Montecito Sanitary District & Montecito Water District
Enhanced Recycled Water Feasibility Analysis

Technical Memorandum 8
RECYCLED WATER TREATMENT OPTIONS AT MSD

DRAFT FINAL | November 2022

carollo

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This document is released for the purpose of information exchange review and planning only under the authority of Lisa J. Arroyo, May 2022, California PE No. 57518.

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Abbreviations

AACE	Association for the Advancement of Cost Engineering International
AF	acre-feet
AFY	acre-feet per year
ADWF	average dry weather flow
AL	action level
AOP	advanced oxidation process
ATW	advanced treated water
AWPF	advanced water purification facility
AWT	advanced water treatment
AWTO	advanced water treatment operator
BAC	biologically-enhanced activated carbon
Carollo	Carollo Engineers
CCR Title 22	Title 22 of the California Code of Regulations
DAF	dissolved air flotation
DBP	disinfection byproduct
DDW	Division of Drinking Water
DPR	direct potable reuse
EC	electrical conductivity
ESCP	enhanced source control program
FAT	full advanced treatment
gph	gallons per hour
gpm	gallons per minute
GWR	groundwater rule
IPR	indirect potable reuse
LRV	log removal value
MBR	membrane bioreactor
MCL	maximum contaminant level
MF	membrane filtration
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
mg-min/L	milligrams per minute per liter
mJ/cm^2	millijoules per square centimeter
mL	milliliter
MSD	Montecito Sanitary District

MWD	Montecito Water District
NDMA	N-Nitrosodimethylamine
NL	notification level
NPR	non-potable reuse
NTU	nephelometric turbidity unit
NWRI	National Water Research Institute
O&M	operations and maintenance
PDT	pressure decay test
Pretreatment Program	industrial pretreatment and pollutant source control program
RO	reverse osmosis
SF	square feet
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TM	technical memorandum
TOC	total organic carbon
UF	ultrafiltration
UV	ultraviolet
UVT	ultraviolet transmittance
WRF	Water Research Foundation
WRP	water reclamation plant
WTP	water treatment plant
WWTP	wastewater treatment plant

Technical Memorandum 8

RECYCLED WATER TREATMENT OPTIONS AT MSD

Technical Memorandum (TM) 8 develops recycled water treatment trains for non-potable reuse (NPR), indirect potable reuse (IPR), and direct potable reuse (DPR) projects. For projects that utilize dissolved air flotation (DAF) (either primary or secondary), all recycled water treatment trains will require low pressure membrane filtration (MF) (e.g., MF or ultrafiltration [UF]) followed by reverse osmosis (RO). For projects that utilize membrane bioreactors (MBRs), low pressure membranes after MBR are not necessary and MBR is simply followed by RO. Implementation of IPR requires additional treatment barriers compared to NPR, and implementation of DPR requires additional treatment barriers compared to IPR, all of which is detailed in the sections below.

For each treatment option, simple process schematics, design criteria, preliminary sizing, conceptual site plans, and cost estimates are completed.

8.1 Summary of Treatment Trains Analyzed

Seven treatment trains were developed to reflect the options for NPR, IPR, or DPR. These Advanced Water Treatment (AWT) treatment trains are summarized in Table 8.1. Additional information about each train is provided in the sections below.

Table 8.1 Summary of Alternative Reuse Treatment Trains

Reuse Type	Treatment Train	Wastewater Treatment	Advanced Treatment	Feed Flow	Finished Water Flow
Non Potable	1A	Conventional activated sludge + DAF(1)	UF - Partial RO - UV	0.38 mgd	0.3 mgd
	1B	MBR	Chlorine	0.3 mgd	0.3 mgd
	1C	Conventional activated sludge	Cloth filter – UV	0.3 mgd	0.3 mgd
Indirect Potable	2A	MBR	RO - UV/AOP	0.7 mgd	0.56 mgd
	2B	Conventional activated sludge + DAF(1)	UF - RO - UV/AOP	0.7 mgd	0.56 mgd
	3	Conventional activated sludge + DAF (@ Montecito)	UF – RO – UV/AOP (@ Carpinteria)	1.9 mgd	1.5 mgd

Reuse Type	Treatment Train	Wastewater Treatment	Advanced Treatment	Feed Flow	Finished Water Flow
Direct Potable at MSD	4A	MBR	Ozone/BAC - UF - RO - UV/AOP	0.7 mgd	0.56 mgd
	4B	Conventional activated sludge + DAF[1]	Ozone/BAC - UF - RO - UV/AOP	0.7 mgd	0.56 mgd
Direct Potable at Santa Barbara	5A	Conventional activated sludge + DAF[1]	Ozone/BAC - UF - RO - UV/AOP	7.7 mgd	6.2 mgd
	5B			4.6 mgd	3.7 mgd

Abbreviations: AOP - advanced oxidation process; BAC - biologically enhanced activated carbon; mgd - million gallons per day; MSD - Montecito Sanitary District; UV - ultraviolet.
Notes:
(1) DAF is necessary for oil and grease removal ahead of membrane treatment. DAF can be placed either before or after conventional activated sludge treatment.

8.2 Non-Potable Water Reuse

In discussions with the project team, the presumed total dissolved solids (TDS) target of the recycled water is ~1,000 milligrams per liter (mg/L), based on recycled water projects implemented in Santa Barbara and Goleta. Chloride data from Santa Barbara averages 340 mg/L, which has proven acceptable to some (but not all) vegetation. Recent sampling by MSD indicated TDS values in the ~1,400 mg/L range and chloride values in the ~400 mg/L range. Salt and chloride levels in this range will be problematic for some plants. To reduce TDS and chloride, this analysis assumes that RO would be employed on a side stream, as detailed below.

Multiple non-potable treatment trains are evaluated here. The treatment trains are:

- Treatment Train A – Using secondary clarifier effluent that has either primary DAF or secondary DAF, treatment will include a full stream UF followed by partial stream RO for TDS reduction and UV disinfection for the full flow. Train A will take a feed flow of 0.38 mgd. The goal is 50 percent RO permeate in the blended flow, so with 80 percent recovery the RO will require 0.19 mgd of feed flow. The RO permeate would blend with ~0.15 mgd of UF filtrate, resulting in ~0.3 mgd of blended recycled water. The full flow will be disinfected by UV, noting that the UV dose will be 80 millijoules per square centimeter (mJ/cm^2) following the National Water Research Institute (NWRI) UV Guidelines with a small 10 percent safety factor based upon a ultraviolet transmittance (UVT) of 65 percent (which allows for compliance with the RO not in operation). For this analysis, no stabilization of RO permeate is envisioned, as the split stream treatment will result in sufficient hardness, alkalinity and pH in the blended recycled water.
  - Costs and system size can readily be adjusted **down** by simply removing the partial stream RO, resulting in no reduction of TDS and chloride.
  - Costs and system size can readily be adjusted **up** by simply doubling the RO capacity, resulting in 100 percent RO as part of a potable reuse system.
- Treatment Train B – This train entails the use of an MBR followed by chlorine disinfection. The existing chlorine contact basin would be used to achieve the CT required for non-potable reuse. 0.3 mgd of chlorinated effluent would be used for non-potable reuse, with the remainder going out the existing outfall.

- Treatment Train C – Secondary clarifier effluent would be further treated using a cloth filter and UV disinfection. The addition of primary or secondary DAF would not be needed for this train. 0.3 mgd of secondary effluent would be treated for non-potable reuse.

8.2.1 Regulations for Non-Potable Reuse

In California, recycled water is regulated by the State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW). Title 22 of the California Code of Regulations (CCR Title 22) establishes the treatment requirements for recycled water as well as the approved uses based on the level of treatment[1]. Title 22 defines four classifications of recycled water determined by the level of treatment provided, total coliform bacteria, and turbidity levels. The highest level of treatment for non-potable recycled water must comply with the requirements for "Disinfected Tertiary Recycled Water," which entails a water that is oxidized, coagulated, filtered, and disinfected according to the requirements summarized in Table 8.2[2].

Table 8.2 Non-Potable Unrestricted Use Recycled Water Treatment and Quality Standards for California

Category	Compliance Approach	Requirements
Filtration Requirements	Media Filters	< 2 NTU (average) and <10 NTU (maximum)
	Membrane Filters	< 0.2 NTU (average) and <0.5 NTU (maximum)
Disinfection Requirements	Chlorine Disinfection	CxT > 450 milligrams per minute per liter (mg-min/L); 90 minutes modal contact time at peak dry weather flow
	UV Disinfection	UV dose 50 mJ/cm^2 after RO; 80 mJ/cm^2 after MF/UF; or 100 mJ/cm^2 after media filter
	Alternative Disinfection	Demonstrate 5-log (i.e., 99.999 percent) virus inactivation
Bacterial Indicators	Daily Effluent Sampling	Total coliform: < 2.2/100 milliliters (mL) (7-day median) < 23/100 mL (not more than one sample exceeds this value in 30 days) < 240/100 mL (maximum)

8.2.2 Treatment Train Details and Design Criteria

For this project, the criteria for "Disinfected Tertiary Recycled Water" applies and will be met with a combination of UF, UV light disinfection and a side-stream RO system for TDS and chloride reduction.

[1] SWRCB October 2018. Regulations Related to Recycled Water. Title 17 and Tile 22 Code of Regulations.
[2] The requirements for oxidized and coagulated wastewater are non-quantitative. Oxidized wastewater is "wastewater in which the organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen". Coagulated wastewater is "oxidized wastewater in which colloidal and finely divided suspended matter have been destabilized and agglomerated upstream from a filter by the addition of suitable floc-forming chemical".

The treatment requirements for "Disinfected Tertiary Recycled Water" are met as described in Table 8.3.

Table 8.3 Treatment Processes for NPR and Their Role in Meeting Regulatory Requirements

Process	Description
UF	• MF process. • Reduces turbidity in filtrate to meet the regulatory limits. • Provides reduction in total coliform bacteria
Partial Stream RO	• Removes TDS and chlorides.
UV Disinfection	• Provides required virus inactivation. • Further reduces total coliform bacteria below regulatory limits.

The NPR treatment train is shown in Figure 8.1 for both MBR and non-MBR options. The design criteria for each process are summarized in Appendix 8A.

