Evaluation of Alternatives for Phosphorus Removal Interim Report

RIDEM Lafayette Hatchery

North Kingston, Rhode Island

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Table of Contents

Evaluation of Alternatives for Phosphorus Removal
Interim Report
RIDEM Lafayette Hatchery

1 Executive Summary 3
1.1 Recommendations 3
1.1.1 Recommended Technology 3
1.1.2 Recommended Bench Scale Testing and Pilot Testing Program 4
1.1.3 Recycle Option 4
1.2 Project Primary Focus 5

2 Design Concept 6
2.1 Basis of Design 6
2.2 Sources of Phosphorus 7
2.3 Design Flow 9
2.4 Treatment System 10
2.5 Design Layout 11

3 Evaluation of Selected Alternatives 12
3.1 Tertiary Filtration 12
3.1.1 Deep Bed Up-Flow Continuous Backwash Filters 13
3.1.2 Synthetic Media Filters 13
3.1.3 Disc Filters 14
3.2 Ballasted Floc Separation 14
3.3 Membrane Filtration 15
3.4 Constructed Wetlands 17
3.5 System Operator 18

4 Solids Waste Management 19

5 Environmental Impacts 20
5.1 Surface Water Quality 20
5.2 Groundwater Quality 20
5.3 Disturbance to Wetlands 20
5.4 Stormwater Discharge 20
5.5 Air Quality 21
5.6 Noise 21

6 Cost Analysis of Selected Alternatives 22
6.1 Capital Costs 22
6.2 O&M Costs 22

6.3 Life Cycle Costs Net Present Value 23
6.4 Design-Build-Operate 25

Tables

		Page
2.1	Wastewater Design Criteria	7
3.1	Tertiary Filtration Options	12
3.2	Ballasted Floc Separation Options	15
3.3	Hollow Fiber Membrane Filtration Options	16
4.1	Opinion of Probable Cost of Alternatives	24

Figures

		Page
2.1	Phosphorus Fractions	8
2.2	Phosphorus Mass Balance – Worst Case Condition	8
2.3	Phosphorus Mass Balance – Average Conditions	9
2.4	In-Stream Treatment with Reuse	10
2.5	Conceptual Site Plan	End of Report
2.6	Treatment Building Layout	End of Report
2.7	Hydraulic Profile	End of Report

Appendices

Appendix A Phosphorus Laboratory Results
Appendix B Bench Scale Test Reports
Appendix C Tertiary Filtration Manufacturer's Literature & Dimensions
Appendix D Ballasted Floc Separation Manufacturer's Literature & Dimensions
Appendix E Membrane Filtration Manufacturer's Literature & Dimensions
Appendix F Constructed Wetlands Standard Detail

1 Executive Summary

This Evaluation of Alternatives Report for Phosphorus Removal (Report) provides the Rhode Island Department of Environmental Management (DEM) with recommendations for phosphorus treatment alternatives for the Lafayette State Trout Hatchery to comply with its effluent permit limit of 0.025 mg/l (milligrams per liter), or 25 parts per billion (ppb). This report presents a screening of potentially feasible alternatives; development and consolidation of the most feasible options; and summary and opinion of probable life cycle cost for each technically-feasible alternative. Technologies that are recommended for piloting are also presented.

1.1 Recommendations

Based on a preliminary review and screening of vendor proposals, phosphorus treatment options were consolidated into four (4) alternatives:

- Alternative 1 – Tertiary Filtration
- Alternative 2 – Ballasted Floc Separation
- Alternative 3 – Membrane Filtration
- Alternative 4 – Constructed Wetlands

It is recommended that the treatment system be designed for 2.0 MGD (million gallons per day) to account for potential future use of the empty raceway. Costs included in this report reflect a 2.0 MGD system.

1.1.1 Recommended Technology

In terms of compliance with RIPDES Permit No. RI0110035, capital and operating costs, Alternative 1 – Tertiary Filtration with chemically-enhanced Sludge Thickening and Dewatering, provides the lowest net present worth value. The capital cost for this alternative, including project development and other "soft" costs, is $3.6 million.

The Tertiary Filtration alternative consists of three technologies, and it should be noted that this recommendation relates to two of those technologies: deep bed upflow continuous backwash filters, and synthetic-media filters, which can potentially meet the discharge requirements via a two-stage process. The third technology, tertiary disc filters, is not recommended for further consideration due to the need for an additional upstream pretreatment step, which adds substantially to the opinion of cost.

It should be noted that while Alternative 1 provides the lowest net present worth value, Alternative 2 is fairly close, with a difference in net present worth of $390,000. Therefore, we recommend that Alternative 1 – Tertiary Filtration and Alternative 2 – Ballasted Flocculation Separation both be considered for design. A selection procedure is presented in Section 1.1.2 below.

1.1.2 Recommended Bench Scale Testing and Pilot Testing Program

Given that this proposed wastewater treatment system will need to reliably reduce phosphorus levels to near the limit of technology, coupled with the variability of phosphorus levels in the hatchery effluent, it is recommended that a selection procedure utilizing two steps be utilized to select the technology best suited to treating the Lafayette Hatchery effluent.

Step 1: Perform Bench Scale Testing. The cost for Alternatives 1 and 2 are fairly close, with a total present worth difference of approximately $390,000 favoring Alternative 1. It is recommended that rigorous bench scale testing be performed on four processes, two from Alternative 1 (excluding tertiary disc filters) and two from Alternative 2. The two highest performing technologies would then be recommended for pilot testing, as described below in Step 2.

The bench scale study would cost approximately $30,000, including vendor, laboratory, and engineering costs. The engineering component would involve preparing testing specifications for vendors, collecting the test samples, and distributing the samples to each of the four vendors. Providing each vendor with the same sample is an important step given the variability of the soluble nonreactive phosphorus (sNRP) concentrations. Specifications would be assembled based on the results of the initial bench scale studies to ensure vendors are running the same tests for a direct comparison.

Step 2: Perform Pilot Testing. Based upon the bench scale testing results, the two preferred and best performing processes will be selected to participate in the piloting program. In addition to confirming the ability of the piloted processes to meet the discharge requirements, piloting will allow for quantifying and finalizing of estimated costs for chemical use, sizing of facilities and dewatering requirements of the chemical sludge. Pilot testing will also allow for observation of the process under actual discharge conditions, including "stress testing" the technology under worst case conditions (which can be simulated during the pilot). The results from pilot testing will be useful in informing the final decision by DEM as to which technology to select. Vendors charge for this service and an allowance has been provided in the opinion of cost. The pilot testing allowance provides for pilot testing of two technologies.

1.1.3 Recycle Option

It is possible that a portion (25%) of the effluent from the treatment system be used as recycle water, for providing flow to the unused raceway at the hatchery. Reuse water may require additional forms of treatment such as gas management for carbon dioxide and oxygen, as well as disinfection. If a recycle stream design were pursued, the temperature, pH, and concentrations of dissolved oxygen, dissolved carbon dioxide, hardness, alkalinity, nitrogen, and metals would need to be evaluated closely during pilot testing. Any additional treatment components needed for a recycle stream would increase the capital and annual costs and would result in a more complex system to operate.

1.2 Project Primary Focus

The Lafayette Hatchery's discharge is regulated by a RIPDES permit which sets limits on the amount of pollutants that the hatchery is allowed to discharge. Until recently, phosphorus was not regulated; however, the hatchery has been identified as a source of phosphorus discharge to Belleville Pond. The hatchery's 2010 RIPDES permit sets a monthly average limit of 0.025 mg/l (25 ppb) for Total Phosphorus, consistent with a TMDL (Total Maximum Daily Load) calculation for Belleville Pond, which was completed by the DEM Office of Water Resources (OWR).[1] Based on monitoring data, it has been determined that the hatchery cannot comply with its total phosphorus limit using their existing processes and equipment.[2]

Effluent Phosphorus consists of both soluble and particulate fractions. Particulate phosphorus can be removed by settling or filtration. The soluble fraction must also be removed to achieve a low effluent concentration of 0.025 mg/l (25 ppb) total phosphorus. The soluble form can be divided into reactive and non-reactive fractions. Soluble Reactive Phosphorus (sRP) can be chemically precipitated and removed with the particulate fraction. Soluble nonreactive phosphorus (sNRP) is difficult to cost-effectively remove. The principle source of phosphorus at the hatchery is through uneaten food and fish feces. There also exists varying levels of background phosphorus in the well water. Water quality data for the hatchery outfall indicate the following:

Levels from Hatchery Database[3]:

Total Phosphate as P	0.136 mg/l
Dissolved Phosphate as P	0.072 mg/l

This compares with recent sampling efforts collected under worse-case conditions (laboratory results are provided in Appendix A and discussed further in Section 2.2):

Total Phosphorus	1.46 mg/l
Total Dissolved Phosphorus	0.94 mg/l
sNRP concentration	0.83 mg/l

This data underscores the variability in phosphorus levels in the hatchery effluent.

As the allowable total maximum daily loadings (TMDLs) are expressed as annual loads, the Lafayette Hatchery should seek to have the Discharge Limitations set to an annual loading, with a suitable technology based upset concentration limit. Regulating the effluent on a concentration basis is an important issue as the permit limits are at the limits of technology. Additionally, permit compliance is based on a monthly grab sample; therefore, regulation on a concentration basis puts the facility in a potential permit violation based on a single bad day of treatment system performance.[4]

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[1] RIPDES Permit No. RI0110035, signed September 29, 2010.

[2] DEM Water Resources hatchery RFQ_final_10125.

[3] Ref. 5 rev 4 revised 030217 Lafayette hatchery water quality data for consultant.xls.

[4] Benisch et al; Tertiary Phosphorus Removal Pilot Tests Technology Limits In Coeur D' Alene, ID; WEF Water Practice, 2007.

2 Design Concept

2.1 Basis of Design

The Lafayette Hatchery's discharge is regulated by a RIPDES permit which sets limits on the amount of pollutants that the hatchery is allowed to discharge. Until recently, phosphorus was not regulated; however, the hatchery has been identified as a source of phosphorus discharge to Belleville Pond. The hatchery's 2010 RIPDES permit sets a monthly average limit of 0.025 mg/l (25 ppb) for Total Phosphorus, consistent with a TMDL (Total Maximum Daily Load) calculation for Belleville Pond, which was completed by the DEM Office of Water Resources (OWR).[5] Based on monitoring data, it has been determined that the hatchery cannot comply with its total phosphorus limit using their existing processes and equipment.[6]

Reports provided by DEM indicate that the chemical profile of the well water at the hatchery has high carbon dioxide content (42 mg/l), with low alkalinity (5-6 mg/l) and hardness (30 mg/l). Desired levels of alkalinity and hardness at the hatchery have been set at 50 mg/l and above. The concentration of carbon dioxide is reduced to 3 mg/l and hardness and alkalinity both increased to 50 mg/l to make the water suitable for culturing fish. This is achieved by aerating the well water to strip off carbon dioxide and then treating with sodium bicarbonate ($NaHCO_3$) and calcium chloride ($CaCl_2$) to adjust the alkalinity and hardness, respectively.[7]

Water supply is obtained from three gravel packed wells located on hatchery property. The mean daily facility flow, from September 2006 to June 2009, was reported to be 1.82 MGD. Flows typically range from 1.75 to 2.0 MGD. Flows are presently averaging 1.5 MGD.[8]

Treatment alternatives need to be considered to assure compliance with RIPDES Permit No. RI0110035 to meet phosphorus limits of 0.025 mg/l (25 ppb). Wastewater criteria are presented in Table 2.1. As indicated in the table, existing permit requirements for BOD5, TSS and Ammonia are already met. To achieve the phosphorus limit, an 82% reduction of phosphorus is needed. For evaluation purposes, a minimum performance objective of 90% removal will be required.

Based on the criteria concentration of 0.025 mg/l and the permitted discharge of 2.5 MGD, the allowable load for the Lafayette Trout Hatchery was set to 86 kg/yr (189 lbs/yr)[9]. The permit, as issued, limits the Effluent Total Phosphorus to an average monthly concentration 0.025 mg/l (25 ppb). As the allowable total maximum daily loadings (TMDLs) are expressed as annual loads, the Lafayette Hatchery should seek to have the Discharge Limitations set to an annual loading, with a suitable technology based upset concentration limit. For example, at current average flows of 1.5 MGD, the allowable

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[5] RIPDES Permit No. RI0110035, signed September 29, 2010.

[6] DEM Water Resources hatchery RFQ_final_10125.

[7] Hagos, K.W.; The Status of Fish Hatcheries in Rhode Island: A Scheme for Improving Effluent Quality at Lafayette Trout Hatchery; URI Coastal Institute, 2009.

[8] Ref. 6 rev 3 - Lafayette hatchery effluent DMR data 010109-123116.xls.

[9] Office of Water Resources Rhode Island Department of Environmental Management, Total Maximum Daily Load To Address The Phosphorus Impairment To Belleville Ponds And Belleville Upper Pond Inlet, September 2010.

concentration for Total Phosphorus would be 0.041 mg/l (41ppb). At flows of 2.0 MGD, the allowable concentration for Total Phosphorus would be 0.031 mg/l (31ppb). Regulating the effluent on a annual loading basis instead of a concentration basis is an important issue as the permit limits are at the limits of technology. Additionally, permit compliance is based on a monthly grab sample; therefore, regulation on a concentration basis puts the facility in a potential permit violation based on a single bad day of treatment system performance or contaminated sample.[10]

Table 2.1
Wastewater Criteria

Parameter	Existing Effluent	Required Final Effluent
BOD (Biochemical Oxygen Demand) (5 Day)	< 5 mg/L	5 mg/L
TSS (Total Suspended Solids)	< 5 mg/L	5 mg/L
Ammonia, Total (as N)	< 0.5 mg/L	1.368 mg/L
Phosphorus, Total	0.14 mg/L	0.025 mg/L

Wastewater constituents are monthly average concentrations

Allowable Phosphorus load for the Lafayette Trout Hatchery was set to 86 kg/yr (189 lbs/yr)

Projected average day = 1.5 MGD; based on existing conditions

Projected peak day = 2.5 MGD; based on permitted flow

2.2 Sources of Phosphorus

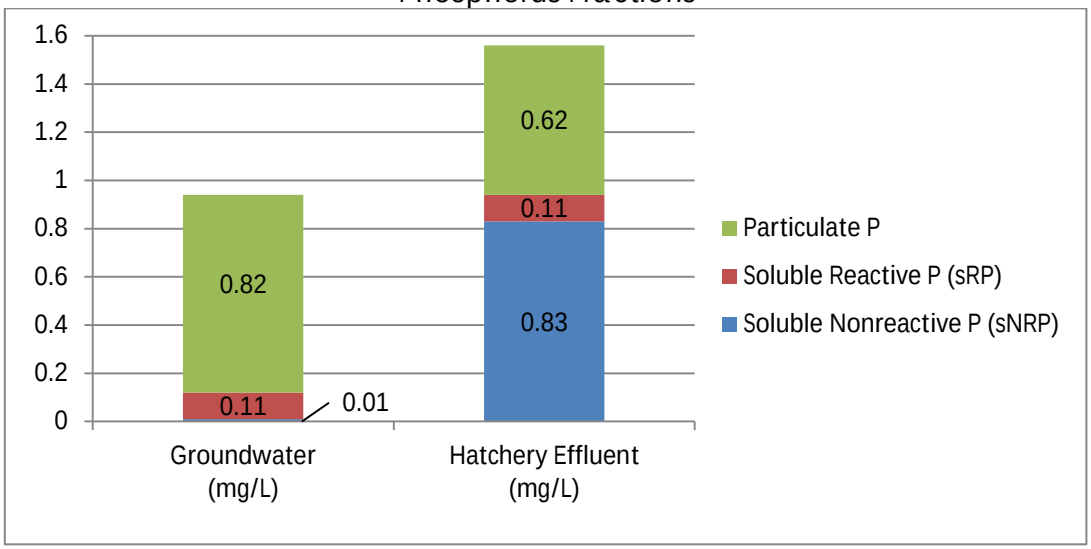
Effluent Phosphorus contains both soluble and particulate (insoluble) fractions. Particulate phosphorus can be removed by settling or filtration. A portion of the soluble fraction must also be removed to achieve low effluent concentrations of 0.025 mg/l (25 ppb) total phosphorus. The soluble form can be divided into reactive and non-reactive fractions. Soluble Reactive Phosphorus (sRP) can be chemically precipitated and removed with the particulate fraction. Soluble nonreactive phosphorus (sNRP) is difficult to cost-effectively remove.

Samples were collected from the hatchery on October 13, 2017 and analyzed for orthophosphate as phosphorus and total phosphorus, both for filtered and unfiltered results. The hatchery effluent sample was collected under worse-case conditions, where the fish were fed just prior to sample collection. Particulate phosphorus was determined by subtracting the filtered total phosphorus from the unfiltered total phosphorus. Soluble reactive phosphorus is made up of organic phosphate and orthophosphate. Concentrations of dissolved organic phosphorus are assumed to be negligible; therefore the sRP concentration is equal to the dissolved phosphorus concentration from orthophosphate. The sNRP was

[10] Benisch et al; Tertiary Phosphorus Removal Pilot Tests Technology Limits In Coeur D' Alene, ID; WEF Water Practice, 2007.

determined by subtracting the filtered orthophosphate as phosphorus from the filtered total phosphorus. The results are summarized in Figure 2.1 and the laboratory analytical report is provided in Appendix A.

