West Basin Facility Plan Project 7054

TECHNICAL MEMORANDUM 5

Rock Creek WRRF Tertiary Expansion Evaluation

FINAL / November 2024

Produced by: carollo

Clean Water Services

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Abbreviations

ADW	average dry weather
ADWF	average dry weather flow
Al	aluminum
CAMP®	concentrated, accelerated, motivated, problem-solving
CAPEX	capital expenditure
CCB	chlorine contact basin
CIP	clean-in-place
coag	coagulation
DEQ	Oregon Department of Environmental Quality
District	Clean Water Services
floc	flocculation
gfd	gallons per square foot per day
GMF	granular media filtration
gpm/sf	gallons per minute per square foot
HLR	hydraulic loading rate
MAO	Mutual Agreement and Order
MDDW	maximum day dry weather
MF	microfiltration
mg P/L	milligrams of phosphorus per liter
mg/L	milligrams per liter
mgd	million gallons per day
mm	millimeter
MMDW	max month dry weather
MMDWF	max month dry weather flow
NPDES	National Pollutant Discharge Elimination System
NTS	natural treatment system
OPEX	operating expenditure
PF	peaking factor
ppd	pounds per day
ppd/sf	pounds per day per square foot
sf	square feet
SLR	solids loading rate
TM	technical memorandum
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
UF	ultrafiltration
USEPA	United States Environmental Protection Agency
WRRF	Water Resource Recovery Facility

TM 5 ROCK CREEK WRRF TERTIARY EXPANSION EVALUATION

5.1 Background

Tertiary treatment is required for the Rock Creek Water Resource Reclamation Facility (WRRF) to meet stringent effluent total phosphorus (TP) and total suspended solids (TSS) limits. The facility's current tertiary treatment system consists of tertiary clarification, high-rate clarification, and granular media filtration. This system has allowed Clean Water Services (District) to reliably meet their historical effluent limits. Tertiary treatment expansion will be required to accommodate projected growth in the facility's service area. Expansion may also be driven by potential future effluent limits.

The District is currently working with the Oregon Department of Environmental Quality (DEQ) to clarify their effluent TP limit. The District anticipates that the maximum monthly median effluent TP concentration from May through October will be either 0.1 milligrams of phosphorus per liter (mg P/L) (their current National Pollutant Discharge Elimination System [NPDES] limit) or 0.5 mg P/L (consistent with the Mutual Agreement and Order [MAO] for the 2020–2022 operating seasons). Tertiary treatment requirements differ significantly between these two alternatives, and both were considered below. Additionally, an effluent aluminum limit may be imposed following the United States Environmental Protection Agency's (USEPA) issuance of aquatic life criteria for aluminum. Given the uncertainty surrounding future tertiary treatment requirements, three scenarios were developed (summarized in Table 5.1):

- Scenario A reflects the requirements if the District's work to update the Tualatin Basin phosphorus total maximum daily load (TMDL) is successful and the effluent requirements from the MAO from the 2020–2022 operating seasons that allowed facilities to operate to meet a 0.5 mg P/L limit are reinstated. In this scenario, tertiary clarification, high-rate clarification, and tertiary alum addition for direct filtration are not necessary to meet the effluent TP limit of 0.5 mg P/L.
- Scenario B reflects the current NPDES permit limit of 0.1 mg P/L. This scenario assumes that while an effluent TP limit of 0.1 milligrams per liter (mg/L) is imposed, an effluent aluminum limit will not be imposed. Based on previous operating experience with Actiflo, the facility will be capable of meeting the TP limit but may have a high effluent aluminum concentration if not filtered. Tertiary alum addition will be necessary in this scenario; however, effluent from the high-rate clarifiers does not necessarily need to be filtered. While this scenario was developed through buildout for the current analysis, it is only considered a viable option for near-term operation under the current 0.1 mg/L limit. It is assumed that an aluminum limit would prevent this alternative from being utilized as a long term compliance strategy.
- Scenario C reflects the current NPDES permit limit of 0.1 mg P/L and assumes an effluent aluminum limit is also imposed. If enacted, the District anticipates this will require all the secondary effluent to be filtered. Given the District's historical difficulty in filtering high-rate clarifier effluent, it is assumed that the west secondary effluent is directly filtered (i.e., the Actiflo® process is only used to dose coagulant).

Table 5.1 Future Tertiary Treatment Requirements by Potential Permit Limit Scenario

Parameter(1)	Scenario A	Scenario B	Scenario C
Motivation	Successful TMDL Revision	Necessary to meet 0.1 mg P/L in 2025	Requirement to meet 0.1 mg P/L and future Al limit
TP Limit	0.5 mg P/L	0.1 mg P/L	0.1 mg P/L
Aluminum Limit	N/A(2)	None(3)	Enacted
TSS Limit	N/A(4)	N/A(4)	N/A(4)

Notes:
(1) Drivers are discussed in greater detail in section 5.1.2.
(2) An aluminum (Al) limit would likely not impact Scenario A as the 0.5 mg/L effluent TP limit could be achieved without tertiary alum addition.
(3) It may be possible to satisfy an Al limit in the near term with this scenario. Given its increasing reliance on Actiflo and the high alum doses that would be necessary to meet the 0.1 mg P/L, it was not considered likely that this Scenario would be able to meet an Al limit through buildout.
(4) The effluent TSS mass load limit was not treated as a driver for future tertiary treatment in this analysis (section 5.1.2.2).

5.1.1 Existing Tertiary Treatment System

Currently, tertiary treatment at the Rock Creek WRRF consists of tertiary clarification, high-rate clarification, and tertiary filtration. Tertiary clarification has been achieved through four Claricones. A portion of the secondary effluent (typically from the east secondary treatment trains) is dosed with alum and directed to the tertiary clarifiers in the dry weather season as required (up to the rated capacity of 5 million gallons per day [mgd] per unit) to meet the facility's 0.1 mg P/L effluent TP limit.

The Rock Creek WRRF has 10 constant level, mono-media tertiary filters (numbered 5 through 14) located on the east side of the facility. Each of the existing filters has a surface area of 900 square feet (sf) and is backwashed with a combination of air and water. Design criteria for the granular media filters are summarized in Table 5.2.

Table 5.2 Existing Granular Media Filter Design Criteria

Design Criterion	Value
Filter type	mono-media, 1.4 mm Anthracite
Media depth (inches)	48
Number of filters	10
Area per filter (sf)	900
Total filtration area (sf)	9,000
Hydraulic loading rate (gpm/sf)	
Average dry weather (ADW)	3.4(1); 3.0(2)
Maximum month dry weather (MMDW)	4.0(1,3); 3.9(2)
Maximum day dry weather (MDDW)	5.2(1,3); 5.0(2)

Notes:
(1) CH2M Hill (1993) Tertiary Complex Rock Creek Advanced Wastewater Treatment Plant. Record Drawings.
(2) CH2M Hill (2004) Rock Creek Facility - Phase 6A Expansion and Upgrades. Conformed Drawings.
(3) MMDW and MDDW hydraulic loading rates were not specified. Values estimated by applying the peaking factors determined from the projected filter influent at 2045 to the ADW design criterion.
gpm/sf - gallons per minute per square foot; mm - millimeter.

Two high-rate clarifiers (Actiflo) were installed at the Rock Creek WRRF in 2014 to provide additional tertiary and peak flow treatment capacity. These high-rate clarifiers replaced the historically under-performing west tertiary clarifiers (Clarifiers 5 and 6) and west filters (Filters 1 through 4) that previously treated west secondary effluent in dry weather conditions. Under peak wet weather flow conditions, primary effluent may bypass secondary treatment and be sent directly through Actiflo. Effluent from the Actiflo system was designed to be directed to the chlorine contact basins; however, provisions were also made to direct some or all the flow to the east filters for further treatment. The District has noted that effluent from the Actiflo system rapidly fouls the filters and has minimized loading sent to the filters.

5.1.2 Drivers for Tertiary Treatment Expansion

The District has identified several drivers that may impact future tertiary treatment expansion requirements at the Rock Creek WRRF. These drivers include current NPDES permit limit requirements for TP and TSS, potential effluent permit limits for aluminum, and the potential for expanding reuse water production at the facility. Importantly, several of these factors are unresolved and future tertiary treatment expansion will differ significantly depending on which limits are imposed. Each of these drivers are discussed individually below followed by a summary of the alternatives that were ultimately evaluated for tertiary treatment expansion.

5.1.2.1 Effluent Total Phosphorus Limit

The District is currently working with the DEQ to clarify the effluent TP limit for the Rock Creek WRRF. In 2020 the District started an MAO with the DEQ to allow Rock Creek WRRF to discharge to a maximum monthly median TP limit of 0.5 mg P/L from May through September. This MAO was developed to provide an opportunity to evaluate the impact of ceasing alum addition to tertiary processes on aluminum in the Tualatin River. The MAO was renewed in 2021 and 2022 to allow the District to collect information in support of revising the phosphorus TMDL. Since CAMP® the timeline for revising the TMDL has continued to be uncertain. A separate MAO was obtained for operation in 2023 and 2024 that reduces the TP limit to 0.4 mg/L and 0.3 mg/L in each of these years. The purpose of this MAO is to provide the opportunity for testing the tradeoff between effluent aluminum concentration and effluent phosphorus. After this MAO expires, the Rock Creek WRRF may be required to meet the current NPDES monthly median effluent TP permit of 0.1 mg P/L from May through September unless another MAO is established. This uncertainty for both the near-term and long-term phosphorus limits is the driver behind an evaluation to determine the tertiary treatment needs under either the 0.1 or 0.5 mg/L phosphorus limits presented in this technical memorandum (TM).

5.1.2.2 Effluent TSS Mass Load Limit

Under the District's current watershed-based NPDES permit, each of the District's facilities have individual effluent TSS limits as well as a bubbled TSS mass load limit. The bubbled TSS mass load governs in general, with low river flow conditions imposing the most stringent limits. The current maximum month total combined effluent TSS mass load from the Rock Creek, Durham, and Forest Grove WRRFs is 3000 pounds per day (ppd). The District is currently working to secure an increase in the TSS mass load limit; however, this may not be incorporated into the next version of the NPDES permit. While the TSS mass load limit may dictate future tertiary treatment requirements at the Rock Creek WRRF, the present tertiary expansion evaluation assumed it would not, due to options available to reduce the combined load discharged to the river.

Figure 5.1 depicts the TSS mass load allocation between the Rock Creek, Durham, and Forest Grove WRRFs as well as the effluent TSS concentration required at the Rock Creek WRRF with the following assumptions:

- The current bubbled TSS mass load limit remains through 2075.
- Maximum month effluent flows were estimated from the projected baseflows for each facility (flow and load projections from 2023-07-19). It was assumed that flows from the Hillsboro WRRF would be transferred to the Forest Grove WRRF for treatment. Historical maximum month effluent flow rate to baseflow flow rate peaking factors for each facility (Table 5.3) remain constant.
- The effluent TSS from the Durham and Forest Grove WRRFs are 4 mg/L and 10 mg/L, respectively.
- Effluent flow and load reductions due to reuse from each facility are negligible.

These assumptions represent a conservative lower limit for the effluent TSS mass load available for the Rock Creek WRRF. As shown in Figure 5.1, the portion of the total bubbled TSS mass load limit available for the Rock Creek WRRF would decrease from approximately 1600 ppd currently to approximately 1000 ppd at 2045 and less than 350 ppd at 2075. This would reduce the allowable average maximum month effluent TSS concentration from approximately 2 mg/L currently to approximately 1.5 mg/L at 2045 and less than 0.5 mg/L at 2075. If these assumptions hold, the alternatives for tertiary expansion at the Rock Creek WRRF would be limited—as discussed below, only membranes would be able to meet the effluent TSS concentrations required by buildout reliably.

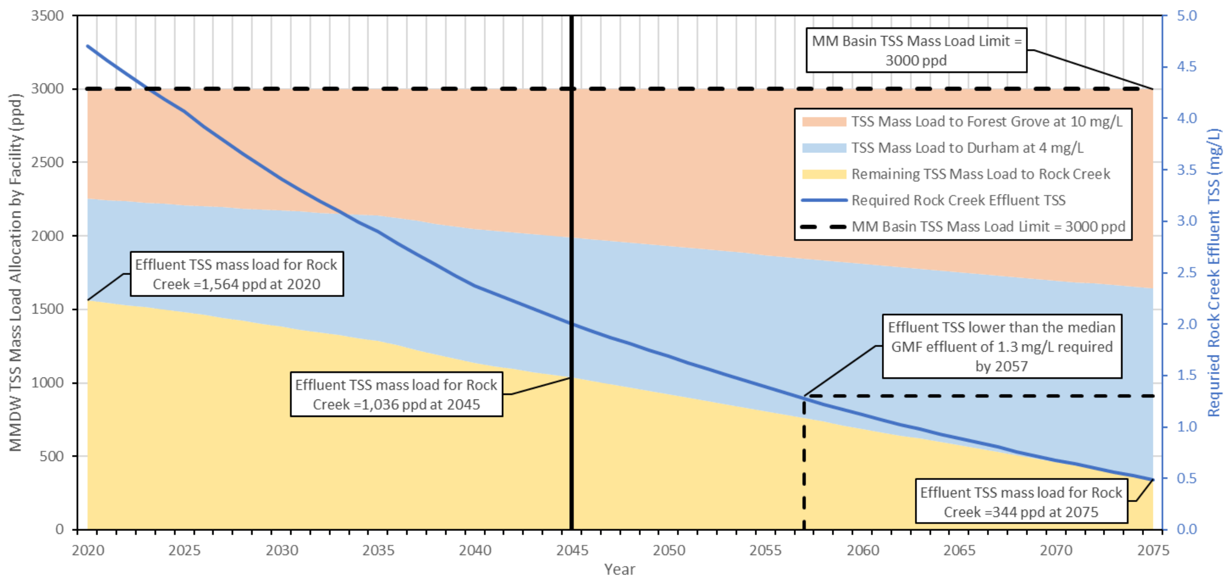


Figure 5.1 Maximum Month TSS Mass Load Allocation and Effluent TSS Requirements for a Constant Bubbled TSS Mass Load Limit

Table 5.3 Effluent Flow and TSS Concentrations Assumed in Developing Figure 5.1

Facility	MMDW/Baseflow PF(1)	Effluent TSS (mg/L)
Rock Creek WRRF	1.17	Calculated
Durham WRRF	1.17	4
Forest Grove WRRF	1.75	10

Notes:
(1) Peaking factors (PF) developed from historical data during low river flow conditions.
MMDW - max month dry weather.

Several alternatives may allow for a higher effluent TSS mass load allocation to the Rock Creek WRRF, including:

- Petition for an increase in the bubbled effluent TSS mass load limit.
- Reduce effluent TSS concentrations:
  - Durham WRRF:
    - This may be difficult given that the configuration (disinfection prior to filtration) limits tertiary polymer addition.
  - Forest Grove WRRF:
    - The current compliance point is at the natural treatment system (NTS) outfall (F001), meaning reduction in effluent TSS from the NTS would be necessary. It is not expected that secondary effluent TSS reduction through secondary clarifier optimization or the installation of tertiary filters would improve final effluent quality. The district has historically encountered high NTS effluent TSS concentrations under high peak flows which resuspend settled solids.
- Increase effluent reuse:
  - Effluent reuse is currently practiced at the Durham and Rock Creek WRRFs.

Without an increase in the TSS mass load limit or improvements elsewhere to increase the effluent TSS mass load allocation to the Rock Creek WRRF, the following options would be available to reduce the effluent TSS concentration of the Rock Creek WRRF:

- Optimize granular media filter performance. The granular media filters have historically achieved a median dry weather effluent TSS concentrations of 0.6 mg/L without tertiary alum addition (2020 through 2022) and 1.5 mg/L with tertiary alum addition (2015 through 2019). The District will be conducting filter stress testing in the summer of 2024 to identify the performance limits of the existing granular media filters. While it is unlikely that the granular media filters would be able to reliably meet the conservative effluent TSS concentration of less than 0.5 mg/L required at buildout, improvements may be used in conjunction with other alternatives.
- Install tertiary treatment technologies capable of reliably achieving lower effluent TSS concentrations (e.g., membrane filters).

The District is currently exploring the alternatives above as part of larger planning efforts. Given the uncertainty surrounding the bubbled TSS mass load limit as well as the availability of multiple potential alternatives to increase the effluent TSS mass load limit allocated to the Rock Creek WRRF, the assumption that the bubbled TSS mass load limit would not govern future tertiary treatment decisions was considered reasonable. Conclusions from the current analysis may need to be revisited if this assumption becomes untenable in the future.

5.1.2.3 Potential Effluent Aluminum Limit

The District uses alum precipitation for phosphorus removal. The USEPA issued a rule establishing aluminum aquatic life criteria applicable to Oregon in December of 2020. Based on dedicated testing completed during the East Basin Facility Plan, the District anticipates that an aluminum limit would, if imposed, require filtration of all secondary effluent. Scenario C was developed to evaluate the impact of an aluminum limit. Given the uncertainty in the timing and magnitude of an aluminum limit, Scenario B was developed to evaluate current tertiary operations which would continue until an aluminum limit was enacted. While it might be possible for Scenario B to meet both the 0.1 mg/L TP limit and an aluminum limit in the near term, the operating data are not available to support this as a viable condition through buildout.

5.1.2.4 Potential Reuse Water

The District is working to expand reuse water supply from the Rock Creek WRRF. The expanded reuse distribution system will convey reuse water to the Hillsboro area using the existing flow transfer system between the Rock Creek WRRF and the valve interchange system (colloquially referred to by the District as the "Christmas Tree"). The District has raised the possibility of reconfiguring solids handling at the Forest Grove WRRF such that additional reuse water could be delivered to users in the Forest Grove area through one of the two flow transfer system pipelines.[1]

Expanding the production of reuse water at the Rock Creek WRRF would have several benefits, including expanding the District's portfolio of beneficial products, reducing the effluent TSS mass load, and reducing the effluent thermal load. For the present analysis, the impact of reuse was conservatively not included in the tertiary treatment alternative evaluations. Current and future reuse at the Rock Creek WRRF were considered, however, as part of the tertiary treatment technology screening.

5.1.3 Tertiary Treatment Technology Screening

A high-level screening of tertiary treatment technologies was conducted prior to alternatives development and evaluation for each scenario. Three tertiary treatment technologies were considered for expansion at the Rock Creek WRRF based on the anticipated permit limits: granular media filters, cloth disk filters, and membranes.

[1] Carollo Engineers, Inc. (February 2024) Dedicated Solids Transfer Pipeline Evaluation. Technical Memorandum 8. West Basin Facility Plan Project 7054.
Carollo Engineers, Inc. (March 2023). West Basin Alternatives CAMP® Documentation. Technical Memorandum 1. West Basin Facility Plan Project 7054.

5.1.3.1 Granular Media Filtration

Granular media filtration (GMF) is a widely employed method to remove particulates from all types of water sources and is currently used at the Rock Creek WRRF to filter secondary and tertiary effluent. In GMF, suspended particles are removed from the water as it flows through a bed of filter media. There are two primary mechanisms of particle removal in GMF, surface filtration and depth filtration, as illustrated in Figure 5.2. Surface filtration, also known as screening, is the process in which the particulates are caught on the surface of the filter media and do not penetrate the media bed at all. With surface filtration, there is very little particulate storage capacity due to retention only occurring on the surface of the media. Conversely, for depth filtration the principal particle removal mechanisms occur within in the filter media bed via sedimentation and impaction, interception, adhesion, flocculation, chemical or physical adsorption, and biological growth. The volume of the media bed of a depth filter allows for a larger particulate storage capacity within the filter which results in longer filter run times. In actuality, the two mechanisms of removal are not mutually exclusive. For instance, a deep bed can still remove large particles at the surface via straining, and a filter that is designed to remove particles via particle size exclusion (i.e., surface filtration) can build up a layer of solids that can act as a depth filter and increase removal performance.

