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CITY OF SUNNYVALE

MASTER PLAN AND PRIMARY TREATMENT DESIGN

TECHNICAL MEMORANDUM

FILTRATION:
MASTER PLAN

FINAL
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in association with HDR

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CITY OF SUNNYVALE

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1.0 INTRODUCTION

This technical memorandum (TM) presents an analysis and selection of process alternatives for filtration at the City of Sunnyvale's (City's) Water Pollution Control Plant (WPCP). The selected filtration processes proposed for the WPCP are based on providing the needed improvements through build-out (2035) to meet the City's goals and objectives. The recommendations presented herein are an update to and expansion of the recommendations included in the City's WPCP Strategic Infrastructure Plan (SIP).

The evaluation was completed using a two-step process: (1) a one week internal peer review was held on September 9th through 12th, 2013 which was attended by process experts from the Carollo/HDR team and (2) a two-day workshop on October 14th and 15th, 2013, during which time the Carollo/HDR team presented the recommended liquid and solids treatment processes to the City staff. The key findings and recommendations developed for the filtration process are summarized in this TM, as well as in the October workshop meeting minutes and presentation slides included in Appendix A.

2.0 SUMMARY OF RECOMMENDATIONS

The key findings and recommendations for the filtration process include:

- Continue using the existing dual media filters (DMFs) for both Bay discharge and production of recycled water (RW) until either: (1) the need for denitrification filters is required to meet more strict nitrogen standards (anticipated to be no earlier that 2040±) or (2) a full membrane bioreactor (MBR) secondary facility becomes operational.
- Eliminate current batch production of RW by filtering all secondary effluent to Title 22 standards and dedicating a portion of the disinfection process to RW production.
  - This requires performing a filter re-rating study when the actual filter loading rates begin to reach 5 gallons per minute per square foot (gpm/SF). Filter loading rates will reach 5 gpm/SF when the filter influent flow reaches 21 mgd, which is projected to occur around 2019.
  - In addition to the re-rating study, implement a polymer dosing system at the DMFs to optimize filter performance.
- Implement potable water blending to meet RW peak demands, water quality objectives, and redundancy needs. Potable water blending needs are anticipated to be minimal.

Table 1 summarizes how these recommendations (the Master Plan recommendations) compare with the SIP recommendations. The subsequent sections of this TM summarize the rational for the Master Plan recommendations. These sections also include explanation as to why some SIP recommendations are no longer recommended for further consideration.

Table 1 Comparison of Master Plan and SIP Recommendations
Master Plan and Primary Treatment Design
City of Sunnyvale

Process/ Technology	Strategic Infrastructure Plan (SIP) (2011)	Master Plan (2014)
Filtration (General)	• Replace the existing filtration media, backwash pumps, and air blowers, valving, piping and other process elements nearing the end of their useful life	• Same as SIP
Filtration for Bay Discharge	• Continue use of existing DMFs for Bay discharge	• Same as SIP
Filtration for Recycled Water Production	• If a conventional activated sludge process is implemented for secondary treatment, implement a 4-mgd cloth media filter process dedicated to the production of recycled water • If a membrane bioreactor (MBR) process is implemented for secondary treatment, do not implement any additional filtration process for the production of recycled water. An MBR process will provide sufficient filtration to meet recycled water requirements	• If a conventional activated sludge process is implemented for secondary treatment, filter the total secondary effluent flow with the existing DMFs to produce Title 22 quality effluent. • Same as SIP

The analysis conducted in the October 2013 workshops and summarized herein was based on replacing the existing secondary treatment process (an oxidation pond system) with a new secondary treatment process (i.e., conventional activated sludge or MBR) to meet anticipated nutrient removal limits. To meet the anticipated limits, the City would implement the first stage of the new secondary treatment plant by 2023±.

As part of the Master Plan, the City is considering implementation of a split-flow secondary treatment alternative. The split flow alternative allows for a phased approach to the secondary treatment improvements to provide more flexibility in dealing with future regulatory uncertainties. If the split-flow treatment alternative is implemented, the findings and recommendations for the filtration process would be different based on the secondary process selected.

If conventional activated sludge (AS) split-flow treatment is implemented, the findings and recommendations for the filtration process would be as follows:

- Use only effluent treated by the new AS system for RW production. The effluent from the new AS system should be of higher quality than that produced by the existing pond system. In addition, the effluent flow produced by the new AS process will exceed the anticipated RW demand.

- Piping, gates, valves, and/or other equipment modifications would be required at the filtration process to isolate the higher quality AS effluent from the lower quality pond effluent and ensure the RW flow is comprised entirely of AS effluent.

If MBR split-flow treatment is implemented, the findings and recommendations for the filtration process would be as follows:

- Only effluent treated by the new MBR system would be used for RW production. The effluent from the new MBR system should be of higher quality than that produced by the existing pond system. In addition, the effluent flow produced by the new MBR process would exceed the anticipated RW demand.

- Additional piping, gates, valves, and/or other equipment would be required to convey MBR effluent directly to the disinfection process and bypass the DMF filtration process. The MBR process would meet Title 22 requirements for filtration and no additional filtration would be required. With this configuration the DMFs would be operated at a lower filter loading rate, and as a result, would produce higher quality effluent and potentially require less backwashing and polymer use.

- Implement piping, gates, valves, pumping modifications, and/or other equipment as needed at the influent end of the disinfection process to isolate the higher quality MBR effluent from the lower quality pond effluent.

During the master planning process, the Santa Clara Valley Water District (SCVWD) expressed interest in evaluating use of the City's effluent for indirect potable reuse (IPR). The final filtration recommendations may be modified pending the results of a separate IPR evaluation.

3.0 BACKGROUND

Three of the existing dual media filters were built in 1975. A fourth filter was added in 1980. Each filter has 960 square feet of surface area. The location of the filters is shown in Figure 1. Additional information on the existing filters can be found in the SIP "Recycled Water Treatment Alternatives" TM, included in Appendix B.

The City is currently in the process of converting the gaseous chlorine system to liquid sodium hypochlorite system following recommendations from the SIP. Since the SIP, the City engaged Hydroscience Engineers and Kennedy Jenks Consultants to conduct a Feasibility Study for Recycled Water Expansion (FSRWE), which was completed in April 2013. The FSRWE evaluated the demands from new recycled water clients in the City's service area, provided additional recommendations for addressing recycled water quality concerns, and identified a potential increase in RW demands from Apple.

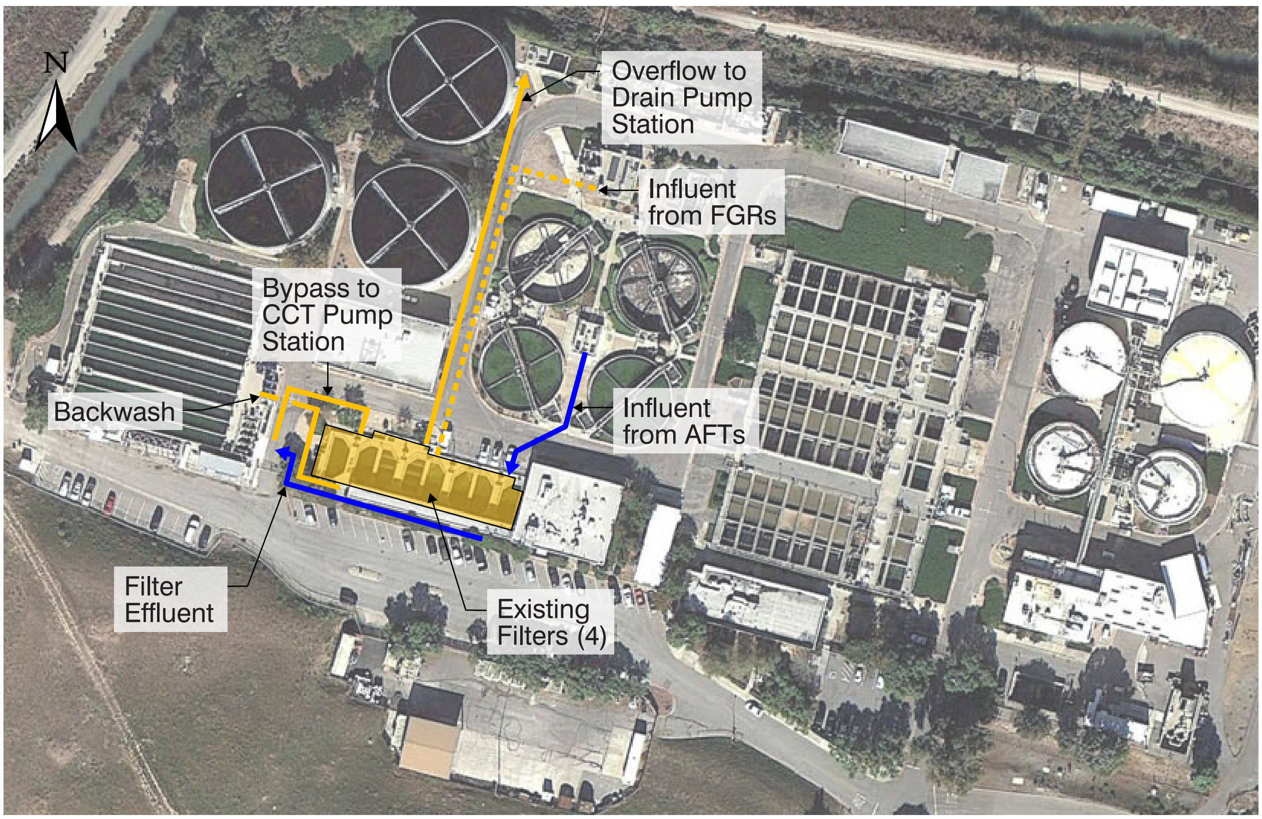
3.1 Regulatory Considerations and Implications

Currently the WPCP discharges filtered effluent to the Bay through the Guadalupe Slough and provides RW to the City's RW distribution system using the Recycled Water Pump Station (RWPS), located at the south end of the chlorine contact tanks (CCTs). Bay discharge and recycled water quality limits presented in the SIP and FSRWE are summarized in Table 2.

The City's permit for Bay discharge does not currently include explicit filtration requirements. However, the Basin Plan (excerpt included in Appendix D) indicates that the WPCP is required to provide "Equivalent Protection" to its current filtration process prior to Bay discharge. It was assumed that some level of effluent filtration would be required throughout the planning period.

In addition to Title 22 regulatory requirements, the FSRWE included two water quality objectives for RW effluent: (1) a total dissolved solids (TDS) limit of 760 millgrams per liter (mg/L); and (2) no visible color. As stated in the FSRWE, the TDS concentration of the current RW effluent exceeds the water quality objective, and there is a green tint to the water that is aesthetically undesirable. These two water quality issues are caused by the influent water quality and the existing treatment process.

Between 2007 and 2011, the average TDS concentration of the RW effluent was 930 mg/L. This is significantly higher than the average TDS concentration of the WPCP influent, which was 760 mg/L in 2010 and 2011. City staff noted that the increase in TDS through the WPCP is caused by evaporation in the secondary treatment oxidation ponds. When the new secondary treatment process (a conventional activated sludge or membrane bioreactor system) is implemented, the effluent TDS is anticipated to be the same as the influent TDS, about 760 mg/L. Since completion of the FSRWE, the City discovered that seawater intrusion is occurring in the collection system. This is estimated to contribute up to 200 mg/L



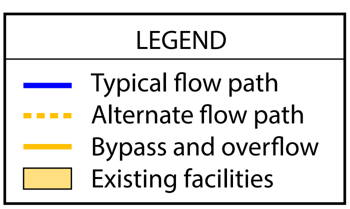


Figure 1
CURRENT DUAL MEDIA FILTERS AND PIPING LAYOUT
FILTRATION
MASTER PLAN AND PRIMARY TREATMENT DESIGN
CITY OF SUNNYVALE

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of TDS to the WPCP final effluent. The City is dealing with this intrusion issue. If mitigated, the existing treatment process may meet the targeted TDS limit before the new secondary treatment process is implemented.

Table 2 Sunnyvale Final Effluent Water Quality Objectives
Master Plan and Primary Treatment Design
City of Sunnyvale

Parameter	Bay Discharge	Recycled Water[1]
cBOD (5-day, 20^{o} C)	20 mg/L Daily Maximum 10 mg/L Monthly Average	20 mg/L Daily Maximum 10 mg/L Monthly Average
Bacterial Residual	35 MPN/100 mL[2]	<2.2 MPN/100 mL[3] 7-day Median <23 MPN/100 mL[3] Single Sample in 30 Days <240 MPN/100 mL[3] Single Sample Maximum
Turbidity	n/a	<2 NTU Daily Average <5 NTU 95% of the time within a 24 hour period <10 NTU Instantaneous Maximum
CT (Chlorine Residual x Contact Time)	n/a	>450 mg/L-min
Contact Time	n/a	>90 minutes (modal)
Chlorine Residual	0.0 mg/L Instantaneous Maximum	5 mg/L

Notes:
(1) City of Sunnyvale Order No. 94-069.
(2) Enterococcus.
(3) Total Coliform.
(4) MPN: Most probable number.

The green tint to the water is induced by algal growth in the oxidation ponds. This would remain an issue for RW customers until the existing oxidation pond process is replaced with a new secondary treatment process.

3.2 Prior Filtration Considerations

3.2.1 SIP Recommendations

The SIP recommended a new dedicated 4 million gallons per day (mgd) recycled water facility utilizing cloth media disk filters to allow the WPCP to move away from the current "batch production" of recycled water, which is further described in Appendix B. The existing dual media filters would continue to be used for Bay discharge. Additionally the SIP also recommended a project to replace the existing filter media and effluent valves. These improvements are underway and anticipated to be complete by 2015.

3.2.2 FSRWE Recommendations

The 2013 FSRWE identified additional RW demands and recommended a dedicated 1.7 mgd membrane bioreactor (MBR) facility for RW production, which would be expanded to a capacity of 3.6 mgd as RW demands increase. An MBR facility would eliminate the potential problems associated with the algae-induced color generated from the pond system. Additional information on the FSRWE is included in Appendix C.

4.0 ALTERNATIVES CONSIDERED

4.1.1 Alternatives Previously Considered

The SIP evaluated five filtration technologies:

- DMFs
- Continuous backwash filters
- Compressible media filters
- Ultrafiltration (UF) membranes
- Cloth media filters

The SIP recommended DMFs, UF membranes, and cloth media filters for further evaluation. DMFs were selected over continuous backwash filters because DMFs are anticipated to have a lower energy cost as well as the City's experience with DMFs. Compressible media filters were eliminated from consideration because there are limited installations of this technology in California.

The FSRWE expanded upon the SIP and evaluated UF membranes and MBRs for color removal to meet the City's water quality objectives for RW effluent. The FSRWE also introduced and evaluated a potable water blending alternative.

4.1.2 Alternatives Considered for Master Plan

Based on an initial pre-screening conducted during the internal peer review held in September 2013, it was decided that continuous backwash filters, compressible media filters, and cloth media filters would not be considered for further evaluation. Continuous backwash filters and compressible media filters were eliminated for the same reasons they were eliminated in the SIP analysis. Cloth filters were eliminated because they would only be implemented to supplement the capacity of the existing DMFs. Once it was determined that the existing DMFs could be operated to provide sufficient capacity through the master planning period, there was no capacity needs for cloth filters.

The internal peer-review team recommended further evaluation of DMFs operated in batch mode and DMFs operated continuously in conjunction with UF membranes, membrane bioreactors or potable water blending.

5.0 ALTERNATIVE ANALYSIS

Based on the anticipated regulations and the findings of the SIP and FSWRE, both near-term and long-term filtration alternatives were developed and evaluated. Near-term alternatives were developed to address the filtration needs that are anticipated prior to the replacement of the existing secondary treatment system (2023±). The primary filtration need during this period is to remove the “green color” from RW effluent, which is caused by algae growth in the existing oxidation pond process. Long-term alternatives consider build-out conditions, which assumes replacement of the pond system by a new secondary treatment technology (i.e., activated sludge). Replacing the pond process will eliminate the color issue. Table 3 summarizes the planning parameters that were assumed for the near and long-term alternatives.

Table 3 Flow Objectives
Master Plan and Primary Treatment Design
City of Sunnyvale

Description	Near-Term	Long-Term(1)
Planning Period	Present-2023	2023-2035
Peak Flows Through Filters, mgd	< 22.9(2)	34.7(3)
Peak Daily Recycled Water Demand, mgd	1.7 (3.0)(4)	3.6
Color Removal Required	Yes	No

Notes:
(1) Separate filtration is only required if the WPCP selects a conventional activated sludge process. No additional filtration is needed if a membrane bioreactor (MBR) is selected as the secondary process.
(2) In the near-term, the peak influent flow to the plant will be equalized in the ponds. Peak flow through the filters is anticipated to be approximately equal to the maximum month flow (MMF) plant influent flow. This is projected to be 22.9 mgd in 2025 as presented in the Flow and Loads TM.
(3) In the long-term, the peak influent flow to the plant will be equalized in diurnal equalization basins upstream of the secondary treatment process. The projected 2035 equalized peak day flow is shown here.
(4) Number in parentheses accounts for near-term RW demands from Apple.

The DMFs were included in each near-term and long-term alternative because the overall structural and mechanical components are considered to be in “good condition” based on the findings of the SIP and 2006 Asset Condition Assessment (Carollo). Given the age and condition the DMFs, they are anticipated to have a useful service life for the master planning period and beyond (2050±).

In addition to this, the DMFs have sufficient capacity to treat the 2035 MMF for bay discharge. They are also anticipated to have sufficient capacity to treat the projected peak recycled water demand with some additional process modifications. All treatment capacity analysis performed as part of the Master Plan is based on three filters in service and one unit in backwash mode.

Title 22 requirements allow a maximum filter loading rate of 5 gpm/SF for RW production. This allowable rate would be exceeded when the peak flow to the filters exceeds 20.7 mgd, which is anticipated to occur around 2019, per the flow projections presented in the Flow and Loads TM. Re-rating studies have been performed at similar filtration facilities to allow a higher maximum allowable RW filter loading rate than included in the Title 22 requirements. Based on Carollo/HDR’s experience, it is anticipated a filter re-rating study would allow the existing DMFs filters to be rated at maximum RW filter loading rate of about 7.5 gpm/SF. At this rating, the filters would have RW capacity of 31.1 mgd. With some additional process improvements, this is anticipated to be sufficient through the projected buildout flow. This is described in further detail in subsequent sections.

When the actual filter loading rates begin to reach 5 gpm/SF, it is recommended the City perform a filter re-rating study on the existing DMFs, so they can be used to their full capacity. Re-rating studies are estimated to cost $200,000± and can take up to eighteen monthes to get Department of Health Services (DOHS) approval. In addition to the re-rating effort, a new polymer dosing system could be implemented to optimize the filter performance. It is recommended the City conduct pilot testing to determine the selection of optimum polymer dosing requirements.

5.1 Near-Term Alternatives Analysis

5.1.1 Near-Term Alternatives

Four alternatives were considered to address the near-term filtration needs:

- DMF (Existing Batch Operation).
- DMF (Continuous) + UF.
- DMF (Continuous) + membrane bioreactors (MBRs).
- DMF (Continuous) + Potable Water Blending.

In alternatives 2 through 4, it is assumed that the existing DMFs would no longer operate in batch mode. In order to eliminate batch mode operation, modifications to the CCTs would be required. These modifications would allow certain chlorine tanks to be dedicated for RW production. These modifications are described in the Disinfection TM.

5.1.1.1 DMF (Existing Batch Operation)

The City has expressed a desire to move away from “batch mode” recycled water production, which requires the WPCP to shut down the fixed growth reactors (FGR), air flotation tanks (AFT) and DMFs in order to adjust polymer dosing and filtration rates to meet recycled water quality objectives. Additionally, the current Sodium Hypochlorite Disinfection Project has also identified that this process “occurs daily” and is “inefficient and difficult to control.” For these reasons, this alternative is not recommended for further consideration.

5.1.1.2 DMF (Continuous) + UF

This alternative includes:

- Filtering the total secondary effluent flow through the DMFs to Bay discharge quality.
- Diverting a portion of the filter effluent to a UF facility, which would produce Title 22 quality effluent for RW needs; and treating the remainder of the DMF effluent for Bay discharge.

As part of this master plan effort, it was suggested that an UF process could be implemented to remove the color from the filter effluent diverted for RW use. This assumption is based on similar algae removal experience utilized in water treatment. For this alternative, the full AFT effluent would be filtered through the DMFs and a sidestream would be diverted to a dedicated UF facility for RW production. The remainder of the filter effluent would be discharged to the Bay. A comparable installation is shown in Figure 2 and a conceptual site location is shown in Figure 3. A UF facility has a lower capital cost and would be easier to operate than a MBR facility.

