Final Study Report

GOLETA SANITARY DISTRICT

Climate Adaptation Plan

Prepared for
Goleta Sanitary District

June 2022

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770 Paseo Camarillo
Suite 310
Camarillo, CA 93010
805.914.1500
esassoc.com

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CHAPTER 1
Introduction

The Goleta Sanitary District (District) has undertaken this study to develop a Climate Adaptation Plan for its wastewater collection, treatment, recovery and discharge facilities. The purpose of the Climate Adaptation Plan is to assess the vulnerability of the District's assets to coastal hazards with future projected sea level rise due to climate change.[1] The Climate Adaptation Plan will identify adaptation strategies that the District can take in the future to reduce the District's potential vulnerabilities, thereby improving the District's resiliency to sea level rise. The following sections summarize the study purpose and background on the District and surrounding Goleta Slough.

1.1 Purpose

The purpose of the Climate Adaptation Plan is to assess the vulnerability of the District's assets to future projected sea level rise with climate change and identify adaptation strategies that the District can take in the future to reduce the District's potential vulnerabilities, thereby improving the District's resiliency to sea level rise. This report documents the District's vulnerabilities to coastal, fluvial and estuarine hazards with sea level rise. This report also considers potential adaptation strategies that the District could implement in the future to reduce vulnerability and improve resiliency to sea level rise.

1.2 Background

The District's Water Resource Recovery Facility (WRRF) is located approximately 2,300 feet from the Pacific Ocean shoreline in Goleta, California and is situated on the northern face of Mescalitan Island within Goleta Slough (**Figure 1**). The watershed that drains into Goleta Slough is about 45 square miles and includes the drainages of seven creeks: Atascadero, Carneros, Las Vegas, Maria Ygnacia, San Jose, San Pedro and Tecolotito Creeks. Goleta Slough has experienced several large flood events over the past century, including major floods which forced the closure of the Santa Barbara Airport in 1969 and 1995. As the climate changes and sea levels rise, the risk of flooding and other adverse impacts to District infrastructure due to elevated water levels within Goleta Slough will increase.

The District's wastewater system may be subjected to flooding by four mechanisms:

- Existing and future chronic coastal erosion (beach and bluff), tidal inundation and groundwater emergence associated with sea level rise

[1] This report focuses on sea level rise as a primary climate stressor for the District and does not consider other potential climate stressors.

- Existing and future extreme coastal storm event flooding and wave run-up impacts associated with sea level rise
- Existing (and future) fluvial flooding in Goleta Slough associated with extreme rainfall-runoff events that flood the Slough
- Estuarine flooding caused by elevated water levels in Goleta Slough associated with moderate fluvial flows into the Slough in combination with a closed and elevated Goleta Slough mouth at Goleta Beach

SOURCE: ESA, ESRI

Goleta Sanitary District Climate Adaptation Plan

Figure 1
Project Location and Vicinity Map

1.2.1 Goleta Slough Management

This section summarizes the hydrology of Goleta Slough and its management by others in order to provide context of flooding and adaptation in the Slough as documented in the *Goleta Slough Area Sea Level Rise and Management Plan* (ESA 2015b). Goleta Slough has been greatly reduced in size and function over the past two centuries through a combination of natural processes, land use changes, and other human activities. The 2015 management plan comprises an update to previous Slough management plans and includes new detailed information and analysis of future conditions projected to occur as the climate changes over the next century.

Goleta Slough is a lagoon (aka coastal estuary) that has formed behind Goleta Beach and is typically perched above ocean water levels. Goleta Beach and the lagoon mouth channel that forms across the beach control the water surface elevation in the Slough. The closure, opening, and elevation of the mouth changes throughout the year: in summer, the mouth of the Slough is closed by sand that is built up by waves; in winter, larger rain events that fill the Slough enough to overtop the beach, which causes the mouth channel to breach the beach berm and scour the mouth channel. The Slough can remain open to ocean tides for a period of time after each breach until sufficient wave energy builds the beach berm up again.

In recent years the lagoon has often been mechanically breached by excavating through the beach berm in order to open the lagoon mouth during extended periods of closure. Following these mechanical breaches, the lagoon eventually returns to closed conditions. This most often occurs during the following dry season, with the timing of mouth closure varying depending on wave conditions and the amount of streamflow entering the lagoon from the watershed. Managed breaches had historically been conducted by the Santa Barbara Flood Control District with the presumptive goal of reducing flood risk and improving water quality (ESA 2015b).

In 2013, the Flood Control District decided not to continue managed breaching of the lagoon. This decision was attributed to the high expected costs of the biological studies that would be necessary to renew the permits. A limited number of managed breaches have occurred since 2013 under emergency permits strictly to prevent flooding during major rain events; meanwhile the City of Santa Barbara has commissioned studies to evaluate the impact of managed breaches on the local ecology and to plan for the long-term management of the Goleta Slough estuary (ESA 2015b).

The following are the Goleta Slough Area Sea Level Rise and Management Plan's key findings related to sea level rise at Goleta Slough:

- Recognize that the future management of the Slough inlet will have a very significant impact on water levels and have a large effect on the distribution of habitats and species within the Slough Ecosystem.
- Manage the Goleta Slough inlet to maintain tidal circulation, water quality, and diversity and resilience of species and habitats.
- Establish provisions for the long-term management of the Slough mouth, including ongoing monitoring with adaptive management to achieve well-defined goals and to allow for compliance with future permitting requirements.
- View sediment as a resource that can be used within the Slough to increase the resiliency of the habitats as sea level rises.
- Deposition of sediment from the watershed onto tidal marshlands and flats within the Slough should be encouraged to maximize marsh accretion relative to sea level rise.
- Improve ecological linkages, increase resiliency and reduce habitat fragmentation by restoring tidal action to diked areas and provide more adjacent upland habitat for transgression.
- Identify and pursue priority projects to protect, enhance and/or expand key habitat areas, taking advantage of existing open space areas that are already near the typical elevation range for these habitats.

- Identify and pursue priority projects to protect the most vulnerable infrastructure so as to increase the threshold water surface elevation at which flood damage becomes likely.
- Require the consideration of future sea level rise and Slough inlet management practices when determining flood risk and identifying flood hazard areas.
- Minimize the construction of new vulnerable infrastructure within flood hazard areas.

Management actions taken by others to manage Goleta Slough has the potential to impact and/or benefit low lying District assets. Thus, local coordination will be important as asset managers around Goleta Slough plan for future sea level rise.

CHAPTER 2
Sea Level Rise Scenarios

The primary climate driver for this study is sea level rise. This chapter documents the planning horizons (timeframes) and sea level rise scenarios evaluated for the Goleta Sanitary District Climate Adaptation Plan. Section 2.1 summarizes current state guidance on sea level rise. Section 2.2 presents the planning horizons and sea level rise scenarios selected for the project.

2.1 California State Sea Level Rise Policy Guidance

In 2018, the California Ocean Protection Council (OPC) updated the *State of California Sea Level Rise Guidance* (CA OPC 2018), which includes projections for sea level rise at various locations along the coast of California through 2150. The guidance is based on the science update prepared by the OPC and the California Natural Resources Agency, in collaboration with the Governor's Office of Planning and Research, the California Energy Commission, and the California Ocean Science Trust (Griggs et al. 2017). The CA OPC Guidance presents different sea level rise values based on two global greenhouse gas emissions scenarios:

High Emissions Scenario – This scenario assumes a future where there are no significant local or global efforts to limit or reduce emissions. This scenario assumes high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long-term to high energy demand and GHG emissions.

Low Emissions Scenario – This scenario assumes more aggressive emissions reduction actions corresponding to the aspirational goals of the 2015 Paris Agreement, which calls for limiting mean global warming to less than 2 degrees Celsius and achieving net-zero greenhouse gas emissions in the second half of the century. This scenario is considered challenging to achieve and would include updated climate policies, concerted action by all countries, and a shift to a lower emissions service and information economy. It is not possible to achieve the low emissions scenario through 2050 based on the current global emissions trajectory.

The 2018 CA OPC Guidance provides a range of probabilistic projections of sea level rise, which was an update specifically designed to help inform decision-makers. However, these projections may underestimate the likelihood of extreme sea level rise, particularly under high-emissions scenarios, so an extreme scenario, called the H++ scenario, was also included in the guidance. The H++ scenario assumes rapid ice sheet loss on Antarctica, which could drive rates of sea level rise 30-40 times faster than the sea level rise experienced over the last century. The updated guidance also identified different risk aversion projections that correspond to different levels of risk tolerance. These levels are represented as low, medium-high, and extreme risk aversion:

- The low risk aversion projection is appropriate for adaptive, lower consequence projects (e.g., unpaved coastal trails).
- The medium-high risk aversion projection is appropriate as a precautionary projection that can be used for less adaptive, more vulnerable projects or populations that will experience medium to high consequences as a result of underestimating sea level rise (e.g., coastal housing development).
- The extreme risk aversion projection is appropriate for high consequence projects with little to no adaptive capacity and which could have considerable public health, public safety, or environmental impacts (e.g., coastal power plant, wastewater treatment plant, etc.).

While the CA OPC Guidance provides projections through 2150, it is important to note that sea level rise is expected to continue for centuries, because the earth's climate, cryosphere[2], and ocean systems will require time to respond to the emissions that have already been released to the atmosphere. Although sea level rise is typically presented as a range in the amount of sea level rise that will occur by a certain date (e.g., 1-2 feet of sea level rise by 2050), it can also be presented as a range of time during which a certain amount of sea level rise is projected to occur (e.g., 1.5 feet of sea level rise between 2040 and 2070). Even if emissions are reduced to levels consistent with the low-emissions-based projections, sea levels will continue to rise to higher levels, just at a later date.