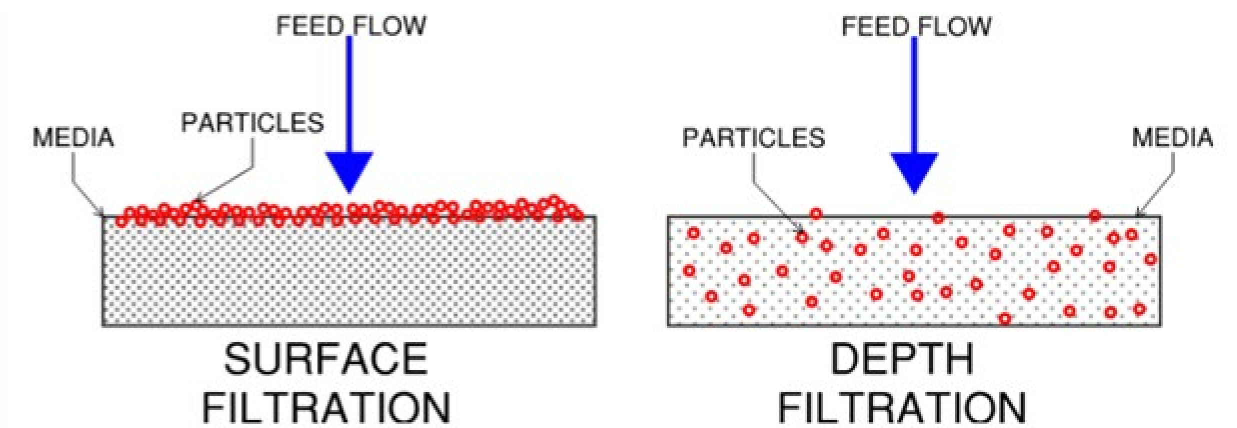
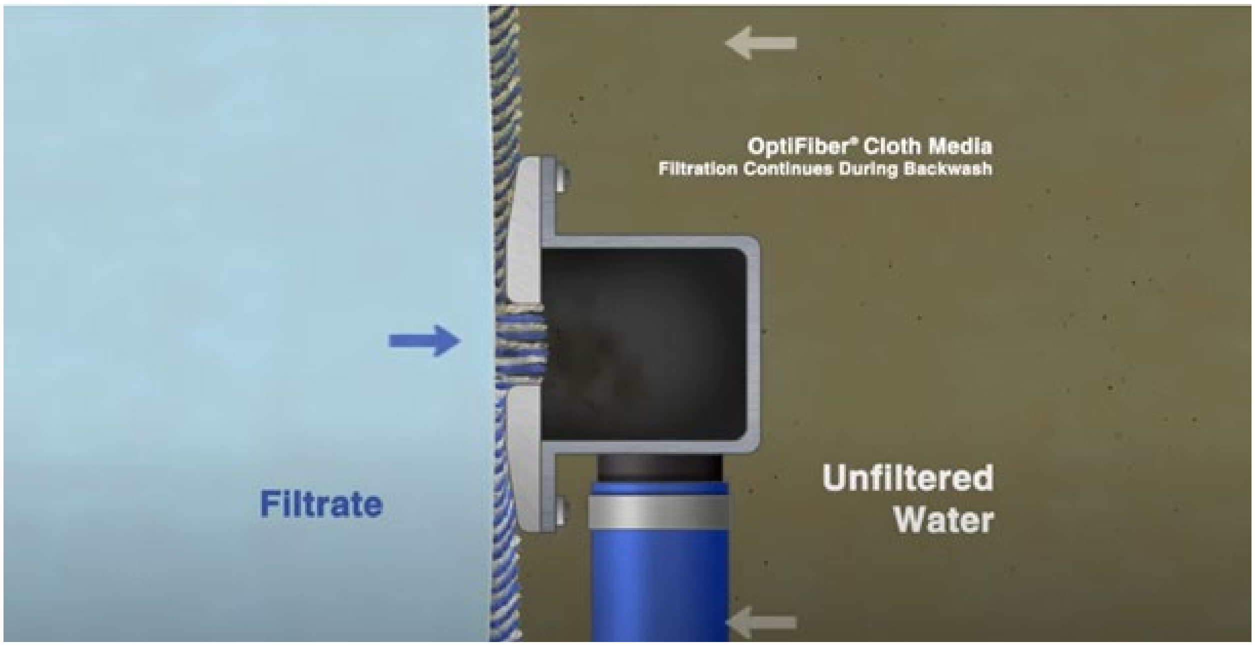


Figure 5.2 Surface and Depth Filtration

Conventional downflow GMF are among the most robust and reliable GMF technologies. When designed with a suitable media design and backwash system, these filters can remove particles to a high level while handling significant variability in secondary effluent water quality.

5.1.3.2 Cloth Disk Filters

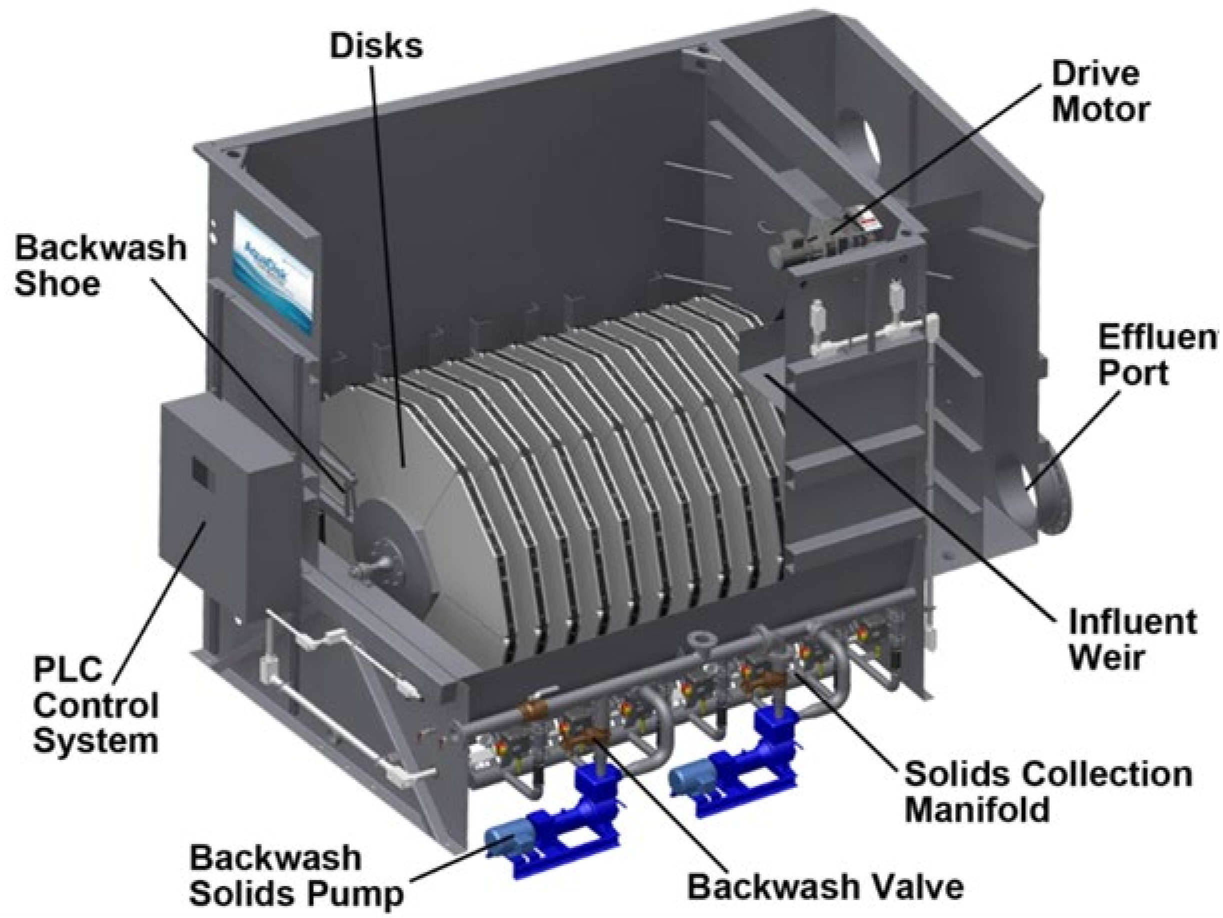
The use of cloth media for filtration was introduced into the national wastewater treatment industry in 1991 and has been growing in its applicability and prevalence since that time. This process uses cloth media to filter out particles found in the secondary effluent. There are a large variety of cloth media filter configuration options, including flow mode (inside-out vs. outside-in), operation submergence (fully vs. partially submerged), filter disk design (circular or square disks with or without panel segments vs. lateral type of media elements), and cloth materials (nylon/polyester pile fiber vs. polyester microscreen). This evaluation only considers cloth pile disk filters (referred to throughout this TM as cloth disk filters), as shown in Figure 5.3. Cloth disk filters typically provide superior solids removal due to the pile employing a similar removal mechanism as depth filtration.



Source: Aqua-Aerobic System, Inc.

Figure 5.3 Pile Fiber Cloth Media Filter - Backwash Mode

The typical cloth disk filter employs cloth pile media mounted on multiple disks to provide a large filtration area within a small footprint. The cloth disks can be aligned vertically making the total filter surface area significantly greater than the actual plan view area of the filter, allowing for higher flow rates through a given footprint. The cloth disks are placed in either a metal tank or a concrete basin, depending on the project requirements. Each disk is composed of multiple panels that can be individually removed for inspection, maintenance, or replacement. A typical Aqua Aerobics AquaDisk® filter configuration, which is a common system used for tertiary filter applications, is shown in Figure 5.4. For larger capacity systems, a MegaDisk® variant can be used to roughly double the hydraulic capacity of each disk. The overall filter configuration for a MegaDisk® is the same but has larger cloth disks (106 sf versus 54 sf), integral components, and ancillary equipment.



Source: Aqua-Aerobic System, Inc.

Figure 5.4 Cloth Media Filter System

5.1.3.3 Membrane Filters

Tertiary membrane filtration employs low-pressure microfiltration (MF) or ultrafiltration (UF) membranes that have pores in the sub-micron (less than 1 micrometer) range. Membrane filtration removes particles by means of physical size exclusion (i.e., straining) and results in low turbidity/TSS effluent due to the extremely small pore sizes. MF/UF provides the most robust physical barrier and produces the highest effluent quality out of the tertiary treatment alternatives evaluated in this report.

This process generally operates by passing feed water through membrane modules containing thousands of hollow fibers. Pressure gradient, either hydraulic or vacuum pressure, depending on the configuration, is the filtration driving force. The high-quality water that passes through the fibers is called the permeate and the reject is called retentate. In a pressurized membrane system, membrane modules are contained in a pressure vessel where pumps are used to pressurize the feed water and force it through the fibers. Alternatively, in a submerged membrane configuration, the membrane modules are submerged in a feed water tank and water is passed through the membrane by applying vacuum pressure, typically from the suction of a centrifugal pump. A pressurized membrane system was assumed for the current analysis.

While MF/UF produces high quality effluent, applications have increased complexity. In order to protect the membrane fibers from unwanted grit or debris, ultra-fine screening or straining (maximum of 1 mm; sub-400 micron recommended) is required upstream of tertiary membrane filtration. Additionally, membrane integrity and performance are maintained through periodic air scouring and chemical cleaning. Cleaning protocols are specific to membrane and feedwater quality but generally involve maintenance cleans (daily to weekly) and a more thorough monthly clean (clean-in-place [CIP]). Backwashes are typically performed every 20-60 minutes.

5.1.3.4 Screening Outcome

A relative comparison of the advantages and disadvantages of the three tertiary treatment technologies considered are summarized in Table 5.4. Based on this comparison, only granular media and membrane filters were carried forward in the treatment alternatives analysis. Cloth media filters were not carried forward for the following reasons:

- Cloth media filters typically produce effluent with higher TSS concentrations than granular media filters. Given that the District currently employs granular media filters at the Rock Creek WRRF, installing cloth media filters would likely produce comparatively poorer quality effluent. While cloth media filters may be able to satisfy effluent permit limits under some conditions (e.g., Scenario A), they may limit the District’s ability to meet more stringent effluent limits that may be imposed in the future.
- It is unclear if cloth media filters could maintain an effluent TP concentration less than 0.1 mg P/L reliably. This precludes their consideration for Scenarios B and C.

Table 5.4 Comparison of tertiary treatment technologies

Technology	General Advantages	General Disadvantages	Effluent quality	CAPEX	OPEX	Constructability
GMF	▪ Robust and reliable treatment. ▪ Flexibility with media selection. ▪ Flexibility with backwash hydraulics. ▪ Numerous operational tools for optimization.	▪ Higher capital cost compared to synthetic/ pressure filter alternatives.	▪ Anticipated effluent TSS < 3 mg/L, often < 2 mg/L	$$	$	Difficult - Major construction project, challenging to sequence.
Cloth Media (Pile) Filters	▪ Low number of filters required. ▪ Small footprint. ▪ Low hydraulic head required.	▪ Potentially maintenance intensive depending on use and feed water quality. ▪ Increased amount of proprietary equipment.	▪ Anticipated effluent TSS < 5 mg/L, often < 3 mg/L	$-$$	$	Good - Relatively small structures required.
MF/UF	▪ Excellent effluent quality. ▪ Potential for a smaller footprint with a two-story membrane facility. ▪ Facility layout is flexible allowing for greater siting options.	▪ High capital and operating cost. ▪ Treatment redundancy with the WRRF. ▪ Sensitive to process upsets.	▪ Excellent - suitable for all requirements. ▪ Effluent TSS ~0 mg/L	$$$	$$$	Difficult - Major construction project, challenging to sequence.

Notes:
CAPEX - capital expenditure; OPEX - operating expenditure.

5.2 Tertiary Treatment Alternatives

Based on the tertiary treatment technology screening, alternatives were developed for granular media and membrane filters for the three potential permit limit scenarios (summarized in Table 5.5). While developing and evaluating the tertiary treatment alternatives, it was found that granular media filters would be able to meet the effluent requirements of Scenarios A and B. Given the comparably high CAPEX and OPEX for membranes, membrane treatment alternatives were not developed for Scenarios A and B.

A simplified flow balance and mass balance spreadsheet model was developed to estimate the hydraulic and solids loading for each of the alternatives. The performance assumptions adopted for each unit process are included in Table 5.6. Additional details on the assumptions adopted for the model and the historical data analyses to underpinning the unit process performance assumptions are provided in Appendix 5A.

Each alternative was developed to provide tertiary treatment capacity in two phases. The first would provide capacity through the end of the planning period (2045) and the second through buildout (2075). The most straightforward expansion would be the construction of three additional granular media filters on the east side of the facility. This would provide capacity slightly past the end of the planning period (2049). This year was adopted as the targeted year to provide capacity through for the remaining tertiary treatment alternatives to allow the Phase 1 projects to be compared.

Table 5.5 Summary of Tertiary Treatment Alternatives Evaluated

Parameter	Scenario A	Scenario B	Scenario C	Scenario C
Expanded/Added Filtration Technology(1)	Granular Media	Granular Media	Granular Media	Membrane
East Secondary Effluent TSS (mg/L)	4.0–5.7(2)	4.0–5.7(2)	4.0–5.7(2)	4.0–5.7(2)
East to west secondary effluent diversion	None	None	None	As required
West Secondary Effluent TSS (mg/L)	8.8–16.5(2)	8.8–16.5(2)	8.8–16.5(2)	8.8–16.5(2)
Claricones	Not operating	Operating	Operating	Operating
Alum Dose (mg/L)	No alum addition	52(3)	52(3)	52(3)
Effluent TSS (mg/L)	N/A	7.6–8.0(4)	7.6–8.0(4)	7.6–8.0(4)
West Tertiary Clarifiers	N/A	N/A	**Operating(5)**	**Operating(5)**
Alum dose (mg/L)	N/A	N/A	28(6)	28(6)
Effluent TSS (mg/L)	N/A	N/A	7.9–8.3(7)	7.9–8.3(7)
East Direct Filtration	Not operating	Operating	Operating	Operating
Alum Dose (mg/L)	No alum addition	19(8)	19(8)	19(8)
Effluent TSS (mg/L)	Calculated(9)	Calculated(9)	Calculated(9)	Calculated(9)
Actiflo	Not operating	Operating	Operating	Operating
Operating mode	Bypassed	Full Actiflo	Coag + Floc only	Coag + Floc only
Effluent directed to	GMFs	CCB1/2	GMFs	Membranes
Alum dose (mg/L)	No alum addition	63(10)	19(8)	19(8)
Effluent TSS (mg/L)	Calculated(9)	7.0–10.8(11)	Calculated(9)	Calculated(9)
East Granular Media Filters	**Operating**	**Operating**	**Operating**	Operating
Effluent TSS (mg/L)	0.6(12)	1.5(13)	1.5(13)	1.5(13)
West Granular Media Filters	N/A	N/A	**Operating(5)**	N/A
Effluent TSS (mg/L)	N/A	N/A	1.5(13)	N/A
Membrane Filters	N/A	N/A	N/A	**Operating**
Effluent TSS (mg/L)	N/A	N/A	N/A	0(14)

Notes:
(1) Processes set in **bold** for each configuration are those that were considered for expansion in each alternative. (2015–2023).
(2) Median and load-weighted 92nd percentile dry weather secondary effluent TSS concentrations (2015–2023).
(3) Median dry weather Claricone alum dose (52 mg/L, 2015–2019).
(4) Estimated from linear regression model fitted to dry weather Claricone and east secondary effluent TSS concentration data (2015–2019).
(5) The west tertiary clarifiers and granular media filters were returned to service only as necessary.
(6) Median dry weather west tertiary clarifier alum dose (27.6 mg/L, 2005–2011).
(7) Estimated from linear regression model fitted to dry weather west tertiary clarifier and secondary effluent TSS concentration data (2005–2011).
(8) Median dry weather direct filtration alum dose (19 mg/L, 2015–2019).
(9) Effluent TSS concentrations were estimated from secondary effluent TSS concentrations and precipitated alum solids.
(10) Median dry weather Actiflo alum dose (63 mg/L, 2019–2020).
(11) Actiflo design criteria and tested result (7 mg/L) and median dry weather Actiflo effluent TSS (10.8 mg/L, 2015–2019).
(12) Median dry weather granular media filter effluent TSS without tertiary alum addition (0.6 mg /L; 2020–2022).
(13) Median dry weather granular media filter effluent TSS with tertiary alum addition (1.5 mg /L; 2015–2019).
(14) Assumed complete suspended solids removal by membrane filters.
CCB - chlorine contact basin; coag - coagulation; floc - flocculation.

5.3 Scenario A - Phosphorus Limit of 0.5 mg/L

Scenario A assumes that the effluent TP limit of 0.5 mg/L from the MAO for the 2020–2022 operating seasons is adopted. The capacity of existing tertiary treatment facilities at the Rock Creek WRRF were evaluated under this scenario to determine when expansion may be triggered (summarized in Section 5.3.1). Only granular media filters were evaluated for Scenario A due to the comparatively high cost of membrane filters. This analysis included identifying significant improvements needed to implement the alternative and developing planning-level capital and life-cycle costs.

- Based on the District's operating experience when the MAO for the 2020–2022 operating seasons was in effect, tertiary alum would not be necessary. This led to the following assumptions:
  - Existing tertiary clarifiers would not be used.
  - Existing high-rate clarifiers would not be operated. The bypass channel may be used, however, to transfer west secondary effluent flows to the east via the high-rate clarifier effluent pump station.
  - No alum would be added to direct filtration streams.

5.3.1 Current Capacity and Trigger for Expansion

The current capacity of the existing tertiary treatment facilities under Scenario A was evaluated as part of the Rock Creek Capacity Assessment.[2] The capacity of the existing granular media filters was evaluated based on the design and redundancy criteria summarized in Table 5.6. From this analysis, the existing granular media filters will have sufficient capacity through the year 2032 (Figure 5.5 and Figure 5.6).

Table 5.6 Tertiary Filtration Design Criteria.

Flow/Load Condition	Design Criteria	Redundancy Criteria	Performance Assumption	Reference
MMDWF	HLR = 4 gpm/sf SLR = 0.45 ppd/sf	All units in service	Effluent TSS < 0.6 mg/L	▪ HLR calculated from Phase 3 design criteria. ▪ SLR from 2014FP. ▪ Effluent TSS represents the median percentile of the 2020-2022 measured dry weather effluent TSS.
ADWF	HLR = 4 gpm/sf SLR = 0.45 ppd/sf	1 filter out of service	Effluent TSS < 0.6 mg/L	▪ HLR calculated from Phase 3 design criteria. ▪ SLR from 2014FP. ▪ Effluent TSS represents the median percentile of the 2020 – 2022 measured dry weather effluent TSS.

Notes:
ADWF - average dry weather flow; gpm/sf - gallons per minute per square foot; HLR - hydraulic loading rate; ppd/sf - pounds per day per square foot; MMDWF - max month dry weather flow; SLR - solids loading rate.

[2] Carollo Engineers, Inc. (February 2024). Rock Creek WRRF Capacity Assessment. Technical Memorandum 2. West Basin Facility Plan Project 7054.