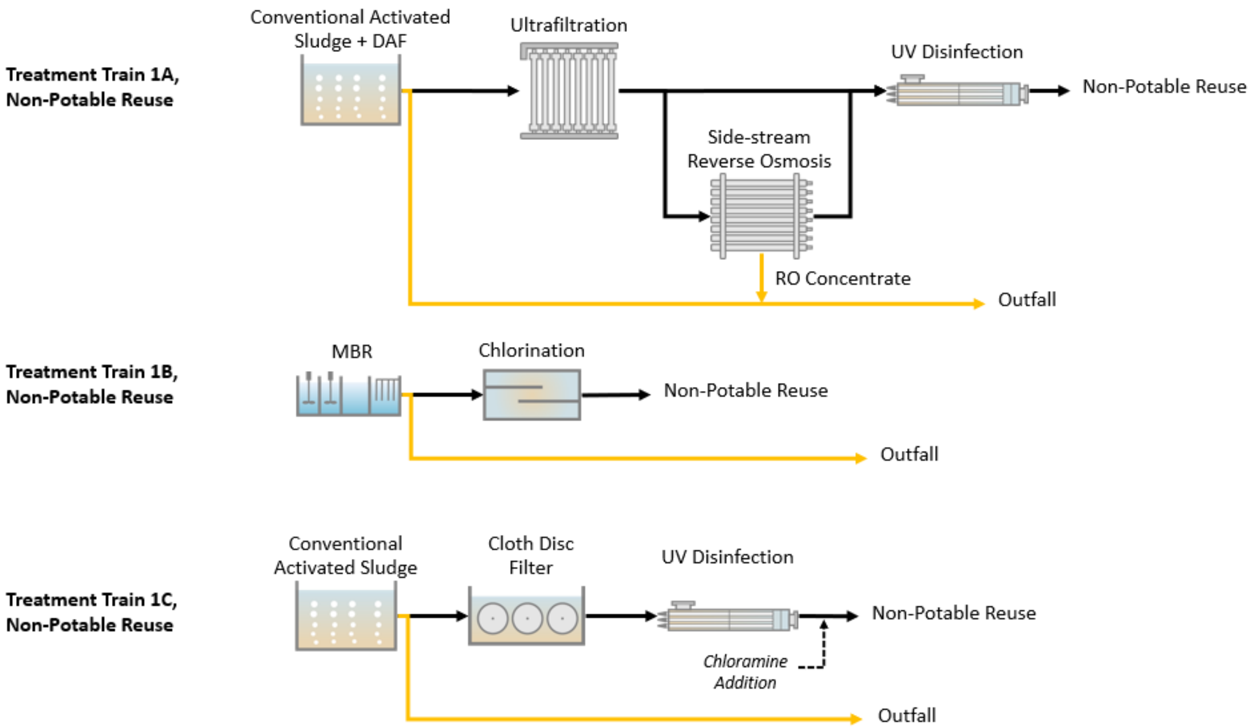


Figure 8.1 Non-Potable Water Reuse Treatment Trains (a) MBR and (b) no MBR

8.2.3 Treatment Train Layout and Footprint

A reuse facility is needed on the MSD site for Treatment Trains 1A and 1C, which have additional reuse-specific treatment. For Treatment Train 1B, either the greenfield or retrofit MBR would need to be implemented, and the existing chlorine contact basin would be used, so not additional reuse facility is needed.

An overall site plan with the location of the non-potable reuse facility is shown in Figure 8.2, with the layout for the non-potable reuse system shown in Figure 8.3 and Figure 8.4. The layout shown is for Treatment

Train 1A, which is the larger facility. A facility for train 1C would be significantly smaller. Should MSD want to create a second story on the reuse facility, it could be used for office and meeting space.

Figure 8.2 Overall Site Plan for NPR at MSD; the Facility is Sized for NPR with the Potential to Expand to IPR

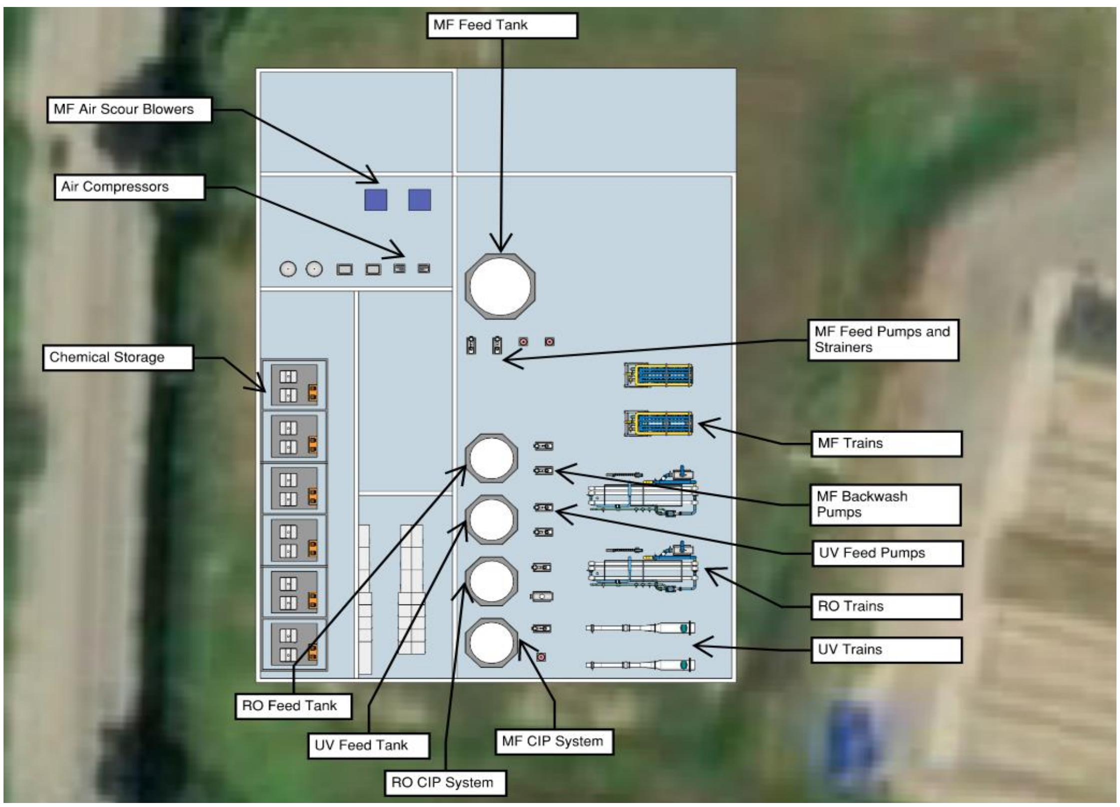


Figure 8.3 NPR System Layout at MSD

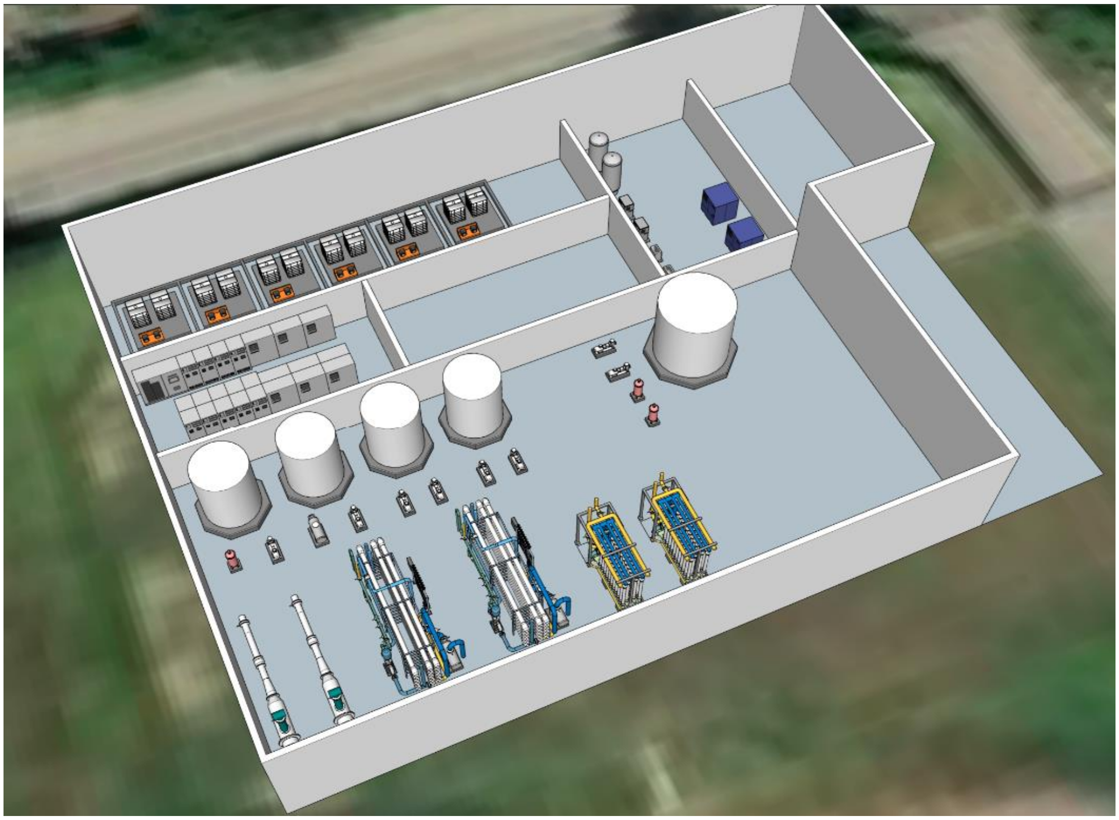


Figure 8.4 Isometric View of NPR Treatment Train Layout at MSD

The layout is for a non-MBR based wastewater effluent as described in Treatment Train 1A. The layout provided also includes space for an expansion to indirect potable reuse (i.e., the treatment train discussed in 8.3.2 below). The total area required for the advanced water purification facility (AWPF) building is 15,000 square feet (sf).

Flow to the recycled water treatment system will be equalized. For efficient MBR operation, that equalization would occur ahead of the MBR, as detailed in TM6. For options that do not include an MBR, equalization of secondary effluent would occur to allow for consistent capture and treatment of the average dry weather flow (ADWF). Post treatment, for NPR, another 100,000 gallons of storage is needed to allow for peak instantaneous demand for irrigation.