Table 1 presents State-recommended projections for the Santa Barbara area in terms of low, medium-high and extreme risk aversion (outlined by dark blue boxes in Table 1). CA OPC suggests that decision makers take a precautionary, risk-averse approach of using the medium-high sea level rise projections across the range of emissions scenarios for longer lasting projects with low adaptive capacity[3] and high consequences[4]. CA OPC and CA Coastal Commission (2021) recommend incorporating the H++ scenario in planning and adaptation strategies for projects that could result in threats to public health and safety, natural resources and critical infrastructure such as large power plants, wastewater treatment, and toxic storage sites. Table 1 includes the RCPs with probabilities and the non-probabilistic H++ scenario (depicted in blue on the right-hand side). High emissions scenario represents RCP 8.5; low emissions scenario represents RCP 2.6. Table 1 presents high-emission (RCP 8.5) projections of sea level rise up to 2050 because the sea level rise projections for the different emissions scenarios are similar before 2050. The probabilities included in Table 1 do not represent the actual probabilities of occurrence of sea level rise, but provide probabilities that the ensemble of climate models used to estimate the contributions of sea level rise will predict a certain amount of sea level rise (OPC 2018).

[2] The cryosphere is the portions of the Earth's surface where water is in solid form, like glaciers and ice caps.
[3] Adaptive capacity is the ability of a system or community to evolve in response to, or cope with the impacts of sea level rise.
[4] Consequences are a measure of the impact resulting from sea level rise, typically quantitative.

TABLE 1
OPC (2018) STATE GUIDANCE: PROJECTED SEA LEVEL RISE FOR SANTA BARBARA AREA IN FEET

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...		5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.3	0.2 -	0.4	0.5	0.7	1.0
	2040	0.5	0.3 -	0.7	0.8	1.1	1.6
	2050	0.7	0.4 -	1.0	1.2	1.8	2.5
Low emissions	2060	0.7	0.4 -	1.0	1.4	2.2	
High emissions	2060	0.9	0.6 -	1.3	1.6	2.5	3.6
Low emissions	2070	0.9	0.5 -	1.3	1.7	2.8	
High emissions	2070	1.1	0.7 -	1.7	2.1	3.3	4.9
Low emissions	2080	1.0	0.5 -	1.5	2.0	3.6	
High emissions	2080	1.4	0.9 -	2.1	2.7	4.3	6.3
Low emissions	2090	1.1	0.6 -	1.8	2.4	4.4	
High emissions	2090	1.7	1.1 -	2.6	3.3	5.3	7.9
Low emissions	2100	1.2	0.6 -	2.0	2.9	5.3	
High emissions	2100	2.1	1.2 -	3.1	4.1	6.6	9.8
Low emissions	2110*	1.3	0.7 -	2.1	3.0	5.9	
High emissions	2110*	2.2	1.4 -	3.2	4.2	6.9	11.5
Low emissions	2120	1.4	0.7 -	2.4	3.5	7.0	
High emissions	2120	2.5	1.7 -	3.7	4.9	8.2	13.7
Low emissions	2130	1.5	0.8 -	2.6	3.9	8.0	
High emissions	2130	2.9	1.8 -	4.2	5.6	9.5	16.0
Low emissions	2140	1.6	0.8 -	2.9	4.4	9.1	
High emissions	2140	3.1	2.0 -	4.8	6.4	11.0	18.6
Low emissions	2150	1.8	0.7 -	3.2	5.0	10.5	
High emissions	2150	3.5	2.2 -	5.3	7.2	12.6	21.4

2.2 Sea Level Rise Scenarios Selected for Goleta Sanitary District Climate Adaptation Plan

Considering the updated guidance discussed above, public webinars on the guidance update process[5], the latest science on sea level rise and the need to use existing sea level rise hazard data for portions of this study, the following planning horizons and sea level rise scenarios are selected for the Goleta Sanitary District Climate Adaptation Plan.

2.2.1 Planning Horizons

The planning horizons of 2050 and 2080 were selected for the purposes of the project. These horizons were selected based on the need to plan for near- and long-term impacts related to sea level rise, as well as the existence of available coastal hazard maps that were developed for these planning horizons. Most climate models show strong agreement on the amount of sea level rise

[5] More information can be found here: http://www.opc.ca.gov/climate-change/updating-californias-sea level-rise-guidance/

that is likely to occur by 2050, and start to diverge after 2050 based on the range of potential emissions scenarios (OPC 2013). Therefore, it is important to consider a range of sea level rise scenarios for future planning and projects with timeframes that look beyond 2050.

The planning horizons are consistent with sea level rise policy guidance documents and consistent with existing hazard mapping performed for the area by the U.S. Geological Survey (USGS) Coastal Storm Modeling System (CoSMoS) (O'Neill et al. 2018) and by ESA (ESA 2015c). Years 2050 and 2080 are used to characterize the potential vulnerability timing of impacts to the wastewater system associated with sea level rise. The updated guidance introduces planning horizons beyond 2100 but these projections are presented with caution by the authors. As described in OPC (2018), most climate model experiments do not extend beyond 2100, which results in a large increase in uncertainty in projections beyond 2100. Therefore, this study does not assess sea level rise amounts projected beyond 2100.

The 2050 and 2080 planning horizons are recommended so that decisions about operations and site improvements can be matched to the timeframe for project lifespans and to facilitate the identification of triggers for potential adaptation measures. By using the planning horizons of 2050 and 2080, we can assess a range of sea level rise that could occur in Goleta Slough in the mid and long-term whether or not the amounts of sea level rise are realized at, before or after these years. These planning horizons (years) determine the amounts of sea level rise that are used to assess vulnerability to coastal flooding hazards and the timeframes over which consequent impacts and potential adaptation strategies are evaluated.

2.2.2 Sea Level Rise Scenarios

The sea level rise scenarios proposed for this study were selected to be consistent with the latest guidance and to utilize available coastal hazard maps for the Goleta area. The available existing information for future hazards includes USGS CoSMoS 3.0 (O'Neill et al. 2018) and coastal hazard mapping by ESA for Santa Barbara County (ESA 2015).

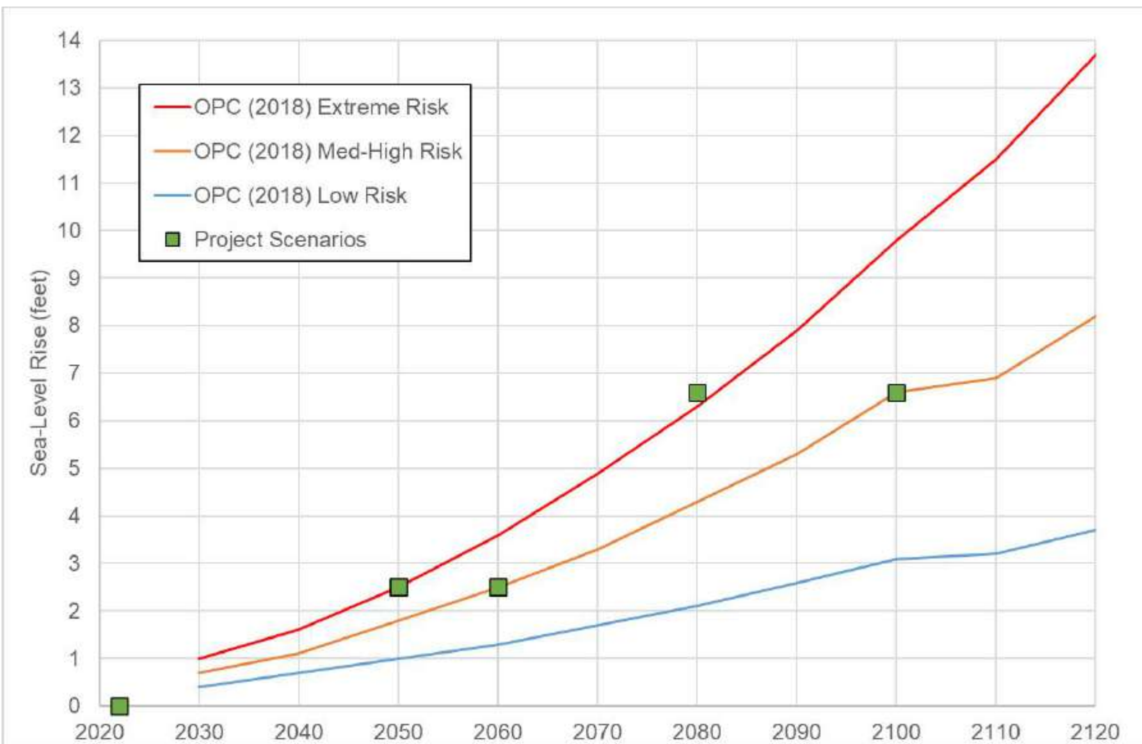
Per the latest State guidance, this study considers the probabilistic projections of sea level rise for the medium-high risk aversion scenarios as well as consideration of the H++ scenario. To account for uncertainties in sea level rise over time, and a range of assets at risk, this study uses the probabilistic projections for Medium-High and Extreme Risk Aversion levels from Table 1. A total of three sea level rise scenarios are used to perform the vulnerability assessment and adaptation plan, including existing conditions (no sea level rise) as well as future sea level rise of 2.5 feet and 6.6 feet. **Table 2** presents the proposed future sea level rise scenarios based on the State-recommended projections for each risk aversion level.

In order to conduct the vulnerability assessment, ESA conducted updated modeling of the Goleta Slough lagoon, and relied on the available coastal hazard maps from USGS CoSMoS and ESA. Updated modeling and existing hazard maps were selected that best match the sea level rise scenarios presented in Table 2. While the available coastal hazards maps do not exactly match the proposed sea level rise scenarios in Table 2, the differences are acceptable given the uncertainties associated with sea level rise.

TABLE 2
PROPOSED SEA LEVEL RISE SCENARIOS FOR PROJECT

	Approximate timing based on OPC (2018) projections	
Sea Level Rise Scenario	**Extreme Risk Aversion**	**Medium-High Risk Aversion**
0 feet (Existing Conditions)	n/a	n/a
2.5 feet	2050	2060
6.6 feet	2080	2100

Figure 2 presents a chart of the sea level rise projections based on the CA OPC (2018) guidance. Although the publicly available hazard maps were not evaluated at the exact sea level rise amounts of OPC (2018) tabulated in Table 1, they are representative of the new guidance within a reasonable amount of uncertainty.



SOURCE: ESA, OPC 2018

Goleta Sanitary District Climate Adaptation Plan

Figure 2
Sea Level Rise Projections for Santa Barbara Area with Project Scenarios

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CHAPTER 3
Data Collection

The vulnerability assessment for this study (Chapter 4) relies on spatial analysis overlaying wastewater asset maps with hazard maps. Geospatial data were collected for the pertinent flooding and erosion hazards as well as wastewater assets for District and other contributing jurisdictions. This chapter describes the specific data sources utilized for the study.