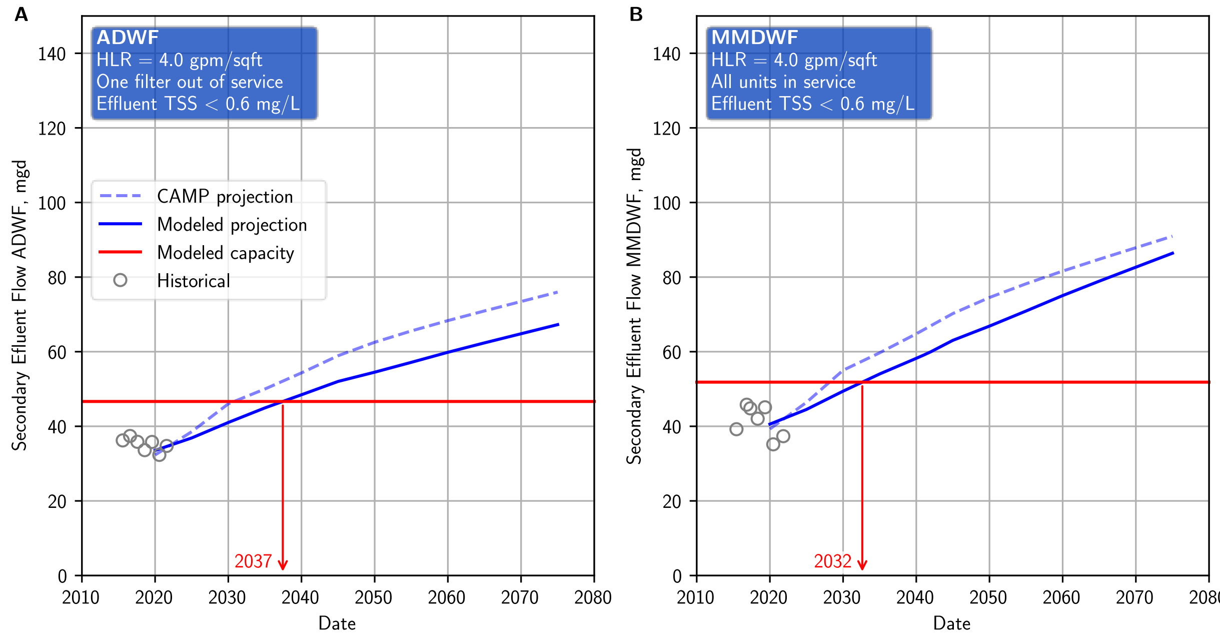


Figure 5.5 Tertiary Filtration HLR Trigger Plots for Scenario A

CAMP® projections and modeled projections refer to the flow and load projections prepared for the West Basin Alternatives CAMP® and those updated on 2023-07-19. See Section 2.1.1 of TM 2 *for additional information.*

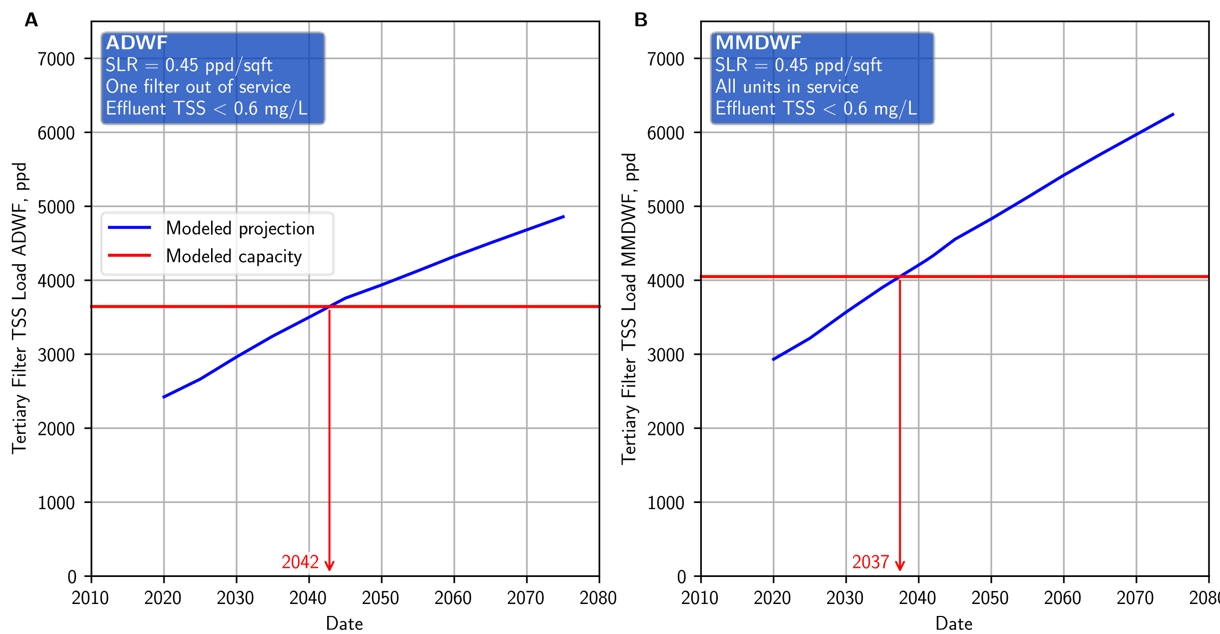


Figure 5.6 Tertiary Filtration SLR Trigger Plots for Scenario A

5.3.2 Expansion with Granular Media Filters

Only GMFs were evaluated for Scenario A due to the comparatively high cost of membrane filters. To meet the future capacity requirements with an effluent TP limit of 0.5 mg P/L, granular media filtration may be expanded on the east side of the facility or reinstated on the west. Expansion on the east side of the facility was selected since construction will be more difficult on the west side and will require construction of supporting infrastructure that will duplicate capacity available on the east. The issues attending reinstating the filters on the west are discussed in section 5.4.2.

During the last tertiary filtration capacity expansion in 2005, infrastructure was provided to support three additional future granular media filters (for a total of 13). These filters would provide sufficient capacity through 2049. The site plan for these filters, together with the four more that would be required by buildout, is shown in Figure 5.7.

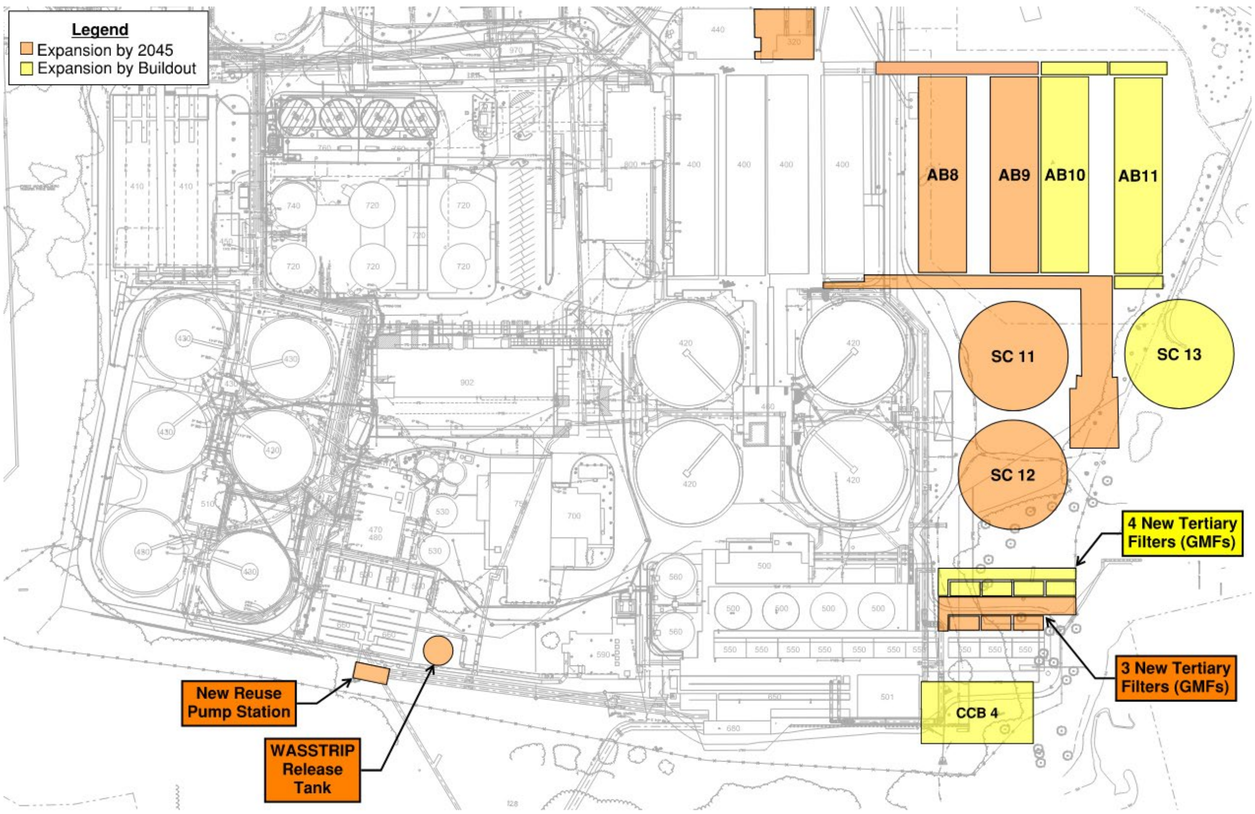


Figure 5.7 Site Plan for GMF Expansion for Scenario A

5.4 Scenarios B and C - Phosphorus Limit of 0.1 mg/L

Scenarios B and C assume that the effluent TP limit of 0.1 mg/L in the current NPDES permit is maintained. The capacity of existing tertiary treatment facilities at the Rock Creek WRRF were evaluated under this scenario to determine when expansion may be triggered (summarized in Section 5.4.1). Two tertiary treatment alternatives were developed and evaluated for this alternative: granular media filtration and membrane filtration (summarized in Sections 5.4.2 and 5.4.3, respectively). This analysis included identifying significant improvements needed to implement each alternative and developing planning-level capital and life-cycle costs.

Tertiary treatment alternatives were developed and evaluated assuming the following secondary effluent flow distribution for MMDW:

- Scenario B:
  - Claricones were base loaded up to 20 mgd.
  - Remaining east secondary effluent flows were sent to the direct filtration channel until the granular media filters capacity was reached.
  - The balance of secondary effluent flows were sent to Actiflo.
- Scenario C:
  - Claricones were base loaded up to 20 mgd.
  - Remaining east secondary effluent flows were sent to the direct filtration channel. For the membrane filtration alternative, these flows were limited by the granular media filter capacity.
  - For alternatives where west tertiary clarification is not available:
    - The balance of secondary effluent flows (west secondary effluent flows and east secondary effluent flows exceeding the granular media filter capacity) were passed through the coagulation and flocculation reactors of the Actiflo system, but polymer and sand would not be added (i.e., Actiflo would serve as a direct filtration channel). The Actiflo direct filtration effluent was then filtered through granular media or membrane filters.
  - For alternatives with west tertiary clarification:
    - West secondary effluent flows were first passed through the west coagulation and flocculation reactors and on to tertiary clarifiers 5 and 6 before being filtered (either through the west granular media filters or membrane filtration via the Actiflo system).
    - For the membrane filtration alternative, east secondary effluent flows exceeding the granular media filter capacity were combined with the west secondary effluent and passed through the coagulation and flocculation reactors of the Actiflo system, but polymer and sand would not be added (i.e., Actiflo would serve as a direct filtration channel). The Actiflo direct filtration effluent was then filtered through membrane filters.

As noted in section 5.1.2.3, Scenario B was developed as an interim operating strategy between current conditions and an eventual aluminum limit. While Scenario B would not be viable through buildout with an aluminum limit, the scenario was developed herein to provide a consistent basis for comparison.

Importantly, the secondary effluent flow distribution assumed for Scenario C deviates from historical operating practice at the Rock Creek WRRF and will result in direct filtration fractions that are significantly higher than the maximum adopted in previous capacity evaluations. Upwards of 70 percent of the flow to the granular media filters will be from direct filtration in these alternatives. Previous capacity evaluations have limited the direct filtration fraction to approximately 30 percent to meet the 0.1 mg/L TP effluent limit. The District will test the granular media filters under this higher direct filtration fraction in the summer of 2024 to determine performance and capacity. The results of this analysis may need to be revisited if these dedicated tests find that higher direct filtration fractions result in deteriorated performance or prohibitively shortened filter run times.

5.4.1 Current Capacity and Trigger for Expansion

The capacity of the existing tertiary treatment facilities under Scenarios B and C were evaluated as part of the Rock Creek Capacity Assessment.[3] The capacity of the existing granular media filters was evaluated based on the design and redundancy criteria summarized in Table 5.7. From this analysis, the existing granular media filters will have sufficient capacity through the year 2051 for Scenario B (Figure 5.8 and Figure 5.9). For Scenario C, the existing granular media filters are out of capacity currently if the secondary effluent TSS from the west secondary clarifiers is elevated (Figure 5.10 and Figure 5.11, showing the 92nd percentile west secondary effluent TSS concentration of 16.5 mg/L). Under more typical conditions (i.e., median effluent TSS concentrations from both the east and west sides of the facility), the existing granular media filters will have sufficient capacity through 2027. Importantly, the District anticipates that the earliest effluent aluminum limits may be issued are with their 2028 NPDES permit and that they would be implemented with a compliance schedule. It is anticipated that the District would be able to return to historical tertiary operation to meet the 0.1 mg/L TP limit (filtering east secondary effluent through the existing granular media filters and treating west secondary effluent with Actiflo) during this period.

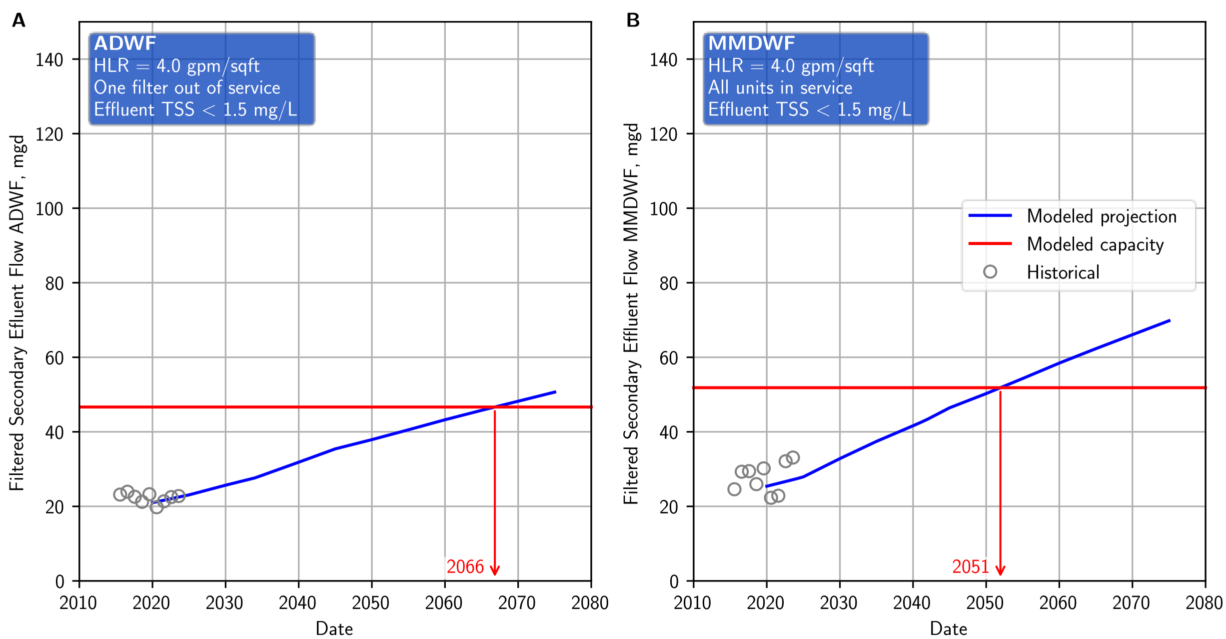


Figure 5.8 Tertiary Filtration HLR Trigger Plots for Scenario B

[3] Carollo Engineers, Inc. (February 2024). Rock Creek WRRF Capacity Assessment. Technical Memorandum 2. West Basin Facility Plan Project 7054.

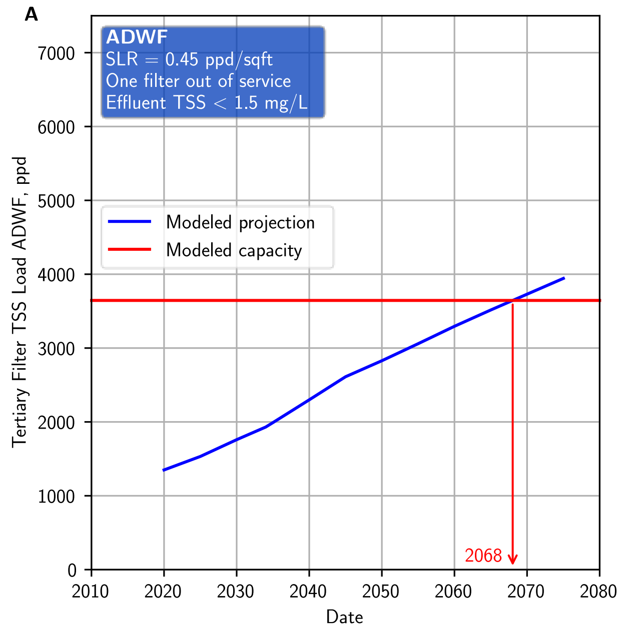


Figure 5.9 Tertiary Filtration SLR Trigger Plots for Scenario B

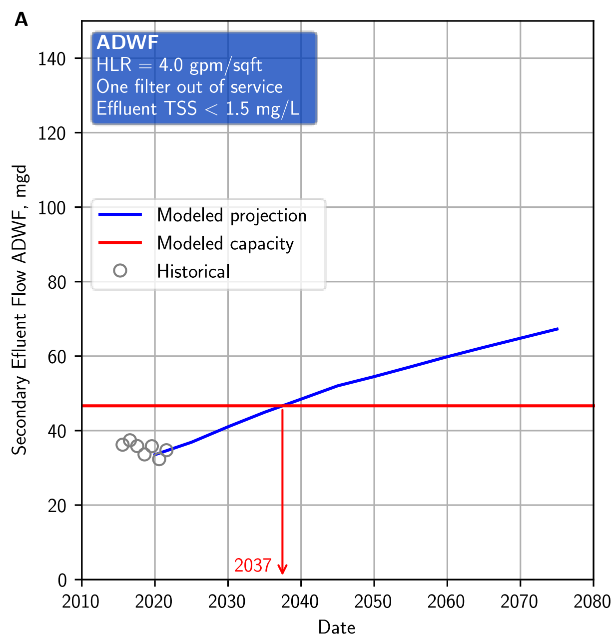


Figure 5.10 Tertiary Filtration HLR Trigger Plots for Scenario C

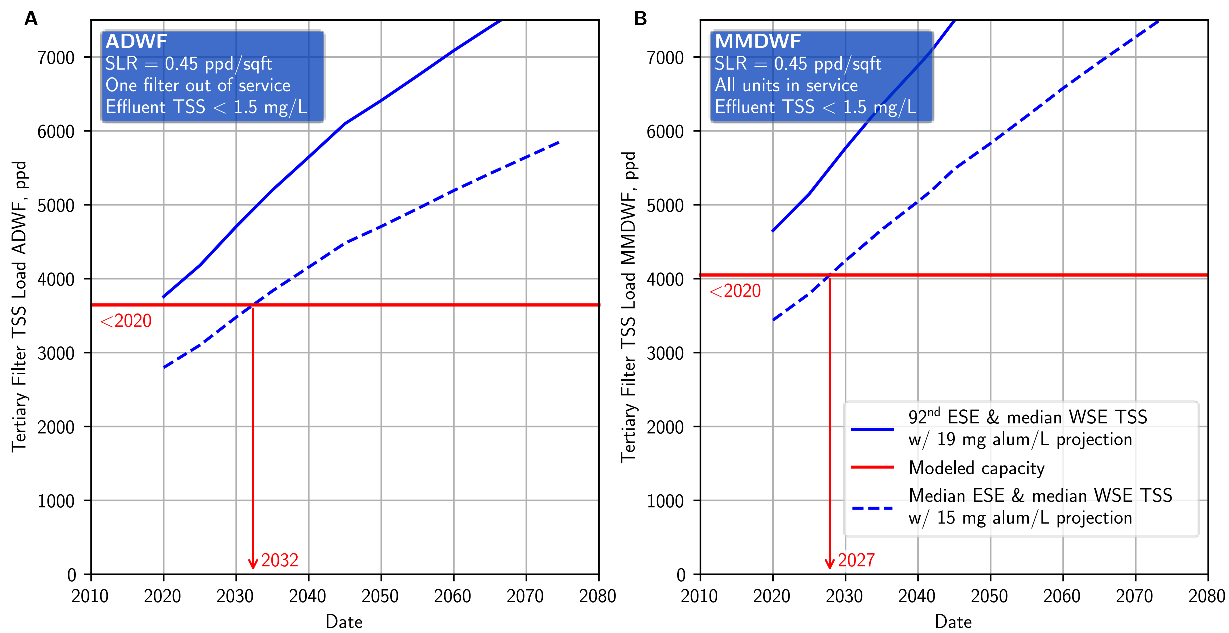


Figure 5.11 Tertiary Filtration SLR Trigger Plots for Scenario C

The upper projections assumed the median east secondary effluent TSS concentration (4.0 mg/L), the load-weighted 92nd percentile west secondary effluent TSS concentration (16.5 mg/L), and the median direct filtration alum dose (19 mg/L). The lower projections depict the median east and west secondary effluent TSS concentrations (4.0 mg/L and 8.8 mg/L, respectively) and the more recent typical direct filtration alum dose (15 mg/L).

5.4.2 Expansion with Granular Media Filters

As noted above, no additional GMFs are required for Scenario B through the planning period. For Scenario C, eight additional filters would be required to provide capacity by trigger year of 2027 to 2032. The additional granular media filters required for each scenario are given in Table 5.7.

Table 5.7 Total Additional Granular Media Filters Required by Phase

Phase	Scenario B	Scenario C
Initial Construction (by 2032)	0(1)	8(1)
Buildout	3(1)	12(1)

Notes:
(1) Total additional granular media filters are the total number of filters required in addition to those currently on site. For example, eight additional filters are required (18 total) for Phase 1 of Scenario C and 12 additional filters are required (22 total) to provide capacity in Scenario C through buildout.

The site layout for granular media filter expansion to meet Scenario C are shown in Figure 5.12. As shown, there is sufficient space for the filters required through buildout if eight granular media filters are provided on the east and the remaining four are reinstituted on the west.