There is some uncertainty regarding the feasibility of this alternative to remove color. Before the UF could be selected for implementation, it is recommended the City conduct pilot tests to determine whether UF will be effective at removing color. As a first step, the City would first conduct a bench-scale pilot test, which could be performed in a short period of time (about one month). If this test yields promising results, the City could then conduct pilot testing with a trailer-mounted UF unit to determine performance of actual UF technology over an extended period (i.e., six months) to determine the performance and viability of the process over a range of operating conditions. If UF alone does not remove color, an oxidant such as potassium permanganate ($KMnO_4$) could be added to facilitate color removal.

Figure 2
3 MGD ULTRAFILTER INSTALLATION
FILTRATION
MASTER PLAN AND PRIMARY TREATMENT DESIGN
CITY OF SUNNYVALE

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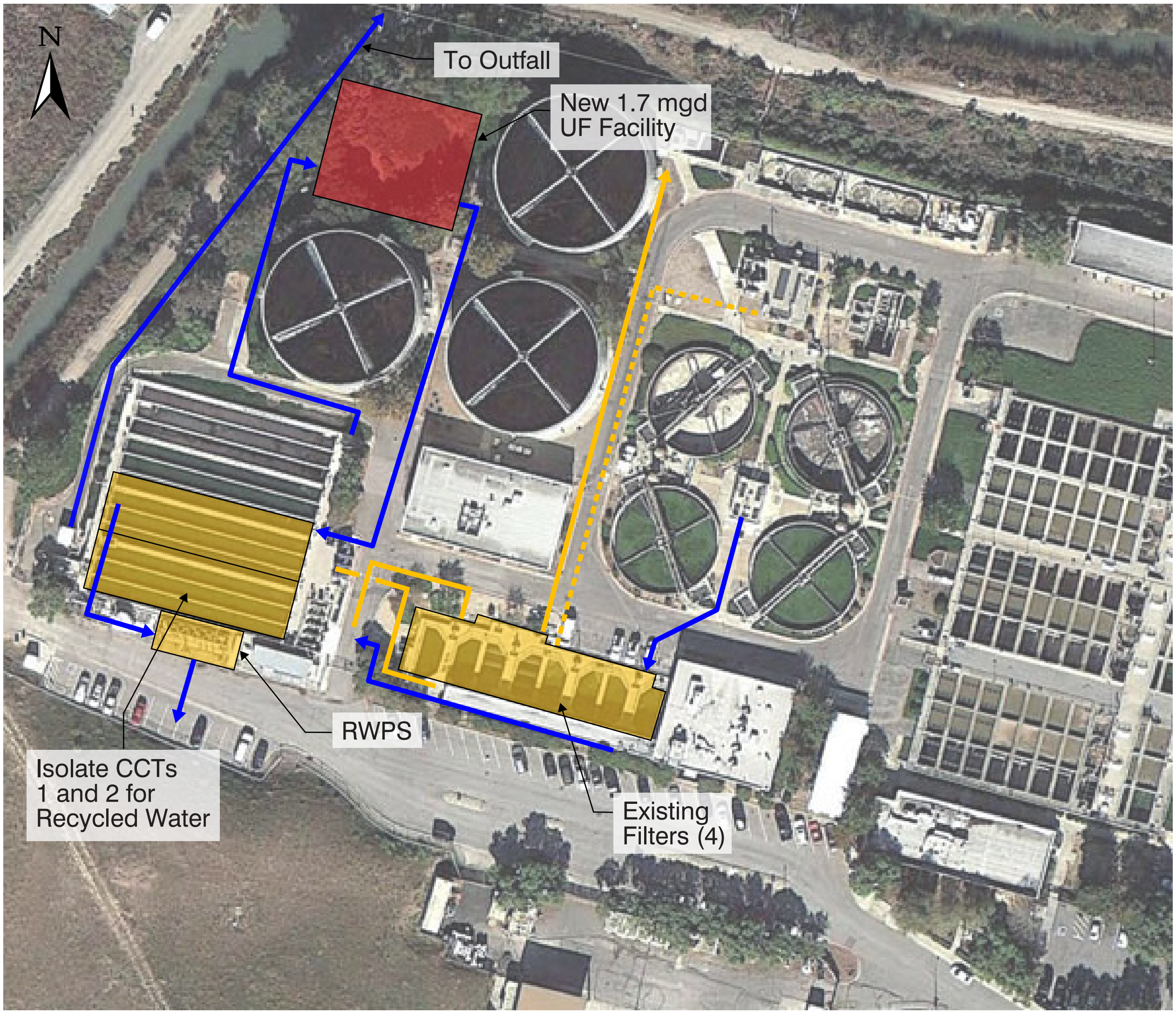


LEGEND
Typical flow path
Alternate flow path
Bypass and overflow
Existing facilities
New facilities

Figure 3
PRELIMINARY ULTRAFILTER FACILITY LAYOUT
FILTRATION
MASTER PLAN AND PRIMARY TREATMENT DESIGN
CITY OF SUNNYVALE

5.1.1.3 DMF + MBR

The alternative includes:

- Diverting a portion of the primary effluent to a small MBR facility, which would produce Title 22 quality filtered effluent for RW needs.
- Treating the remaining primary effluent with the existing secondary treatment process and DMFs for Bay discharge.

The FSRWE recommended an MBR facility as a way to produce a RW supply without having to deal with the color issue. In this alternative, the Bay discharge flows would continue to be treated through the WPCP's existing treatment process. A selected volume of primary effluent would be treated in an MBR system that is dedicated for RW use. While this alternative would achieve both the Bay discharge and RW filtration objectives, MBRs require a significant capital and O&M investment.

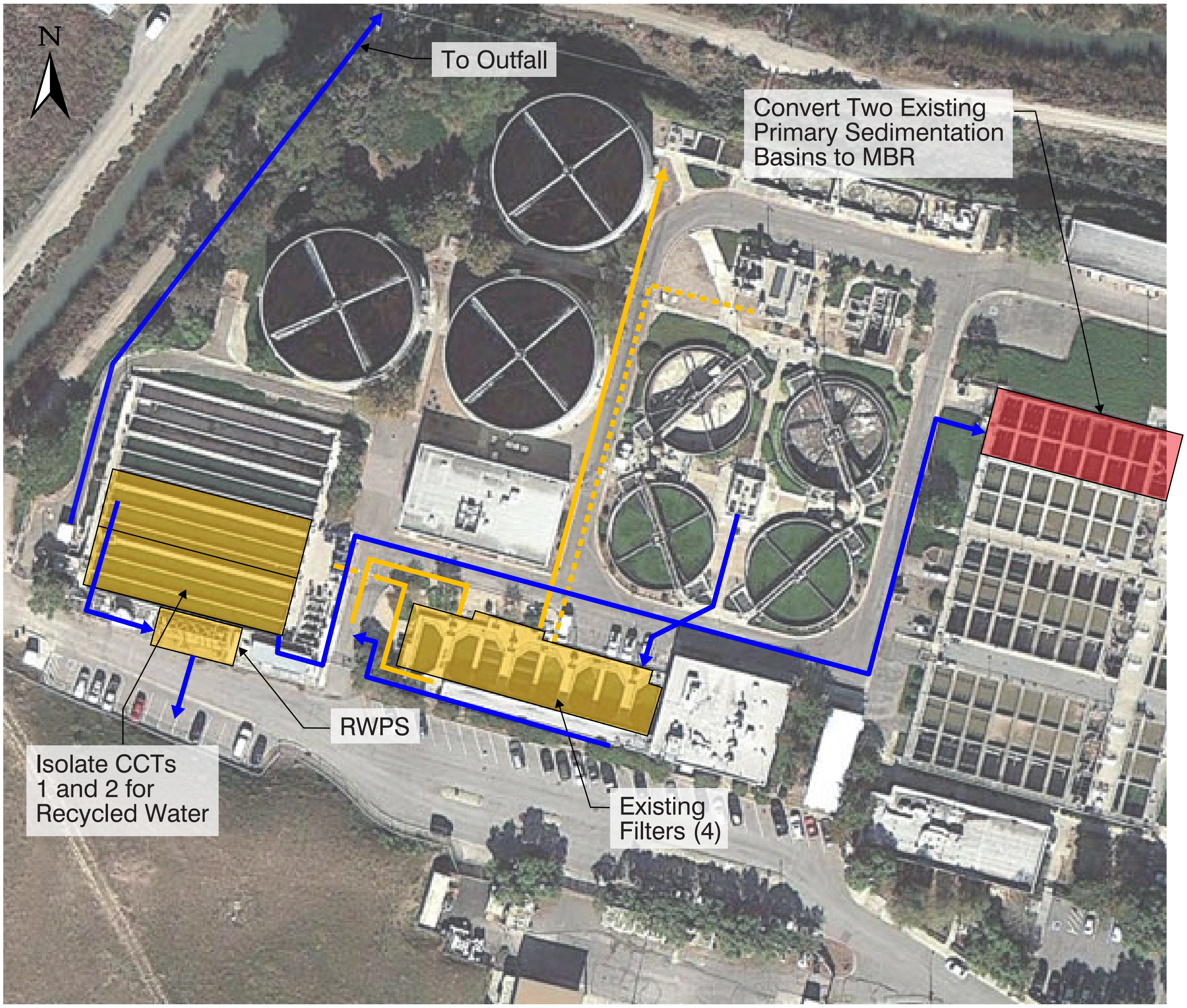
During the October workshop, the option of converting an existing primary sedimentation tank for use as an MBR was discussed as a potential cost saving measure (illustrated in Figure 4). However, even with this approach, it appears that the MBR alternative would only be cost effective if MBRs are selected as the future secondary treatment process. It should be noted that if MBRs are selected for the future secondary treatment process, the existing filtration process would no longer be needed to meet Bay discharge and RW quality objectives and the existing filtration process would be abandoned and/or demolished.

5.1.1.4 DMF (Continuous) + Potable Water Blending

This alternative includes:

- Filtering the total secondary effluent flow with the existing DMFs to produce Title 22 quality effluent. This requires performing a filter re-rating study to allow the existing DMFs to filter recycled water at a higher surface loading rate.
- Diverting a portion of the DMF effluent for RW use; and treating the remainder of the DMF effluent for Bay discharge.
- Purchasing potable water to supplement peak recycled water demands and dilute color.

With this alternative, the existing treatment process would be modified to treat the entire filter effluent to meet Title 22 requirements. This alternative will require increased polymer doses at the AFTs to allow the DMFs to filter the full effluent flow to RW quality standards. As previously noted, this alternative would also require the City to conduct a re-rating study on the existing DMFs so they can be rated for a higher filter loading rate for RW production. Based on Carollo/HDR's experience, it is anticipated a filter re-rating study would allow the existing DMFs filters to be rated at maximum RW filter loading rate of about 7.5 gpm/SF. At this loading rate, the filters would have sufficient capacity to treat the project 2025 peak flow through the filters.



LEGEND
Typical flow path
Alternate flow path
Bypass and overflow
Existing facilities
New facilities

Figure 4
PRELIMINARY MBR LAYOUT
FILTRATION
MASTER PLAN AND PRIMARY TREATMENT DESIGN
CITY OF SUNNYVALE

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With this alternative, the filter effluent diverted for RW use would be supplemented with potable water, as needed to meet RW demands and to dilute the color of the effluent to a desirable level. The FSRWE identified several potable water supply sources that are available to the City, and showed that potable water can be blended with the City's recycled water to satisfy the City's recycled water objectives. A tentative 80:20 blend of RW and potable water was presented in the FSRWE. The actual blend will depend on peak demands and the pond effluent water quality.

While there are additional costs incurred from shorter filter run times and higher filter polymer doses for the portion of the final effluent that would be discharged to the Bay, these costs are lower than constructing a UF or MBR facility dedicated for RW production. The ability to filter the full secondary effluent flow to Title 22 quality standards would also eliminate the need to modify filter influent/effluent piping and operate separate filter trains for Bay discharge and for RW demands.

5.1.2 Net Present Value Analysis

A net present value (NPV) evaluation of the alternatives was prepared and is summarized in Table 4. The net present value analysis includes capital cost and annual O&M costs including power, maintenance and labor costs. Based on this analysis, the low cost alternatives are DMF (Existing Batch Operation) and DMF (Continuous Operation) with Potable Water Blending. Although these alternatives include additional cost for potable water and polymer use, these costs were found to be less than the cost to construct and operate an MBR or UF facility.

Table 4 Near-Term Alternatives NPV Comparison
Master Plan and Primary Treatment Design
City of Sunnyvale

	DMF (Existing Batch Operation)	DMF (Continuous) + UF	DMF (Continuous) + MBR	DMF (Continuous) + Potable Water Blending
Capital Cost	$3.0M ±	$9.1M ±	$15.9M ±	$3.7M ±
Annual O&M Cost	$349K ±	$215K ±	$588K ±	$470K ±
Net Present Value (NPV)	$4.9M ±	$10.3M ±	$19.0M ±	$6.2M ±

Notes:
(1) Costs in this table should only be used for alternatives comparison only. Cost estimates exclude common facilities (e.g., common yard piping, etc.)
(2) Power costs are based on an electricity cost of $0.20/kWh.
(3) Net present value is based on a 6-year life cycle between 2017 and 2023.

Recent discussions with the City indicate the cost of potable water may increase by about 20 percent over the planning period. If this potable water cost increase were to occur, this alternative would still have a lower net present value than the UF and MBR alternatives.

5.1.3 Evaluation Summary

Table 5 summarizes how each alternative meets the City's evaluation criteria for the Master Plan, which is described further in the SIP Validation TM.

Table 5 Evaluation Summary of Screening Alternatives
Master Plan and Primary Treatment Design
City of Sunnyvale

Evaluation Criteria	DMF (Existing Batch Operation)	DMF (Continuous) + UF	DMF (Continuous) + MBR	DMF (Continuous) + Potable Water Blending
Effluent water quality	-	+(2)	+	0
Reliability	-	0	0	0
Ease of O&M	-	-	-	-
Maximize Resources	0	0	0	-
Power Usage	+	-	-	+
Flexibility	0	+	+	0
Ease of Implementation/ Compliance	0	-	-	+
Site Efficiency	0	-	-	+
Net Present Value (NPV)	+	-	-	+

Notes:
(1) Legend: + Better; 0 Neutral; - Worse.
(2) Performance of UF needs to be proven through pilot testing.

Based on the analysis summarized in Table 5, DMF (Continuous Operation) with Potable Water Blending is recommended over the other alternatives because: (1) it has a low capital and O&M cost; (2) it is simple to implement and operate, which facilitates unattended operation; and (3) there are no stranded assets with this alternative after the new secondary treatment process is implemented.

The near-term operating criteria for this alternative are summarized in Table 6.

Table 6 Near-Term DMF Operating Criteria Master Plan and Primary Treatment Design City of Sunnyvale			
Condition	**Flow, mgd**	**Filters, No.**[(1)]	**Filtration Rate, gpm/sf**[(2)]
2025 AAF	17.8	3[(3)]	6.44
2025 MMF[(3)]	22.9	4	5.52

Notes:
(1) Number of filters assumes that one filter is in backwash operation, e.g., filter loading rates based on either 2 or 3 filters in operation.
(2) Surface area of each filter = 960 sf.
(3) One filter available for shutdown and maintenance.

5.2 Long-Term Alternatives

Only one alternative was considered for the long-term considerations for two reasons: (1) the existing filters would be able filter the full WPCP effluent during a majority of the year; and (2) there would no longer be color-removal requirements after the existing secondary pond process is replaced with an activated sludge process.

5.2.1 DMF (Continuous) + Potable Water Blending

This alternative includes:

- Filtering the total secondary effluent flow with the existing DMFs to produce Title 22 quality effluent. This requires performing a filter re-rating study to allow the existing DMFs to filter recycled water at a higher surface loading rate.
- Diverting a portion of the DMF effluent to the RW disinfection process for RW use; and disinfecting the remaining effluent to meet Bay discharge requirements and discharging it to the Bay.
- Purchasing potable water to supplement peak recycled water demands and dilute color.

This alternative is the same as the near-term alternative, with one exception – the filter influent is anticipated to be higher quality with the implementation of a new secondary treatment process. As noted earlier, treating the full secondary effluent flow to Title 22 filtration standards would require the City to conduct a re-rating study on the existing DMFs.

The long-term operating criteria for this alternative are summarized in Table 7.

Table 7	Long-Term DMF Operating Criteria Master Plan and Primary Treatment Design City of Sunnyvale		
Condition	**Flow, mgd**	**Filters, No.(1)**	**Filtration Rate, gpm/sf(2)**
2035 AAF	20.4	3(3)	7.4(4)
2035 MMF	26.2	4	6.3
2035 Equalized Peak Day Flow	34.7	4	8.4(5)

Notes:
(1) Number of filters assumes that one filter is in backwash operation, e.g., filter loading rates based on either 2 or 3 filters in operation.
(2) Surface area of each filter = 960 sf.
(3) One filter available for shutdown and maintenance.
(4) It is anticipated that the filter re-rating study will allow the filters to be operated at about 7.5 gpm/sf for recycled water (RW) production.
(5) During peak flow events, the filter loading rate will exceed the projected re-rated filter loading rate of about 7.5 gpm/SF.

Under 2035 AAF conditions, three filters (2 operating + 1 backwashing) would be able to filter the projected flow of 20.4 mgd at 7.4 gpm/sf, which is within the projected re-rated filter loading rate. AAF conditions allow the WPCP to shut down one filter for routine maintenance and/or rehabilitation.

Under 2035 MMF conditions, four filters (3 operating + 1 backwashing) would be able to filter a projected flow of 26.2 mgd at 6.3 gpm/sf, which is within the projected re-rated filter loading rate.

As noted in Table 7, sometime between 2025 and 2035, peak day flow events during the wet weather months (typically December through March) could load the filters higher than the expected re-rated filter loading rate of about 7.5 gpm/sf. During these times, filter effluent would not be able to be used for RW needs and it is recommended that potable water be used to meet RW demands. RW demands during peak flow events are anticipated to be low, based on historical RW demand at the City during wet weather seasons. As a result, it is anticipated that the potable water usage would be low as well.

5.3 Implications of Split Flow Secondary Treatment on Long Term Alternatives

During the October 2013 process workshop the City expressed interest in implementing a split-flow secondary treatment process. This would include treating a portion of the primary effluent flow with a new conventional activated sludge process or MBR process, and treating the remainder of the primary effluent flow with the existing oxidation pond/FGR/AFT process facilities. For more information on the split flow treatment alternatives considered for the Master Plan refer to the Secondary Treatment TM.

If split-flow treatment is implemented, only the effluent produced by the new secondary treatment process would be used for RW production. Piping, gates, valves and/or other equipment would need to be implemented to isolate the higher quality conventional AS or MBR effluent from the lower quality pond effluent for RW production.

Given an MBR system would meet Title 22 requirements for filtration, the MBR effluent would bypass the existing DMF process and flow directly to the disinfection process. With this process configuration, the DMFs would operate at a lower filter loading rate, and as result would produce higher quality effluent and potentially require less backwashing and polymer use.

6.0 IMPLEMENTATION CONSIDERATIONS

The recommended near-term and long-term alternatives both use existing facilities, so implementation considerations are minimal. However, the following items are noted:

- CCT modifications are described in the Disinfection TM.
- A filter re-rating study would need to be performed to maximize the RW treatment capacity of the existing DMFs. A polymer dosing study should be performed around the same time to optimize filter performance.
- Perform piping and valve inspection and perform necessary replacement prior to the implementation of the new secondary treatment process.
- Currently the filter backwash is sent to the ponds. Once use of the ponds is discontinued, a separate backwash storage and metering system would need to be installed (use of one of the existing AFT tanks appears to be feasible)..

Additional implementation considerations are discussed in the Program Implementation Plan TM.

7.0 SITE CONSIDERATIONS

The existing DMFs would continue to be used throughout the planning period and would be replaced when either: (1) a total nitrogen (TN) limit of 3 mg/L is required (anticipated no sooner than 2040±); or (2) a full-scale MBR facility is constructed. If a TN limit of 3 mg/L is required, the existing DMFs would need to be replaced with denitrification filters to achieve this low effluent nitrate concentration (product literature is included in Appendix E).

Additional site planning considerations are discussed in the Site Layout Considerations TM.

8.0 FINDINGS/RECOMMENDATIONS

The potential re-rating of the existing DMFs and the availability of potable water for blending could allow the WPCP to cost effectively filter all the secondary effluent to Title 22 standards. While there are additional costs incurred from shorter filter run times and higher filter polymer doses for the portion of the final effluent that would be discharged to the Bay, these costs are lower than constructing and operating either a UF or MBR facility.

Therefore, it is recommended that following filtration-related improvements be implemented:

- Continue using the existing DMFs for both Bay discharge and production of recycled water (RW) until either: (1) the need for denitrification filters is required to meet more strict nitrogen standards (anticipated to be no earlier that 2040±) or (2) a full MBR secondary facility becomes operational.
- Eliminate current batch production of RW by filtering all secondary effluent to Title 22 standards and dedicating a portion of the disinfection process to RW production.
  - This requires performing a filter re-rating study when the actual filter loading rates begin to reach 5 gpm/SF. Filter loading rates will reach 5 gpm/SF when the filter influent flow reaches 21 mgd, which is projected to occur around 2019.
  - In addition to the re-rating study, implement a polymer dosing system at the DMFs to optimize filter performance.
- Implement potable water blending to meet RW peak demands, water quality objectives, and redundancy needs. Potable water blending needs are anticipated to be minimal. The existing DMFs should be able to meet RW water quality objectives and requirements during all flow conditions except peak day flows at buildout. During these periods, the RW demand is anticipated to be negligible based on historical RW usage.