3.1 Hazard Data

Hazard data were obtained in GIS format to conduct an exposure analysis of wastewater assets for the study. ESA gathered available data on coastal hazards with sea level rise for the extent of the District's coastal assets, including the District's Water Resource Recovery Facility (WRRF), coastal portions of the District's collection system, and the ocean outfall. ESA also downloaded available FEMA fluvial flood hazard data for Goleta Slough and San Pedro Creek. The following sections list the hazard sources utilized for this study. ESA compiled these hazard data in GIS for mapping and analysis of wastewater asset exposure levels with sea level rise (see Chapter 4).

3.1.1 Coastal Flooding, Erosion, and Groundwater

Tidal inundation, coastal storm flooding, beach and bluff erosion, and groundwater hazard data with sea level rise are outputs from the USGS CoSMoS 3.0 (USGS 2018). Tidal inundation and coastal storm flooding hazard zones compiled for this study include corresponding low-lying areas mapped by CoSMoS that may also inundate or flood.

3.1.2 Coastal Storm Wave Run-Up

Wave run-up hazard data from the Santa Barbara County Coastal Resilience study (ESA 2015c) was utilized to map wave damage hazards along Goleta Beach. This hazard zone indicates areas of potential high momentum forces from wave set up and waves running up and over the beach and landward property.

3.1.3 Goleta Slough Extreme Lagoon Water Levels

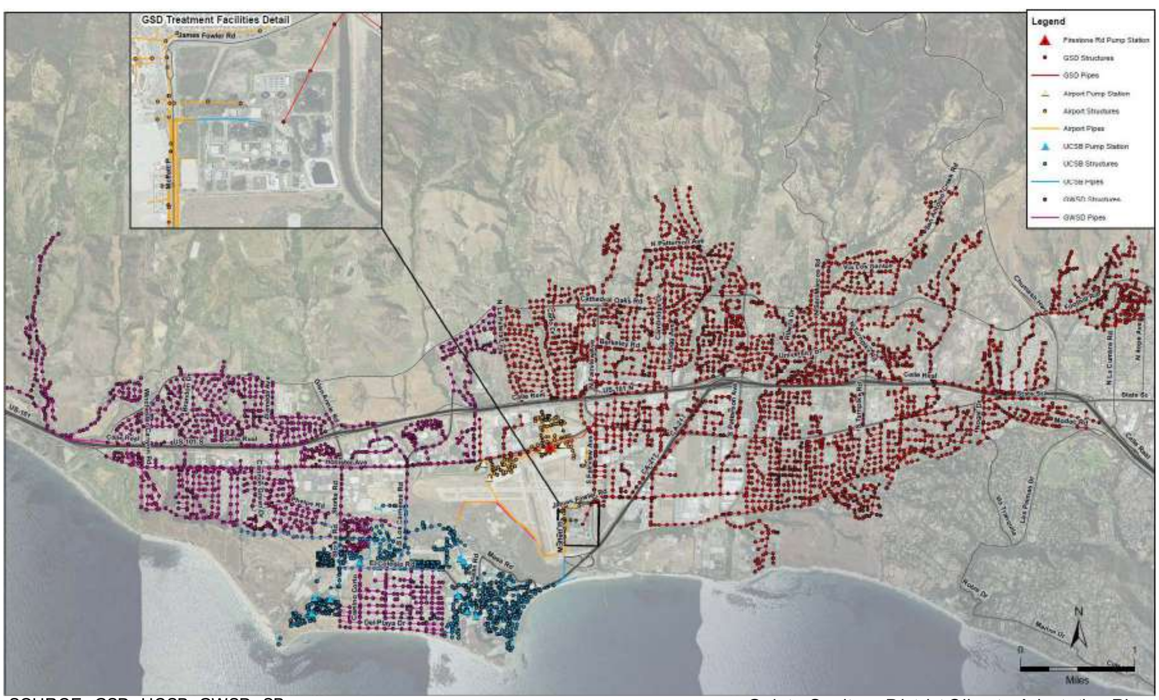
ESA applied a Quantified Conceptual Model (QCM) of Goleta Slough inlet opening and closure and water levels that ESA developed previously for the 2015 Goleta Slough Area Sea Level Rise and Management Plan (ESA 2015a). ESA ran the QCM for three sea level rise scenarios (existing conditions, 2.5 and 6.6 feet sea level rise) and two mouth management scenarios (continuing existing management and modified/adaptive future management) to estimate existing and future extreme lagoon water levels in Goleta Slough. ESA then used readily available LiDAR topographic data from a public source to map Goleta Slough extreme lagoon water level flood extents. See **Appendix A** for more information on the QCM.

3.1.4 Existing fluvial flooding

ESA obtained the most recent available FEMA Flood Insurance Study and Flood Insurance Rate Map (FEMA 2018) for Goleta Slough and San Pedro Creek to define existing fluvial flood hazards for the 100-year event. Santa Barbara County Flood Control confirmed no recent flood modeling has been performed for Goleta Slough and San Pedro Creek since the effective September 2018 FEMA maps were released (J. Frye, personal communication, August 26, 2021).

3.2 Wastewater Asset Data

District wastewater assets include manholes, cleanouts, junction boxes, and drop structures (collectively referred to as structures), pumps, pipes and other wastewater collection and treatment facilities. Georeferenced asset data were obtained by MNS from the various jurisdictions that convey wastewater District treatment facilities. These data were used along with the hazard data in GIS to create asset exposure maps and tabulate exposed assets by hazard and sea level rise scenario (see Section 5). **Figure 3** shows the extents of wastewater assets that flow to the District.



SOURCE: GSD, UCSB, GWSD, SB Airport, ESRI

Goleta Sanitary District Climate Adaptation Plan

Figure 3
Wastewater Assets

3.2.1 Goleta Sanitary District

Collection system GIS data on pipe and structure locations were obtained from the District. The District's outfall pipe and maintenance access vault were approximated in GIS from aerial imagery and as-built drawings provided by the District. District structures represented by points include manholes, cleanouts, drop structures and the Firestone Road Pump Station. District pipes represented by lines include gravity and force mains.

3.2.2 Santa Barbara Airport

Collection system GIS data on pipes and structures were obtained from the City of Santa Barbara, Airport Department. Structures represented as points include lift stations, manholes, cleanouts and interceptors. Detailed review and validation of Santa Barbara Airport (Airport) GIS data is not within the scope of this study because the current study is focused on District assets. Based on an initial review, the Airport GIS data appears to be redundant of other jurisdictions in some areas and is possibly not accurate or up to date in some areas. A minor effort was made to reduce redundancy for pump stations, but not for other features such as manholes and pipes. This Airport GIS data should be revised and/or updated for use in any study focused on Airport assets.

3.2.3 Goleta West Sanitary District

Collection system GIS data on pipes and structures were obtained from MNS records. MNS provides GIS services to update and maintain the Goleta West Sanitary District (GWSD) GIS database. Structures represented as points include manholes and cleanouts. Pipes are represented as lines.

3.2.4 University of California, Santa Barbara

Collection system GIS data on pipes and structures were obtained from the University of California, Santa Barbara (UCSB) Design, Facilities & Safety Services Department. Structures represented as points include pumps, manholes, cleanouts and other structures. Pipes are represented as lines.

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CHAPTER 4
Vulnerability Assessment

This chapter presents the methods and findings of the sea level rise vulnerability assessment using spatial data for coastal hazard zones (described in Section 3.1) and wastewater assets (described in Section 3.2). ESA assessed the vulnerability of wastewater pipes, lift stations, and other structures in the District and other contributing jurisdictions. The discussion focuses on District assets exposed to various hazards. Exposures of other jurisdiction assets are documented in the summary tables for context and future coordination purposes, but are not assessed or discussed in the text because the scope of this study is limited to District assets.

In order to develop an effective adaptation plan and policies to address sea level rise vulnerability, the risk of not taking action must be understood first. For this reason, the vulnerability assessment analyzes impacts from a “no action” scenario in which asset managers do not prepare for or respond to sea level rise. By considering this scenario, the District, neighboring jurisdictions and other decision makers can understand the full potential impacts of sea level rise, identify areas and/or individual assets with the greatest vulnerabilities, and then plan adaptation to reduce identified vulnerabilities.

Vulnerabilities of wastewater assets were determined for each hazard type considered in this study: coastal, fluvial, and estuarine hazards. An asset’s vulnerability to a given hazard is a function of the quantity of exposed assets, the consequences of exposure, and the adaptive capacity of the asset (i.e., asset’s ability to be modified to mitigate or avoid exposure). Asset exposures were determined by intersecting each asset layer with each hazard zone in ArcGIS. In general, point assets (like manholes, pump stations) in each hazard zone are counted while linear assets (like collection pipes and force mains) are measured in feet. The resulting asset exposure for each hazard type is summarized in the following sections. Hazard Exposure maps that overlay assets and hazards are provided in **Appendices C, D and E**. Assets exposed to each hazard for each time horizon are summarized in the following sections with accompanying discussion of the consequences and adaptive capacity of the assets exposed.

4.1 Coastal Hazard Exposure

Coastal hazards analyzed include the following 5 categories of permanent and temporary impacts without action. The categories are distinguished between chronic long-term impacts and temporary extreme event-based impacts.

- Areas subject to the potential future **beach and bluff erosion** hazard zones may be lost entirely (permanent impacts, greatest consequences). Beach erosion consists of landward shoreline movement and scour of assets built on or within the beach. Bluff erosion includes sloughing and erosion of the bluff top and face due to coastal erosion from wave action on the toe of bluff as well as terrestrial erosion processes.