Figure 2.1
Phosphorus Fractions



The concentrations of total phosphorus increased from 0.94 mg/l in the groundwater to 1.46 mg/l in the hatchery effluent, indicating a 0.62 mg/l input from hatchery operations. Under these worse-case conditions, 60 percent of the total phosphorus is supplied by the groundwater and 40 percent is supplied through the fish feed. Under average conditions, 18 percent of the total phosphorus is supplied by the groundwater and 82 percent is supplied through the fish feed. Figure 2.2 and Figure 2.3 show the mass balance of phosphorus under these two conditions as a pounds per day equivalent.

Figure 2.2
Phosphorus Mass Balance – Worse-Case Conditions

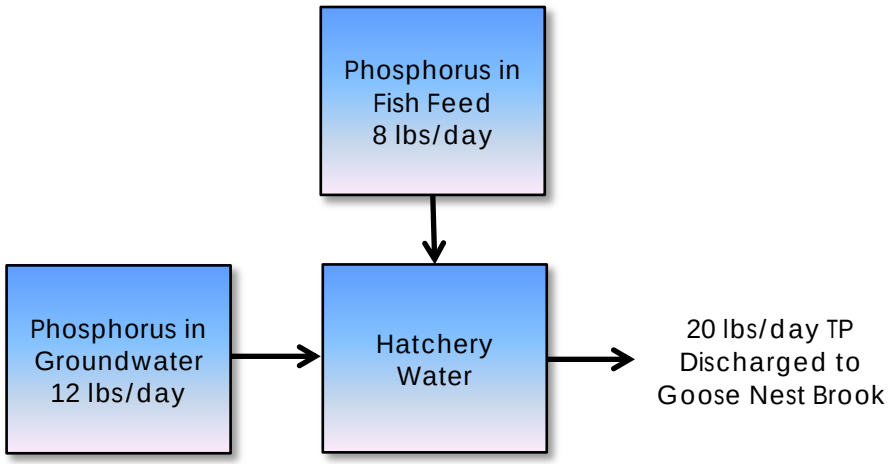
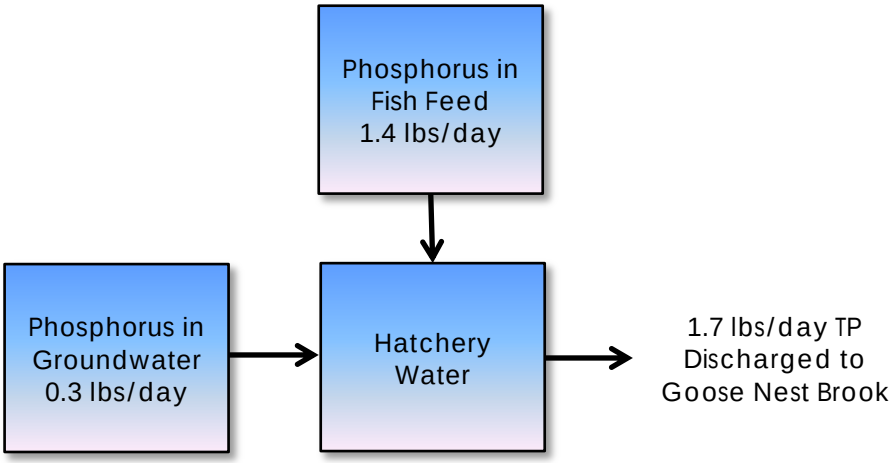


Figure 2.3
Phosphorus Mass Balance – Average Conditions



A sNRP concentration of 0.83 mg/L was measured leaving the hatchery. Assuming this is a representative number of typical worse-case conditions at the hatchery, the level of phosphorus can only be treated as low as 0.83 mg/L under such conditions. However, bench scale testing of the ballasted floc technologies, Actiflo® and CoMag®, reached total phosphorus concentrations as low as 0.022 mg/L and 0.014 mg/L, respectively. Both hatchery effluent samples for the bench scale tests were also collected under the worse-case scenario conditions and were collected on different days. The Actiflo® and CoMag® bench scale test reports are provided in Appendix B.

This discussion indicates that there is significant variability in phosphorus levels between average and worst-case conditions, and also that the sNRP levels may vary considerably. Both of these factors impact the ability to treat to levels near the limits of technology, and must be factored into the treatment system evaluation and selection.

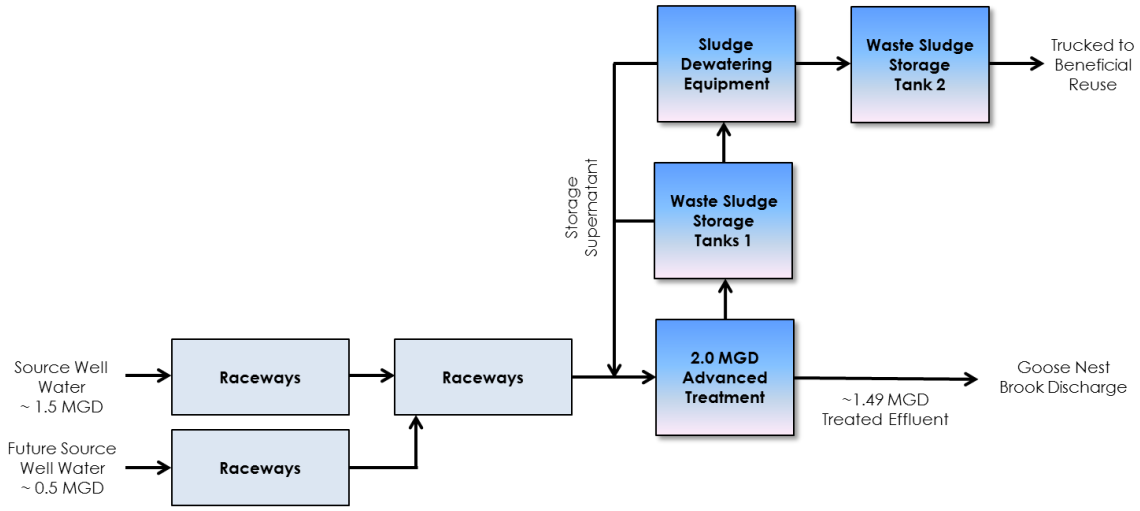
2.3 Design Flow

Final determination of the concepts and flows for consideration were made by DEM at a workshop meeting held on July 13, 2017 (see Figure 2.4).

Utilizing Best Management Practice (BMP) with chemical addition and filtration at the Lafayette Hatchery is estimated to only achieve an overall effluent quality of roughly 0.080 mg/l (80 ppb) to 0.100 mg/l (100 ppb) total phosphorus. Without treatment of the soluble phosphorus in the hatchery effluent, the permit objective of 0.025 mg/l (25 ppb) total phosphorus cannot be achieved.

The treatment layout concept to be evaluated is an end of pipe facility, where all of the hatchery discharge will be treated in a single facility. The design will treat higher flows of 2.0 MGD (2,000,000gpd), with the assumption that future flows may increase by 0.5 MGD (500,000gpd) to restore the raceways presently out of service due to lack of water.

Figure 2.4
In-Stream Treatment



It is possible that a portion (25%) of the effluent from the treatment system be used as recycle water for the hatchery. Reuse water will require treatment to a higher water quality level to eliminate impacts to the fish culture operation. Reuse water may require additional forms of treatment such as gas management for carbon dioxide and oxygen, as well as disinfection. If a recycle stream design were pursued, the temperature, pH, and concentrations of dissolved oxygen, dissolved carbon dioxide, hardness, alkalinity, nitrogen, and metals would need to be evaluated closely during pilot testing. Any additional treatment components needed for a recycle stream would increase the capital and annual costs.

2.4 Treatment System

The principle mechanism for phosphorus removal involves the creation of a chemical precipitate using iron and aluminum metal salts. Polymers will be used as flocculant aids. Based on bench scale testing results performed by two vendors, iron salts were found to be the most effective at removing phosphorus from the hatchery effluent samples. (Bench scale test reports are provided in Appendix B.)

Seven (7) alternative treatment options were also discussed during the July 13, 2017 workshop meeting. Information on these treatment alternatives can be found in the July 2017 Comparison of Alternatives for Phosphorus Removal Interim Report. Based on a preliminary review and screening of vendor proposals, options were consolidated into four (4) treatment technologies applicable to advanced tertiary phosphorus removal for further review, including:

1. Tertiary Filtration
2. Ballasted Floc Separation
3. Membrane Filtration
4. Constructed Wetlands

Operational costs can be only estimated at this time, and will be refined further following the piloting of recommended technologies. All process options need to include Sludge Thickening and Dewatering. Each Alternative is discussed in more detail in the following section. Costs are presented in Section 6.

2.5 Design Layout

The proposed location of the treatment system is west of the hatchery building and north of the raceways (see Figure 2.5 at the end the report). The treatment system will be enclosed in a pre-engineered building approximately 120' x 40' and will consist of pumps, a chemical feed system, chemical storage, safety equipment (sink, eye-wash station, and extinguisher), the selected treatment technology, and the sludge dewatering equipment. An alternative location for the pumps would be at the end of the hatchery raceways. The final location of the pumps would be determined through a hydraulic analysis and selection of pump type, to be performed during design. The treatment system layout with flow arrows is shown in Figure 2.6 at the end of the report.

The hatchery effluent will be pulled into the treatment system through the rotary pumps and 0.5 MGD will be recycled to the existing unused raceway, while the remaining 1.5 MGD will be discharged to Goose Nest Brook. The hydraulic profile is provided as Figure 2.7 at the end of the report.

The solids removed during treatment will be discharged to one of the two sludge holding tanks. The first tank will be used to store sludge produced from the treatment technology. Any liquid separated from the solids by gravity will flow back to the treatment technology and the settled solids will go into the dewatering equipment for thickening. Liquid separated from the solids in the dewatering equipment will also return to the treatment system. The dewatered solids will be stored in the second sludge holding tank awaiting transportation to a disposal facility. See Section 4 for details on disposal of the processed sludge.

3 Evaluation of Selected Alternatives

Each treatment alternative is presented in detail in the following sections with a discussion of estimated performance, advantages and disadvantages, and estimated relative costs.

3.1 Tertiary Filtration

Three (3) types of tertiary filtration technologies were considered:

- Deep bed up-flow continuous backwash filters (Blue Water Technologies Blue Pro® and Parkson DynaSand®);
- Synthetic-media filters (Schreiber Fuzzy Filter®)
- Tertiary disc filters (Kruger Hydrotech Discfilter)

Manufacture's literature as well as system dimensions are provided for each of these technologies in Appendix C.

Refer to Table 3.1 for a performance summary. Deep bed up-flow continuous backwash filters and synthetic media filters when used in a two-stage arrangement may be able to demonstrate meeting requirements by direct filtration, dependent upon the chemical dosages required. The third choice in this alternative, Disc Filters, do require upstream pretreatment due to the sensitivity to chemical loadings, which would result in additional equipment to purchase, install, operate, and maintain. Disadvantages of the continuous backwash filter and fuzzy filter process is a higher hydraulic profile than other treatment processes due to the height of the filter units. Piloting is needed to confirm that the continuous backwash filter and fuzzy filter can meet phosphorus treatment objectives.

Table 3.1
Tertiary Filtration Options

Process	Tertiary Filtration			
Vendor	**Blue Water Blue Pro®**	**Parkson DynaSand®**	**Schreiber Fuzzy Filter®**	**Kruger Discs Filter**
Estimated Cost	$1,261,000	$392,000	$590,000	*
Phosphorus Level	< 0.025 mg/L**	< 0.025 mg/L**	< 0.025 mg/L**	> 0.025 mg/L
Pros	Well tested competitive technology.	Well tested competitive technology.	Well tested competitive technology.	Well tested competitive technology.
Cons	Sensitive to loadings. High hydraulic profile.	Sensitive to loadings. High hydraulic profile.	Sensitive to loadings. High hydraulic profile.	Requires pretreatment step. Sensitive to loadings.

* Manufacturer would not provide a quote due to inability of treatment technology to meet the objective without pretreatment.

** < 0.025 mg/L achieved contingent on levels of sNRP and to be confirmed through pilot testing.

3.1.1 Deep Bed Up-Flow Continuous Backwash Filters

The Blue Pro® deep bed up-flow continuous backwash filters utilizes a two-stage process with two (2) up-flow filters in series. Parkson's DynaSand® deep bed up-flow continuous backwash filters can be provided as a one-stage process or a two-stage process. A one-stage process is recommended by Parkson for phosphorus removal at the hatchery. The DynaSand® piloting unit has the capability of testing under either condition.

In the deep bed up-flow process, feed water is passed upwards through the sand bed and exits the top of the filter as clean water. At the same time, sand is removed from the bottom, cleaned and returned to the top by an air lift. A portion of the filtered water is used to wash the sand and leaves the filter as a reject stream. Blue Pro® further provides reactive surface sites within the media bed, resulting in forced contact of chemical species with a continuously regenerated hydrous ferric oxide (HFO) coating that forms on the surface of the sand media.

The deep bed up-flow process is made up of cells that each contain multiple units. A redundant cell has been provided in the Blue Pro® and DynaSand® system costs, allowing for one cell in the system to be offline for maintenance or emergency repairs.

The need for upstream pretreatment is eliminated with the use of a two-stage process, which also provides for multipoint chemical injection, resulting in reduced chemical usage and sludge production. Whether or not a one-stage process can achieve the treatment requirements in a single process step would need to be confirmed during pilot testing.

3.1.2 Synthetic Media Filters

The Schreiber Synthetic-media Fuzzy Filter® was considered due to recent success treating aerated lagoon effluent in California. The filters were preceded by Heron Innovator's SAF (Suspended Air Flotation) process and were pilot tested to meet Title 22 Standards[11] with NTU of less than 2.

The Schreiber Fuzzy Filter® represents itself as an innovative and cost effective compressible media filter for water and wastewater treatment systems. Advantages are that it has a compact, modular footprint. The Filter operates in an up-flow design and achieves a reported high rate of solids removal through the use of synthetic fiber spheres. The low density and high porosity of the media results in more solids captured per volume of media. Because the filter media is compressible, the total porosity of the filter bed can be altered to meet influent characteristics by mechanically compressing the media. The filter media also represents a departure from conventional filter media in that the fluids to be filtered flow through the media as opposed to flowing around the media as in sand and anthracite filters. This feature allows for higher hydraulic loadings. A disadvantage is that filtration is not continuous. When the media is backwashed, the unit is off-line. A redundant unit has been provided in the system costs, allowing for one unit to be offline for the backwash cycle, maintenance, and/or emergency repairs.

[11] Title 22 California Code of Regulations, California Department of Public Health's Recycled Water Regulations.

The Schreiber Fuzzy Filter® can be provided as a one-stage process or a two-stage process. The need for upstream pretreatment could be eliminated by use of a two-stage process, which also provides for multipoint chemical injection, resulting in reduced chemical usage and sludge production. The vendor's representative recommended a one-stage process for phosphorus removal at the hatchery. Whether or not a one-stage process can achieve the treatment requirements in a single process step would need to be confirmed through pilot testing.

3.1.3 Disc Filters

Tertiary disc filters are typically used as a polishing filtration step. An upstream pretreatment step is required, which increases the cost and operational complexity of this technology. Manufacturers offer disc filters generally in two influent flow directions: filtering inside to outside; or filtering outside to inside. Drum filters are also utilized. The flow direction choice primarily affects the method of solids removal by pressure backwash or vacuum/reject pumping of the submerged or active filter area. The type of cloth media also varies from random weave fiber pile, to woven mesh (10 micron nominal) cloth.

Disc filters are sensitive to solids loading and would need to be paired with an intermediate treatment process installed upstream in order to achieve the desired phosphorus limit. Pairing disc filters with a second treatment process would increase costs associated with installation, maintenance, and labor.

3.2 Ballasted Floc Separation

Ballasted floc separation processes are provided by proprietary equipment. Two (2) ballasted floc separation vendors contacted for this project include:

- Actiflo® (Kruger)
- CoMag® (Evoqua)

Bench scale testing was conducted by both Actiflo® and CoMag®. Test results showed that both technologies were able to achieve the phosphorus goal of less than 0.025 mg/L. Bench Scale Test Reports are provided in Appendix B. Both vendors are confident of meeting the limits without additional upstream pretreatment, however, Actiflo® recommends adding a gravity sand filter after the treatment system as a measure of precaution. A gravity sand filter would increase the cost of a ballasted floc system by approximately $800,000. Pilot testing would be needed to determine the necessity of adding a gravity sand filter.

Typical of both vendors, the process consists of a clarification process that combines solids contact with ballast addition and solids recirculation. The result is a high-rate settling of solids utilizing a process that does not require backwashing, resulting in a smaller footprint and greater reliability than other technologies. The ballast media is in the form of sand or magnetite that greatly increases the settling capacity of the resulting floc particles. As the chemical sludge is wasted, the ballast is subsequently stripped from the concentrated floc and recirculated.