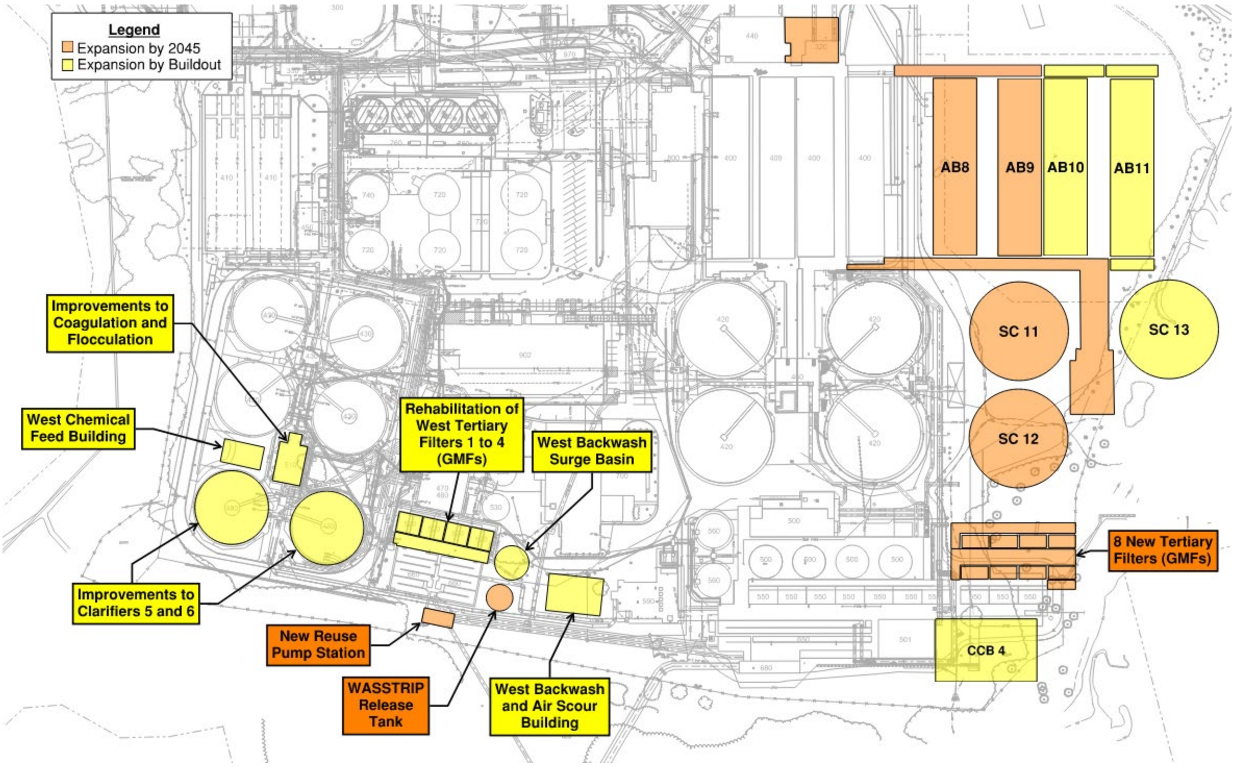


Figure 5.12 Site Plan for GMF Expansion to Meet Scenario C

The original granular media filters on the west were decommissioned in 2015 as part of the tertiary treatment expansion project. Historically, these filters underperformed relative to those on the east. The condition assessment completed as part of the 2008 facility plan identified the following deficiencies:[4]

- Ineffective backwash: District staff reported that they do not believe that the existing surface spray-wash system is working effectively. The ineffectiveness of the surface spray may be a function of the spray-wash system itself, excessive media loss, or a combination of both. Media loss reduces the spray system effectiveness because it increases the distance between the media and spray nozzles.
- Underdrain issues: Media "cratering" and media loss to the backwash equalization basins are currently observed. Both cratering and media loss are evidence that the underdrain system is failing and/or the gravel support layer is disturbed.
- Leaky valves: Leaking backwash valves are problematic, and cause excessive recycle flows. The significance of the recycle flows was discovered in calibrating the process model.
- Media characteristics: Filter L/D ratio, where L is the media depth and D is the effective media size, is used to quantify the theoretical filter particle removal efficiency. The west media has an L/D of around 700, which is lower than the recommended value of 1,000. The best approach to increasing the West Filter L/D may be to increase the media depth, as putting a finer media in this relatively shallow filter will exacerbate the current problem with frequent backwash cycling.

[4] Carollo Engineers, Inc., (April 2006). Existing Facilities and Current Operational Practices. Technical Memorandum 2.1. Rock Creek Advanced Wastewater Treatment Facility Plan.

To remedy these deficiencies, the 2008 facility plan identified the following components for rehabilitation:[5]

- Demolish the existing filter underdrain system and replace it with a new nozzle underdrain system.
- Replace the existing media to match that of the east side.
- Upgrade the existing surface wash system and/or install an air scour system.
- Upgrade the existing control system to provide automated backwashing.
- Replace and raise the launder to operate with the new media.

In addition to these mechanical problems, significant structural deficiencies in the west filters were also identified in the alternatives analysis completed prior to decommissioning.[6] Finally, the west side of the facility is seismically unstable, and the existing west filters are at risk of damage from internal spreading and differential settlement in a Cascadia Subduction Zone event.[7] The District's policy has been to prefer expanding capacity in areas less seismically unstable and to include seismic resiliency as part of new capital improvement projects. Based on this, the following improvements were considered necessary to reinstate the west filters:

- Retrofit/demolition and replacement of existing west filter structural components to match the design of the east filters.
- New backwash surge basins (previous west surge tanks were re-tasked for Ostara and WASSTRIP).
- New backwash and air scour system including new building.
- Potential hydraulic improvements to allow greater secondary effluent flow split control between east and west facilities.

Tertiary clarification on the west side will also need to be reinstated. This will require the following improvements:

- New chemical feed building.
- New mixers in the coagulation and flocculation basins.
- Updating the clarifier mechanisms in Clarifiers 5 and 6.

5.4.3 Expansion with Membrane Filters

Given that the existing granular media filters have sufficient capacity through nearly buildout for Scenario B, a membrane filtration alternative was not considered for this scenario. For Scenario C, two membrane filtration capacities were evaluated (Table 5.8). The lower capacity requirements resulted from the selective filtration of the west secondary effluent through the membranes while retaining the same granular media filter design criteria above (HLR less than or equal to 4 gpm/sf and SLR less than or equal to 0.45 ppd/sf). By directing the west secondary effluent to the membrane filters, the east granular media filters can operate with a HLR greater than 3.7 gpm/sf. The higher capacity requirements resulted from the adoption of a HLR criterion similar to current operation (3 gpm/sf) where the east filters see the solids load of both the east and west secondary effluent.

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[5] Carollo Engineers, Inc. (November 2008). Liquid Treatment Alternatives. Technical Memorandum 3.2a. Rock Creek Advanced Wastewater Treatment Facility Plan.
[6] Carollo Engineers, Inc. (January 2011). Secondary and Tertiary Transfer Alternatives Evaluation. Technical Memorandum 1.
[7] Carollo Engineers, Inc. (May 2018). Seismic Resiliency Study. Rock Creek Advanced Wastewater Treatment Facility.

Table 5.8 Membrane Filter Capacity Required by Granular Media Filter Capacity Rating and Construction Phase

Phase	Granular Media Filters Not Derated			Granular Media Filters Derated		
	Membrane Net Flow (mgd)	Membrane Flux (gfd)	Membrane Racks Required(1)	Membrane Net Flow (mgd)	Membrane Flux (gfd)	Membrane Racks Required(1)
Initial construction (by 2032)	20	20	14	27	20	17
Buildout	40	20	25	47	25	23

Notes:
(1) Membrane racks were assumed to be 45 feet long, 6 feet wide, and contain 100 Toray hollow fiber UF modules. Each module was assumed to have a membrane area of 969 sf for a total membrane area of 96,900 sf per rack. It was assumed that up to two racks would be out of service at a time for maintenance or cleaning. A membrane recovery of 92.4 percent was assumed.
gfd - gallons per square foot per day.

Membrane filtration capacity was estimated based on the MMDW flow. It was assumed that this is a reasonable approximation of the required capacity given that the effluent TP limit is a monthly median and that secondary effluent flows could be distributed between the membrane filtration and the existing granular media filters to modulate flow variation to the former. A more comprehensive evaluation of expected diurnal flow variability is recommended to refine the membrane capacity requirement and determine the capacity of the existing GMFs to accommodate more variable flows.

The site plan for the lower membrane capacity is shown in Figure 5.13. As shown, a 24,800 sf membrane facility may be located between the existing east tertiary complex and the future Secondary Clarifier 12. The membrane facility shown in Figure 5.13 is for a two-story structure with membrane racks and electrical equipment on the ground level and support systems including screening, backwash supply and equalization tanks, and clean in place systems in the basement. It was assumed that this facility would be constructed in an initial phase to provide 20 mgd of membrane capacity by 2045 but sized for an eventual 40 mgd of capacity required by buildout.

A conservative membrane flux rate of 20 gfd was assumed to develop this site plan. While this is a typical flux rate for direct membrane filtration of chemically coagulated, flocculated, and unsettled secondary effluent, the flux rate that may be sustained will depend on the membranes, chemical dosing, secondary effluent characteristics, and other site-specific conditions. Pilot testing is recommended to determine the maximum flux rate for membrane filtration of this stream if this option is pursued.

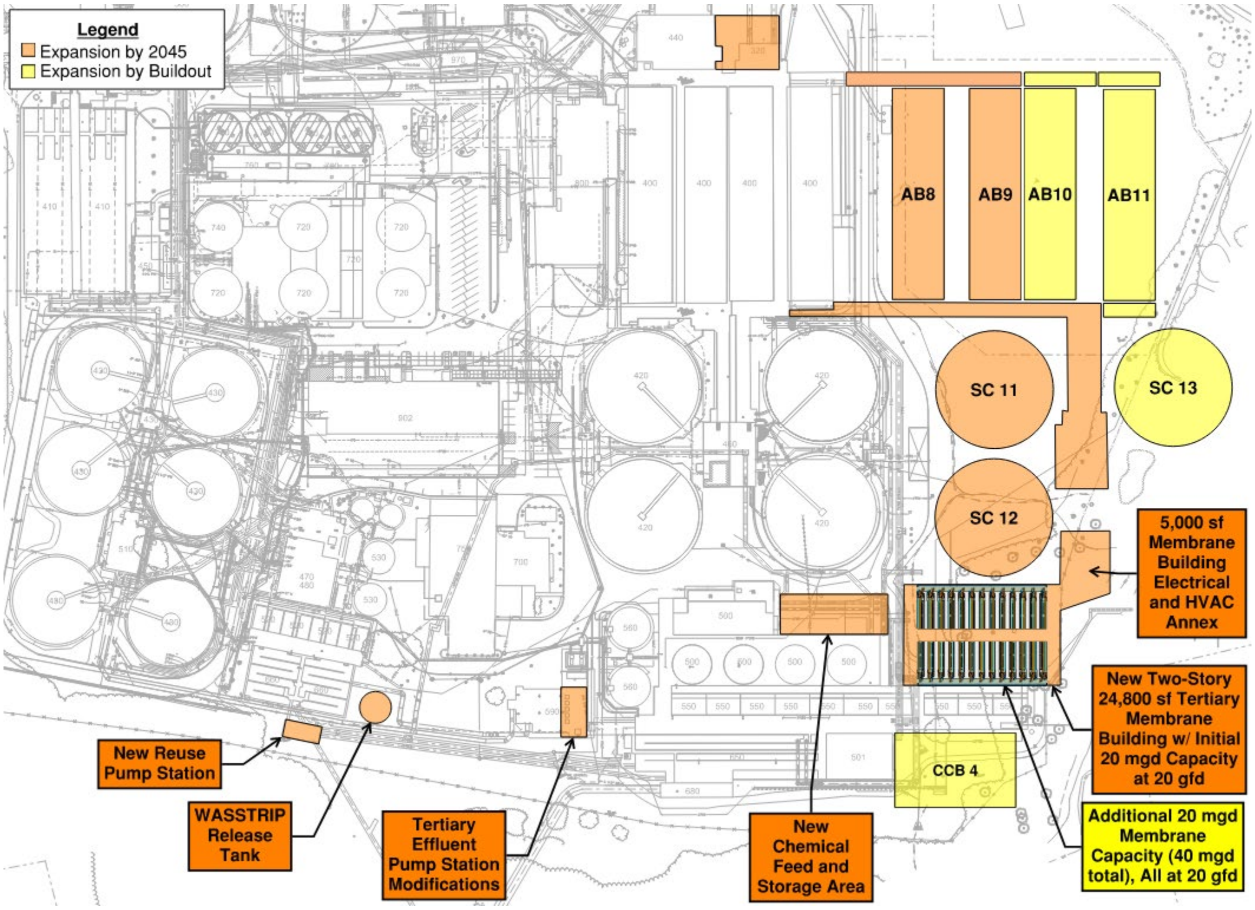

Figure 5.13 Site Plan for Tertiary Membrane Filtration for Scenario C with GMF able to Achieve 4 gpm/sf

With a derating of the granular media filter HLR capacity, 33 mgd of east secondary effluent, together with 17 mgd of west secondary effluent will need to be filtered through the membranes by buildout. Providing membrane capacity to filter this flow would require one of the following:

- Significant construction in the wetlands located on the southeast corner of the site. This would also encroach into the vegetated corridor of Witch Hazel Creek and may enter the flood plain. This was considered infeasible.
- Construction of a second membrane filtration facility on the west side of the site to split the flow. This would require demolition of Secondary Clarifiers 5 and 6 and the west coagulation/flocculation basins to make the necessary space available. This was considered undesirable given the seismic instability of the southwest corner of the site.
- Rehabilitating the west tertiary clarifiers to allow the west secondary effluent to be settled prior to filtration. It is expected that this would increase the flux that could be sustained through the membranes.

Based on this last option, Figure 5.14 shows the site plan for tertiary membrane filtration with a derating of the granular media filters. As with the lower capacity alternative, this site plan assumes the tertiary membrane facility will be sized to accommodate buildout flows but will provide capacity through the planning period following initial construction. Through the planning period, the membranes would provide up to 27 mgd of capacity for direct filtration at 20 gfd. To achieve the buildout capacity of 47 mgd, it was assumed that a flux of 25 gfd could be sustained if the west tertiary clarifiers and chemical coagulation and flocculation systems were improved.

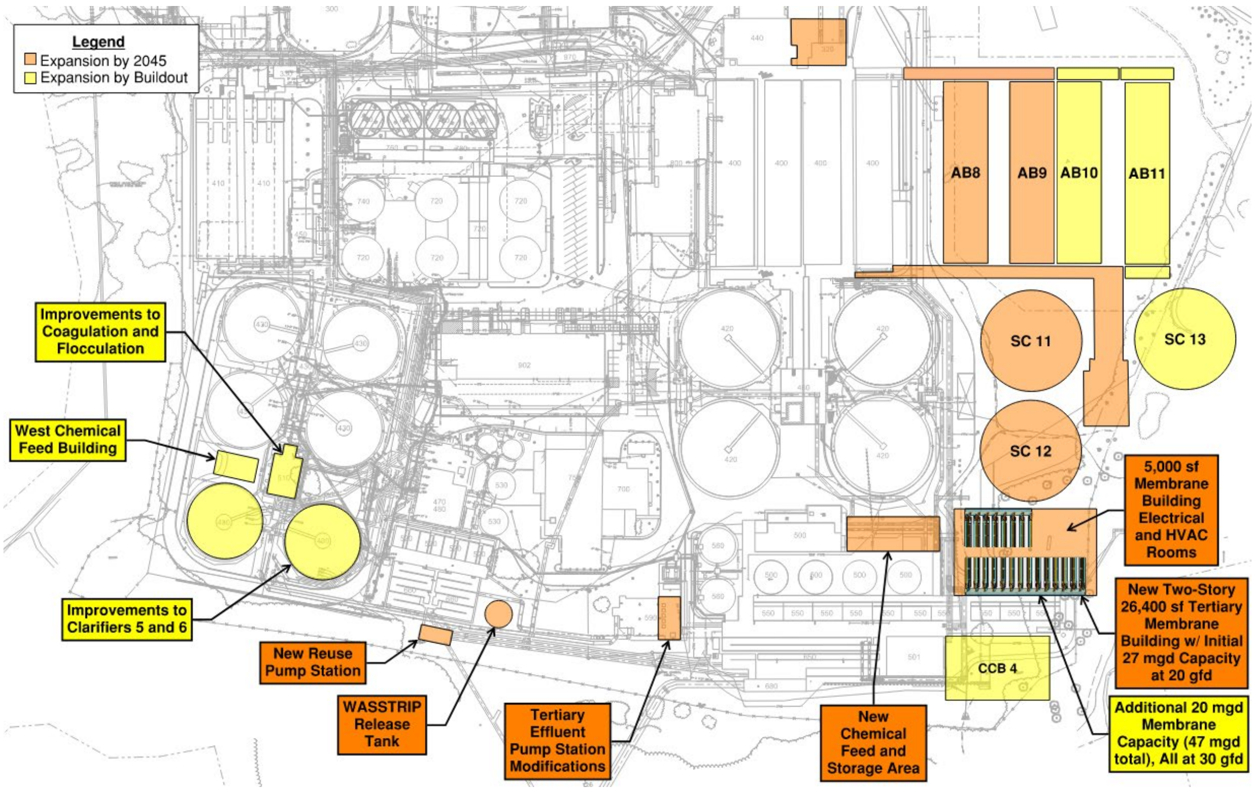

Figure 5.14 Site Plan for Tertiary Membrane Filtration for Scenario C with the GMF Derated to 3 gpm/sf.

While it is anticipated that a higher flux could be sustained with sedimentation of approximately 1/3 of the pretreated membrane influent, pilot testing is recommended to validate the 25 gfd flux assumed herein.

5.5 Alternative Comparison

A comparison of the two phosphorus limits is provided in Table 5.9 (detailed opinions of probable costs are summarized in Appendix 5B). As shown, the tertiary expansion for Scenario B results in the fewest additional granular media filters and the lowest net present worth cost; however, as noted above, it is not anticipated that this scenario would be a viable option through buildout with an effluent aluminum limit. In this Scenario, the west secondary effluent is treated through the existing Actiflo process and is not subsequently filtered. In contrast, the alternatives considered for Scenarios A and C assume that all secondary effluent is filtered.

Operating costs are the lowest in Scenario A due to the lack of tertiary alum addition required to meet an effluent TP limit of 0.5 mg/L. Scenario C requires the most improvements and would incur the highest capital and operating costs. Meeting Scenario C with granular media filters would be approximately half the cost of meeting a 0.1 mg/L TP limit with membrane filtration.

Table 5.9 Phosphorus Limit and Tertiary Technology Impact Comparison

	Scenario A	Scenario B	Scenario C	Scenario C
	TP Limit = 0.5 mg/L Al Limit = n/a GMF	TP Limit = 0.1 mg/L No Al Limit GMF	TP Limit = 0.1 mg/L Al Limit GMF	TP Limit = 0.1 mg/L Al Limit Membrane
Phase 1 (Capacity to 2045)				
Total additional GMFs(1)	3	0	8	0
Total membrane capacity (mgd)	0	0	0	20 to 27
Present Worth Project Costs	$13M	$0M	$34M	$110M to $129M
Present Worth Operating Costs	$1M	$5M	$5M	$11M to $13M
Present Worth Total Costs	$13M	$5M	$39M	$121M to $143M
Phases 1 and 2 (Capacity to Buildout)				
Total additional GMFs(1)	7	3	12	0
Total membrane capacity (mgd)	0	0	0	40 to 47
Present Worth Project Costs	$24M	$6M	$62M	$124M to $149M
Present Worth Operating Costs	$2M	$15M	$14M	$35M to $41M
Present Worth Total Costs	$27M	$21M	$76M	$159M to $190M

Notes:
(1) Total additional granular media filters are the total number of filters required in addition to those currently on site. For example, three additional filters are required (13 total) for Phase 1 of Scenario A and seven additional filters are required (17 total) to provide capacity in Scenario A through buildout.

As depicted in the site plans, none of the treatment technologies considered were disqualified by site constraints. The next three granular media filters are relatively easy to construct and would satisfy the initial expansion required in Scenario A. These three filters would also provide much of the initial capacity required if granular media filtration is pursued under an effluent aluminum limit (Scenario C). The five additional filters required initially would also fit next to the current tertiary filters with sufficient space for future east secondary expansion. The membrane facility required to meet Scenario C with membrane filtration was also found to fit in the space available.

5.6 Summary, Recommendations, and Limitations

Based on this analysis, tertiary treatment expansion at the Rock Creek WRRF will differ significantly depending on which regulatory scenario plays out (summarized in Table 5.10). While the site was found to be able to accommodate the two treatment technologies evaluated—granular media filtration and membrane filtration—the costs to achieve 0.5 mg/L TP and 0.1 mg/L TP with and without an effluent aluminum limit differ by more than $100M. Granular media filtration is the lowest cost tertiary treatment alternative and may be able to satisfy all three Scenarios; however, the success of this technology is predicated on the granular media filters performing as they have historically under conditions outside their historical operating range.

The following are recommended for potential future work based on the findings of this analysis:

- From this analysis, it was also found that the District's granular media filters will need to operate outside their historic range to filter all the secondary effluent. This analysis assumed that the filters would continue to perform as they have historically, but this will need to be verified through performance testing. Table 5.10 summarizes recommendations for future testing.

Table 5.10 Recommendations for Further Testing

	Phosphorus Limit of 0.5 mg/L	Phosphorus Limit of 0.1 mg/L
Pretreatment Requirement	N/A(1)	▪ Based on recent improved performance, is pre-treatment required upstream of granular media filters? ▪ Is pre-treatment required upstream of membrane filters? ▪ What flux can be sustained through membrane filters? ▪ Can Actiflo® performance be changed to allow for filtration of Actiflo® effluent?
Design Criteria	▪ Can the monthly HLR be pushed to 5 gpm/sf while still maintaining filter performance?	▪ Can the monthly GMF SLR be increased above 0.45 ppd/sf?

Notes:
(1) The District was able to reliably meet a 0.5 mg/L effluent TP limit without pretreatment.

- This analysis found that the comparably poor secondary effluent TSS from the west secondary clarifiers drove the SLR to the granular media filters in all scenarios. An investigation into the underlying source of the high effluent TSS from the west secondary clarifiers is recommended to determine if improvements are feasible.
- For Scenario B, it was assumed that the existing Actiflo process would be able to achieve effluent TSS and TP concentrations consistent with its design criteria (less than 7 mg/L and less than 0.07 mg/L, respectively). While the District has been able to achieve these levels previously with sufficient alum doses, additional performance testing and optimization of the Actiflo process over a range of secondary effluent characteristics is recommended.