- Areas in the potential future **tidal inundation** hazard zone would be impacted regularly by inundation (permanent impacts, greatest consequences). Tidal inundation represents the potential for chronic infiltration of brackish/salt water to occur at high tides.
- Areas in the **groundwater emergence** hazard zone would be similarly impacted regularly by inundation (permanent impacts, greatest consequences).
- Areas in the potential future **coastal storm flooding** hazard zone would be inundated by extreme high ocean water levels caused by storm surge (temporary impacts, significant consequences). Temporary infiltration of brackish water may occur at unsealed manholes or other access structures. USGS CoSMoS storm scenarios assume that the storm coincides with a "high spring tide (tide levels that occur approximately twice every month). This represents a near-worst case scenario, with the 'King Tide' being slightly higher but much less frequent, occurring typically only during two ~3- to 4-day periods per year."
- Areas in the potential future **coastal storm wave run-up** hazard zone may be damaged or disrupted from flowing water, but assets are likely recoverable, and would return to service when waves and floodwaters recede (temporary impacts, low to moderate consequences).

Table 3 summarizes the number of structures and length of pipe in each jurisdiction that are exposed to each coastal hazard under the three sea level rise scenarios. The following subsections summarize the quantity (count or length) of wastewater assets exposed to each hazard type with discussion on the consequences of each exposure category and the adaptive capacity of exposed assets. Asset exposure maps for the coastal hazard types are provided in **Appendix C**.

TABLE 3
COASTAL HAZARD EXPOSURE SUMMARY

			Existing Sea Level				2.5 Feet Sea Level Rise (2050 timeframe)[1]					6.6 Feet Sea Level Rise (2080 timeframe)[1]				
Agency	Asset	Unit	TID	GW	FLD	WR	ER	TID	GW	FLD	WR	ER	TID	GW	FLD	WR
GSD	Firestone Rd. LS	ct	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Outfall Vault	ct	0	0	0	1	0	0	0	0	1	1	0	1	1	1
	Structures	ct	0	53	54	0	3	1	54	53	0	4	50	74	107	0
	Outfall Pipe	FT	246	230	901	48	0	833	513	1k	283	79	1.4k	1.2k	1.8k	381
	Other Pipes	FT	69	15.4k	12.5k	0	468	208	16.0k	12.3k	0	709	10.9k	19.6k	25.3k	0
Airport	Lift Station	ct	0	0	3	0	0	0	0	3	0	0	3	2	4	0
	Structures	ct	0	20	75	0	0	5	21	75	0	0	88	66	123	0
GWSD	Structures	ct	0	54	73	0	0	4	54	74	0	9	66	60	98	0
UCSB	Lift Station	ct	0	0	0	1	0	0	0	1	1	0	1	0	2	1
	Structures	ct	0	16	7	0	12	2	16	9	0	35	21	22	78	2

Abbreviations: ct-count, FT-feet, TID-tidal inundation, GW-groundwater emergence, FLD-coastal storm flooding, WR-coastal storm wave run-up, ER-coastal erosion

1 Date corresponds to the extreme risk aversion curve for sea level rise by OPC 2018.

4.2.1 Beach and Bluff Erosion

A total of three District structures along Austin Road bluff top are exposed to bluff erosion with 2.5 feet sea level rise. Five structures are exposed to coastal erosion with 6.6 feet sea level rise, including shoreline erosion past the outfall maintenance vault at Goleta Beach and bluff erosion at four structures along Austin Rd.

With 2.5 feet sea level rise, 468 feet of pipe along Austin Rd bluff top is exposed to bluff erosion. The exposed length increases to 709 feet with 6.6 feet sea level rise. In addition, 79 feet of unrestrained outfall pipe at Goleta Beach are exposed to shoreline erosion with 6.6 feet sea level rise.

The District's outfall pipe and associated maintenance vault at Goleta Beach Park are exposed to coastal storm flooding and wave run-up under existing conditions that may lead to coastal erosion around the structure. The outfall pipe landward of the maintenance vault is comprised of unrestrained pipe segments that are at risk of destabilization if shoreline erosion proceeds landward of the maintenance vault. Thus, it appears the outfall pipe will need to be "restrained" for a distance inland of the maintenance vault based on estimates of coastal erosion projections. The District currently has an initial adaptation plan to remove and/or abandon the maintenance vault when needed (S. Wagner, District, personal communication, June 1, 2021).

Consequences and Adaptive Capacity

The exposed Austin Road sewers currently service 8 of the 10 bluff-top single-family residences on the beach side of Austin Road. Two homes remain on septic systems. The homes on the north side of Austin Road are primarily served by sewer lines located in easements between Austin Road and Louisiana Place. Bluff erosion that would cause failure of the District sewer assets on Austin Road would first affect the homes themselves on the beach side. Such erosion would also remove access to the homes on the north side of Austin Road and minimize any associated sewer flow. The sewer lines are local on Austin Road and convey no other flows (L. Astorga, District, personal communication, November 1, 2021). District staff estimate that potential failure of the sewer lines on Austin Road could involve the spill of several hundred gallons of wastewater (L. Astorga, District, personal communication, November 1, 2021). A spill could potentially result in regulatory and legal action against the District. Protective measures which may be required to mitigate coastal erosion risks to residences between sewer collection system infrastructure and the coastal bluff are likely to protect existing wastewater assets, if implemented by others. The adaptive capacity of the gravity sewers exposed to bluff erosion is low. While hardening assets to reduce risks of failure is possible, it may not be effective depending on the extent of shoreline erosion. If property protection measures are not implemented by others, incremental abandonment/capping of District facilities as properties and associated infrastructure are lost to erosion would minimize any District facility loss and sanitary sewer overflow (SSO) volume.

A potential failure of the existing unrestrained outfall pipe segments landward of the maintenance vault would likely result in a substantial spill of treated wastewater at the point of joint separation and result in a violation of the District's NPDES permit (Order No. R3-2017-0021, NPDES No. CA0048160). Minimal ability to divert treated wastewater flows and challenging repair conditions would likely cause a potential spill to extend over a significant duration. The adaptive capacity of the unrestrained outfall pipe segments is moderate and would require excavation and installation of joint restraining devices at each pipe joint or replacement pipe. Due to the location of the outfall pipeline, extensive permitting would be required to complete this installation, and construction conditions would be challenging.

4.2.2 Tidal Inundation

Tidal inundation exposure in this study represents inundation from typical monthly spring tide conditions. No District structures are exposed to tidal inundation under existing conditions. One structure is exposed with 2.5 feet sea level rise and 50 are exposed with 6.6 feet sea level rise.

Not including the outfall pipe, 69 feet of pipe is exposed to tidal inundation under existing conditions under San Pedro Creek. The exposed pipe length increases to 208 feet with 2.5 feet sea level rise, and to 10,869 feet exposed with 6.6 feet sea level rise. In addition, 246 feet of outfall pipe (landward of the beach access vault) is exposed within the main Slough channel. Tidally-exposed outfall pipe length increases to 1,400 feet with 6.6 feet of sea level rise.

Consequences and Adaptive Capacity

Tidal exposure of buried pipes indicates the area above them may convert to wetlands (e.g., existing upland open space areas may convert to wetland). Thus, these sections of pipe will potentially become harder to access for maintenance.

Tidal inundation of areas with wastewater assets will also result in increased rates of inflow and infiltration (I&I) into the wastewater collection system. These additional flows will have multiple impacts:

- Increased flow rates within the collection system, potentially beyond the capacity of the collection system to convey wastewater. This could result in SSOs and regulatory action against the District.
- Increased flows of wastewater to the WRRF resulting in higher pumping and treatment costs.
- Increased levels of chlorides and total dissolved solids (TDS) from brackish/saltwater I&I into WRRF influent flows could potentially impact the treatment process and quality of final effluent and recycled water.

The adaptive capacity of District assets is high. Pipelines and manholes experiencing infiltration can be lined or wrapped to reduce I&I issues. Manhole frames and covers outside of roadways can be raised to elevate frames and covers above maximum water levels. Manhole frames and covers unable to be raised can be sealed to reduce inflow. These adaptations are not anticipated to fully address these identified consequences, but can reduce them substantially.

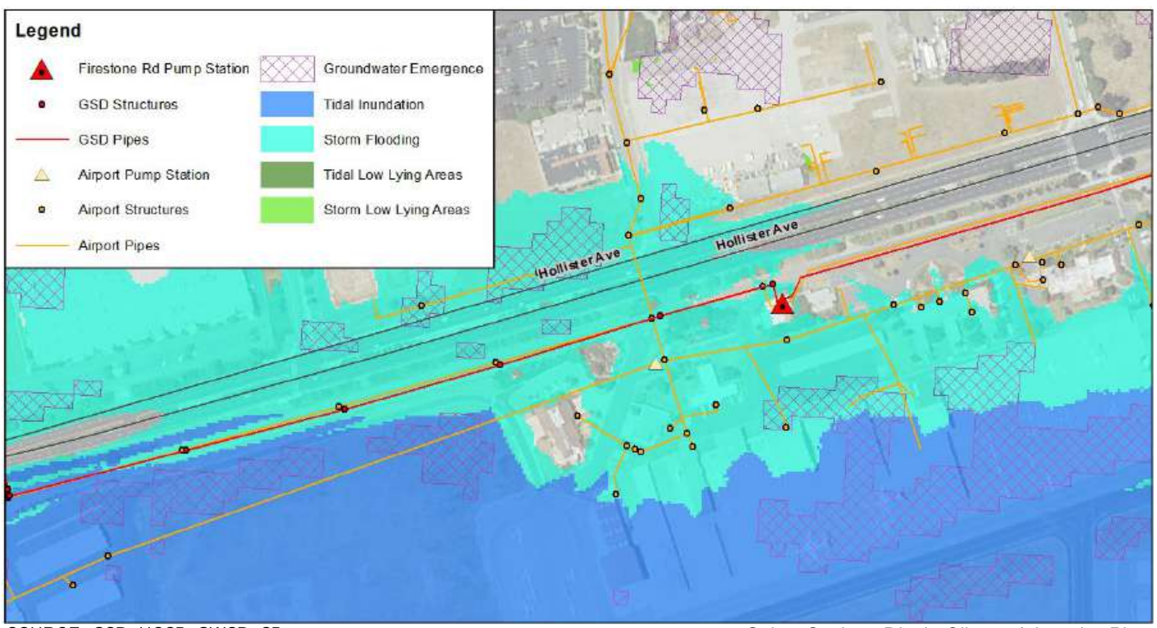
The same adaptations are applicable for other agency assets, but they are not owned or maintained by the District. The District has less control over implementation of identified adaptation measures for other agency assets and the capacity of the District to adapt to impacts to other agency assets is therefore considered moderate.