The cost and footprint of installing two ballasted flocculation systems for redundancy would be fairly expensive, considering redundancy is not needed for backwash cycles. In lieu of true redundancy, backup mechanical equipment has been included in the system costs for storage and change-out in the event of any mechanical failures. Manufacture's literature as well as system dimensions are provided for each of these technologies in Appendix D.

Advantages of ballasted floc separation processes are that it can achieve the treatment requirements in a single process step. Both Actiflo® and CoMag® systems would need to be pilot tested to confirm the ability to perform as well as handle plant upsets. A comparison of the two (2) options considered for ballasted floc separation is provided in the following table using comparable construction costs:

Table 3.2
Ballasted Floc Separation Options

Process	Tertiary Filtration	
Vendor	**Veolia Actiflo®**	**Evoqua CoMag®**
Estimated Cost	$935,999	$835,000
Phosphorus Level	< 0.025 mg/L*	< 0.025 mg/L*
Pros	Bench scale testing shows TP requirement can be met.	Bench scale testing shows TP requirement can be met.
Cons	Requires additional structure	Requires additional structure

* < 0.025 mg/L achieved contingent on levels of sNRP and to be confirmed through pilot testing.

3.3 Membrane Filtration

Three (3) membrane filtration vendors contacted for this project include:

- BioTRIPURE™ Hollow Fiber Membrane Systems
- KOCH PURON® Hollow Fiber Membrane Systems
- Pentair X-Flow Hollow Fiber Membrane System

Hollow Fiber Membrane Systems are compact and fully automated PLC controlled systems furnished with multiple membrane modules. The UF (ultrafiltration) Membrane is an effective treatment for reuse of secondary/tertiary effluent, phosphorus removal and pre-treatment for reverse osmosis (RO). The modules typically operate using inside-out membrane technology. Inside-out technology means the feed passes along the inside of the lumen and through the membrane wall as purified water. This approach minimizes dead space and eliminates the potential of solids build-up within the module housings. The membrane wall acts as a physical barrier for all particles and molecular structures larger than 0.03

microns. This ultrafilter pore rating will provide for a 6-log rejection of bacteria, germ and large organic molecules and a 4-log rejection of viruses. The end result of the membrane process is purified water or UF permeate with turbidity levels of less than 0.1 NTU and Silt Density Index (SDI) levels of <3.

Each membrane module contains approximately 15,000 hollow fiber lumens which are bundled into sections separated by corrugated plates contained within a 9.5" diameter thermoplastic housing. All system functions are fully-automated to maximize product recovery rates and minimize operator attention.

The membranes undergo an automated hydraulic flush mode every 20 – 30 minutes based on the feed water characteristics. The membranes are cleansed every 12 – 24 hours based on feed stream characteristics using a combination of sodium hypochlorite and sodium hydroxide followed by acid to reduce the system TMP and maintain membrane flux. Each system is made-up of skids containing multiple membrane modules. A redundant skid is included in the system costs allowing for one skid to be offline for the hydraulic flush mode, maintenance, and/or emergency repairs.

Manufacture's literature as well as system dimensions are provided for each of these technologies in Appendix E.

Advantages of Hollow Fiber Membrane Systems are that it can achieve the treatment requirements in a single process step. This technology is commonly used in water reuse, and thus may be expected to consistently produce an effluent of high water quality. Recognizing that a portion of the effluent is being reused in the hatchery, the risk of upset and resultant consequences on the fish may be an important consideration. Disadvantages may include a higher energy component typical of membrane systems.

Table 3.3
Hollow Fiber Membrane Filtration Options

Process	Tertiary Filtration		
Vendor	**BioTRUPURE™**	**Koch Puron®**	**Dynasand Pentair X-Flow**
Estimated Cost	$1,558,000	$1,350,000	$1,901,105
Phosphorus Level	< 0.025 mg/L*	< 0.025 mg/L*	< 0.025 mg/L*
Pros	Industry proven technology. Fully automated system.	Industry proven technology. Fully automated system.	Industry proven technology. Fully automated system.
Cons	Higher energy component.	Higher energy component.	Higher energy component.

* < 0.025 mg/L achieved contingent on levels of sNRP and to be confirmed through pilot testing.

3.4 Constructed Wetlands

Wetlands have proven to be a well-established and cost-effective method for treating wastewater, such as municipal or domestic sewage, industrial and agricultural wastewater, landfill leachate, and storm water runoff.[12] Phosphorus removal processes include chemical precipitation, sedimentation, and substrate adsorption. Research indicates loading sensitivities, with one study finding that the overall removal efficiency for phosphate decreased markedly from 71.2%–31.9% as the hydraulic loading rate increased.[13] A standard detail of a constructed wetland is provided in Appendix F.

Adsorption is the most important phosphorus removal process in the wetlands. Adsorption of phosphorus occurs due to reactions with iron, calcium and magnesium present in sediments. Adsorption of phosphorus to iron ions takes place under aerobic and neutral to acidic conditions to form stable complexes. If the conditions are anaerobic, adsorption to iron ions is less strong.[14] Over time the sorption capacity of the soils will decrease as the sorption sites become saturated.[15]

Decomposition of litter (dead plants) and organic matter in the wetland also takes up phosphorus. This process results in storage of phosphorus in the organic matter which will be released eventually. Removal of phosphorus from the water does not result in its complete removal from the wetland system. Nitrogen is eliminated from the system in the form of Nitrogen gas, but phosphorus is only physically removed from the water and is either adsorbed to the metals ions, taken up by plants, or fixed in the clay minerals. Unless permanently fixed through adsorption or removed by harvesting, the phosphorus will be released.

Treatment through constructed wetlands is limited to the warmer months. Freezing that occurs in the winter can lead to flooding and hydraulic failure.[16] For this reason, it is common practice in colder climates to store effluent for later treatment during warmer months. In just one week, the hatchery would have to store 14 million gallons onsite.

Constructed wetlands require a relatively large area for treatment. Hatchery staff have reported seasonal flooding onsite, which would limit the depth of the wetland. One reference stated that approximately 90% nutrient removal from landfill leachate can be achieved with a residence time of approximately 14 days.[17] Even with a constructed wetland depth of 2 feet, and assuming no space for soil or vegetation (i.e. an empty pool), over 40 acres would be required to meet this residence time.

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[12] Webb, J.M.; Quinta, R.; Papadimitriou, S.; Norman, L.; Rigby, M.; Thomas, D.N.; Le Vay, L. Halophyte filter beds for treatment of saline wastewater from aquaculture. Water Res. 2012, 46, 5102–5114.

[13] Lin, Y.F.; Jing, S.R.; Lee, D.Y.; Wang, T.W. Nutrient removal from aquaculture wastewater using a constructed wetlands system. Aquaculture 2002, 209, 169–184.

[14] Ishadeep Khanijo, Nutrient removal from wastewater by wetland systems, 2007.

[15] National Risk Management Research laboratory, Office of Research and Development, USEPA; Constructed Wetlands Treatment of Municipal Wastewater. 2000, Page 5.

[16] McBean, E.; Mulamoottil, G.; Rovers, F. Constructed Wetlands for the Treatment of Landfill Leachates. CRC Press LLC, 1999, Page 36.

[17] McBean, E.; Mulamoottil, G.; Rovers, F. Constructed Wetlands for the Treatment of Landfill Leachates. CRC Press LLC, 1999, Page 22.

A constructed wetland was designed by Fuss & O'Neill for Providence Water in 2014. This constructed wetland was designed for stormwater management with a depth of approximately 3 feet and a surface area of approximately 0.14 acres. The estimated cost of this system was $257,000 to construct.

Treatment removal efficiencies for phosphorus are seasonal, and dependent on plant and soil uptake which decreases over time. There is not enough space onsite to install a constructed wetland or the storage tanks that would be required during the winter months. This process cannot meet phosphorus treatment objectives.

3.5 System Operator

Each of the treatment technologies, coupled with a dewatering system, will require an operator. While some tasks will be vendor specific, in general many of the operator commitments will be common for all of the alternatives. The operator would be responsible for the following tasks:

- Order polymer and coagulant for chemical addition.
- Order ballasted flocculation media (if technology is selected).
- Sample for phosphorus and other required operational and permitting parameters.
- Compile discharge monitoring reports.
- Monitor system performance and adjusting settings as-needed.
- Operate the sludge dewatering equipment.
- Transport, or arrange for transport of sludge for disposal.
- Perform routine maintenance on the pump station, treatment system, and sludge dewatering system.

If a truck is purchased for transport of sludge, then an employee would need a Commercial Driver's License to transport the sludge. This service can also be contracted out.

The system would not need to be staffed on second- or third-shift, or on weekends. It would need to be checked daily during the week and the operator would need to be on-call during off-hours to respond to emergency alarms. System maintenance would need to occur monthly. Sludge dewatering and hauling would need to occur approximately 3 days a week, but this number may change based on pilot testing results.

Given the sophistication of the treatment process and the sludge handling system, it is assumed that the operator would need a wastewater operator license, as regulated by the Board of Certification of Operators of Wastewater Treatment Facilities. There are four grades of licenses (1 through 4) and the required grade of license would be determined by the Board. Refer to the *Rules and Regulations for Wastewater Treatment Facility Operators* for details on licensing requirements (Appendix G). The operator salary requirements would be based on the required grade of license and the amount of time needed to run the dewatering equipment.

4 Solids Waste Management

Processes for sludge handling, storage, thickening, decanting to concentrate, and removal are common to all treatment concepts. Removal may be application to agricultural land for beneficial reuse, or simply offsite disposal. Sludge dewatering is required to reduce the volume of sludge prior to removal and/or disposal. Actual chemical sludge generation rates and dewaterability must be determined through testing on sludges produced during a pilot testing program.

For general disposal of sludge through land application, a Beneficial Use Determination (BUD) application needs to be submitted to the RIDEM Office of Waste Management. Historically, solids collected from sumps in the raceways have been disposed of in a field at the Great Swamp Management Area in West Kingston. This may continue to be a disposal option.

General land disposal is not a viable option during the winter months and agricultural land application is only viable during growing seasons. Unlike most crops, corn crops have two growing seasons per year, extending the period of time in which composted sludge can be applied to the same area. During the colder months of the year, the sludge will need to be disposed of through alternative means. On average, 75 percent of the municipal wastewater sludge in Rhode Island is disposed of through incineration.[18]

The Office of Waste Management (OWM) was contacted to discuss the uniqueness of the solid waste that would be produced at the hatchery, and OWM indicated that any agricultural land application would need to be supplemented with nitrogen through composting (i.e. addition of yard and/or leaf waste to the chemical sludge). If the hatchery were to compost the sludge, then a composting application would need to be submitted to the OWM, not a BUD application. A composting application is only required if the operation is medium to large scale in size (greater than or equal to 25 cubic yards on-site). Small composting operations do not need to submit an application.

Previous methods of transporting solids collected from the hatchery were through the hatchery stocking truck. The truck needed to be disinfected after each trip of solids transportation. Given the potential health risk to the fish, the labor required for disinfecting the truck, and the volume of sludge that will be generated, it is recommended that a separate vehicle or roll-off trailer be obtained for this purpose.

Each treatment alternative will generate a solids reject stream, which will be directed to a sludge holding tank. Sludge will then be dewatered and/or thickened, and then directed to a roll-off or similar container for removal. The dewatering technology should be tested as part of the pilot testing program. Technologies for dewatering consideration during piloting include the following:

- Rotary Screw Press
- Rotary Drum Thickener
- Centrifuge
- Belt Filter Press

[18] Faulker, Tim; In-State Facilities Incinerate R.I.'s Wastewater Sludge, ecoRI News, October 21, 2013.

5 Environmental Impacts

The analysis herein evaluated alternatives designed to ensure compliance with the RIPDES discharge permit. The selected plan was chosen based on its technical feasibility while recognizing the environmental impacts of each option. While the selected plan represents an environmentally feasible and acceptable plan, potential impacts have been identified with implementation. Most of the impacts are associated with construction related activities of the new facilities and will therefore be temporary in nature. These impacts, as well as potential mitigating strategies, are evaluated below.

5.1 Surface Water Quality

No negative impacts to surface water quality are anticipated from construction of the treatment system. Erosion and sedimentation control measures will be implemented as required to prevent runoff into nearby surface waters during construction.

The hatchery currently discharges to Goose Nest Brook and will continue to do so after the treatment system is installed. Water quality is expected to improve as a result of this project. Following the implementation of the treatment system, the hatchery effluent will be treated to a higher degree in terms of nutrient removal, thus improving water quality in Goose Nest Brook and downstream.

5.2 Groundwater Quality

The hatchery site is not located on or near any existing public water supply from groundwater source. The use of the site in the future as a source of potable groundwater is both impractical and unlikely. There will be no impact on individual wells or groundwater quality as a result of this project. The hatchery discharge is a point source discharge into Goose Nest Brook and therefore will not have any impact on existing groundwater quality conditions.

If sludge disposal utilizing composting for nutrient enrichment of the sludge is selected, then this evaluation will need to be modified based on site specific features.

5.3 Disturbance to Wetlands

Portions of the site are within the Riverbank Wetland associated with the Annaquatucket River and are within the 50-foot Perimeter Wetland of the bordering freshwater wetlands associated with the swamp and overbank areas associated with the Annaquatucket River. As a result, the project is subject to Rhode Island Department of Environmental Management wetland regulations and requires a Request for Preliminary Determination application as described in Rule 9.0 of the Rules and Regulations Governing the Administration and Enforcement of the Fresh Water Wetlands Act.

5.4 Stormwater Discharge

As with any construction project, there exists a potential for soil erosion and sediment washed away into surface water during storm events. Depending upon the area of soil disturbance associated with the

proposed construction activities, it is likely that the project will require development of a Soil Erosion and Sediment Control (SESC) Plan in accordance with Standard 10 of the RIDEM Stormwater Design and Installation Standards Manual. Appropriate erosion and sediment control measures, such as hay bales and silt fences, are used to prevent the dispersion of sediments into wetlands and water courses. Disturbed vegetated areas need to be loamed, seeded, and mulched as soon as possible to re-establish the vegetation cover and prevent erosion. The use of silt sacks in catch basin drainage systems are also recommended to reduce the amount of sediment discharged into water courses.

5.5 Air Quality

No long term change in existing air quality is anticipated as a result of the proposed plan. Construction may cause a short-term increase in total suspended particulate matter and emissions from construction equipment in the area, although the level will not be sufficient to impact ambient air quality.

Once construction is completed, the new treatment system will have no negative impact on air quality.

5.6 Noise

The new treatment facility will be designed to reduce noise levels from operations. Noise generating operations will be mitigated by acoustical enclosures, use of sound attenuating construction materials such as acoustic block and insulation, and equipment specifications that will dictate allowable noise levels emanating from the equipment.

The construction of the new treatment system will involve the use of various trucks and construction equipment. The new construction may temporarily elevate the noise levels from the hatchery site above current background levels.

The impact of construction noise can be mitigated by enforcing a weekday work schedule and normal daytime working hours. Equipment and construction noise, while noticeable, is not expected to raise noise levels from the site boundary above levels that would be considered deleterious.

6 Cost Analysis of Selected Alternatives

An opinion of probable cost for each technically feasible alternative was developed, including a breakdown of construction and estimated increase in annual O&M costs. Pilot testing has not been completed; therefore a 20% construction contingency was included for this stage of the project. This cost analysis is intended to provide a direct comparison of the phosphorus removal alternatives.

6.1 Capital Costs

Capital costs were first based on proposals solicited from manufacturers. Multiple proposals were obtained where possible and the equipment cost averaged where equipment features were similar. Factors were added for equipment installation, building additions and structural modifications where needed. Note that the power demands for each alternative vary significantly, therefore the standby power generator allowance similarly varies for each alternate. A 15% factor was added for Contractor Overhead and Profit to obtain a construction subtotal.

Development costs were added to cover Preliminary Engineering, Final Design, and Construction Administration using typical industry values. An allowance for piloting is provided for all alternatives. A 2% allowance was provided for Legal, Fiscal and Administrative Costs estimated to be incurred by the RIDEM for the project. At present, no Land Acquisition is anticipated; however a line item was included at this preliminary stage.

6.2 O&M Costs

The existing operating budget was examined and used to create a baseline for this analysis. The O&M categories were consolidated into the following:

- Labor – one full-time person at a rate of $20/hour. Note that one alternative requires less operator attention
- Power – note that the three alternatives have a significant variation is power demands
- Chemicals – all chemical supplies
- Maintenance – all equipment maintenance and replacement budgets
- Residuals – all sludge, screenings and grit disposal costs

This analysis estimated the increase in annual O&M costs for each alternative over the existing budget. Each alternative was assumed to require one (1) additional staff person, due to increased sludge management needs. Vendor proposals included estimated power use. Textbook values were used to determine sludge production rates at this stage. Chemical use was determined using average costs proposed by technologies that bench scale tested.

6.3 Life Cycle Costs Net Present Value

A preliminary life cycle present worth cost analysis was prepared for each of the three (3) alternatives. The life cycle cost analysis included the following assumptions:

- Costs are converted to present day dollars.
- A 20-year planning period is used.
- The discount rate was assumed to be 3.5%.
- The net present value (NPV), or Total Present Worth is calculated as the sum of the capital cost plus the present worth of the uniform series of annual O&M costs.