APPENDIX A – PROCESS ALTERNATIVES REVIEW WORKSHOP MINUTES AND SLIDES – OCTOBER 15, 2013

Engineers...Working Wonders With Water™

CONFERENCE MEMORANDUM

Project:	Master Plan and Primary Treatment Design	**Conf. Date:**	October 15, 2013
Client:	City of Sunnyvale	**Issue Date:**	October 31, 2013
Location:	West Conference Room		

Attendees:

City:
John Stufflebean
Kent Steffens
Craig Mobeck
Bhavani Yerrapotu
Bryan Berdeen
Dan Hammons
Melody Tovar
Manuel Pineda
Mansour Nasser
Alo Kauravlla

SCVWD:
Hossein Ashktorab
Luis Jaimes

Carollo/HDR/Subconsultants:
Jim Hagstrom
Jamel Demir
Jan Davel
Katy Rogers
Anne Conklin
Daniel Cheng
Scott Parker
Walid Karam
James Wickstrom

Boris Pastushenko
David Jenkins
Alex Ekster
J.B. Neethling

Dana Hunt
Hany Gerges
June Leng

Ray Goebel

Purpose: Process Alternatives Review Workshop (Workshop 2)

Distribution: Attendees **File:** 9265A.00

Discussion:
The following is our understanding of the subject matter covered in this conference. If this differs with your understanding, please notify us.

1. **FILTRATION**
   a. **Discussion**
      1) Regulatory Considerations and Implications
         a) The Basin Plan does not explicitly require filtration, but cites the use of filtration as a factor by which the South Bay treatment plants provide "equivalent protection" and hence qualify for an exception to the Basin Plan

prohibition on “shallow water” discharges. After some discussion, it was noted that the Master Plan will assume a filtration requirement for Bay discharge.

b) At the moment, Apple’s recycled water quality requirements are very stringent, sometimes more than potable water requirements. However, they seemed open to adjusting their requirements during negotiations with SCVWD. It was agreed to move forward with the assumption to provide Title 22 quality recycled water to Apple.

c) Some questions regarding TDS levels in WPCP influent. Overall water supply TDS is low. The City has discovered a pipe that is introducing Bay water to the collection system. The flow is estimated to be around 0.5 mgd and contributes 2,600 mg/l of TDS. The City is currently working to seal the leak, which should lower the influent TDS to the WPCP.

2) Long Term Alternatives

   a) Analysis indicates that it is viable to continue use of the existing dual media filters.

   b) A filter re-rating study should be perform to allow production of Title 22 quality water at higher filter loading rates (precedent set for this).

   c) The analysis of alternatives indicates that supplementing with potable water is the lowest NPV option.

   d) There was discussion on how peak flows would affect filter operation. It was noted that San Jose has loaded their filters at 9 gpm/sf during peak flows, and that the main considerations of peak flow loading is the exceedances of Title 22 filtration rate limits and a shortened filter run time.

   e) It was noted that potable water blending will provide additional reliability to the recycled water system.

3) Short Term Alternatives

   a) The existing chlorine contact basins can be modified to allow for a dedicated recycled water channel (eliminates batch operation).

   b) With this modification, the existing filters, supplemented by potable water, could meet the near-term recycled water demands.

   c) It was noted that the interim filtration requirements would need to be refined to consider the split treatment scenario.

   d) While MBR and UF were only presented as short term solutions, there was interest in determining how much these facilities would impact the future secondary treatment costs.

4) SCVWD staff indicated that their Board has just approved funding for an indirect potable reuse (IPR) study. Therefore, the City should include IPR in the future MP process planning considerations. It was noted that the decision for the secondary processes will need to be made in the spring of 2014. Therefore, SCVWD will need to provide a clear direction for IPR prior to that. All agreed that the consideration of IPR will impact the short and long term recommendations for the filtration process.

5) **It is recommended that the existing filter facilities continue to be utilized for both Bay discharge and recycled water needs.**

b. **<u>Decisions</u>**

1) Final decision on filtration approach will be pending SCVWD's IPR evaluation.

c. **<u>Action Items</u>**

1) Carollo needs to determine impacts of peak flows on the final recommendation.
2) A separate meeting will be scheduled between the City and the master plan team to discuss possible impacts of IPR.

2. **DISINFECTION**.

a. **<u>Discussion</u>**

1) Regulatory Considerations and Implications
   a) Current disinfection requirements include effluent limits for total coliform (for recycled water) and enterococcus (for Bay discharge). CECs, THMs and NDMA are future long-term considerations.
2) Alternatives
   a) Based on near-term Bay discharge and recycled water demands, continue transition from gaseous chlorine to HOCl disinfection.
      (1) Dedicate three chlorine contact tanks (CCTs) to Bay discharge and one CCT to recycled water.
      (2) Identified need to add aqueous ammonia feed station to disinfect fully nitrified AS effluent. This avoids break-point chlorination to maintain the required chlorine residual (and also mitigates THM formation). THMs will continue to be monitored.
      (3) UV could become an alternative when NDMA and THMs are regulated (long-term issue).
      (4) Ozone would be an effective AOP for CECs (whether added to HOCl or UV or as a standalone single treatment technology).
   b) There was a discussion on whether or not to add ammonia to free chlorine after the new secondary process comes online. Carollo/HDR recommended that the Master Plan analysis assume that ammonia addition is needed for chloramination. When TN limits become a reality, one option is to evaluate a dual disinfection process – chloramination followed by free chlorine. This is currently done in LA County.
   c) The group noted that CEC's could be a direct concern if IPR is implemented.
   d) Two ideas were proposed to mitigate THM formation:
      (1) Perform breakpoint chlorination to mitigate NDMA. It was noted that free chlorine would not be effective for NDMA control.
      (2) Add ozone prior to the filters, which allows the filters to more effectively remove precursors for THMs.

e) Carollo/HDR concluded that building an MBR for the near term recycled water demands alone is not a cost effective option.

f) **Carollo/HDR recommended that master planning site space be reviewed and potentially allocated at the WPCP for not only the HOCl and aqueous ammonia facilities, but for potential UV and ozone facilities.**

3) Layouts

a) Based on accommodating potential IPR needs, It was noted that an 8,000 sf RO facility will most likely not fit on the WPCP site if conventional AS is selected (MBRs provide space for an RO facility.

b. **Decisions**

1) Continue with the conversion to HOCl disinfection.

2) In future, once the NAS system is operational, add aqueous ammonia to chloraminate.

3) If NDMA limits precludes the continued addition of aqueous ammonia, monitor THM formation. If THMs become an issue, consider conversion to UV.

4) Once CECs become regulated, consider installation of an ozone system.

c. **Action Items**

1) Carollo to evaluate additional disinfection alternative to minimize THM production – chloramination followed by free chlorine disinfection.

HEADWORKS

a. **Summary of Recommendations**

1) Provide bar screens before pumping.

2) Build headworks structure for build-out flows. Analyze the phasing of mechanical equipment based on flow requirements.

3) Provide odor control for entire headworks facility.

4) Pump station

a) Rectangular wetwell.

b) Dual wetwell configuration

c) Dry-pit pumps

d) Vertical non-clog or submersible non-clog pumps

5) Screening

a) 3/8-inch bar spacing.

b) 3 duty screens, 1 standby screen, 1 bypass channel.

c) Multiple-rake or catenary screen (Duperon).

6) Screenings Conveyance

a) Shaftless screw conveyors.

7) Screenings Washing

a) Auger with Spray Washing.

8) Grit Removal

a) Eutek HeadCell.

b) Two duty plus one standby unit with hydraulic capacity for peak hourly flow, and treatment capacity for peak day flow.

9) Grit Washing

a) Huber Coanda.

b) One standby unit.

b. **Discussion**

1) Influent Pumping

a) There was concern regarding the long shafts inherent to dry pit non-clog pumps. The meeting participants agreed that dry pit submersible pumps should be further evaluated since they do not have associated long shafts.

b) It was noted that the cleaning requirements for the wetwells will be minimal since daily flows should provide sufficient scour.

c) The Master Plan team noted the difficulty of expanding headworks structures. After some discussion, there was general consensus that the headworks structure should be constructed for the buildout flows during the upcoming design, whereas the equipment will be phased in as flows increase.

2) Screening

a) Question raised about getting screenings out (30 foot depth) – sufficient experience noted for this approach. Should be focus of next rounds of field trips.

b) The selection of screen spacing was discussed (trade off of finer materials capture vs. effective organics separation. It was noted to the City that once the new headworks is constructed, the plant will be faced with a new reality – dealing with screenings at the front end of the plant (and not downstream in places like the digesters).

c) The SIP showed that the screenings washing/compacting facility will be housed in a canopy. However, the current assumption is that the screenings washing/compacting facilities will be housed in a masonry building for odor control. There was general agreement regarding this approach.

d) The screens will lift rags and solids above grade, eliminating the need for an angled screw conveyor between the screens and the washer/compactor.

3) Grit Removal

a) The grit study found that the grit at Sunnyvale is larger than typical grit found at similar plants. However, the grit settles slower than typical grit of similar size. The result is that the required grit facilities (Headcell or aerated grit basin) would need to be 60% larger than an equivalently sized facility at a typical treatment plant.

b) The NPV analysis recommends the selection of the HeadCell technology based on cost and footprint. However, it was noted that inspection and maintenance considerations will need to be further refined.

4) Grit Washing
   a) There was general agreement that even though Coanda is 25 – 30% more expensive than a cyclone, it produces higher quality grit and should be selected.
   b) The City expressed the desire to have a standby Coanda unit. Carollo/HDR recommend having a standby unit.

c. **Decisions**

1) Provide screens ahead of influent pumping.
2) Select 3/8" bar spacing.
3) Build headworks structure for buildout flows but phase in additional equipment as flows increase.
4) Provide odor control at the headworks.
5) Provide a pump station with a rectangular, dual, dry-pit configuration.
6) Provide shaftless screw conveyors for screenings conveyance.
7) Provide auger with spray washing for screenings washing/compaction.
8) Provide a building to house the screening and grit handling equipment.
9) Provide HeadCell for grit removal.
10) Provide Coanda for grit washing and dewatering.

d. **Action Items**

1) Schedule site visits to influent pump stations that are configured with a rectangular dry pit.
2) Resolve pump selection as part of pre-design
3) Carollo to identify potential sole-source equipment issues associated with the headworks implementation.

3. **THICKENING**

a. **Summary of Recommendations**

1) Based on analysis of alternatives, rotating drum thickeners (RDTs) are the recommended technology for thickening of WAS only
2) Could be used for co-thickening if that is desired
3) Could be co-located with dewatering facility

b. **Discussion**

1) Odor control will need to be provided as part of this facility.

c. **Decisions**

1) Provide RDTs to thicken WAS.

d. **Action Items**

1) City to visit some RDT facilities.

4. **DIGESTION**

a. **Summary of Recommendations**

1) Modify to allow all digester to operate as primary units.
2) Potential need identified for two additional digesters (needs to be evaluated after AS plant comes on-line). New digesters would be the same size as Digester No. 4.
3) Provide space for either pre-process or post-processing technologies.

b. **Discussion**

1) Regulatory Considerations and Implications.
   a) No current or near-term drivers for Class A sludge
   b) 503 regs drive HRT detention time (minimum of 15 days), but criteria used is typically more like 20 days. Analysis of future digester needs is based on 20 days.
2) It was noted that space should be left for pre-processing (sonication) and post-processing (drying) because industry trends indicate that these technologies will gain traction in the future.
3) Brought up the possibility of producing green waste pellets. It was noted that SRCSD tried a pelletizing operation, but discovered that it was costing $350/ton to operate, which is very expensive.
4) Co-thickening primary sludge and WAS can bring the sludge up between 5%-6% prior to digestion (determine sensitivity on future digester needs).
5) Regarding the possibility of receiving FOG, Carollo/HDR's experience is that projected FOG loadings are typically double the actual amounts generated. It was also noted that the City's SMaRT station will be rebuilt around 2021/2022, and any food/FOG waste can be considered as part of that renewal effort.

c. **Decisions**

1) Provide space for primary sludge screening.
2) Provide space for two additional digesters with the same capacity as Digester No. 4.
3) Provide space for possible FOG station to receive FOG and liquefied food waste.

d. **Action Items**

1) Carollo/HDR to show the impact of FOG and food waste in digester gas projections during the plant energy balance exercise.
2) Carollo/HDR to determine sensitivity of digester capacity as a function of sludge thickness.

5. **DEWATERING**

a. **Summary of Recommendations**

1) Centrifuges were lowest NPV alternative – but screw presses still under consideration.

b. **Discussion**

1) The group discussed the O&M requirements between screw presses and centrifuges. It was noted that centrifuges are more labor intensive but screw presses are more costly. Operations staff felt that screw presses could be operated with less attention.

2) Implementing centrifuges or screw presses are both viable options for sludge dewatering. The decision is largely dependent on O&M preferences.

c. **Decisions**

1) Delay the decision of sludge dewatering technology, until City staff visits screw press and centrifuge dewatering facilities and determines technology preferences.

d. **Action Items**

1) Carollo to organize site visits to screw press and centrifuge dewatering facilities with City staff.

6. **ODOR CONTROL**

a. Summary of Recommendations

1) Provide bioscrubbers for odor control

2) Near Term – Implement odor control at headworks and primary sedimentation tanks.

3) Long Term – Implement odor control at thickening/dewatering facilities.

b. Discussion

1) Odor testing at the plant site revealed that there are no major issues with RSC and VOCs.

2) Field testing work indicated odor issues associated with the existing headworks/primary sedimentation tanks.

c. Decision Log

1) Provide odor control at the headworks and primary sedimentation tanks as part of the Phase 1 project.

d. Action Items

1) None

Prepared By:

Daniel Cheng

DC:JD:dc

This workshop module will be a success if …

- ✓ Establish filtration technology for:
  - ✓ Recycled water
  - ✓ Bay discharge

Agenda

- Future regulations and their anticipated impact
- SIP and other recommendations
- Long-term alternatives analysis
- Short-term alternatives analysis
- Recommendations
- Next steps

Regulations

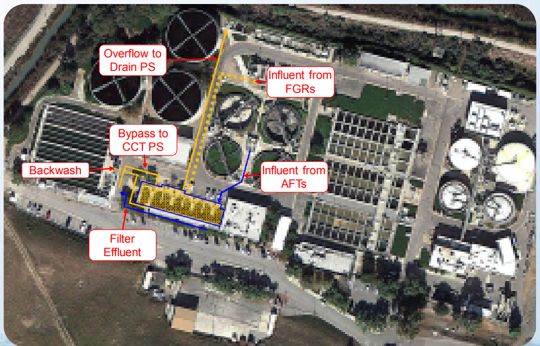
Why do you need filtration at the WPCP?

- Bay discharge
  - Guadalupe Slough
  - Discharge to a "dead-end" (does not flush year round) slough is prohibited
- Recycled water:
  - Title 22
    - Turbidity: 2 NTU
    - Total Coliform: 2.2 MPN/100 mL
  - Color (short-term issue)
    - Requires membranes, oxidation, or through dilution with potable water

Filtration provides exemption from the Basin Plan

SIP and Other Recommendations

Existing Dual-Media Filter Layout

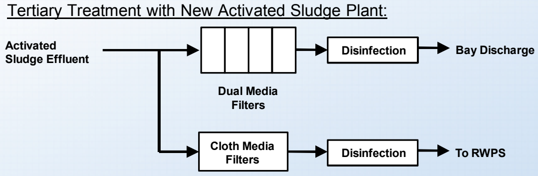


SIP Recommendations

- Bay discharge:
  - Waiver from dead-end slough requirements (Basin Plan) conditioned on compliance with effluent limitations
  - Continuous use of DMF
- Recycled water:
  - Need for continuous recycled water production:
    - New cloth filters
    - 4 mgd recycled water demand (~2035), with a possible expansion to 8 mgd

SIP Long-Term Recommendations

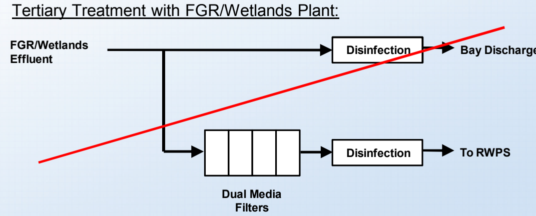
Tertiary Treatment with New Activated Sludge Plant:



Tertiary Treatment with New MBR Plant:

SIP Peer Review Long-Term Recommendations

Tertiary Treatment with FGR/Wetlands Plant:



FSRWE (2013) Summary Findings

- Feasibility Study for Recycled Water Expansion (FSRWE) (2013) identified:
  - 1.7 mgd required by 2017
    - 3 mgd with Apple included (outside of service area, identified after the FSRWE)
  - 3.6 mgd required between 2017 and 2033 (without Apple)
  - Peak demands (up to 6.4 mgd) would be met with potable water

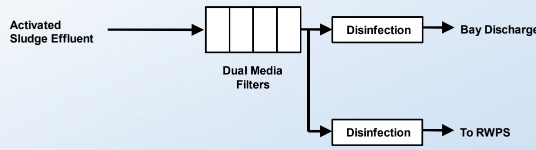
FSRWE (2013) Summary Findings

Continued

- In the near term (up until activated sludge, ~2022/2023):
  - Need to remove color resulting from pond treatment
  - MBR or MF/UF, depending on selected secondary treatment process
- TDS higher than desired:
  - Existing (average, 2011): 930 mg/L
  - Water Quality Objectives: 760 mg/L

Long-Term Alternatives Analysis (Beyond 2022/23)

DMF-Only Alternative for Continuous Recycled Water Production – Long Term



Modifications to CCT to allow Continuous Recycled Water Production

DMF-Only Alternative - Filter Loading Rates (2035 Flows) – Bay Discharge

Condition	2035 Flow, mgd	Bay Discharge, mgd	Filters in use, no.	SLR, gpm/sf	Design SLR, gpm/sf
Summer: ADAF	20.4	16.8	3 of 4	4.9	5.8
Winter: ADMMF	26.2	26.2	3 of 4	6.3	5.8

Note:
ADAF = Average Day Annual Flow
ADMMF = Average Day Maximum Month Flow

DMF-Only Alternative - Filter Loading Rates (2035 Flows) – Recycled Water

Condition	2035 Flow, mgd	Recycled Water, mgd	Filters in use, no.	SLR, gpm/sf	Maximum SLR, gpm/sf
Summer: ADAF	20.4	3.6	3 of 4	4.9	5.0
Winter: ADMMF	26.2	Potable water[(1)]	3 of 4	6.3	5.0

Note:
1. Potable water purchase:
   a. Could be avoided if Title 22 SLR were to be increased.
   b. Does not include purchases to meet peak demands.