4.2.3 Coastal Flooding and Wave Run-Up

A total of 54 District structures are exposed to coastal storm flooding under existing conditions. The number of exposed structures is 53 with 2.5 feet sea level rise and 107 with 6.6 feet sea level rise. The outfall maintenance vault at Goleta Beach is exposed to coastal storm wave run-up under existing conditions and with future sea level rise. No other District structures are exposed to wave run up. The slight decrease in exposed structures from zero to 2.5 feet of sea level rise is due to variations in the CoSMoS storm flood extents mapped for those scenarios.

The Firestone Road lift station is potentially exposed to coastal storm flooding with 6.6 feet sea level rise. The pump house itself is not within the coastal flood hazard zone but Firestone Road and the area surrounding the pump house is shown as flooded by the 100-year coastal storm (see **Figure 4**). Other roads are exposed to coastal storm flooding that provide access to the WRRF from the north: South Fairview Avenue near Hollister Avenue and James Fowler Road near the Santa Barbara Airport.

Thousands of feet of pipes are exposed to coastal flooding under existing and future sea levels. Note that the unrestrained portion of outfall pipe that is within the wave run-up hazard zone may be affected if the pipe is exposed by coastal erosion (see Section 5.1.1).



SOURCE: GSD, UCSB, GWSD, SB Airport, ESRI

Goleta Sanitary District Climate Adaptation Plan

Figure 4
Firestone Road Pump Station Coastal Flooding Exposure with 6.6 Feet Sea Level Rise

Consequences and Adaptive Capacity

Extreme coastal flooding events may temporarily limit access of the Firestone Road lift station with 6.6 feet of sea level rise. Extreme coastal flooding and wave run-up into Goleta Slough has the potential to cause increased rates of I&I into the wastewater collection system under existing conditions and future sea level rise will exacerbate this issue. Additionally, infrastructure may be harder to access from above for emergency maintenance during flood events. The additional brackish/saltwater flooding of the collection system will have multiple consequences:

- Increased flow rates within the collection system during coastal storm events.
- Increased flows of wastewater to the WRRF, resulting in higher pumping and treatment costs.
- Increased levels of chlorides and TDS in WRRF influent flows could potentially impact the treatment process and quality of final effluent and recycled water.

The adaptive capacity of District assets is high. Pipelines and manholes experiencing infiltration can be lined or wrapped to reduce I&I issues. Manhole frames and covers outside of roadways can be raised to elevate frames and covers above maximum water levels. Manhole frames and covers unable to be raised can be sealed to reduce inflow. These adaptations are not anticipated to fully address these identified consequences, but can reduce them substantially.

4.2.4 Groundwater Emergence

Groundwater emergence was evaluated to identify sewer structures that may become exposed to inflows as groundwater ponds at the ground surface in certain areas. A total of 53 District structures are exposed to potential groundwater emergence under existing conditions. The number of exposed structures increases to 54 with 2.5 feet sea level rise and 74 with 6.6 feet sea level rise. Not including the outfall, 15,441 feet of pipe are exposed to groundwater emergence under existing conditions. The length increases to 16,042 feet exposed with 2.5 feet sea level rise, and to 19,616 feet exposed with 6.6 feet sea level rise. Groundwater emergence above buried pipes indicates the area may convert to wetlands. Thus, these sections of pipe will potentially become harder to access for maintenance.

Underground/deep facilities such as the District's water reclamation facility will become exposed to rising groundwater levels associated with sea level rise.

Consequences and Adaptive Capacity

Increased groundwater will result in increased rates of I&I into the wastewater collection system. These additional flows will have multiple impacts:

- Increased flow rates within the collection system.
- Increased flows of wastewater to the WRRF, resulting in higher pumping and treatment costs.
- Increased levels of chlorides and TDS in WRRF influent flows could potentially impact the treatment plant process and quality of final effluent and recycled water (groundwater may be salty).

Additionally, increased groundwater levels could result in impacts to the below-grade reclaimed water storage tanks and chlorine contact tanks. If these facilities are not full, there is a potential risk of floatation of these tanks.

The adaptive capacity of District collection system assets is high. Pipelines and manholes experiencing infiltration can be lined or wrapped to reduce issues. Manhole frames and covers outside of roadways can be raised to elevate frames and covers above maximum water levels. Manhole frames and covers unable to be raised can be sealed to reduce inflow. These adaptations are not anticipated to fully address these identified consequences, but can reduce them substantially.

The adaptive capacity of reclaimed water storage tanks and chlorine contact tanks is moderate. Additional research will be required to determine if design criteria used to design the facilities is sufficient to resist floatation with increased groundwater levels. If floatation is a risk, adaptation efforts are potentially significant, although feasible.

The same adaptations are applicable for other agency assets, but they are not owned or maintained by the District. The District has less control over implementation of identified adaptations and the capacity for the District to adapt other agency assets is therefore considered moderate.

4.2 Fluvial Flooding

The fluvial flood exposure was determined from current effective FEMA flood rate insurance mapping. This mapping represents the 100-year creek and river flooding from extreme precipitation in the watershed draining into Goleta Slough, as well as coastal flooding along the coast with current sea level. The asset exposure map for fluvial flooding is provided in **Appendix D**. While not examined in detail for this study, it is generally understood that today's 100-year fluvial flood may become more frequent with climate change due to more intense extreme precipitation events. Additionally, the resulting flooding from any given event will become more extensive in the future as downstream water levels in Goleta Slough increase with sea level rise.

In association with extreme fluvial floods, the District has observed creek bank erosion along eastern plant boundary (San Pedro Creek). Bank erosion may threaten pond berm stability along San Pedro Creek.

Table 4 summarizes the number of sewer structures in each jurisdiction that are exposed to existing 100-year fluvial flooding based on current FEMA flood mapping. A total of 341 District structures are exposed to extreme fluvial flooding, as delineated by the FEMA 100-year event. Length of pipe exposed to flooding is not reported as consequences are expected to be minimal (i.e., the buried pipe would be unaffected by temporary flooding above ground).

In addition to the flood exposures shown in Table 4, extreme fluvial flooding inundates many access roads to the Firestone Road lift station (Firestone Road, Hollister Avenue) and the District WWTF itself (South Fairview Road, James Fowler Road, Moffett Place).

TABLE 4
FLUVIAL FLOODING HAZARD EXPOSURE SUMMARY

Jurisdiction	Asset	Unit	Fluvial Flooding Exposure (100-year event)
GSD	Firestone Rd. LS	count	1
	Structures	count	341
Airport	Lift Station	count	5
	Structures	count	155
GWSD	Structures	count	178
UCSB	Lift Station	count	0
	Structures	count	61

SOURCE: ESA/SB County, USGS, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

4.2.1 Consequences and Adaptive Capacity

Fluvial Flooding will result in increased rates of I&I into the wastewater collection system. These additional flows will have multiple impacts:

- Increased flow rates within the collection system, potentially beyond the capacity of the collection system to convey wastewater. This could result in SSOs and regulatory action against the District.
- Increased flows of wastewater to the WRRF, resulting in higher pumping and treatment costs.

Additionally, flood conditions may limit access to some manholes which could cause challenges if a blockage occurs and cannot be accessed for clearing. Access to the Firestone Road lift station WRRF may be limited during extreme fluvial flooding events.

Unabated creek bank erosion along the eastern WRRF boundary adjacent to San Jose Creek could potentially result in a failure of the sludge stabilization basins and flow equalization basins.

The adaptive capacity of District assets is high. Pipelines and manholes experiencing infiltration can be lined or wrapped to reduce issues. Manhole frames and covers outside of roadways can be raised to elevate frames and covers above maximum water levels. Manhole frames and covers unable to be raised can be sealed to reduce inflow. These adaptations are not anticipated to fully address these identified consequences, but can reduce them substantially.

The adaptive capacity to address access issues during extreme fluvial flooding is low, and would require significant access modifications, or relocation of facilities to enhance access.

The adaptive capacity to reduce erosion risks along the eastern WRRF boundary is high and could consist of protecting the existing slopes to resist erosion.

The same adaptations are applicable for other agency assets, but they are not owned or maintained by the District. The District has less control over implementation of identified adaptations and the capacity for the District to adapt other agency assets is therefore considered moderate.

4.3 Estuarine Flooding

The estuarine flood represents a combined condition where (1) the beach berm builds up at Goleta Slough mouth over the summer season and subsequently (2) creek flows from a moderate rain event fill the Slough behind the closed mouth until the water level overtops the beach berm and scours the mouth so that the Slough can drain to tidal levels. The following sections summarize the modeling effort to estimate extreme estuarine flooding in Goleta Slough and exposure of wastewater assets to this flood source.

4.3.1 Goleta Slough Quantified Conceptual Model

The Quantified Conceptual Model (QCM) provides a framework predicting the long-term evolution of lagoon mouth and lagoon water levels (Behrens et al. 2015). This framework uses empirical data and parameterizations to quantify the hydrology of lagoon, coastal influences to the beach, and hydraulics of the mouth. Here, we used QCM for an 8-year simulation of Goleta Slough considering existing conditions, as well as mid-century (2.5 feet) and late-century (6.6 feet) sea level rise scenarios (see Table 1). The Goleta Slough lagoon mouth channel is currently managed by breaching the lagoon mouth channel such that the channel bed elevation (i.e., the mouth channel thalweg) typically does not exceed 9 feet NAVD88 on an emergency basis. With sea level rise, emergency lagoon mouth management would be required more frequently with higher costs to maintain a channel elevation of 9 feet NAVD88. Therefore, adaptive emergency breaching of the lagoon to the projected sea level rise was also considered in this study. Here, simulations of sea level rise scenarios are performed by assuming existing breaching (thalweg elevation limited to 9 feet NAVD88) and adaptive breaching (thalweg elevation limited to 9 feet NAVD88 plus sea level rise of 2.5 feet or 6.6 feet). The lowest and highest levels of ocean tides, and simulated lagoon water levels and thalweg elevations at the mouth are reported in **Table 5**. Additional details on the Goleta Slough QCM modeling and results are presented in **Appendix A**.

