# Appendix 5-2. Tertiary Treatment Enhanced Phosphorus Reduction

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# List of Tables and Figures

The enhanced phosphorus reduction analysis is based upon continuing enhanced biological phosphorus removal (EBPR) followed by tertiary treatment.  This section presents the tertiary phosphorus reduction alternative analysis including tertiary treatment technology screening, basis of evaluation, comparison of three viable treatment alternatives, economic evaluation, and recommendation.

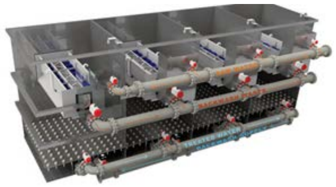
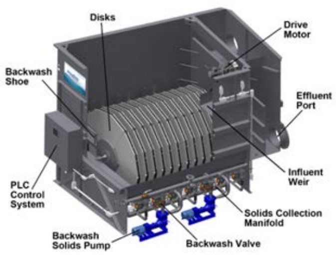
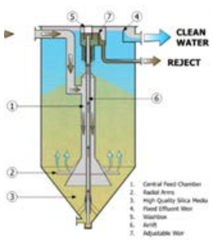
# Section 1: Tertiary Treatment Technology Screening

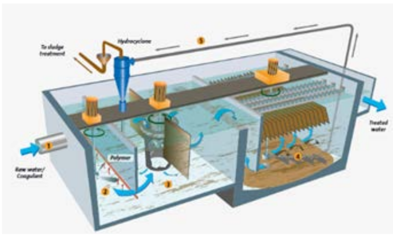
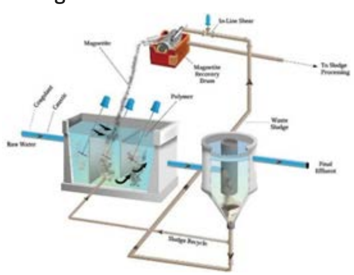
A review of tertiary treatment technologies was completed with the goal of selecting three alternatives for detailed analysis. Technologies considered included:

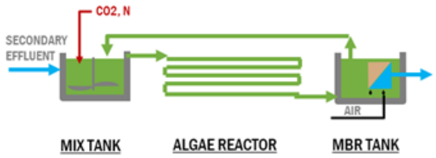
- Conventional filtration
- Cloth media filtration
- Continuous backwash deep bed filtration
- Ballasted flocculation
- CoMag™ ballasted sedimentation
- CLEARAS advanced biological nutrient recovery

Table E-1 presents typically effluent TP performance of each technology along with advantages and disadvantages.  All technologies reviewed have the capability to reduce TP discharges below the monthly effluent TP criteria of roughly 0.3 mg/L. Based upon the technology screening, conventional filters, cloth media filtration and single-stage continuous deep-bed backwash filtration were selected for further analysis based upon the screening decision listed in Table E-1.

Table E-1. Tertiary Treatment Enhanced Phosphorus Reduction Technology Screening

| Alternative | Typical Effluent TP Performance | Advantages | Disadvantages | Screening Decision |
|---|---|---|---|---|
| Conventional Filters<br> | • Monthly < 0.3 mg/L<br>• Annual < 0.2 to 0.25 mg/L | • Well established for facilities of similar size<br>• Non-proprietary<br>• Medium maintenance<br>• Low backwash volumes (5 to 7%)<br>• Excellent particulate removal | • Large footprints<br>• Medium-high capital costs<br>• Medium operating costs<br>• High support equipment (blowers, pumps, air scour, mudwell, clear well.)<br>• May require polymer<br>• Monthly TP discharges less than 0.1 mg/L require upstream solids contact or equal treatment process | Selected for further evaluations based |
| Cloth Media Filtration<br><br><br>c | Traditional Cloth Pile Media<br>• Monthly < 0.3 mg/L<br>• Annual < 0.2 to 0.25 mg/L<br><br>Microfiber Media<br>• Monthly < 0.1 mg/L if PO4-P is less than 0.03 mg/L | • Well established<br>• Non-proprietary<br>• Medium footprint<br>• Low capital costs<br>• Low backwash volumes (5 to 7%) without need for backwash tank<br>• Low headloss/energy cost | • Medium operating costs<br>• Higher effluent solids than conventional filters<br>• Need for flocculation tank upstream of filters<br>• Media prone to biofouling and scaling with ferric chloride increases requires more maintenance<br>• Cloth media replaced every 7 years<br>• Monthly TP discharges less than 0.1 mg/L require upstream solids contact or equal treatment process<br>• Limited microfiber application | Selected for further evaluations |
| Continuous Backwash Deep Bed Filters<br><br> | • Monthly < 0.1 mg/L | • Simple to operate and maintain<br>• Minimal support equipment<br>• Low operations staffing<br>• No moving parts in filters and mechanical equipment limited to airlift compressor<br>• No/low polymer<br>• Low media loss<br>• Low energy/operating costs<br>• Can be competitively bid<br>• Excellent particulate removal<br>• No backwash tanks<br>• Medium footprint | • Higher unit capital costs<br>• Bed hardening requires quarterly air lancing<br>• Algae/bristles can clog filter air lift pump<br>• Medium backwash volume (7.5%)<br>• Airlift tubes replaced every 2 to 3 years.<br>• Acid addition required for Nexom™ filter | Selected for further evaluations based upon simplistic operations, minimal support equipment, proven ability to achieve very low TP discharges, and low O&M costs. |

