Very nice job

Oxnard Wastewater Treatment Plant Facility Plan

Brine Concentrate Disposal Analysis

Engineering 481: Wastewater Treatment Engineering

Spring 2019

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1. Introduction

1.1 Background

The Oxnard Wastewater Treatment Plant (OWTP) is located in the City of Oxnard on the coast of Southern California, 60 miles northwest of Los Angeles ("About Oxnard" 2019). Oxnard is the largest and most populous city in Ventura County, known for its agricultural resources and pristine beaches ("About Oxnard" 2019). Figure 1 below illustrates the size of the service area for the OWTP within Ventura County to include the City of Oxnard, City of Port Hueneme, Channel Islands Beach Community District, United States Navy Bases Port Hueneme and Point Mugu, El Rio, Nyeland Acres, Las Posas Estates, and several significant industrial users (City of Oxnard Wastewater Division 2015).

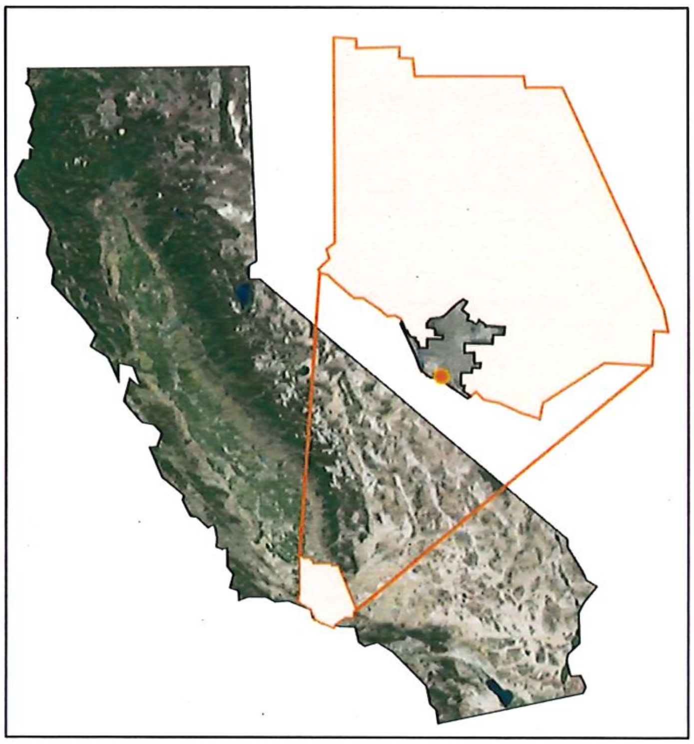

Figure 1: Service area for Oxnard Wastewater Treatment Plant within Ventura County.

Currently, 6.25 million gallons per day (MGD) of the total effluent (approximately 30%) is transferred to the onsite Advanced Water Purification Facility (AWPF) for further treatment, while the remaining 15.1 MGD is discharged into the Pacific Ocean (Carollo Engineers 2017). Like any other municipal wastewater treatment facility discharging into waters of the United States, Oxnard's effluent discharge is required to comply with the National Pollutant Discharge

Elimination System (NPDES), enforced by the Environmental Protection Agency (EPA) ("Municipal Wastewater" 2018). Due to the advanced membrane treatment at the AWPF, 1.55 MGD of brine concentrate is produced from the backwash of the membranes. Brine is a highly concentrated salt solution and at the OWTP, is discharged in the ocean with the secondary effluent (Marshall 2018).

1.2 Purpose and Scope

The purpose of the Oxnard WWTP facility plan is to develop alternatives for brine concentrate discharge that is currently being produced in the Advanced Water Purification Facility at a rate of 1.55 MGD. With anticipated expansion of the AWPF, as the facility is only in Phase I, the production of brine concentrate is expected to increase. Phase II of the AWPF states that 25 MGD of the wastewater effluent will be sent to advanced treatment, reducing the amount of secondary effluent being ocean discharged to only times of peak wet weather flow (CH2M Hill 2013). The reduction of secondary effluent being ocean discharged, will result in a lack of dilution for the brine concentrate. The analysis to determine other methods of discharge will be subject to alternatives that fulfill the designated constraints and criteria, limited by economic and technical feasibility. Proposed alternatives will be detailed with regards to their specific construction costs, operation and maintenance costs, permitability, and other criteria established by the community.

1.3 Objective

The objective of the Oxnard WWTP facility plan is to recommend a disposal method for brine concentrate that is produced during membrane treatment at the Advanced Water Purification Facility onsite. The design will be chosen from the developed alternatives based on the weights of each criteria proposed.

2. Basis of Design

This section reviews the basis of design that will aid in alternative design constraints and considerations. The basis will cover the following topics: 1) current population of service area, 2) influent flow patterns, 3) projected changes in service area, water use, and population, and 4) effects of water conservation trends.

2.1 Population

As of 2017, the population of Oxnard was estimated to be 210,037 according to the most recent study conducted by the United States Census Bureau ("U.S. Census Bureau QuickFacts" 2018). Because the Oxnard WWTP collects beyond just the City of Oxnard, the total service area population is estimated to be around 250,000 people with over 40,000 connections (Ventura County 2040 General Plan 2017). Figure 2 below outlines the service area for the treatment facility with respect to the location of the facility itself.

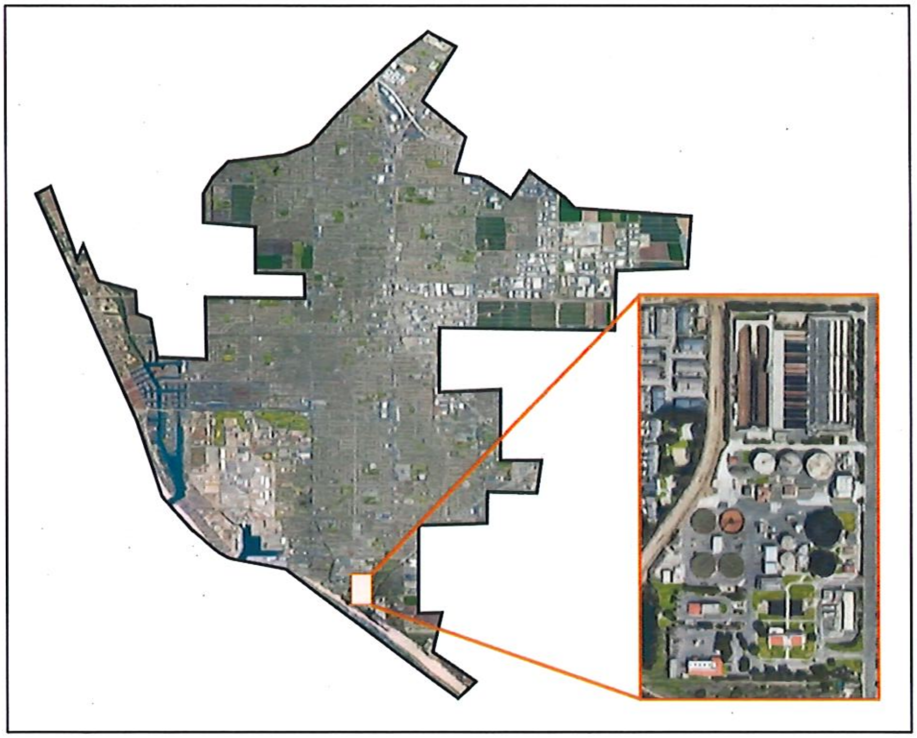

Figure 2: Service area for the Oxnard WWTP with respect to the location of the facility itself.

2.2 Flows

The Oxnard WWTP is permitted for a design capacity of 31.7 million gallons per day (MGD) but is currently averaging a dry weather flow of approximately 20 MGD (Carollo Engineers 2017). Influent flows and loads were analyzed between 2009 and 2013, revealing a steady decline as shown in Figure 3 below (Carollo Engineers 2017).

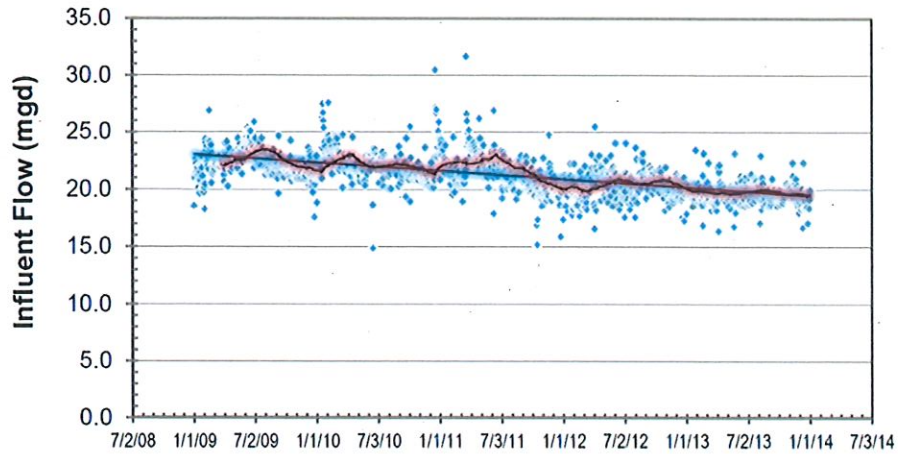

Figure 3: Influent flow data between 2009 and 2013 (Carollo Engineers 2017).