In addition to the performance assumptions that should be verified through future testing, the previous analysis was predicated on several significant assumptions that, if changed, may alter the conclusions and recommendations. These assumptions include:

- The necessity to filter all the secondary effluent if subject to an effluent aluminum limit. Given the uncertainty surrounding the potential aluminum limit, it was assumed that filtration of all secondary effluent would be required to meet an effluent TP limit of 0.1 mg/L if an effluent aluminum limit was also enforced. The magnitude of the limit could change the conclusions of this analysis for Scenario C.
- It was assumed that alum would be the metal salt used for tertiary chemical phosphorus removal. The District prefers alum to ferric chloride (the other most commonly used metal salt for phosphorus precipitation). It was anticipated that switching to ferric chloride would likely result in an equally stringent effluent iron limit. Like with alum, the magnitude of this limit would impact potential tertiary treatment requirements. If an iron limit would allow for the discharge of a higher unfiltered secondary effluent fraction and ferric could be safely integrated into tertiary treatment at the Rock Creek WRRF, it may be more cost effective than filtering all secondary effluent to meet an aluminum limit.
- This analysis assumed that the effluent TSS mass load limit will not drive tertiary treatment technology selection or process performance. As discussed in section 5.1.2.2, several alternatives are available to maintain or increase the effluent TSS mass load that may be discharged at the Rock Creek WRRF such that granular media filters would likely remain a viable option for all three Scenarios considered. However, if these are not realized, membrane filtration may be the only viable tertiary treatment technology.
- It was assumed that effluent reuse requirements would not drive tertiary treatment technology selection or process performance. While granular media filtration can produce Class A reuse water, more specialized reuse applications (for example, direct reuse with an industrial partner) may be better suited by membrane filtration.

APPENDIX 5A

HISTORICAL DATA, DESIGN CRITERIA, AND PERFORMANCE ASSUMPTIONS

HISTORICAL DATA, DESIGN CRITERIA, AND PERFORMANCE ASSUMPTIONS

This appendix details the historical process data analysis that was completed to support the process performance assumptions adopted in the tertiary expansion evaluation.

Granular Media Filter Design Criteria

The granular media filters (GMF) are rated in terms of the hydraulic loading rate (HLR) and solids loading rate (SLR) applied to the filters. Simplified HLR and SLR calculations have been used historically to evaluate GMF capacity at the Rock Creek WRRF. These calculations include filters in backwash and are not adjusted for filter runtime. This has been a reasonable simplification to date given the District's preference to operate the filters with loadings that achieve relatively long run times (typically exceeding 24 hours).

GMF stress testing conducted in the summer of 2005 identified a maximum SLR of 0.32 ppd/sf for direct filtration to maintain an effluent TSS concentration less than 2 mg/L.[1] This value was increased to a range of 0.4 ppd/sf to 0.45 ppd/sf in the 2009 Facilities Plan Liquid Treatment Alternatives analysis based on subsequent experience at higher SLRs in the summer of 2006.[2] The upper end of this range (0.45 ppd/sf) was adopted in the 2014 Facilities Plan capacity assessment. This SLR criterion was developed with the following limitations:

- A minimum direct filtration alum dose of 40 mg alum/mg soluble reactive phosphorus.
- A maximum direct filtration fraction of 33 percent (up to 10 mgd with 20 mgd being treated by the Claricones).
- Filtering blended east secondary effluent and tertiary clarifier effluent (rather than the direct filtration and tertiary clarifier effluent streams being filtered separately).

In the GMF testing completed as part of the 2009 Facility Plan, filter effluent TSS was correlated with the applied SLR (where the solids load includes both biological solids from the secondary effluent and precipitated solids resulting from tertiary alum addition). Given the interdependence of solids and hydraulic loading on tertiary filter runtime and overall performance, SLR design criteria were used in the present capacity assessment to derate the HLR design criteria based on an overall mass balance analysis of tertiary treatment at the Rock Creek WRRF.

[1] Carollo Engineers, Inc. (November 2008). Summer Tertiary Testing. Technical Memorandum 2.4. Rock Creek Advanced Wastewater Treatment Facility Plan.
[2] Carollo Engineers, Inc. (November 2008). Liquid Treatment Alternatives. Technical Memorandum 3.2a. Rock Creek Advanced Wastewater Treatment Facility Plan.

Secondary Effluent Flow Distribution

It was assumed that primary effluent flow would be distributed between east and west secondary treatment trains to maximize flow to the west subject to hydraulic and typical flow distribution limitations. This resulted in a conservative secondary effluent solids load to tertiary treatment given the higher secondary effluent TSS concentrations adopted for the west (discussed below). West secondary effluent flow under the maximum month dry weather condition was taken as the lesser of 16.6 mgd and 37.6 percent of the total secondary effluent flow.

- The 16.6 mgd limit is based on a hydraulic limitation identified as part of the last hydraulic capacity of the facility. A new hydraulic model is being developed as part of the West Basin Facility Plan Project. Given the significant contribution of the west secondary effluent TSS to the overall tertiary solids loading rate, the present analysis may need to be revisited if a different capacity is identified.
- Historically, the average dry weather east-west flow split has been 37.6 percent (Table 5A.1).

Table 5A.1 Historical Dry Weather West Secondary Effluent Flow Percent of Total Secondary Effluent Flow (Percent)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	184	36.2	3.1	27.5	33.0	34.5	34.8	38.9	40.1	43.1	43.9
2016	184	37.1	3.3	25.1	33.8	34.5	38.4	39.4	39.5	39.6	49.1
2017	184	37.2	4.9	19.9	25.4	37.7	39.2	39.6	40.0	40.4	53.6
2018	184	38.2	4.8	20.8	30.0	38.2	38.8	39.1	47.9	48.9	49.1
2019	184	36.8	2.7	32.2	33.4	33.9	38.3	39.0	40.1	40.1	40.2
2020	184	40.1	2.1	38.1	38.5	38.9	39.2	39.5	44.2	44.4	47.1
2021	184	38.8	2.5	25.6	34.4	39.3	39.6	39.8	39.9	40.0	41.0
2022	184	39.0	1.8	31.7	36.0	38.1	39.1	40.1	41.3	41.9	43.5
2023	164	34.3	3.6	27.0	29.9	31.3	33.0	38.0	39.3	39.8	40.9
All available	1636	**37.6**	3.7	19.9	30.8	34.8	38.9	39.5	40.3	42.2	53.6

Notes:
(1) Values set in **bold** are those used in the analysis.
Min - minimum; Max - Maximum; Std. Dev - standard deviation; 5th - 5th percentile; 25th - 25th percentile; 50th - median; 75th - 75th percentile; 92nd - 92nd percentile; 95th - 95th percentile.

Effluent TSS Concentrations

Historical process data for the secondary clarifiers and tertiary unit processes were reviewed to determine appropriate values for estimating capacity.

West Secondary Effluent TSS Concentration

The arithmetic mean of the historical (2015 through 2023) dry weather west secondary effluent TSS concentration of 8.8 mg/L (Table 5A.2) was adopted as the typical west secondary effluent TSS concentration.

Table 5A.2 Historical dry weather west secondary effluent TSS concentration (Hach WIMS VarNum 648, mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	110	8.17	3.64	3.00	4.80	5.60	6.80	9.60	13.20	15.42	26.40
2016	105	16.56	5.11	8.40	9.68	12.40	15.20	20.80	24.27	26.00	31.20
2017	100	8.97	3.52	2.60	4.78	6.70	8.40	10.40	14.40	15.64	23.20
2018	103	12.04	6.20	4.40	6.40	8.40	9.60	13.70	23.55	24.59	36.70
2019	104	11.68	7.15	5.60	6.46	7.80	9.20	13.60	19.70	26.22	55.20
2020	101	9.51	4.11	4.80	5.60	6.80	8.20	10.80	15.73	17.20	28.40
2021	104	8.57	3.86	4.20	4.80	5.80	7.60	9.85	15.18	16.79	22.80
2022	103	11.58	8.15	3.60	5.40	6.40	8.60	13.10	23.70	25.38	52.00
2023	92	6.61	5.02	2.80	3.40	4.20	5.20	8.08	9.80	10.89	47.00
All available	922	10.46	6.07	2.60	4.60	6.60	**8.80**	12.20	19.60	22.00	55.20

Notes:
(1) Values set in **bold** are those used in the analysis.

The 92nd percentile of the historical (2015 through 2023) load-weighted dry weather west secondary effluent TSS concentration of 16.48 mg/L (Table 5A.3) was adopted as the maximum west secondary effluent TSS concentration. The load-weighted concentration was determined by estimating the west secondary effluent TSS load for each statistical condition and year and dividing this by the corresponding west secondary effluent flow. The value used was therefore the 92nd percentile west secondary effluent TSS load (2180 ppd) divided by the 92nd percentile west secondary effluent flow (15.85 mgd).

Table 5A.3 Historical dry weather west secondary effluent load-weighted TSS concentration (mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	N/A	8.21	32.33	3.35	4.89	6.14	7.59	9.06	11.95	12.51	19.41
2016	N/A	16.41	34.93	11.18	11.35	13.40	15.74	20.23	19.97	21.44	16.95
2017	N/A	9.07	20.90	4.58	5.94	6.76	8.47	10.03	12.47	12.65	10.40
2018	N/A	11.66	35.19	6.76	8.81	8.73	9.97	12.78	17.09	18.23	20.35
2019	N/A	11.64	81.32	6.28	7.26	8.28	9.36	12.28	17.35	21.41	39.46
2020	N/A	9.42	37.74	4.97	6.42	7.56	8.53	9.98	13.30	13.52	17.56
2021	N/A	8.47	35.50	6.29	5.66	6.31	7.45	8.82	12.53	14.61	17.71
2022	N/A	11.01	31.27	4.06	6.12	8.59	10.09	10.52	14.34	16.31	25.72
2023	N/A	6.73	27.26	2.92	3.41	4.34	6.72	7.10	8.24	9.22	28.47
All available	N/A	10.41	37.65	3.82	5.22	7.44	8.96	11.44	**16.48**	17.93	21.73

Notes:
(1) Values set in **bold** are those used in the analysis.

East Secondary Effluent TSS Concentration

The arithmetic mean of the historical (2015 through 2023) dry weather east secondary effluent TSS concentration of 3.97 mg/L (Table 5A.4) was adopted as the typical west secondary effluent TSS concentration.

Table 5A.4 Historical Dry Weather East Secondary Effluent TSS Concentration (mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	102	4.78	1.18	2.60	3.08	3.94	4.69	5.64	6.52	6.65	7.55
2016	106	4.64	1.28	2.05	3.11	3.70	4.35	5.50	6.71	6.79	7.75
2017	106	4.45	1.32	2.22	2.77	3.50	4.20	4.99	6.58	7.21	10.19
2018	94	4.94	3.69	2.00	2.87	3.61	4.20	5.30	6.54	7.48	37.36
2019	104	3.80	1.10	1.50	2.31	3.05	3.67	4.34	5.17	5.52	7.98
2020	78	4.45	1.65	1.85	2.34	3.25	4.27	4.93	7.09	8.24	8.79
2021	103	3.59	0.94	1.52	2.32	2.95	3.50	4.13	4.82	4.95	7.50
2022	101	3.59	0.87	0.50	2.38	3.04	3.59	4.05	4.76	4.98	6.19
2023	94	3.50	0.88	1.95	2.33	2.85	3.32	4.11	4.82	5.24	5.81
All available	888	4.19	1.71	0.50	2.50	3.26	**3.97**	4.79	6.22	6.69	37.36

Notes:
(1) Values set in **bold** are those used in the analysis.

The 92nd percentile of the historical (2015 through 2023) load-weighted dry weather east secondary effluent TSS concentration of 4.74 mg/L (Table 5A.5) was adopted as the maximum east secondary effluent TSS concentration. The load-weighted concentration was determined by estimating the least secondary effluent TSS load for each statistical condition and year and dividing this by the corresponding east secondary effluent flow. The value used was therefore the 92nd percentile east secondary effluent TSS load (1265 ppd) divided by the 92nd percentile east secondary effluent flow (26.4 mgd).

Table 5A.5 Historical dry weather east secondary effluent load-weighted TSS concentration (mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	N/A	4.83	18.61	3.14	3.14	4.05	4.62	5.66	6.37	6.35	5.85
2016	N/A	4.76	10.22	2.31	3.23	3.81	4.52	5.94	5.72	5.50	6.80
2017	N/A	4.47	11.19	2.55	3.01	3.63	4.56	4.80	5.77	5.84	5.56
2018	N/A	5.12	41.60	2.51	3.33	3.80	4.35	5.38	6.63	6.82	29.86
2019	N/A	3.82	11.35	1.89	2.73	3.26	3.66	4.04	4.76	5.08	5.73
2020	N/A	4.50	15.11	2.63	3.06	3.76	4.33	4.60	6.49	6.73	6.46
2021	N/A	3.64	11.69	1.80	2.39	3.02	3.52	4.09	4.37	4.90	5.03
2022	N/A	3.65	6.56	0.55	2.51	3.32	3.65	3.67	3.97	4.61	5.46
2023	N/A	3.53	9.36	2.44	2.65	3.09	3.35	3.88	4.40	4.55	4.43
All available	N/A	4.27	13.25	0.55	2.92	3.43	4.00	4.69	**5.74**	5.89	29.86

Notes:
(1) Values set in **bold** are those used in the analysis.

East and West Secondary Effluent TSS Co-occurrence

As shown in Figure 5A.1, secondary effluent TSS concentrations exceeded the historical load-weighted 92nd percentile concentrations in both east and west trains less than 3 percent of the time in the dry weather season (equivalent to approximately 5 days each season). Accordingly, assuming co-occurrence of 92nd percentile secondary effluent TSS concentrations on both the east and west side of the facility with maximum month flows was considered overly conservative. Two secondary effluent concentration conditions were evaluated which paired the arithmetic median concentration for one side of the facility was paired with and 92nd percentile on the other.

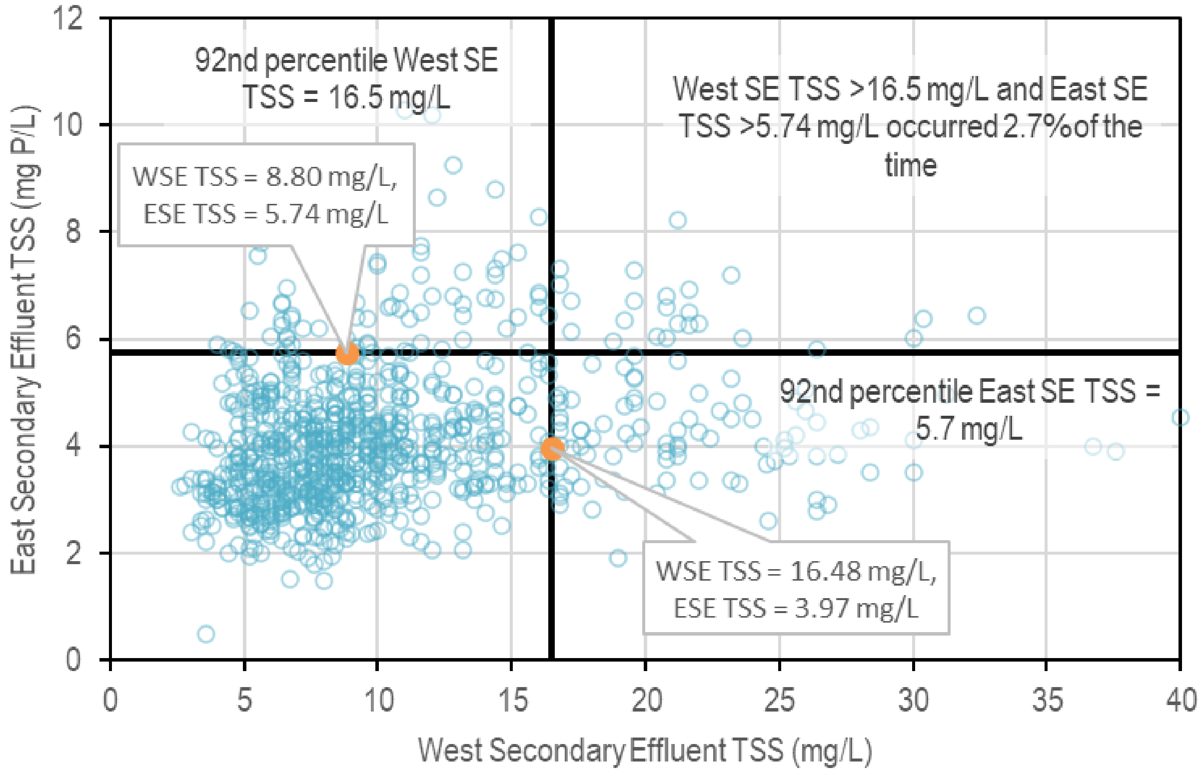

Figure 5A.1 Historical (2015 through 2023) Dry Weather East Secondary Effluent TSS vs. West Secondary Effluent TSS Concentrations

Claricone Effluent TSS Concentration

Historical dry weather east secondary effluent and Claricone effluent TSS concentrations were used to estimate TSS removal in the process. Historical Dry weather Claricone effluent TSS concentrations are summarized in Table 5A.6.

Table 5A.6 Historical Dry Weather Claricone Effluent TSS Concentration (Hach WIMS VarNum 1164, mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	104	8.45	2.16	3.60	6.00	7.20	8.00	9.65	11.20	12.28	16.80
2016	84	7.98	1.88	3.60	5.26	6.80	8.00	8.80	10.40	11.14	14.20
2017	86	7.22	1.78	4.00	5.20	6.00	6.90	8.00	9.17	9.60	14.40
2018	102	7.65	1.99	3.60	4.80	6.80	7.60	8.40	10.00	10.60	16.80
2019	88	8.07	2.52	2.80	4.80	6.80	7.60	9.20	10.40	13.04	19.20
2023	53	5.54	2.14	1.60	3.92	4.60	5.00	6.00	7.60	9.76	16.00
All available	517	7.65	2.23	1.60	4.40	6.30	7.40	8.80	10.40	11.28	19.20

A simple linear regression model was fitted to the historical data to estimate the Claricone effluent TSS concentration from the east secondary effluent TSS concentration (Figure 5A.2). While the correlation between these variables is low (as evident by the low R2 of the linear model), it was adopted since the fit with a linear model including the alum solids was not substantially better. Adopting the simple linear model provided a plausible positive correlation which resulted in more conservative solids loading to the GMFs than a constant effluent TSS concentration would have. As shown, the Claricone effluent TSS concentrations adopted for the present analysis based on the two east secondary effluent TSS concentrations evaluated (7.56 mg/L and 7.99 mg/L) fall between the historical median and 75th percentile dry weather Claricone effluent TSS concentrations (7.4 mg/L and 8.8 mg/L, respectively).

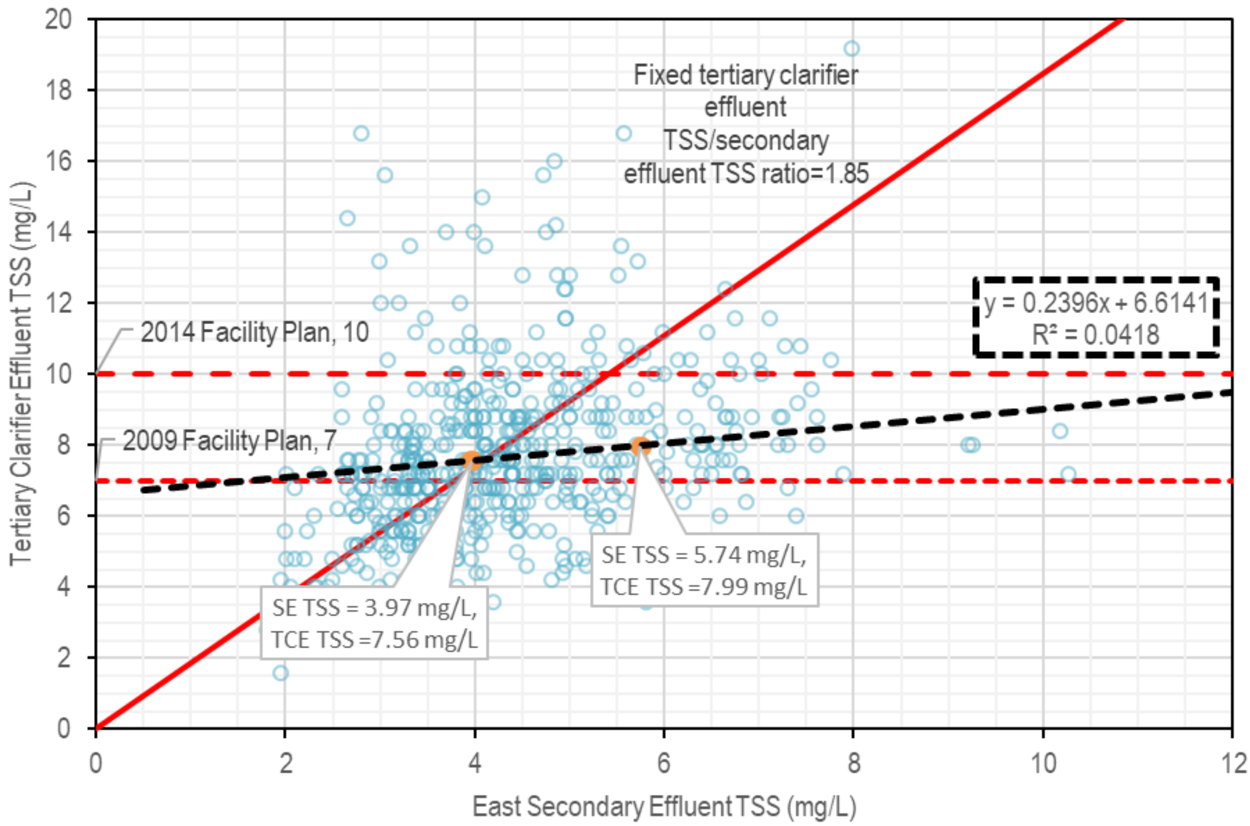

Figure 5A.2 Claricone Effluent TSS vs. East Secondary Effluent TSS

Actiflo Effluent TSS Concentration

A range of effluent TSS concentrations from Actiflo were evaluated:

- The original design criterion of 7 mg/L. The District has been able to achieve this in the past with sufficient alum and polymer doses.
- The median effluent TSS concentration during the dry weather season when Actiflo was operating (10.8 mg/L. Historical Actiflo operating configuration data were incomplete; to determine this value, effluent TSS data were filtered to only include those on days when the effluent TP concentration was less than 0.3 mg/L. These data are summarized in Table 5A.7.