8.3 Indirect Potable Reuse

Two IPR treatment trains are evaluated here, as follows:

- Treatment Train 2A – Following MBR, treatment will include a full stream RO and UV AOP at the ADWF of 0.7 mgd, resulting in 0.56 mgd of new water.
- Treatment Train 2B – Using WRP effluent that has either primary DAF or secondary DAF, treatment will include a full stream UF, RO, and UV AOP at the ADWF of 0.7 mgd, resulting in 0.56 mgd of new water.
- Treatment Train 3 – A third IPR alternative is also considered, in which secondary effluent from MSD is sent to Carpinteria for treatment at their AWPF. This alternative does not have a layout defined

here because additional reuse treatment does not occur on the MSD site. This alternative would require upgrades to the wastewater treatment at MSD, via either the inclusion of DAF or replacement with MBR. It would also require equalization to provide a consistent flow of 0.7 mgd of secondary effluent.

Engineering analysis for Treatment Trains 2A and 2B includes stabilization of the purified water. Infrastructure (piping, pumping) for Trains 2 and 3 is detailed in a TM09.

8.3.1 Regulations for Indirect Potable Reuse

Regulations for IPR reuse via groundwater recharge are contained in CCR Title 22, Division 4, Chapter 3 (Water Recycling Criteria). Within Title 22, there are regulations for groundwater recharge via both surface spreading and subsurface application/direct injection. Some of the key requirements for IPR are as follows:

Source Control: IPR projects must use treated wastewater from a wastewater management agency that administers an industrial pretreatment and pollutant source control program (Pretreatment Program). The source control program must include several elements, including an assessment of the fate of site-specific chemicals through the wastewater and recycled water treatment systems, monitoring and investigation of chemical sources, and an outreach program to minimize discharge of chemicals into the source water. Because of the higher rigor (and cost) associated with a Pretreatment Program for potable water reuse, a more detailed approach is now implemented for potable water reuse projects, called the Enhanced Source Control Program (ESCP).

Pathogen Control: IPR treatment must provide 12-log reduction of enteric virus, 10-log reduction of *Giardia* cysts, and 10-log reduction of *Cryptosporidium* oocysts. In addition, there are requirements for how projects must verify that the treatment processes they are using can achieve the required levels of pathogen reduction. The pathogen reduction requirements are based on achieving a pathogen concentration in the treated water that meets an established risk threshold. This threshold is the same for drinking water, IPR, and DPR.

Treatment Train: For GWR via direct injection, which would be the case for an IPR project collaborating with Carpinteria, full advanced treatment (FAT) is required prior to injection. FAT requires all flow to go through both RO and an AOP that achieves 0.5-log reduction of 1,4-dioxane. While microfiltration or ultrafiltration are not required for FAT from a pure regulatory standpoint, the protozoa reduction of these membranes is important, as is their role in pretreatment ahead of RO. In addition to these requirements, all Cryptosporidium and Giardia reduction credit must be accomplished prior to injection. Virus credit is granted for retention time in the aquifer.

Chemical Control: All IPR projects must meet all current drinking water standards, including maximum contaminant levels (MCLs), disinfection byproducts (DBPs), and action levels (ALs). These constituents must be monitored quarterly. Constituents with secondary MCLs must be monitored annually. In addition, the regulations impose limits on total organic carbon (TOC) of wastewater origin, as a bulk mechanism to control chemical pollutants in the treated water. For groundwater rule (GWR) projects, no more than 0.5 mg/L of TOC from the recycled water may be present in the blended groundwater. Because these projects are required to provide FAT with RO that achieves an effluent TOC below 0.5 mg/L, diluent water is not required. The injected water is generally already in compliance with the maximum TOC requirement of 0.5 mg/L.

Environmental Buffer: Requirements for environmental buffers describe the minimum characteristics that these buffers must provide. Smaller environmental buffers (e.g., shorter groundwater travel time) provide less response time, treatment, and/or dilution, which results in an increase in advanced treatment requirements. A minimum aquifer retention time of 2 months is required. The retention time must be verified using a tracer study.

Additional Monitoring: Quarterly monitoring must be conducted for priority toxic pollutants, a list of site-specific unregulated chemicals to be determined in conjunction with the State Board, and constituents with notification levels (NLs). Monitoring must be conducted in recycled water and at downgradient groundwater monitoring wells.

8.3.2 Treatment Train Details and Design Criteria

In the treatment trains proposed here, the IPR regulations for GWR via direct injection are met using MF followed up full-stream RO and UV/AOP, i.e., full advanced treatment. Treatment Train 1 accomplishes membrane filtration via the use of MBR, while Treatment Train 2 has a standalone UF process upstream of the RO. These unit processes achieve the requirements for GWR as described in Table 8.4.

Table 8.4 Treatment Processes for IPR via Groundwater Recharge and Their Role in Meeting the Regulatory Requirements

Process	Description
MBR or UF	• Reduces turbidity in filtrate to meet the following: – No more than 0.2 nephelometric turbidity units (NTU) more than 5 percent of the time within a 24-hour period. – No more than 0.5 NTU at any time. • Removes pathogens via size exclusion through membranes. • Provides necessary pretreatment upstream of RO and UV AOP similar to all existing California potable reuse plants.
RO	• Reduces total organic carbon to meet regulatory limit of 0.5 mg/L. • Reduces TDS. • Decreases level of all chemicals with high molecular weights, and uncharged chemicals with low molecular weights. • Removes pathogens via size exclusion. • Effectively removes many contaminants of emerging concern, including PFAS.
UV/AOP	• Combination disinfection and chemical oxidation process. • Provides pathogen disinfection. • Achieves oxidation requirement by providing no less than 0.5-log (69 percent) reduction of 1,4-dioxane. Providing this level of reduction also ensures that other unregulated chemicals are also reduced through this process. • Provides final chemical abatement, including for 1,4-dioxane and N-Nitrosodimethylamine (NDMA).

The pathogen log removals for each process are summarized and compared to the total required log removals in Table 8.5.

Table 8.5 Pathogen Log Removal Values (LRVs) per Process for the IPR Treatment Trains

Process	Pathogen Log Removals by Pathogen Category		
	Virus	*Giardia*	*Cryptosporidium*
Treatment Train 2A (MBR-Based)			
MBR(1)	1	2.5	2.5
RO(2)	2	2	2
UV AOP	6	6	6
Groundwater Basin	6(3)	0	0
Total	**15**	**10.5**	**10.5**
Required	**12**	**10**	**10**
Treatment Train 2B (WRP with DAF)			
WRP(4)	0+	0+	0+
UF(5)	0	4	4
RO(2)	2	2	2
UV AOP	6	6	6
Groundwater Basin	6(3)	0	0
Total	**14**	**12**	**12**
Required	**12**	**10**	**10**

Notes:

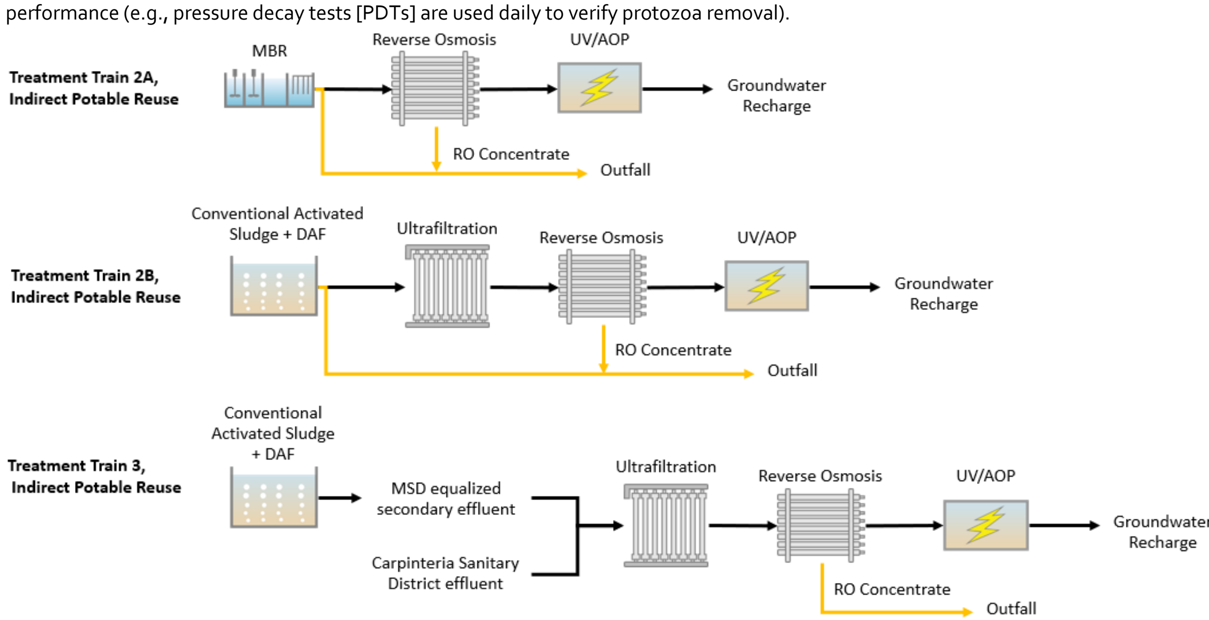
(1) MBR credits are based on Tier 1 approach from Water Research Foundation (WRF) 4997, *Membrane Bioreactor Validation Protocols for Water Reuse.*

(2) Can receive up to 1 log credit during permitting for electrical conductivity (EC) as a monitoring surrogate; 1.5 log credit for TOC, and 2 for strontium. An additional half log can typically be gained once the facility is operational.

(3) 1-log virus credit is granted for each month spent in the ground. If retention time shorter than 6 months is used the pathogen credits would be reduced accordingly.

(4) Pathogen removal through the wastewater treatment plant (WWTP) would need to be evaluated and confirmed through a 3 to 12 months study including evaluation of a broad range of pathogens and surrogates.

(5) UF systems can remove virus (2 to 4+ LRV) but currently are not credited due to the lack of a reliable surrogate to be used daily to verify performance (e.g., pressure decay tests [PDTs] are used daily to verify protozoa removal).