It was hypothesized that the decline between 2009 and 2013 was likely result of the statewide drought present during that period of time (Carollo Engineers 2017). The city's efforts to reduce water usage proved to be effective despite the simultaneous growth in population. Since 2014, the average influent flow has stabilized around 20 MGD. While the growth rate of the City of Oxnard has slowed over previous years, it is expected that the "city should continue to see further growth well into its future" ("Oxnard, California Population 2019" 2019). With a combination of anticipated population growth and restoration to normal rainfall patterns following the drought, Figure 4 below shows the city's projections on influent flow for the future (Carollo Engineers 2017). Being an older study, the projections have already shown deviation from the last five years of operational data.

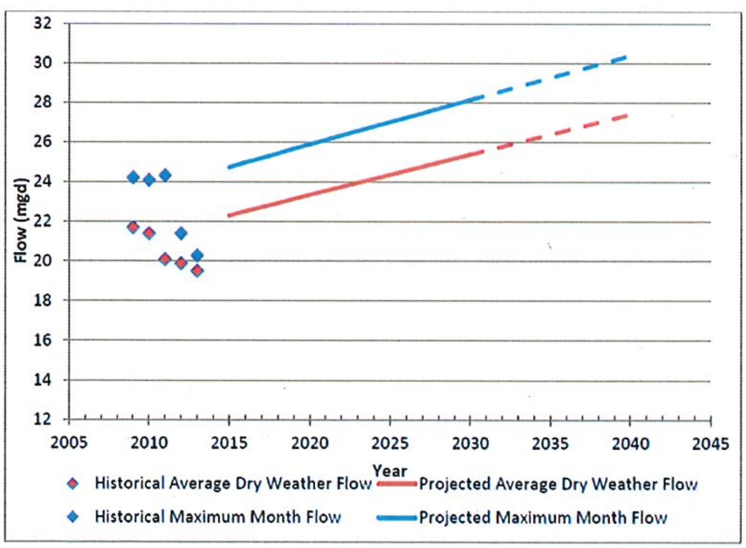

Figure 4: Projected influent flows for Oxnard WWTP (Carollo Engineers 2017).

The majority of the flows entering the Oxnard WWTP are result of residential and commercial dischargers (Carollo Engineers 2017). As of 2015 there were 38 significant industrial users, most of which are food-processing facilities that require packaging and washing fresh vegetables (Carollo Engineers 2017). Others include metal and paper processing plants, as well as the two United States Navy Bases Port Hueneme and Point Mugu (Carollo Engineers 2017). Two local oil refineries also contribute approximately 2 MGD to the influent flow with their desalter concentrate (Carollo Engineers 2017).

2.3 Projected Changes in Service Area, Water Use, and Population

Based on available data, no expansions or modification to the current service area is expected. With there being approximately 14,000 private septic systems in Ventura County, it is possible some might be added to one of the 19 collection systems in the county if construction were to expand into the more rural areas (Ventura County 2040 General Plan 2017). Changes in service area depend on the geological location of increased flow and whether the plant could handle the increase. Having already 15 pump stations and averaging well below their permitted influent flow, Oxnard WWTP is likely able to connect additional laterals as necessary (Ventura County 2040 General Plan 2017).

Water usage awareness in California has been on the rise since the effects of the drought began to take toll in 2011 (Helsel 2019). During the heart of the drought emergency in 2015, former Governor Jerry Brown ordered urban areas to reduce water use by 25 percent (Helsel 2019). Even though the drought has been official lifted in the City of Oxnard, water conservation is still of importance to the residential users. With regards to the industrial water use, existing users are anticipated to show no increase in discharge; however new industry is likely to blossom with a growing population (Carollo Engineers 2017).

According to the United States Census Bureau, the population of Oxnard increased approximately 5 percent between the 2010 and 2017 census ("U.S. Census Bureau QuickFacts" 2018). Provided its coastal attraction, moderate temperature, and military presence, the population of Oxnard is expected to increase well into its future ("Oxnard, California Population 2019" 2019).

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2.4 Effects of Water Conservation Trends

As noted in Figure 3 in Section 2.2, influent flows have decreased between the years of 2009 and 2013 likely due to water conservation within the city (Carollo Engineers 2017). The construction of the Advanced Water Purification Facility (AWPF) in 2015 allowed the Oxnard WWTP to reclaim 6.25 MGD certified for landscape, turfgrass, and food crop irrigation along with industrial or commercial cooling tower makeup, industrial boiler feed, and recreational impoundments (Carollo Engineers 2017). Reclamation of water is a growing technology to conserve water, limited by public perception.

SUMMARIZE EXPECTATIONS OF THE IMPACT (REDUCTION) IF ANY WATER CONSERVATION MIGHT HAVE ON INFLOW TO THE WWTP OVER YOUR DESIGN LIFE PERIOD

3. Regulatory Requirements

Wastewater treatment plants are closely regulated by multiple state and federal agencies to ensure public health and safety as well as environmental conservation. The following sections will describe the permit and agency approval requirements along with specific water quality and biosolids standards that must be upheld at the Oxnard WWTP.

3.1 Permit & Agency Approval Requirements

Permits and agency approvals are to be considered with any upgrade or modification within a wastewater treatment system. The California State Water Resources Control Board (SWRCB) governs wastewater collection systems, requiring that they monitor for sanitary sewer overflows and that each have a sewer system management plan to account for eleven elements such as future capacity, operations and maintenance, and emergency response plan (Carollo Engineers 2017). Wastewater discharge is primarily regulated by the Clean Water Act (CWA) and the California Water Code (Carollo Engineers 2017). The Environmental Protection Agency (EPA) enforces the CWA with issuance of National Pollutant Discharge Elimination Systems (NPDES) permits to regulate the discharge of pollutants into United States waterways that must be reissued every five years at a minimum (Carollo Engineers 2017). On a state level, the State Water Resources Control Board (SWRCB) and the Los Angeles Regional Water Quality Control Board (LARWQCB) both establish water quality criteria for discharging into regional basins, inland surface waters, enclosed bays, estuaries, and the ocean (Carollo Engineers 2017). When water reclamation is involved, the California Division of Drinking Water and Department of Public Health are obligated to develop uniform water recycling criteria appropriate to each particular use of water (Carollo Engineers

2017). With regards to air quality regulations, the Oxnard WWTP is required to abide by the federal (EPA and Occupational Safety and Health Administration), state (California Air Resources Board and Cal-OSHA), and local level (Ventura County Air Pollution Control District) (Carollo Engineers 2017).

3.2 Water Quality Standards

Effluent water quality standards for the Oxnard WWTP are regulated by NPDES NO. CA0054097, effective as of December 1st, 2018 (CRWQCB 2018). The effluent standards defined within the permit are specific to their authorized discharge location through a one-mile outfall into the Pacific Ocean (CRWQCB 2018). The Oxnard WWTP is permitted to discharge 31.7 MGD of secondary treated effluent mixed with 3.1 MGD of brine from the onsite advanced water purification facility (CRWQCB 2018). Upon expansion of the AWPF, the Oxnard WWTP would be required to update their NPDES permit if brine concentrate production were to exceed their current flowrate. Table 1 below reveals the effluent standards defined by their NPDES permit, listing a small fraction of the parameters the wastewater treatment plant is required to monitor (CRWQCB 2018).

Table 1: NPDES effluent limitations for ocean discharge (CRWQCB 2018).

Parameter	Units	Effluent Limitations[1]					Performance Goals
		Average Monthly[2]	Average Weekly	Maximum Daily[3]	Instantaneous Maximum[4]	Average Monthly	Average Monthly
Biochemical Oxygen Demand 5-day @ 20°C[5 7]	mg/L	30	45	--	--	--	--
	lbs/day[6]	7,960	11,900	--	--	--	--
$BOD_5 20^0$ Removal Efficiency[7]	%	85	--	--	--	--	--
Oil and Grease	mg/L	25	40	--	75	--	--
	lbs/day[6]	6,630	10,600	--	19,900	--	--
Total Suspended Solids	mg/L	30	45	--	--	--	--
	lbs/day[6]	7,960	11,900	--	--	--	--
TSS Removal efficiency[7]	%	85	--	--	--	--	--
Settleable solids	ml/L	1.0	1.5	--	3	--	--
Turbidity	NTU	75	100	--	225	--	--
Temperature[8]	F^0			--	100	--	--
pH	Units	Within the limits of 6 to 9 at all times					

All other parameters that are limited by the CWA, as outlined by the NPDES permit, can be found in Appendix A which is divided into three sections: 1) marine aquatic life toxicants, 2) human health toxicants (carcinogenic), and 3) human health toxicant (non-carcinogenic). Most are required to comply with average monthly standards, while others are more stringent and are required to comply by instantaneous standards (CRWQCB 2018).