ADAF = Average Day Annual Flow
ADMMF = Average Day Maximum Month Flow

Evaluation of Long-Term Alternatives

	1 DMF (Bay) + Cloth Filter (Recycle)	2 DMF (Bay + Recycle)
Reliability	0	+
Ease of O&M	-	+
Maximize Resources	0	0
Power Usage	-	+
Flexibility	0	0
Ease of Implementation/ Compliance	-	+
Site Efficiency	-	+
Net Present Value (NPV)	$12.3M ±	$4.1M ±

+ Better | 0 Neutral | - Worse

Evaluation of Long-Term Alternatives

	1 DMF (Bay) + Cloth Filter (Recycle)	2 DMF (Bay + Recycle)
Reliability	0	+
Ease of O&M	-	+
Maximize Resources	0	0
Power Usage	-	+
Flexibility	0	0
Ease of Implementation/ Compliance	-	+
Site Efficiency	-	+
Net Present Value (NPV)	$12.3M ±	$4.1M ±

+ Better	0 Neutral	- Worse

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Short-Term Alternatives Analysis (Until 2022/23)

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Basis of Short-Term Alternatives Comparison

- 1.7 mgd recycled water demand through 2022/2023, after which:
  - Activated sludge system likely online
  - Color removal no longer an issue
- Color can be addressed through either:
  - Membrane filtration
  - Oxidation
  - Dilution with potable water

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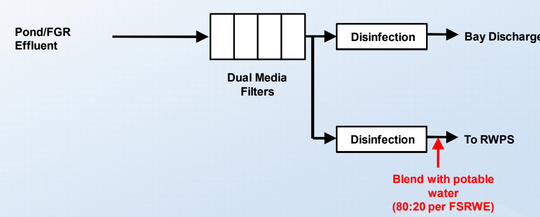
DMF-Only Alternative for Continuous Recycled Water Production – Near Term



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Evaluation of Short-Term Alternatives

	1 DMF (Bay/Recycle – Batch Operation)	2 DMF (Bay) + UF (Recycle)	3 DMF (Bay) + Small MBR (Recycle)	4 DMF (Bay) + DMF/Potable (Recycle)
	Batch	Continuous		
Reliability	-	0	0	0
Ease of O&M	-	-	-	+
Maximize Resources	0	0	0	-
Power Usage	+	-	-	+
Flexibility	0	+	+	0
Ease of Implementation/ Compliance	0	-	-	+
Site Efficiency	0	-	-	+
Net Present Value (NPV)	$4.9M ±	$10.3M ±	$19.0M ±	$6.2M ±

+ Better	0 Neutral	- Worse

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Evaluation of Short-Term Alternatives

	1 DMF (Bay/Recycle – Batch Operation)	2 DMF (Bay) + UF (Recycle)	3 DMF (Bay) + Small MBR (Recycle)	4 DMF (Bay) + DMF/Potable (Recycle)
	Batch	Continuous		
Reliability	-	0	0	0
Ease of O&M	-	-	-	+
Maximize Resources	0	0	0	-
Power Usage	+	-	-	+
Flexibility	0	+	+	0
Ease of Implementation/ Compliance	0	-	-	+
Site Efficiency	0	-	-	+
Net Present Value (NPV)	$4.9M ±	$10.3M ±	$19.0M ±	$6.2M ±

+ Better	0 Neutral	- Worse

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Recommendations and Next Steps

Recommendations

- Continuous recycled water production with DMFs:
  - Low NPV
  - Simple to implement and operate (facilitates unattended operation)
  - No stranded assets beyond 2022/2023
  - CCT modifications required beyond 2022/2023
- Undertake the re-rating study to increase SLR of the DMFs
- Concern
  - Need to revisit implication of color in effluent due to split-treatment option

Next Steps

- Complete the modifications to the DMFs
  - Filter upgrades
  - Separate polymer dosing facility for the DMFs
- Develop CIP project for modifications to the CCTs

This Meeting will be a Success if …

✓ Establish filtration technology for:
  - ✓ Recycled water
  - ✓ Bay discharge

End

New UF Layout

Example of a 3 mgd UF facility Emmons, ND

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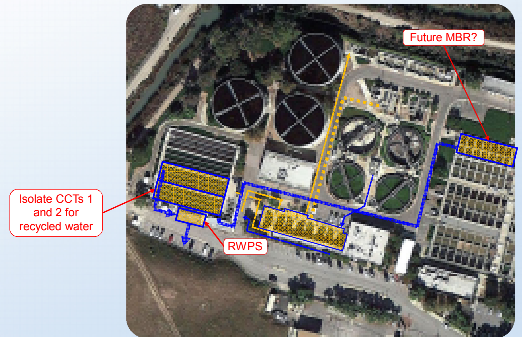
Future 1.7 mgd MBR



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Technical Memorandum

APPENDIX B – 2009 SIP RECYCLED WATER TREATMENT ALTERNATIVES TM

BROWN AND CALDWELL

Technical Memorandum

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Prepared for: City of Sunnyvale, Sunnyvale, CA

Project Title: WPCP Strategic Infrastructure Plan

Project No: 135083

Technical Memorandum

Subject: Recycled Water Treatment Alternatives

Date: October 10, 2009

To: Lorrie B. Gervin, P.E., City of Sunnyvale

From: Lloyd A. Slezak, Project Manager, Brown and Caldwell

Prepared by: ______________________________

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Reviewed by: ______________________________

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1. EXECUTIVE SUMMARY

The existing tertiary treatment system at the Sunnyvale Water Pollution Control Plant (WPCP) is used to produce both recycled water, which must have a turbidity less than 2 nephelometric turbidity units (NTU), and treated effluent for Bay discharge, which must have a turbidity less than 10 NTU. Switching between operation modes presents significant operational and compliance monitoring challenges. Under recycled water production operation, polymer dose is approximately 1.8 times greater than during Bay discharge mode. In addition, the dual media filters (DMF) are backwashed more frequently. We have evaluated a parallel recycled water system that would produce 4 million gallons per day (mgd) of recycled water (8 mgd, ultimate). A treatment capacity of 4 mgd (8 mgd, ultimate) is in line with the most recent recycled water master plan performed in 2000. We performed this evaluation for both the plant replacement and the plant rehabilitation scenarios. We identified several Title 22 approved filtration technologies and evaluated them on relative life cycle cost, energy consumption, footprint requirement, process maturity and resource consumption. Using these criteria, we selected DMF, cloth media filtration and membrane filtration for detailed evaluation which included planning level cost estimates. For the plant rehabilitation scenario, we recommend planning for new dissolved air flotation (DAF) units followed by DMF. This alternative has a higher present worth value than DAF followed by cloth media filters, however we do not recommend assuming that a cloth media system downstream of the oxidation pond will be feasible due to uncertainty regarding technology performance. Ultimately, pilot testing of this uncertain configuration could lead to a successful execution of the lower cost approach but, for prudent planning at this juncture, the cost and consequences of the DMF based system should be assumed. In addition, we recommend that the City pilot test DMF filtration (using chemical addition) downstream of DAF operating under Bay discharge mode (10-NTU). If successful, this would significantly reduce the capital cost by eliminating the need for dedicated DAF units. For the plant replacement scenario, where conventional activated sludge treatment could precede cloth filters and result in a proven treatment technology configuration, we recommend cloth media filtration, which had the lowest cost (capital and operating) of all alternatives. For the plant rehabilitation scenario, two new chlorine contact tanks (CCTs) would be required at 4-mgd recycled water capacity; four new CCTs would be required at 8-mgd recycled water capacity. For the plant replacement, we assumed that a new ultraviolet light (UV) disinfection system would be constructed.

2. INTRODUCTION

The tertiary treatment system at the Sunnyvale WPCP consists of: DAF and DMF, followed by disinfection. Currently, the fixed growth reactors (FGRs) are upstream of the DAF units, however we recommend operating them downstream of the DAF units to promote more stable operation as shown in Figure 2-1 (see "Nitrification Process Improvements TM"). Tertiary treatment is required for effluent disposal to the San Francisco Bay (Bay). During Bay discharge, the effluent turbidity cannot exceed 10 NTU on an instantaneous basis. The tertiary treatment system is also used to produce recycled water. During recycled water production, turbidity prior to disinfection cannot exceed 2 NTU on a daily average basis. Thus, the tertiary treatment system is operated in two distinct operational modes: 1) Bay discharge (or 10 NTU) and 2) recycled water (or 2 NTU). To meet the more stringent recycled water treatment requirements, polymer dose to the DAF and the chlorine dose to disinfection must be increased. Switching between these two operational modes has resulted in significant operational challenges for WPCP operations staff.

The purpose of this technical memorandum (TM) is to summarize the existing tertiary treatment system at the WPCP, discuss challenges with current operations, and investigate viable alternatives to increase recycled water production to meet future demand. Since recycled water demand is much less than Bay discharge, it would be costly to produce 2-NTU water continuously. The recycled water system improvements presented in the Condition Assessment and Unit Process Improvements TM (Brown and Caldwell) consisted of a parallel process train to continuously produce 2-NTU recycled water. Table 2-1 summarizes recycled water flow projections presented in the Recycled Water Master Plan (EOA, Inc., 2000). The maximum total annual recycled water demand is predicted to range between 4.5 and 5.0 mgd if all projects were constructed. The current recycled water demand is approximately 1 mgd (approximately 2 mgd, maximum month). For this analysis, the parallel recycled water system was sized for 4 mgd with the possibility of expansion to 8 mgd. This sizing is in line with the most recent recycled water flow projections. We evaluated recycled water treatment technologies for both the plant rehabilitation scenario and the plant replacement scenario.

Table 2-1. Summary of Maximum Projected Recycled Water Demand (adapted from City of Sunnyvale Recycled Water Master Plan, EOA, Inc., 2000)

Description	Maximum Projected Flow (mgd)
Current Demand	0.64
Near-term Demand	0.34
Mid-term Demand	0.24
Long-term Demand (within Sunnyvale)	2.3
Long-term (outside Sunnyvale)	1.0 to 1.5
Total	4.5 to 5.0

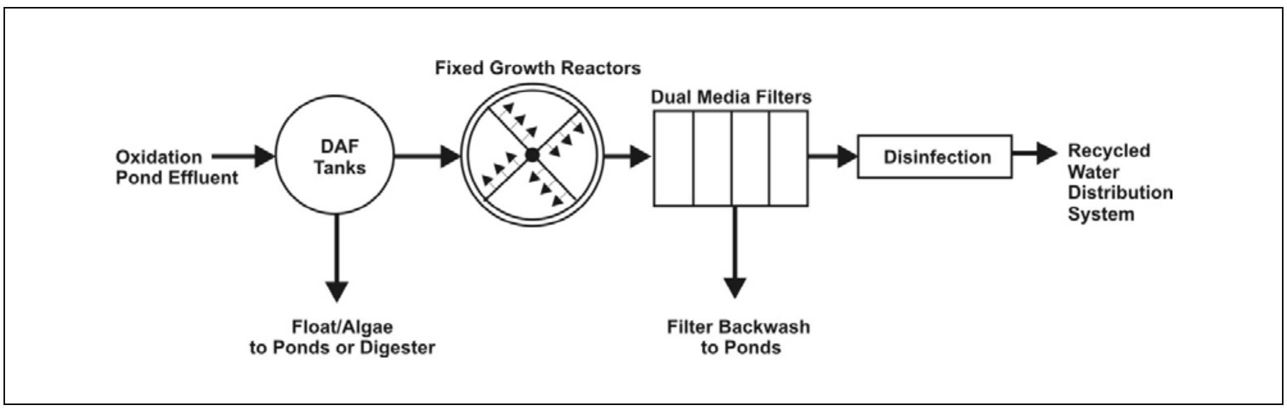

Figure 2-1. Process flow diagram for Sunnyvale WPCP tertiary treatment system. This configuration assumes that the FGRs would be downstream of the DAFs to promote more stable nitrification (see "Nitrification Process Improvements TM"). During recycled water operation, DAF polymer dose and chlorine dose are significantly higher than during Bay discharge operation.

3. EXISTING SYSTEM AND OPERATIONAL CHALLENGES

Recycled water represents a drought-resistant water source to the City of Sunnyvale and is one of the City's Level of Services (LOS). In addition, the use of recycled water reduces potable water consumption and the mass loading of pollutants to the Bay. This section provides an overview of the existing recycled water system at the WPCP; the recycled water distribution system is not considered in this analysis.

3.1 Overview of Existing System

Table 3-1 summarizes the elements of the tertiary treatment system at the WPCP. There are four DAF units that currently treat FGR effluent. Flotation is required prior to filtration due to the high algae content of oxidation pond effluent which passes through the FGRs. If not removed, algae will severely impede DMF performance and increase the frequency of backwashing (which will decrease overall recovery). Historically, polymer has been added to the DAF as a flocculation aid to improve solid-liquid separation. Polymer dosage is determined by the operation mode; recycled water operation requires higher polymer dose than Bay discharge mode.

DAF effluent is treated through four DMF units. The DMF units were designed for a flux of 5.8 gallons per minute per square foot (gpm/sf), equivalent to 8 mgd per unit, assuming all units in service. At 2035 flows (18 million gallons per day [mgd] annual average daily flow [AADF], 22.4 mgd maximum month flow), the loading would be 4.3 gpm/sf.[1] At ultimate flows (29 mgd AADF, 36 mgd maximum month flow[2]), one additional filter would need to be constructed to maintain a loading less than 5.8 gpm/sf.

DMF effluent is disinfected in four, serpentine CCTs using a liquid/gaseous chlorine system. The CCTs were designed for a 60-minute detention time for Bay discharge. At 2035 flows (using maximum month flow for sizing), the plant would need 3 of the 4 CCTs, and at ultimate flows (using maximum month flow for sizing) the plant would require 5 CCTs (all existing 4 CCTs plus 1 new CCT). Dechlorination prior to discharge to the Bay is performed by injecting sulfur dioxide. Dechlorination is not required for recycled water production; however treated effluent is partially dechlorinated with sodium bisulfite after disinfection to reduce the chlorine residual in the distribution system so as not to negatively impact end users. Two CCTs would be necessary for recycled water production at 4 mgd; four CCTs would be required for ultimate recycled water production (8 mgd).[3] If new CCTs were constructed, they would be designed specifically for recycled water production and would, presumably, eliminate the operational challenges associated with the existing units.

During recycled water production, the Recycled Water Pump Station (RWPS) pumps water to the distribution system. The RWPS has six pumps with a maximum total capacity of approximately 8 mgd. However, peak pumping is limited to approximately 6.5 mgd due to a pressure sustaining valve at the San Lucar storage tank (City of Sunnyvale 2008 Recycled Water Annual Report, March 13, 2009). The existing RWPS has sufficient capacity to meet future recycled water demand (4 mgd); no improvements are necessary. For the ultimate

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[1] Filters were sized using maximum month flows increased by 6.7 percent to account for filter backwash.

[2] The maximum month flow for the ultimate flow was determined using the same maximum month to AADF peaking factor for the projected 2035 flow.

[3] For recycled water production, chlorine disinfection requires a 90 minute modal contact time in a CCT according to Title 22. A contact time of 120 minute is assumed to account for hydraulic inefficiencies in the CCTs. Each CCT has a volume of 111,300 gallons. Therefore, each CCT has 2-mgd of treatment capacity, or 4-mgd total. The CCTs may have more treatment capacity, but dye testing would be necessary to confirm this.

recycled water demand (8 mgd), the pressure sustaining valve would need to be repaired to increase distribution capacity.

Table 3-1. Summary of Existing Tertiary Treatment System Processes	
Description	Value
DAF System	
Number of Tanks	4
Diameter, ft	60
Side Water Depth, ft	7
Filters	
Number of Units	4
Length, ft	32
Width, ft	30
Filter Media Depth. in	66
Anthracite, in	48
Sand, in	18
Pea gravel, in	7.5
Maximum Filtration Rate, gpm/sf	5.8
Maximum Backwash Rate, gpm/sf	35
Air Backwash Rate, cfm/sf	4
Chlorine Contact Tanks	
Number of Units	4
Number of Pass (per unit)	3
Width (per pass), ft	10
Length (per pass), ft	124
Depth (per pass), ft	12

3.2 Operational Challenges

The existing tertiary system was not designed to produce treated effluent for both Bay discharge and recycled water production. As a result this poses several operational challenges to plant staff. During recycled water operation, the DAF polymer dose is significantly higher (approximately 1.8 times) than during Bay discharge. As a consequence, DMF backwashing is performed daily, presumably due to the higher polymer dose. At elevated polymer doses, there is a higher possibility that DAF effluent (and therefore DMF influent) will contain residual polymer which can increase DMF headloss. Bay discharge operation results in DMF backwash approximately every 3 days, presumably due to the lower polymer dose. It is also important to note that filtration rates during recycled water operation are much lower than during Bay discharge.

Plant operations staff must routinely reconfigure the DAF polymer dosing depending on the operation mode. During peak recycled water demand periods, staff may reconfigure the process train on a daily basis. When operation is switched from Bay discharge to recycled production, for approximately 2 to 3 hours, DMF effluent does not meet 2-NTU recycled quality even though DAF polymer dose is increased. This represents an additional cost attributed to the current configuration. Plant staff have observed occasional upsets in tertiary treatment performance, where DMF effluent turbidity has been greater than 10 NTU when switching to Bay discharge mode. Switching modes also poses challenges to disinfection. Recycled water production requires higher chlorine dosages so that when Bay discharge is resumed, it can be difficult to sufficiently dechlorinate before discharge. Needless to say, this is a cumbersome and labor-intensive way to operate. The inefficiencies associated with the mode switching can result in the use of potable water to supplement recycled water, which eliminates the benefits of recycled water use to Sunnyvale.

In addition to the operational challenges, there are challenges associated with compliance monitoring. When the plant is in recycled water production mode, it is not possible to collect effluent samples for compliance monitoring. This can pose problems for constituents that require frequent sampling events. Construction of a dedicated recycled water system that would operate in parallel with the tertiary treatment system would mean that Bay discharge would continue regardless of recycled water production.

4. OVERVIEW OF RECYCLED WATER REGULATIONS

Recycled water regulations in California are dictated by Title 22 California Code of Regulations. Recycled water for surface irrigation requires disinfected tertiary (i.e. filtered, nitrification is not required under Title 22) recycled water, which has been biologically oxidized and meets the following criteria:

1. Has been coagulated[4] and passed through natural undisturbed solids or a bed of filter media pursuant to the following:
    a. At a rate that does not exceed 5 gpm/sf in mono, dual or mixed media gravity or pressure filtration systems, or does not exceed 2 gpm/sf in traveling bridge automatic backwash filters; and
    b. The filtered wastewater turbidity does not exceed any of the following; a daily average of 2 NTU, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU at any time.

OR

2. Has been passed through a micro, nano, or reverse osmosis membrane following which the turbidity does not exceed any of the following: 0.2 NTU more than 5 percent of the time within a 24-hour period and 0.5 NTU at any time.

AND

3. Has been disinfected by either:
    a. A chlorine disinfection process that provides a CT of 450 mg-minutes/L with a modal contact time of not less than 90 minutes, based on peak dry weather design flow, or
    b. A disinfection process that, when combined with filtration, has been demonstrated to achieve 5-log inactivation of virus.

There are several alternative technologies to conventional filtration that can meet the filtration requirements and have been documented as accepted by the California Department of Public Health (see Treatment Technology Report for Recycled Water, February 2009). This TM does not cover all filtration technologies in exhaustive review but provides a review of select technologies. For the plant rehabilitation scenario, we assumed that chlorine disinfection would be used for disinfection because of the impact algae could have on the efficiency of UV disinfection. The green color of the water could reduce UV transmittance.[5] For the plant replacement scenario where the pond system would be replaced with an activated sludge process, we assumed that UV disinfection would be used which would eliminate potential disinfection by-products discharge problems that are associated with chlorine based disinfection methods.

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[4] Coagulation may be waived if the filter effluent does not exceed 2 NTU, the filter influent is continuously measured, the filter influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and automatically activated chemical addition or diversion facilities are provided in the event filter effluent turbidity exceeds 5 NTU.

[5] Membrane (either microfilter or ultrafilter) filtered effluent could have less color than other filtration technologies. However, pilot testing would be necessary to confirm. To be conservative, we assumed chlorine disinfection would be used for membranes for the plant rehabilitation scenario.

5. OVERVIEW OF SELECT FILTRATION TECHNOLOGIES

This section includes an overview of five main types of filtration technologies including: conventional depth filtration, continuous backwash filters, fuzzy filters, membrane filters and cloth media filters.

5.1 Conventional Depth Filtration

In the conventional depth filtration process, water filters down through a bed of filter media. Particulates are removed in the filter bed by several mechanisms which include straining, adhesion, impaction, sedimentation, flocculation and interception. Filter media typically rests on top a layer of gravel. An underdrain system, which collects filter effluent, is typically under the layer of gravel. Over time, the accumulation of material in the filter bed will increase head loss, and can eventually result in particle breakthrough in the effluent. Backwashing is performed where flow is reversed through the filter media (using filter effluent) to remove particles. An air scour can also be performed. After backwash, the filter is returned to service. The DMF process is one type of depth filtration process. In the DMF process, two layers of media (typically anthracite and sand) are used.

5.2 Continuous Backwash Filtration

The continuous backwash filter is a granular filter, similar to the DMF process. However, it continuously produces treated effluent since it is never out of service for backwashing. There are currently nine suppliers of Title 22 certified upflow continuous backwash filtration technologies; the Dynasand filter (Figure 5-1), manufactured by Parkson Corp. (Fort Lauderdale, FL), is one example. It is Title 22 approved for a flux of 5 gpm/sf, which is the same flux as DMF. Influent enters the bottom of the sand bed and flows upward. A portion of the sand is continuously washed so that a backwash cycle is not necessary, and the filter is never out of service for backwashing. Continuous backwash filters will have similar footprint requirements to DMF, but will have higher energy costs associated with the continuous backwashing.