(6)

Figure 8.5 Indirect Potable Water Reuse Treatment Trains with (a) MBR and (b) no MBR

8.3.3 Treatment Train Layout and Footprint

The footprint of an IPR facility in Montecito is the same as that shown above for the NPR facility in Figure 8.2 and Figure 8.3, because that layout has been sized for potential expansion to IPR. For Treatment Train 3, additional footprint would be needed at Carpinteria's advanced water purification facility. Analysis of the additional footprint needed is not within the scope of this work and has not been conducted.

8.4 Direct Potable Reuse at MSD

Two DPR treatment trains are evaluated here; both serve to purify water ahead of addition to Montecito Water District's (MWD's) Bella Vista Water Treatment Plant (WTP), which is designated as raw water augmentation:

- Treatment Train 5 - Following MBR, treatment will include a full stream ozone, BAC, UF, RO and UV AOP at the ADWF. The second membrane filtration step is required to achieve the pathogen reduction targets. Additional monitoring systems and storage/dilution systems are included in this analysis. The DPR system will produce 0.56 mgd of new water.
- Treatment Train 6 - Using WRP effluent that has either primary DAF or secondary DAF, treatment will include a full stream ozone, BAC, UF, RO, and UV AOP at the ADWF. Additional monitoring systems and storage/dilution systems are included in this analysis. The DPR system will produce 0.56 mgd of new water.

Engineering analysis for both options includes stabilization of the purified water. Infrastructure (piping, pumping) for this option is detailed in TM9. Direct potable reuse with the City of Santa Barbara, which would require Santa Barbara to do the treatment and purification, is included in a subsequent section.

8.4.1 Regulations for Direct Potable Reuse

Regulations for DPR in California are not yet finalized but are well developed. Assembly Bill 574 was signed into law in October 2017 and requires that DDW develop raw water augmentation regulations by 2023. Since then, DDW has published a proposed framework and a second edition framework stating that they intend both raw and treated water augmentation to be regulated under one uniform regulation published in 2023 (SWRCB 2019). Most recently, DDW published Addendum version 8-17-2021 to A Framework for Direct Potable Reuse (SWRCB 2021), which provides the second draft of regulations as they might be housed within a new Article under the Surface Water Treatment chapter of Title 22 of the California Code of Regulations. The draft regulations contain extensive requirements for treatment, monitoring, source control, reporting, and more, as described further below.

There is currently one operating DPR system in the country, in Big Spring, Texas. There are no DPR systems in California, and any DPR project proposed will be on the leading edge and will need to work closely with DDW. It is important to note that a small DPR project will face additional challenges in terms of demonstrating sufficient technical, managerial, and financial capacity to successfully build and operate a DPR project without existing precedents.

Enhanced Source Control: An enhanced source control program must be implemented by the wastewater management agency to limit contaminants in wastewater used in DPR projects. The source control program has several required elements, including investigation and monitoring of State Board-specified chemicals and contaminants and an outreach program to industrial, commercial, and residential dischargers within the service area contributing to the DPR project. In addition, a sewershed surveillance program must be implemented to provide early warning of a potential occurrence that could adversely impact the DPR treatment. It must include online monitoring that may indicate a chemical peak resulting from an illicit discharge, coordination with the pretreatment program for notification of discharges above allowable limits, and monitoring of local surveillance programs to determine when community outbreaks of disease occur.

Feed Water Monitoring: Prior to operation, the feed water to a DPR project must be monitored monthly for a minimum of 24 months for regulated contaminants (i.e., those with an MCL), priority pollutants, NLs, a specific list of solvents, DBPs, and DBP precursors.

Pathogen Control: Treatment and monitoring systems must be designed and validated to attain 20, 14, and 15-log reduction credit for virus, Giardia, and Cryptosporidium, respectively. The treatment train must consist of at least four separate treatment processes for each pathogen type (a single process can receive credit for multiple pathogens), and each credited process must demonstrate at least 1-log reduction of the target pathogen. For each treatment process that is proposed to receive pathogen reduction credit, a validation study must be conducted and a report of the results must be submitted to the State Board. The regulations contain specific requirements for what must be provided in the validation study to verify the proposed pathogen credit and the proposed online surrogate monitoring for ongoing demonstration of process performance.

Treatment Train: In addition to RO and an advanced oxidation process, as required for IPR, the treatment train for DPR must include ozone/BAC ahead of RO[3]. It must also include UV disinfection with a dose of at least 300 mJ/cm^2. The system must be designed to meet certain response time requirements to ensure that diversion and/or shutoff can occur in the event of a failure to meet the pathogen and/or chemical control requirements.

Chemical Control: DPR systems must meet several requirements for chemical control.

- Finished water must meet all current drinking water standards, including MCLs, DBPs, and ALs. Monthly monitoring in the product water is required.
- The TOC shall not exceed 0.5 mg/L prior to distribution.
- Nitrate and nitrite must be continuously monitored in the RO permeate. Continuous monitoring of lead and/or perchlorate may also be required if the required weekly grab samples indicate that it is justified. The control system must be designed to automatically divert purified water if there is an exceedance of the TOC limit, the nitrate MCL, and potentially levels for perchlorate and lead.
- In order to address a potential chemical peak, the system must provide sufficient mixing at some point prior to distribution to attenuate a one-hour elevated concentration of a contaminant by a factor of ten. This dilution can occur at any point in the treatment and distribution process before the water is consumed. Examples include:
  - Blending within a WWTP, such as occurs with return activated sludge recycle streams.
  - Blending in an equalization basin, such as primary equalization or secondary effluent equalization.
  - Blending within a distribution system, such as blending within a water storage reservoir before distribution to customers.
- DBP formation must be evaluated by characterizing chemicals to evaluate precursors, byproduct production, and options to minimize DBP formation.

[3] The latest version of the draft regulations has included a provision that allows for a treatment train without ozone/BAC, provided that the purified water comprises 10 percent or less of total water supplied on a continuous basis. Partial ozone/BAC treatment is allowable if purified water will comprise up to 50 percent of the total water supplies. For example, if the purified water were going to make up 25 percent of the water supplied, then approximately 75 percent of the purified water would need to be treated through ozone/BAC.

Additional Monitoring: Extensive chemical monitoring is required on an ongoing basis in the feed water to the DPR project, the effluent from the advanced oxidation process, and the finished water prior to entering distribution[4]. In each location, monthly sampling is required for all MCLs, secondary MCLs, NLs, priority toxic pollutants, alert levels, DBPs and DBP precursors, and specified solvents. Weekly sampling is required for nitrate, nitrite, perchlorate, and lead. In addition, quarterly sampling is required for chemicals known to cause cancer or reproductive issues for at least three years.

Operations: The draft DPR regulations contain new requirements for advanced water treatment operators (AWTOs). The AWTO certification goes from grade 3 to grade 5. In order to obtain AWTO certification, a grade 3 water or wastewater treatment operator certification is needed[5]. There must be one chief and one shift operator that are AWTO grade 5 certified. An AWTO grade 5 must be present on site at all times[6]. All operators at the advanced treatment facility must be AWTO certified (can be at any grade).

8.4.2 Bella Vista Water Treatment Plant

The role of Bella Vista Water Treatment Plant is different for the two Montecito DPR alternatives. In Treatment Train A, purified recycled water would be blended with the finished water from the WTP, increasing the overall production from the location. In this option, additional virus credits would be needed by free chlorination as part of reclaimed water purification, which is shown below in Table 8.7.

For Treatment Train B, the treatment credits at the Bella Vista WTP are necessary to meet the draft DPR requirements; therefore in this alternative, the purified water would be blended upstream of the WTP. Recent work conducted for WRF Project 5049, *Benefits and Challenges in Pathogen Removal when Blending Advanced Treatment Water with Raw Water upstream of a Surface Water Treatment Plant in DPR*, has provided insights into the potential impacts of blending advanced treated water (ATW) upstream of the Bella Vista WTP. The project conducted bench and pilot testing on blends of ATW and conventional surface water to characterize potential impacts on WTP performance. Although the study found that the effects of blending are site specific, and treatment specific, there are some general takeaways that are relevant for a future DPR project at Bella Vista WTP.

In general, for RO-based DPR treatment trains, blending ATW with conventional surface water resulted in lower TOC, turbidity, and alkalinity in the WTP feedwater. The reduction in TOC generally also resulted in a reduced coagulant dose needed for charge neutralization. ATW contributions of up to 50 percent of the feed water did not add challenges to coagulation, flocculation, sedimentation, and filtration processes in terms of turbidity and TOC removal. In some cases, a benefit was observed in terms of the performance of these processes. In addition, blending with ATW reduced chlorine demand in the filtered water, but did not show a significant impact on DBP formation.

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[4] DDW may allow for the finished water sampling location to be used to satisfy the requirement for the post-oxidation sampling point.

[5] Obtaining AWT Grade 3 certification requires passing an exam; higher levels of certification require increasing levels of experience operating advanced treatment processes. See https://www.awtoperator.org/awto-certification/ for additional information.

[6] The latest version of the draft regulations does allow for some degree of remote operations. A project must submit an operations plan that demonstrates an equivalent degree of operational oversight and reliability with either unmanned operation or operation under reduced operator oversight. The chief or shift operator must still be able to monitor operations and exert physical control over the treatment facility within a maximum of one hour.

Blends greater than 50 percent ATW were not tested in this WRF study. For a DPR project at Bella Vista WTP, the ATW flow would be 0.56 mgd, or about 388 gallons per minute (gpm). Based on available flow data, there are times during periods of lower demand where 0.56 mgd would represent more than 50 percent of the source water to Bella Vista WTP. Additional pilot testing is recommended to further characterize the impacts of blending at higher proportions of ATW on the water treatment processes.

8.4.3 Treatment Train Details and Design Criteria

The treatment trains proposed here have been selected to meet the draft DPR regulations. The unit processes and their associated role in meeting these requirements are described in Table 8.6. The treatment train process flow diagram is shown in Figure 8.6.