| Alternative | Typical Effluent TP Performance | Advantages | Disadvantages | Screening Decision |
|---|---|---|---|---|
| | | • Potential to add second stage to further reduce TP discharges if needed | | |
| Ballasted Flocculation<br>(Actiflo, Densadeg or equal)<br> | • Monthly < 0.2 mg/L<br>• Annual < 0.1 to 0.2 mg/L | • Simple to operate<br>• Medium footprint<br>• Sludge recirculation reduces coagulant dosing<br>• No recycle flow<br>• Well established for facilities of similar size | • Proprietary<br>• Medium to high capital costs<br>• Medium operating costs<br>• High maintenance requirements<br>• High support equipment (mixers, tanks, return pumps, waste pumps, cyclones.)<br>• Sand loss leads to accumulation in downstream processes (digesters)<br>• More susceptible to shock flow load and cold temperature than filters<br>• Requires polymer and ballasting agent (Actiflo™) | Screened due to high equipment requirements, high maintenance needs, higher O&M costs, proprietary system, concerns with ballasting agents in downstream processes. and high chemical demands to reduce TP discharges. |
| CoMag™ Ballasted Sedimentation<br> | • Monthly < 0.1 mg/L | • Excellent effluent without filters<br>• Simple to operate<br>• Low headloss<br>• Medium capital costs<br>• Medium footprint<br>• Sludge recirculation reduces coagulant dosing<br>• No recycle flow<br>• Low operations staffing<br>• Magnetite is relatively inexpensive | • Proprietary – one manufacturer<br>• High support equipment (mixers, clarifiers, return pumps, waste pumps/valves.)<br>• Medium operating costs<br>• Magnetite loss leads to accumulation in downstream processes (digesters)<br>• Limited magnetite suppliers<br>• More susceptible to shock flows and cold temperature than filters<br>• Requires polymer and ballasting agent | Screened due to high equipment requirements, concerns with ballasting agents in downstream processes, and cannot be competitively bid. |
| Membrane Filtration | • Monthly < 0.1 mg/L | • Excellent effluent quality<br>• Non-proprietary | • Very high capital costs (2-3x other alternatives)<br>• High operations and maintenance costs<br>• High support equipment requirements<br>• Multiple chemicals for cleaning membranes<br>• Loss of filtration/flow back-up with equipment failure | Screened due to high capital and operating costs. |
| CLEARAS Advanced Biological Nutrient Recovery | • Monthly < 0.1 mg/L | • Excellent effluent quality<br>• Proprietary | • See membrane filters disadvantages<br>• Very large footprint | Screened due to high capital and operating |

| Alternative | Typical Effluent TP Performance | Advantages | Disadvantages | Screening Decision |
|---|---|---|---|---|
|  | | • Recoverable resource (algae) | • One supplier<br>• No installations of similar size | costs and lack of installations |

## 1.1 Basis of Evaluation

### 1.1.1 Flows and Loadings

This evaluation uses the projected 2050 flows and loadings presented in Section 2 of the Facility Plan for facility evaluation. Secondary effluent quality is based upon (1) BioWin process model predicted performance at Year 2050 dynamic flow and loading conditions with tertiary filters and (2) historical plant operations with flows pro-rated to 2050 conditions.

### 1.1.2 Effluent Criteria

Facility evaluations are based upon reducing TP discharges below the TP effluent criteria listed in Table E-2. In addition, this analysis assumes a maximum monthly TP discharge of 0.3 mg/L.

**Table E-2. Enhanced Phosphorus Reduction Effluent Criteria**

| Effluent Criteria | Units | Total Phosphorus | Averaging Period |
|---|---|---|---|
| Lake Pepin Waste Load Allocation | kg/year | 17,407 | 12-month rolling average |
| Minnesota River Eutrophication Study | kg/d | 100 | Monthly (June-Sep) |
| Concentration of 0.3 mg/L at AWWF | kg/d | 61.3 | 12-month rolling average |

### 1.1.3 Process Flow Scheme

Tertiary filter sizing is based upon the process flow scheme presented in Figure E-1 where secondary effluent is treated to further reduce phosphorus discharges via ferric chloride addition followed by filtration. The secondary effluent flow treated is based upon reducing the combined filtered effluent and remaining secondary effluent (if any) to 80 percent of the effluent criteria listed in Table E-2.

Filtered effluent quality is based upon (1) BioWin predicted values with filtration and (2) estimated performance when using historical secondary effluent with filtration. BioWin modeling assumes ferric chloride is added to the centrate and mixed liquor flow as needed to maintain monthly secondary effluent TP discharges below 1 mg/L. Typical tertiary effluent maximum month performance used when evaluating historical data is shown in Figure E-1. The most conservative of the two approaches is used for facility sizing.

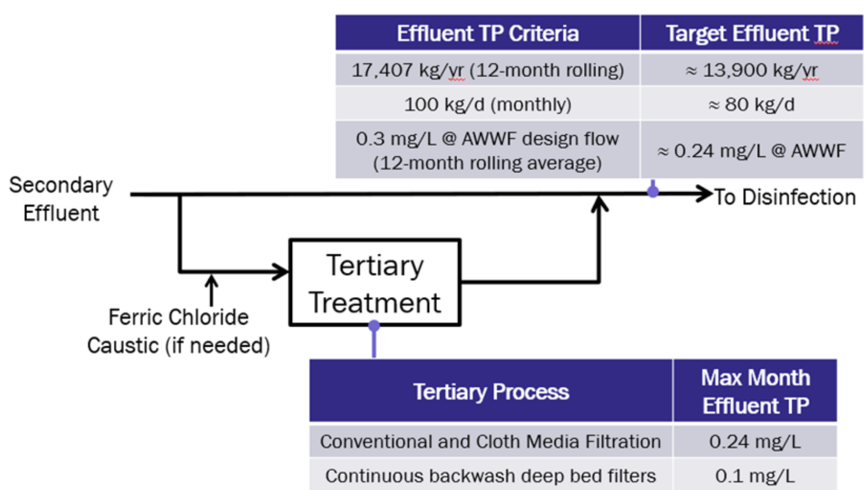



**Figure E-1. Tertiary Phosphorus Reduction Flow Scheme.**

### 1.1.4 Filtration Rates and Redundancy

Filtration facility sizing is based upon the criteria shown in Table E-3. Redundancy criteria for this evaluation is based upon N+2 filters at annual average conditions and N+1 and peak filtration flows where N is the number of filters needed to meet the filtration rate criteria. The peak filtration rate is defined by Great Lakes -Upper Mississippi River Board (GLUMRB) 10 States Standards. Alternatives with peak filtration rate capacities higher than 5 gpm/sf are discussed under each alternative including potential impacts to peak flow filtration capacity.

**Table E-3. Tertiary Filtration Maximum Filtration Rates**

| Condition | Units | Cloth Pile Media Filters | Continuous Backwash Deep Bed or Dep Bed Conventional Media Filters |
|---|---|---|---|
| Annual average | gpm/sf | 3.5 | 4.0 |
| Peak flow | gpm/sf | 5.0 | 5.0 |

## 1.2 Alternative Description

### 1.2.1 Alternative 1 – Conventional filters

Alternative 1 is a conventional, downflow sand filter, which is a type of granular media filter. It can be single (or mono)-media (i.e., sand or equal), dual-media (i.e., anthracite over sand), or multi-media (i.e., anthracite, sand, and garnet). The various configurations of granular media filters include shallow (30 to 48 inches media) or deep bed (up to 72 inches), pressure or gravity, downflow or upflow, and continuous or intermittent backwash. Conventional downflow filters typically follow a batch backwash operation. Downflow filters operate semi-continuously, meaning operators can take them offline for periodic backwashing. The flow rate through these filters can be constant or variable. Downflow filters are typically backwashed intermittently and often include air scouring. Figure E-2 illustrates a conventional deep bed granular filter.