Table 5A.7 Historical Dry Weather Actiflo Effluent TSS Concentration (Hach WIMS VarNum 1138, mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	64	14.05	3.80	6.40	8.12	11.60	14.00	16.00	18.70	19.88	27.00
2016	74	12.03	5.67	2.40	5.60	8.50	10.40	13.90	19.80	25.24	30.80
2017	76	11.02	3.45	3.20	5.50	9.20	11.20	12.45	14.80	15.95	26.00
2018	62	9.95	4.32	0.80	4.00	7.30	9.00	12.40	15.93	19.44	22.40
2019	54	9.21	5.13	2.00	4.66	6.10	8.50	10.30	14.65	17.36	30.80
All available	330	11.34	4.80	0.80	4.80	8.40	**10.80**	13.60	17.20	19.60	30.80

Notes:
(1) Values set in **bold** are those used in the analysis.

West Tertiary Clarifier Effluent TSS Concentration

Historical dry weather west secondary effluent and tertiary clarifier effluent TSS concentrations were used to estimate TSS removal in the process. The west tertiary clarifiers were decommissioned as part of the tertiary upgrades completed between 2012 and 2014. TSS concentration data from 2005 through 2011 were evaluated to determine historical performance (Table 5A.8).

Table 5A.8 Historical dry weather west tertiary clarifier effluent TSS concentration (Hach WIMS VarNum 332, mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2005	168	7.01	2.21	2.20	3.67	5.60	6.60	8.33	10.40	10.93	16.80
2006	176	6.42	1.81	2.20	3.80	5.35	6.20	7.40	8.80	9.20	13.60
2007	184	8.21	3.69	3.20	4.40	5.75	7.50	9.30	13.35	14.80	29.20
2008	181	8.15	2.79	3.60	5.60	6.80	7.60	8.80	10.40	11.60	27.60
2009	182	7.89	2.09	3.60	4.80	6.80	7.60	9.10	10.40	11.58	20.00
2010	184	8.24	2.55	3.40	4.86	6.40	7.70	9.60	11.60	13.14	18.40
2011	174	10.82	6.27	2.50	5.60	7.20	8.40	12.00	20.00	24.28	42.80
All	1249	8.11	3.59	2.20	4.40	6.00	7.40	9.20	11.80	13.84	42.80

A simple linear regression model was fitted to the historical data to estimate the effluent TSS concentration from the west secondary effluent TSS concentration (Figure 5A.3). The west tertiary clarifier effluent TSS concentration was generally lower than the west secondary effluent TSS concentration (the gray diagonal line depicts parity between the two). While the correlation between these variables is low (as evident by the low R2 of the linear model), it was adopted since the fit with a linear model including the alum solids was not substantially better. Adopting the simple linear model provided a plausible positive correlation which resulted in more conservative solids loading to the GMFs than a constant effluent TSS concentration would have. As shown, the west tertiary clarifier effluent TSS concentrations adopted for the present analysis based on the two west secondary effluent TSS concentrations evaluated (7.92 mg/L and 8.29 mg/L) fall between the historical median and 75th percentile dry weather west tertiary clarifier effluent TSS concentrations (7.4 mg/L and 9.2 mg/L, respectively). Importantly, the median and 92nd percentile west secondary effluent TSS concentrations during this period are generally comparable with the effluent TSS concentrations seen in the last seven years (cf. Table 5A.2 and Table 5A.9).

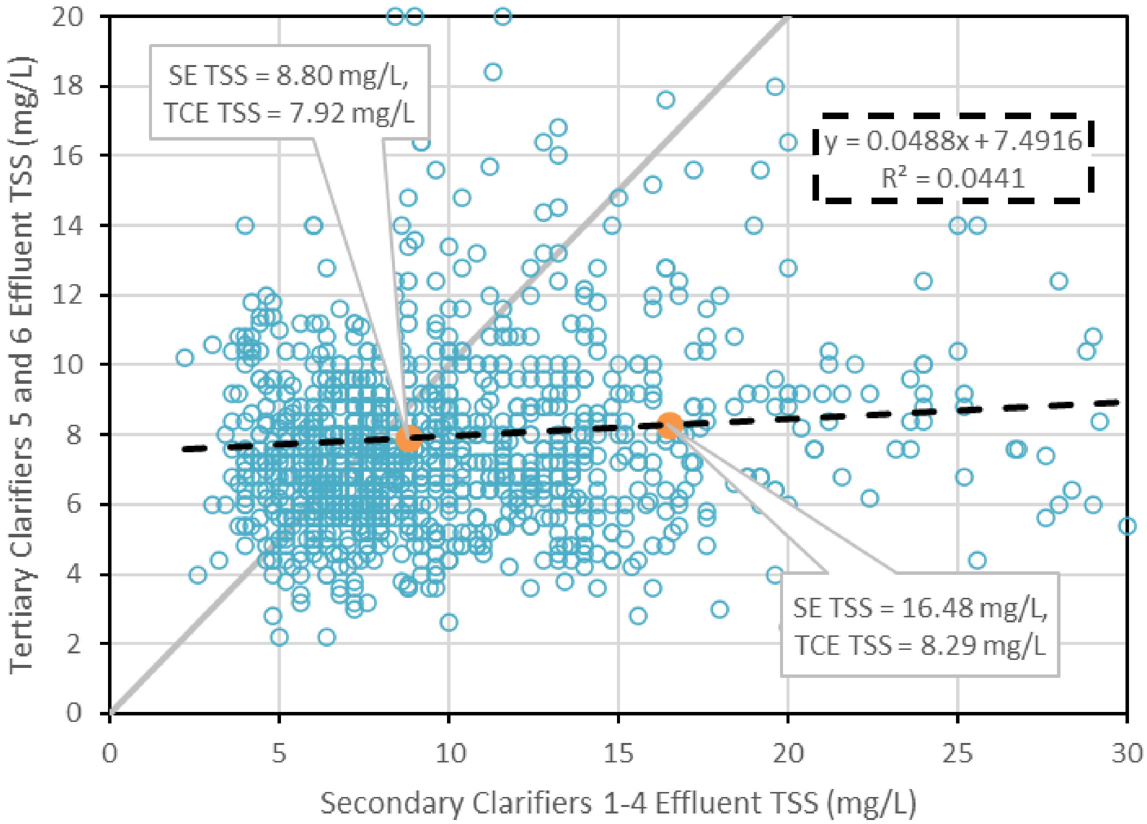

Figure 5A.3 West Tertiary Clarifier Effluent TSS vs. West Secondary Effluent TSS

Table 5A.9 Historical dry weather west secondary clarifier effluent TSS concentration (Hach WIMS VarNum 198, mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2005	182	8.85	12.38	2.20	4.00	5.00	6.20	7.80	15.98	19.58	151.00
2006	182	8.65	3.82	3.60	5.21	6.80	7.80	9.20	13.20	14.00	39.60
2007	184	11.07	4.89	4.60	6.00	8.00	10.00	13.20	16.40	17.57	44.80
2008	184	12.08	5.69	3.60	6.60	8.80	11.10	13.60	17.50	20.00	48.00
2009	183	9.97	5.74	3.20	5.20	6.80	8.40	11.85	15.93	17.56	58.00
2010	184	18.60	27.93	3.60	4.00	6.40	9.80	18.30	46.00	64.25	280.00
2011	184	19.40	22.31	3.60	4.63	6.70	10.00	20.30	51.70	74.25	136.00
All	1283	12.67	15.37	2.20	4.60	6.80	8.80	13.20	21.60	33.00	280.00

Granular Media Filter Effluent TSS Concentration

Historical GMF effluent TSS concentration data were used to estimate the performance of the existing and future GMFs (summarized in Table 5A.10). Data from 2023 were excluded since tertiary operation during this year was not reflective of either effluent TP limit.

Table 5A.10 Historical Dry Weather East GMF Effluent TSS Concentration (Hach WIMS VarNum 1354, mg/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	104	1.61	0.95	0.50	0.70	1.10	1.40	1.83	2.90	3.09	7.20
2016	105	2.19	1.31	0.80	1.00	1.50	1.80	2.50	4.00	4.40	9.70
2017	101	1.93	1.72	0.50	0.60	1.20	1.70	2.20	2.80	3.00	15.50
2018	105	1.56	1.08	0.50	0.60	0.80	1.30	1.90	2.93	3.28	8.60
2019	105	1.32	1.05	0.50	0.50	0.80	1.20	1.50	2.03	2.20	10.30
2020	104	0.96	0.42	0.50	0.50	0.60	0.90	1.13	1.44	1.60	3.40
2021	102	0.67	0.33	0.50	0.50	0.50	0.50	0.80	0.96	1.20	2.90
2022	104	0.68	0.35	0.50	0.50	0.50	0.50	0.73	1.00	1.19	3.20
2023	91	0.59	0.19	0.50	0.50	0.50	0.50	0.60	0.85	1.00	1.60
2015–2019	520	1.72	1.28	0.50	0.60	1.00	**1.50**	2.00	**2.98**	3.41	15.50
2020–2022	310	0.77	0.39	0.50	0.50	0.50	**0.60**	0.90	**1.30**	1.46	3.40
All available	921	1.29	1.11	0.50	0.50	0.60	1.00	1.60	2.40	2.90	15.50

Notes:
(1) Values set in **bold** are those used in the analysis.

Tertiary Alum Doses

Direct Filtration Alum Dose

The median historical east direct filtration alum dose of 19 mg/L was assumed to be sufficient to reach a median effluent TP concentration of 0.1 mg/L. Historical dry weather direct filtration alum doses are summarized in Table 5A.11.

Table 5A.11 Historical Dry Weather East Direct Filtration Alum Dose (Hach WIMS VarNum 1369, mg alum/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	186	19.9	4.5	1.0	13.0	19.0	19.0	19.8	25.0	26.0	32.0
2016	147	21.8	7.5	9.0	18.3	19.0	19.0	19.0	37.0	43.7	44.0
2017	152	15.5	4.8	1.0	12.0	13.0	13.0	17.0	25.0	25.0	27.0
2018	153	18.9	2.5	5.0	18.0	18.0	19.0	19.0	19.0	19.0	36.0
2019	132	17.1	4.6	1.0	12.0	13.0	19.0	19.0	24.0	24.0	30.0
2020	4	8.3	6.2	3.0	3.3	4.5	6.5	10.3	14.8	15.7	17.0
All available	774	18.6	5.5	1.0	12.0	17.0	**19.0**	19.0	25.0	26.0	44.0

Notes:
(1) Values set in **bold** are those used in the analysis.

Claricone alum dose

The median historical Claricone alum dose of 52 mg/L was assumed to be sufficient to reach a median effluent TP concentration of 0.1 mg/L. Historical dry weather Claricone alum doses are summarized Table 5A.12.

Table 5A.12 Historical Dry Weather Claricone Alum Dose (Hach WIMS VarNum 1369, mg alum/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2015	189	48.0	10.0	1.0	32.4	41.0	47.0	57.0	62.3	64.0	65.0
2016	158	53.2	14.3	3.0	26.9	48.0	60.0	61.0	67.0	67.0	68.0
2017	161	38.5	14.0	10.0	14.0	28.0	41.0	48.0	54.0	57.0	67.0
2018	157	50.8	14.3	3.0	14.8	48.0	54.0	59.0	61.0	63.4	72.0
2019	169	49.3	14.9	1.0	11.0	46.0	53.0	58.0	60.0	64.0	66.0
All available	838	47.7	14.7	1.0	14.0	41.0	**52.0**	59.0	63.0	65.0	72.0

Notes:
(1) Values set in **bold** are those used in the analysis.

Actiflo Alum dose

The median historical Actiflo alum dose of 63 mg/L was assumed to be sufficient to reach a median effluent TP concentration of 0.1 mg/L. Historical dry weather Actiflo alum doses are summarized in Table 5A.13.

Table 5A.13 Historical Dry Weather Actiflo Alum Dose (Hach WIMS VarNum 6911, mg alum/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2019	142	62.3	10.6	1.0	42.0	60.0	63.0	66.0	72.0	73.0	102.0
2020	14	64.4	6.6	54.0	54.7	61.3	65.5	67.5	71.8	73.8	77.0
All available	157	62.1	11.4	1.0	41.8	60.0	**63.0**	66.0	72.0	73.0	102.0

Notes:
(1) Values set in **bold** are those used in the analysis.

The Actiflo design criteria[3] specified an alum dose range of 50 and 100 mg/L.

West Tertiary Clarifier Alum Dose

The median historical west tertiary clarifier alum dose of 27.6 mg/L was assumed to be sufficient to reach a median TP concentration of 0.1 mg/L. The west tertiary clarifiers were decommissioned as part of the tertiary upgrades completed between 2012 and 2014. Alum dose data from 2005 through 2011 were evaluated to determine historical performance (Table 5A.14).

Table 5A.14 Historical Dry Weather West Tertiary Clarifier Alum Dose (Hach WIMS VarNum 607, mg alum/L)

Year	Count	Mean	Std. Dev.	Min	5th	25th	50th	75th	92nd	95th	Max
2005	171	24.6	15.3	1.4	7.6	15.2	21.9	30.7	39.2	42.0	121.6
2006	177	25.4	12.9	5.2	12.4	16.0	20.8	29.6	48.1	53.7	61.8
2007	184	22.6	7.3	1.2	10.1	19.1	20.4	27.7	32.2	36.4	50.6
2008	184	24.6	10.6	9.7	14.3	18.4	20.3	28.1	43.0	46.0	64.7
2009	183	30.5	10.2	18.4	19.3	22.0	27.4	37.8	47.1	48.6	57.0
2010	181	38.5	10.2	1.7	19.5	31.4	38.6	47.5	51.5	51.9	52.3
2011	176	60.8	11.4	16.9	45.3	52.5	59.5	66.4	72.5	73.2	127.0
All	1256	32.4	16.9	1.2	12.9	19.5	**27.6**	43.5	59.1	65.5	127.0

Notes:
(1) Values set in **bold** are those used in the analysis.

[3] Carollo Engineers, Inc. (April 2014). Rock Creek Advanced Wastewater Treatment Facility Tertiary Treatment Project Contract/Specifications. Volume 2. Division 11. Project No. 6493.

APPENDIX 5B DETAILED OPINION OF PROBABLE COSTS

DETAILED OPINION OF PROBABLE COSTS

All cost estimates are Class 5, order-of-magnitude estimates as defined by the American Association of Cost Engineers (AACE). A Class 5 estimate is one that is made without detailed engineering data and uses techniques such as cost curves and scaling factors applied to similar projects. The overall expected level of accuracy of the cost estimates presented is -20 to -50 percent on the low end and + 30 to +100 percent on the high end. This means that bids can be expected to fall within a range of 50 percent under to 100 percent over the estimate for each project. This is consistent with the guidelines established by the AACE for planning level studies.

Cost estimates were developed with the following approach:

- January 2024 was adopted as the current cost basis.
- Unit pricing developed prior to the current cost basis were escalated based on the Engineering News-Record Construction Cost Index (ENR CCI). The ENR CCI for the current cost basis was 13,515.
- Alternatives were compared on a net present cost basis. For each alternative, capital and operating costs were escalated to the year of occurrence to develop the cost series. These costs were then discounted to the current cost basis for comparison.
- Two analysis periods were used to develop net present costs from the cost series of each alternative:
  - Planning period (costs from 2024 through 2045).
  - Buildout period (costs from 2024 through 2075).
- For each alternative, tertiary treatment capacity was expanded in two phases (summarized in Table 5B.1):
  - For the first phase (initial) expansion, projects were developed to reach the end of the planning period (2045). Capacity in the initial phase was provided to reach approximately 2049 for all alternatives. This was the year at which the capacity of three additional granular media filters would be reached for Scenario A.
  - For the second phase expansion, capacity was developed to reach buildout (2075).

Table 5B.1 Project Commissioning Year by Expansion Phase

Project Timing	Scenario A TP limit = 0.5 mg/L Al limit = n/a GMF	Scenario B TP limit = 0.1 mg/L No Al limit GMF	Scenario C TP limit = 0.1 mg/L Al limit GMF	Scenario C TP limit = 0.1 mg/L Al limit Membrane
Phase 1 (Capacity through the planning period)	2032(1)	n/a(2)	2032(1)	2032(1)
Phase 2 (Capacity to buildout) Year capacity reached with Phase 1 Improvements/Existing(2)	2049	2061	2050	2049
Phase 3 (Capacity beyond buildout) Year capacity reached with Phase 2 improvements	2075	2075	>2075(3)	2075

Notes:
(1) Phase 1 completed by 2032 based on earliest anticipated permit compliance schedule.
(2) Existing tertiary treatment capacity sufficient through the planning period for Scenario B.
(3) Estimated SLR is 92% of the 0.45 ppd/sf capacity at 2075.

- Capital improvement projects would be commissioned in the corresponding year given in Table 5B.1.
  - Construction of each project would take four years.
  - Project costs were escalated to the midpoint of construction (two years before the commissioning year).
- Costs common to all alternatives were excluded from the analysis.
- Capital repair and replacement costs were annualized relative to the design life of the component.
- Assumptions adopted to develop costs for all alternatives are summarized in Table 5B.2.

Table 5B.2 Assumptions Adopted for All Alternatives to Develop Probable Costs

Parameter	Value	Notes/Reference
Capital Improvement Unit Costs		
Pile Direct Cost ($/sf)	44.60(1,2)	Provided by the District, based on Secondary Clarifier 3 at the Forest Grove WRRF
Dry Weather Season Duration (days)	183	NPDES permit, May 1 through October 31
Operating Unit Costs		
Operations And Maintenance Labor ($/hr)	69.61(1,3)	East Basin Master Plan, Table 1.1, p. 1-3
Power ($/kWh)	0.07(1,3)	East Basin Master Plan, Table 1.1, p. 1-3
Pumping Efficiency	65%	
Blower Efficiency	70%	
Polymer		
Polymer Cost ($/lb [neat])	1.07(1,3)	East Basin Master Plan, Table 1.1, p. 1-3
West Tertiary Clarifier Polymer Dose	1 mg/L	
Claricone Polymer Dose	1 mg/L	
Actiflo Polymer Dose	1 mg/L	
Alum		
Alum Cost ($/dry ton)	420.00(1,3)	East Basin Master Plan, Table 1.1, p. 1-3
Alum Solids Precipitation (lb/lb alum)	0.338	$Al2(SO4)3{\cdot}14H2O \rightarrow Al(OH)3{\cdot}1.25H2O$
Actiflo Microsand		
Microsand Cost ($/dry ton)	288.29(1,4)	Treguer et. al (2012)(5)
Loss Rate (lb/mgd)	16.69(1,4)	Treguer et. al (2012)(5)
Granular Media Filters		
Filter Run Time (hours)	36	
Air Scour Duration (minutes)	4	
Routine Inspection Per Filter (min/day)	5	76 hr/yr
Anthracite ($/dry ton)	1400(1)	
Loss Rate (in/yr)	1	
Solids Disposal		
Local (July–October) ($/wet ton)	16.55(1,3)	East Basin Master Plan, Table 1.1, p. 1-3
Long Distance (November–June) ($/wet ton)	20.77(1,3)	East Basin Master Plan, Table 1.1, p. 1-3
Dewatered TS concentration	20%	The District, 2023 centrifuge project
Average dry weather solids disposal ($/dry ton)	3.59(1)	Calculated from dry weather duration and TS

Parameter	Value	Notes/Reference
Capital Improvement Markups		
Contingency	30%	West Basin Alternatives CAMP
Contractor General Conditions	10%	West Basin Alternatives CAMP
Contractor Overhead and Profit	12%	West Basin Alternatives CAMP
Engineering, Legal, and Administration	20%	West Basin Alternatives CAMP
Project cost to direct cost ratio ($/$)	1.922	Calculated from markups
Component Design Life		
Treatment or pumping structures	50 years	East Basin Master Plan, p. 1-4
Treatment or pumping mechanical and electrical	20 years	East Basin Master Plan, p. 1-4
Project construction duration	4 years	Used to develop costs series to midpoint of construction.
Price escalation rate (annual inflation rate)	2% per year	East Basin Master Plan, Table 1.1, p. 1-3;
Discount rate (interest rate used to determine present value of future cash)	4% per year	East Basin Master Plan, Table 1.1, p. 1-3

Notes:
(1) Expressed on current cost basis (January 2024).
(2) May 2020, ENR CCI of 11418.
(3) June 2020, ENR CCI of 11436.
(4) October 2012; ENR CCI of 9376.
(5) Treguer, R.; Blari, B.; Klaper; R.; Royer, S.; and Magruder, C. (2012) Evaluation of Actiflo® Carb Process for the Combined Removal of Trace Organic Compounds and Phosphorus during Wastewater Tertiary Treatment. Proceedings of the Water Environment Federation. WEFTEC 2012. pp. 7176–7196.