Table 8.6 Treatment Processes Used for DPR and Their Role in Meeting Regulatory Requirements

Process	Description
Ozone	• Provides pathogen disinfection. • Facilitates biological treatment by breaking down organic carbon for removal by the downstream biological filters. • Reduces concentrations of some chemicals and metals, such as iron and manganese, through chemical oxidation, thereby: – Decreasing toxicity of product water and potentially RO concentration. – Providing effective pretreatment of water upstream of membranes thereby reducing fouling potential and required level of chloramines.
BAC Filtration	• Biological filtration process. • Removes organic carbon, made more bioavailable by the upstream ozone process. • Decreases level of some chemicals, including NDMA. • Reduces turbidity. • Can provide some nitrification
UF	• Same as IPR; see Table 8.4.
RO	• Same as IPR; see Table 8.4.
UV/AOP	• Same as IPR; see Table 8.4.
Chlorination	• Provides pathogen disinfection.
Stabilization (calcite contactors)	• Provides corrosion control. • Required for water treated by RO.
Blending	• Meets draft DPR blending requirement to reduce a one-hour chemical spike by a factor of 10. • Provides response time if a monitoring alarm were to signal an issue in the upstream treatment.

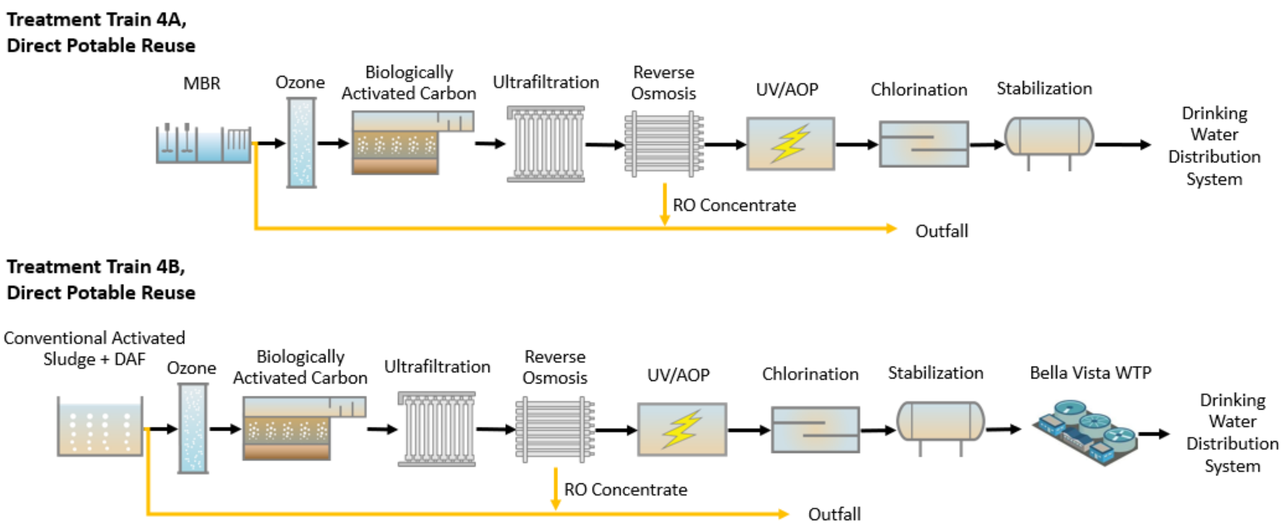


Figure 8.6 Direct Potable Water Reuse Treatment Trains with (a) MBR and (b) no MBR

Table 8.7 Pathogen LRVs per Process for DPR Treatment Trains at MSD

Process	Pathogen Log Removals by Pathogen Category		
	Virus	*Giardia*	*Cryptosporidium*
Treatment Train 4A (MBR-Based)			
MBR(1)	1	2.5	2.5
Ozone/BAC(2)	6	6	1
UF(3)	0	4	4
RO(4)	2	2	2
UV AOP	6	6	6
Chlorination(5)	6	0	0
Total	**21**	**20.5**	**15.5**
Required	**20**	**14**	**15**
Treatment Train 4B (WRP with DAF)			
WRP(6)	0+	0+	0+
Ozone/BAC(2)	6	6	1
UF(3)	0	4	4
RO(4)	2+	2	2
UV AOP	6	6	6
Chlorination(5)	2	0	0
Bella Vista WTP	4	3	2
Total	**20**	**21**	**15**
Required	**20**	**14**	**15**

Notes:
(1) MBR credits are based on Tier 1 approach from WRF 4997, *Membrane Bioreactor Validation Protocols for Water Reuse*.
(2) Based on United States Environmental Protection Agency protocols with a contact time of 6.24 mg-min/L, the project will result in the credits assigned to Pure Water San Diego, shown here.
(3) UF systems can remove virus (2 to 4+ LRV) but currently are not credited due to the lack of a reliable surrogate to be used daily to verify performance (e.g., PDTs are used daily to verify protozoa removal).
(4) Can receive up to 1 log credit during permitting for EC as a monitoring surrogate; 1.5 log credit for TOC, and 2 for strontium. An additional half log can typically be gained once the facility is operational.
(5) Chlorination credits based upon the Australian WaterVal analysis, which has been approved by the State of California for up to 6 log reduction of virus.
(6) Pathogen removal through the WWTP would need to be evaluated and confirmed through a 3 to 12 months study including evaluation of a broad range of pathogens and surrogates.

8.4.4 Treatment Train Layout and Footprint

The overall site plan for the AWPF is shown in Figure 8.7, which includes the location of the future AWPF as well as the use of an existing aeration basin to achieve the required 10:1 dilution of a one-hour chemical peak. The layout for the DPR treatment train at MSD is shown in Figure 8.8 and Figure 8.9. The total area required for the AWPF building is 15,000 sf.

Figure 8.7 Overall Site Plan for DPR at MSD. Site plan assumes the use of retrofit MBR for Treatment Train 4A.