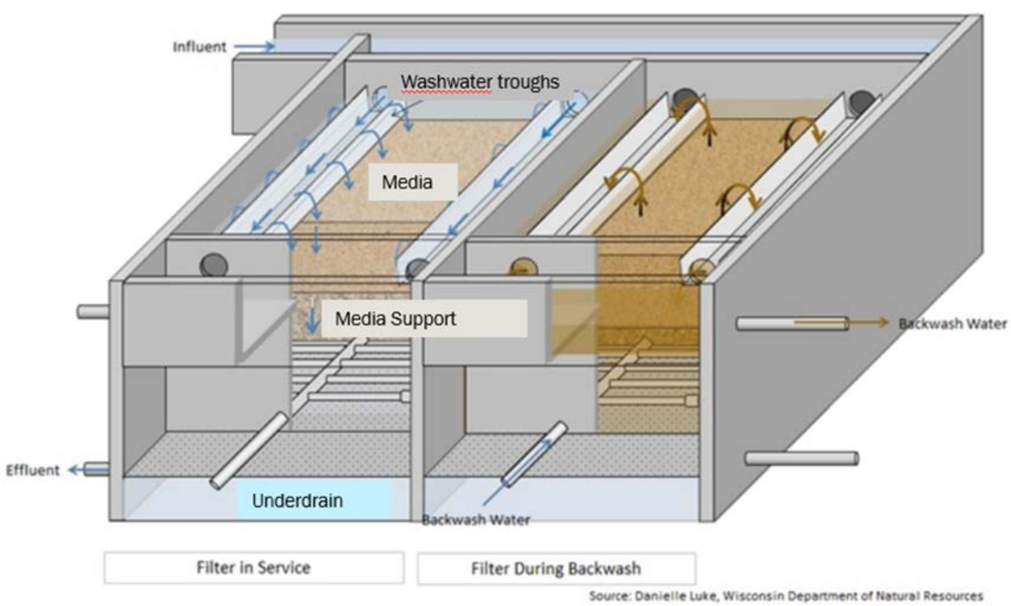



**Figure E-2. Conventional Deep Bed Granular Filter**

Candidate manufacturers of conventional filters include

- Xylem Water Solutions U.S.A., Inc. (Leopold tertiary filtration system),
- WesTech (Gravity Filter)

This analysis is based upon a Leopold deep bed (72-inches) mono-media down flow filtration system.

Table E-4 list the design data for the conventional filtration system. The filtration system consists of ten 60-ft by 20-ft wide filters as shown in Figure E-2. The filtration system requires a mudwell for backwash storage and clearwell for backwashing the filters. Each tank is equal in size to two filter cells. Filtration system sizing is controlled by the target maximum filtration rate of 4 gpm/sf at average conditions resulting in a peak filtration capacity of 78 mgd at 5 gpm/sf even though the maximum secondary effluent flow requiring treatment is 65 mgd. Filter feed pump station capacity is based upon 78 mgd. For particulate/TP removal, it is common for conventional downflow filter peak filtration rate capacity to be as high as 8 gpm/sf (125 mgd) depending upon the influent TSS load.

Ferric chloride demands represents the additional combined usage for secondary and tertiary treatment and additional solids generation represents inert chemical solids produced from ferric addition plus additional solids removed across the filters. The ferric chloride demands are based upon plant historical secondary effluent TP concentrations resulting in higher values than calculated with BioWin simulations.

**Table E-4. Alternative 1 Conventional Filters Design Data**

| Item | Units | 2040 Design Year | 2050 Design Year |
|---|---|---|---|
| Annual average design flow | mgd | 40 | 44 |
| Filter feed pump station capacity, firm | mgd | 78 | 78 |
| Filters | | | |
| Total | No. | 10 | 10 |
| Length | ft | 60 | 60 |
| Width | ft | 20 | 20 |
| Media depth | inches | 72 | 72 |
| Filtration rate | | | |
| Average flow | mgd | 45 | 51 |
| Peak flow for TP reduction goals | mgd | 55 | 65 |
| Average – 2 out of service | gpm/sf | 3.3 | 3.7 |
| Peak- 1 out of service | gpm/sf | 3.5 | 4.2 |
| Design Peak at 5 gpm/sf-1 OOS | mgd | 78 | 78 |
| Capacity at 8 gpm/sf-1 OOS | mgd | 125 | 125 |
| Backwash return pumping station capacity, firm | mgd | 6 | 6 |
| Ferric Chloride | | | |
| Average (40% solution strength) | gpd | 700 | 730 |
| Bulk Storage Tanks at 7500 gallons | No. | 2 | 2 |
| Additional solids generated - average | lb/d | 3300 | 3400 |

Figure E-3 presents a preliminary filtration building layout. The layout assumes secondary effluent flows by gravity to the filter feed pump station where flow is pumped to the filters and flows by gravity to the chlorine contact tank. All filtration system layouts assume the filter complex is located near the existing chlorine contact tanks in an area currently occupied by the aerated pond. The filter complex will be connected to the existing plant tunnel system near the Maintenance Building elevator.

