0
Otter Valley Union High School	04 Otter Creek	0.025	0.004	17%	10%	$ 96,444	$ 96,444	Micro	$0	$0	$0
Pittsford	04 Otter Creek	0.085	0.059	69%	37%	$ 100,744	$ 100,744	Micro	$0	$0	$0
Sheldon Springs	12 Missisquoi Bay	0.054	0.012	23%	13%	$ 96,444	$ 96,444	Micro	$0	$0	$0
Shoreham	04 Otter Creek	0.035	0.008	22%	29%	$ 100,744	$ 100,744	Micro	$0	$0	$0
West Pawlet	01 South Lake B	0.040	0.011	28%	38%	$ 100,744	$ 100,744	Micro	$0	$0	$0

Facilities Not Included in Cost Estimate Based on Existing Removal Technology or Existing Low Permit Limits											
Facility	Lake Segment	Permitted Flow (mgd)	2012 Flow (mgd)	Percent Hydraulic Capacity Used	Percent P	1.0 or 0.2 TetraTech Reported Costs All WWTFs($)	1.0 or 0.1 TetraTech Reported Costs All WWTFs($)	Combined Scenario	0.2 All Upgrade Scenario	0.2 or 0.8 Combined Cost Estimate	Total Cost for Plants that "immediately" need TMDL upgrades.
Alburgh	13 Isle LaMotte	0.130	0.131	101%	5%	$0	$0	Upgraded	$0	$0	$0
Burlington Electric	05 Main Lake	0.365	0.118	32%	34%	$0	$0	Ex Limits Below Proposed	$0	$0	$0
Pittsford Fish Hatchery	04 Otter Creek	2.600	2.292	88%	48%	$0	$0	Ex Limits Below Proposed	$0	$0	$0
Salisbury Fish Hatchery	04 Otter Creek	1.310	0.784	60%	30%	$0	$0	Ex Limits Below Proposed**	$0	$0	$0
South Burlington Airport Park	05 Main Lake	3.300	1.776	54%	93%	$ 128,000	$ 128,000	Upgraded	$0	$0	$0
Shelburne #1	06 Shelburne Bay	0.440	0.260	59%	78%	$ 100,744	$ 100,744	Upgraded	$0	$0	$0
Shelburne #2	06 Shelburne Bay	0.660	0.329	50%	79%	$ 100,744	$ 100,744	Upgraded	$0	$0	$0
South Burlington Bart. Bay	06 Shelburne Bay	1.250	0.628	50%	81%	$ 100,744	$ 100,744	Upgraded	$0	$0	$0
Stowe	05 Main Lake	1.000	0.284	28%	25%	$0	$ 100,744	Upgraded	$0	$0	$0
Troy/Jay	12 Missisquoi Bay	0.800	0.051	6%	14%	$ 876,444	$ 876,444	Upgraded	$0	$0	$0
Vergennes	04 Otter Creek	0.750	0.330	44%	59%	$ 100,744	$ 100,744	Upgraded*	$0	$0	$0
Waterbury	05 Main Lake	0.510	0.189	37%	950%	$0	$0	Upgraded	$0	$0	$0
Weed Fish Culture Station	05 Main Lake	11.500	3.392	29%	12%	$0	$0	Ex Limits Below Proposed	$0	$0	$0

Note: Several plants have just completed upgrades and have phosphorus levels over 80% because of the 5-year average. *If Vergennes cannot meet new limits, they may need the Waterbury scenario project at $7.8M. **Salisbury Fish Hatchery requires a phosphorus upgrade unrelated to the LC TMDL at a cost of $11.4M due to the 2014 VT WQ Standards.