3.3 Biosolids Standards

The Oxnard WWTP currently ships 100 tons of Class B biosolids (18% by weight) per day to Holloway Landfill near Bakersfield, California approximately three hours away (Ines 2019). The Environmental Protection Agency regulates biosolid incineration, land application, and surface disposal under the Code of Federal Regulations (40 CFR 503) (Carollo Engineers 2017). The code establishes pathogen density reduction requirements, vector attraction requirements, metal concentration limitations, and site management for land application (Carollo Engineers 2017). Some of the specific quantities of these limitations and how often a facility is required to submit a summary of the current state of their biosolids can be found in Appendix B. According to the regulations, wastewater facilities are required to submit a summary of their compliance annually; more often depending on their production of biosolids (CFR 2018).

Not all biosolids can be used for their nutrient and organic matter content as land application due to their pathogen density. To ensure protection of public health and the environment, land applied biosolids are classified as either Class B or A. Class B biosolids require application site management and a secondary permit from the EPA (Carollo Engineers 2017). Class A biosolids do not require additional permits as they are commonly noted as "exceptional quality biosolids" (Carollo Engineers 2017). Appendix C summaries the status of county ordinances on land application of biosolids in California. The California Department of Food and Agriculture regulates the required nutrient grade of a fertilizer to include that of biosolids (Carollo Engineers 2017).

DIDN'T REALIZE HOW MANY COUNTIES HAVE BAN ON LAND APPLICATION.

4. Existing Facilities

The following section describes the existing facilities within the Oxnard WWTP to include the 1) collection system, 2) preliminary treatment, 3) primary treatment, 4) secondary treatment, 5) disinfection process and discharge, 6) biosolids treatment, and 7) the advanced water purification facility (AWPF). Appendix D illustrates the path in which liquids and solids are treated within the facility. A site plan of the Oxnard WWTP with labeled structures can be found in Appendix E. A recent condition assessment of the Oxnard WWTP indicated that 40% of the facility is in "poor"

IT WOULD BE APPROPRIATE (AND HELPFUL) TO HAVE THIS FIGURE IN THE TEXT INSTEAD OF THE APPX or "very poor" condition and 72% is at "moderate", "high", or "very high" risk of experiencing failures (City of Oxnard Wastewater Division 2015). A 10-year rehabilitation plan has been established to reduce the risk of failures; structures with high risk of failure will be noted in the subsequent sections.

4.1 Collection System

The sanitary sewer collection system is typical for communities of Oxnard's size, operating with 407 miles of gravity sewer lines (ranging from 6 to 66 inches), 23 miles of pressurized force mains (ranging from 4 to 20 inches), and 15 lift stations (Carollo Engineers 2017). Table 2 below differentiates the different pipe materials currently used in the gravity sewer system. Note that 70% is composed of vitrified clay pipe which is known for cracking over time ("Damage Analysis" 2019).

ONLY FROM POOR INSTALLATION PRACTICES. I HAVE LOOKED AT 100 YEAR OLD CLAY PIPES THAT LOOKED BRAND NEW.

Table 2: Gravity sewer pipe material separated by length and percentage (Carollo Engineers 2017).

Material	Length, ft	Percent of Total, %
Asbestos Cement Pipe (ACP)	15,618	0.8%
Cast Iron (CIP)	1,275	0.1%
Centrifugally Cast, Glass-Fiber-Reinforced, Polymer Mortar (CCFRPM)	22,447	1.1%
Ductile Iron (DIP)	320	0.0%
Fiberglass Reinforced Pipe (FRP)	15,757	0.8%
High Density Poly Ethylene (HDPE)	64,559	3.2%
Polymer Resin Concrete (PRC)	3,816	0.2%
Polyvinyl Chloride (PVC)	453,325	22.4%
Reinforced Concrete Pipe (RCP)	14,641	0.7%
Vitrified Clay Pipe (VCP)	1,420,147	70.0%
Unknown	16,260	0.8%
Total	**2,028,166**	**100.0%**

4.2 Preliminary Treatment

The headworks (preliminary treatment) of the plant consists of four mechanical screens, two manual screens, two aerated grit chambers each coupled with two hoppers, and six 18,000 gpm pumps (Carollo Engineers 2017). It is designed to remove large solids first entering the plant as well as grit which is abrasive to many functions within the equipment further down the treatment train. Due to the service area being within a beach community, sand is a common burden the facility faces. The headworks is not shown during public tours due to extreme odor, health, and safety concerns (Ines 2019). According to the condition assessment, it ranks a 1 for criticality and B for vulnerability, 1A being the worst (City of Oxnard Wastewater Division 2015). Degradation of the concrete, steel, and fiberglass is limiting the structural integrity and results in a safety hazard for the staff. Numerous complaints including a lawsuit concerning nuisance odors has surfaced from neighboring property owners (City of Oxnard Wastewater Division 2015).

4.3 Primary Treatment

Primary treatment occurs after the larger solids are screened out and the raw wastewater is gravity fed into four circular 105-foot diameter basins (known as primary clarifiers) used to settle out heavy solids and inorganic materials (City of Oxnard Wastewater Division 2015). The primary clarifiers, one of which is offline, were installed in 1972 and are now in 1A critical condition, experiencing extensive corrosion, inefficient flows over the weirs, odor complaints, and arbitrary treatment (City of Oxnard Wastewater Division 2015). Each basin has a sludge collector, sludge pump, and surface scum removal system as shown in Figures 5 and 6 below. Note the apartment complexes that can be seen behind the basin in Figure 5 as well as the birds and poor quality of water in Figure 6. To minimize the velocity over the weir, the basin was designed to have a double layered wall of weirs so the flow could be divided among twice as many.

WHAT DOES THIS MEAN?

Figure 5: One of four primary clarifiers onsite.

Figure 6: Scrapping mechanism of primary clarifier.

SKIMMER

To enhance flocculation and sedimentation, the primary treatment also includes addition of ferric chloride and polymer to destabilize the suspended particles in the primary influent wastewater and form larger particles of floc that are more likely to settle out (CRWQCB 2018). Figure 7 below illustrates the large tanks of ferric chloride they must store onsite.

Figure 7: Ferric chloride storage onsite.

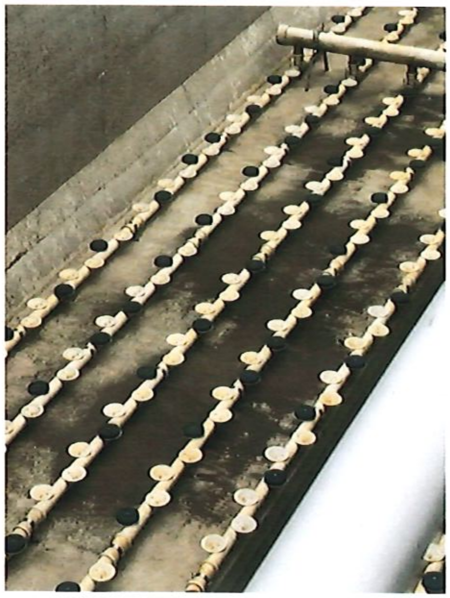
4.4 Secondary Treatment

? ARE YOU SURE ? WOULD CONTRIBUTE TO TOXICITY ISSUES IN EFFLUENT.

The primary effluent flows into an interstage pump station that consists of three variable-speed pumps used to transfer the flow into two biotowers, one 140-ft diameter and one 100-ft diameter (Carollo Engineers 2017). The current biotowers contain a copper media in which microorganisms form a slime layer and feed on the nutrients within the water that passes though, in return reducing the biological oxygen demand (BOD) value of the water (Ines 2019). Since their installation in 1975, the two biotowers are now experiencing high risk of tank wall failure and pose a concern for staff safety; the Oxnard WWTP have plans to decommission them September 2019 (2,15). From there, flow is then pumped into one of the two activated sludge tanks each containing three channels that can be run in series or parallel. Each channel is 450 feet long, 17 feet deep, and has fixed fine bubble diffusers fed by five single-stage centrifugal blowers as shown in Figure 8 below (CRWQCB 2018).

Figure 8: Activated sludge tanks, empty (left) and full (right).

The activated sludge tanks, also referred to as aeration basins, enable aerobic bacteria to feed on the organic matter within the water. Oxnard WWTP faces an accumulation of snails in the biotowers and as a result, requires that they rotate the activated sludge tanks every year to clean out the snail shells that end up in the aeration basins (Ines 2019). Figure 9 below reveals the accrual of broken snail shells at the base of an empty aeration basin.



PERHAPS THE MEDIA HAS SOME COPPER TO KILL SNAILS.

Figure 9: Accumulation of snail shells at base of empty activated sludge tank.

Post-aeration, the flow is then sent to 1 of the 18 underground rectangular secondary sedimentation tanks used to settle out activated sludge (CRWQCB 2018). The settled sludge is removed with a plastic flight-and-chain sludge collector system and is sent to a centralized return activated sludge pump station consisting of a wet well and four mixed flow pumps (CRWQCB 2018). The secondary effluent water is then gravity transferred to the chlorine contact tank for disinfection (Ines 2019). Figure 10 below shows the covers to the 18 rows of secondary sedimentation tanks.