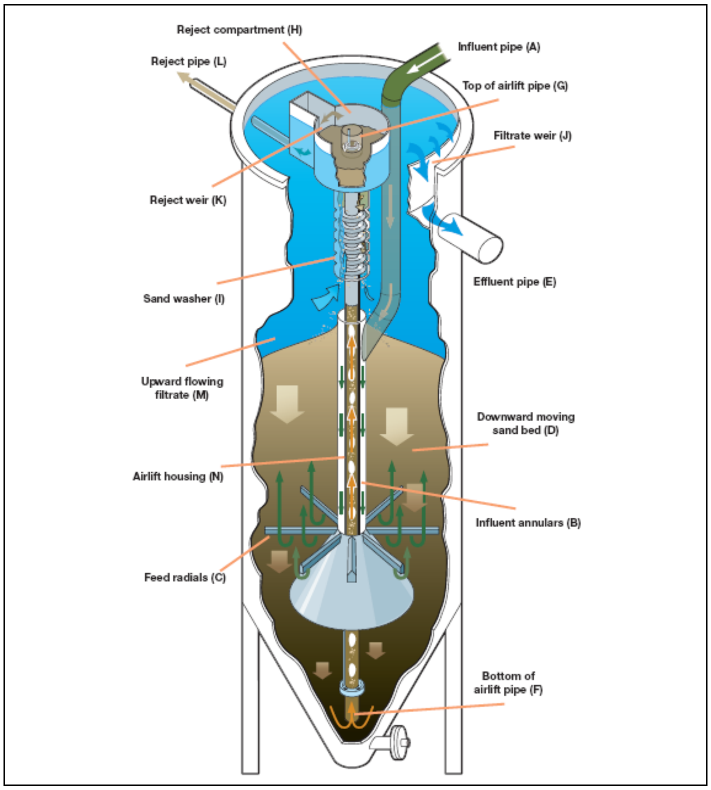

Figure 5-1. Dynasand filter manufactured by Parkson Corpororation. (Source: Parkson website - http://www.parkson.com/files/Product%20Brochures/PC%20FbrglsTankOilWtrSep/PC%20DynaSand.pdf)

5.3 Fuzzy Filter

The Fuzzy Filter (Figure 5-2), manufactured by Schreiber LLC (Trussville, AL), uses a low-density, high-porosity synthetic media. The process is Title 22 certified for a flux of 30 gpm/ft^2. Because the media is compressible, the porosity can be altered for different applications by compressing it between two porous plates. Influent enters the bottom of the filter and travels up through the media. During the backwash cycle, the unit is taken out of service and an air scour and wash cycle using filtered effluent is performed to remove solids from the media. The Fuzzy Filter process will have a smaller footprint than a DMF or continuous backwash system due to the higher flux rates. The Fuzzy Filter has mostly been used in smaller plants; there are currently no installations larger then 1 mgd in California.

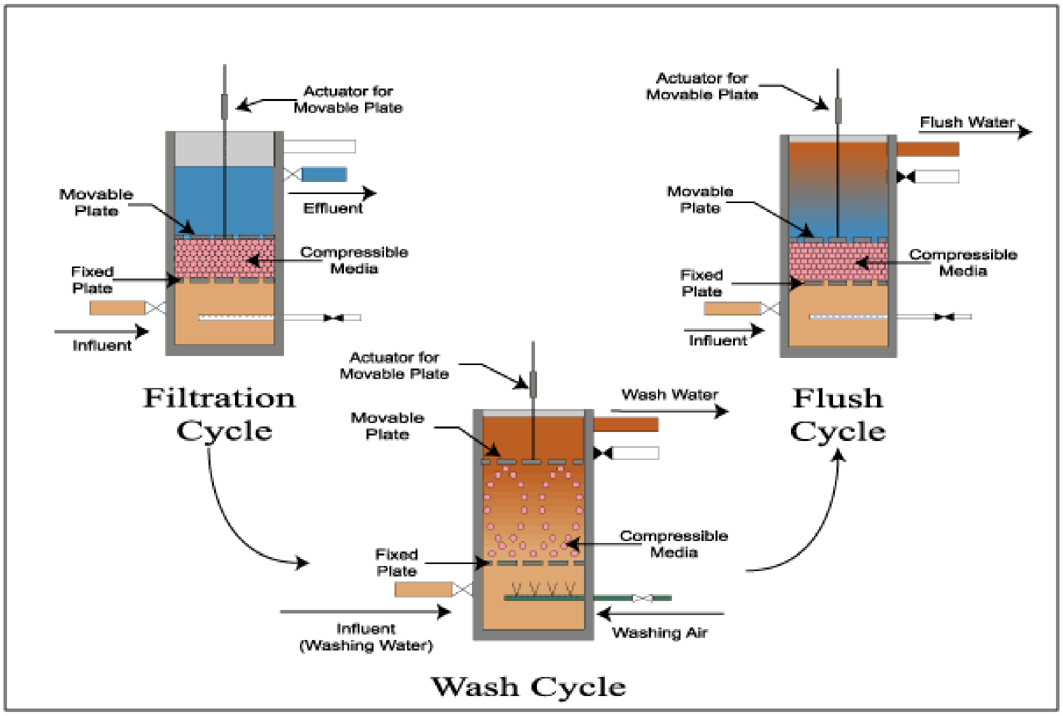

Figure 5-2. Fuzzy Filter manufactured by Schreiber LLC. (Source: Schreiber website - http://www.schreiberwater.com/html/equipment/fuzzyfilter.html)

5.4 Membrane Filtration

Membrane processes for recycled water are typically either ultrafilters (UF) or microfilters (MF). The pore size of MF units is typically 0.1 to 0.4 microns; UF pore size is typically 0.01 microns. Membranes can be operated in either pressure-driven or vacuum-driven modes. For pressure-drive systems, water is filtered through the membrane using feed pumps. The membrane is routinely backwashed (approximately every 10 to 30 minutes) to remove accumulated debris. For a vacuum system, membranes are immersed in a process tank, and water is pulled through the membranes using a vacuum pump. Similar to pressure-driven membranes, vacuum membranes must be backwashed frequently; a relax cycle can be used in lieu of backwash where the vacuum pumps are turned off to allow the membrane to recover. Membrane aeration is typically used with vacuum systems to mitigate membrane fouling. Either membrane configuration eventually will require a chemical cleaning to remove material that is not removed from backwashing or relaxing, typically after several months. Chemical cleaning is typically performed with sodium hypochlorite; acid cleaning may also be necessary in some instances. Membrane lifetime will vary depending on operation and cleaning frequency. Typically, membranes are replaced approximately every 5 to 10 years.

There are currently 17 membrane suppliers that are Title 22 approved for recycled water production. However, there are only a few that have multiple installations in California. Membrane systems represent a small footprint technology that, in general, will be more expensive than traditional tertiary filtration. In addition, the energy costs associated with pumping and the chemicals necessary for cleanings will increase operations and maintenance (O&M) costs. Figure 5-3 presents a picture of a full-scale (7.8 mgd), pressure driven MF system manufactured by Pall Coporation (East Hills, NY).

Figure 5-3. Full-scale Pall MF system (Source: Pall website - http://www.pall.com/water_8149.asp)

5.5 Cloth Media Filtration

Cloth media filtration is a low energy process that uses cloth media to filter out solids. The cloth media is submerged in a process tank and water filters through the cloth media. The media is routinely cleaned using vacuum headers that remove solids from the cloth media surface. Aqua Aerobic Systems, Inc. (Rockford, IL) is one of six Title 22 approved cloth media suppliers. The AquaDisk manufactured by Aqua Aerobic Systems, Inc. is an example of a submerged fixed cloth-media filter. The cloth media is Title 22 approved for a flux of 6 gpm/sf. Figure 5-4 presents an example of the AquaDisk system. Water flows through the media by gravity, and over time the solids will accumulate on the outside of the cloth while water flows to the inside. Solids will also settle out in the tank, and can be routinely removed through a sludge valve. As solids continue to accumulate, the tank level rises and, once a set level is reached, the backwash cycle will initiate. During backwash, a vacuum pump removes solids from the surface of the cloth media as disks are slowly rotated. Similar to membranes, cloth media will need to replaced approximately every 5 to 10 years.

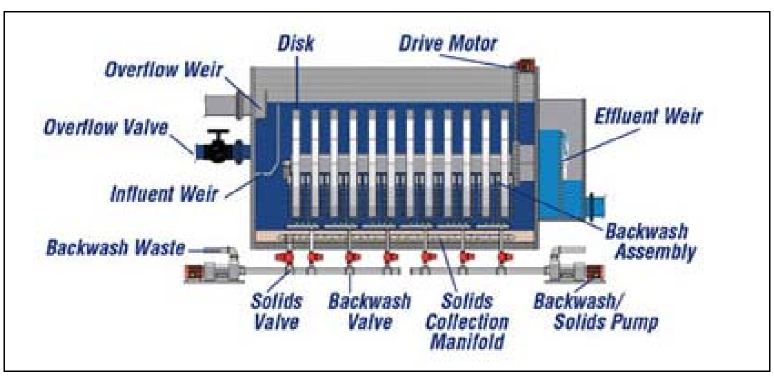

Figure 5-4. Cloth media filter (AquaDisk) manufactured by Aqua Aerobic Systems, Inc. (Source: Aqua Aerobic Systems, Inc. website - http://www.aqua-aerobic.com/aquaDisk.asp)

6. ALTERNATIVES ANALYSIS

6.1 Evaluation of Technologies

Table 6-1 provides a comparison of the five filtration technologies identified in section 5. With the exception of membranes, all filtration technologies are low energy systems. The DMF and continuous backwash filters have the highest footprint requirements due to limiting the filtration flux rate to 5 gpm/sf. Cloth media filters will have lower footprint requirements than DMF due to the higher flux rate and stacking of treatment surface area. Membranes will also have lower footprint requirements than DMF despite the lower filtration flux rates. This is because membranes have much more area in a smaller space than DMF. Membranes will have the highest cost of all technologies both due to capital, chemical and energy costs. Membranes and granular filtration are mature processes that have several full-scale installations in California. The fuzzy filter and cloth media filtration technologies are newer technologies. Of the two, cloth media filtration has more installations.

Of the five technologies identified in Table 6-1, DMFs, cloth media and membranes were considered for subsequent evaluation. DMFs were selected over continuous back wash filters because DMFs will have lower energy costs. In addition, the City has direct experience with DMF technology. The fuzzy filter process was eliminated because it has limited installations in California. Currently, there are no fuzzy filter installations greater than 1 mgd in California.

Table 6-1. Summary of Filtration Technologies that were Considered for the WPCP for the Production of Recycled Water

Technology	Life Cycle Cost	Energy Consumption	Footprint Requirement	Process Maturity	Resource Consumption
DMF	Med	Low	High	Mature	Low
Continuous Backwash Filters	Med/High	Low	High	Mature	Low
Fuzzy Filters	Low	Low	Low	Evolving	Low
Membranes	High	High	Low	Mature	High
Cloth Media Filters	Low	Low	Med	Evolving/Mature	Low

6.2 Alternatives Analysis – Plant Rehabilitation Scenario

The technologies identified in Table 6-1 were evaluated for implementation into the plant rehabilitation scenario.

6.2.1 Evaluation of Feedwater Quality – Plant Rehabilitation Scenario

For the plant rehabilitation scenario, there are four potential feed water locations for the recycled water system.

- Oxidation pond effluent– this would represent the worse quality feed water because effluent suspended solids and algae would not be removed prior to filtration.
- Bay Discharge DAF effluent –DAF effluent under the current polymer dosing would be better than oxidation pond effluent. However, this effluent would not meet the Title 22 regulations for granular

filtration that requires an influent turbidity less than 5 NTU. If turbidity is greater than or equal to 5 NTU, coagulation is required. Use of coagulation could produce a suitable feed water for DMF, but testing (full-scale or pilot-scale) would be necessary to confirm. There is no limit for influent turbidity if membranes are used.

- DMF effluent – The DMF effluent at current polymer dose would be 10 NTU or less. In order to meet Title 22 requirements, an additional filtration step would be necessary.
- Dedicated DAF effluent – this configuration would provide the highest quality feedwater for the processes. Presumably, the new DAF would be operated with polymer dosing similar to current dosing strategies for producing recycled water.

Table 6-2 presents an analysis of each previously identified recycled water filtration technology (with the exception of fuzzy filter and continuous backwash filters) and each feedwater location. DMF is only recommended using the effluent from a new, dedicated DAF. For the cloth media filters, a high-quality feed water will improve process performance. Therefore, a new, dedicated DAF would also be used upstream of the cloth media filters. Aqua Aerobic Systems, Inc., (manufacturer of cloth media technology) has expressed concern with using their technology downstream of a DAF unit due to potential media blinding from polymer use; pilot testing would be necessary to confirm process performance because of the presence of algae and residual polymer in the influent. The membrane could be placed downstream of the existing DAF or DMF, or downstream of a new DAF. Similar to the cloth media, we recommend a pilot test due to the potential for fouling from the residual polymer and algae.[6]

Table 6-2. Recommendations for Feedwater for each Tertiary Filtration Technology for the Plant Rehabilitation Scenario for the Production of Recycled Water

Technology	Oxidation Pond Effluent	DAF Effluent (Operating at 10 NTU Bay Discharge)	DMF Effluent (Operating at 10 NTU Bay Discharge)	Dedicated DAF Effluent (Operating at 2-NTU Recycled Water Discharge)
Dual Media Filters	Not Recommended	Existing Process Testing Would be Required	Not Recommended	Proven
Membranes	Not Recommended	Pilot Testing Would be Necessary	Pilot Testing Would be Necessary	Pilot Testing Would be Necessary
Cloth-Media Filters	Not Recommended	Not Recommended	Not Recommended	Pilot Testing Would be Necessary

6.2.2 Alternative Identification – Plant Rehabilitation Scenario

As a result of the preliminary screening (filtration technology and feedwater source), we identified three potential treatment alternatives. A process flow diagram of each alternative is shown in Figure 6-1. For Alternative 1, a new DAF and DMF would be installed. For Alternative 2, a new cloth media filter would be located downstream of a new DAF. For Alternative 3, new membrane filters would be located downstream of the tertiary DMFs. Both Alternative 2 and 3 would require pilot testing to confirm required performance.

[6] Membrane fouling due to algae is a common concern. Huang et al., 2009 provide a critical review of membrane pretreatment to mitigate membrane fouling.

The DAF units were sized for a loading of 6 gpm/sf.[7] Each filtration technology was de-rated to account for the difficulty associated with filtering pond effluent. We sized the DMF filters using the existing filter loading rates during recycled water production (2 gpm/sf).[8] We sized the cloth media filters for a filter flux of 3.25 gpm/sf, which is considerably less than Title 22 rated filter flux (6 gpm/sf). We assumed there would be three cloth media units (2 duty/1 standy). The membrane filters were sized at a flux of 35 gallons per square foot per day (gfd) with 3 trains total (2 duty/1 standby).

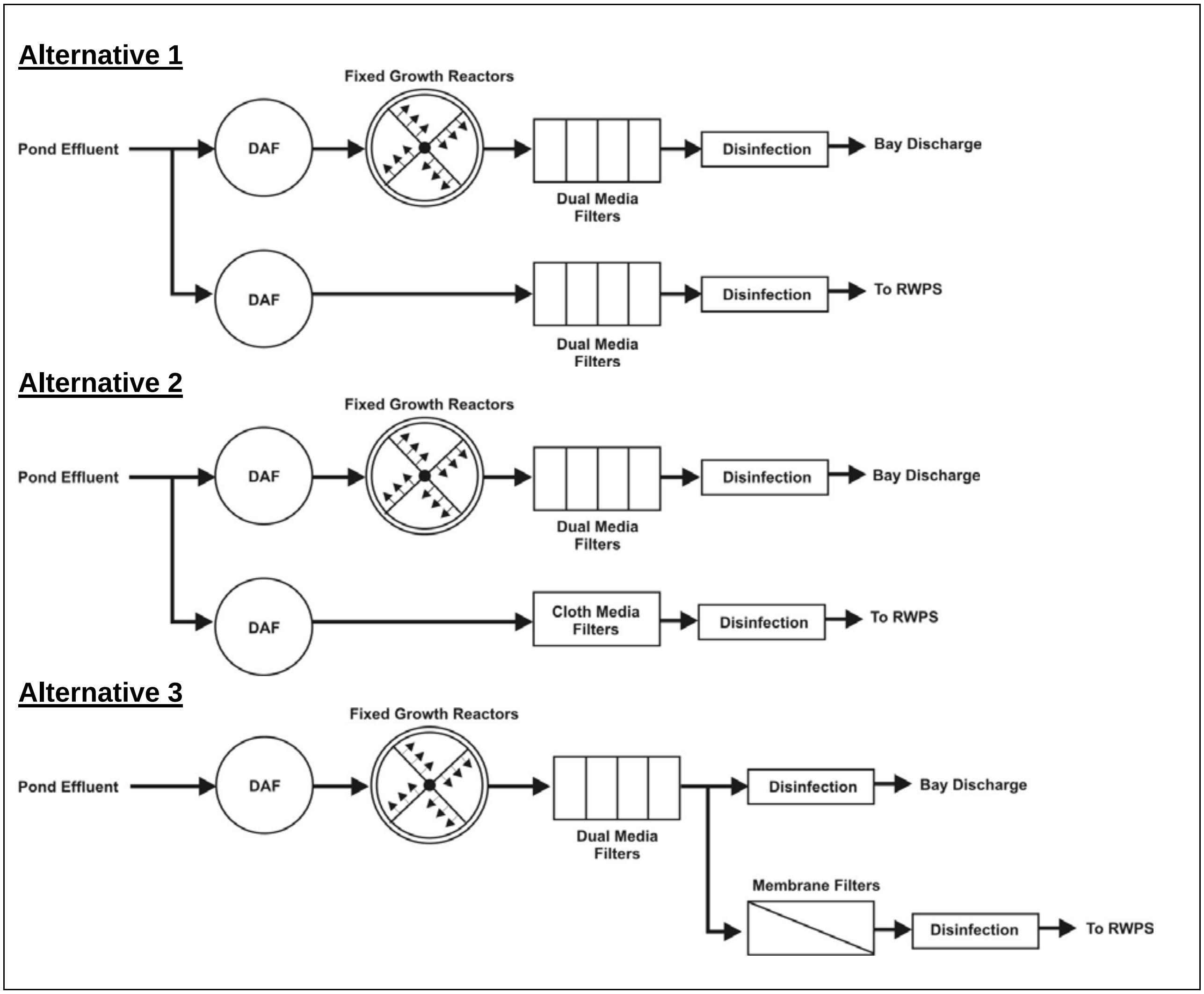

Figure 6-1. Process flow diagram for each recycled water alternative for the plant rehabilitation scenario.

[7] This DAF loading rate is consistent with the value used in the TM: Upgrade Alternatives for the Air Flotation Tanks (AFT) at the Sunnyvale WPCP

[8] Higher flux rates may be possible with continuous coagulant addition upstream of the DMF. However, testing (either pilot-scale or full-scale) would be necessary to confirm.

6.2.3 Cost Analysis – Plant Rehabilitation Scenario

Planning level cost estimates were determined to estimate capital and selected operating costs. The cost estimate was performed assuming the DMF, DAF and cloth media filters would be constructed with concrete tanks; membrane filter equipment would be located on a concrete pad. These costs are meant to be used to compare technologies and should not be used to estimate actual project costs. Table 6-3 presents the capital costs associated with each alternative.[9] Alternative 3 had the highest capital cost ($5.5 million) followed by Alternative 1 ($4.8 million) and Alternative 2 ($3.6 million).

Table 6-3. Comparable Capital Costs for 4-mgd Recycled Water System for the Plant Rehabilitation Scenario

Parameter	Alternative 1 DAF Followed by DMF	Alternative 2 DAF followed by Cloth Media	Alternative 3 Membrane Filters
DAF	$1,928,000	$1,928,000	---
Filtration	$2,864,000	$1,715,000	$5,495,000
Total	$4,792,000	$3,643,000	$5,495,000

Selected operating costs were determined assuming that 730 million gallons of recycled water would be produced per year (or 4-mgd production for 6 months per year which represents projected near-term operating condition) (Table 6-4). All alternatives include DAF; therefore, DAF operating costs were not included (with the exception of polymer use). The difference in operational costs between the alternatives will be determined by the polymer cost, electrical cost, chemical cost for membrane cleaning, and replacement cost. The difference in the polymer costs between alternatives is due to the difference in dose; Alternatives 1 and 2 require a higher dose than Alternative 3. Electrical costs were calculated assuming $0.20/kWhr.[10] All alternatives have a replacement cost. We assumed 10-year replacement for the membranes; 7-year replacement for the cloth media; and 10-year replacement for the granular media. Replacement costs represent installed costs, but do not include costs associated with disposal of spent equipment. Maintenance costs and parts replacement were not included.

Alternative 2 has the lowest operation cost ($177,000/yr) due to the low electrical cost and replacement cost associated with the cloth media filtration. Alternative 1 operation costs are higher ($206,000/yr) and are due to the higher replacement costs associated with the granular media. We assumed a 10-year replacement cycle. In reality, this replacement may be less frequent; the existing DMF media is over 20 years old. Alternative 3 has the highest operating cost ($215,000/yr) because of the chemical requirements and replacement costs

[9] Table 6-3 does not include costs for startup, contingency, insurance or bonds. There is no significant civil work included (i.e. piles, cut and/or fill, yard piping, demo, landscape, etc.). Allowances were made for above-ground interconnecting piping as required.