Capital cost, increase in annual O&M cost, and present worth of each of these values, is presented in the following table. In terms of both Capital and Operating Costs, Alternative 1, Tertiary Filtration provides the lowest net present value. To finalize estimated costs for chemical use, sizing of facilities and dewatering of the chemical sludge, piloting will be necessary.

The capital costs and life-cycle costs are summarized on Table 4.1.

Table 4.1
Opinion of Probable Cost of Alternatives

FUSS & O'NEILL	OPINION of PROBABLE COST of ALTERNATIVES for PHOSPHORUS REMOVAL		
Alternative / Cost Item	1 - Tertiary Filtration	2 - Ballasted Floc Separation	3 - Membrane Filtration
Phosphorus Construction Costs			
Phosphorus Removal Treatment System	$748,000	$886,000	$1,604,000
Treatment System Building	$400,000	$400,000	$400,000
Sludge Thickening, Dewatering, & Storage	$900,000	$900,000	$900,000
Generator	$40,000	$70,000	$160,000
Process Piping (Internal & Yard)	$200,000	$200,000	$200,000
Civil/Site	$50,000	$50,000	$50,000
Electrical & Controls	$100,000	$100,000	$100,000
Subtotal Construction	$2,438,000	$2,606,000	$3,414,000
Comparative Bench Scale Testing	$30,000	$30,000	$30,000
Pilot Testing for Two Equipment Vendors	$80,000	$80,000	$80,000
Development Costs[1] (~20%)	$488,000	$522,000	$683,000
Permitting (~2%)	$49,000	$53,000	$69,000
Legal, Fiscal, Administrative (~2%)	$49,000	$52,120	$69,000
Contingency (~20%)	$488,000	$522,000	$683,000
Land Acquisition	$0	$0	$0
CAPITAL TOTALS	**$3,622,000**	**$3,865,120**	**$5,028,000**
Additional Annual Operating Costs			
Labor[2]	$41,600	$41,600	$27,800
Power[3]	$4,300	$7,100	$45,000
Chemicals	$50,000	$50,000	$50,000
Media	$0	$2,000	$0
Maintenance	$3,600	$9,000	$38,000
Residuals[4]	$50,000	$50,000	$50,000
ANNUAL O&M TOTALS	$149,500	$159,700	$210,800
ANNUAL O&M PRESENT WORTH[5]	**$2,125,000**	**$2,270,000**	**$2,996,000**
TOTAL PRESENT WORTH	**$5,747,000**	**$6,136,000**	**$8,024,000**

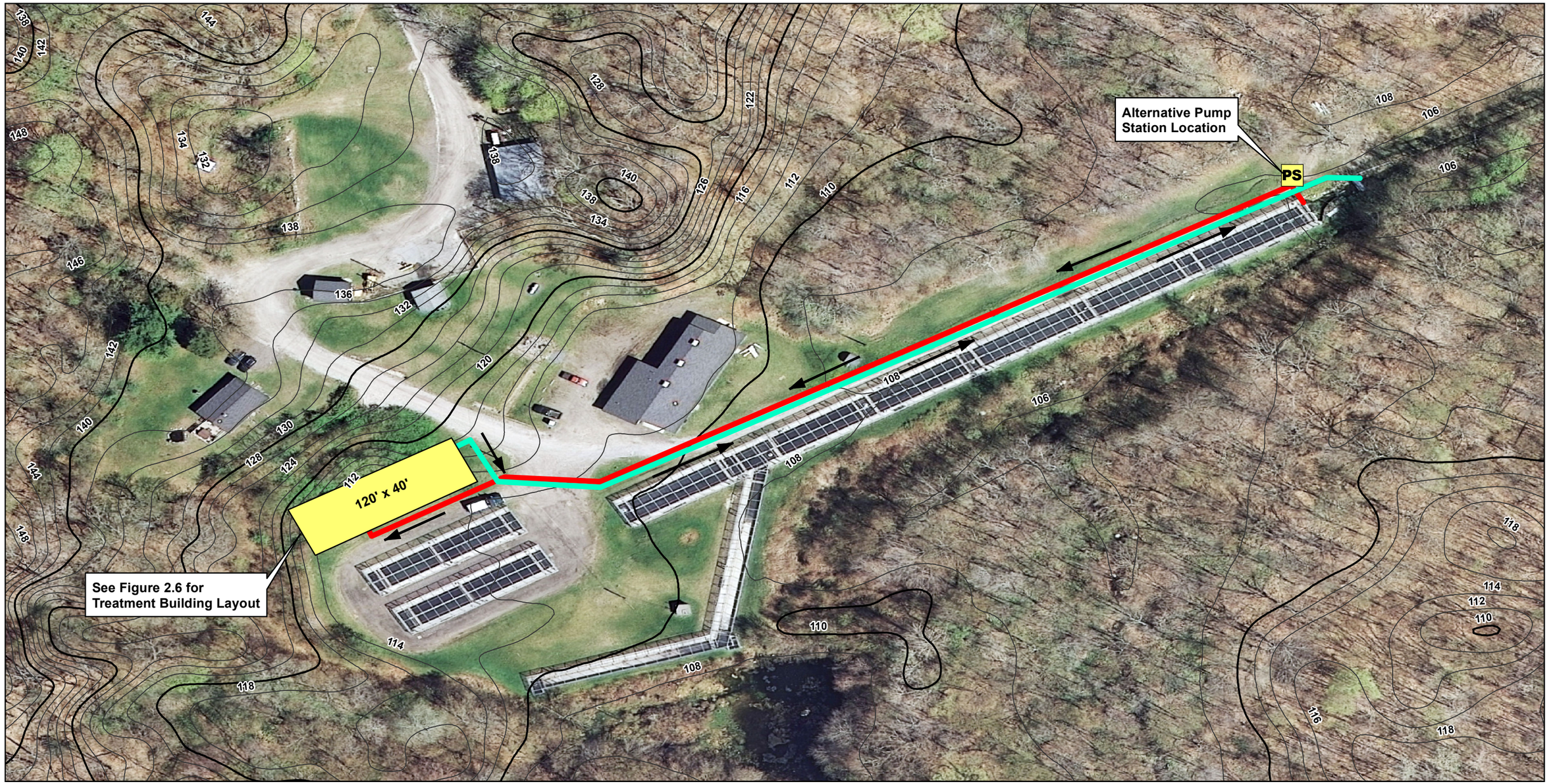
1. Covers Preliminary Engineering, Final Design, and Construction Administration.
2. Assumes one new full-time staff personnel at $20/hr.
3. Assumes power cost of $0.10/kWh.
4. Cost of residuals disposal can be reduced through land application disposal.
5. PW value use 3.5%; Factor = 14.212.

6.4 Design-Build-Operate

In the United States, the prevalent delivery method of large capital investment projects involves independent phases contracted by the owner. Traditionally, an initial contract is awarded for the design and bid assistance of the project, leading to a separate contract for the construction process. The operation is typically the responsibility of the owner unless an operation and maintenance contract is awarded to a third party. In this delivery method, the client holds the ownership and title along with the risk and responsibility. Alternative delivery methods have become more common, particularly where owners have limited knowledge of the technical aspects of the project.

Design-Build constitutes the most common alternative delivery method within the United States. In this process, a single contract is awarded for both design and construction phases. In this method, operation and maintenance services are contracted separately. Less common alternative delivery methods include Build-Operate-Transfer or Build-Own-Operate-Transfer. These methods are generally undertaken as a public-private partnership in which the private-sector partner assumes ownership of the project along with the associated risk and responsibility for a contracted time period before transferring ownership to the public-sector partner. In this method, financing is almost exclusively provided by the private-sector partner which is recovered during the operation phase prior to transfer. Other alternative delivery methods may occasionally be found consisting of variations on the above approaches.

We contacted the various vendors regarding this method of implementation, and it appears to be seldom used. The technologies that could be contracted out as Design-Build-Operate or Build-Operate are Kruger's Actiflo, BioProcessH2O's BioTRIPURE™, and Pentair X-Flow's Dynatec Ultratfiltration System. These delivery methods were not evaluated during this phase of the project because they can be very costly and don't typically align with standard government procurement procedures.



Treatment System Building
10 Foot Surface Elevation Contour
2 Foot Surface Elevation Contour
PS Pump Station
Hatchery Effluent Piping
Treatment Effluent Piping

1"= 100'

0 25 50 100 Feet

N

CONCEPTUAL SITE PLAN

RIDEM Lafayette Hatchery

North Kingstown Rhode Island

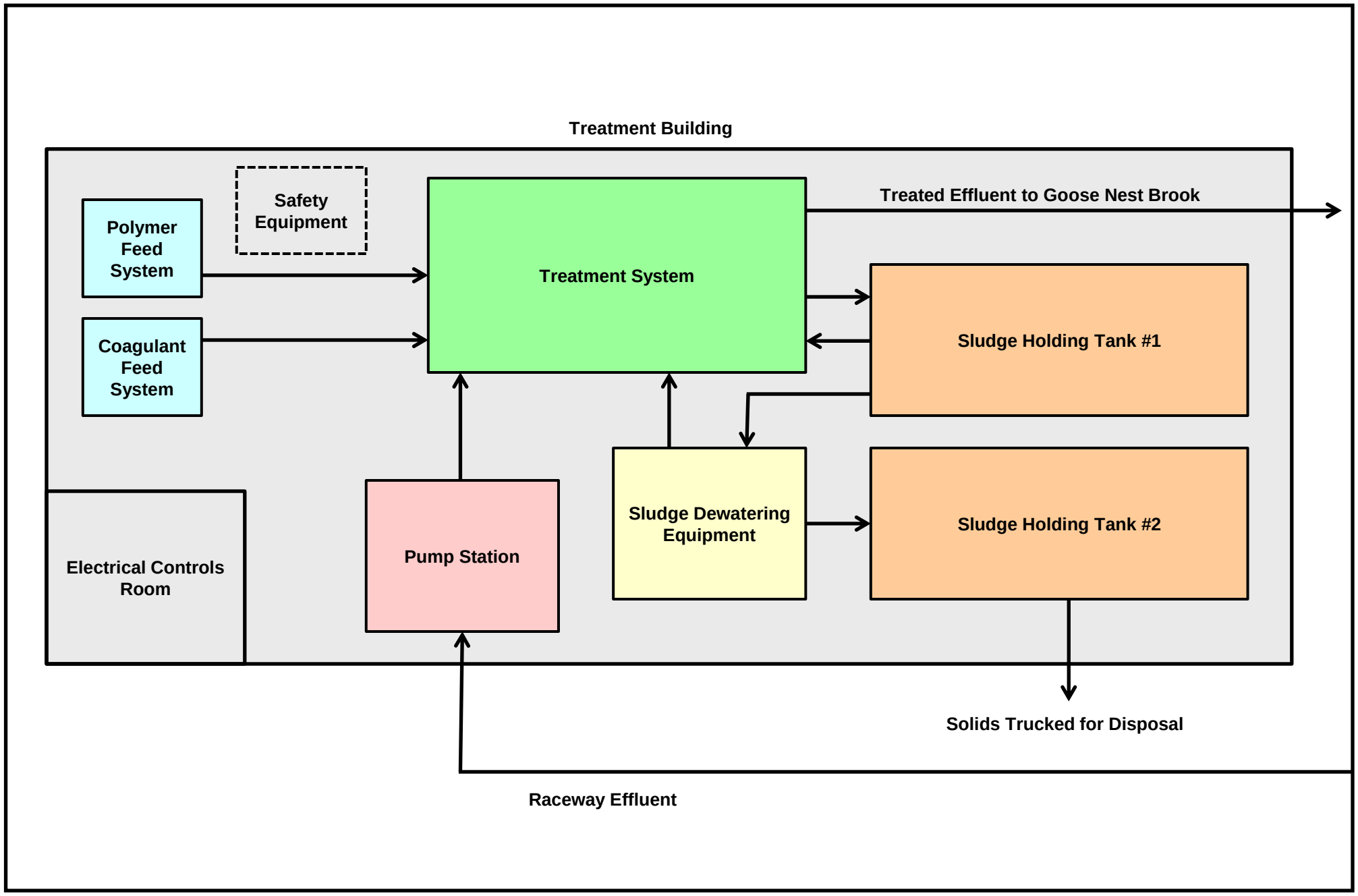
FUSS & O'NEILL
317 Iron Horse Way, Suite 204
Providence, RI 02908
401.861.3070

Figure 2.5

Disclaimer: This map is not the product of a Professional Land Survey. It was created by Fuss & O'Neill, Inc. for general reference, informational, planning and guidance use, and is not a legally authoratative source as to location of natural or manmade features. Proper interpretation of this map may require the assistance of appropriate professional services. Fuss & O'Neill, Inc. makes no warrantee, express or implied, related to the spatial accuracy, reliability, completeness, or currentness of this map.

Data Source(s):
2011 RIDEM Multispectral Orthophotography of Rhode Island; 0325001750. Published by USGS, 2011. Posted by RIGIS.
Elevation Contours, 2 Foot Interval and 10 Foot Interval; contours2ft11 and controus10ft11. Published by URI EDC, 2013. Posted by RIGIS.

K:\P2015\0756\A10\Data\MXD\Conceptual Site Plan.mxd



SCALE: N.T.S.

FUSS & O'NEILL
317 IRON HORSE WAY, SUITE 2014
PROVIDENCE, RI 02908
401.861.3070
www.fando.com

RIDEM

TREATMENT BUILDING LAYOUT

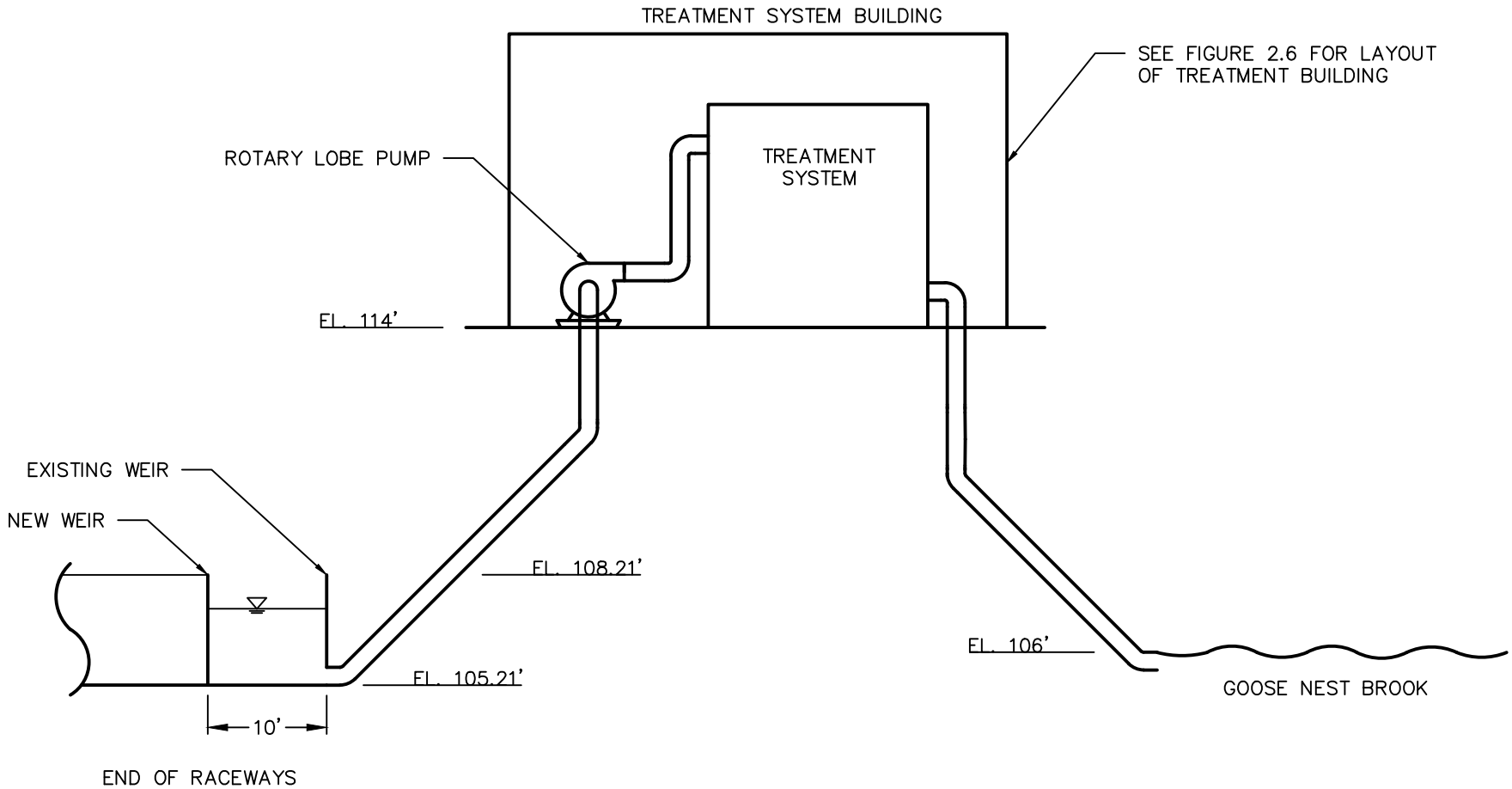
LAFAYETTE HATCHERY PHOSPHORUS REMOVAL

NORTH KINGSTON RHODE ISLAND

PROJ. No: 20150756.A10
DATE: FEBRUARY 2018

FIG 2.6

File Path: F:\P2015\0756\A10\Deliverables\Task 3



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RIDEM

HYDRAULIC PROFILE

LAFAYETTE HATCHERY PHOSPHORUS REMOVAL

NORTH KINGSTON CONNECTICUT

PROJ. No.: 20150756.A10
DATE: OCTOBER 2017

FIG 2.7

File Path: J:\DWG\P2015\0756\A10\Civil\Profile\20150756A10_PRF01.dwg Layout: PF-101 Plotted: Wed, January 31, 2018 - 8:43 AM User: rschnabel
Plotter: DWG TO PDF.PC3 CTB File: FO.STB
MS VIEW: LAYER STATE:

Appendix A

Phosphorus Laboratory Results

New England Testing Laboratory, Inc.
(401) 353-3420

REPORT OF ANALYTICAL RESULTS

NETLAB Work Order Number: 7J13010
Client Project: Fuss & O'Neill / Lafayette Hatchery

Report Date: 17-October-2017

Prepared for:

Charlene
Laura Marcolini & Associates
2155 Diamond Hill Road
Cumberland, RI 02864

Richard Warila, Laboratory Director
New England Testing Laboratory, Inc.
59 Greenhill Street
West Warwick, RI 02893
rich.warila@newenglandtesting.com

Samples Submitted:

The samples listed below were submitted to New England Testing Laboratory on 10/13/17. The group of samples appearing in this report was assigned an internal identification number (case number) for laboratory information management purposes. The client's designations for the individual samples, along with our case numbers, are used to identify the samples in this report. This report of analytical results pertains only to the sample(s) provided to us by the client which are indicated on the custody record. The case number for this sample submission is 7J13010. Custody records are included in this report.