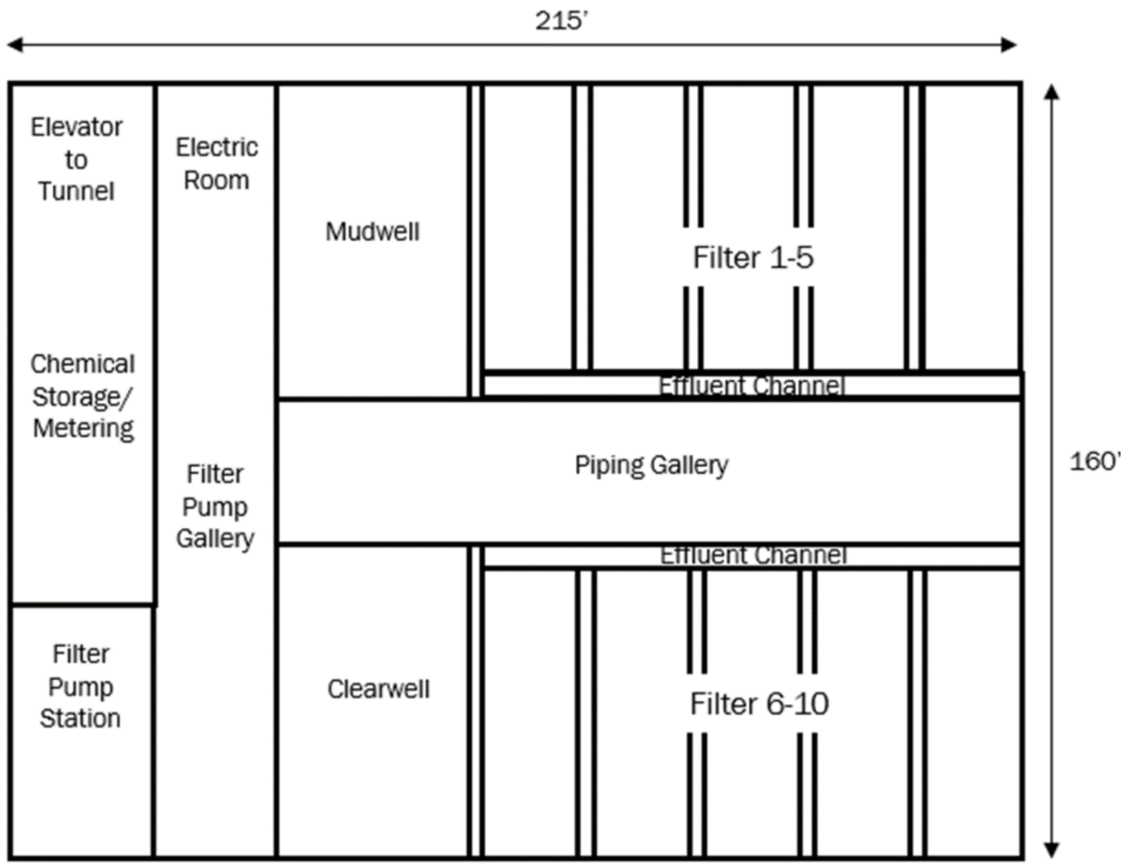



**Figure E-3. Alternative 1 – Conventional Deep Bed Granular Filter Layout**

### 1.2.2 Alternative 2 – Cloth Media Filters

Alternative 2 uses cloth media disc filtration for TP reduction. These filters use surface filtration through high-density woven fiber or polyester media, with a pore size of 5 to 10 µm. The flow orientation for these systems can be outside-in or inside-out. Each disc comprises multiple pie-shaped media disc sections held in a vertical plane as shown in Figure E-4. During filtration, the discs remain stationary and either partially or fully submerged. A solids mat forms on the discs as solids accumulate on and within the media, providing additional filtration causing the liquid level to increase. The system automatically backwashes the filters based on water level differential or preset time intervals, with one or two discs cleaned in sequence as they rotate. The remaining discs remain in filtration mode.

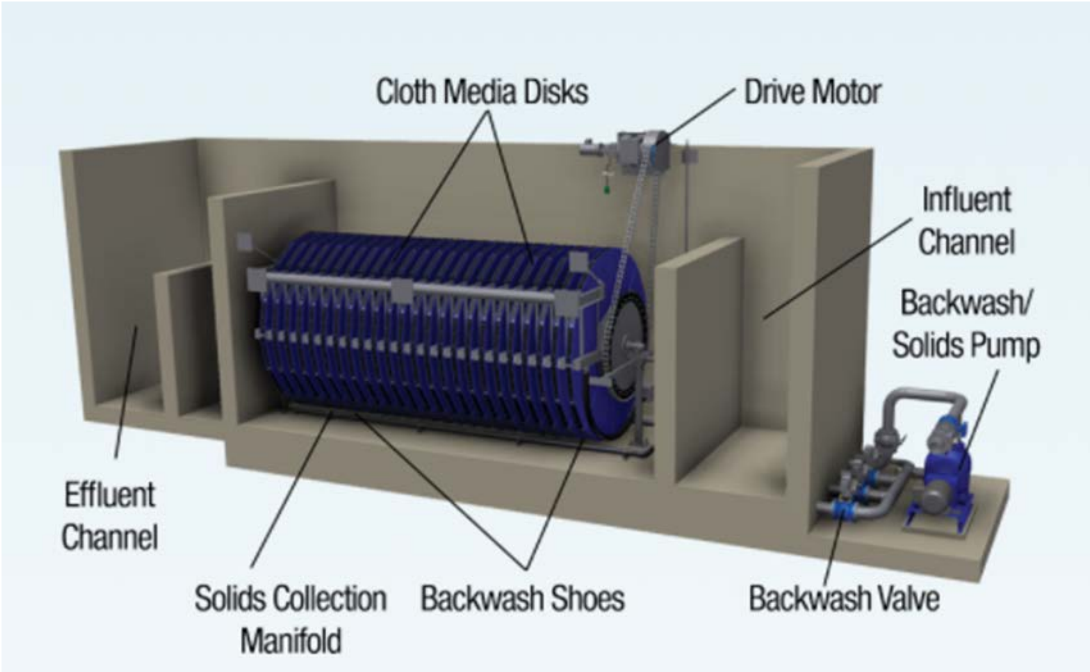



**Figure E-4. Cloth Media Disk Filters**
(Source: Aqua Aerobics)

Candidate manufacturers for a cloth media filtration system include:

- Aqua-Aerobics (AquaDisk™ or MegaDisk™),
- Veolia (Hydrotech™ Discfilter),
- WesTech (SuperDisc™ Discfilter).

This analysis is based upon Aqua-Aerobics MegaDisk system.

Table E-5 lists the design data for the cloth media filtration system. The filtration system consists of six filters which are roughly 10-feet in diameter and 20-feet long. Each filter contains 24 disks for a total filtration area of 2,582 sf/filter. The filtration system assumes the backwash solids pumps discharge to a sump for backwash return to the primary clarifier influent.

Filtration system sizing is controlled by the target filtration rate at average conditions. A peak filtration rate of 93 mgd is achievable at 5 gpm/sf with one unit out of service even though the maximum secondary effluent flow requiring treatment is 65 mgd. A peak filtration rate of 6 gpm/sf (111 mgd) is typical for cloth media filters but requires the influent TSS load, including ferric solids remain less than 2 lb/sf. Filter feed pump station capacity is based upon 93 mgd.

Ferric chloride demands represents the additional combined usage for secondary and tertiary treatment and additional solids generation represents inert chemical solids produced from ferric addition plus additional solids removed across the filters. The ferric chloride demands are based upon plant historical secondary effluent TP concentrations resulting in higher values than calculated with BioWin simulations.