[10] Electrical costs were determined by estimating the additional natural gas that would be required to operate equipment. Current gas costs $1.04/Therm. Assuming a 30 percent efficiency for the engines, this equates to $0.12/kWhr. Increase to $0.20/kWhr to account for costs associated with equipment operation and maintenance and to impose additional burden on alternatives requiring more electric power, reflecting a Level of Service objective to minimize power use.

$$Cost = \frac{\$1.04}{Therm} * \frac{1 Therm}{100{,}000 BTU} * \frac{3412 BTU}{kWhr} * \frac{1}{0.3}$$

$$Cost = \frac{\$0.12}{kWhr}$$

associated with the membrane filters. There will be a reduction in chlorine requirements for disinfection with Alternative 3 because the membrane filtered effluent will be free of particles. Particles present in filter effluent will increase chlorine requirements because they exhibit a chlorine demand. However, the savings in sodium hypochlorite that could be realized with Alternative 3 is not expected to reduce the operating costs enough to be competitive with Alternatives 1 or 2.

Table 6-4. Opinion of Select Operating Costs for 4-mgd Recycled Water System in the First Year Assuming an Annual Production of 730 Million Gallons for the Plant Rehabilitation Scenario

Parameter	Alternative 1 DAF Followed by DMF	Alternative 2 DAF followed by Cloth Media	Alternative 3 Membrane Filters
Chemical Costs			
Polymer Use[1]	$170,000	$170,000	$96,000
Membrane Cleaning[2]	---	---	$6,000
Electrical Costs			
Dual Media Filters[3]	$3,000	---	$3,000
Cloth Media Filters[4]	---	$1,000	---
Membranes	---	---	$41,000
Replacement Cost			
Dual Media Fitlers[5]	$33,000	---	---
Cloth Media Filters[6]	---	$6,000	---
Membranes[7]	---	---	$69,000
Annual Cost	$206,000	$177,000	$215,000

[1] *Assuming $7.74/gallon of polymer ($0.9/lb at 8.6 lb/gal). Bay discharge requires 17 gallons per million gallons treated; recycled water requires 30 gallons per million gallons treated*

[2] *Includes costs for chemicals used for clean in place and maintenance washes*

[3] *Includes cost of backwash pumps and air scour*

[4] *Includes cost for drive motors and backwash pumps*

[5] *Assume 10-year replacement. 2,900 cu.ft. of sand at $22/cu. ft. (installed); 7,740 cu. ft. anthracite at $30/cf (installed). Include 11.5-percent markup for tax and shipping.*

[6] *Assume 144 units at $220/unit. Include 26.5-percent markup for tax, shipping and installation.*

[7] *Assume $1,600 per module at 342 modules. Assume 10 year replacement. Include 26.5-percent markup for tax, shipping and installation*

The present worth value of each alternative is shown in Table 6-5. We assumed a 5-percent interest rate, 2-percent inflation, and a 10-year life cycle. Alternative 3 had the highest present worth value ($7.3 million) followed by Alternative 1 ($6.6 million). Alternative 2 had the lowest present worth value ($5.2 million).

Table 6-5. Opinion of Present Worth Value for 4-mgd Recycled Water System for Plant Rehabilitation Scenario (10-year life cycle, 5-percent interest, 2-percent inflation)

Parameter	Alternative 1 DAF Followed by DMF	Alternative 2 DAF followed by Cloth Media	Alternative 3 Membrane Filters
Capital Cost	$4,792,000	$3,643,000	$5,495,000
Annual Operations Cost in the First Year	$206,000	$177,000	$215,000
Life Cycle Cost	$1,757,000	$1,510,000	$1,834,000
Present Worth Value	$6,549,000	$5,153,000	$7,328,000

6.3 Alternatives Analysis – Plant Replacement Scenario

The technologies identified in Table 6-1 were evaluated for implementation into the plant replacement scenario.

6.3.1 Alternative Identification – Plant Replacement Scenario

A process flow diagram of each alternative for the plant replacement scenario is shown in Figure 6-2. For this scenario, the oxidation ponds would be replaced with an activated sludge process. The effluent from the activated sludge alternative would be fully nitrified, which would eliminate the need for the FGRs. In addition, there would no longer be a need for the DAF for algae removal. For each alternative, we assumed that the secondary effluent could be used as a feedwater. For Alternative 1, a new DMF would be installed. For Alternative 2, a new cloth media filter would be installed. For Alternative 3, new membrane filters would be installed. Neither Alternatives 2 nor 3 would require pilot testing to confirm performance since both cloth media and membranes have been shown to operate treating activated sludge effluent. However, pilot testing would determine site specific operating information that could optimize process design.

We sized the DMF filters for a filter loading rate of 5 gpm/sf. The cloth media filters were sized assuming a filter flux of 6 gpm/sf. We assumed 2 cloth media filters (1 duty/1 standby). The membrane filters were sized for 4 mgd and a filter flux of 35 gfd.

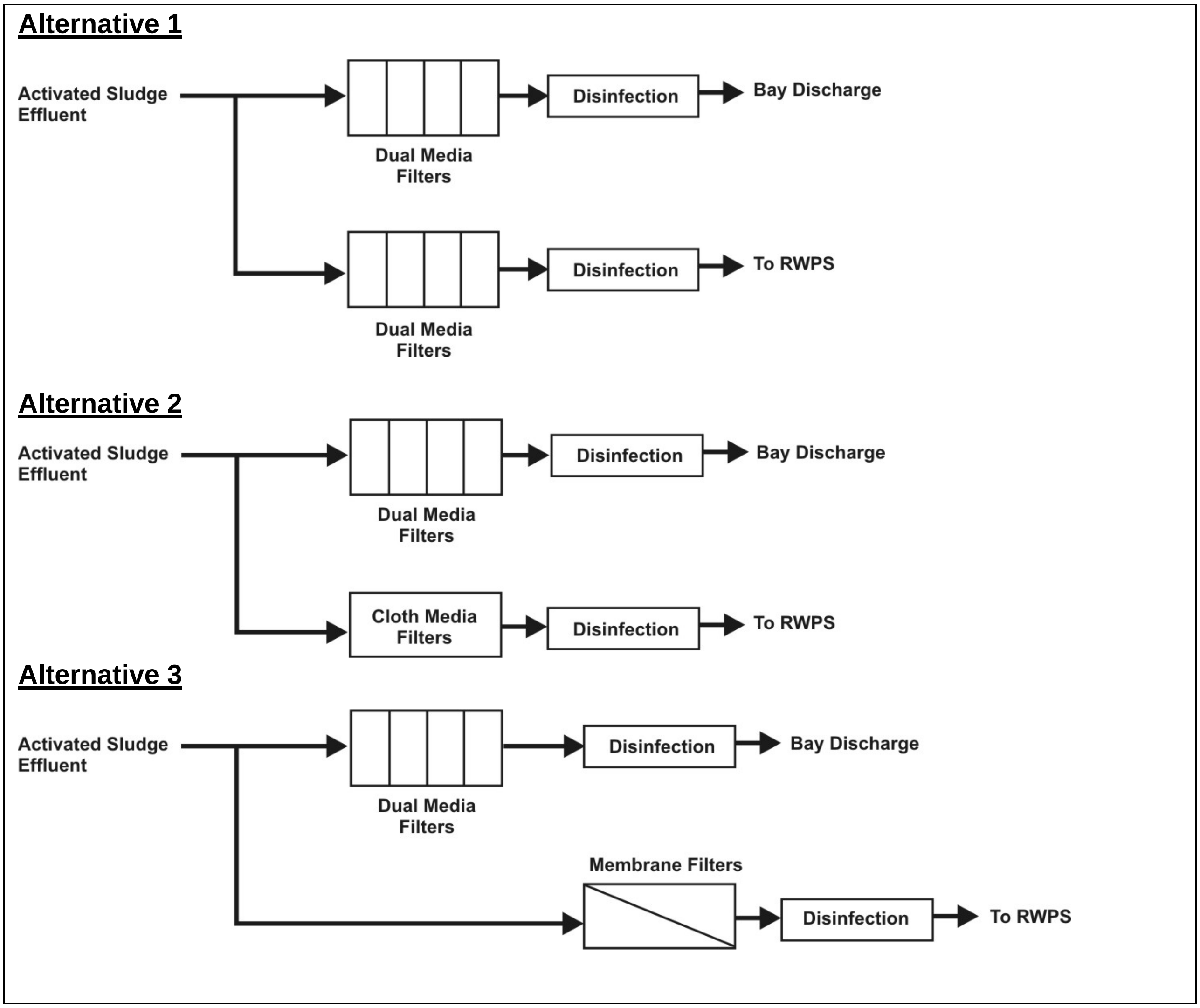

Figure 6-2. Process flow diagram for each recycled water alternative for the plant replacement scenario.

6.3.2 Cost Analysis – Plant Replacement Scenario

Planning level cost estimates were determined to estimate capital and selected operating costs. The cost estimate was performed assuming the DMF and cloth media filters would be constructed with concrete tanks; membrane filter equipment would be located on a concrete pad. These costs are meant to be used to compare technologies and should not be used to estimate actual project costs. Table 6-6 presents the capital costs associated with each alternative.[11] Alternative 3 had the highest capital cost ($3.7 million) followed by Alternative 1 ($1.5 million) and Alternative 2 ($1.2 million). The larger capital cost of Alternative 3 is due to the equipment costs associated with the membranes.

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[11] Table 6-3 does not include costs for startup, contingency, insurance or bonds. There is no significant civil work (i.e. piles, cut and/or fill, yard piping, demo, landscape, etc.). Allowances were made for above-ground interconnecting piping as required.

Table 6-6. Comparable Capital Costs for 4-mgd Recycled Water System for Plant Replacement Scenario			
Parameter	Alternative 1 DMF	Alternative 2 Cloth Media	Alternative 3 Membrane Filters
Total	$1,494,000	$1,205,000	$3,707,000

Similar to the plant rehabilitation scenario, selected operating costs were determined assuming that 730 million gallons of recycled water would be produced per year (Table 6-7). The difference in operational costs between the alternatives will be determined by the chemical cost for membrane cleaning, and replacement cost. As before, electrical costs were calculated assuming $0.20/kWhr. We assumed 10-year replacement for the membranes; 7-year replacement for the cloth media; and 10-year replacement for the granular media. Replacement costs represent installed costs, but do not include costs associated with disposal of spent equipment. Maintenance costs and parts replacement were not included.

Alternative 2 has the lowest operation cost ($4,000/yr) due to the low electrical cost and replacement cost associated with the cloth media filtration. Alternative 1 operation costs are higher ($17,000/yr) and are due to the higher replacement costs associated with the granular media. We assumed a 10-year replacement cycle. In reality, this replacement may be less frequent; existing DMF media is over 20 years old. Alternative 3 has the highest operating cost ($80,000/yr) because of the chemical requirements and replacement costs associated with the membrane filters.

Table 6-7. Opinion of Select Operating Costs for 4-mgd Recycled Water System in the First Year Assuming an Annual Production of 730 Million Gallons for the Plant Replacement Scenario			
Parameter	Alternative 1 DMF	Alternative 2 Cloth Media	Alternative 3 Membrane Filters
Chemical Costs			
Membrane Cleaning[1]	---	---	$4,000
Electrical Costs			
Dual Media Filters[2]	$3,000	---	$3,000
Cloth Media Filters[3]	---	$1,000	---
Membranes	---	---	$27,000
Replacement Cost			
Dual Media Fitlers[4]	$14,000	---	---
Cloth Media Filters[5]	---	$3,000	---
Membranes[6]	---	---	$46,000
Annual Cost	$17,000	$4,000	$80,000

[1] Includes costs for chemicals used for clean in place and maintenance washes

[2] Includes cost of backwash pumps and air scour

[3] Includes cost for drive motors and backwash pumps

[4] Assume 10-year replacement. 1,180 cu. ft.f of sand at $22/cf. (installed); 3,140 cu. ft. anthracite at $30/cu. ft. (installed). Include 11.5-percent markup for tax and shipping.

[5] Assume 72 units at $220/unit. Include 26.5-percent markup for tax, shipping and installation.

[6] Assume $1,600 per module at 228 modules. Assume 10 year replacement. Include 26.5-percent markup for tax, shipping and installation

The present worth value of each alternative is shown in Table 6-8. We assumed a 5-percent interest rate, 2-percent inflation, and a 10-year life cycle. Alternative 2 has the lowest present worth value ($1.2 million). The present worth value of Alternative 3 was higher ($1.6 million), and Alternative 3 had the highest present worth value ($4.4 million).

Table 6-8. Opinion of Present Worth Value for 4-mgd Recycled Water System for Plant Replacement Scenario (10-year life cycle, 5-percent interest, 2-percent inflation)			
Parameter	Alternative 1 DMF	Alternative 2 Media	Alternative 3 Membrane Filters
Capital Cost	$1,494,000	$1,205,000	$3,707,000
Annual Operations Cost in the First Year	$17,000	$4,000	$80,000
Life Cycle Cost	$145,000	$34,000	$682,000
Present Worth Value	$1,639,000	$1,239,000	$4,389,000

7. PLANNING LEVEL RECOMMENDATIONS

7.1 Plant Rehabilitation Scenario

For the plant rehabilitation scenario, we recommend Alternative 1 (DAF followed by DMF). Although Alternative 1 has a higher capital cost and life cycle cost than Alternative 2 (cloth media filtration), we do not recommend operating cloth media on oxidation pond water due to the uncertainty in performance. A pilot study of cloth media filtration is required before the technology could be further considered for this application.

Figure 7-1 presents a conceptual layout for Alternative 1 for the plant rehabilitation scenario. The DAF and DMF units would be designed to be modular to meet the future recycled water demand (8 mgd). Two new CCTs are included. Table 7-1 summarizes the requirements for Alternative 1. It may be possible to operate the DMF units treating DAF effluent (operated in Bay Discharge mode) if chemical were added upstream of the DMF units. If possible, this would eliminate the need for new, dedicated DAF units and could reduce the size of the DMF units. We recommend that chemical addition upstream of the DMF units while the DAF is operated in Bay discharge mode is tested to determine if this is possible.

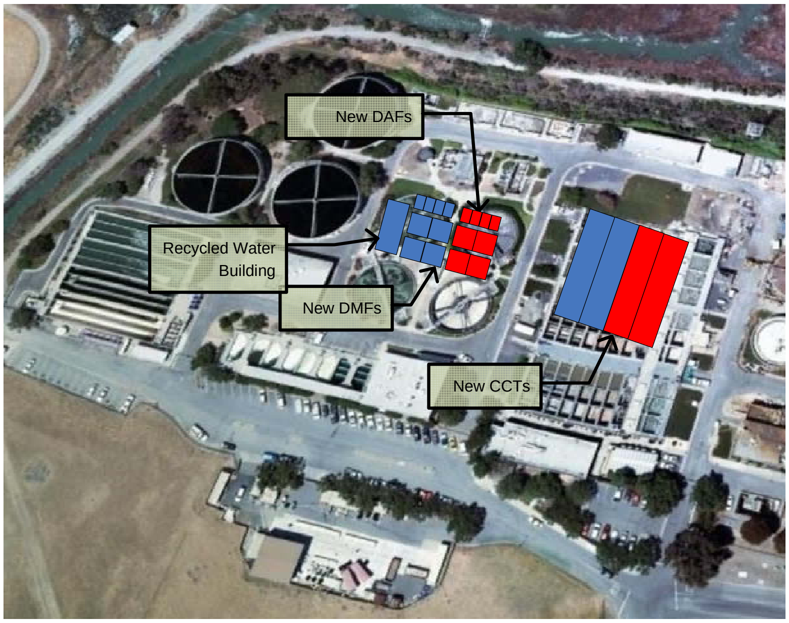

Figure 7-1. Conceptual layout of Alternative 1 for the plant rehabilitation scenario at buildout flows. (Additional footprint requirements for ultimate flows are indicated in red).

Table 7-1. Summary of Alternative 1 Requirements for the Plant Rehabilitation Scenario

Description	Value (4 mgd)	Value (8 mgd)
DAF System		
Number of Tanks	4	8
Length, ft	15	15
Width, ft	10	10
Filters		
Number of Units	4	8
Length, ft	22	22
Width, ft	22	22
Filter Media Depth, in	66	66
Chlorine Contact Tanks		
Number of Units	2	4
Number of Pass (per unit)	3	3
Width (per pass), ft	10	10
Length (per pass), ft	124	124
Depth (per pass), ft	12	12

7.2 Plant Replacement Scenario

For the plant replacement scenario, we recommend Alternative 2 (cloth media). Alternative 2 had the lowest capital and operating costs of the three alternatives. Conversion of the plant to an activated sludge process would produce a suitable feedwater to the cloth media process.

Figure 7-2 presents a conceptual layout for Alternative 2 for the plant replacement scenario. Similar to the plant rehabilitation scenario, the cloth media filters and UV system would be designed to be modular to meet the future recycled water demand (8 mgd). UV disinfection may or may not be the final recommendation for plant replacement scenario; chlorine contact could be used in place of UV disinfection. Table 7-2 summarizes the requirements for Alternative 2 using UV disinfection.

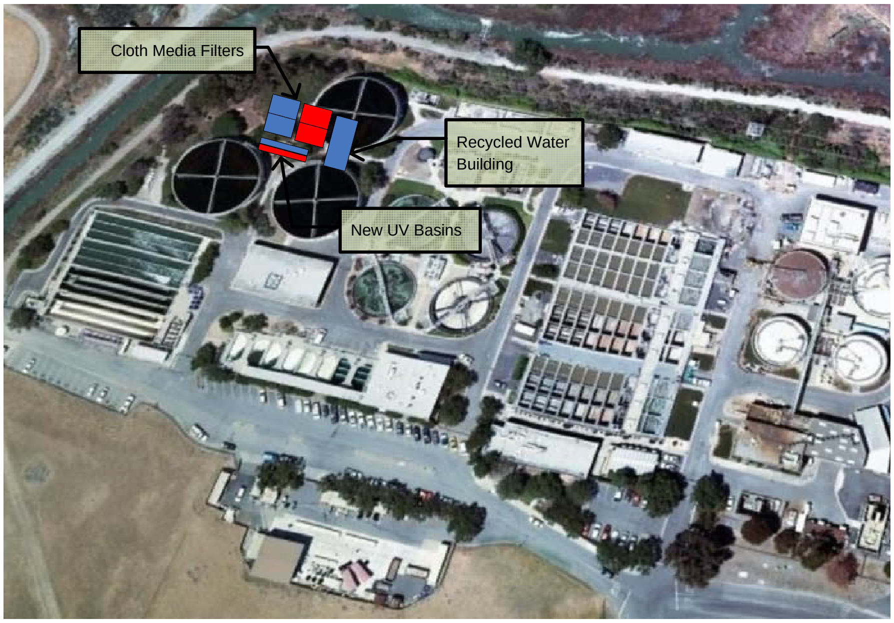

Figure 6-2. Conceptual layout of Alternative 2 for the plant replacement scenario at buildout flows and ultimate flows. (Additional footprint requirements for ultimate flows are indicated in red).

Table 6-2. Summary of Alternative 2 Requirements for the Plant Replacement Scenario		
Description	Value (4 mgd)	Value (8 mgd)
Cloth Media Filters		
Number of Units	2	4
Number of Disk Filters per Unit	8	8
Length, ft	18	18
Width, ft	10	10
Height, ft	12	12
UV Disinfection		
Number of UV Channels	2	4
Length, ft	42	42
Width, ft	2	2
Depth, ft	6	6

REFERENCES

City of Sunnyvale Recycled Master Plan, 2000. Prepared by EOA Inc.

City of Sunnyvale 2008 Recycled Water Annual Report, March 13, 2008. Prepared by EOA Inc.

Condition Assessment Review and Unit Process Improvements – Draft TM, April 2009. Prepared by Brown and Caldwell.

Huang, H., Schwab, K., and Jacangelo, J. (2009) Pretreatment for Low Pressure Membranes in Water Treatment: A Review. *Env. Sci. and Tech. 43 (9) 3011-3019.*

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Treatment Technology Report for Recycled Water, February 2009, State of California Division of Drinking Water and Environmental Management (http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWdocuments/RecycledWaterTechnologylisting2-09.pdf)

Upgrade Alternatives for the Air Flotation Tanks (AFT) at the Sunnyvale WPCP – Draft TM, April 2009. Prepared by Brown and Caldwell.