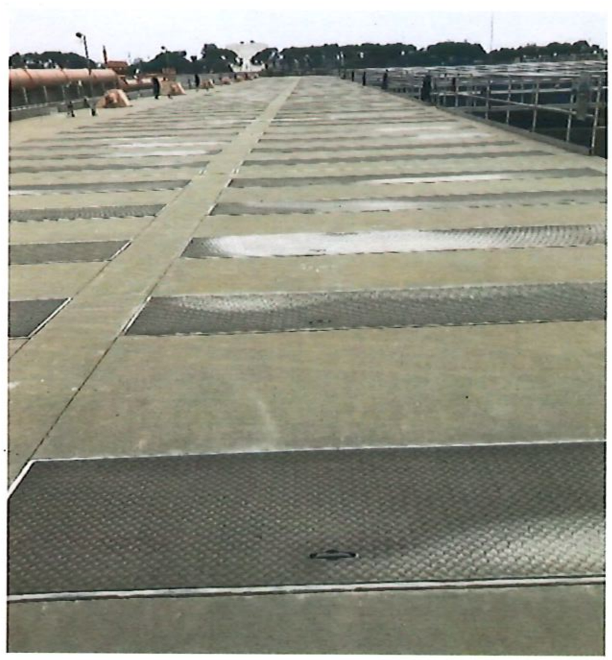


Figure 10: Secondary sedimentation tanks onsite.

Due to the structural integrity of the biotowers and the continual repairs required for the diffuser grid in the activated sludge tank, the condition assessment of the secondary treatment within the facility received a score of 1A/B (City of Oxnard Wastewater Division 2015).

4.5 Disinfection Process and Discharge

Immediately as the effluent leaves the secondary sedimentation tanks, sodium hypochlorite is injected to the turbulent flow as it is gravity fed to the chlorine contact tank, as shown in Figure 11 below (CRWQCB 2018).

Figure 11: Sodium hypochlorite injection following secondary sedimentation.

Provided that the facility needs to stabilize effluent pump operations or balance daily flow, the chlorinated water will be sent to one of the two 2.5-million-gallon sized equalization basins as shown in Figure 12 below (CRWQCB 2018). When peak flows subside, the water can be injected with sodium hypochlorite, then transferred to the chlorine contact basins with the help of three vertical mixed flow pumps (Carollo Engineers 2017).

Figure 12: Equalization basins sized to hold 2.5 million gallons.

Once arrived at one of the two chlorine contact basins, the water will flow through three 145 feet long channels to allow time for disinfection to occur (CRWQCB 2018). Figure 13 below shows a portion of the contact basin used promote contact time between the disinfectant and pathogens. According to the condition assessment, the chlorine contact basin is more than 50 years old and has poor flow patterns that lead to settling of solids and algae growth (City of Oxnard Wastewater Division 2015).

Figure 13: Chlorine contact basin used to promote contact time between disinfectant and pathogens.

Because chlorine residual is toxic to aquatic organisms, the chlorine must be completely removed prior to discharge which can be done almost immediately with the addition of sodium bisulfite

(CRWQCB 2018). The storage and filling station of sodium bisulfite can be seen in Figure 14 below.

Figure 14: Sodium bisulfite storage and filling station.

Once dechlorinated, the effluent is transferred to the discharge pump station that leads it to a 6,800-foot outfall pipe that was last modified in 1978 (Carollo Engineers 2017). Figure 15 below illustrates the exact discharge location into the Pacific Ocean, just offshore of Ormond Beach. The effluent exits the pipe though multi-port diffusers and has a capacity of 50 MGD (Carollo Engineers 2017).

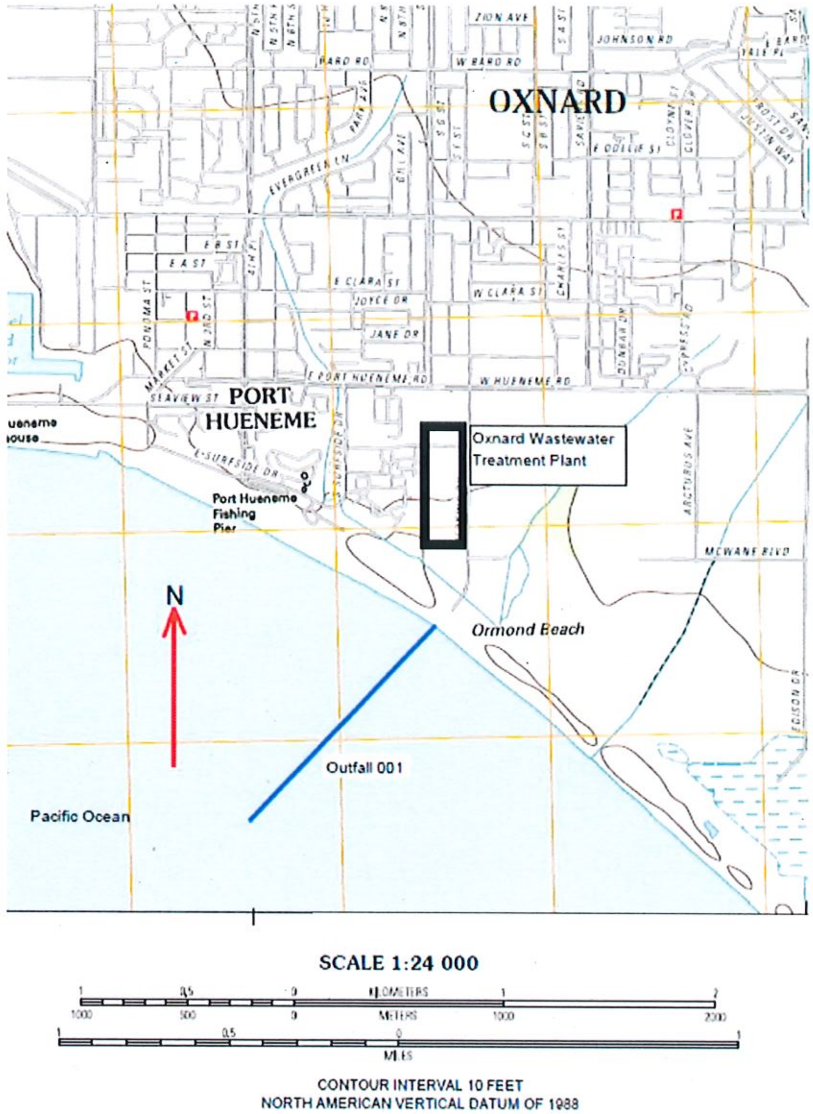


Figure 15: Ocean outfall of Oxnard WWTP effluent discharge (CRWQCB 2018).

The water quality standards noted in the NPDES permit is only applicable to the effluent being discharged into the ocean. There are no standards that are required to be met at specific stages in the treatment process.

4.6 Biosolids Treatment

The treatment of biosolids consists of two gravity thickeners, two dissolved air flotation thickeners, three anaerobic digesters, and four belt filter presses (Carollo Engineers 2017). Primary sludge and scum that settled in primary treatment is collected and sent to one of the two 59-foot diameter gravity thickeners; the sludge is mixed with polymer and ferric chloride to aid in flocculation

(Carollo Engineers 2017). Secondary sludge is sent to one of the two 25-foot diameter dissolved air floatation thickeners; polymer is added to help separate the solids from the liquid (Carollo Engineers 2017). Dissolved air floatation thickeners use fine air bubbles to float the sludge particles to the surface, where they are then scraped off (Carollo Engineers 2017). Both primary and secondary sludge is pumped from their respective thickener to one of the three anaerobic digesters (City of Oxnard Wastewater Division 2015). Figure 16 below shows two of the three anaerobic digesters used to biologically decompose organic matter. Anaerobic digestion reduces pathogens in sludge to ensure it is in compliance with regulatory requirements for final disposal (Carollo Engineers 2017).

Figure 16: Two of the three anaerobic digesters onsite.

The biogas that is produced during the decomposition in the anerobic digester (primarily methane) is collected and used to run three co-generation engines that power approximately 30-40% of the entire facility (Ines 2019).

Once the sludge has been treated in the anaerobic digester, the sludge is ran through one of the four belt filter presses that aids in the dewatering of the sludge from a solids content of less than 3 percent to a range of 18 to 20 percent (Carollo Engineers 2017). Polymer is added to promote flocculation and better separate the solids from the liquid. Approximately 100 tons of "Class B" dewatered biosolids are then hauled to Holloway Landfill near Bakersfield, California every day, requiring 4 trucks per day (Ines 2019). The plant anticipates replacement of the belt presses Summer 2019 (Ines 2019).

Due to the belt filter presses not having been overhauled in more than 20 years and one of the two gravity thickeners being out of service, along with one of the three anaerobic digesters, the condition assessment rated the biosolids treatment as being in poor condition with a 1B.

4.7 Advanced Water Purification Facility

Currently, 8 MGD of chlorinated secondary effluent is transferred to the advanced water purification facility to go through a series of tertiary treatment techniques including microfiltration, reverse osmosis, and ultraviolet/advanced oxidation processes (CRWQCB 2018). Figure 17 below illustrates the process flow schematic of the AWPF.