Lab ID	Sample	Matrix	Date Sampled
7J13010-01	Source H20	Water	10/13/2017
7J13010-02	Discharge	Water	10/13/2017

Request for Analysis

At the client's request, the analyses presented in the following table were performed on the samples submitted.

Discharge

Total Suspended Solids	SM2540-D
Total Phosphorous	SM4500-P-E
ortho-Phosphate	SM4500P-E
Dissolved Phosphorous	SM4500-P-E
Dissolved Ortho-Phosphate	SM4500P-E

Source H20

Total Suspended Solids	SM2540-D
Total Phosphorous	SM4500-P-E
ortho-Phosphate	SM4500P-E
Dissolved Phosphorous	SM4500-P-E
Dissolved Ortho-Phosphate	SM4500P-E

The analytical methods provided are documented in the following references:

Manual of Methods for Chemical Analysis of Water and Water Wastes, EPA-600/4-79-020 (Revised 1983), USEPA/EMSL.
Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998, APHA, AWWA-WPCF.
40 CFR 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act*, Office of Federal Register National Archives and Records Administration.

Results:

Sample: Source H20
7J13010-01 (Water)

General Chemistry

	Result	Reporting Limit	Units	Date Analyzed
ortho-Phosphate as P	**0.27**	0.02	mg/L	10/13/17 10:10
Total Phosphorous	**0.94**	0.02	mg/L	10/13/17
Total Suspended Solids	**16**	2	mg/L	10/16/17

Dissolved General Chemistry

	Result	Reporting Limit	Units	Date Analyzed
ortho-Phosphate as P	**0.11**	0.02	mg/L	10/13/17 9:55
Phosphorous	**0.12**	0.02	mg/L	10/13/17

Sample: Discharge
7J13010-02 (Water)

General Chemistry

	Result	Reporting Limit	Units	Date Analyzed
ortho-Phosphate as P	**0.12**	0.02	mg/L	10/13/17 10:10
Total Phosphorous	**1.56**	0.02	mg/L	10/13/17
Total Suspended Solids	**16**	3	mg/L	10/16/17

Dissolved General Chemistry

	Result	Reporting Limit	Units	Date Analyzed
ortho-Phosphate as P	**0.11**	0.02	mg/L	10/13/17 9:55
Phosphorous	**0.94**	0.02	mg/L	10/13/17

Case Narrative

The samples were all appropriately cooled and preserved upon receipt. The samples were received in the appropriate containers. The chain of custody was adequately completed and corresponded to the samples submitted.

All samples were analyzed in accordance with 40 CFR 136 approved methodologies.

New England Testing Laboratory
59 Greenhill Street
West Warwick, RI 02893
1-888-863-8522

7 J 1 3010 L

Chain of Custody Record

Project No. 531
Project Name/Location: FOSS & O'NEILL / LAFAYETTE HATCHERY
Client: LAURA MARCOLINI & ASSOCIATES, INC.
Report To: LAURA @ LMA INC.US
Invoice To: CHARLENE @ LMAINC.US

Date	Time	Comp	Grab	Sample I.D.	Aqueous	Soil	Other	No. of Containers	Preservative	Total Phosphorous	pH	TSS, Total ortho-Phosphate	Dissolved TP	Dissolved ortho-Phosphate				
10/13/17			X	SOURCE H2O	X			1	NON/ICE		•	X	X	X				
			X	SOURCE H2O	X			1	H2SO4/ICE	X	•							
			X	DISCHARGE	X			1	NON/ICE		•	X	X	X				
			X	DISCHARGE	X			1	H2SO4/ICE	X	•							

Tests**

Sampled By:	Date/Time	Received By:	Date/Time	Laboratory Remarks:	Special Instructions:
[signature]	8:53 AM				DETECTION LEVELS TO/BELOW PERMIT CONCENTRATION 0.025 mg/L
Relinquished By: [signature]	Date/Time	Received By: [signature]	Date/Time 10/13 9:13	Temp. Received: 6C	

**Netlab Subcontracts the following tests: Radiologicals, Radon, TOC, Asbestos, UCMRs, Perchlorate, Bromate, Bromide, Sieve, Salmonella, Carbamates

EXPEDITED IF POSSIBLE
Turnaround Time [Business Days]: **5 Days**

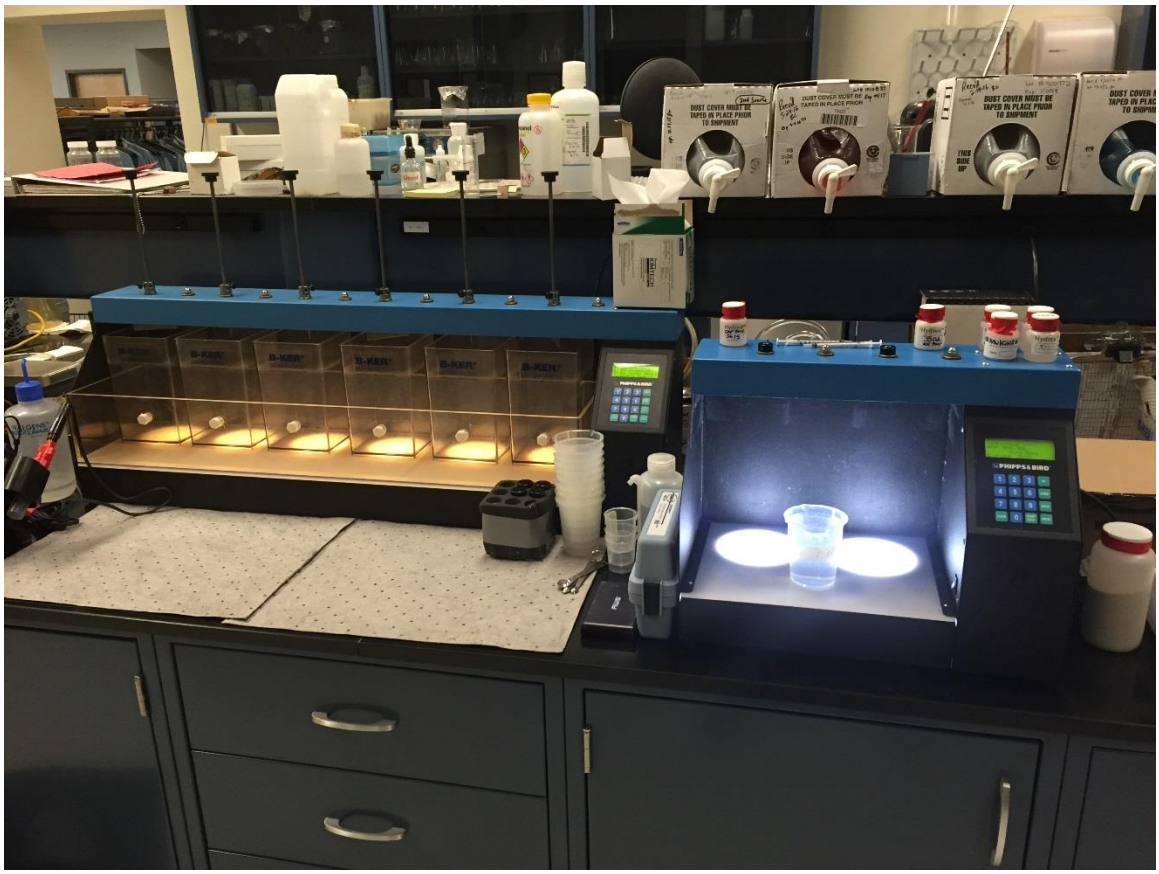
Appendix B

Bench Scale Test Reports (Actiflo® and CoMag®)

ACTIFLO®

Bench Scale Test Report

Lafayette Fish Hatchery, RI



Kruger
4001 Weston Parkway
Cary, NC 27513 USA
Tel: 919-677-8310 ● Fax: 919-677-0082
Web site: www.krugerusa.com

TABLE OF CONTENTS

1. *Executive Summary* *0*
2. *Bench-Scale Test Procedure* *1*
3. *Materials and Methods* *1*
4. *Chemical Dosing Example Calculations* *2*
5. *Conclusions* *3*

APPENDIX A: Testing Summary Table *6*

1. Executive Summary

Kruger personnel performed ACTIFLO Process bench scale simulation testing to verify the effectiveness of ACTIFLO for TP removal on August 29th and 30th, 2017 and the results from testing are as follow below.

					Kruger Benchtop Results						Cameron Testing Labs Results			
Date	Jar #	Coagulant		NaOH	Turbidity	OP	Filt OP	TP	Filt TP	Alkalinity	TP	Filt TP	TSS	Sample Number
		Type	mg/L	mg/L	NTU	mg/L as P	mg/L as P	mg/L as P	mg/L as P	mg/L as CaCO3	mg/L as P	mg/L as P	mg/L	
	RAW	-	-	-	0.8	0.147	0.041	0.230	0.056	20.2	0.613	-	< 5.0	RAW
29-Aug-17	1	Ferric	40	-	5.0	0.070	-	-	-	-	0.254	-	-	F-40
29-Aug-17	2	Ferric	60	-	13.8	0.075	-	-	-	-	0.100	-	-	F-60
29-Aug-17	3	Ferric	60	64	0.58	0.014	-0.004	0.047	0.052	-	0.055	0.031	<12.5	F-60b, FF-60b
30-Aug-17	4	Ferric	80	64	0.53	0.007	0.003	0.008	0.010	-	0.022	-	<12.5	F-80
30-Aug-17	5	Ferric	100	64	0.50	0.004	-0.047	0.005	0.000	38.8	0.028	0.032	<12.5	F-100, FF-100
30-Aug-17	6	XL-8	100	-	2.14	0.065	-	-	-	-	-	-	-	-
30-Aug-17	7	XL-8	100	64	1.63	0.076	-	-	-	-	-	-	-	-

Notes to the summary table above are as follows:

1) The testing period occurred after water was shipped to Kruger in Cary, NC to observe treatment on raw water
    a. TP samples were analyzed according to SM 4500 P-B/E
    b. Filtered TP samples were analyzed after filtering through a 0.45 micron nylon syringe filter

2) Standard method of optimization was used during testing
    a. Change only one variable at a time
    b. Utilize turbidity and benchtop OP as surrogate for treatability
    c. Lab samples are grabbed at “optimum chemistry”
    d. Optimum chemistry defined as lowest OP values while accounting for target goal of < 0.02 mg/L TP

3) General Performance Goals
    a. ACTIFLO simulation was to confirm chemistry and demonstrate treatment performance, to include TP and turbidity removal.

4) Performance Results
    a. Performance goals were achieved based on benchtop analysis
    b. Raw water alkalinity was insufficient for coagulation chemistry to achieve goal TP removal, even with PACl (denoted as XL-8 in summary table above)

c. Greater than 90% removal of TP was demonstrated based on 3rd party lab samples (Cameron Testing Labs)

2. Bench-Scale Test Procedure

ACTIFLO Beaker Procedure

1. Pre-program Phipps & Bird Stirrer 4 Memory Settings for Sequential Operation
    a. Memory 1: 120 seconds @ 300 RPM
    b. Memory 2: 15 seconds @ 300 RPM
    c. Memory 3: 45 seconds @ 225 RPM
    d. Memory 4: 120 seconds @ 0 RPM
2. Start Pre-Programmed Sequential Operation Mixer
3. Memory 1/Coagulation Mixing Step
    a. Add desired coagulant dosage near shaft immediately after mixing begins to disperse coagulant
4. Memory 2/Rapid Flocculation Step
    a. Add desired polymer dosage between shaft and corner of beaker so as not to allow the polymer to adhere to either
5. Memory 3/Gentle Flocculation Step
    a. Observe flocculation
6. Memory 4/Settling Step
    a. Allow settling prior to sampling, allow the sample to settle for 90 - 120 seconds
7. Collect samples for analysis

3. Materials and Methods

Equipment

- HACH 2100P Turbidimeter, Kruger
- HACH DR5000 for benchtop P analysis, Kruger
- Orion 3-Star Benchtop pH Meter, Kruger
- Phipps & Bird 6-place gang stirrer, jar testing equipment, Kruger

Chemicals

- Coagulant, Hydrex 3251 Ferric Sulfate, 46% concentration, SG = 1.58
- Coagulant, Kemira XL-8 PACl, 100% concentration, SG = 1.25
- Polymer, Hydrex 3502 (Dry, Anionic PAM, Med-High MW)
- Microsand, Hydrex 9609 (~120 micron effective size)

4. Chemical Dosing Example Calculations

Coagulant Dosing Example Calculation

- Ferric Sulfate 46% solution and 1.58 SG
- Therefore, 1.0 ml solution = 726.8 mg active Fe2SO4
- Volume of water used in the jar tests is 2 liter
- 110 µl Ferric solution in 2 liter raw water sample = 40 mg/L Fe2SO4

Polymer Dosing Example Calculation

- Mix 1.0 g dry polymer in 1-Liter DI water, using the Phipps & Bird Stirrer, to produce a 0.1% solution (1 g/L) stock solution
- Therefore, 1.0 ml solution = 1.0 mg active PAM
- Volume of water used in the jar tests is 2 liter
- 1.0 ml polymer solution dose into 2 liter raw water sample = 0.5 mg/L polymer

Sand Concentration Dosing Example Calculation

- Add 10 g microsand to jar
- Volume of water used in the jar tests is 2 liter
- 10 g microsand in 2 liter raw water sample = 5 g/L sand

5. Conclusions

The ACTIFLO simulation bench scale testing results demonstrated that the process is a viable treatment technology to achieve the desired results for effluent TP, given the raw water criteria observed during the August 2017 jar testing simulation. The ACTIFLO bench scale testing was able to remove upwards of 96 percent of the influent TP.

It is important to note that low level TP reporting can be inherently affected by the method standard deviation when analyzing below a certain concentration, as seen in the table below.

TABLE 4500-P:I. PRECISION AND BIAS DATA FOR MANUAL PHOSPHORUS METHODS

Method	Phosphorus Concentration			No. of Laboratories	Relative Standard Deviation %	Relative Error %
	Orthophosphate µg/L	Polyphosphate µg/L	Total µg/L			
Vanadomolybdophosphoric acid	100			45	75.2	21.6
	600			43	19.6	10.8
	7000			44	8.6	5.4
Stannous chloride	100			45	25.5	28.7
	600			44	14.2	8.0
	7000			45	7.6	4.3
Ascorbic acid	100			3	9.1	10.0
	600			3	4.0	4.4
	7000			3	5.2	4.9

Accounting for the standard deviation, to reliably meet a 0.02 mg/L TP effluent limit based on method SM4500 P-B/E, the target effluent goal would have to be a maximum of 0.0183 mg/L TP. This is likely pushing the limits of any available technology.

Further bench scale testing may be investigated with other coagulants or if raw water quality observed was not representative of expected normal conditions. On-site pilot testing may also be recommended to fully quantify daily or seasonal changes in raw water quality while demonstrating the ACTIFLO process' ability to remove TP.