APPENDIX C – 2013 FEASIBILITY STUDY FOR RECYCLED WATER EXPANSION (FSRWE) (EXCERPT)

SECTION 10 – WASTEWATER TREATMENT ALTERNATIVES

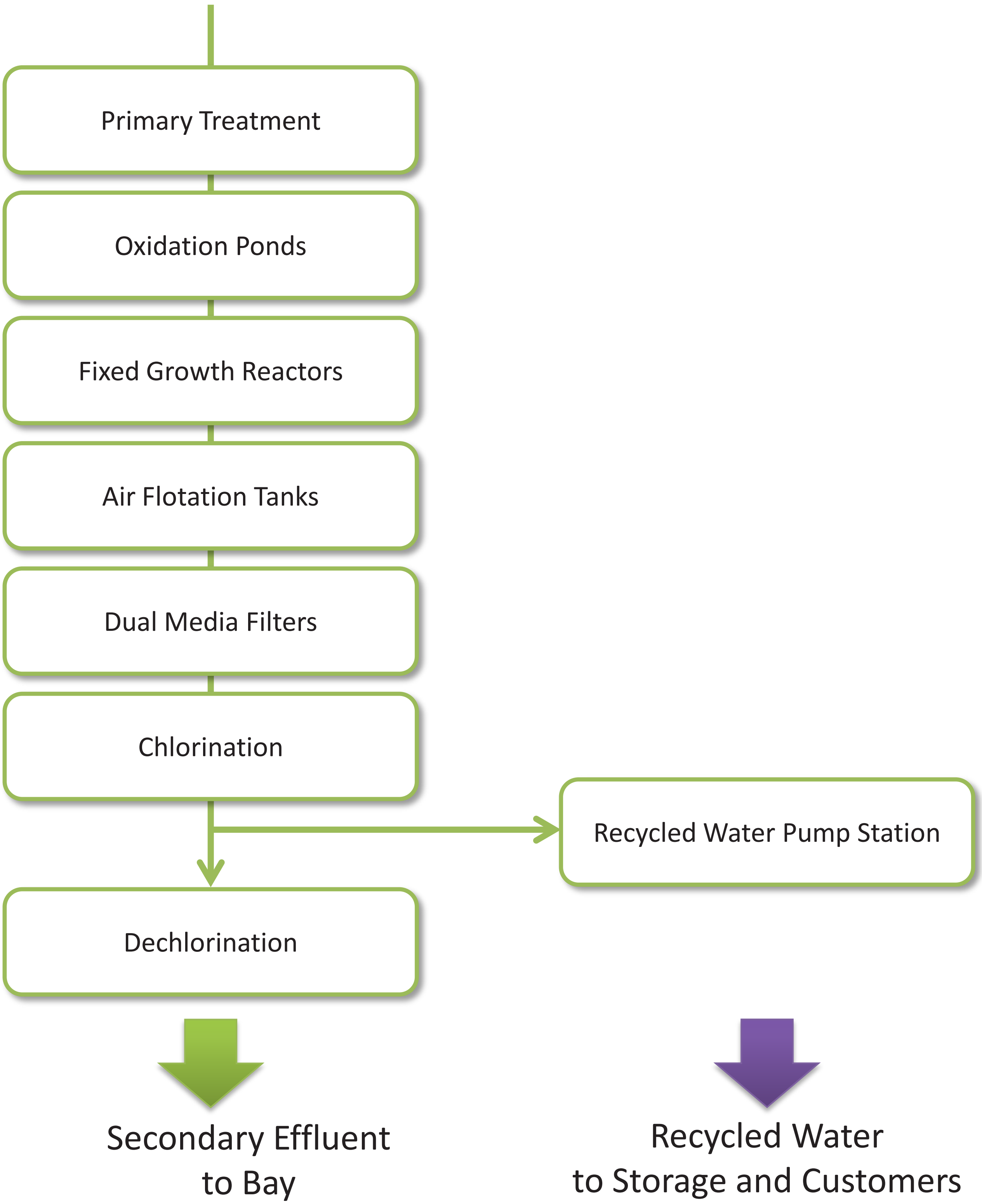
The City is interested in modifying the wastewater treatment process to continuously produce recycled water that will meet the near-term recycled water demand of City customers. Desired co-benefits of a recycled water project include TDS and color reduction. The water quality objectives were discussed in **Section 3.3**. Kennedy/Jenks Consultants (K/J) developed a TM describing four treatment alternatives for the City's consideration, of which, the City selected one for implementation.

This section presents the selected alternative to address the City's production reliability, capacity, water quality, O&M, and regulatory compliance needs. The TM prepared by K/J is included as **Appendix L** and provides a comprehensive description of each alternative.

10.1 Existing Wastewater Treatment Background

The WPCP treatment process includes influent grinders, pre-aeration/grit removal, primary sedimentation, oxidation ponds, fixed growth reactor nitrification, dissolved air flotation (DAF) with coagulation aided by polymer dosage, dual media filtration (DMF), chlorination, and dechlorination (EOA, 2012). Since 1998, the City has produced recycled water at its WPCP. The recycled water and secondary effluent production modes use the same treatment process but have different operational parameters, such as chemical dosage and disinfection level. The WPCP process flow schematic is shown in **Figure 10-1** and the site layout is shown in **Figure 10-2**. Due to operational issues, the WPCP runs in two alternating modes, as described below.

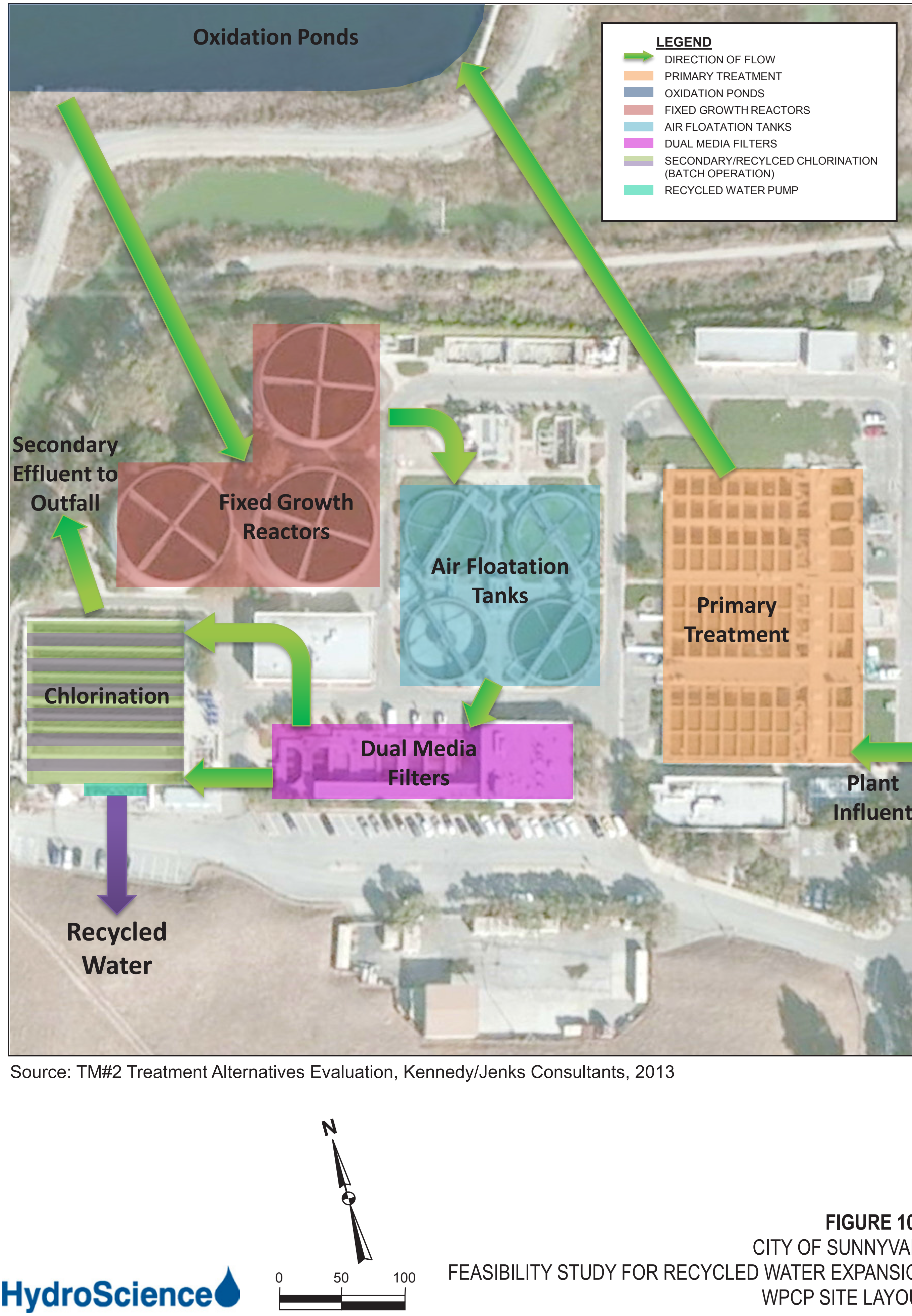
- **Mode 1 – Secondary Effluent Discharge:** The entire advanced secondary treated municipal effluent is discharged to the San Francisco Bay and no recycled water is produced. The secondary capacity of the WPCP is approximately 16 MGD. Due to less stringent regulatory limits for turbidity compared to recycled water use, less polymer and chlorine are required during the treatment process when effluent is discharged to the Bay. As a result, the WPCP realizes lower operating costs. However, the recycled water system is reliant upon stored recycled water, and the system frequently is supplemented with potable water when recycled water is not available.
- **Mode 2 – Recycled Water Batch Production:** The entire WPCP flow is treated to meet Title 22 of the California Code of Regulations for disinfected tertiary recycled water, which is a higher level than under Mode 1. The recycled water that is produced is stored for subsequent distribution to the City customers primarily for irrigation use. Approximately 1,100 AFY of recycled water is produced under this mode, and the City has several operational concerns associated with this batch mode recycled water production, including:
    - Operational complexity and labor required to switch between Mode 1 and Mode 2;
    - Limited recycled water storage capacity, which requires frequent batch production during the summer irrigation season to meet recycled water demands; and
    - Excessive chlorination during the transition from Mode 2 to Mode 1 raises concerns of potential negative effluent bioassay impacts.



Source: TM#2 Treatment Alternatives Evaluation, Kennedy/Jenks Consultants, 2013

FIGURE 10-1
CITY OF SUNNYVALE
FEASIBILITY STUDY FOR RECYCLED WATER EXPANSION
WPCP PROCESS FLOW SCHEMATIC

HydroScience



Source: TM#2 Treatment Alternatives Evaluation, Kennedy/Jenks Consultants, 2013

HydroScience

FIGURE 10-2
CITY OF SUNNYVALE
FEASIBILITY STUDY FOR RECYCLED WATER EXPANSION
WPCP SITE LAYOUT

10.2 Recycled Water Objectives

The City plans to upgrade the secondary treatment processes as part of the Strategic Infrastructure Plan (SIP) over the next ten years. Following implementation of the SIP, the type of secondary treatment processes at the WPCP will change, which is expected to reduce the secondary TDS concentration to approximately 760 mg/L. Therefore, the evaluation of alternatives considered how the future need for TDS reduction technologies, such as reverse osmosis (RO), could change.

As described in **Section 6.3**, the near-term demand is estimated to increase to 3,123 AFY, with a targeted annual average day treatment demand of 3.6 MGD. The City's current objective is to develop a treatment system with the capacity to meet the near-term recycled water demand while being adaptable to future SIP processes; ideally resulting in no stranded assets. It is also the design objective to produce recycled water continuously, rather than via a batch process.

10.2.1 Strategic Infrastructure Plan Coordination

Three secondary treatment technologies were considered as a part of the SIP: MBR, activated sludge, and wetlands. The potential secondary treatment options presented in the SIP, and the recycled water production alternatives are interconnected and the benefits are interdependent. The TM evaluates how each recycled water alternative fits into the context of the overall SIP improvements and the combined cost. Specifically, the TM discussion addresses:

- The impact to the overall cost of SIP (considering the various SIP alternatives) by implementing the various recycled water alternatives; and
- The cost impact of stranded assets.

10.3 Recycled Water Treatment Alternatives

The following alternatives were identified and evaluated in the TM (K/J 2012):

- **Alternative 1 – Blending with Potable Water:** Blend recycled water with potable water to increase volume and reduce TDS.
- **Alternative 2 – Microfiltration/Ultrafiltration (MF/UF):** Treat a sidestream of WPCP secondary effluent with MF to eliminate batch recycled water production.
- **Alternative 3 – Microfiltration/Reverse Osmosis (MF/RO):** Treat a sidestream of WPCP secondary effluent with MF and RO to eliminate batch recycled water production and to reduce TDS.
- **Alternative 4 – Membrane Bioreactor (MBR):** Treat a sidestream of WPCP primary effluent with MBR to eliminate batch recycled water production, avoid TDS increase through secondary processes at WPCP. An option to add RO after the MBR system would reduce TDS.

After the initial consideration of alternatives, a workshop was held in September 2012 with the City to further understand long-term goals and preferences and to narrow the focus of the evaluation. The staff attending the workshop included planners, engineers, and operators, which provided a variety of viewpoints and preferences. While discussing the various alternatives with the City, the City indicated that they do not want to consider Alternative 1 as a long-term option. As such, this alternative was eliminated from further consideration.

Furthermore, due to the operational challenges the City currently experiences, and based on the comprehensive evaluation of the SIP alternatives in conjunction with alternatives presented for the purpose of the Feasibility Study, the City has elected to proceed with the implementation of an MBR system (Alternative 4) since this would prevent stranded assets upon implementation of the SIP and the treatment capacity (and cost) can be phased with minimal operational challenges. In addition, implementing a MBR treatment system to produce recycled water would decrease the overall capacity requirements for the SIP. This would offset a portion of the water treated in the secondary process that was recommended as part of the SIP. The 22.4 MGD secondary treatment requirement for the SIP would be reduced to 18.8 MGD, since 3.6 MGD would be diverted and treated by MBR as part of the recycled water project.

A detailed description of each alternative as well as the expanded SIP evaluation is discussed in further detail in the attached TM (**Appendix L**).

10.3.1 Evaluation Criteria

Evaluation criteria were developed to provide a basis to compare the alternative treatment technologies that could enhance the production of recycled water at the WPCP and address the City's objectives. A short description of each criterion is provided in **Table 10-1**.

Table 10-1: Alternative Treatment Technologies Evaluation Criteria[1]

Criterion	Description
Eliminates Batch Operation	Identifies whether or not an alternative would eliminate the current batch production of recycled water. Alternatives with continuous operation are more favorable.
Eliminates Potable Blending	Identifies if an alternative would require blending of recycled water with potable water during non-peak demand periods. Additional potable water use conflicts with the purpose of recycled water to provide a reliable, drought-proof source to offset potable water use. Therefore, alternatives requiring blending are considered less favorable.
Degree of Operational Complexity	Identifies if an alternative simplifies current operations or introduces additional technologies that require staff training.
Capital, O&M and Lifecycle Costs	Estimates capital, annual O&M, and 30-year lifecycle costs for each alternative. These costs represent planning-level costs (Class 5 per standard AACE cost estimating guidelines) with an estimated range of -30 to +50 percent. O&M costs include energy, chemicals, and potable water. Assumes potable water is purchased from SCVWD starting at $625/AFY in 2013 and escalates over time (see **Appendix L**) and does not include the cost to purchase water to meet peak day demands (which is a cost to be shouldered by all alternatives). Lifecycle costs are calculated at net present value (NPV) and assume a 30-year life, 6% loan/bond rate, 13% loan/bond issuance cost, 2.5% inflation, and 3.1% real discount rate. Detailed lifecycle cost analyses are included in App. C of the TM (**Appendix L**).
Building/Equipment Footprint	Estimates the building and/or equipment footprint for each alternative.
Other	Identifies any additional benefits or concerns, such as removal of ammonia or potential future regulatory issues (i.e. constituents of emerging concern [CECs]).

10.3.2 Selected Alternative – Membrane Bioreactor (MBR)

The selected alternative (Alternative 4) consists of installing a MBR system to treat a sidestream of the WPCP flow. A MBR system combines activated sludge biological treatment with an integrated membrane system to provide both secondary treatment and tertiary filtration. A MBR system includes MF or UF membranes for solids/liquid separation, eliminating the need for separate secondary clarifiers and tertiary filtration to achieve a low turbidity effluent.

After initial degritting and primary sedimentation, a portion of the WPCP flow would be diverted to the MBR system, treated to tertiary quality, and then sent to the head of CCTs #1 and #2 for disinfection. The remainder of the WPCP flow would continue through the WPCP, treated to secondary standard, and then disinfected in CCTs #3 and #4 and discharged to the Bay.

A MBR system would eliminate the need for batch production and allow for continuous production of recycled water for distribution and/or storage. Only the portion of the WPCP flow necessary to meet customer demand would be diverted to the MBR system, allowing for continuous operation of the recycled water treatment system.

MBR systems do not remove salts and therefore must be followed by advanced treatment or potable blending for TDS reduction/removal, if desired; however, in this case, the WPCP flow diverted to the MBR system would bypass the oxidation ponds, which introduce algae and increase TDS in the WPCP flow thereby improving the color and the TDS of the recycled water.

The MBR system would treat 3.6 MGD to produce the desired amount of recycled water. A schematic of this scenario is presented in **Figure 10-3**. The demand and TDS characteristics of the various flow streams are presented in **Table 10-2**.

Table 10-2: Water Quality and Quantity Impacts

Parameter	MBR Treatment
Average Annual Demand	3,123 AFY
Average Day Design Flow	3.6 MGD
Average TDS	760 mg/L
MBR Design Capacity	3.6 MGD

At a planning level, this alternative is estimated to have a NPV capital cost of approximately $29M, an average annual O&M cost of $2.1M, and a NPV lifecycle cost of $85M. The unit cost would be $910 per AF of recycled water produced. The capital and life cycle costs represent the total estimated cost to develop an MBR treatment system to meet the 3.6 MGD capacity, and does not account for the potential cost-savings associated with reducing the necessary capacity of the proposed treatment process that will be recommended as part of the WPCP Master Plan. The footprint of a MBR system enclosed in a building or canopy is expected to be 47,000 SF for this alternative. The evaluation criteria for this alternative are summarized in **Table 10-3**.

Table 10-3: Summary of Evaluation Criteria

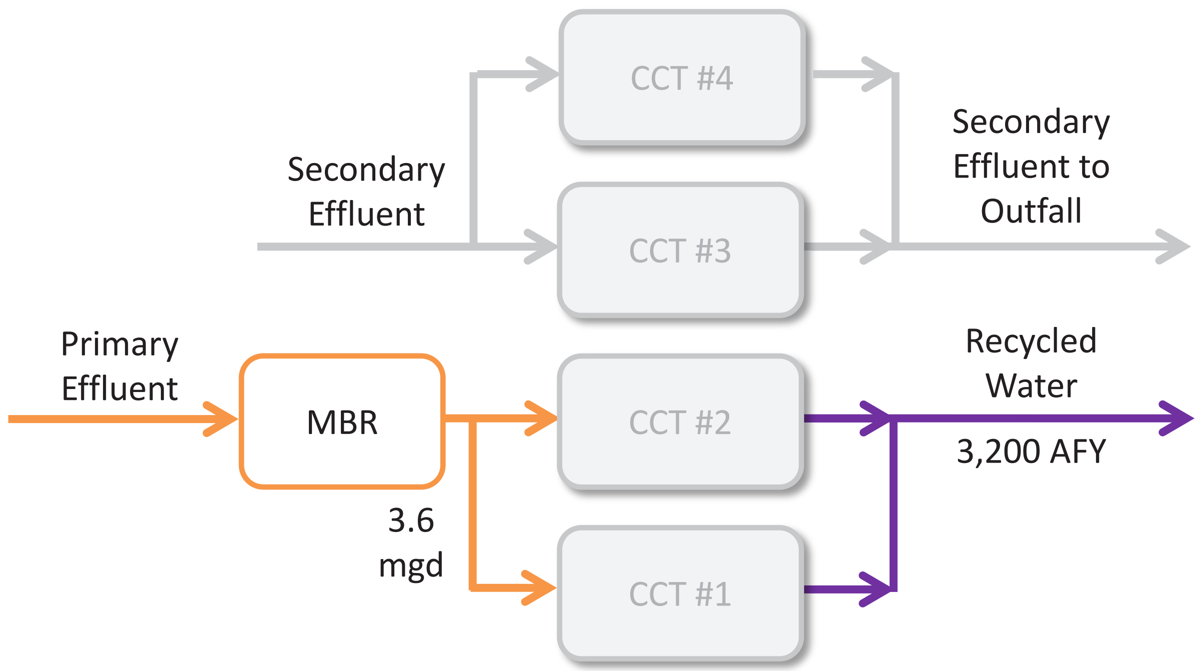
Evaluation Criterion	MBR Alternative
Eliminates Batch Operation	Yes
Eliminates Potable Blending	Yes
Operational Complexity	Moderate: Eliminates complexity of batch operation but introduces MBR technologies.
Capital Cost (NPV $M)	$29M
Average Annual O&M Cost ($/year over 30 years)	$2.1M/year
Lifecycle Cost (NPV $M)	$85M
Unit Cost ($/AF of recycled water produced)	$910/AF
Building/Equipment Footprint	47,000 SF
Other	There could be future regulatory concerns regarding CECs since MF does not remove all of these constituents.