TABLE 5
RANGES OF MODELED WATER LEVELS AND THALWEG ELEVATIONS IN GOLETA SLOUGH (FEET NAVD88)

Case	Sea Level Rise	Breaching	Ocean Tides (feet NAVD)	Modeled Lagoon Water Levels (feet NAVD)	Modeled Thalweg Elevations (feet NAVD)
1	0 feet (existing)	Existing	-2.7 – 7.4	0.95 – 10.1	1.0 – 8.6
2	2.5 feet	Existing	0.1 – 9.9	3.5 – 11.2	3.5 – 9
3	6.6 feet	Existing	4.2 – 14.0	8.4 – 13.4	7.6 – 9
4	2.5 feet	Adaptive	0.1 – 9.9	3.5 – 11.2	3.5 – 11.0
5	6.6 feet	Adaptive	4.2 – 14.0	5.5 – 15.2	7.6 – 15.2

4.3.2 Goleta Slough Flooding

Our analysis indicates that future estuarine flood levels increase less than the amount of sea level rise. This is likely because of the flat land elevations at the higher flood levels (hypsometry) surrounding the Goleta Slough basin; the area of flooding increases with elevation and "spreads out laterally" rather than rising as much as projected sea levels. The asset exposure map for estuarine flooding is provided in **Appendix E**. The Goleta Slough modeling effort (see **Appendix A**) presumes that emergency mouth management (existing or adaptive) would occur ahead of significant precipitation events in the future. If the mouth isn't breached, the extents of estuarine flooding would be greater than shown in **Appendix E** and would cause greater impacts than summarized below.

Table 6 summarizes the number of structures in each jurisdiction that are exposed to estuarine flooding from Goleta Slough under each sea level rise and mouth management scenario. A total of 4 District structures are exposed to estuarine flooding from Goleta Slough under existing conditions. The number of exposed structures increases to 8 with 2.5 feet sea level rise for both existing mouth management and adaptive mouth management is implemented. The number further increases to 39 exposed structures with 6.6 feet sea level rise under existing mouth management, and to 69 exposed structures under adaptive mouth management for the same sea level. In addition to the exposures summarized in Table 6, James Fowler Road is exposed to estuarine flooding with 2.5 feet sea level rise and greater.

TABLE 6
ESTUARINE HAZARD EXPOSURE SUMMARY

			Existing Sea Level	2.5 Feet Sea Level Rise		6.6 Feet Sea Level Rise	
Jurisdiction	**Asset**	**Unit**	**Existing Mouth Mgmt.**	**Existing Mouth Mgmt.**	**Adaptive Mouth Mgmt.**	**Existing Mouth Mgmt.**	**Adaptive Mouth Mgmt.**
Goleta Sanitary District	Firestone Rd. LS	count	0	0	0	0	0
	Structures	count	4	8	8	39	69
Airport	Lift Station	count	0	1	1	2	2
	Structures	count	5	17	17	85	112
GWSD	Structures	count	5	10	10	25	34
UCSB	Lift Station	count	0	0	0	0	0
	Structures	count	7	10	10	34	70

SOURCE: ESA/SB County, USGS, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

Consequences and Adaptive Capacity

Estuarine Flooding will result in increased rates of I&I into the wastewater collection system. These additional flows will have multiple impacts:

- Increased flow rates within the collection system, potentially beyond the capacity of the collection system to convey wastewater. This could result in SSOs and regulatory action against the District.
- Increased flows of wastewater to the WRRF, resulting in higher pumping and treatment costs.
- Increased levels of chlorides and total dissolved solids (TDS) from brackish/saltwater I&I into WRRF influent flows could potentially impact the treatment plant process and quality of final effluent and recycled water.

Flood conditions may limit access to some manholes, which could cause challenges if a blockage occurs and cannot be accessed for clearing. Additionally, access to the WRRF may be limited during extreme flooding conditions. Access to the District's lift station is not anticipated to be significantly impacted.

The adaptive capacity of District assets is high. Pipelines and manholes experiencing infiltration can be lined or wrapped to reduce issues. Manhole frames and covers outside of roadways can be raised to elevate frames and covers above maximum water levels. Manhole frames and covers unable to be raised can be sealed to reduce inflow. These adaptations are not anticipated to fully address these identified consequences, but can reduce them substantially.

The adaptive capacity to address access issues during extreme estuarine flooding is low, and would require significant access modifications, or relocation of facilities to enhance access.

The same adaptations are applicable for other agency assets, but they are not owned or maintained by the District. The District has less control over implementation of identified adaptations and the capacity for the District to adapt other agency assets is therefore considered moderate.

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CHAPTER 5
Adaptation Measures

Upon reviewing the specific District asset vulnerabilities (Chapter 4), the project team identified several adaptation measures that can increase the resilience of District assets to sea level rise and maintain treatment functionality. Three adaptation measures were selected by District for analysis in this study, while additional adaptation measures are discussed generally in this chapter and identified for study in future planning efforts.

Adaptation measures selected for analysis in this study are:

- Recycled water underground storage tank anchoring
- Firestone Road Pump Station floodproofing
- San Pedro Creek bank stabilization along District ponds

Adaptation measures identified for future study include:

- Collection system I&I management (manholes, pipes, junctions, etc.)
- Protection of ocean outfall access vault at Goleta Beach from erosion and wave run-up
- Austin Road collection system modifications
- District WRRF access improvement

The following sections document the above adaptation measures. Measures selected for analysis are described with conceptual design graphics, potential timing of implementation and probable engineering cost estimates.

5.1 Adaptation Measures Analyzed

For this study, ESA was scoped to analyze three adaptation measures that address key District vulnerabilities to sea level rise and associated hazards. After conversations with the District about potential vulnerabilities identified (Chapter 4) and potential suitable adaptation measures to address these vulnerabilities, the District selected the following adaptation measures for analysis: improve the resilience of the recycled water underground storage tank and chorine contact tank, improve flood management of the Firestone Road pump station, and improve protection of the San Pedro Creek bank along the District ponds. These three adaptation measures are summarized below.

5.1.1 Recycled Water Underground Storage Tank and Chlorine Contact Basin

Rising groundwater levels associated with sea level rise in Goleta Slough will increase buoyancy forces on underground facilities such as the recycled water underground storage tank and chlorine contact basin. MNS conducted a simplified buoyancy analysis of the existing below-grade recycled water storage tank and chlorine contact basin based on available record drawings and coastal hazard data for late century (6.6 feet sea level rise and 100-year coastal storm).

Both structures were constructed with extended base slabs to counteract buoyant forces to prevent floatation; however, the assumptions used in sizing these extended slabs are unknown. Geotechnical reports for original construction of the structures were not available for preparation of this analysis. The analysis for both structures includes an assumption of fresh water (non-sea water) groundwater levels up to the grade/ground surface surrounding each structure, with each structure empty. This analysis scenario represents the potential groundwater conditions in the future with 6.6 feet of sea level rise during a 100-year coastal storm event. Groundwater has the potential to rise within 3.3 feet of the ground surface in this location by late century with 6.6 feet sea level rise. During a storm event, saturated soils could be expected to come up to grade on a temporary basis.

The results of the analysis indicate both structures are potentially at substantial risk of floatation if drained of water, with the recycled water storage tank being more severely at risk. Conservative values are assumed for the weight of soil and soil resistance friction angle. It is recommended that the District conduct a geotechnical analysis of the backfill and native soil to determine more accurate values for the weight of soil and soil resistance friction angle, and the buoyancy calculations be updated accordingly. If the updated calculations continue to show a substantial risk of floatation, adaptation alternative should be evaluated to prevent floatation. These adaptation alternatives could include the following:

- Document operational procedures to maintain water in the structures except during periods of sufficiently low groundwater,
- Add weight to the structures to resist floatation
- Install piles or other structural modifications to enhance resistance to uplift

Costs associated with conducting the recommended geotechnical investigation and updating calculations is estimated to be approximately $20,000. Costs to mitigate floatation issues cannot be developed without additional information on the severity of the issue and an analysis of available alternatives.

5.1.2 Firestone Road Pump Station

The Firestone Road pump station is within the FEMA 100-year flood zone for precipitation-driven river flooding. Otherwise, access to the pump station may be impaired during extreme (100-year) coastal flooding at the end of the century based on CoSMoS flood mapping for 6.6 feet sea level rise (see **Figure 4**). MNS completed an evaluation of necessary improvements to reduce risks associated with flooding of the Firestone Road Pump Station.

The Firestone Road Pump Station is located within a FEMA 100-year floodplain with a Base Flood Elevation of 18 feet. It is anticipated sea level rise could further exacerbate future flood risk; an estimate of 2.5 feet of additional flood depth was used as a basis for the evaluation. The ground elevation at the pump station site is approximately 14 feet, resulting in a maximum flood depth elevation of 6.5 feet. The effects of future sea level rise and climate change on the extents of the 100-year fluvial flooding event were not examined in this study. We recommend that future lift station flood proofing design for fluvial flood resilience includes updated hydraulic modeling of the fluvial flood event in Goleta Slough basin for existing conditions and future sea level rise and climate change driven changes in precipitation.

The wall surrounding the pump station was not designed as a hydraulic structure, nor to resist hydraulic loading. A structural analysis of the existing wall demonstrated a flood condition in excess of 3 feet above grade could result in failure of the wall. Additionally, installation of a waterproof membrane or coating would be required to reduce stormwater entering the pump station site. Either replacement of the existing wall with a new more robust wall, or construction of a new, appropriately designed wall, surrounding the entire site should be considered. Additionally, there is an existing rolling gate at the front of the pump station to provide access withing the site, which does not provide any protection against flood waters. To address this issue, a hydraulic gate which automatically closes when exposed to flood waters is recommended. The proposed gate would need to be integrated into the existing wall, or new structure if constructed.

A total budget of approximately $500,000 is recommended for improvements to flood proof the Firestone Road pump station.