APPENDIX A- Testing Summary Table

ACTIFLO Simulation Testing – *Lafayette Fish Hatchery, RI*

											Kruger Benchtop Results						Cameron Testing Labs Results			
Date	Jar #	Vol (L)	Coagulant			Polymer			NaOH	Sand	Turbidity	OP	Filt OP	TP	Filt TP	Alkalinity	TP	Filt TP	TSS	Sample Number
			Type	mg/L	(uL)	Type	mg/L	mL	mg/L	g/L	NTU	mg/L as P	mg/L as P	mg/L as P	mg/L as P	mg/L as CaCO3	mg/L as P	mg/L as P	mg/L	
	RAW	-	-	-	-	-	-	-	-	-	0.8	0.147	0.041	0.230	0.056	20.2	0.613	-	< 5.0	RAW
29-Aug-17	1	2	Ferric	40	110	3502	0.5	1.0	-	5.00	5.0	0.070	-	-	-	-	0.254	-	-	F-40
29-Aug-17	2	2	Ferric	60	166	3502	0.5	1.0	-	5.00	13.8	0.075	-	-	-	-	0.100	-	-	F-60
29-Aug-17	3	2	Ferric	60	166	3502	0.5	1.0	64	5.00	0.58	0.014	-0.004	0.047	0.052	-	0.055	0.031	<12.5	F-60b, FF-60b
30-Aug-17	4	2	Ferric	80	221	3502	0.5	1.0	64	5.00	0.53	0.007	0.003	0.008	0.010	-	0.022	-	<12.5	F-80
30-Aug-17	5	2	Ferric	100	276	3502	0.5	1.0	64	5.00	0.50	0.004	-0.047	0.005	0.000	38.8	0.028	0.032	<12.5	F-100, FF-100
30-Aug-17	6	2	XL-8	100	160	3502	0.5	1.0	-	5.00	2.14	0.065	-	-	-	-	-	-	-	-
30-Aug-17	7	2	XL-8	100	160.0	3502	0.5	1.0	64	5.00	1.63	0.076	-	-	-	-	-	-	-	-

SUBJECT: Lafayette Fish Hatchery CoMag Jar Test Results

DATE: September 7, 2017

FROM: Dan Casey

Objective

The objective of these jar tests were to evaluate the ability of the CoMag® Process, on the bench scale, to meet and exceed the treatment goals of <0.025 mg/L Total Phosphorus from the discharge of the Lafayette Fish Hatchery, RI. These jar tests were used to examine different coagulants; PACl, Sodium Aluminate, Aluminum Sulfate and Ferric Chloride, and their ability to achieve the ultra-low TP.

Procedure

There were four coagulants tested during this study:

- Aluminum based products
  - PACl – CES 2000
  - Sodium Aluminate (SA)
  - Aluminum Sulfate (Alum)
- Iron based product
  - Ferric Chloride

Each coagulant was diluted to a 5% neat solution. Doses were based off of mg/L as metal of the coagulant.

Aries 1668 dry anionic polymer was used for all tests. The polymer was mixed at a low concentration with distilled water prior to dosing.

One series of jar tests (4 jars in total) was conducted for each coagulant. Jar tests were conducted mimicking the CoMag® process conditions in terms of detention times, mixing energies as well as with magnetite as the ballast.

Each series of jar tests performed were dosed on the same mg/L as metal dose strategy; 3, 9, 12, and 18 for a direct comparison of performance. Each jar had 6 g/L of magnetite added, as well as 1 mg/L (dry weight) of polymer dosed. NaOH was used for pH adjustment for Ferric Chloride and Alum to the desired optimal range for TP removal when needed.

All TP testing was performed by Evoqua with the following equipment; TNT 843 test vails, DRB 200 and DR 2800. It should be noted the detection limit of the TNT 843 vials is 0.05 mg/L. The DR 2800 displays results below this detection limit and it is Evoqua's experience these results are close to the reported value. These values were used for the initial evaluation to prove the capability of the CoMag Process. If further testing is desired, lower detection limit test methods should be used.

Results

Below you will find the results tabulated for each coagulant used. Note, Sodium Aluminate has a naturally high pH and a higher basicity than the other coagulants. It was found in the jar tests that the SA drove the pH higher than optimal and there was no TP reduction seen. In result of this, the SA data is not shown and was not evaluated further.

Table 1. PACl – CES 2000 Jar Test Results

Series 1	Untreated	JAR 1	JAR 2	JAR 3	JAR 4
PACl Dose (mg/L as Al)	-	3	9	12	18
PACl Dose (mg/L as product rec'd)	-	23	68	91	136
PACl Dose (ppmv)	-	17	51	68	101
Volume (5% soln) in a 1L Jar (in ml)	-	0.34	1.01	1.35	2.03
Flocculent (mg/L) Aries 1668	-	1.0	1.0	1.0	1.0
pH Adjust (Y/N)	-	N	N	N	N
Operating pH	7.6	7.16	7.12	7.06	7
Magnetite (g/L)	-	6	6	6	6
Total Phosphorus (mg/L)	0.129	0.075	0.035	0.036	0.017
% TP Reduction	-	41.9%	72.9%	72.1%	86.8%

Table 2: Ferric Chloride Jar Test Results

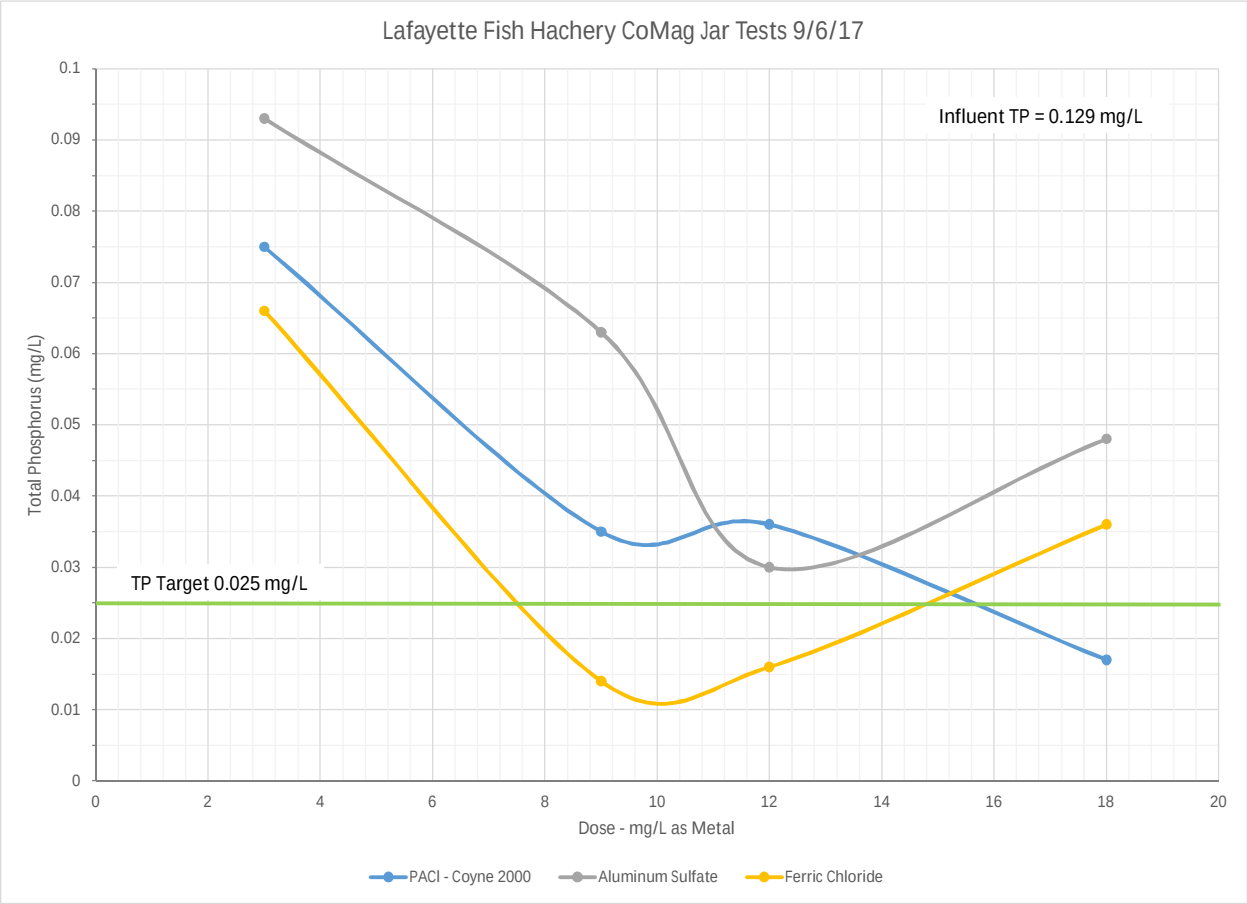
Series 3	Untreated	JAR 9	JAR 10	JAR 11	JAR 12
Ferric Dose (mg/L as Fe)	-	3	9	12	18
Ferric Dose (mg/L as product rec'd)	-	23	68	90	136
Ferric Dose (ppmv)	-	16	49	65	97
Volume (5% soln) in a 1L Jar (in ml)	-	0.32	0.97	1.30	1.95
Flocculent (mg/L) Aries 1668	-	1.0	1.0	1.0	1.0
pH Adjust (Y/N)	-	N	Y	Y	Y
Operating pH	7.6	7.46	6.04	6.04	6.02
Magnetite (g/L)	-	6	6	6	6
Total Phosphorus (mg/L)	0.129	0.066	0.014	0.016	0.036
% TP Reduction	-	48.8%	89.1%	87.6%	72.1%

Table 3: Alum Jar Test Results

Series 4	Untreated	JAR 13	JAR 14	JAR 15	JAR 16
Alum Dose (mg/L as Al)	-	3	9	12	18
Alum Dose (mg/L as product rec'd)	-	69	206	275	412
Alum Dose (ppmv)	-	52	155	207	310
Volume (5% soln) in a 1L Jar (in ml)	-	1.03	3.10	4.13	6.20
Flocculent (mg/L) Aries 1668	-	1.0	1.0	1.0	1.0
pH Adjust (Y/N)	-	N	N	N	N
Operating pH	7.6	6.32	6.29	6.36	6.4
Magnetite (g/L)	-	6	6	6	6
Total Phosphorus (mg/L)	0.129	0.093	0.063	0.03	0.048
% TP Reduction	-	27.9%	51.2%	76.7%	62.8%

Figure 1 below shows the dose response curve for each of the coagulants evaluated. This curve shows Ferric Chloride was able to achieve TP below the 0.025 mg/L target.

Figure 1: Jar Testing Dose Response



Conclusions/Observations

- The TP target of 0.025 mg/L was achievable with a Ferric Chloride dose of 9 and 12 mg/L as Fe when the pH was adjusted to 6.0 SU.
- A polymer dose of 1 mg/L was used throughout the tests and proved to be sufficient for treatment goals.
- Further testing should be considered while using ultra low detection limit TP testing kits to validate the chemistry put forth in these results. These results show the feasibility, but do not provide a process/chemical consumption guarantee.

Appendix C

Tertiary Filtration
Manufacturer's Literature & Dimensions
(Blue Pro®, Dynasand®, and Fuzzy Filter®)

PHOSPHORUS REMOVAL TO 20 µg/L

Advanced Phosphorus Removal

Nexom is the industry leader in the development of technologies for phosphorus removal from wastewater. With advanced control techniques and patented nutrient removal systems, Nexom can provide you with a cost effective solution to meet your phosphorus level needs.

The Blue PRO® system provides a unique approach to chemical dosing, with significantly lower chemical use across the entire wastewater treatment plant than competitors. No other chemical dosing is required in the plant to achieve the lowest phosphorus discharge requirements. Nexom's unique chemical control system provides an advantage due to its cost efficiency and ability to seamlessly integrate into and respond to the needs of existing wastewater treatment systems. The chemical dose used with Blue PRO methods is so much lower than the competition that the comparative savings represent a return on the capital investment in less than three years.

The Blue PRO process is the leading technology for phosphorus reduction to any level. For phosphorus discharge limits as low as 0.02 mg/L (20 µg/L) P, Blue PRO provides reductions in chemical usage, equipment footprint, and associated operations and maintenance costs over alternative technologies. The Blue PRO platform is the most effective and most inexpensive tertiary treatment solution where additional considerations are needed, such as denitrification or metals removal.

A Blue PRO installation in Grangeville, Idaho for 0.05 mg/L phosphorus with a chemical dose of only 10 mg/L of Fe.

The Blue PRO® System

How does the Blue PRO process work? Using Nexom's Centra-flo® continuous backwash gravity sand filters, a unique control system, and the patented Blue PRO process for reactive filtration, phosphorus is removed from wastewater streams through an array of mechanisms. Most importantly, Blue PRO systems optimize adsorption.

Nexom's reactive filtration process overcomes a critical obstacle to achieving efficient phosphorus removal in bulk aqueous solutions by providing reactive surface sites within the media bed, resulting in forced contact of chemical species with high adsorptive capacity. The adsorptive surface in Blue PRO filters is a continuously regenerated hydrous ferric oxide (HFO) coating that forms on the surface of the sand media. Coagulation followed by filtration simply cannot compare to the efficiency of adsorptive phosphorus removal.

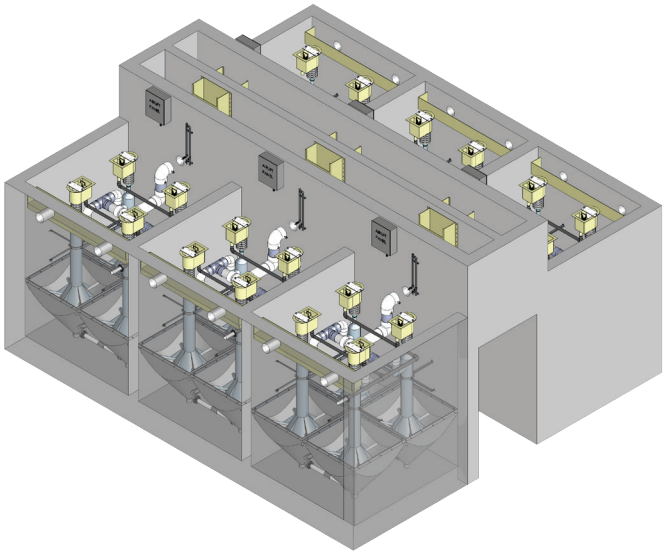
Waste HFO, phosphorus, and solids are removed from the filter through the backwash or reject stream. Recycling this reject upstream provides the added benefit of removing phosphorus in plant clarification systems, further guaranteeing the achievement of the discharge phosphorus target as well as lowering the chemical dose. The phosphorus is chemically bound, leaving the plant with the sludge, rather than releasing in effluent streams or digestion. Integration of Nexom's phosphorus removal technology does not require change in the plant's sludge handling system. The Blue PRO system uses over 30% less chemical than other technologies, therefore producing less sludge. The waste HFO also helps with odor control and can reduce water content in biosolids.

Blue PRO Applications:

- **Advanced total phosphorus removal**
- **Metals removal, including mercury**
- **Combined denitrification**
- **Algae mitigation**

For more information, please contact **Nexom**:
888.710.2583 | www.nexom.com

The Blue PRO® system is available in several models and configurations. The modular nature of the filters allows for easy system expansion. The filters are available as freestanding fiberglass or stainless steel units or as in-ground concrete cells. Control systems and smaller filters may be skid mounted for mobility or ease of commissioning.



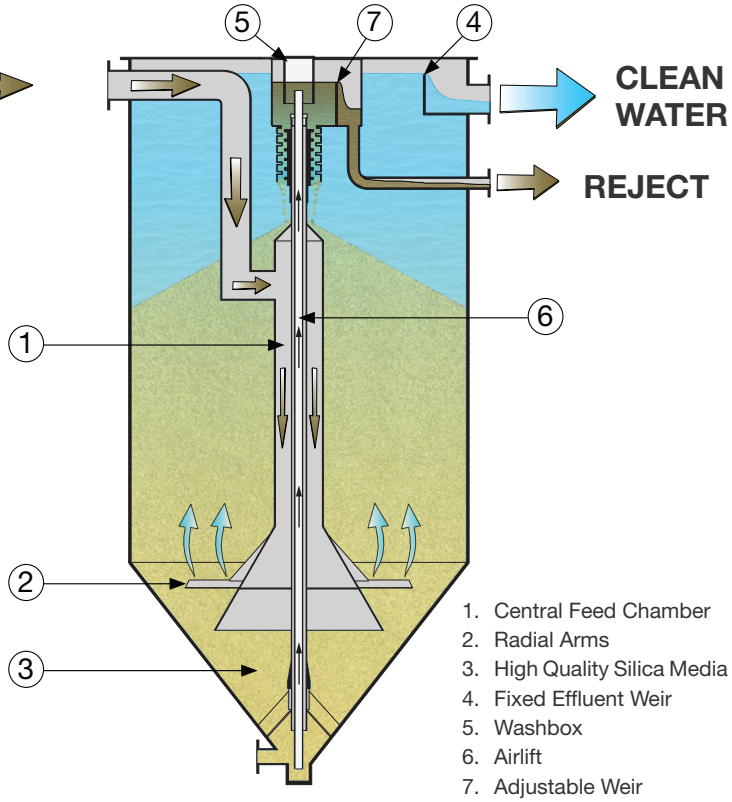
4.3 MGD Blue PRO system design for 0.07 mg/L TP in a Massachusetts WWTP.