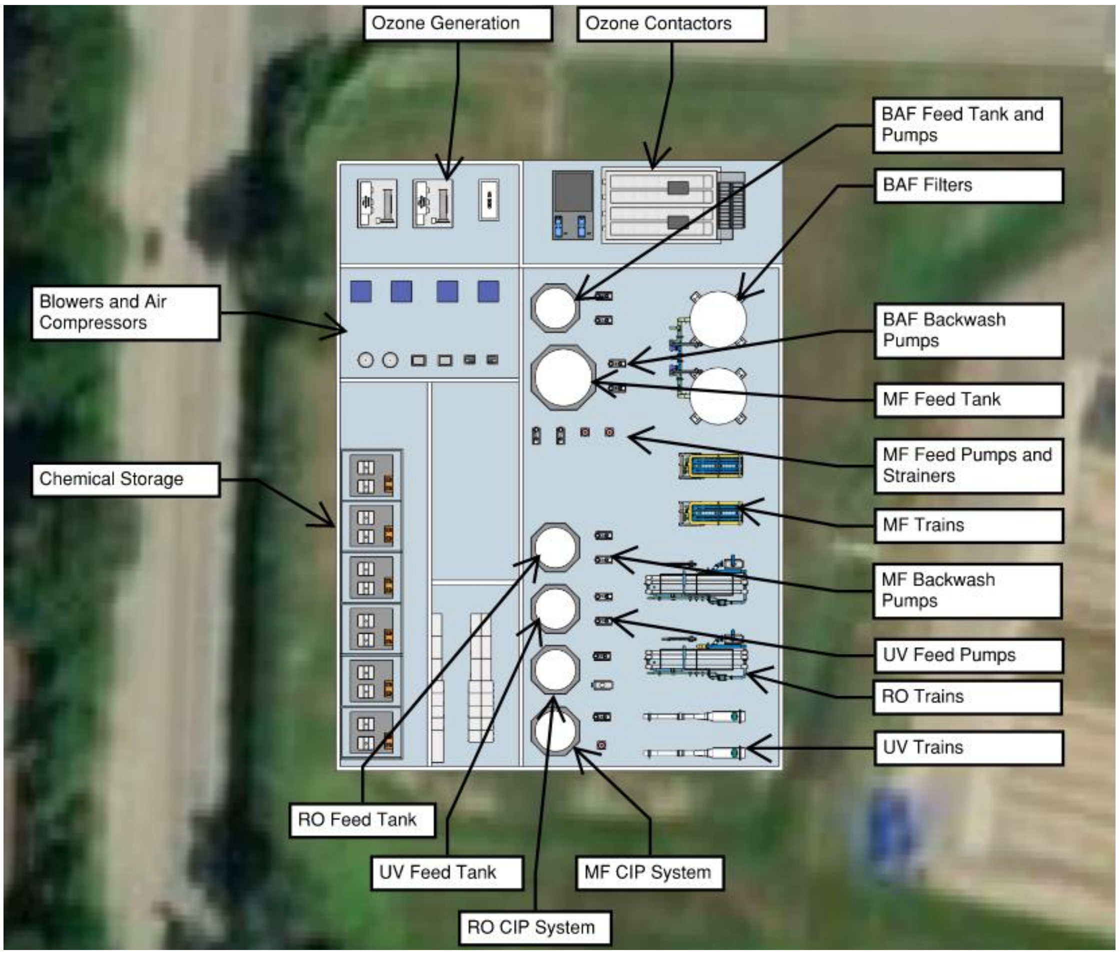


Figure 8.8 DPR Treatment Train Layout at MSD

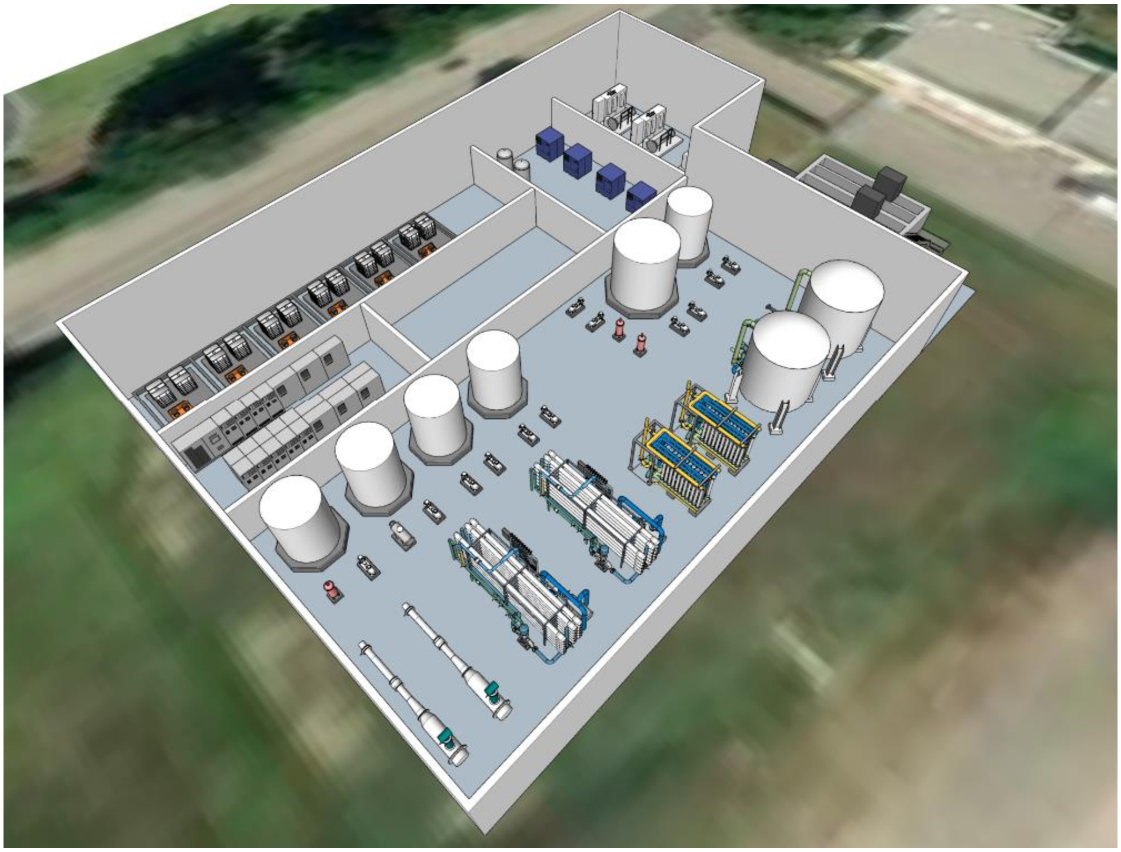


Figure 8.9 Isometric View of DPR Treatment Train at MSD

8.5 Direct Potable Reuse at Santa Barbara

One DPR treatment train is evaluated for Santa Barbara here, serving to purify water ahead of addition to Santa Barbara's Cater WTP, which is designated as raw water augmentation:

- Treatment Train 5 – Using WRP effluent that has either primary DAF or secondary DAF, treatment will include a full stream ozone, BAC, UF, RO, and UV AOP at the ADWF. Additional monitoring systems and storage/dilution systems are included in this analysis.

For Treatment Train 5, two different treatment capacities are to be used, as follows:

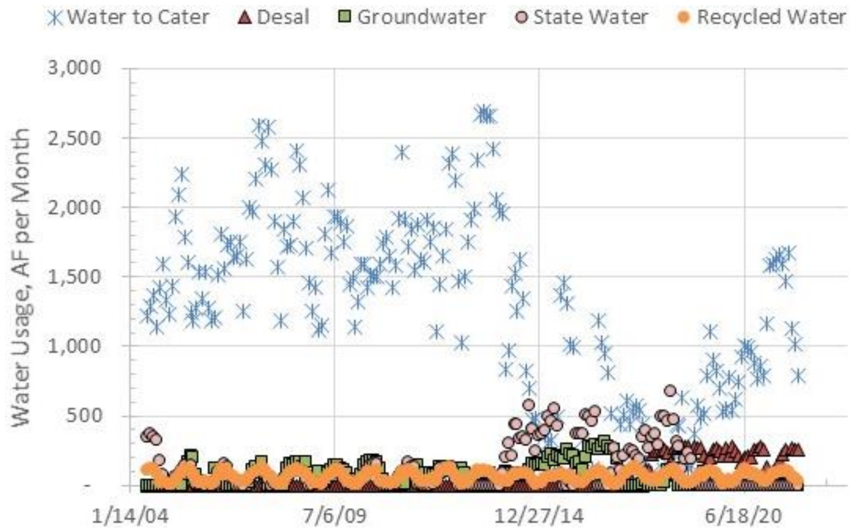
- Treatment Train 5A: Production Rate 6.2 mgd – This production rate is based on the maximum feed flow rate that could be accomplished through equalization of the combined MSD and El Estero ADWFs. From TM1, the anticipated maximum ADWF from MSD is 0.7 mgd. From TM2, the average monthly influent flow to El Estero is 6.96 mgd. For this analysis, a feed flow to advanced purification is assumed to be 7.7 mgd. This scenario represents the maximum purified water that could be produced using wastewater from MSD and El Estero; an alternate use of potable water would need to be identified during the wet season when purified water production would exceed potable water demands.
- Treatment Train 5B: Production Rate 3.7 mgd – The low-end production rate is based on the wet season potable water use (average monthly use, November through February) minus the amount of water produced by desal (which, looking to the future and according to the City of Santa Barbara,

would be 5,000 AFY). The result from the analysis below is 4,120 acre-feet per year (AFY) of purified water production, which is 3.7 mgd. Details are as follows:

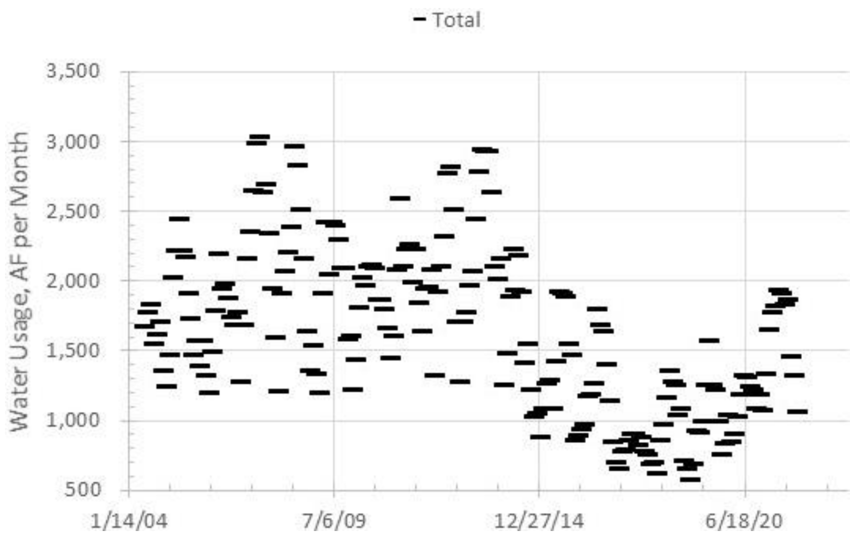
- Monthly water use data provided by the City of Santa Barbara, from 2004 to 2021 was examined.
- This data set includes water to Cater ("Cachuma", "Cachuma Overlap", "Gibralter", "Devil's Canyon", and "Mission Tunnel"), water from Groundwater, water from State Water, and Recycled Water (see the figure below).
- The data shows a significant reduction in water usage toward the end of 2014, with relatively consistent usage from 2014 to 2021.
- Examining the total usage since 2015, the graph below shows an average monthly usage fluctuating over the wet season between ~500 acre-feet (AF) to ~2,000 AF.
- In total, the wet season data suggests:
  - From 2004 to 2014: Average Monthly Usage: 1,579 AF.
  - From 2015 to 2021: Average Monthly Usage: 760 AF.
  - From 2004 to 2021: Average Monthly Usage: 1,257 AF.
- In conclusion, for this analysis, the annual low-end production for AWPF utilizes the data from 2015 to 2021, with an average wet season monthly usage of 760 AF minus desalination flows.
  - (760 X 12) – 5,000 = 4,120 AF/YR of DPR purified water production.

Engineering analysis includes stabilization of the purified water. Infrastructure (piping, pumping) for this option is detailed in a subsequent task.

(a)



(b)



(c)

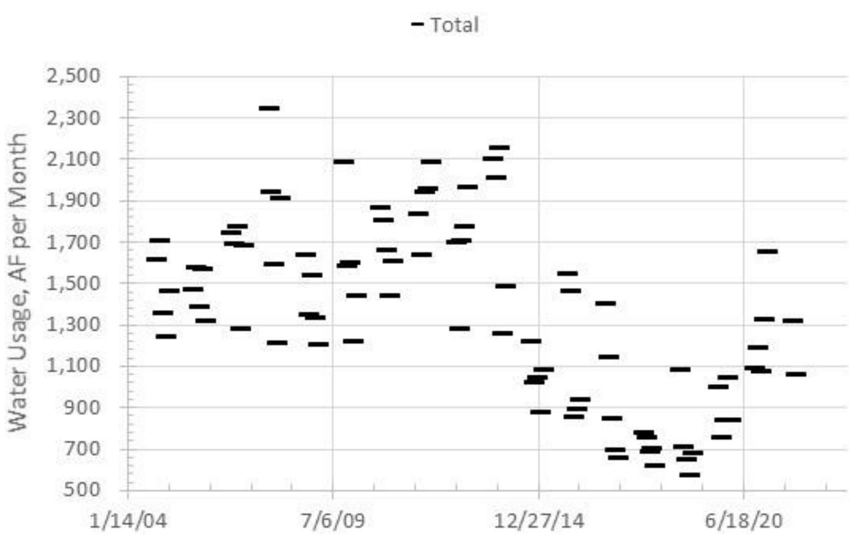


Figure 8.10 Monthly Water Supplies in Santa Barbara (a) All Data, (b) Totals for All Data, (c) Totals for November through March Only

8.5.1 Cater WTP

The general impacts of purified water on conventional water treatment processes were discussed previously in Section 8.4.2 . In the two scenarios identified for raw water augmentation to Cater WTP, the DPR source water could make up 100 percent of the supply to Cater WTP at certain times during the year. We would expect significant impacts to a conventional WTP with a 100 percent purified water feed; the ability of the plant to receive its existing credits could be impacted. Additional pilot work would be needed to characterize the treatability and impacts of this configuration on the conventional surface water treatment.

8.5.2 Treatment Train Details and Design Criteria

The treatment processes for this option are the same as those used for the Montecito DPR option discussed above in Table 8.6 and shown in Figure 8.6(b). The pathogen credits that would be sought for each treatment process compared to the requirements are summarized in Table 8.8.