Table E-5. Alternative 2 Cloth Media Filter Design Data

| Item | Units | 2040 Design Year | 2050 Design Year |
|---|---|---|---|
| Annual average design flow | mgd | 40 | 44 |
| Filter feed pump station capacity, firm | mgd | 95 | 95 |
| Flocculation Basin | | | |
| Detention time at average flow | min. | 11.5 | 10 |
| Number of trains | No. | 2 | 2 |
| Size/train (width x length x SWD) | feet | 20 x 80 x 15 | 20 x 80 x 15 |
| MegaDisk Filters | | | |
| Total | No. | 6 | 6 |
| Disks per filter | No. | 24 | 24 |
| Area per filter | sf | 2,582 | 2,582 |
| Filtration rate | | | |
| Average flow | mgd | 45 | 51 |
| Peak flow for TP reduction goal | mgd | 55 | 65 |
| Average – 2 out of service | gpm/sf | 3.0 | 3.4 |
| Peak- 1 out of service | gpm/sf | 3.0 | 3.5 |
| Design Peak at 5 gpm/sf-1 OOS | mgd | 93 | 93 |
| Capacity at 6 gpm/sf-1 OOS | mgd | 111 | 111 |
| Backwash return pumping station capacity | mgd | 7 | 7 |
| Ferric Chloride | | | |
| Average (40% solution strength) | gpd | 700 | 730 |
| Bulk Storage Tanks at 7500 gallons | No | 2 | 2 |
| Additional solids generated - average | lb/d | 3300 | 3400 |

Figure E-5 shows a filtration building layout for the MegaDisk installation. This alternative also includes a flocculation basin upstream of the filters (Figure E-6) to promote solids removal as recommended by Aqua-Aerobics.

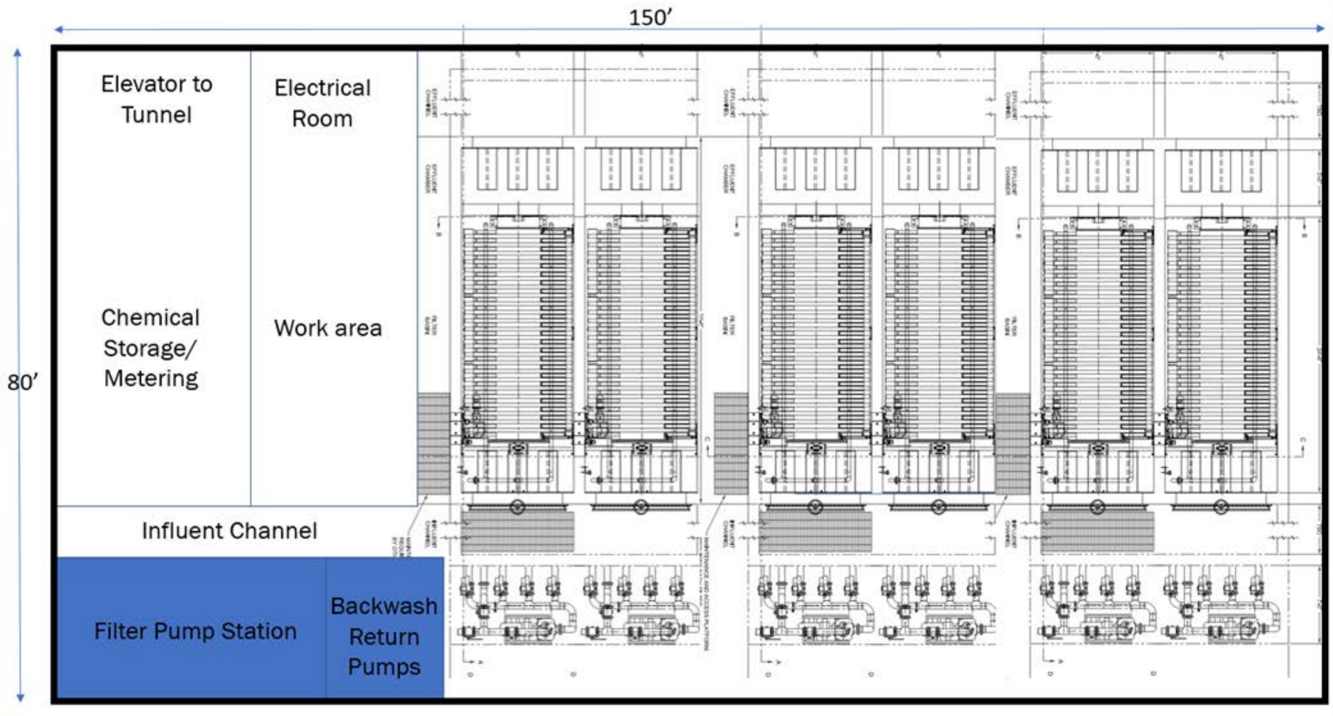



Figure E-5. Alternative 2 – Cloth Media Filter Building Layout


Figure E-6. Alternative 2 – Cloth Media Filter Layout with Flocculation Basin

### 1.2.3 Alternative 3 – Continuous Backwash Deep Bed Filter

Alternative 3 is a continuous-backwash deep bed upflow sand filter. For this alternative, filter influent enters near the bottom of the filter and flows upward through the media while the sand bed counter currently moves downward to the bottom of the filter. The filtered effluent exits the top of the media bed, overflows a weir, and discharges from the weir catchment. When the sand and accumulated solids reach the bottom of the filter, an airlift pump lifts the mixture through the airlift pipe. This process creates a scouring action of the media particles as they travel to the top of the bed. The filter internally recycles the sand media and cleans the sand by passing it through a washer/separator. The lighter, filtered particles remain in suspension and flow to the backwash return sump. The filter, therefore, continuously cleans the sand bed and produces a continuous filtrate and reject stream. This system does not require separate backwash pumps or backwash downtime. Figure E-7 shows the key components of the continuous backwash filters.