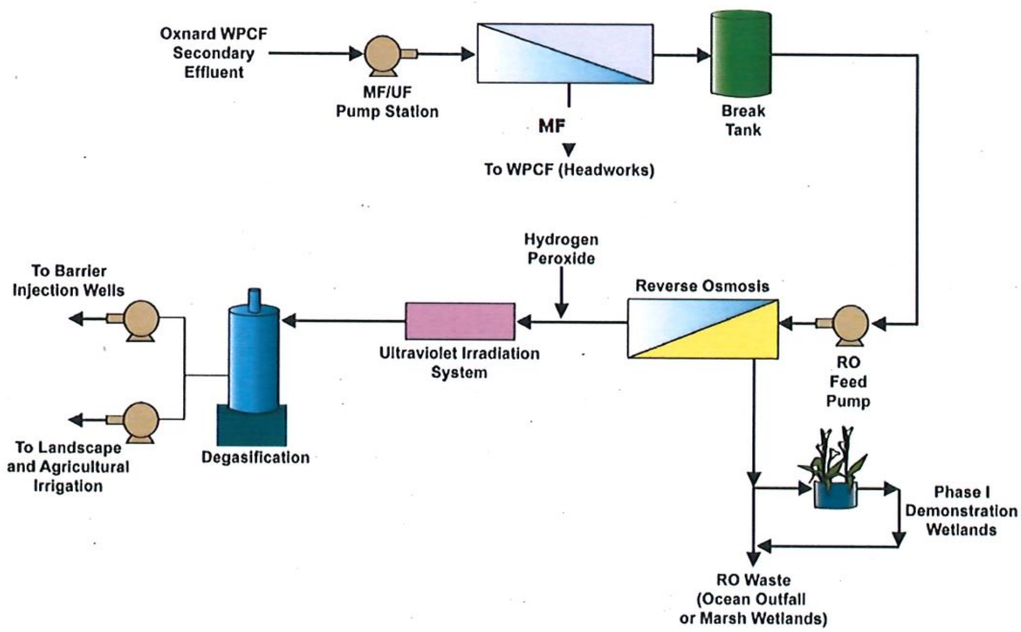


Figure 17: AWPF process flow schematic (CH2M Hill 2013).

The AWPF has about 80 percent recovery, producing around 6.25 MGD of finished water for non-potable Title 22 reuse, primarily irrigation for River Ridge Golf Course and local strawberry, raspberry, and sod fields (Ines 2019). Backwash wastewater from the microfiltration is returned to the headworks for full primary and secondary treatment (CRWQCB 2018). Limited to 1.55 MGD of concentrated brine, the waste from the reverse osmosis process is mixed with the plant's secondary effluent and discharged into the Pacific Ocean (CRWQCB 2018). To ensure that the

AWPF is always operating at its current maximum capacity, the equalization basin is used during the day to adjust for the lower flows at night that do not meet 8 MGD, in attempt to stabilize diurnal patterns (Ines 2019).

The City operates the AWPF under its Groundwater Enhancement and Treatment (GREAT) program which is looking to increase the treated flow to the facility's designed capacity of 25.0 MGD under its Phase II upgrade (CH2M Hill 2013). Phase I was implemented in 2015 and produces 6.25 MGD of recycled water (CH2M Hill 2013). The GREAT program aims to 1) reduce the amount of ocean discharge from Oxnard WWTP, 2) provide municipal and industrial recycled water for landscape irrigation and industrial processes, 3) provide agricultural irrigation water, and 4) implement groundwater injection to limit seawater intrusion (CH2M Hill 2013). The Groundwater Replenishment Reuse Project (GRRP), under the GREAT program, is currently evaluating the feasibility of injecting the effluent from the AWPF into the groundwater system to impose on seawater intrusion as well as limit the amount of water that is being discharged into the ocean with no chance of recovery (Hopkins Groundwater Consultants, Inc. 2014). The Oxnard Saline Treatment Wetlands project, also under the GREAT program, is evaluating the potential of wetlands as a natural treatment technology for advanced water treatment concentrate waste streams (Dahm et al. 2012). With all of the various projects under the GREAT program, the Oxnard WWTP is likely to reclaim more of its effluent and decrease the amount of flow that gets discharged into the Pacific Ocean.

5. Preliminary Alternatives

Five preliminary alternatives were developed to manage the disposal of brine concentrate that is currently being produced in the Advanced Water Purification Facility at a rate of 1.55 MGD. With anticipated expansion of the AWPF, the production of brine concentrate is expected to increase, and the secondary effluent of which it was diluted with during ocean discharge is expected to decrease significantly. The screening methods, description of each alternative, and screening results will be discussed.

5.1 Screening Methods

The preliminary alternatives will be evaluated based on how well each complies with the weighted criteria. Table 3 below reveals the list of criteria that is commonly considered for design upgrades along with a weight of importance, scored one to five, five being the highest importance, that will be used to screen the five preliminary alternatives for brine concentrate disposal.

Table 3: Weighted criteria used to screen preliminary alternatives.

Criteria	Weight
Health and Safety	5
Capital Costs	5
O&M Costs	4
Permitability	3
Compatibility	3
Enviornmental Sustainability	2

WHO PROVIDED THE WEIGHTS ?

As a government operated facility, health and safety of the operators and the community should always be held to the highest priority, and for this reason is given a weight of five. Due to the lack of funds budgeted for wastewater capital improvements in the City of Oxnard, capital cost is given a weight of five, as the alternative will not be considered if the cost to construct is extraneous. The operation and maintenance (O&M) costs associated with each alternative is given a weight of four as annual expenses should be limited to save for maintenance in older, failing systems within the facility. Permitability and compatibility were both given a weight of three considering the ease of obtaining a permit and ease of implementing the alternative into the current system. Environmental sustainability was given a weight of two as environmental permits already required will account for it.

After the preliminary alternatives have been identified, the Delphi method will be used where each criterion listed will be given a score one to five, five being the most desired. By multiplying the weight of the criterion by the score received, the sum of all weighted scores for each alternative will determine the total score. The highest two scoring alternatives will be chosen for further analysis.

5.2 Description of Alternatives

Five preliminary alternatives to manage the disposal of brine concentrate from the membrane treatment in the AWPF include constructed wetlands, deep well injection, electrolysis volume reduction, return to headworks, and continue with ocean discharge. Each preliminary alternative will be compared by addressing each alternative's advantages and disadvantages. The two alternatives that score the highest will be further discussed.

5.2.1 Constructed Wetlands

Natural treatment systems have proven to effectively treat and polish wastewater effluent but have not been widely used as a method to treat brine concentrate produced from reverse osmosis ("Brine-Concentrate Treatment" 2009). Constructed wetlands use plants to biologically and chemically "remove constituents from water and reduce micropollutant concentrations in the concentrate" through evapotranspiration ("Brine-Concentrate Treatment" 2009). Halophytes are often used as they have a very high tolerance to salinity. Studies have found that the chemical constituents of concern in the membrane concentrate get reduced to levels that are safe enough to provide a positive habitat value ("Brine-Concentrate Treatment" 2009). Advantages associated with constructed wetlands include aesthetic, educational, and recreational opportunities, habitat value, natural treatment process, decreased power needs compared to that of mechanical systems, and removal of specific constituents has been proven in previous studies ("Brine-Concentrate Treatment" 2009). Disadvantages include the requirement of a large footprint, potential hazard to wildlife and groundwater, and potential loss of water via evaporation ("Brine-Concentrate Treatment" 2009).

5.2.2 Deep Well Injection

Deep well injection consists of using subsurface geologic formations such as where oil or gas has been previously extracted to inject the liquid concentrate ("Brine-Concentrate Treatment" 2009). The depth at which it is injected determines what class of well it is regulated as under the Underground Injection Control program ("Brine-Concentrate Treatment" 2009). The classes are addressed to limit any chance of groundwater contamination. Advantages include reuse of old extraction wells, full-scale treatment method, and small footprint with regards to acreage. Disadvantages include potential to cause damage to equipment and pumps with high salinity and solids content, infeasible in areas with seismic activity, and high capital cost.

5.2.3 Electrodialysis Volume Reduction

Landfill disposal is only feasible if volume reduction is preformed prior due to the high percentage of liquid in brine concentrate. Electrodialysis (ED) was chosen as the method of volume reduction which uses an electrical current to remove salt ions dissociated in solution ("Brine-Concentrate Treatment" 2009). The semipermeable membrane that separates positively charged ions (cations) from negatively charged ions (anions) is commonly referred to as an electrodialysis membrane. Advantages of this alternative using landfill disposal with electrodialysis volume reduction includes higher water recovery, lower fouling potential due to nonionic contaminants, and small footprint. Disadvantages include lack of study specific to brine concentrate, high capital cost, and high operation and maintenance costs.

5.2.4 Return to Headworks

Return of brine concentrate to the headworks requires that the facility be able to handle an increased amount of flow, especially if the AWPF is looking to expand tertiary treatment to 25 MGD with its Phase II upgrade. This alternative suggests that the brine concentrate be combined with the influent wastewater where the brine is anticipated to settle with the solids. Advantages of this include low capital cost, ease of compatibility with current system, and small footprint. Disadvantages include potential to cause corrosion to equipment due to increased salinity, especially pumps and potential to disrupt effluent quality.