Table 8.8 Pathogen LRVs per Process for DPR at Santa Barbara

Process	Pathogen Log Removals by Pathogen Category		
	Virus	*Giardia*	*Cryptosporidium*
Treatment Train 5 (WRP)			
WRP(6)	0+	0+	0+
Ozone/BAC(2)	6	6	1
UF(3)	0	4	4
RO(4)	2+	2+	2+
UV AOP	6	6	6
Chlorination(5)	2+	0	0
Cater WTP	4	3	2
Total	**20+**	**21+**	**15+**
Required	**20**	**14**	**15**

Notes:

(1) MBR credits are based on Tier 1 approach from WRF 4997, *Membrane Bioreactor Validation Protocols for Water Reuse*.

(2) Based on United States Environmental Protection Agency protocols with a contact time of 6.24 mg-min/L, the project will result in the credits assigned to Pure Water San Diego, shown here.

(3) Ultrafiltration systems can remove virus (2 to 4+ LRV) but currently are not credited due to the lack of a reliable surrogate to be used daily to verify performance (e.g., PDTs are used daily to verify protozoa removal).

(4) Can receive up to 1 log credit during permitting for EC as a monitoring surrogate; 1.5 log credit for TOC, and 2 for strontium. An additional half log can typically be gained once the facility is operational.

(5) Chlorination credits based upon the Australian WaterVal analysis, which has been approved by the State of California for up to 6 log reduction of virus. The low LRV shown here is representative of a relative contact time (Value 9 mg-min/L, based upon a t10 contact time of 6 minutes, and a minimum wastewater temperature of 15 degrees Celsius, and a pH of <8.5). Sampling for pH and temperature could allow for lower contact time values to meet the target credits. Higher residuals could also be applied to result in increased pathogen credits.

(6) Pathogen removal through the WWTP would need to be evaluated and confirmed through a 3 to 12 months study including evaluation of a broad range of pathogens and surrogates.

8.5.3 Treatment Train Layout and Footprint

The treatment train layout for DPR at Santa Barbara for treatment train 7a, i.e., a purified water production of 6.2 mgd, is shown in Figure 8.11 and Figure 8.12. The site used was the City of Santa Barbara's Corporation Yard, which was identified as a location for potable reuse in Santa Barbara's 2017 Potable Reuse Feasibility Study. It was assumed that the full site would be available for use for potable reuse. For the smaller DPR option with a production rate of 3.7 mgd, the layout would be smaller than what is shown here.

These layouts do not include storage tanks to achieve the 10:1 required dilution of a one-hour chemical peak; for this analysis, it is assumed that the dilution would be achieved in Lauro Canyon Reservoir upstream of Cater WTP. The reservoir has a capacity of 640 AF (208 million gallons [MG]), which would be sufficient to achieve 10:1 dilution of a one hour flow in the 6.2 mgd production scenario (260,000 gallons per hour [gph]).

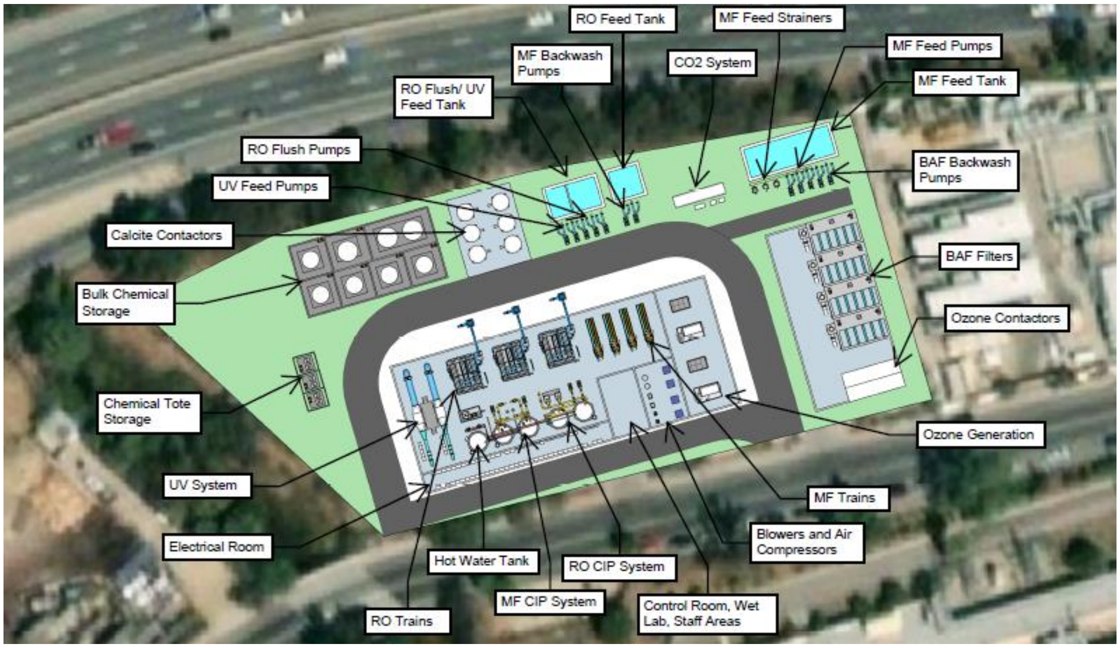


Figure 8.11 DPR Treatment Train Layout in Santa Barbara

Figure 8.12 Isometric View of DPR Treatment Train in Santa Barbara

8.6 Treatment Train Costs

8.6.1 Planning Level Cost Estimate

The Association for the Advancement of Cost Engineering International (AACE) has suggested levels of accuracy for five estimate classes. These five estimate classes are presented in the AACE International Recommended Practice No. 18R-97 (Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries). Table 8.9 presents a summary of these five estimate classes and their characteristics, including expected accuracy ranges (AACE, 2020).

Table 8.9 Classes of Cost Estimates

Estimate Class	Maturity Level of Project Definition Deliverables(1)	End Usage(2)	Methodology(3)	Expected Accuracy Range(4)
Class 5	0 percent to 2 percent	Concept Screening	Capacity factored, parametric models, judgement, or analogy	L: -20 percent to -50 percent H: +30 percent to +100 percent
Class 4	1 percent to 15 percent	Study or Feasibility	Equipment factored or parametric models	L: -15 percent to -30 percent H: +20 percent to +50 percent
Class 3	10 percent to 40 percent	Budget, Authorization, or Control	Semi-detailed unit costs with assembly level line items	L: -10 percent to -20 percent H: +10 percent to +30 percent
Class 2	30 percent to 75 percent	Control or Bid/Tender	Detailed unit cost with forced detailed take-off	L: -5 percent to -15 percent H: +5 percent to +20 percent
Class 1	65 percent to 100 percent	Check Estimate or Bid/Tender	Detailed unit cost with detailed take-off	L: -3 percent to -10 percent H: +3 percent to +15 percent

Notes:
(1) Expressed as percent of complete definition.
(2) Typical purpose of estimate.
(3) Typical estimating method.
(4) Typical variation in low and high ranges at an 80 percent confidence interval.

The quantity and quality of the information required to prepare an estimate depends on the end use for that estimate. Typically, as a project progresses from the conceptual phase to the study phase, preliminary design and final design, the quantity and quality of information increases, thereby providing data for development of a progressively more accurate cost estimate. A contingency is often used to compensate for lack of detailed engineering data, oversights, anticipated changes, and imperfection in the estimating methods used. As the quantity and quality of data becomes better, smaller contingency allowances are typically utilized. For this project, cost estimates are developed following the AACE International Recommended Practice No. 18R-97 estimate classes 5 and 4.

8.6.2 Capital and Operations and Maintenance Cost Basis

Capital costs are based on vendor quotes and similar facilities with allowances for civil, mechanical, structural, and electrical improvements, as well as engineering cost.

Construction costs presented typically include an estimating contingency, sales tax, general conditions, and contractor's overhead and profit. The percentages assumed for these factors are shown in Table 8.10.

Total project costs presented typically include a fee for engineering, legal, and administration, as well as an owners reserve for change orders. The percentages assumed for these factors are also shown in Table 8.10.

Table 8.10 Basis for Estimating Capital Costs

Item	Estimated Cost	Estimated Cost of "A"
Equipment / Infrastructure Cost Total	**"A"**	**100 percent**
Sales Tax	8 percent of 1/2 "A"	4 percent
Estimating Contingency(1)	30 percent	31 percent
General Conditions(1)	12 percent	16 percent
Contractor Overhead and Profit(1)	12 percent	18 percent
Bonds and Insurance(1)	2.5 percent	4 percent
Construction Cost Total	**"B"**	**174 percent**
Engineering, Legal, and Administrative	20 percent of "B"	35 percent
Owner's Reserve for Change Orders	5 percent of "B"	9 percent
Project Cost Total	**"C"**	**217 percent**

Notes:
(1) The construction cost elements are applied sequentially, e.g., the sales tax is calculated and added on to the equipment cost, then the estimating contingency is 30 percent of the sum of equipment cost and sales tax.

Operations and maintenance (O&M) costs were developed for the proposed AWPF facility. These O&M costs include power consumption, chemical consumption, maintenance, and staffing. The staffing costs were developed using the results of a Carollo Engineers (Carollo) survey of IPR operations, with extrapolation to DPR requirements. For DPR, the staffing costs assume that 3 AWTO Grade 5 operators will be needed to provide full staff for 12 hours/day and skeletal staff for 12 hours/day, with an AWTO Grade 5 operator on call at all times. Staffing costs for both IPR and DPR also include regulatory and compliance staff, as well as new lab staff to supplement existing lab staff, which would encompass costs associated with regulatory compliance (e.g., preparing plans, water quality sampling).

8.6.3 Cost Estimates

The costs for reuse treatment and annual reuse treatment O&M for each treatment train are summarized in Table 8.11. These costs are just for the reuse treatment component, and do not include upgrades to the wastewater treatment plant (i.e. MBR or addition of DAF, covered in TM6), conveyance (covered in TM9), wastewater re-treatment, or treatment at a water treatment plant. Montecito-specific costs are also included; these are only different for certain regional projects and are calculated based on Montecito's proportional share of the total purified water production.