Detailed Opinion of Probable Costs for Scenario A

Table 5B.3 Detailed Opinion of Probable Direct Capital Cost for Phase 1 Granular Media Filter Expansion

Item	Unit Cost	Quantity	Total Cost
Granular Media Filters (3 at 900 sf)			
Existing Filter Demolition	$-	1	$-
Construction Difficulty Allowance	$-	1	$-
Filter Structural Cost Total	$3,544,850	1	$3,544,850
Filter Mechanical—Valves, Actuators, Flow Meters	$361,500	1	$361,500
Filter Mechanical—Piping	$800,700	1	$800,700
Filter I&C	$750,000	1	$750,000
Backwash Supply Mechanical—Valves, Actuators, Flow Meters	$126,000	1	$126,000
Backwash Supply Mechanical—Pumps/Blowers	$-	1	$-
Backwash Supply Mechanical—Piping	$-	1	$-
Air Scour Mechanical—Piping	$119,000	1	$119,000
Air Scour Mechanical—Pumps/Blowers	$-	1	$-
Backwash Surge Basin Structural	$-	1	$-
Backwash Recycle Mechanical—Piping	$8,000	1	$8,000
Backwash Recycle Mechanical—Pumps/Blowers	$-	1	$-
Backwash Recycle Mechanical—Valves, Actuators, Flow Meters	$-	1	$-
Structural Civil Work	$420,090	1	$420,090
Piles	$44.60/sf	7,638 sf	$340,656
Yard piping	$919,521	1	$919,521
Total Direct Cost			**$7,390,317**
Contingency (30 %)			$2,217,095
Subtotal			$9,607,412
General Conditions (10 %)			$960,741
Subtotal			$10,568,154
Overhead and Profit (12 %)			$1,268,178
Total Construction Cost			**$11,836,332**
Engineering, Legal, and Administration (20 %)			$2,367,266
Total Project Cost			**$14,203,599**

Table 5B.4 Detailed Opinion of Probable Direct Capital Cost for Phase 2 Granular Media Filter Expansion

Item	Unit Cost	Quantity	Total Cost
Granular Media Filters (4 at 900 sf)			
Existing Filter Demolition	$-	1	$-
Construction Difficulty Allowance	$1,000,000	1	$1,000,000
Filter Structural Cost Total	$3,909,259	1	$3,909,259
Filter Mechanical—Valves, Actuators, Flow Meters	$482,000	1	$482,000
Filter Mechanical—Piping	$1,064,100	1	$1,064,100
Filter I&C	$1,000,000	1	$1,000,000
Backwash Supply Mechanical—Valves, Actuators, Flow Meters	$126,000	1	$126,000
Backwash Supply Mechanical—Pumps/Blowers	$-	1	$-
Backwash Supply Mechanical—Piping	$-	1	$-
Air Scour Mechanical—Piping	$158,200	1	$158,200
Air Scour Mechanical—Pumps/Blowers	$-	1	$-
Backwash Surge Basin Structural	$-	1	$-
Backwash Recycle Mechanical—Piping	$8,000	1	$8,000
Backwash Recycle Mechanical—Pumps/Blowers	$-	1	$-
Backwash Recycle Mechanical—Valves, Actuators, Flow Meters	$-	1	$-
Structural Civil Work	$391,600	1	$391,600
Piles	$44.60/sf	7,120 sf	$317,553
Yard piping	$1,220,874	1	$1,220,874
Total Direct Cost			**$9,677,587**
Contingency (30 %)			$2,903,276
Subtotal			$12,580,862
General Conditions (10 %)			$1,258,086
Subtotal			$13,838,949
Overhead and Profit (12 %)			$1,660,674
Total Construction Cost			**$15,499,623**
Engineering, Legal, and Administration (20 %)			$3,099,925
Total Project Cost			**$18,599,547**

Table 5B.5 Scenario A Cost Series, Net Present Cost

Year	CAPEX	Filter Routine Inspection	Filter Backwash Supply Pumping	Filter Backwash Waste Pumping	Filter Air Scouring	Filter Media Loss	Filter Valve, Actuator, Flow Meter Replacement
2024	$-	$-	$-	$-	$-	$-	$-
2025	$-	$-	$-	$-	$-	$-	$-
2026	$-	$-	$-	$-	$-	$-	$-
2027	$-	$-	$-	$-	$-	$-	$-
2028	$-	$-	$-	$-	$-	$-	$-
2029	$-	$-	$-	$-	$-	$-	$-
2030	$12,612,389	$-	$-	$-	$-	$-	$-
2031	$-	$-	$-	$-	$-	$-	$-
2032	$-	$5,421	$7,569	$6,307	$1,253	$6,721	$13,869
2033	$-	$5,315	$7,544	$6,287	$1,229	$6,589	$13,597
2034	$-	$5,211	$7,517	$6,264	$1,205	$6,460	$13,331
2035	$-	$5,109	$7,488	$6,240	$1,181	$6,334	$13,069
2036	$-	$5,008	$7,445	$6,204	$1,158	$6,209	$12,813
2037	$-	$4,910	$7,400	$6,167	$1,135	$6,088	$12,562
2038	$-	$4,814	$7,354	$6,128	$1,113	$5,968	$12,315
2039	$-	$4,720	$7,306	$6,089	$1,091	$5,851	$12,074
2040	$-	$4,627	$7,257	$6,048	$1,070	$5,737	$11,837
2041	$-	$4,536	$7,209	$6,008	$1,049	$5,624	$11,605
2042	$-	$4,447	$7,160	$5,966	$1,028	$5,514	$11,378
2043	$-	$4,360	$7,109	$5,924	$1,008	$5,406	$11,154
2044	$-	$4,275	$7,057	$5,881	$988	$5,300	$10,936
2045	$-	$4,191	$7,004	$5,837	$969	$5,196	$10,721
2046	$-	$4,109	$6,922	$5,768	$950	$5,094	$10,511
2047	$11,795,013	$4,028	$6,840	$5,700	$931	$4,994	$10,305
2048	$-	$3,949	$6,759	$5,632	$913	$4,896	$10,103
2049	$-	$9,034	$13,355	$11,129	$2,089	$11,200	$22,258

Year	CAPEX	Filter Routine Inspection	Filter Backwash Supply Pumping	Filter Backwash Waste Pumping	Filter Air Scouring	Filter Media Loss	Filter Valve, Actuator, Flow Meter Replacement
2050	$-	$8,857	$13,193	$10,994	$2,048	$10,981	$21,822
2051	$-	$8,683	$13,040	$10,867	$2,008	$10,765	$21,394
2052	$-	$8,513	$12,888	$10,740	$1,968	$10,554	$20,974
2053	$-	$8,346	$12,736	$10,613	$1,930	$10,347	$20,563
2054	$-	$8,182	$12,585	$10,487	$1,892	$10,144	$20,160
2055	$-	$8,022	$12,434	$10,362	$1,855	$9,945	$19,764
2056	$-	$7,865	$12,287	$10,239	$1,818	$9,750	$19,377
2057	$-	$7,710	$12,140	$10,117	$1,783	$9,559	$18,997
2058	$-	$7,559	$11,994	$9,995	$1,748	$9,372	$18,625
2059	$-	$7,411	$11,848	$9,874	$1,713	$9,188	$18,259
2060	$-	$7,266	$11,704	$9,753	$1,680	$9,008	$17,901
2061	$-	$7,123	$11,553	$9,628	$1,647	$8,831	$17,550
2062	$-	$6,984	$11,404	$9,503	$1,615	$8,658	$17,206
2063	$-	$6,847	$11,256	$9,380	$1,583	$8,488	$16,869
2064	$-	$6,712	$11,109	$9,257	$1,552	$8,322	$16,538
2065	$-	$6,581	$10,963	$9,136	$1,522	$8,159	$16,214
2066	$-	$6,452	$10,815	$9,013	$1,492	$7,999	$15,896
2067	$-	$6,325	$10,669	$8,891	$1,462	$7,842	$15,584
2068	$-	$6,201	$10,524	$8,770	$1,434	$7,688	$15,279
2069	$-	$6,080	$10,381	$8,651	$1,406	$7,537	$14,979
2070	$-	$5,960	$10,238	$8,532	$1,378	$7,390	$14,685
2071	$-	$5,844	$10,098	$8,415	$1,351	$7,245	$14,397
2072	$-	$5,729	$9,958	$8,298	$1,325	$7,103	$14,115
2073	$-	$5,617	$9,820	$8,183	$1,299	$6,963	$13,838
2074	$-	$5,506	$9,683	$8,069	$1,273	$6,827	$13,567
2075	$-	$5,399	$9,547	$7,956	$1,248	$6,693	$13,301

Table 5B.6 Scenario A Total Net Present Cost Summary

Cost	Net Present Cost
CAPEX	
CAPEX Subtotal	$24,407,402
OPEX	
Filter Routine Inspection	$269,837
Filter Backwash Supply Pumping	$431,162
Filter Backwash Waste Pumping	$359,302
Filter Air Scouring	$62,388
Filter Media Loss	$334,539
Filter Valve, Actuator, Flow Meter Replacement	$672,294
OPEX Subtotal	$2,129,522
Total (CAPEX + OPEX)	$26,536,923

Detailed Opinion of Probable Costs for Scenario B

Table 5B.7 Detailed Opinion of Probable Direct Capital Cost for Phase 2 Granular Media Filter Expansion

Item	Unit Cost	Quantity	Total Direct Cost
Granular Media Filters (3 at 900 sf)			
Existing Filter Demolition	$-	1	$-
Construction Difficulty Allowance	$-	1	$-
Filter Structural Cost Total	$2,948,302	1	$2,948,302
Filter Mechanical—Valves, Actuators, Flow Meters	$361,500	1	$361,500
Filter Mechanical—Piping	$800,700	1	$800,700
Filter I&C	$750,000	1	$750,000
Backwash Supply Mechanical—Valves, Actuators, Flow Meters	$126,000	1	$126,000
Backwash Supply Mechanical—Pumps/Blowers	$-	1	$-
Backwash Supply Mechanical—Piping	$-	1	$-
Air Scour Mechanical—Piping	$119,000	1	$119,000
Air Scour Mechanical—Pumps/Blowers	$-	1	$-
Backwash Surge Basin Structural	$-	1	$-
Backwash Recycle Mechanical—Piping	$8,000	1	$8,000
Backwash Recycle Mechanical—Pumps/Blowers	$-	1	$-
Backwash Recycle Mechanical—Valves, Actuators, Flow Meters	$-	1	$-
Structural Civil Work	$294,800	1	$294,800
Piles	$44.60/sf	5,360 sf	$239,057
Yard piping	$811,245	1	$811,245
Total Direct Cost			**$6,458,604**

Item	Unit Cost	Quantity	Total Direct Cost
Contingency (30 %)			$1,937,581
Subtotal			$8,396,185
General Conditions (10 %)			$839,619
Subtotal			$9,235,804
Overhead and Profit (12 %)			$1,108,296
Total Construction Cost			**$10,344,100**
Engineering, Legal, and Administration (20 %)			$2,068,820
Total Project Cost			**$12,412,921**

Table 5B.8 Scenario B Cost Series, Net Present Cost

Year	CAPEX	Filter Routine Inspection	Filter Backwash Supply Pumping	Filter Backwash Waste Pumping	Filter Air Scouring	Filter Media Loss	Filter Valve, Actuator, Flow Meter Replacement	Alum	Polymer	Microsand
2024	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2025	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2026	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2027	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2028	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2029	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2030	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2031	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
2032	$-	$-	$-	$-	$-	$-	$-	$343,360	$53,362	$8,180
2033	$-	$-	$-	$-	$-	$-	$-	$342,379	$52,315	$8,020
2034	$-	$-	$-	$-	$-	$-	$-	$341,289	$51,290	$7,863
2035	$-	$-	$-	$-	$-	$-	$-	$340,097	$50,284	$7,708
2036	$-	$-	$-	$-	$-	$-	$-	$338,262	$49,298	$7,557
2037	$-	$-	$-	$-	$-	$-	$-	$336,356	$48,331	$7,409
2038	$-	$-	$-	$-	$-	$-	$-	$334,382	$47,384	$7,264
2039	$-	$-	$-	$-	$-	$-	$-	$332,344	$46,455	$7,121
2040	$-	$-	$-	$-	$-	$-	$-	$330,246	$45,544	$6,982
2041	$-	$-	$-	$-	$-	$-	$-	$328,175	$44,651	$6,845
2042	$-	$-	$-	$-	$-	$-	$-	$326,045	$43,775	$6,711
2043	$-	$-	$-	$-	$-	$-	$-	$323,862	$42,917	$6,579
2044	$-	$-	$-	$-	$-	$-	$-	$321,628	$42,075	$6,450
2045	$-	$-	$-	$-	$-	$-	$-	$319,346	$41,250	$6,324
2046	$-	$-	$-	$-	$-	$-	$-	$315,718	$40,442	$6,200
2047	$-	$-	$-	$-	$-	$-	$-	$312,102	$39,649	$6,078
2048	$-	$-	$-	$-	$-	$-	$-	$308,500	$38,871	$5,959
2049	$-	$-	$-	$-	$-	$-	$-	$304,911	$38,109	$5,842
2050	$-	$-	$-	$-	$-	$-	$-	$301,337	$37,362	$5,727

Year	CAPEX	Filter Routine Inspection	Filter Backwash Supply Pumping	Filter Backwash Waste Pumping	Filter Air Scouring	Filter Media Loss	Filter Valve, Actuator, Flow Meter Replacement	Alum	Polymer	Microsand
2051	$-	$-	$-	$-	$-	$-	$-	$297,958	$36,629	$5,615
2052	$-	$-	$-	$-	$-	$-	$-	$294,587	$35,911	$5,505
2053	$-	$-	$-	$-	$-	$-	$-	$291,228	$35,207	$5,397
2054	$-	$-	$-	$-	$-	$-	$-	$287,880	$34,516	$5,291
2055	$-	$-	$-	$-	$-	$-	$-	$284,544	$33,840	$5,187
2056	$-	$-	$-	$-	$-	$-	$-	$281,279	$33,176	$5,086
2057	$-	$-	$-	$-	$-	$-	$-	$278,025	$32,526	$4,986
2058	$-	$-	$-	$-	$-	$-	$-	$274,785	$31,888	$4,888
2059	$6,206,803	$-	$-	$-	$-	$-	$-	$271,558	$31,263	$4,792
2060	$-	$-	$-	$-	$-	$-	$-	$268,346	$30,650	$4,698
2061	$-	$3,053	$5,777	$4,814	$706	$3,785	$7,810	$264,999	$30,049	$4,606
2062	$-	$2,993	$5,702	$4,752	$692	$3,711	$7,657	$261,674	$29,459	$4,516
2063	$-	$2,934	$5,628	$4,690	$678	$3,638	$7,507	$258,373	$28,882	$4,427
2064	$-	$2,877	$5,554	$4,629	$665	$3,567	$7,359	$255,094	$28,316	$4,341
2065	$-	$2,820	$5,481	$4,568	$652	$3,497	$7,215	$251,840	$27,760	$4,256
2066	$-	$2,765	$5,408	$4,506	$639	$3,428	$7,074	$248,548	$27,216	$4,172
2067	$-	$2,711	$5,335	$4,445	$627	$3,361	$6,935	$245,283	$26,682	$4,090
2068	$-	$2,658	$5,262	$4,385	$614	$3,295	$6,799	$242,045	$26,159	$4,010
2069	$-	$2,606	$5,190	$4,325	$602	$3,230	$6,666	$238,836	$25,646	$3,931
2070	$-	$2,554	$5,119	$4,266	$591	$3,167	$6,535	$235,654	$25,143	$3,854
2071	$-	$2,504	$5,049	$4,207	$579	$3,105	$6,407	$232,500	$24,650	$3,779
2072	$-	$2,455	$4,979	$4,149	$568	$3,044	$6,281	$229,375	$24,167	$3,705
2073	$-	$2,407	$4,910	$4,092	$557	$2,984	$6,158	$226,279	$23,693	$3,632
2074	$-	$2,360	$4,841	$4,035	$546	$2,926	$6,037	$223,211	$23,229	$3,561
2075	$-	$2,314	$4,774	$3,978	$535	$2,868	$5,919	$220,172	$22,773	$3,491

Table 5B.9 Scenario B Total Net Present Cost Summary

Cost	Net Present Cost
CAPEX	
CAPEX Subtotal	$6,206,803
OPEX	
Filter Routine Inspection	$40,011
Filter Backwash Supply Pumping	$79,009
Filter Backwash Waste Pumping	$65,841
Filter Air Scouring	$9,251
Filter Media Loss	$49,605
Filter Valve, Actuator, Flow Meter Replacement	$102,359
Alum	$12,664,412
Polymer	$1,582,793
Microsand	$242,636
OPEX Subtotal	$14,835,917
Total (CAPEX + OPEX)	$21,042,720

Detailed Opinion of Probable Costs for Scenario C, Granular Media Filtration

Table 5B.10 Detailed Opinion of Probable Direct Capital Cost for Phase 1 Granular Media Filter Expansion

Item	Unit Cost	Quantity	Total Direct Cost
Granular Media Filters (8 at 900 sf)			
Existing Filter Demolition	$-	1	$-
Construction Difficulty Allowance	$1,500,000	1	$1,500,000
Filter Structural Cost Total	$9,329,044	1	$9,329,044
Filter Mechanical—Valves, Actuators, Flow Meters	$964,000	1	$964,000
Filter Mechanical—Piping	$2,117,700	1	$2,117,700
Filter I&C	$2,000,000	1	$2,000,000
Backwash Supply Mechanical—Valves, Actuators, Flow Meters	$126,000	1	$126,000
Backwash Supply Mechanical—Pumps/Blowers	$-	1	$-
Backwash Supply Mechanical—Piping	$-	1	$-
Air Scour Mechanical—Piping	$315,000	1	$315,000
Air Scour Mechanical—Pumps/Blowers	$-	1	$-
Backwash Surge Basin Structural	$-	1	$-
Backwash Recycle Mechanical—Piping	$8,000	1	$8,000
Backwash Recycle Mechanical—Pumps/Blowers	$-	1	$-
Backwash Recycle Mechanical—Valves, Actuators, Flow Meters	$-	1	$-

Item	Unit Cost	Quantity	Total Direct Cost
Structural Civil Work	$1,109,790	1	$1,109,790
Piles	$44.60/sf	17,000 sf	$758,203
Yard piping	$1,746,953	1	$1,746,953
Total Direct Cost			**$19,974,691**
Contingency (30 %)			$5,992,407
Subtotal			$25,967,099
General Conditions (10 %)			$2,596,710
Subtotal			$28,563,808
Overhead and Profit (12 %)			$3,427,657
Total Construction Cost			**$31,991,465**
Engineering, Legal, and Administration (20 %)			$6,398,293
Total Project Cost			**$38,389,758**

Table 5B.11 Detailed Opinion of Probable Direct Capital Cost for Phase 2 Granular Media Filter Expansion

Item	Unit Cost	Quantity	Total Direct Cost
Granular Media Filters (4 at 900 sf, west)			
Existing Filter Demolition	$750,000	1	$750,000
Construction Difficulty Allowance	$3,000,000	1	$3,000,000
Filter Structural Cost Total	$4,701,689	1	$4,701,689
Filter Mechanical—Valves, Actuators, Flow Meters	$482,000	1	$482,000
Filter Mechanical—Piping	$1,064,100	1	$1,064,100
Filter I&C	$1,000,000	1	$1,000,000
Backwash Supply Mechanical—Valves, Actuators, Flow Meters	$126,000	1	$126,000
Backwash Supply Mechanical—Pumps/Blowers	$540,000	1	$540,000
Backwash Supply Mechanical—Piping	$42,000	1	$42,000
Air Scour Mechanical—Piping	$158,200	1	$158,200
Air Scour Mechanical—Pumps/Blowers	$288,000	1	$288,000
Backwash Surge Basin Structural	$-	1	$-
Backwash Recycle Mechanical—Piping	$8,000	1	$8,000
Backwash Recycle Mechanical—Pumps/Blowers	$-	1	$-
Backwash Recycle Mechanical—Valves, Actuators, Flow Meters	$-	1	$-
Structural Civil Work	$558,030	1	$558,030
Piles	$44.60/sf	10,146 sf	$452,514
Yard piping	$2,543,604	1	$2,543,604
Subtotal			$15,714,136

Item	Unit Cost	Quantity	Total Direct Cost
West Backwash/Air Scour Building			
Building	$400/sf	5000 sf	$2,000,000
Piles	$44.60/sf	5000 sf	$223,001
Yard piping	$400,000	1	$400,000
Subtotal			$2,623,001
West Secondary/Tertiary Effluent Flow Splitting Improvements			
Allowance	$1,200,000	1	$1,200,000
West Chemical Feed Building			
Building	$400/sf	2500 sf	$1,000,000
Piles	$44.60/sf	2500 sf	$111,500
Chemical feed allowance	$1,000,000	1	$1,200,000
Subtotal			$2,111,500
West Coagulation/Flocculation Improvements			
Allowance	$500,000	1	$1,200,000
West Clarifiers 5 And 6 Improvements			
Allowance	$1,451,971	1	$1,451,971
Total Direct Cost			**$23,600,609**
Contingency (30 %)			$7,080,183
Subtotal			$30,680,791
General Conditions (10 %)			$3,068,079
Subtotal			$33,748,870
Overhead and Profit (12 %)			$4,049,864
Total Construction Cost			**$37,798,735**
Engineering, Legal, and Administration (20 %)			$7,559,747
Total Project Cost			**$45,358,482**