5.2.5 Continue Ocean Discharge

Continuation of ocean discharge is a feasible option for Oxnard WWTP until Phase II of the AWPF becomes effective. Phase II intends to increase treatment from 8 MGD to 25 MGD and in result, virtually eliminate secondary effluent ocean discharge during average flow conditions. Without the mixture of secondary effluent, the brine concentrate will not be diluted when it is discharged into the ocean. Advantages of continuing with ocean discharge include no capital costs and no additional construction or operational work. Disadvantages include changes in effluent quality, potential to cause corrosion to outfall pipe, and potential buildup of solids in pipe.

5.3 Evaluation of Screening Results

Based on the advantages and disadvantages discussed for each alternative, the Delphi method was used to score each criterion with respect to each preliminary design. The score, weighted score, and total weighted score for each alternative can be found in Table 4 below.

Table 4: Delphi matrix to score the preliminary alternatives.

Criteria	Weight	Constructed Wetland Alternative 1		Deep Well Injection Alternative 2		Electrodialysis Alternative 3		Return to Headworks Alternative 4		Ocean Discharge Alternative 5	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Health and Safety	5	4	20	3	15	3	15	5	25	5	25
Capital Costs	5	3	15	3	15	1	5	4	20	5	25
O&M Costs	4	3	12	1	4	1	4	1	4	2	8
Permitability	3	3	9	2	6	4	12	4	12	3	9
Compatibility	3	4	12	3	9	2	6	3	9	5	15
Enviornmental Sustainability	2	5	10	2	4	2	4	3	6	1	2
Total Weighted Score			78		53		46		76		84

The initial screening allowed justification to rule out deep well injection, electrodialysis, and return to headworks for further analysis. Because the constructed wetland and continuation of ocean discharge designs resulted in the greatest total weighted score, the following section will give a more detailed description of these two selected initial alternatives.

6. Description of Selected Initial Alternatives

6.1 Constructed Wetlands

The Oxnard Saline Treatment Wetlands project, under the GREAT program, already conducted an environmental study on the implementation of constructed wetlands to remove contaminants from brine concentrate. The pilot research study lasted three years and consisted of twelve one-meter wetland tank mesocosms to model six wetland types in duplicates (CH2M Hill 2007). The six wetland types modeled include: surface flow high marsh (water depth: 4 inches), surface flow low marsh (18 inch), horizontal subsurface flow (-4 inches), peat-based vertical upflow (saturated), submerged aquatic vegetation (18 inches), and saltgrass evaporation (saturated) (CH2M Hill 2007). The study concluded that the effluent was not found to be toxic to indicator organisms and there was significant removal of nutrients and heavy metals (CH2M Hill 2007).

WHICH WORKED "BEST"?

NOW IN THE SEDIMENT & PLANTS.

The projected discharge location of the brine concentrate into the Ormond Beach wetlands can be seen in Figure 18 below. The specific location in which would best for discharge based on geographical and environmental standards is beyond the scope of this project. Note that the wetlands shown in Figure 18 extend down the coastline, but the highlighted location is where discharge would occur.

Figure 18: Ormond Beach wetlands discharge location.

In addition to finding a feasible discharge alternative, the California Coastal Conservancy has been focused on restoring the Ormond Beach wetlands of which once used to be 1,100 acres, now only 250 acres. The brine concentrate would aid in restoring what is left of the wetlands which is degrading from compaction due to human use and dumping, suffering from lack of flushing ("Ormond Beach Wetlands" 2010). The wetlands at Ormond Beach have been "used as a city dump, developed with a magnesium smelting plant and with the electrical generating plant, and drained for agriculture" (City of Oxnard 2012). Working in conjunction with the Coastal Conservancy would ensure that the wetlands not only act as a discharge location but also aid in restoration of the wetlands.

Wetlands do more than provide habitat for animals and plants in the watershed; they also can act as flood control, protection from shoreline erosion, filtration, groundwater recharge, recreation, and education (City of Oxnard 2012). They act as natural sponges to trap that absorb excess nutrients, sediment, and other pollutants. The GREAT program highly values education and intends to incorporate a demonstration wetland outside of the AWPF. This educational wetland would divert 20,000 gallons per day of effluent to be treated in the three-stage configuration shown in Figure 19 below.

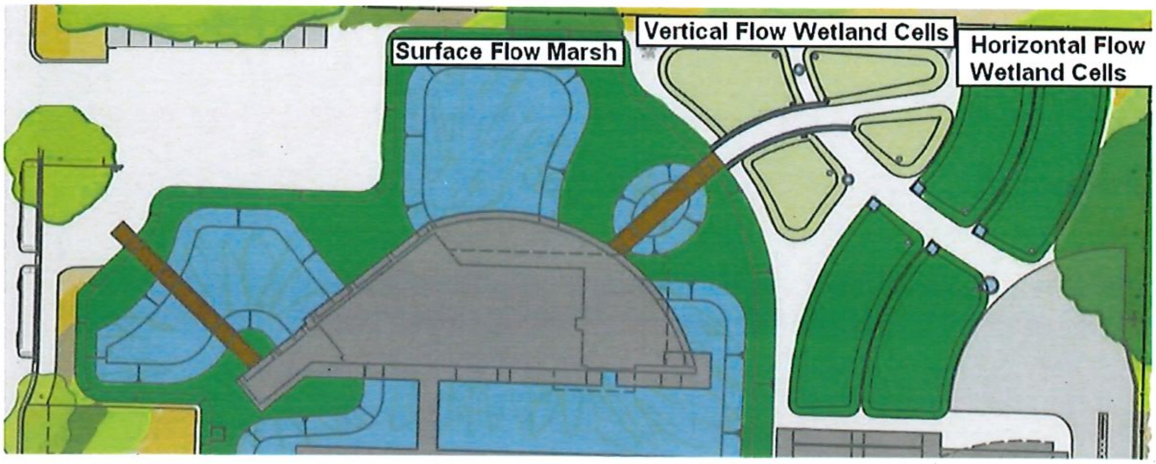


Figure 19: Three-stage demonstration wetland outside of AWPF.

The layout of wetland includes 1) four horizonal flow wetland cells that have supplemental aeration of the gravel bed to reduce BOD content and support natural nitrification of ammonia, 2) four vertical flow wetland cells that have thick beds of peat and compost, supplemented with reduced carbon to facilitate the denitrification, and biological selenium reduction to elemental selenium that will precipitate to the bottom of the wetland and 3) the surface flow marsh that aids in the aesthetic appearance of the facility ("Ormond Beach Wetlands" 2010). Because salt precipitation is expected in this demonstration marsh, the horizontal and vertical flow cells are designed with four cells so some can be taken offline for cleaning annually. The accumulated precipitates will be transferred to the landfill. Because the wetlands at Ormond Beach are much larger, cleaning of the precipitates will not be required. IT WILL EVENTUALLY BE REQUIRED!

6.2 Continue Ocean Discharge

The continuation of ocean discharge is highly dependent on the facility's ability to renew their NPDES permit once secondary effluent dilution of the brine concentrate is eliminated after the Phase II upgrade of the AWPF. Ocean discharge permits are focused primarily on total suspended solids (TSS), biochemical oxygen demand, toxicity, and residual chlorine that might affect marine organisms and their habitat. TSS effluent limits are one of the primary concerns with continuation of ocean discharge with the majority being brine concentrate. The composition of the brine concentrate will need to be further researched.

The current ocean outfall pipe was constructed in 1964 and modified in 1978; it is likely that a new outfall pipe or structural upgrades at a minimum will be required within the next ten years whether Phase II is implemented or not. Because of the age of the pipe, the continuation with ocean discharge may result in an increase in operation and maintenance costs as the pipe continues to age.

7. Detailed Analysis of Initial Alternatives

This section further analyzes the two selected alternatives, the constructed wetlands and continuation with ocean discharge. Construction costs, operation and maintenance costs, permitability, and community criteria will all be discussed to better assess which alternative to recommend for implementation.

7.1 Constructed Wetlands

7.1.1 Construction Costs

Construction costs associated with the installation of the constructed wetlands is a little ambiguous considering the land's current state. Though it once was a wetland, it has since been used as a dump and fails to provide a healthy habitat for wildlife as it has poor flushing rates. Costs associated with this alternative prior to implementation include clean-up costs and lining the ground to prevent seepage into the groundwater. The estimated construction cost for a natural treatment system capable of handling 1-MGD flow is $9,600,000 ("Brine-Concentrate Treatment" 2009). Because the current brine concentrate effluent is 1.65 MGD, it is appropriate to size the wetland to handle flows of 3-MGD accounting for the Phase II upgrade that is expected to increase the brine concentrate effluent. Accounting for the increased flow and that the wetland is already partially constructed, it can be assumed the capital cost will be around 20 million dollars.

7.1.2 Operation and Maintenance Costs

Operation and maintenance costs associated with a natural treatment system that treats a flow of 1 MGD is estimated to be $286,500 ("Brine-Concentrate Treatment" 2009). Due to the increased flowrate associated with this alternative, the estimated cost for O&M should be around $500,000. Expected O&M consists of inspection of the inlet, control structure, and flow inspection, monthly water quality monitoring, periodic vector management, and annual vegetation management ("Brine-Concentrate Treatment" 2009).