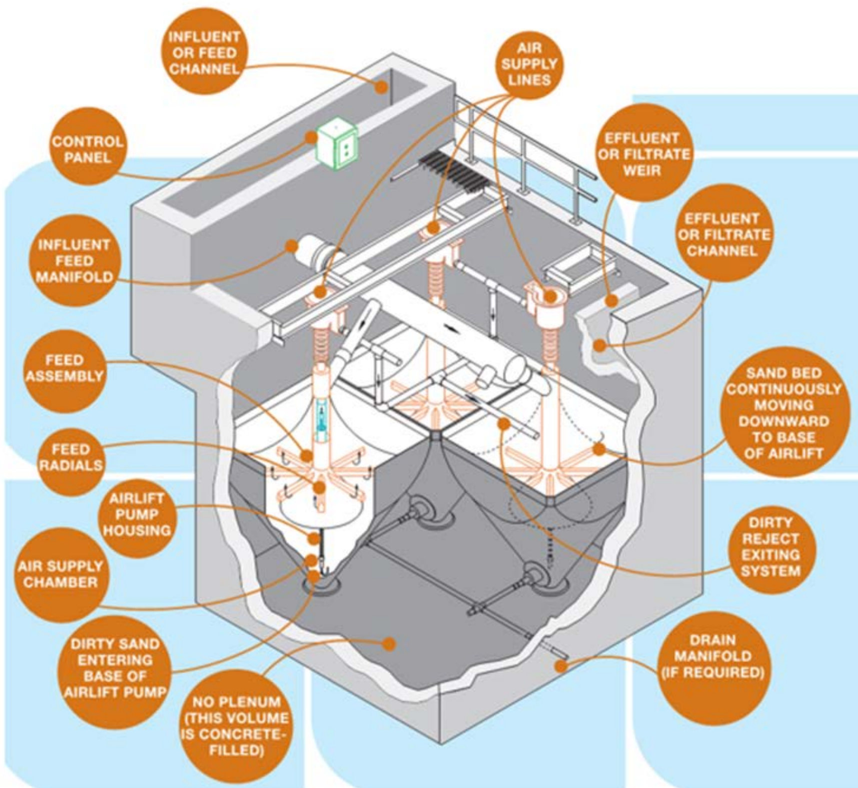



**Figure E-7. Continuous Backwash Filters**

(Source: Parkson)

Candidate manufacturers of a continuous backwash deep bed filter include:

- DynaSand® filters by Parkson,
- Blue PRO® filters by Nexom,
- SuperSand™ filters by WesTech.

This analysis is based upon the Parkson DynaSand filters.

Table E-6 lists the design data for the continuous backwash filters. The filtration system consists of sixteen 14.2 foot wide by 42.5 foot long filter modules with a media bed depth of 80-inches. Each filter module contains 12 filter cells as shown in Figure E-8. Filtration system sizing is controlled by the target maximum filtration rate of 4.0 gpm/sf at average conditions resulting in a peak filtration capacity of 70 mgd at 5 gpm/sf even though the maximum secondary effluent flow requiring treatment is 50 mgd. The lower filtered flow rate reflects targeting a lower filtered effluent TP of 0.1 mg/L which requires more chemical. If lower chemical dosages are desired, filtration sizing similar to Alternative 1 could be used requiring four additional filter modules.

Ferric chloride demands represents the additional combined usage for secondary and tertiary treatment and additional solids generation represents inert chemical solids produced from ferric addition plus additional solids removed across the filters.

**Table E-6. Alternative 3 Continuous Backwash Deep Bed Filters Design Data**

| Item | Units | 2040 Design Year | 2050 Design Year |
|---|---|---|---|
| Annual average design flow | mgd | 40 | 44 |
| Filter feed pump station capacity, firm | mgd | 70 | 70 |
| Filters modules | | | |
| Total | No. | 14 | 16 |
| Length | ft | 42.5 | 42.5 |
| Width | ft | 14.2 | 14.2 |
| Area per filter | sf | 602 | 602 |
| Filtration rate | | | |
| Average flow | mgd | 40 | 47 |
| Peak flow for TP reduction goal | mgd | 40 | 50 |
| Average – 2 out of service | gpm/sf | 3.8 | 3.9 |
| Peak- 1 out of service | gpm/sf | 3.5 | 3.8 |
| Design Peak at 5 gpm/sf-1 OOS | mgd | 61 | 70 |
| Backwash return pumping station capacity | mgd | 6 | 6 |
| Ferric Chloride | | | |
| Average (40% solution strength) | gpd | 1070 | 1260 |
| Bulk Storage Tanks at 7500 gallons | No | 3 | 3 |
| Additional solids generated - average | lb/d | 4600 | 5400 |

Figure E-8 shows a filtration building layout for a Parkson Dynasand filter complex.