Additional Features

Since many plants requiring phosphorus mitigation also require nitrogen control, Nexom provides the option to simultaneously denitrify in the same vessel with the Blue PRO process. With slight modifications, Nexom can provide a unique and efficient system for total nutrient reduction.

Besides phosphorus, Blue PRO methods are effective at removing many other contaminants, such as mercury, arsenic, chromium, and uranium. Minor adjustments in water chemistry may be implemented for the removal of metals and other contaminants, including zinc, lead, copper, iron, and manganese. Nexom has installations for removal of these contaminants in wastewater plants as well as groundwater systems, including self-contained package treatment systems.

INFLUENT → **+ CHEMICAL** →



1. Central Feed Chamber
2. Radial Arms
3. High Quality Silica Media
4. Fixed Effluent Weir
5. Washbox
6. Airlift
7. Adjustable Weir

Nexom's Blue PRO technology is covered by multiple patents and patents pending.

The Blue PRO Advantages:

- **Low capital and O&M costs**
- **Continuous flow – no interruption for backwash or changing media**
- **Modular design easily handles capacity increases**
- **Simple operation & low chemical use**

For more information, please contact **Nexom**:
888.710.2583
www.nexom.com

Manufacturer's representative:

Nexom

FILTER

technologies for cleaner water

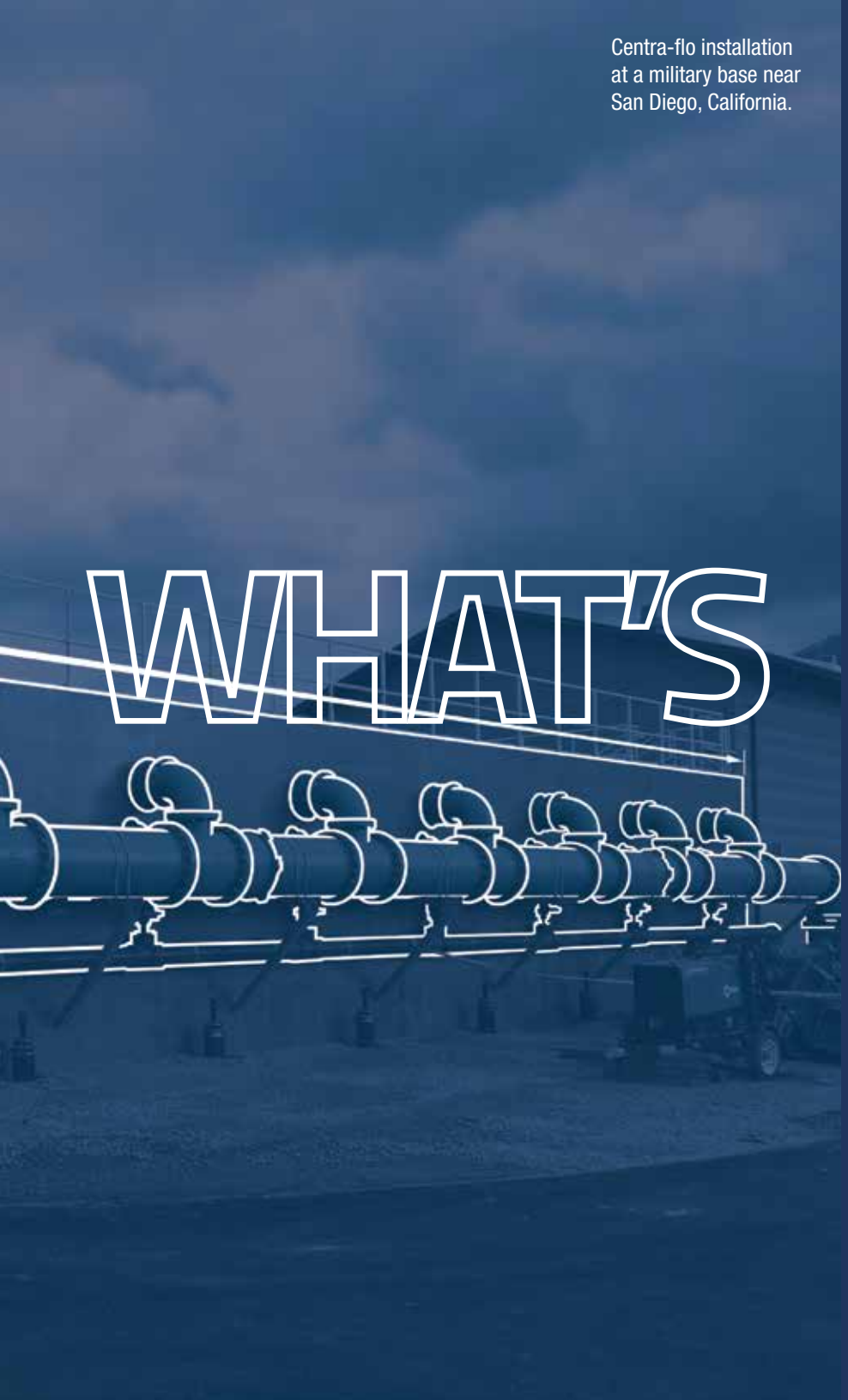
infini-D™ ZERO-DOWNTIME CLOTH DISK FILTER

BluePRO®

BlueNite®

EcoBELT™

WELCOME TO



Centra-flo installation at a military base near San Diego, California.

WHAT'S NEXT.

The wastewater industry has seen how nutrients and energy costs expose the limits of existing solutions. Nexom provides design support and supplies the next wave of proven technologies so consulting engineers can confidently exceed all municipal or industrial demands.

Nexom has been fueling the revolution since 1997. Since then, we have supplied our technologies for more than 300 treatment systems. Having tested our technologies to the extreme at our own full-scale facilities, we ensure the facility you build exceeds expectations, not nutrient limits.

Nexom™

infini-D™ ZERO-DOWNTIME CLOTH DISK FILTER p.3

BluePRO® REACTIVE FILTRATION FOR PHOSPHORUS & METALS p.9

BlueNite® BIOLOGICAL DENITRIFICATION p.15

EcoBELT™ ROTATING BELT FILTER FOR PLANT OPTIMIZATION p.21

For many plants, filters exist to meet phosphorus or suspended solids limits, but redundancy requirements and overcompensation for expected downtime has put the solution out of reach.

Now, thanks to the infini-D Zero-Downtime Cloth Disk Filter, it's time to say

Goodbye, solids and phosphorus,

HELLO, BUILT-IN REDUNDANCY.

infini-D™ Zero-Downtime Cloth Disk Filters can be installed above- or in-ground to accommodate site hydraulic flow patterns.

Only infini-D™ cloth disk filters have individual effluent ports

This means your filter continues producing high effluent quality while allowing you to isolate the effluent from a specific disk to evaluate disk performance or perform routine maintenance.

infini-D™

ZERO-DOWNTIME CLOTH DISK FILTER

The infini-D Zero-Downtime Cloth Disk Filter has a low backwash rate and filters continuously while backwashing; this, combined with the pile cloths variable pore space, prevents long-term fouling. The entire system fits into a small footprint and can be installed into steel or concrete tanks.

TECHNOLOGY:
Cloth disk filtration

ADVANTAGES:

- Remove solids and phosphorus
- Maintain individual disks with filter on-line
- Inspect performance of individual disks
- Pile cloth provides filteration without long-term fouling

APPLICATIONS:

- Phosphorus removal
- TSS reduction
- Post-mechanical plant tertiary filtration
- Post-lagoon filtration
- Reuse/Recycle

Flow through the infini-D™ cloth disk filter

Influent enters the infini-D filter tank and passes through the cloth filter media that removes suspended solids. Individual cartridges' filtered flow is visible through discharge ports. This design allows operators to monitor each cartridge's operation and quickly isolate a disk's performance.

The disk filter panels do not rotate: the panels are stationary and the vacuum head rotates around the disk during the backwash cycle. In the event a filter cloth needs replacing, each disk is easily removable without taking the entire filter off-line.

Also, by fixing filter disks in place, infini-D filters eliminate rotating seals, thereby preventing effluent contamination in the event of a seal failure.

infini-D™
ZERO-DOWNTIME
CLOTH DISK FILTER

HOW IT WORKS

No dewatering to remove a disk

Each infini-D filter disk cartridge can be removed, inspected and replaced without stopping filtration, and all from outside the tank.

Each unit consists of one to six disks, a vacuum pump assembly and the gear drive, axle and sprocket.

Without dewatering, operators can remove the entire filter disk from the tank by closing the disk's valve or capping the discharge port outside the tank, disconnecting the discharge port, and lifting out the cartridge. They can inspect and replace the pile cloth as needed, then reinstall the cartridge. As each disk has its own discharge port, the filter continues to operate even with filter panels removed.

Building a better backwash

Solids accumulate on the cloth media during filtration, restrict liquid flow through it, and cause the level in the tank to rise. Backwashing begins when the level reaches a predetermined point.

The vacuum head rotates across the disk's face. Only the infini-D filter rotates the vacuum head in alternating directions, more effectively cleaning the cloth's pile.

- The non-contact vacuum head **extends filter cloth life** by avoiding excessive cloth wear.
- The tapered vacuum head enables **even cleaning of the disk surface**.
- The octagonal disk design reduces dead corners.

Backwash does not disrupt filtration since only 5% of the panel surface is cleaned at once. Turbidity does not change during backwashing.

Disk size and number of disks within a given infini-D configuration may vary based on factors including flow and loading.

Look inside history being made.

It's not just about improving filter performance or simplifying operations. Only infini-D Zero-Downtime Cloth Disk Filters have patented advances that build redundancy right in.

A. **Patented individual effluent ports** enable individual disk maintenance without taking the filter offline.
B. **Pile-cloth disks** trap particles more effectively and resist fouling.
C. **Vacuum-cleaning assembly** rotates around the pile cloth, removing particulate, eliminating any need for large moving seals associated with rotating disks.

Easy to install. Easy to run. Easy to sleep when you know you'll beat your phosphorus limit.

With proven performance and no need to have a unit offline, life is simpler for the engineers who install infini-D systems and the municipalities and industries who operate them.

infini-D Zero-Downtime Phosphorus Removal Systems ship easily, arriving here at an Indiana site on a flatbed trailer.

Protecting the Great Lakes

The Great Lakes have long struggled with algae blooms, leading to tough regulations on phosphorus. But many of Ontario's lagoon-based wastewater treatment plants were originally designed to remove BOD and TSS—not phosphorus—and need to upgrade their nutrient removal capabilities.

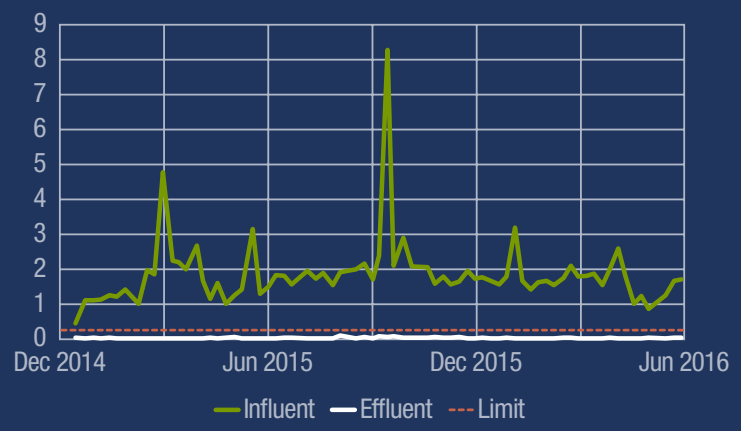
infini-D™
ZERO-DOWNTIME
CLOTH DISK FILTER

HOW IT PERFORMS

The centerpiece of one specific northern Ontario site's chosen solution to remove phosphorus is the infini-D Zero-Downtime Cloth Disk Filter. While it keeps hundreds of kilograms of phosphorus out of the drainage basin every year, efficiently meeting regulatory limits is the real key. That's where the system really stands out.

In its first 18 months of operation, covering 75 discrete samples, the upgraded northern Ontario plant produced no effluent results over 0.1 mg/L, and in two-thirds of those tests phosphorus in the effluent was not detectable at all (below 0.03 mg/L).

Northern Ontario infini-D WWTF Total Phosphorus (mg/L)



For every regulator's action imposing North America's lowest phosphorus limits, Blue PRO provides the

EQUAL & APPROPRIATE REACTION.

In fact, it's countless reactions, happening continuously thanks to the power of Blue PRO's patented reactive filtration. It's how one Alabama town gets down to 20 micrograms per liter (0.02 mg/L) of phosphorus. **Knowing this, how will you react?**

Blue PRO installation at a cheese plant in Wisconsin.

You didn't choose your limits, but you can choose to beat them.

Where even low levels of phosphorus or metals can do a lot of damage, wastewater treatment plants can become targets of regulatory pressure to meet µg/L phosphorus and metals limits. Now, engineers under pressure to upgrade these plants have the tool for the job.

BluePRO®

Meeting phosphorus limits as low as 0.02 mg/L requires more than traditional coagulation and filtration techniques; instead, engineers are turning to Blue PRO's patented reactive filtration, which harnesses chemical reactions performed on the surface of granular media within a sand filter to achieve unmatched performance and efficiency.

TECHNOLOGY:
Reactive filtration in a sand filter platform

ADVANTAGES:

- Hits industry-low phosphorus levels
- Lowest capital, O&M costs
- Continuous flow; no stopping for backwash, no changing media
- Uninterrupted filtrate quality

APPLICATIONS:

- Phosphorus removal
- Trace metals removal
- Great Lakes Mercury compliance

HOW IT WORKS

The difference is reactive filtration.

Blue PRO® reactive filtration is based on the principle of adsorption. The process continuously regenerates a hydrous ferric oxide (HFO) coating on the sand media's surface before it comes into contact with the phosphorus- or metals-laden influent. The sand's collectively large reactive surface area guarantees contact with the targeted phosphorus or metal, which chemically binds with the HFO right on the sand media. The resulting coating, including waste HFO, phosphorus and other solids, are removed through the backwash or reject stream.

Blue PRO uses 30% less chemical than comparative technologies for ultra-low phosphorus. Coagulation followed by physical separations processes (clarifiers, filters, membranes, etc.) cannot compare to the efficiency of reactive filtration.

This reduced chemical use not only lowers costs, it also produces less sludge. Additionally, backwash can be recycled upstream for the added benefit of phosphorus pre-treatment upstream in primary or secondary treatment systems.

Frequently Asked Questions

What influent characteristics are required? The Blue PRO is surprisingly flexible as a tertiary treatment process. Several systems exist with high-strength influents between 5 and 12 mg/L P and TSS up to 50 mg/L. The ultimate treatment configuration will be dependent on the influent loads and treatment goals.

What other metals can a Blue PRO system remove? Nexom has Blue PRO® installations that are permitted for aluminum, arsenic, copper, lead, mercury, phosphorus, zinc, and other trace transition metals.

Does the media need to be replaced or topped up? Thanks to the continually-regenerative reactive filtration process, media is not a consumable. The process imparts a temporary chemical coating to the media that is stripped and reformed cyclically in situ. Many older sand filter designs of 20 years ago were prone to occasional media loss. Our washbox design, coupled with our unique control and monitoring systems, mitigates this concern. A Blue PRO system will waste almost no media in its lifetime, meaning that in a 20-year period, topping up is unlikely to be required, and the media should never need to be replaced.

Go with the Centra-flo®

The Blue PRO filter is built on Nexom's own Centra-flo continuous-backwash sand filter process (pictured at right). In this process, influent enters the vessel (A) and is distributed to the cross-sectional area of the filter near the bottom of the sand column (B). Water is filtered as it flows upward, encountering the sand's hydrous ferric oxide (HFO) coating in a Blue PRO configuration or the attached-growth denitrifying bacteria in a Blue Nite configuration. Meanwhile, the sand (C) is moving downward by gravity to an airlift device (D). While the filtered water exits near the top of the filter (E), the airlift transports the phosphorus- or metals-laden media up into the washbox (F) where the discharged HFO coating and adsorbed contaminates are separated from the media. Water velocities in the washbox are carefully designed to carry away the contaminates (G) while allowing the freshly-scrubbed media to fall to the filter bed (H) as its cycle begins again.

Building on an impressive platform

The Centra-flo® sand filter is efficient, flexible, and approved for water reuse under California Title 22/Class 1A.

How low can you go?

For Blue PRO operators, the question is not whether they can meet their limit, but rather how much will they save on chemistry while still comfortably beating their limit?