WOULD NEED ADDITIONAL COST FOR LONG TERM VEGETATION AND SEDIMENT MANAGEMENT. VEGETATION + SEDIMENT MAY BE A HAZ WASTE PROBLEM SHOULD/WHEN REMOVAL OCCURS

7.1.3 Permitability

Permitability for this constructed wetland is a relatively simple process involving specific state and local regulations. If the system was not lined, it would be much more difficult as it would be considered a Class V injection well. The U.S. Army Corps of Engineers, State Water Resources Conservation Board, Regional Water Quality Board, United States Fish and Wildlife Service, California Department of Fish and Game, and California Environmental Quality Act are just a few of the federal and state agencies that will need to be contacted prior to construction ("Natural Treatment System Design Guide" 2012).

7.1.4 Community Criteria

For the City of Oxnard, odor has been a common concern with neighboring parcels, resulting in several lawsuits. Because the treatment wetland is designed to only be treating brine concentrate, odor should not be a concern for the neighboring parcels. Considering the current condition of the Ormond Beach wetlands, any upgrade would likely be appreciated by the community.

7.2 Continue Ocean Discharge

7.2.1 Construction Costs

Construction costs associated with continuation of ocean discharge is negligible considering that the outfall pipe is already installed. However, if this alternative was chosen, it would be recommended that the Oxnard WWTP install a new outfall pipe as the current one was last modified in 1978. The estimated cost for a new outfall pipe, of the same size and length is approximated to be around ten million dollars ("Brine-Concentrate Treatment" 2009).

7.2.2 Operation and Maintenance Costs

Operation and maintenance costs associated with the continuation of the ocean discharge are very minimal. Assuming an electricity rate of $0.11/kWh and a 25 hp vertical mixed flow pump, the total annual cost associated with running the pump is approximately $18,000 ("U.S. Energy Information Administration" 2019). The cost of operating the pump will be assumed as the only O&M cost for this alternative.

7.2.3 Permitability

Because a new outfall pipe will be installed with this alternative design, permits from the State Water Resources Control Board, Regional Water Quality Control Board, United States Army Corps of Engineers, California Coastal Commission, California Department of Fish and Game, and several other agencies will be required ("Brine-Concentrate Treatment" 2009). One key issue associated with obtaining an NPDES permit is the ability to provide adequate mixed at the location of discharge to protect the marine environment ("Brine-Concentrate Treatment" 2009). The concentration of TSS of the brine concentrate will need to be further analyzed to see if it will be eligible for a NPDES discharge permit.

7.2.4 Community Criteria

No criteria from the community is considered for this alternative as it is an already implemented system.

7.3 Cost Comparison

Table 5 below summarizes the construction and O&M costs relevant to the two alternatives considered. It can be noted that the construction costs for the constructed wetlands is twice as much as the continuation of ocean discharge. Additionally, the operation and maintenance costs associated with the constructed wetlands is almost thirty times greater.

Table 5: Cost comparison between two alternatives.

Costs	Constructed Wetland	Ocean Discharge
Construction ($)	20,000,000	10,000,000
Annual O&M ($)	500,000	18,000

8. Recommendations and Conclusion

Because NPDES permits for ocean discharge are likely to become more stringent on effluent standards, it is recommended that the Oxnard WWTP implement the constructed wetlands at Ormond Beach as a location for brine concentrate discharge. Despite the increased costs associated with the wetland alternative, a large portion of the costs and time have already been invested in when the City of Oxnard decided to conduct the Oxnard Saline Treatment Wetlands pilot project under the GREAT program. Advantages of installing this natural treatment system include aesthetic, educational, and recreational opportunities, habitat value, natural treatment process, decreased power needs compared to that of mechanical systems, and removal of specific constituents has been proven in previous studies ("Brine-Concentrate Treatment" 2009).

Limitations with the continuation of the ocean discharge can be attributed to the uncertainty with the brine concentrate not being diluted with the secondary effluent when Phase II of the AWPF is implemented. Larger concentrations of TSS within the brine concentrate being discharged amplify the risk of being in violation of their NPDES permit. To avoid the chance of installing a new outfall pipe and have the effluent not pass ocean discharge requirements after just years, it is recommended that the Oxnard WWTP implement a constructed wetland system for brine concentrate disposal.

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Appendix

Appendix A: NPDES Effluent Limitations

(From: CRWQCB 2018)

Parameter	Units	Effluent Limitations[1]					Performance Goals Average Monthly
		Average Monthly[2]	Average Weekly	Maximum Daily[3]	Instan-taneous Maximum[4]	Average Monthly	
Marine Aquatic Life Toxicants							
Arsenic	µg/L	--	--	--	--	--	2[9]
Cadmium	µg/L	--	--	--	--	--	1[10]
Chromium VI[11]	µg/L	--	--	--	--	--	8
Copper	µg/L	--	--	--	--	--	30
Lead	µg/L	--	--	--	--	--	23
Mercury	µg/L	--	--	--	--	--	0.3
Nickel	µg/L	--	--	--	--	--	8
Silver	µg/L	--	--	--	--	--	2.5
Selenium	µg/L	--	--	--	--	--	6.4
Zinc	µg/L	--	--	--	--	--	35
Cyanide	µg/L	--	--	--	--	--	25
Chlorine Residual	µg/L	--	--	--	--	--	0.13
Ammonia as N	mg/L	--	--	--	--	--	51.8
Phenolic compounds (non-chlorinated)	µg/L	--	--	--	--	--	5
Phenolic compounds (chlorinated)[11]	µg/L	--	--	--	--	--	0.42
Endosulfan	µg/L	--	--	--	--	--	0.05
Hexachloro-cyclohexane (HCH)[11]	µg/L	--	--	--	--	--	0.1
Endrin	µg/L	--	--	--	--	--	0.05
Chronic toxicity (Test of Significant Toxicity (TST))[12]	Pass or Fail	--	--	Pass	--	--	--
Radioactivity[11]							

Parameter	Units	Effluent Limitations[1]					Performance Goals Average Monthly
		Average Monthly[2]	Average Weekly	Maximum Daily[3]	Instantaneous Maximum[4]	Average Monthly	
Gross alpha[11] [13]	pCi/L	--	--	--	15	--	--
Gross beta[11] [13]	pCi/L	--	--	--	50	--	--
Combined Radium 226 and 228	pCi/L	--	--	--	5	--	--
Tritium	pCi/L	--	--	--	20,000	--	--
Strontium 90	pCi/L	--	--	--	8	--	--
Uranium	pCi/L	--	--	--	20	--	--
Human Health Toxicants – Non-Carcinogens							
Acrolein	µg/L	--	--	--	--	--	10
Antimony	µg/L	--	--	--	--	--	2.5
Bis(2-chloroethoxy) methane	µg/L	--	--	--	--	--	25
Bis(2-chloro-isopropyl) ether	µg/L	--	--	--	--	--	10
Chlorobenzene	µg/L	--	--	--	--	--	2.5
Chromium (III)	µg/L	--	--	--	--	--	8
Di-n-butyl-phthalate	µg/L	--	--	--	--	--	0.33
Dichloro-benzene	µg/L	--	--	--	--	--	2.5
Diethyl phthalate	µg/L	--	--	--	--	--	0.25
Dimethyl phthalate	µg/L	--	--	--	--	--	10
2-Methyl-4,6-dinitrophenol	µg/L	--	--	--	--	--	25
2,4-Dinitrophenol	µg/L	--	--	--	--	--	25
Ethyl benzene	µg/L	--	--	--	--	--	2.5
Fluoranthene	µg/L	--	--	--	--	--	0.25
Hexachloro-cyclo-pentadiene	µg/L	--	--	--	--	--	25
Nitrobenzene	µg/L	--	--	--	--	--	5
Thallium	µg/L	--	--	--	--	--	5
Toluene	µg/L	--	--	--	--	--	0.6

Parameter	Units	Effluent Limitations[1]					Performance Goals Average Monthly
		Average Monthly[2]	Average Weekly	Maximum Daily[3]	Instan-taneous Maximum[4]	Average Monthly	
Tributyltin	µg/L	--	--	--	--	--	0.0263
1,1,1-Trichloro-ethane	µg/L	--	--	--	--	--	2.5
Human Health Toxicants – Carcinogens							
Acrylonitrile	µg/L	--	--	--	--	--	10
Aldrin	µg/L	--	--	--	--	--	0.025
Benzene	µg/L	--	--	--	--	--	2.5
Benzidine	µg/L	0.0068	--	--	--	--	--
	lbs/day[6]	0.0018			--	--	--
Beryllium	µg/L	--	--	--	--	--	2.5
Bis(2-chloroethyl) ether	µg/L	--	--	--	--	--	5
Bis(2-ethylhexyl) phthalate	µg/L	--	--	--	--	--	15
Carbon tetrachloride	µg/L	--	--	--	--	--	2.5
Chlordane[11]	µg/L	--	--	--	--	--	0.5
Chlorodibromo-methane	µg/L	--	--	--	--	--	1.3
Chloroform	µg/L	--	--	--	--	--	1.2
DDT[11]	µg/L	--	--	--	--	--	0.25
1,4-Dichlorobenzene	µg/L	--	--	--	--	--	3
3,3'-Dichloro-benzidine	µg/L	--	--	--	--	--	25
1,2-Dichloroethane	µg/L	--	--	--	--	--	2.5
1,1-Dichloro-ethylene	µg/L	--	--	--	--	--	2.5
Bromodichloro-methane	µg/L	--	--	--	--	--	2.5
Dichloro-methane	µg/L	--	--	--	--	--	2.5
1,3-Dichloro-propene	µg/L	--	--	--	--	--	2.5
Dieldrin	µg/L	--	--	--	--	--	0.05
2,4-Dinitrotoluene	µg/L	--	--	--	--	--	25
1,2-Diphenyl-hydrazine	µg/L	--	--	--	--	--	5