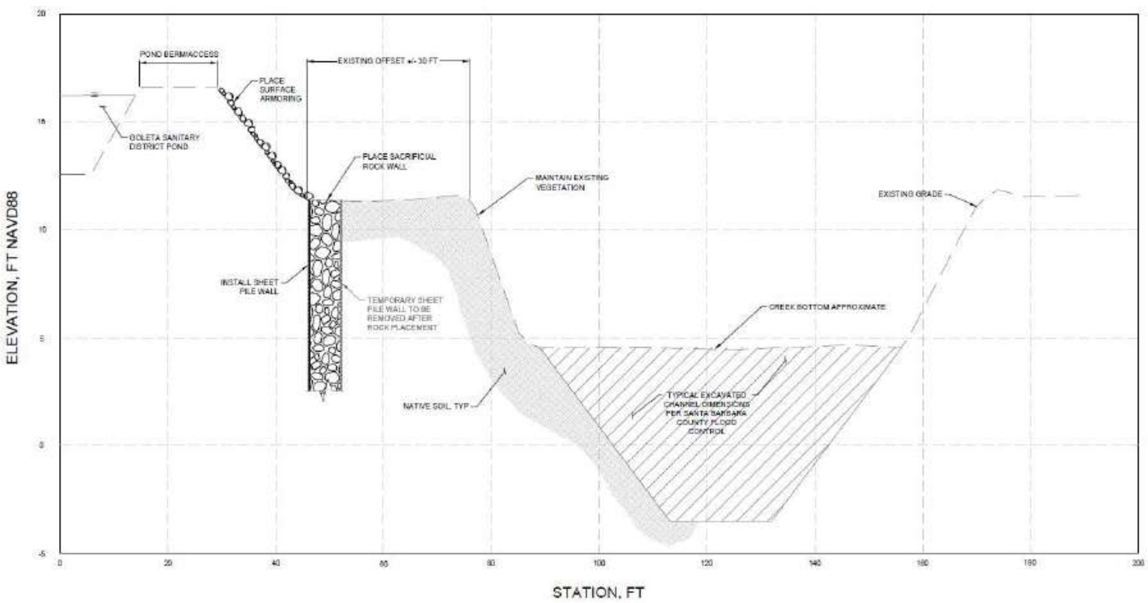
5.1.3 San Pedro Creek bank along District ponds

San Pedro Creek flows from north to south along the east boundary of District property. The Santa Barbara County Flood Control District regularly maintains this lower segment of the creek as a sedimentation basin by excavating accumulated sediment. Bank erosion along the District property has the potential to jeopardize the stability District pond berms adjacent to the creek. The District and ESA team discussed an option to reduce this vulnerability with concepts that include installing sheet piles along the outboard toe of the existing stabilization pond berms and protecting the face of the berms. ESA team developed two conceptual alternatives that build on those elements with varying impact footprints relative to the existing creek bank. Two conceptual creek bank stabilization alternatives are described below, including cross section schematics and opinions of probable cost.

Sacrificial Rock Wall Concept

In addition to armoring the outboard pond berm face and installing sheet pile wall along the toe of the berms, this concept utilizes a sacrificial rock wall that is buried in front of the sheet pile wall to be installed at the outboard toe of the pond berms. The concept has less impact to the existing creek bank in its construction methods and ultimate footprint, limiting work area to the top of the terrace between the pond berm and the creek bank. The sacrificial rock wall, when exposed by future creek bank erosion, would slump in place to provide additional erosion resistance and reduce scour at the face of the sheet pile wall. **Figure 5** shows a cross section schematic of this bank stabilization concept. A large format conceptual cross section and opinion of probable construction cost for the Sacrificial Rock Wall concept is provided in **Appendix F**.

A total budget of approximately $6.1 million is recommended for this alternative based on current material prices. This estimate includes 30% contingency on materials and labor for construction and an additional 30% markup on the construction cost for design, permitting and construction management and other project costs.



SOURCE: ESA

Goleta Sanitary District Climate Adaptation Plan

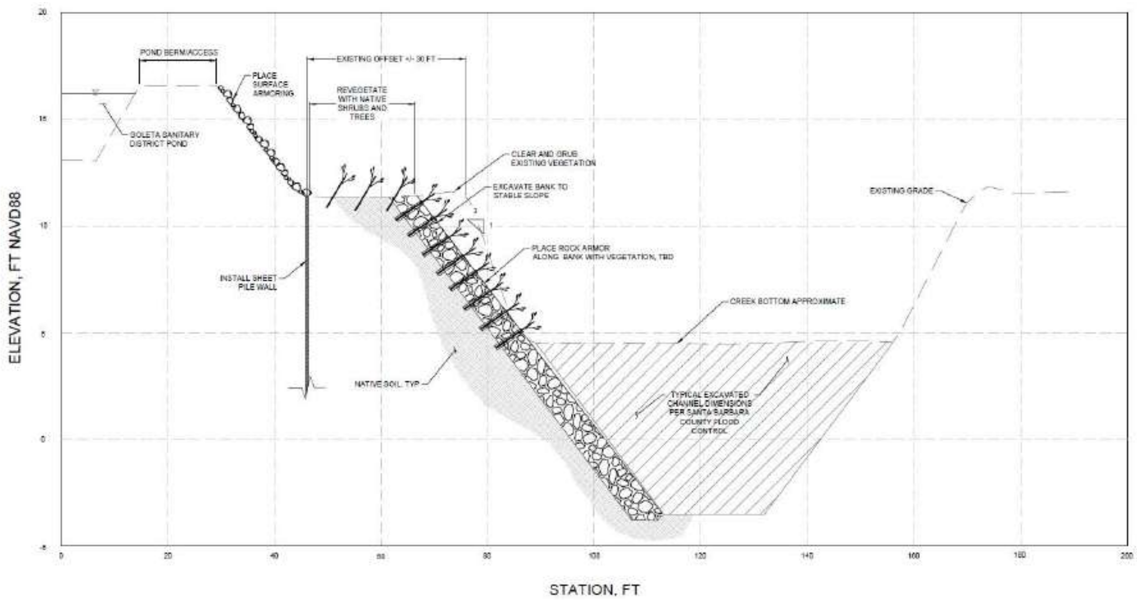
Figure 5
San Pedro Creek bank stabilization conceptual cross section: Sacrificial Rock Wall

Vegetated Rock Slope Protection Concept

In addition to armoring the outboard pond berm face and installing sheet pile wall along the toe of the berms, this concept utilizes vegetated rock slope protection constructed along the creek bank. The concept includes removing existing vegetation from the creek bank, grading the bank to a stable slope and exporting material, placing rock slope protection that is planted with willows and/or big salt brush and irrigated for 5 years during summer. **Figure 6** shows a cross section schematic of this bank stabilization concept. The lower limit of rock armoring on the creek bank is based on typical sediment removal dimensions shown in recent dredging drawings provided by

Santa Barbara County Flood Control (SBCFD 2019). A large format conceptual cross section and opinion of probable construction cost for the Vegetated Rock Slope Protection Concept is provided in **Appendix G**.

A total budget of approximately $4.4 million is recommended for this alternative based on current material prices. This estimate includes 30% contingency on materials and labor for construction and an additional 30% allowance for design, permitting and construction management.



SOURCE: ESA

Goleta Sanitary District Climate Adaptation Plan

Figure 6
San Pedro Creek bank stabilization conceptual cross section: Vegetated Rock Slope Protection

To better understand what vegetation species may be utilized in this concept, ESA assessed the existing conditions of the creek bank including vegetation makeup along the bank at District property and two nearby reference sites during a site visit on March 25, 2022. The existing creek bank vegetation along the District property includes the mousehole tree (*Myoporum laetum*, an invasive), quailbrush or big salt brush (*Atriplex lentiformis*), one non-native tuna cactus (*Opuntia ficus-indica*), and pickleweed (*Salicornia* sp.) at the bank toe. **Figure 7** shows photos taken along the creek bank adjacent to the District ponds. Note that the bank appears steep but was vegetated for the areas that could be accessed.

SOURCE: ESA

Goleta Sanitary District Climate Adaptation Plan

Figure 7
Field photos along San Pedro Creek Bank from March 25, 2022 site visit

Vegetation at two reference sites near the District property was assessed to determine whether willows are present in channels with apparently similar hydrologic conditions as the San Pedro Creek segment (tidally influenced with brackish waters). The two reference sites are summarized below.

- San Pedro Creek banks at S. Fairview Avenue and Olney Street: vegetation includes pickleweed, big saltbrush, coyote brush (*Baccharis pilularis*), Arroyo willow (*Salix lasiolepis*), black sage (*Salvia mellifera*).
- Atascadero Creek banks below the rock weir near the south end of Ward Drive: vegetation includes pickleweed, Arroyo willow, big saltbush

Since willows were observed at these two nearby reference sites, the arroyo willow species may be appropriate for the more extensive bank stabilization concept with vegetated rock armoring (**Figure 6**). Recent literature suggests that willows have some salt tolerance (Ferrus-Garcia et al. 2002; Hangs et al. 2011); however, we recommend further investigation of soil and water salinity at the District property and reference sites to determine the viability of willows. A combination of willows (for stabilization and visual barrier) and big saltbrush (for stabilization) may be an appropriate vegetation makeup for the vegetated rock slope protection element. If further study finds that soil and/or water conditions would not support willows, big saltbrush and other salt tolerant natives could be utilized for rock slope vegetation.

5.2 Adaptation Measures for Future Study

Other additional adaptation measures not analyzed in this study were identified based on the vulnerability assessment. Some of these adaptation measures are already considered within District maintenance efforts. These adaptation measures are summarized below to facilitate further study in the District's future planning efforts.

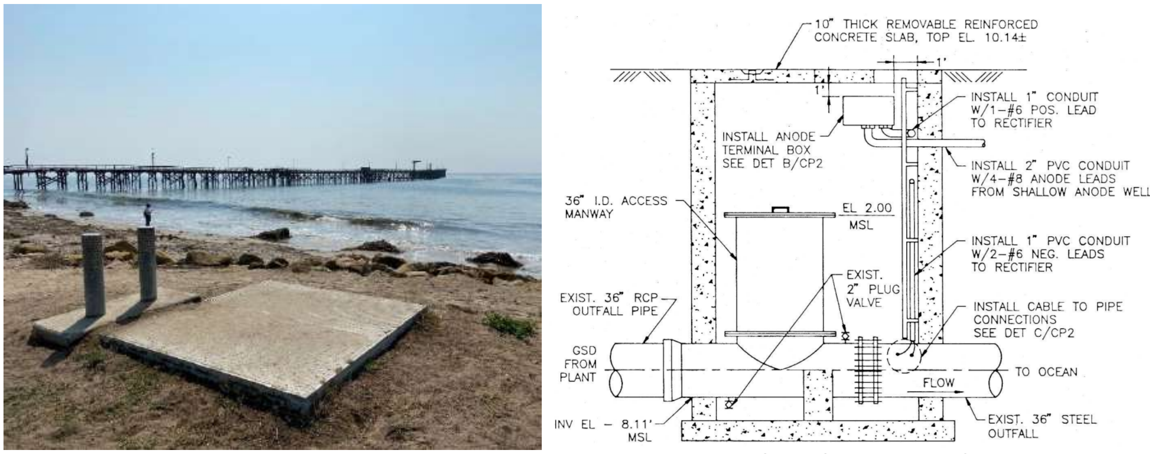
5.2.1 Collection System (Manholes, Pipes, Junctions)

Access structures in the District's collection system will experience increased I&I with sea level rise resulting from regular tidal inundation and groundwater emergence as well as storm flooding events. Potential adaptation strategies to limit I&I for at-grade access structures include sealing and/or raising the structures above grade depending on the location (e.g., raising in open areas versus sealing on roadways).