Table 5B.12 Scenario C, Granular Media Filtration, Cost Series, Net Present Cost

Year	CAPEX	Filter Routine Inspection	Filter Backwash Supply Pumping	Filter Backwash Waste Pumping	Filter Air Scouring	Filter Media Loss	Filter Valve, Actuator, Flow Meter Replacement	Alum	Polymer
2024	$-	$-	$-	$-	$-	$-	$-	$-	$-
2025	$-	$-	$-	$-	$-	$-	$-	$-	$-
2026	$-	$-	$-	$-	$-	$-	$-	$-	$-
2027	$-	$-	$-	$-	$-	$-	$-	$-	$-
2028	$-	$-	$-	$-	$-	$-	$-	$-	$-
2029	$-	$-	$-	$-	$-	$-	$-	$-	$-
2030	$34,089,007	$-	$-	$-	$-	$-	$-	$-	$-
2031	$-	$-	$-	$-	$-	$-	$-	$-	$-
2032	$-	$14,457	$7,569	$6,307	$3,343	$17,923	$31,010	$255,319	$29,159
2033	$-	$14,173	$7,544	$6,287	$3,277	$17,572	$30,402	$254,589	$28,588
2034	$-	$13,895	$7,517	$6,264	$3,213	$17,227	$29,806	$253,779	$28,027
2035	$-	$13,623	$7,488	$6,240	$3,150	$16,890	$29,222	$252,892	$27,478
2036	$-	$13,356	$7,445	$6,204	$3,088	$16,558	$28,649	$251,528	$26,939
2037	$-	$13,094	$7,400	$6,167	$3,027	$16,234	$28,087	$250,111	$26,411
2038	$-	$12,837	$7,354	$6,128	$2,968	$15,915	$27,536	$248,643	$25,893
2039	$-	$12,586	$7,306	$6,089	$2,910	$15,603	$26,996	$247,128	$25,385
2040	$-	$12,339	$7,257	$6,048	$2,853	$15,297	$26,467	$245,568	$24,887
2041	$-	$12,097	$7,209	$6,008	$2,797	$14,997	$25,948	$244,027	$24,399
2042	$-	$11,860	$7,160	$5,966	$2,742	$14,703	$25,439	$242,444	$23,921
2043	$-	$11,627	$7,109	$5,924	$2,688	$14,415	$24,940	$240,821	$23,452
2044	$-	$11,399	$7,057	$5,881	$2,636	$14,132	$24,451	$239,159	$22,992
2045	$-	$11,176	$7,004	$5,837	$2,584	$13,855	$23,972	$237,463	$22,541
2046	$-	$10,956	$6,922	$5,768	$2,533	$13,584	$23,502	$234,765	$22,099
2047	$-	$10,742	$6,840	$5,700	$2,484	$13,317	$23,041	$232,076	$21,666
2048	$28,200,343	$10,531	$6,759	$5,632	$2,435	$13,056	$22,589	$229,397	$21,241
2049	$-	$10,325	$6,677	$5,565	$2,387	$12,800	$22,146	$226,729	$20,825
2050	$-	$15,183	$13,193	$10,994	$3,510	$18,824	$33,823	$224,071	$20,416

Year	CAPEX	Filter Routine Inspection	Filter Backwash Supply Pumping	Filter Backwash Waste Pumping	Filter Air Scouring	Filter Media Loss	Filter Valve, Actuator, Flow Meter Replacement	Alum	Polymer
2051	$-	$14,885	$13,040	$10,867	$3,442	$18,455	$33,160	$221,558	$20,016
2052	$-	$14,594	$12,888	$10,740	$3,374	$18,093	$32,510	$219,052	$19,623
2053	$-	$14,307	$12,736	$10,613	$3,308	$17,738	$31,872	$216,554	$19,239
2054	$-	$14,027	$12,585	$10,487	$3,243	$17,390	$31,247	$214,064	$18,861
2055	$-	$13,752	$12,434	$10,362	$3,180	$17,049	$30,635	$211,584	$18,492
2056	$-	$13,482	$12,287	$10,239	$3,117	$16,715	$30,034	$209,156	$18,129
2057	$-	$13,218	$12,140	$10,117	$3,056	$16,387	$29,445	$206,737	$17,774
2058	$-	$12,959	$11,994	$9,995	$2,996	$16,066	$28,868	$204,327	$17,425
2059	$-	$12,705	$11,848	$9,874	$2,937	$15,751	$28,302	$201,928	$17,083
2060	$-	$12,455	$11,704	$9,753	$2,880	$15,442	$27,747	$199,539	$16,748
2061	$-	$12,211	$11,553	$9,628	$2,823	$15,139	$27,203	$197,050	$16,420
2062	$-	$11,972	$11,404	$9,503	$2,768	$14,842	$26,669	$194,578	$16,098
2063	$-	$11,737	$11,256	$9,380	$2,714	$14,551	$26,146	$192,123	$15,782
2064	$-	$11,507	$11,109	$9,257	$2,660	$14,266	$25,634	$189,686	$15,473
2065	$-	$11,281	$10,963	$9,136	$2,608	$13,986	$25,131	$187,265	$15,170
2066	$-	$11,060	$10,815	$9,013	$2,557	$13,712	$24,638	$184,818	$14,872
2067	$-	$10,843	$10,669	$8,891	$2,507	$13,443	$24,155	$182,390	$14,581
2068	$-	$10,631	$10,524	$8,770	$2,458	$13,180	$23,681	$179,983	$14,295
2069	$-	$10,422	$10,381	$8,651	$2,410	$12,921	$23,217	$177,596	$14,014
2070	$-	$10,218	$10,238	$8,532	$2,362	$12,668	$22,762	$175,230	$13,740
2071	$-	$10,017	$10,098	$8,415	$2,316	$12,419	$22,316	$172,885	$13,470
2072	$-	$9,821	$9,958	$8,298	$2,271	$12,176	$21,878	$170,561	$13,206
2073	$-	$9,628	$9,820	$8,183	$2,226	$11,937	$21,449	$168,258	$12,947
2074	$-	$9,440	$9,683	$8,069	$2,183	$11,703	$21,028	$165,977	$12,693
2075	$-	$9,255	$9,547	$7,956	$2,140	$11,474	$20,616	$163,718	$12,444

Table 5B.13 Scenario C, Granular Media Filtration Total Net Present Cost Summary

Cost	Net Present Cost
CAPEX	
CAPEX Subtotal	$62,289,350
OPEX	
Filter Routine Inspection	$532,682
Filter Backwash Supply Pumping	$424,485
Filter Backwash Waste Pumping	$353,737
Filter Air Scouring	$123,159
Filter Media Loss	$660,409
Filter Valve, Actuator, Flow Meter Replacement	$1,168,368
Alum	$9,417,127
Polymer	$864,914
OPEX Subtotal	$13,798,755
Total (CAPEX + OPEX)	$76,088,105

Detailed Opinion of Probable Costs for Scenario C, Membrane Filtration

Table 5B.14 Detailed Opinion of Probable Direct Capital Cost for Phase 1 Membrane Filter Expansion, Granular Media Filters Rated at 4 gpm/sf

Item	Unit Cost	Quantity	Total Direct Cost
Membrane Facility (40 mgd Facility, 20 mgd initial Capacity)			
Construction difficulty allowance	$1,000,000	1	$1,000,000
Membrane Equipment Costs	$13,442,286	1	$13,442,286
Chem Storage and Feed	$1,357,143	1	$1,357,143
Building Costs	$19,820,000	1	$19,820,000
EI&C	$14,084,583	1	$14,084,583
Piles	$44.60/sf	29,800 sf	$1,329,086
Subtotal			$51,033,098
Actiflo Effluent Pump Station Improvements			
Allowance	$1,000,000	1	$1,000,000
Yard piping and site civil	$12,437,289	1	$12,437,289
Total Direct Cost			**$64,470,387**
Contingency (30 %)			$19,341,116
Subtotal			$83,811,503
General Conditions (10 %)			$8,381,150
Subtotal			$92,192,654

Item	Unit Cost	Quantity	Total Direct Cost
Overhead and Profit (12 %)			$11,063,118
Total Construction Cost			**$103,255,772**
Engineering, Legal, and Administration (20 %)			$20,651,154
Total Project Cost			**$123,906,927**

Table 5B.15 Detailed Opinion of Probable Direct Capital Cost for Phase 2 Membrane Filter Expansion, Granular Media Filters Rated at 4 gpm/sf

Item	Unit Cost)	Quantity	Total Direct Cost
Membrane Facility (Additional 20 mgd capacity)			
Membrane Equipment Costs	$7,295,574	1	$7,295,574
Chem Storage and Feed	$734,694	1	$734,694
Building Costs	$-	1	$-
EI&C	$3,452,167	1	$3,452,167
Total Direct Cost			**$11,482,435**
Contingency (30 %)			$3,444,730
Subtotal			$14,927,165
General Conditions (10 %)			$1,492,716
Subtotal			$16,419,881
Overhead and Profit (12 %)			$1,970,386
Total Construction Cost			**$18,390,267**
Engineering, Legal, and Administration (20 %)			$3,678,053
Total Project Cost			**$22,068,321**

Table 5B.16 Detailed Opinion of Probable Direct Capital Cost for Phase 1 Membrane Filter Expansion, Granular Media Filters Rated at 3 gpm/sf

Item	Unit Cost	Quantity	Total Direct Cost
Membrane Facility (40 mgd Facility, 20 mgd Initial Capacity)			
Construction difficulty allowance	$1,000,000	1	$1,000,000
Membrane Equipment Costs	$16,541,096	1	$16,541,096
Chem Storage and Feed	$1,642,857	1	$1,642,857
Building Costs	$22,956,000	1	$22,956,000
EI&C	$16,504,180	1	$16,504,180
Piles	$44.60/sf	26,400 sf	$1,177,445
Subtotal			$59,821,578
Actiflo effluent pump station improvements			
Allowance	$1,000,000	1	$1,000,000
Yard piping and site civil	$14,866,350	1	$14,866,350
Total Direct Cost			**$75,687,928**

Item	Unit Cost	Quantity	Total Direct Cost
Contingency (30 %)			$22,706,378
Subtotal			$98,394,307
General Conditions (10 %)			$9,839,431
Subtotal			$108,233,737
Overhead and Profit (12 %)			$12,988,048
Total Construction Cost			**$121,221,786**
Engineering, Legal, and Administration (20 %)			$24,244,357
Total Project Cost			**$145,466,143**

Table 5B.17 Detailed Opinion of Probable Direct Capital Cost for Phase 2 Membrane Filter Expansion, Granular Media Filters Rated at 3 gpm/sf

Item	Unit Cost	Quantity	Total Direct Cost
Membrane Facility (Additional 20 mgd Capacity)			
Membrane Equipment Costs	$6,867,432	1	$6,867,432
Chem Storage and Feed	$734,694	1	$734,694
Building Costs	$-	1	$-
EI&C	$3,441,900	1	$3,441,900
Subtotal			
West Secondary/Tertiary Effluent Flow Splitting Improvements			
Allowance	$1,000,000	1	$1,000,000
West Chemical Feed Building			
Building	$400/sf	2500 sf	$1,000,000
Piles	$44.60/sf	2500 sf	$111,500
Chemical feed allowance	$1,000,000	1	$1,000,000
Subtotal			
West Coagulation/Flocculation Improvements			
Allowance	$500,000	1	$500,000
West Clarifiers 5 and 6 Improvements			
Allowance	$1,451,971	1	$1,451,971
Total Direct Cost			**$16,307,497**
Contingency (30 %)			$4,892,249
Subtotal			$21,199,747
General Conditions (10 %)			$2,119,975
Subtotal			$23,319,721
Overhead and Profit (12 %)			$2,798,367
Total Construction Cost			**$26,118,088**
Engineering, Legal, and Administration (20 %)			$5,223,618
Total Project Cost			**$31,341,705**

Table 5B.18 Scenario C Membrane Filtration, Granular Media Filters Rated at 4 gpm/sf, Cost Series, Net Present Cost

Year	CAPEX	Energy Usage	Chemical Costs	Membrane Replacement	Plant Costs	Alum	Polymer
2024	$-	$-	$-	$-	$-	$-	$-
2025	$-	$-	$-	$-	$-	$-	$-
2026	$-	$-	$-	$-	$-	$-	$-
2027	$-	$-	$-	$-	$-	$-	$-
2028	$-	$-	$-	$-	$-	$-	$-
2029	$-	$-	$-	$-	$-	$-	$-
2030	$110,025,805	$-	$-	$-	$-	$-	$-
2031	$-	$-	$-	$-	$-	$-	$-
2032	$-	$151,047	$64,492	$217,925	$150,783	$255,319	$29,159
2033	$-	$148,085	$63,227	$213,652	$147,827	$254,589	$28,588
2034	$-	$145,181	$61,987	$209,462	$144,928	$253,779	$28,027
2035	$-	$142,335	$60,772	$205,355	$142,086	$252,892	$27,478
2036	$-	$139,544	$59,580	$201,329	$139,300	$251,528	$26,939
2037	$-	$136,808	$58,412	$197,381	$136,569	$250,111	$26,411
2038	$-	$134,125	$57,267	$193,511	$133,891	$248,643	$25,893
2039	$-	$131,495	$56,144	$189,716	$131,266	$247,128	$25,385
2040	$-	$128,917	$55,043	$185,996	$128,692	$245,568	$24,887
2041	$-	$126,389	$53,964	$182,350	$126,169	$244,027	$24,399
2042	$-	$123,911	$52,906	$178,774	$123,695	$242,444	$23,921
2043	$-	$121,481	$51,868	$175,269	$121,269	$240,821	$23,452
2044	$-	$119,099	$50,851	$171,832	$118,892	$239,159	$22,992
2045	$-	$116,764	$49,854	$168,463	$116,560	$237,463	$22,541
2046	$-	$114,474	$48,877	$165,160	$114,275	$234,765	$22,099
2047	$13,994,756	$112,230	$47,918	$161,921	$112,034	$232,076	$21,666
2048	$-	$110,029	$46,979	$158,746	$109,837	$229,397	$21,241
2049	$-	$215,744	$91,308	$291,843	$176,788	$226,729	$20,825
2050	$-	$211,513	$89,517	$286,121	$173,322	$224,071	$20,416
2051	$-	$207,366	$87,762	$280,511	$169,923	$221,558	$20,016
2052	$-	$203,300	$86,041	$275,011	$166,592	$219,052	$19,623
2053	$-	$199,314	$84,354	$269,618	$163,325	$216,554	$19,239
2054	$-	$195,406	$82,700	$264,332	$160,123	$214,064	$18,861
2055	$-	$191,574	$81,079	$259,149	$156,983	$211,584	$18,492
2056	$-	$187,818	$79,489	$254,067	$153,905	$209,156	$18,129
2057	$-	$184,135	$77,930	$249,086	$150,887	$206,737	$17,774
2058	$-	$180,525	$76,402	$244,201	$147,929	$204,327	$17,425
2059	$-	$176,985	$74,904	$239,413	$145,028	$201,928	$17,083

Year	CAPEX	Energy Usage	Chemical Costs	Membrane Replacement	Plant Costs	Alum	Polymer
2060	$-	$173,515	$73,435	$234,719	$142,184	$199,539	$16,748
2061	$-	$170,112	$71,996	$230,117	$139,396	$197,050	$16,420
2062	$-	$166,777	$70,584	$225,604	$136,663	$194,578	$16,098
2063	$-	$163,507	$69,200	$221,181	$133,983	$192,123	$15,782
2064	$-	$160,301	$67,843	$216,844	$131,356	$189,686	$15,473
2065	$-	$157,158	$66,513	$212,592	$128,781	$187,265	$15,170
2066	$-	$154,076	$65,209	$208,424	$126,256	$184,818	$14,872
2067	$-	$151,055	$63,930	$204,337	$123,780	$182,390	$14,581
2068	$-	$148,093	$62,676	$200,330	$121,353	$179,983	$14,295
2069	$-	$145,189	$61,447	$196,402	$118,973	$177,596	$14,014
2070	$-	$142,342	$60,243	$192,551	$116,641	$175,230	$13,740
2071	$-	$139,551	$59,061	$188,776	$114,354	$172,885	$13,470
2072	$-	$136,815	$57,903	$185,074	$112,111	$170,561	$13,206
2073	$-	$134,132	$56,768	$181,445	$109,913	$168,258	$12,947
2074	$-	$131,502	$55,655	$177,888	$107,758	$165,977	$12,693
2075	$-	$128,924	$54,564	$174,400	$105,645	$163,718	$12,444

Table 5B.19 Scenario C, Membrane Filtration, Granular Media Filters Rated at 4 gpm/sf, Total Net Present Cost Summary

Cost	Net Present Cost
CAPEX	
CAPEX Subtotal	$124,020,561
OPEX	
Energy Usage	$6,758,641
Membrane Chemicals	$2,868,655
Membrane Replacement	$9,340,875
Plant Costs	$5,932,028
Alum	$9,417,127
Polymer	$864,914
OPEX Subtotal	$35,182,241
Total (CAPEX + OPEX)	$159,202,802

Table 5B.20 Scenario C Membrane Filtration, Granular Media Filters Rated at 3 gpm/sf, Cost Series, Net Present Cost

Year	CAPEX	Energy Usage	Chemical Costs	Membrane Replacement	Plant Costs	Alum	Polymer
2024	$-	$-	$-	$-	$-	$-	$-
2025	$-	$-	$-	$-	$-	$-	$-
2026	$-	$-	$-	$-	$-	$-	$-
2027	$-	$-	$-	$-	$-	$-	$-
2028	$-	$-	$-	$-	$-	$-	$-
2029	$-	$-	$-	$-	$-	$-	$-
2030	$129,169,772	$-	$-	$-	$-	$-	$-
2031	$-	$-	$-	$-	$-	$-	$-
2032	$-	$203,913	$86,578	$291,928	$188,341	$255,319	$29,159
2033	$-	$199,915	$84,880	$286,204	$184,648	$254,589	$28,588
2034	$-	$195,995	$83,216	$280,592	$181,028	$253,779	$28,027
2035	$-	$192,152	$81,584	$275,090	$177,478	$252,892	$27,478
2036	$-	$188,384	$79,985	$269,696	$173,998	$251,528	$26,939
2037	$-	$184,690	$78,416	$264,408	$170,587	$250,111	$26,411
2038	$-	$181,069	$76,879	$259,224	$167,242	$248,643	$25,893
2039	$-	$177,518	$75,371	$254,141	$163,963	$247,128	$25,385
2040	$-	$174,038	$73,894	$249,158	$160,748	$245,568	$24,887
2041	$-	$170,625	$72,445	$244,272	$157,596	$244,027	$24,399
2042	$-	$167,280	$71,024	$239,483	$154,506	$242,444	$23,921
2043	$-	$164,000	$69,632	$234,787	$151,476	$240,821	$23,452
2044	$-	$160,784	$68,266	$230,183	$148,506	$239,159	$22,992
2045	$-	$157,631	$66,928	$225,670	$145,594	$237,463	$22,541
2046	$-	$154,540	$65,615	$221,245	$142,739	$234,765	$22,099
2047	$19,875,528	$151,510	$64,329	$216,907	$139,940	$232,076	$21,666
2048	$-	$148,539	$63,067	$212,654	$137,197	$229,397	$21,241
2049	$-	$253,499	$107,180	$336,729	$199,556	$226,729	$38,109
2050	$-	$248,528	$105,078	$330,127	$195,643	$224,071	$37,362
2051	$-	$243,655	$103,018	$323,654	$191,807	$221,558	$36,629
2052	$-	$238,878	$100,998	$317,307	$188,046	$219,052	$35,911
2053	$-	$234,194	$99,018	$311,086	$184,358	$216,554	$35,207
2054	$-	$229,602	$97,076	$304,986	$180,744	$214,064	$34,516
2055	$-	$225,100	$95,173	$299,006	$177,200	$211,584	$33,840
2056	$-	$220,686	$93,307	$293,143	$173,725	$209,156	$33,176
2057	$-	$216,359	$91,477	$287,395	$170,319	$206,737	$32,526
2058	$-	$212,116	$89,683	$281,760	$166,979	$204,327	$31,888
2059	$-	$207,957	$87,925	$276,235	$163,705	$201,928	$31,263

Year	CAPEX	Energy Usage	Chemical Costs	Membrane Replacement	Plant Costs	Alum	Polymer
2060	$-	$203,880	$86,201	$270,819	$160,495	$199,539	$30,650
2061	$-	$199,882	$84,511	$265,509	$157,348	$197,050	$30,049
2062	$-	$195,963	$82,854	$260,303	$154,263	$194,578	$29,459
2063	$-	$192,120	$81,229	$255,199	$151,238	$192,123	$28,882
2064	$-	$188,353	$79,636	$250,195	$148,273	$189,686	$28,316
2065	$-	$184,660	$78,075	$245,289	$145,365	$187,265	$27,760
2066	$-	$181,039	$76,544	$240,479	$142,515	$184,818	$27,216
2067	$-	$177,490	$75,043	$235,764	$139,721	$182,390	$26,682
2068	$-	$174,009	$73,572	$231,141	$136,981	$179,983	$26,159
2069	$-	$170,597	$72,129	$226,609	$134,295	$177,596	$25,646
2070	$-	$167,252	$70,715	$222,166	$131,662	$175,230	$25,143
2071	$-	$163,973	$69,328	$217,810	$129,080	$172,885	$24,650
2072	$-	$160,758	$67,969	$213,539	$126,549	$170,561	$24,167
2073	$-	$157,606	$66,636	$209,352	$124,068	$168,258	$23,693
2074	$-	$154,515	$65,329	$205,247	$121,635	$165,977	$23,229
2075	$-	$151,486	$64,048	$201,222	$119,250	$163,718	$22,773

Table 5B.21 Scenario C, Membrane Filtration, Granular Media Filters Rated at 3 gpm/sf, Total Net Present Cost Summary

Cost	Net Present Cost
CAPEX	
CAPEX Subtotal	$149,045,300
OPEX	
Energy Usage	$8,326,738
Membrane Chemicals	$3,525,861
Membrane Replacement	$11,367,709
Plant Costs	$6,960,406
Alum	$9,417,127
Polymer	$1,229,979
OPEX Subtotal	$40,827,820
Total (CAPEX + OPEX)	$189,873,120