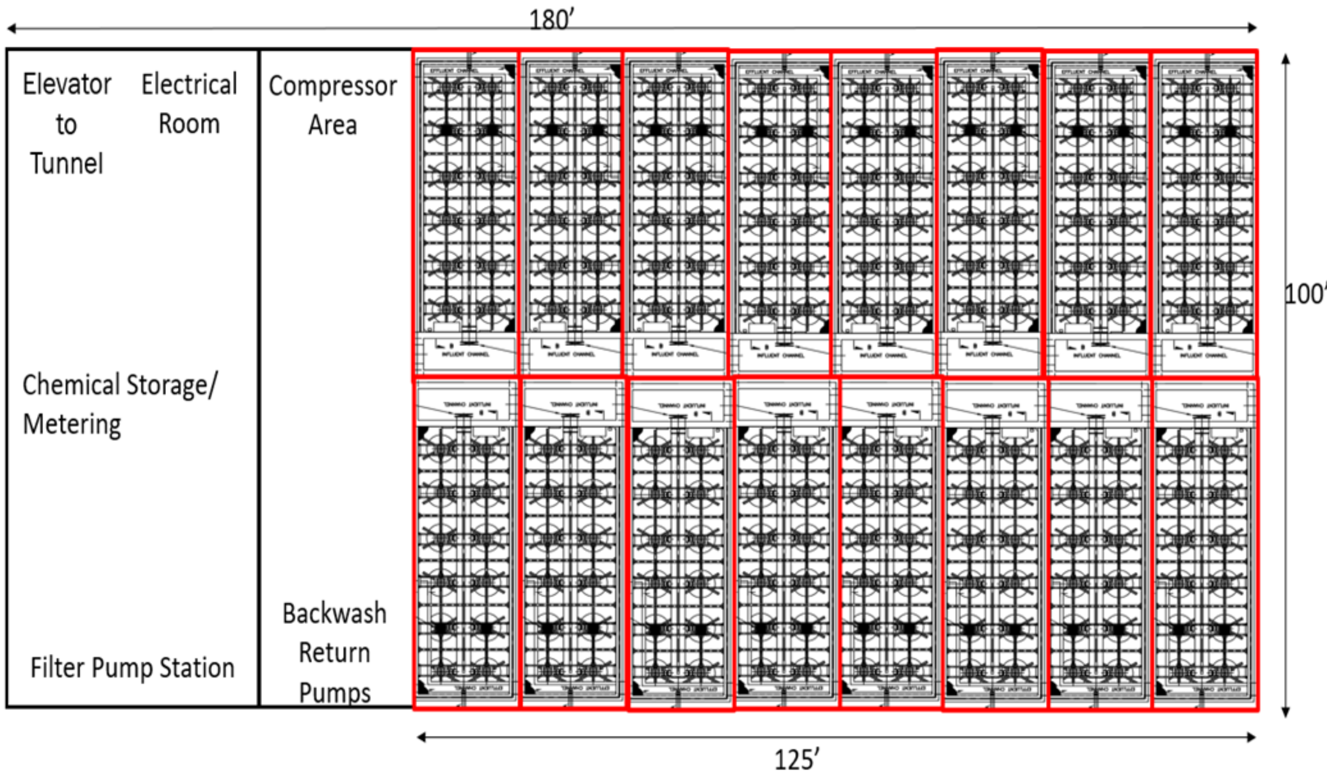



Figure E-8. Alternative 3 – Continuous Backwash Deep Bed Filters Building Layout

## 1.3 Economic Evaluation

Comparative capital costs, operating costs, and life cycle present worth for each alternative were developed to compare each alternative based upon costs. Developed costs represent Class 5 estimates for Conceptual Level Planning and alternative comparison in accordance with the Association for the Advancement of Cost Engineering International (AACE). Expected accuracy for Class 5 estimates typically ranges from -50 to +100 percent, depending on the technological complexity of the project, appropriate reference information and the inclusion of an appropriate contingency determination. Construction costs are based upon process unit costs from similar projects and vendor proposals adjusted to Year 2020 dollars. All cost estimates assume construction begins in 2020 (cost not escalated for construction mid-point) and operations start in 2025. The economic analysis uses the assumptions provided in Tables E-7 and E-8.

Table E-7. Tertiary Filtration Capital Cost Assumptions

| Item | Assumption |
|---|---|
| Net Cost Mark-up | |
| Electrical and Instrumentation (percent of total construction cost) | 22 to 25% |
| Labor | 15% |
| Material | 10% |
| Subcontractor | 10% |
| Construction equipment | 10% |
| Process equipment | 8% |
| Material shipping and handling | 2% |
| Material; sales tax | 8% |
| Gross Cost Mark-ups | |
| Contractor general conditions | 15% |
| Start-up, training, O&M | 2% |
| Undefined detail contingency | 50% |
| Insurance | 2% |
| Bonds | 1.5% |
| Escalation to midpoint | 0% |
| Engineering and administration | 20% |

Table E-8. Tertiary Filtration Annual Operating and Net Present Value Assumptions

| Item | Assumption |
|---|---|
| Electricity | $0.075/kWh |
| Labor rate (O&M staff) | $112,445/FTE |
| Ferric Chloride | $1.35/gallon |
| Solids processing | $700/dry ton |
| Interest rate | 3% |
| Discount rate | 3% |
| Life-cycle cost period | 25 years |
| Life of Buildings/Tanks | 40 |
| Terminal Value Building/Tanks | Straight line depreciation |

### 1.3.1 Capital Costs

Capital costs are based on the following assumptions:

- Filtration complex is located adjacent to the chlorine contact tank in the existing aerated pond area.
- A new tunnel connects the Filtration Building to the existing tunnel near the Maintenance Building elevator access
- Bulk chemical storage and metering facilities are provided in the new building.
- Filter backwash is pumped upstream of the primary clarifiers influent channels.

- Secondary clarifier launder covers are provided to minimize algae which can clog/negatively impact filtration.
- To maintain gravity flow from the filters to the chlorine contact tank, Alternative 1 requires the elevation of the Filter Building floor be higher than the Aerated Pond liquid level. This requirement results in the new filtration area complex boundary (pond area) to be filled. Alternatives 2 and 3 HGL allows the filters bottom elevation to be constructed at the pond bottom elevation (bedrock) and still achieves gravity flow through the filters.
- No provisions for groundwater dewatering have been included in the cost estimates.
- Capital costs assume the aerated pond remains operational. This should be reviewed further since there will periods up to 6 months in which no flow is routed to the pond if all flow less than "the peak flow for TP reduction goal" is filtered.

Table E-9 shows Alternatives 2 and 3 have the same capital cost of $70 million while Alternative 1 capital cost of $83 Million is 18 percent higher. Table E-9 also presents the unit capital costs based upon a peak filtration rates of 5 gpm/sf and higher peak filtrations used in other facility designs/ operations. On a unit cost basis, Alternative 1 and 3 have similar unit capital costs of $1.06 to $1.01/gpd capacity at 5 gpm/sf while cloth media filtration is substantially less at $0.75/gpd capacity. When considering Alternative 1 and 2 peak filtration rates capacity of 8 and 6 gpm/sf respectively, unit capital costs decrease and are within 8 percent at $0.74 and $0.68/gpd capacity, respectively.

### 1.3.2 Annual Operating Costs

The annual operating costs developed for each alternative include the following items:

- Assumes first year of operation is 2025 and continue through year 2050
- Annual average energy costs for filter feed pumps, backwash pumps or air compressors, air scour blowers, backwash return pumps, filter drive units, flash mixing and flocculation mixers, and chemical metering pumps.
- Additional ferric chloride usage for secondary/tertiary systems. Chemical costs for filter cleaning assumed to be negligible. Potential reduced ferric consumption from routing filter backwash laden with ferric chloride solids to the liquid stream are not included since ferric chloride estimates are based upon historical operations rather than BioWin simulations.
- Annual average solids processing costs for additional solids generated. Assumes additional solids generated do not impact solids processing facility sizing.
- Annual operations and maintenance labor hours based on 1800 hours worked each year and paid for 2080 hours per year.
- Annual maintenance materials at 2 percent of equipment costs
- Alternative 2 cloth media replaced every 7 years.

Annual operating costs, except labor, are escalated yearly based upon the average filter feed rate. Labor hours are assumed constant during the 25-year planning cycle. Table E-9 shows the annual operating costs of each alternative are within 7 percent.