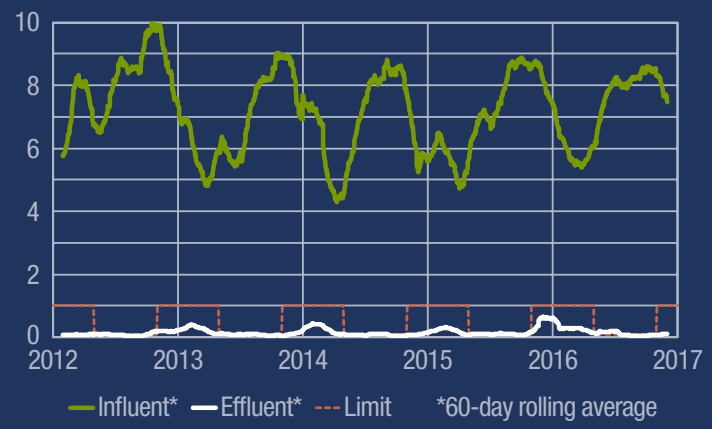
A Blue PRO installation in Idaho.

Performance enables efficiency

With a system that can go to 20 µg/L, the constraint is not the Blue PRO. The only limit is how low you need to go, and metering your dosage to match.

At one Massachusetts Blue PRO installation (11.62 Peak MGD), this means the facility can flatline phosphorus when limits are tight in summer, and save on dosing when limits rise.

Massachusetts Blue PRO WWTF Total Phosphorus (mg/L)



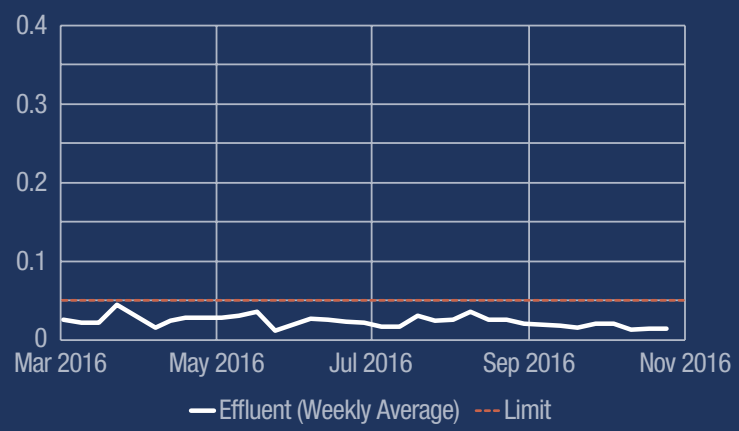
BluePRO®

HOW IT PERFORMS

It's even simpler for another installation in Idaho, where phosphorus limits sit at a consistent 0.05 mg/L and the effluent average is less than half that.

Also, since the Blue PRO is built into a Title-22/Class 1A sand filter platform, it has the added benefit of acing reuse TSS tests: the Idaho facility averaged 2.3 mg/L of effluent TSS while beating its phosphorus limits.

Idaho Blue PRO WWTF Total Phosphorus (mg/L)



Nitrates are often seen as the last piece of the nutrient puzzle, and the need to denitrify them is growing. Nature's tool for the job is denitrifying bacteria, but harnessing their power is no small task. Fear not, here comes Blue Nite®.

With great denitrifying power comes TOTAL NUTRIENT REMOVABILITY.

Blue Nite installation in Maryland.

The simple, flexible, biological way to beat nitrate limits.

Nitrogen represents a unique challenge in wastewater. Even as treatment plants remove ammonia via nitrification, the process causes an increase to the existing level of nitrates, a nutrient growing in notoriety across North America.

Blue Nite®

Blue Nite® is equal to the challenge nitrates present. Built upon a continuous-upflow sand filter platform, Blue Nite creates the optimal conditions required for denitrifying bacteria to thrive.

Those conditions don't happen by accident—they've been specifically designed by Nexom engineers—and **where denitrifiers take hold, nitrates don't last long.**

TECHNOLOGY:
Biological denitrification

ADVANTAGES:

- Nitrate removal to <1 mg/L
- Unique patented control system
- Lowest capital and O&M

APPLICATIONS:

- Municipal treatment
- Industrial nitrate mitigation
- Existing treatment facilities needing end-of-pipe denitrification

Engineered for performance

Design hydraulic loading rates to Blue Nite® filters are determined by heterotrophic respiration rates, influent nitrate levels, nitrate variability, dissolved oxygen (DO) levels, and expected water temperatures. Nexom's design parameters coupled with its proprietary control system optimizes the system to maintain a healthy, stable denitrifying biomass.

Nitrogen gas produced during operation is primarily released from the process as the media passes through the airlift. Removal of gas in this fashion has several benefits that include: eliminating false readings in headloss, eliminating the need to backwash because of gas entrainment, and eliminating the gas bump or upset gas "burps" due to significant nitrogen bubble accumulation typical in static bed filters.

Blue Nite®

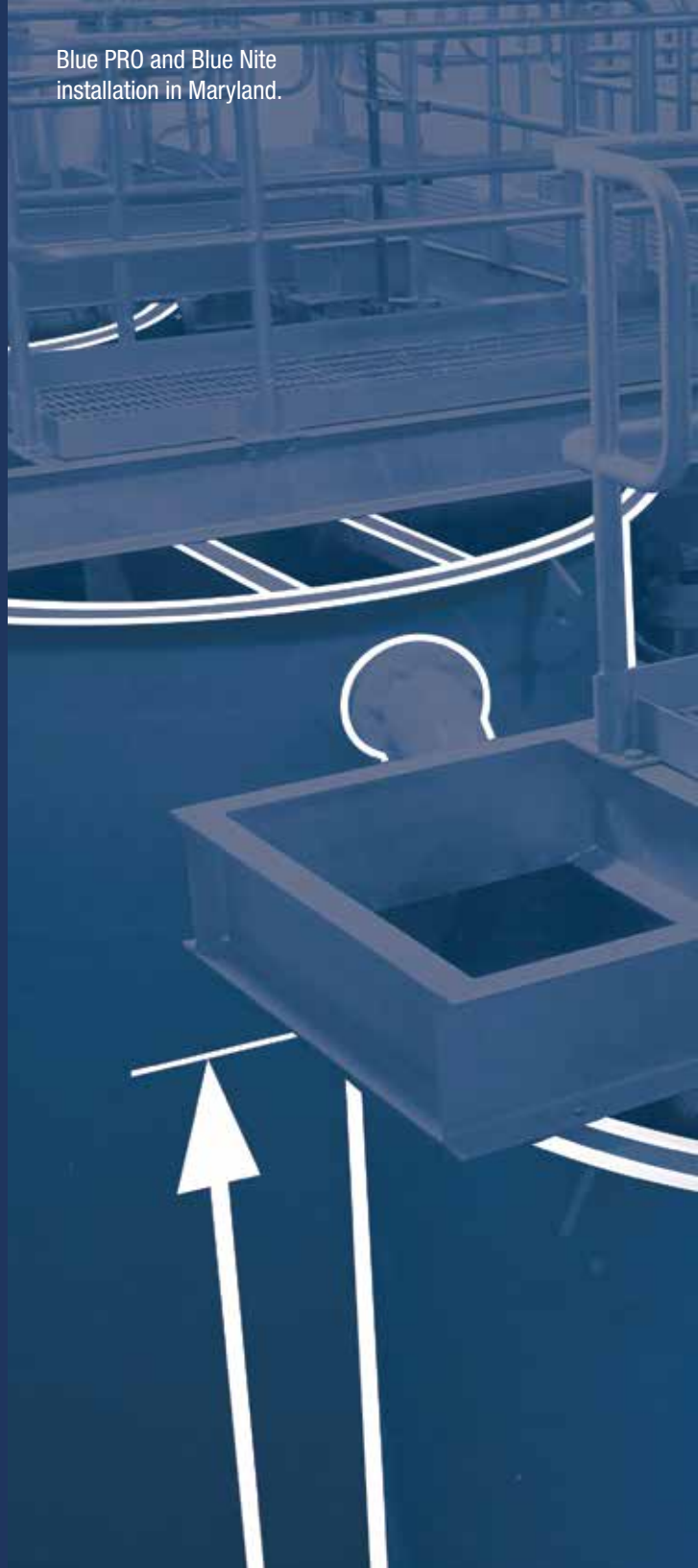
HOW IT WORKS

Frequently asked questions.

What carbon source does Blue Nite use? Blue Nite is flexible and can use many of the most common carbon sources, including methanol, acetic acid, ethanol, glycerin, as well as proprietary products like MicroC®.

What carbon dosing ratio does Blue Nite use? Optimal carbon dosing depends strongly on water characteristics including the dissolved oxygen and nitrate levels as well as the BOD strength of the carbon source. Nexom's chemical engineers can help you determine the ideal ratio at your site to achieve the required denitrification level.

Can our Blue Nite installation be retrofitted at a later time for Blue PRO® reactive filtration if we don't need phosphorus removal yet? Definitely, and we have helped other customers do this before. In fact, the amount of "retrofitting" required is minimal. Because the two systems utilize the same Centra-flo® granular media filtration system as a process platform, the additional infrastructure required is the Blue PRO's dosing system and virtually nothing else. (The same goes for Blue PRO installations being retrofitted for Blue Nite biological denitrification.)



Blue PRO and Blue Nite installation in Maryland.

One tank, many uses.

The same Centra-flo® platform supports both Blue PRO reactive filtration for phosphorus and metals as well as Blue Nite biological denitrification, even in the same tank.

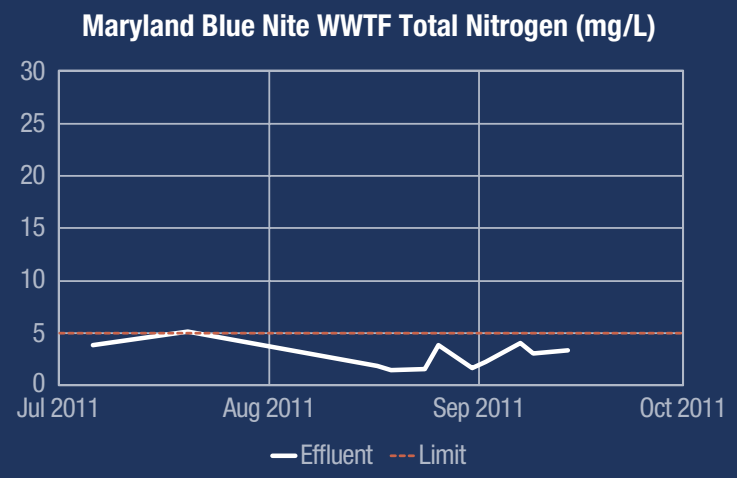
Reducing effluent nitrates may reduce stress and improve sleep (at least for engineers and operators).

With Nexom's denitrification experience standing behind every Blue Nite installation, you can be confident that your plant is in the right hands.

Makes nitrogen disappear into thin air

Blue Nite® reduces Total Nitrogen to less than 5 mg/L, and in many cases much less. At the same time, it can be combined with Blue PRO® technology for a complete nutrient solution in the same vessel.

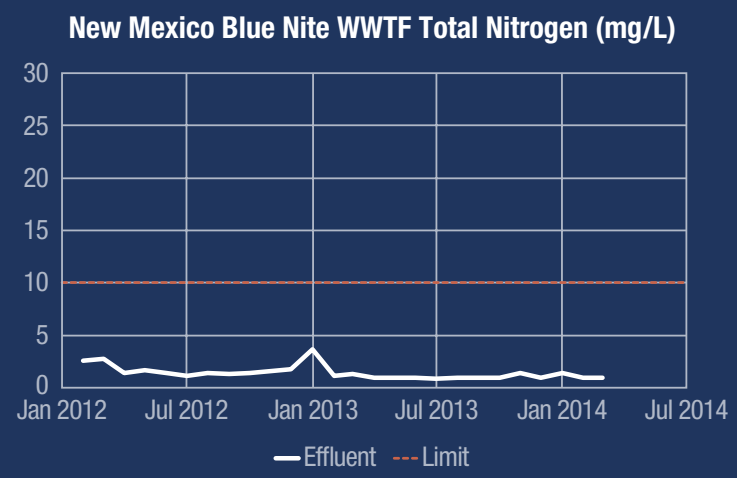
This is what the a military facility in Maryland found. In 2011, it installed a combined Blue PRO and Blue Nite facility to reduce its nutrient impact on the sensitive Chesapeake Bay region, and the results are remarkable.



Blue Nite®

HOW IT PERFORMS

At another site in New Mexico, the Blue Nite technology was selected for its compatibility with phosphorus removal. But that doesn't take anything away from its success removing Total Nitrogen; in the years since installation, the facility has averaged less than a quarter of the allowable 10 mg/L.



Blue Nite installation at a military facility in Maryland.

EcoBELT being tested at a site in Florida.

You can try squeezing the last 0.1% out of your SOTEs, but the low-hanging fruit can COME OFF THE BELT.

How much better would your plant perform with 30% less BOD and 60% less TSS? With an EcoBELT rotating belt filter, you can plug low-capital-investment primary optimization into your process up front, and see the benefits all the way through.

Thanks to EcoBELT's size, performance, and cost, primary treatment is finally scalable.

For a long time, primary treatment has been the least upgradeable part of the entire process. Where disinfection could be added or old diffusers swapped for higher-efficiency diffusers without drastically altering the layout of your plant, primary treatment was literally set in stone (specifically concrete).

EcoBELT is changing all that. With a small footprint, a relatively low capital cost, and proprietary advantages that make it the most operator-friendly rotating belt filter to date, now primary treatment can be upgraded.

So while you are landfilling substantial proportions of your BOD and TSS loading before it hits a secondary treatment process (or even sending the wet solids to a digester to get the biogas out), you might as well toss your worries about your plant's capacity in that landfill or digester, too.

EcoBELT™

TECHNOLOGY:
Rotating belt filtration

ADVANTAGES:

- Reduces BOD by 20-40%, TSS by 30-80%
- Treats in 5% of the footprint required by traditional clarification
- Uses less energy than comparable rotating belt filters

APPLICATIONS:

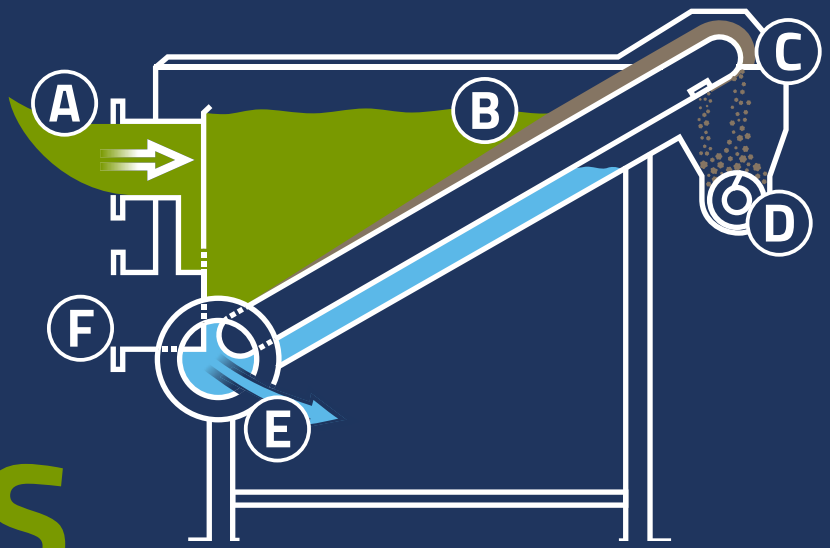
- 0.1-50 MGD plant-optimizing primary treatment
- Increases plant capacity by reducing loading to subsequent processes

EcoBELT™

HOW IT WORKS

EcoBELT in action

Wastewater enters the EcoBELT (A) and the solids that collect on the rotating belt are carried upward (B). The dual cleaning systems (C) cause collected solids to fall off the belt, to be collected and dewatered (D). Water that has filtered through the belt flows out through the effluent port (E), while the overflow port (F) stands ready to handle excessive flow situations.



Frequently asked questions.

Is a coarse screen required before the EcoBELT? While numerous sites have chosen to implement the EcoBELT without a preceding bar screen, to maximize belt-life we recommend a 2” coarse screen upstream.

How does the EcoBELT reduce waste and disposal? While other RBFs push solids out of the process through a flapper gate (resulting in backpressure issues), EcoBELT’s patent-pending integration of a backpressure cone allows solids to exit consistently while ensuring they are reliably dewatered, resulting in less waste and less disposal.

How does the EcoBELT’s mechanical cleaning achieve maximized belt-life? The EcoBELT’s Doctor Blade cleaning process drastically reduces energy costs as compared to blower-based cleaning, but unlike other RBFs’ scraper blades, the Doctor Blade peels solids from the belt without actually contacting the belt. As well, EcoBELT’s patent-pending belt support both maximizes the open area—freeing more belt space for filtration—and also eliminates failure-causing stresses from rod-support lattices.

In practice, the EcoBELT’s belt life is equal or greater than any other RBF belt available. And no system makes it easier or faster to replace a belt, with changes taking 30 minutes rather than the 6-8 hr process common to comparable systems.

Sizes for all situations and redundancy-ready.

EcoBELT plant optimization is available for a wide variety of flows from 0.1-50 MGD, and where redundancy is required, a pair of isolatable belt drives can be installed within the same unit.

Three EcoBELTs await shipment for use in portable wastewater systems.

Won't FOG up

A fully-automated hot water wash flushes the fats, oils and greases that may accumulate over time, particularly in high FOG environments.