Table 8.11 Summary of Treatment and O&M Costs for Each Treatment Train

	Use	Project Partners	Project Size (AFY)	Water Supply Benefit for Montecito (AFY)	Total Reuse Treatment Cost	Total Annual Reuse O&M Cost	Montecito Reuse Treatment Cost	Montecito Reuse O&M Cost
1A	NPR	Montecito Only	128	128	$9,100,000	$945,000	$9,100,000	$945,000
1B	NPR	Montecito Only	128	128	$0	$330,000	$0	$330,000
1C	NPR	Montecito Only	128	128	$5,770,000	$369,000	$5,770,000	$369,000
2A	IPR	Montecito and Carpinteria	560	560	$12,980,000	$1,971,000	$12,980,000	$1,971,000
2B	IPR	Montecito and Carpinteria	560	560	$16,890,000	$2,002,000	$16,890,000	$2,002,000
3	IPR	Montecito and Carpinteria	1,792	560	$69,500,000	$2,484,000	$19,544,000[1]	$699,000[1]
4A	DPR	Montecito Only	560	560	$25,360,000	$3,957,000	$25,360,000	$3,957,000
4B	DPR	Montecito Only	560	560	$25,360,000	$3,957,000	$25,360,000	$3,957,000
5A	DPR	Montecito and Santa Barbara	6,945	560	$112,810,000	$7,065,000	$9,096,000[1]	$570,000[1]
5B	DPR	Montecito and Santa Barbara	4,145	560	$76,310,000	$6,003,000	$10,311,000[1]	$811,000[1]

Notes:
(1) Montecito portion of cost calculated based on proportional share of total purified water production.

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Appendix 8A

TREATMENT TRAIN DESIGN CRITERIA

Treatment train design criteria are summarized below for three of the potable reuse options. The criteria shown are applicable to the other treatment alternatives as follows:

Table 8A.1 Summary of Design Criteria Provided for Potable Reuse Alternatives

<table>
<tr><th>Reuse Type</th><th>Treatment Train</th><th>Wastewater Treatment</th><th>Advanced Treatment</th><th>Finished Water Flow</th><th>Design Criteria</th></tr>
<tr><td rowspan="2">NPR</td><td>1</td><td>MBR</td><td>Partial RO – UV</td><td>0.6 mgd</td><td>RO and UV criteria same as for TT2</td></tr>
<tr><td>2</td><td>Conventional activated sludge + DAF[1]</td><td>UF - Partial RO - UV</td><td>0.6 mgd</td><td>Provided in Tables A.2 – A.6</td></tr>
<tr><td rowspan="2">IPR</td><td>3</td><td>MBR</td><td>RO – UV/AOP</td><td>0.56 mgd</td><td>RO and UV/AOP criteria same as for TT6</td></tr>
<tr><td>4</td><td>Conventional activated sludge + DAF[1]</td><td>UF – RO – UV/AOP</td><td>0.56 mgd</td><td>UF, RO and UV/AOP criteria same as for TT6</td></tr>
<tr><td rowspan="2">DPR at MSD</td><td>5</td><td>MBR</td><td>Ozone/BAC – UF – RO – UV/AOP</td><td>0.56 mgd</td><td>Same as for TT6</td></tr>
<tr><td>6</td><td>Conventional activated sludge + DAF[1]</td><td>Ozone/BAC – UF – RO – UV/AOP</td><td>0.56 mgd</td><td>Provided in Tables A.2 – A.6</td></tr>
<tr><td rowspan="2">DPR at Santa Barbara</td><td>7a</td><td rowspan="2">Conventional activated sludge + DAF[1]</td><td rowspan="2">Ozone/BAC – UF – RO – UV/AOP</td><td>6.2 mgd</td><td>Provided in Tables A.2 – A.6</td></tr>
<tr><td>7b</td><td>3.7 mgd</td><td>Between TT6 and TT7a</td></tr>
</table>

Table 8A.2 Ozone Design Criteria

Process and Criteria	Unit	Alternatives		
		NPR – TT2	DPR at MSD – TT6	DPR at SB – TT7a
Feed Flow	mgd		8.7	0.7
Ozone Production				
Ozone applied dose	mg/L	N/A	21	21
Ozone MTE	percent	N/A	90 percent	90 percent
Ozone Transferred Dose	mg/L	N/A	19	19
Ozone Production	ppd	N/A	123	1,527
Power Consumption	kW	N/A	26	318
Ozone wt percent	percent	N/A	12 percent	12 percent
Ozone contact time	min	N/A	10	10
Ozone CT(1)	mg-min/L(1)	N/A	6.43	6.43
Oxygen Production	ppd	N/A	1,022	12,724

Notes:
(1) Ozone CT required to remove 1 log *Cryptosporidium* at 10 degrees C, according to the equation *Cryptosporidium* LRV = CT*0.0397*(1.09757)^Temperature (EPA 2010). The ability to achieve this CT is dependent on the dose-response curve and must be confirmed through jar testing.

Table 8A.3 BAC Design Criteria

Process and Criteria	Unit	Alternatives		
		NPR – TT2	DPR at MSD – TT6	DPR at SB – TT7a
No. of Filters	No.	N/A	2	4
Filter Area	sq ft	N/A	113	456
Filter Depth	ft	N/A	10	10
Flow per filter		N/A		
All Filters Operating	gpm	N/A	243	1,513
One Filter in Backwash	gpm	N/A	486	2,018
Hydraulic Loading		N/A		
All Filters Operating	gpm/ft	N/A	2.1	3.3
One Filter in Backwash	gpm/ft	N/A	4.3	4.4
EBCT		N/A		
All Filters Operating	min	N/A	34.8	22.5
One Filter in Backwash	min	N/A	17.4	16.9

Table 8A.4 UF Design Criteria

Process and Criteria	Unit	Alternatives		
		NPR – TT2	DPR at MSD – TT6	DPR at SB – TT7a
UF Process				
Type	-			
Flow rate	gpm	486	486	5,570
Number of trains in service	No.	1	1	3
Number of Redundant Trains	No.	1	1	1
Number of Total Trains	No.	2	2	4
Installed Modules per Train	No.	40	20	70
Spare Module Spaces per Train	No.	8	8	8
Temperature correction				
Peak Capacity Design Temperature	°C	15	15	15
Reference Temperature	°C	20	20	20
Temperature Correction Factor	-	1.14	1.14	1.14
Pilot Peak Flux Direct (@Reference Temp)	gfd	70	70	70
Design Peak Flux (@Design Temp)	gfd	61.3	61.3	61.3
Flow Criteria				
Average Feed Flowrate	gpm	486	486	5,570
Feed Water Loss	percent	2.0 percent	2.0 percent	2.0 percent
Gross Filtrate Production	gpm	476	476	5458

Process and Criteria	Unit	Alternatives		
		NPR – TT2	DPR at MSD – TT6	DPR at SB – TT7a
Filtrate Losses	percent	2.0 percent	2.0 percent	2.0 percent
Overall Recovery	percent	96.0 percent	96.0 percent	96.0 percent
System Net Filtrate	gpm	467	467	5347
Instantaneous Factor	-	1.15	1.15	1.15
Online Factor (1/Instantaneous)	percent	87 percent	87 percent	87 percent
Instantaneous Filtrate Production	gpm	548	548	6,277
Module Criteria				
Membrane Area per Module	sq ft	775	775	775
Membrane Area per Train	sq ft	31,000	15,500	54,250
Membrane Area Total	sq ft	62,000	31,000	217,000
Gross Flux Rate	gfd	22.1	44.3	48.3
Instantaneous Flux Rate	gfd	25.4	50.9	55.5
Backwash Criteria				
Type		Reverse Flow Followed By Air Scour and Drain	Reverse Flow Followed By Air Scour and Drain	Reverse Flow Followed By Air Scour and Drain
Backwash Interval per Train				
Minimum	min	20	20	20
Maximum	min	30	30	30
Filtration Flow	Ratio	1.1	1.1	1.1
Backwash Supply Flowrate	gpm	603	603	2,302
Backwash Duration	sec	30	30	30
Air Scour Flowrate	ACFM	280	140	490
Air Scour Duration	Sec	30-60	30-60	30-60
Forward Flush Flowrate	gpm	720	360	1,260
Forward Flush Duration	sec	20	20	20

Table 8A.5 RO Design Criteria

Process and Criteria	Unit	Alternative		
		NPR – TT2	DPR at MSD – TT6	DPR at SB – TT7a
Design Feed Flowrate	gpm	306	467	5,347
Recovery	percent	80 percent	80 percent	80 percent
Permeate Flowrate	gpm	244	373	4,278
Concentrate Flowrate	gpm	61	93	1,069
Feed Flowrate Per Train	gpm	306	467	2,673
Permeate Flowrate per Train	gpm	244	373	2,139
Concentrate Flow per Train	gpm	61	93	535

Process and Criteria	Unit	Alternative		
		NPR – TT2	DPR at MSD – TT6	DPR at SB – TT7a
Number of RO Trains				
In-Service	No.	1	1	2
Reliability	No.	1	1	1
Total	No.	2	2	3
Staging of RO Trains				
1st Stage				
Pressure Vessels per Train	No.	8	12	70
Elements per Pressure Vessels	No.	7	7	7
2nd Stage				
Second Stage	No.	4	6	35
Elements per Pressure Vessels	No.	7	7	7
Number of Elements				
Per Train	No.	84	126	735
Total (In - service)	No.	168	252	2,205
Membrane Area				
Per Element	sq ft	400	400	400
Per Train	sq ft	33,600	50,400	294,000
Total (In-service)	sq ft	33,600	50,400	588,000
Average Flux Rate	11.7	10.5	10.7	10.5

Table 8A.6 Primary UV or UV AOP Design Criteria

Process and Criteria	Unit	Alternative		
		NPR – TT2	DPR at MSD – TT6	DPR at SB – TT7a
Number of Vessels				
In-Service	No.	1	1	1
Reliability	No.	1	1	1
Total	No.	2	2	2
Feed Flowrate	mgd	0.58	0.54	6.16
Feed Flowrate per Reactor	mgd	0.58	0.54	6.16
Lamp aging and Fouling factor	percent	80 percent	80 percent	80 percent
Design inlet UVT	percent	96	96	96
Design outlet UVT	percent	98	98	98
Design NDMA LRV(1)	LRV	N/A	1	1
Design 1,4-dioxane LRV	LRV	N/A	0.5	0.5
Hypochlorite dose	mg/L	N/A	4.75	4.75

Notes:
(1) Assumed NDMA reduction requirement. Bench scale testing required to confirm NDMA in RO permeate.