10.4 Preliminary Siting

Preliminary discussions with the City indicate that the future MBR treatment equipment could be sited at the following locations:

- Administration building (to be demolished as part of the SIP); or
- Sludge lagoons

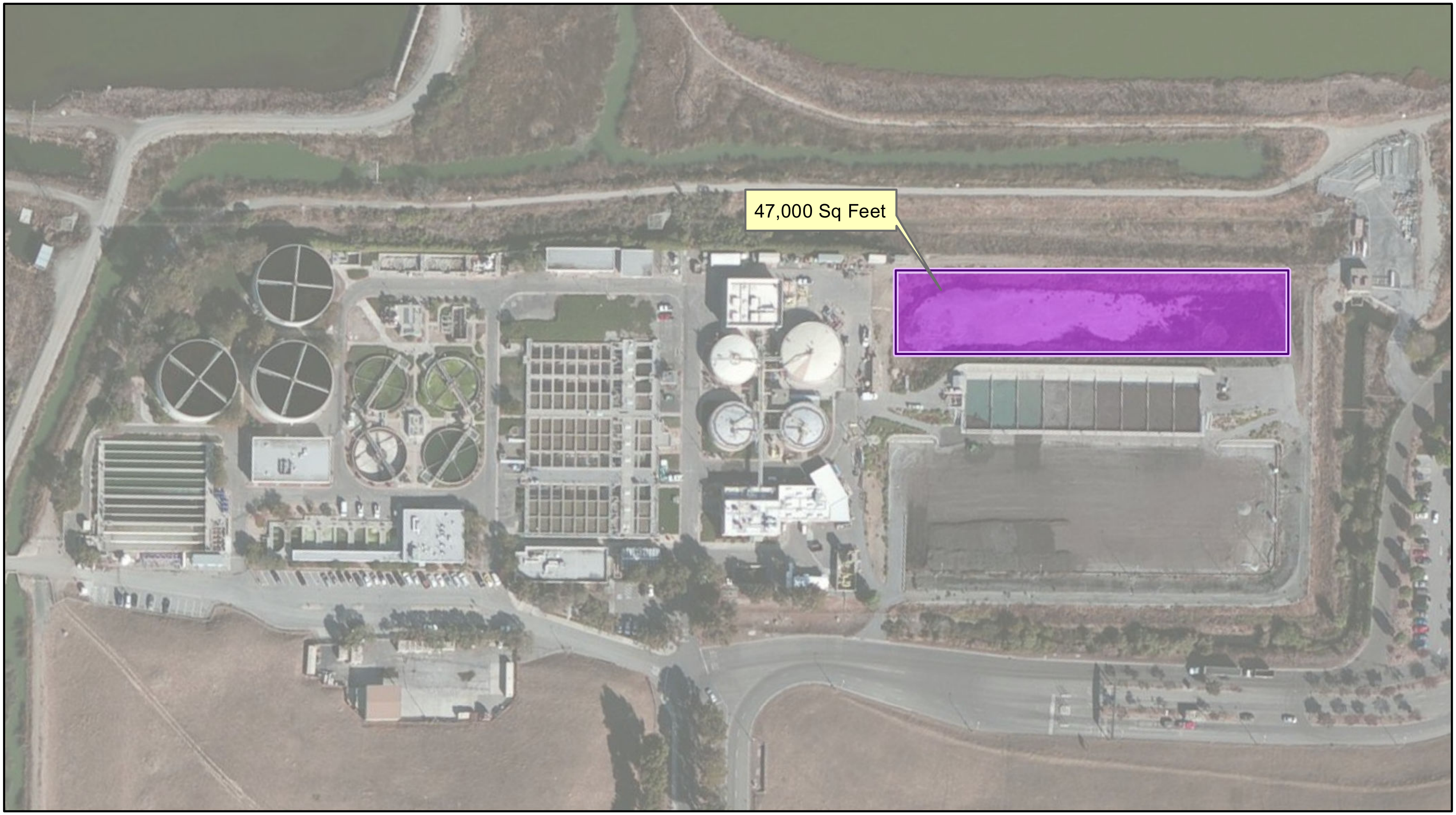
The administration building area is of a sufficient size to allow for the siting of a smaller system. The sludge lagoon and dewatering bed area occupies several acres of the site and could easily fit the MBR system. **Figure 10-4** indicates the preliminary siting for the MBR. Final siting of the MBR system will incorporate other improvements completed as part of the preparation of the WPCP Master Plan.



Source: TM#2 Treatment Alternatives Evaluation, Kennedy/Jenks Consultants, 2013

FIGURE 10-3
CITY OF SUNNYVALE
FEASIBILITY STUDY FOR RECYCLED WATER EXPANSION
MBR FLOW SCHEMATIC

HydroScience



Source: TM#2 Treatment Alternatives Evaluation, Kennedy/Jenks Consultants, 2013

Legend

Preliminary Siting of MBR System

0 100 200 Feet

HydroScience

FIGURE 10-4
CITY OF SUNNYVALE
FEASIBILITY STUDY FOR RECYCLED WATER EXPANSION
PRELIMINARY SITING OF MBR SYSTEM

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APPENDIX D – 2013 SAN FRANCISCO BAY BASIN PLAN

The Water Board will consider granting an exception to the discharge prohibitions only if (a) it has been demonstrated that neither recycling nor discharge to a POTW is technically or economically feasible, and (b) beneficial uses of the receiving water are not adversely affected. Such an exception is based on the Water Board's recognition that discharges allowed under the exception are an integral part of a program to cleanup polluted groundwater and thereby produce an environmental benefit.

Dischargers shall demonstrate that their groundwater extraction and treatment systems and associated operation, maintenance, and monitoring plans constitute acceptable programs for minimizing the discharge of toxic substances and for complying with effluent limitations deemed necessary for protection of the beneficial uses of receiving waters.

Applications for National Pollutant Discharge Elimination System (NPDES) permits to discharge treated groundwater directly to surface waters will be evaluated on a case-by-case basis. In some cases, the applicant may qualify for the requirements of a general NPDES permit for discharge of treated groundwater. The Water Board has adopted general NPDES permits for the following two types of groundwater cleanup projects:

(a) Groundwater polluted by fuel leaks and other related wastes at service stations and similar sites (NPDES General Waste Discharge Requirements for Discharge or Reuse of Extracted and Treated Groundwater Resulting from the Cleanup of Groundwater Polluted by Fuel Leaks and Other Related Wastes at Service Stations and Similar Sites, NPDES No. CAG912002); and

(b) Groundwater polluted by VOCs (NPDES General Waste Discharge Requirements for Discharge and Reuse of Extracted and Treated Groundwater Resulting from the Cleanup of Groundwater Polluted by Volatile Organic Compounds, NPDES No. CAG912003.

These general permits are intended to streamline a common regulatory process and are not available for groundwater discharges with constituents other than fuels and VOCs. The Water Board may renew, revise, or rescind the permits if deemed appropriate. The general permits specify effluent limitations for discharges to surface water bodies, establish self-monitoring requirements, and identify trigger levels for non-routine constituents that are used to determine if additional effluent sampling and treatability studies are needed. Updates to these two general permits are considered every five years.

4.11 MUNICIPAL FACILITIES (POTWs)

Table 4-8 is a list of municipal wastewater treatment facilities (excluding wet weather facilities) within the Region that discharge directly into surface waters. Figure 4-1 shows where these facilities are located in the region. Under normal operational conditions, these POTWs provide a minimum of secondary treatment. In addition, with more than thirty percent of the total flow receives advanced treatment.

Brief discussions of the issues specific to the City and County of San Francisco, South Bay dischargers, the Fairfield-Suisun Sewer District, the Livermore-Amador Valley, and the East Bay Municipal Utilities District are presented below.

4.11.1 City and County of San Francisco

The City and County of San Francisco collects the wastewater in a combined sewer system. That is, the domestic sewage, industrial wastewater, and stormwater runoff are all collected in the same pipes (combined sewer). Such system is subject to overloading during severe storms. Most other communities in California have a separated sewer system: one set of pipes for domestic sewage and industrial wastes and another set for stormwater.

San Francisco is near completion of the primary components of its wastewater facilities master plan. This construction program began in 1974 with the publication of the Master Plan Environmental Impact Statement and Report. The integrated wastewater control system established by the master plan has been designed to provide control and treatment for both dry weather sewage and wet weather storm flows. All dry weather flows currently receive secondary level treatment. At program completion in 1996, all wet weather flows including stormwater runoff will be captured and will receive a specified level of treatment depending on the size of the storm. Pollutant removal from stormwater will be approximately 60 percent system-wide (measured as reduction in total suspended solids).

San Francisco is one of the first municipalities in the nation to complete a comprehensive control program for a combined sewer system. The expenditures for completing the wastewater master plan is about $1.45 billion.

The Southeast Water Pollution Control Plant is a major component of San Francisco's wastewater treatment system. The plant provides secondary level treatment for all dry weather domestic and industrial wastewater from the Bayside drainage area in San Francisco (approximately 75 percent of the total citywide flow). The Oceanside plant provides similar treatment on the Westside. The storage/transports around the periphery of the city store combined sewage for treatment after the storms subside. Additionally, northeast zone storm flows receive treatment at the Northpoint wet weather treatment plant.

4.11.2 South Bay Municipal Dischargers (San José/Santa Clara, Palo Alto, and Sunnyvale)

The South Bay municipal dischargers consist of three sewage treatment facilities: the San Jose/Santa Clara Water Pollution Control Plant (WPCP), the Palo Alto Regional Water Quality Control Plant, and the Sunnyvale WPCP. These three plants serve all of the urban communities of Santa Clara County located in the Region. The South Bay municipal dischargers, as shown in Figure 4-1, presently discharge effluent receiving tertiary treatment (secondary plus nitrification, filtration, and disinfection) to shallow sloughs contiguous with the Bay, south of the Dumbarton Bridge.

The existing discharge locations for the Lower South SF Bay municipal wastewater dischargers are contrary to Basin Plan policy concerning discharge prohibitions (listed in Table 4-1). Exceptions to the first three of these prohibitions are discussed in Section 4.2 Discharge Prohibitions Applicable Throughout the Region.

State Water Board Order WQ 90-5 (1990) found that a net environmental benefit exception to these prohibitions could not be made for the three South Bay municipal discharges. However, the Order found that a finding of equivalent protection can be made if water quality based concentration limits for metals and revised mass loading limits for metals are placed in the dischargers' NPDES permits, if Sunnyvale and San Jose/Santa Clara continue avian botulism control programs, and if San Jose/Santa Clara implements mitigation for loss and degradation of endangered species habitat. Order WQ 90-5 also included provisions that would prevent increases in flows that would adversely impact endangered species habitats. In subsequent NPDES permit reissuances and Water Board resolutions from 1993 through 2003, the South Bay municipal dischargers met the three conditions required to support a finding of equivalent protection. The three conditions for granting the discharge prohibition must be confirmed at each NPDES permit reissuance.

4.11.3 Fairfield-Suisun Sewer District (FSSD)

The FSSD's tertiary wastewater treatment plant has a dry weather treatment capacity of 17.5 million gallons per day (mgd), a wet weather capacity of 40 mgd, and 45 million gallons of off-line storage capacity. The District is currently treating 13 mgd (1993 dry weather data) from a service population of about 111,000. In order to comply with the Water Board's prohibition against dry weather discharges to the Suisun Marsh, FSSD operates a reclamation project in cooperation with the Solano Irrigation District. However, due to various contractual, legal and economic constraints, only about 40 percent of the treatment plant's annual effluent flow is reclaimed for agricultural irrigation. The remainder is discharged to Boynton Slough in Suisun Marsh.

The Water Board required FSSD to conduct an investigation to evaluate the discharge's impact on water quality conditions and beneficial uses of the receiving waters. This investigation was completed in 1987 and found that the discharge has some measurable local effects on water quality in Boynton Slough, but that beneficial uses are not impaired by the discharge. The study concluded that, overall and on a year-round basis, the discharge affords a net environmental benefit to Boynton Slough and the Suisun Marsh.

Given the findings of this study, the plant's high degree of operational redundancy and emergency storage capacity, and continued efforts by FSSD to maximize the use of reclaimed water, the Water Board has granted FSSD an exception to the Basin Plan prohibition. The Water Board allows, through the NPDES permit issued to FSSD, that portion of FSSD's tertiary effluent which cannot be reclaimed to be discharged to Boynton Slough on a year-round basis.

4.11.4 Livermore-Amador Valley

The primary Water Board concern in the Livermore-Amador Valley (Valley) is the increase in salt loading that has occurred in the Valley's main groundwater basin. It is projected that with natural saline sources and and historical basin management practices, and with minimal water recycling, there will be a net salt loading increase from an average of 4,000 tons per year to 6,000 tons per year, resulting in a 10 milligram per liter (mg/L) per year increase in total dissolved solids (TDS) in groundwater. As a result, it has become increasingly important to develop and implement an integrated water/wastewater resource operational plan to protect the water quality and beneficial uses of the groundwater basin.

To achieve this goal, the Water Board supports local water management efforts to concurrently improve the salt balance in the main basin, to increase the local water supply, and to reduce the need for wastewater export through recycled water irrigation and groundwater recharge and other basin management practices.

4.11.4.1 Salt Management in the Livermore-Amador Valley

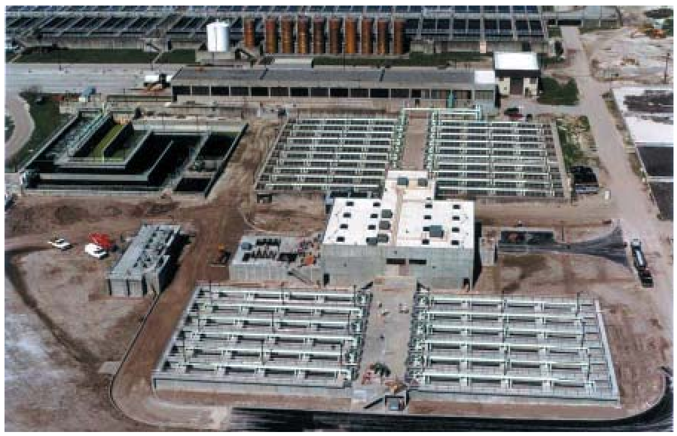
The Livermore-Amador Valley groundwater basin is located in the middle of the Livermore-Amador Valley in eastern Alameda County and is primarily a closed groundwater basin within the Alameda Creek Watershed with multiple groundwater sub-basins of variable water quality. The Main Basin (that portion underlying the Cities of Livermore and Pleasanton) has the highest

APPENDIX E – TETRA DENITE FILTER PRODUCT LITERATURE

TETRA® Denite®
DeepBed™ DENITRIFICATION

The TETRA® Denite® system integrates well with other plant treatment processes to provide superior total nitrogen (TN) and phosphorous removal.

Severn Trent Services offers the TETRA® Denite® System, a practical process for the removal of nitrate-nitrogen (NO_3-N) and suspended solids (SS) in a single treatment step. Denite is a fixed-film biological denitrification process that also serves as a deep bed filtration system capable of removing suspended solids to virtually any final effluent requirement. Denite is used as the final treatment step in the total nitrogen removal process to help each facility meet stringent TN discharge limits of 3 mg/l.



For more information on TETRA® Denite® Systems
visit **www.severntrentservices.com**

UNDERSTANDING
A VALUABLE RESOURCE

SEVERN TRENT SERVICES

WE UNDERSTAND DENITRIFICATION

Denite® Process Description

Biological denitrification processes can be of the fixed-film or suspended growth type. The TETRA Denite system requires one-tenth of the space used with suspended growth systems, greatly facilitating expansion or retrofitting requirements. With Denite, the denitrification process and the filtration process are combined in a single system and provide superior process synergy. NO_3-N is converted to nitrogen gas and captured within the media bed along with suspended solids and biomass formed from the denitrification reaction. The Denite gravity filter system operates in a downflow mode to maintain excellent suspended solids removal, thus avoiding the necessity for clarifiers or additional effluent polishing filters.

The specially sized and shaped granular media used in the fixed-film biological reactors is an excellent support medium for denitrifying bacteria and the deep bed environment is conducive to efficient NO_3-N and solids removal. The specific surface of the 2-3 mm sand is high, 300 square feet per cubic foot. A 4-6 foot depth of media is used that prevents short-circuiting and premature solids breakthrough. The contact between wastewater and biomass is excellent and hydraulic short-circuiting is negligible even during plant upsets.

The media allows for heavy capture of solids of at least 1.0 pound of solids per square foot of filter surface area before backwashing is required. The high solids capture permits operating for extended periods of time and easily handles peak flow periods or plant upsets.

As solids are captured increasing the head loss in the filters, a backwash is required to remove the solids. Because of the heavy loading capacity and media depth, DeepBed™ vessels require heavy-duty backwashing. Concurrent backwash air and water are used during the backwash cycle. The solids slurry removed from the filter media are typically returned to the upstream biological process. Due to the filters high solids loading capacity, the percent of return is less than 4% (<2% typical) of the plant's forward flow.

During the denitrification reaction, nitrogen gas accumulates in the media bed and wastewater is forced to flow around the gas bubbles in the media voids. This reduces the apparent size of the media and also improves the biomass contact and filtration efficiency. The effect of the gas bubbles increases head loss and requires periodic removal in between backwashes. Removing a reactor from service and applying backwash water for a short period of time accomplish this. This nitrogen release cycle, or bump, releases the entrapped nitrogen gas into the atmosphere, reducing the head loss. The TETRA SpeedBump® technology is utilized to conduct a complete system bump cycle without stopping flow to the reactors.

Suspended Solids Removal

The removal of suspended solids from wastewater effluent also lowers BOD since each mg/l of TSS contains 0.4-0.5 mg/l of BOD. Effluent suspended solids also contain nitrogen, phosphorous, and heavy metals. The removal of these solids often decreases 1 mg/l or more of these materials. With proper chemical treatment, effluent total phosphorous concentrations <0.3 mg/l are consistently achieved. Denite filters can easily meet <2 NTU or < 5 mg/l TSS (<2 mg/l TSS typical). Table 1 demonstrates the final effluent quality reported by the City for the Howard Curren AWTP in Tampa, Florida during the period of 1980-2001 where the Denite system is operating.

Nitrogen Removal

The denitrification reaction is time-dependent, and the time required for a specific removal efficiency varies according to the temperature of the wastewater being treated. In practice, filtration rates of 1-3 gpm/ft^2 are designed for water temperatures down to 8 degrees Celsius and 2-5 gpm/ft^2 in warmer waters. Table 2 demonstrates the Denite system's capability to denitrify to low NO_3-N concentrations at low wastewater temperatures. Table 1 demonstrates the consistency of yearly Denite operations for NO_3-N and SS removal.

Table 1: Howard Curren AWTP – Tampa, FL (100 MGD)

Period	MGD	BOD (mg/l)	SS (mg/l)	TN (mg/l)	TKN (mg/l)	NH_3-N (mg/l)	NOx-N (mg/l)
1980-1988	51.3	3.4	2.8	2.8	1.7	0.17	1.06
1989-1998	55.5	2.4	1.6	2.4	1.56	0.18	0.87
1999	50.45	2.6	0.9	2.52	1.46	0.13	1.01
2000	48.5	3.1	0.7	2.24	1.29	0.14	0.95
2001	49.7	2.3	0.8	2.28	1.21	0.15	1.06
Average	51.0	2.76	1.4	2.4	1.5	0.15	0.99

Table 2. Cold Weather Performance Data – Northeast US (Monthly Averages)

	MGD	Wastewater Temperature degrees C	Influent NO_3-N mg/l	Effluent NO_3-N mg/l
Nov 2003	1.01	14.9	11.56	0.45
Dec 2003	1.77	11.6	8.25	0.47
Jan 2004*	1.13	8.5	10.91	0.48
ADF Design	1.0	8	13	0.5
Peak-Day Design	2.36	8	11	0.5

* 15 days were measured <8 degrees C with average effluent NO_3-N of 0.45 mg/l @ 1.09 MGD

WE UNDERSTAND DENITRIFICATION

Denite® System Components and Specifications

- **Filter Vessel:** concrete or steel, round or rectangular-usually 18-20 feet deep with free board.
- **Filter Bottom:** Nozzleless design; stainless steel air headers and pipe laterals; plastic jacketed 5000 psi concrete T Block underdrains.
- **Filter Media:** monomedia granular sand with 2-3 mm effective size at depths of 4-to-6 feet.
- **Support Layers:** gravel in five layers totaling 18 inches deep in a reverse graded fashion.
- **Filter Controls:** consist of split flow influent over Curvilinear Weir™ blocks and standpipe effluent control. The mode is a uniform rate with open or closed valves.
- **Backwash Air:** distributed across the entire area of the filter bottom, supplied by a positive displacement blower at a rate of 3-5 icfm/ft²
- **Backwash Water:** supplied at a rate of 5-6 gpm/ft² with a low head centrifugal pump. The head loss across the filter bottom is 4.0 inches water column.
- **Filter Valves:** pneumatic or electric control valves with double acting cylinders. Isolation valves can be included.
- **Chemical Feed Systems:** includes a methanol storage and feed system with TetraPace™ automatic dosing control. This can be used for other chemical feeds as well.
- **Instrumentation:** PLC with human machine interface and multiple screens included. Also includes outputs for a centralized computer control and/or SCADA system. It also includes flow meters, analyzers, level switches, local panels and system alarms.
- **Filter Operation:** automatic with manual overrides. Backwashing and bumping are time based.
- **Head Requirement:** typically 6-8 feet of water but can be more or less depending on the specific application.
- **System Integration:** works well with other treatment plant processes such as overall nitrogen removal, phosphorous removal and virus removal.

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