Table E-9: Tertiary Filter Capital and Annual Operating Costs and Net Present Value (Basis:2050)

| Item | 1-Conventional Filters | 2 - Cloth Media Filters | 3- Continuous Backwash Deep Bed Filters |
|---|---|---|---|
| Capital Costs | | | |
| Site work | $1,760,000 | $960,000 | $960,000 |
| Tunnel to Maintenance Building | $2,800,000 | $2,800,000 | $2,800,000 |
| Trench for utilities | $410,000 | $410,000 | $410,000 |
| Large yard piping | $2,340,000 | $2,340,000 | $2,340,000 |
| Influent Pump Station | $11,000,000 | $13,900,000 | $10,500,000 |
| Filters/Filter Building | $32,300,000 | $18,720,000 | $26,210,000 |
| Backwash Return or Mudwell Pump Station | $1,700,000 | $1,700,000 | $1,700,000 |
| Flocculation Tanks | $- | $1,560,000 | $- |
| Secondary Clarifier Launder Covers | $1,470,000 | $1,470,000 | $1,470,000 |
| Electrical/I&C | $15,200,000 | $14,600,000 | $13,100,000 |
| Subtotal | $68,980,000 | $58,460,000 | $59,490,000 |
| Escalate to mid-point construction | $- | $- | $- |
| **Total Construction Cost** | **$69,000,000** | **$58,000,000** | **$59,000,000** |
| **Total Construction Cost Range ($ millions)** | **$35 to $140** | **$30 to $115** | **$30 to $120** |
| Engineering/Administration | $13,800,000 | $11,700,000 | $11,900,000 |
| **Total Capital Cost** | **$83,000,000** | **$70,000,000** | **$71,000,000** |
| **Annual Operating Costs (2020 dollars for 2025 operations)** | | | |
| Energy | $ 240,000 | $ 180,000 | $ 170,000 |
| Ferric chloride | $ 240,000 | $ 240,000 | $ 400,000 |
| Solids processing | $ 300,000 | $ 300,000 | $ 440,000 |
| Labor O&M | $ 480,000 | $ 570,000 | $ 390,000 |
| Maintenance materials | $ 140,000 | $ 120,000 | $ 110,000 |
| R&R Equivalent | - | $50,000 | - |
| **Total Annual operating costs** | **$ 1,410,000** | **$ 1,460,000** | **$ 1,510,000** |
| Terminal Value | ($6,800,000) | ($2,300,000) | ($4,500,000) |
| **Net Present Value** | **$120,000,000** | **$112,000,000** | **$113,000,000** |
| Capital cost/gpd capacity | | | |
| at filtration rate of 5 gpm/sf (10-state standards) | $1.06 | $0.75 | $1.01 |
| at filtration rate of x gpm/sf | $0.74 (8 gpm/sf)[a] | $0.68 (6 gpm/sf)[a] | -- |

*Costs presented in 2020 dollars*

*a. Increasing capacity to 125 mgd increases capital cost by roughly $10 million*

*b. Increasing capacity to 110 mgd increases capital cost by roughly $ 5 million*

### 1.3.3 Net Present Value

Net present values (NPV) for each alternative were calculated based upon the capital costs, NPV of annual operating costs, and salvage value of the filtration building and flocculation basins. Table E-9 shows the

NPVs range from $112 Million to $120 million and are considered equal since the values are within 7 percent.

## 1.4 Non-Economic Evaluation

Table E-10 summarizes the non-economic advantages and disadvantages of each alternative. Alternative 1 key advantages include a well-established history at similar sized facilities, ability to handle high TSS loadings, capacity to treat flows up to 125 mgd with expanded influent pump station, and has potential to be used as a combination TP reduction/denitrification filter; however conventional filters do have more support equipment and large footprints. Alternative 2 key features are its simple operations, low backwash volumes, capacity to treat up to 111 mgd with increased pump station; however, these filters will typically have slightly higher effluent solids than conventional filters with less capacity to handle high TSS loadings. Also, cloth media requires regular media replacement every 7 years and is prone to biofouling and scaling with ferric chloride addition increasing maintenance activities to maintain capacity. Alternative 3 is also very simple to operate, low operations staffing, produces low effluent solids/TP with capacity to handle high solids loadings, and has the lowest support equipment requirements. Alternative 3 does have the highest backwash and coagulant requirements, prone to plugging from algae, and limited denitrification capacity if used as a denite filter.

**Table E-10. Tertiary Filtration Non-Economic Comparison**

| Alternative | Advantages | Disadvantages |
|---|---|---|
| **Alternative 1 - Conventional Downflow Filters** | • Well established for facilities of similar size<br>• Medium maintenance<br>• Low backwash volumes (5 to 7%)<br>• Excellent particulate removal<br>• Ability to handle high TSS concentrations without binding,<br>• Capacity up to 125 mgd at 8 gpm/sf with one unit out of service/backwash<br>• Mono-media filters can be used/retrofitted for denitrification/TP reduction | • Large footprints<br>• High headloss<br>• High support equipment (blowers, pumps, air scour, mudwell, clear well.)<br>• May require polymer<br>• Monthly TP discharges less than 0.1 mg/L require upstream solids contact or equal treatment process |
| **Alternative 2 – Cloth Media Filters** | • Well established<br>• Non-proprietary<br>• Medium footprint<br>• Relatively simple operations<br>• Low backwash volumes (5 to 7%) without need for backwash tank<br>• Low headloss/energy cost<br>• Capacity up to 111 mgd at 6 gpm/sf with one unit out of service | • Higher effluent solids than conventional filters with less capacity for high TSS loads<br>• Need for flocculation tank upstream of filters<br>• Media prone to biofouling and scaling with ferric chloride increasing maintenance<br>• Cloth media replaced every 7 years<br>• Monthly TP discharges less than 0.1 mg/L require upstream solids contact clarifier or equal<br>• Limited microfiber application for TP less than 0.1 mg/L. Microfiber systems have very high backwash (>12%) without upstream process<br>• Cannot be used for tertiary denitrification<br>• Fewer facilities of similar size compared to Alternative 1 |

| Alternative | Advantages | Disadvantages |
|---|---|---|
| **Alternative 3 – Continuous Backwash Deep Bed Filters** | • Reliable, simple to operate and maintain<br>• Minimal support equipment<br>• Low operations staffing<br>• No moving parts in filters and mechanical equipment limited to airlift compressor<br>• Capability to produce effluent TP consistently less than 0.1 mg/L<br>• Ability to handle high TSS concentrations without binding,<br>• No/low polymer<br>• Low media loss<br>• Low energy/operating costs<br>• Excellent particulate removal<br>• No backwash tanks<br>• Medium footprint<br>• Potential to add second stage to further reduce TP discharges if needed | • Bed hardening requires quarterly air lancing<br>• Algae/bristles can clog filter air lift pump<br>• Medium backwash volume (7.5%)<br>• Airlift tubes replaced every 2 to 3 years<br>• Limited denitrification capacity<br>• Acid addition required for Nexom™ filter<br>• Fewer facilities of similar size compared to Alternative 1 |

## 1.5 Recommendation

Alternative 1 – Conventional Filters are recommended for enhancing TP reduction based upon its excellent performance and proven experience at similar sized facilities, ability to handle high solids loadings, less prone to plugging/biofouling/scaling, ability to treat flows of 78 mgd with potential to treat peak flows up to 125 mgd, potential to be used as a denitrification filter, and NPV within 7 percent of the other alternatives with lower annual operating costs.