Parameter	Units	Effluent Limitations[1]					Performance Goals
		Average Monthly[2]	Average Weekly	Maximum Daily[3]	Instan-taneous Maximum[4]	Average Monthly	Average Monthly
Halomethanes[11]	µg/L	--	--	--	--	--	4.4
Heptachlor	µg/L	--	--	--	--	--	0.05
Heptachlor epoxide	µg/L	--	--	--	--	--	0.05[14]
Hexachloro-benzene	µg/L	--	--	--	--	--	5
Hexachloro-butadiene	µg/L	--	--	--	--	--	5
Hexachloro-ethane	µg/L	--	--	--	--	--	5
Isophorone	µg/L	--	--	--	--	--	5
N-Nitrosodimethyl-amine	µg/L	--	--	--	--	--	25
N-Nitrosodi-N-propylamine	µg/L	--	--	--	--	--	25
N-Nitrosodiphenyl-amine	µg/L	--	--	--	--	--	5
PAHs[11]	µg/L	--	--	--	--	--	0.097
Total PCBs[11]	µg/L	0.0019	--	--	--	--	--
	lbs/day[6]	0.0005	--	--	--	--	--
TCDD equivalents[11]	µg/L	0.0000000039	--	--	--	--	--
	lbs/day[6]	0.0000001			--	--	--
1,1,2,2-Tetrachloro-ethane	µg/L	--	--	--	--	--	2.5
Tetrachloro-ethylene	µg/L	--	--	--	--	--	2.5
Toxaphene	µg/L	--	--	--	--	--	2.5
Trichloro-ethylene	µg/L	--	--	--	--	--	2.5
1,1,2-Trichloro-ethane	µg/L	--	--	--	--	--	2.5
2,4,6-Trichlorophenol	µg/L	--	--	--	--	--	0.74
Vinyl chloride	µg/L	--	--	--	--	--	2.5

Appendix B: 40 CFR 503 Biosolids Limits and Regulations

(From: CFR 2018)

Table 3 of § 503.13—Pollutant Concentrations

Pollutant	Monthly average concentration (milligrams per kilogram) 1
Arsenic	41
Cadmium	39
Copper	1500
Lead	300
Mercury	17
Nickel	420
Selenium	100
Zinc	2800

1 Dry weight basis.

Table 1 of § 503.16—Frequency of Monitoring—Land Application

Amount of sewage sludge 1 (metric tons per 365 day period)	Frequency
Greater than zero but less than 290	Once per year.
Equal to or greater than 290 but less than 1,500	Once per quarter (four times per year).
Equal to or greater than 1,500 but less than 15,000	Once per 60 days (six times per year).
Equal to or greater than 15,000	Once per month (12 times per year).

1 Either the amount of bulk sewage sludge applied to the land or the amount of sewage sludge prepared for sale or give-away in a bag or other container for application to the land (dry weight basis).

Table 1 of § 503.26—Frequency of Monitoring—Surface Disposal

Amount of sewage sludge 1 (metric tons per 365 day period)	Frequency
Greater than zero but less than 290	Once per year.
Equal to or greater than 290 but less than 1,500	Once per quarter (four times per year).
Equal to or greater than 1,500 but less than 15,000	Once per 60 days (six times per year).
Equal to or greater than 15,000	Once per month (12 times per year).

1 Amount of sewage sludge placed on an active sewage sludge unit (dry weight basis).

Table 1 of § 503.46—Frequency of Monitoring—Incineration

Amount of sewage sludge 1 (metric tons per 365 day period)	Frequency
Greater than zero but less than 290	Once per year.
Equal to or greater than 290 but less than 1,500	Once per quarter (four times per year).
Equal to or greater than 1,500 but less than 15,000	Once per 60 days (six times per year).
Equal to or greater than 15,000	Once per month (12 times per year).

1 Amount of sewage sludge fired in a sewage sludge incinerator (dry weight basis).

Appendix C: Biosolids Land Application Ordinances

(From: Carollo Engineers 2017)

STATUS OF BIOSOLIDS LAND APPLICATION ORDINANCES BY COUNTY

FIGURE 5

CITY OF OXNARD

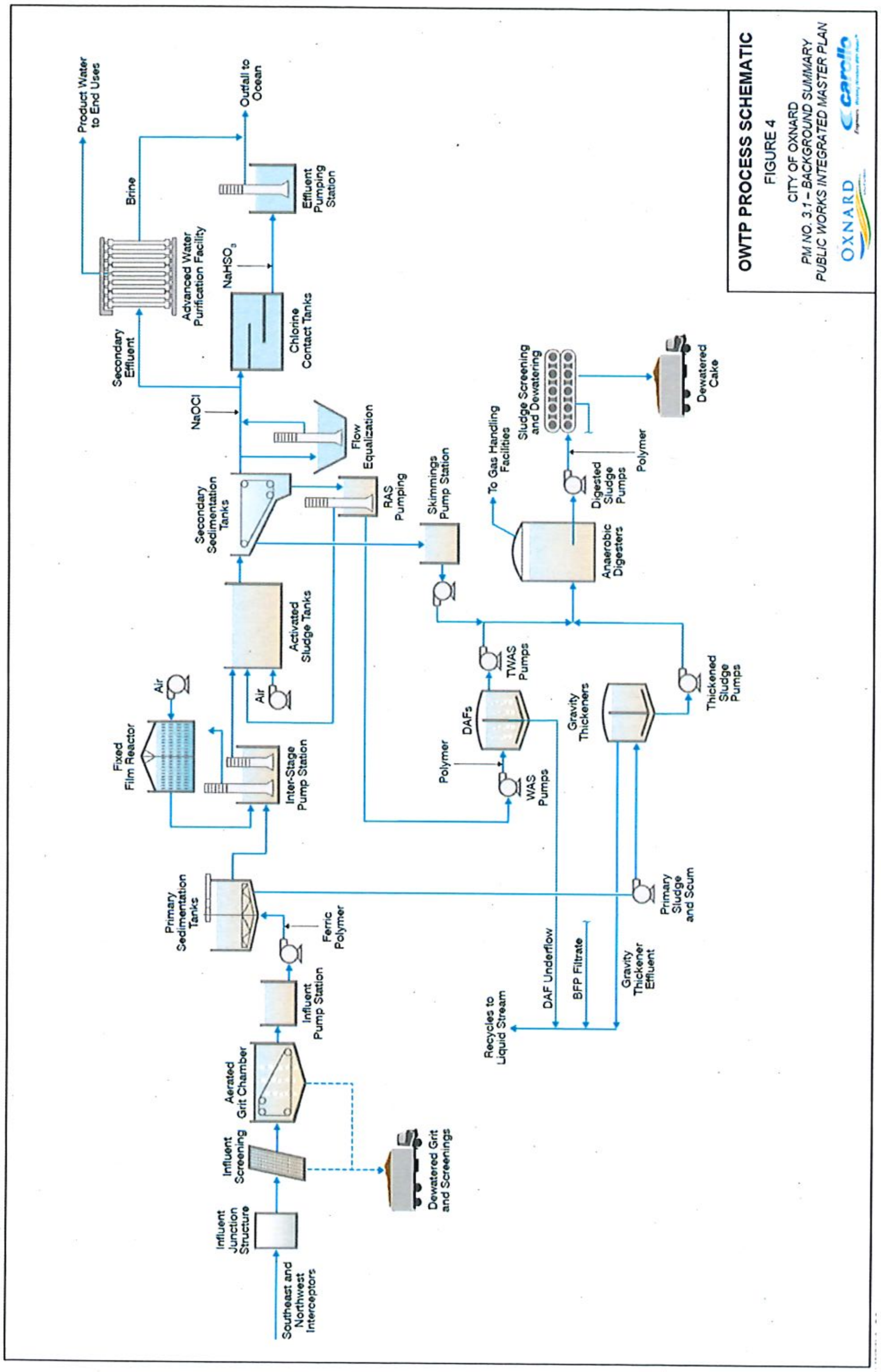
PM NO. 3.1 – BACKGROUND SUMMARY

PUBLIC WORKS INTEGRATED MASTER PLAN

OXNARD carollo

Appendix D: OWTP Process Schematic

(From: Carollo Engineers 2017)



Appendix E: OWTP Site Plan

(From: Carollo Engineers 2017)