Some pipes in the District's collection system were recently lined (S. Wagner pers. Comm.); however, other aged pipes in future tidal inundation and groundwater emergence zones may experience increased I&I with future sea level rise. The District may prioritize upgrades to collection lines in areas exposed to tidal inundation and/or groundwater in the future in conjunction with ongoing maintenance and upgrades to the wastewater collection system.

5.2.2 Outfall Pipe Access Vault

The outfall pipe access vault at Goleta Beach (**Figure 8**) is subject to coastal storm wave run-up under existing conditions and may be exposed to coastal erosion by the end of this century based on USGS CoSMoS projections for 6.6 feet sea level rise. Recent impacts to the outfall have occurred resulting in repairs, suggesting that the outfall access vault and pipe may become exposed to coastal erosion and wave run-up sooner than indicated by CoSMoS projections. Potential adaptation strategies may include removing the access vault. The District currently has an initial adaptation plan to remove and/or abandon the maintenance vault when needed (S. Wagner, District, personal communication, June 1, 2021). The outfall pipe landward of the vault could be stabilized and protected by installing joint restraints and or armoring the pipe (e.g., with reinforced concrete or other armoring) to protect against potential erosive forces from waves with future sea level rise.



SOURCE: ESA, Brown & Caldwell

Goleta Sanitary District Climate Adaptation Plan

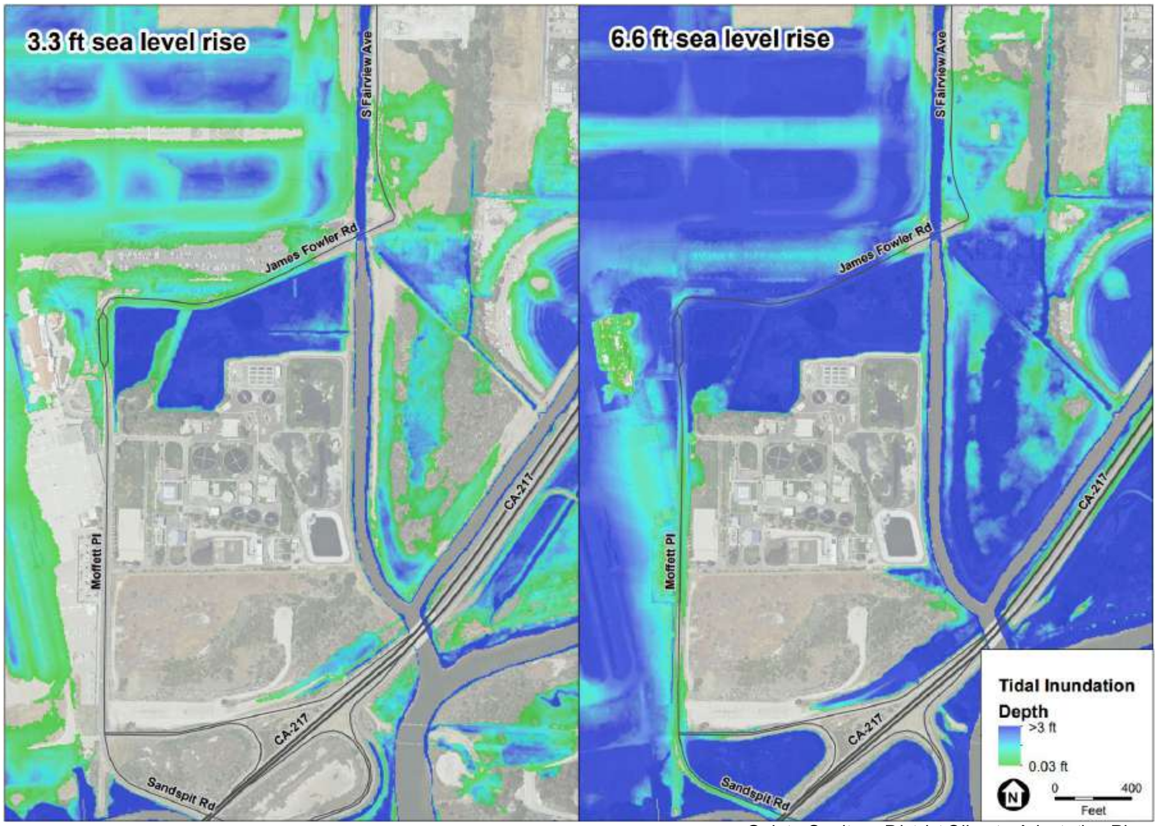
Figure 8
Beach Access Vault Photo (ESA 2021) and Cross Section (Brown and Caldwell 1994)

5.2.3 Austin Road Collection System

The District's collection system on the blufftop properties of Austin Road may become exposed to coastal erosion by mid to late century. Adaptation strategies for the District will depend on private residence strategies. No District action is needed if residences armor the bluff. If residences on the seaward side of Austin Road retreat, the sewer will need to remain in service to serve residences on the landward side of Austin Road. If the road is also rerouted, the sewer may need to be rerouted behind those residences through easements. Other utilities and roadway coordination will be needed as this neighborhood area adapts to sea level rise.

5.2.4 District WRRF Access Maintenance

Storm flooding in Goleta Slough may impair access to the District's WRRF for hours or days during an extreme event today based on USGS CoSMoS maps for coastal flooding and FEMA maps for fluvial flooding. Access to the WRRF is also impaired by estuarine flooding with 2.5 or more feet sea level rise. While sea level rise may lead to more extensive storm flooding events in the future, it will also lead to more frequent inundation of low-lying roadways during normal tidal conditions. **Figure 9** shows tidal inundation depths along Moffat Place and S James Fowler Road with 3.3 feet and 6.6 feet of sea level rise. Access to the WRRF may impaired by regular tidal inundation with 3.3 feet of sea level rise. James Fowler Road may flood 10 inches to 14 inches during regular high tides with 3.3 feet of sea level rise. Flood depth during regular high tides increases to 3.3 feet deep with 6.6 feet of sea level rise. South Fairview Avenue will similarly flood 2 inches to 1.6 feet during high tides with 3.3 feet to 6.6 feet of sea level rise, respectively. Sea level rise planning should be coordinated with City of Santa Barbara, City of Goleta, Santa Barbara Airport and Santa Barbara County on raising these roads above future tidal inundation levels at a minimum. This adaptation measure may be addressed in coordination with other adaptation in Goleta Slough (e.g., Santa Barbara Airport).



SOURCE: USGS, ESRI

Goleta Sanitary District Climate Adaptation Plan

Figure 9
Future tidal inundation of District WRRF access route along S Fairview Ave and Moffett Pl

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CHAPTER 6
Conclusions and Next Steps

The following sections summarize the conclusions of the vulnerability assessment (Chapter 4) and recommended next steps for the District regarding sea level rise adaptation planning and implementation (Chapter 5). Vulnerabilities are discussed in terms of existing conditions and future sea level rise considering the extreme risk aversion curve by OPC (2018) that projects 2.5 feet of sea level rise to occur around 2050 and 6.6 feet of sea level rise to occur around 2080.

6.1 Conclusions

The District WRRF is located on relatively high ground in the Goleta Slough Basin but some facilities around the WRRF are vulnerable to sea level rise and related flooding and erosion hazards. Findings are summarized below for each hazard category evaluated in this study.

Flooding from coastal, fluvial and estuarine sources will expose a number of sewer structures (manholes, inlets, etc.) under existing conditions and worsen with sea level rise. Floodwater seepage through unsealed manholes and other structures will lead to increased flow rates within the collection system, potentially beyond the capacity of the collection system to convey wastewater. This could result in sanitary sewer overflows (SSOs) and regulatory action against the District. Increased flows of wastewater to the WRRF can result in higher pumping and treatment costs. During coastal and estuarine flooding and tidal inundation exposure events, increased levels of chlorides and total dissolved solids (TDS) in WRRF influent flows could potentially impact the treatment process and quality of final effluent and recycled water.

Increased groundwater levels could result in impacts to the Districts treatment and storage facilities including clarifiers, treatment/storage ponds, below-grade reclaimed water storage tanks and chlorine contact tanks. If these facilities are not full, there is a potential risk of floatation that increases with sea level rise. Some facilities (clarifiers, ponds) already have pressure release valves on their bottoms to mitigate this flotation risk under existing conditions.

6.1.1 Coastal Hazards

Chronic **shoreline erosion** may impact the outfall maintenance vault at Goleta Beach and unrestrained outfall pipe landward of the vault before 2080, while extreme storm erosion events may expose the outfall vault and unrestrained pipe sooner. A failure of the existing unrestrained pipe segments landward of the maintenance vault would likely result in a substantial spill of treated wastewater at the point of joint separation. Minimal ability to divert treated wastewater flows and challenging repair conditions would likely cause a spill to extend over a significant duration.

Bluff top sewer infrastructure that runs along Austin Rd. is vulnerable to **bluff erosion** by 2050. While not examined in detail for this study, bank erosion along San Pedro Creek east of the District ponds has the potential to destabilize the perimeter berms of the pond.

Chronic **tidal inundation** from spring tides will inundate sewer structures and may complicate access to and maintenance of several sewer pipes by 2050 as tide levels rise around Goleta Slough. Similarly, structures in low lying areas around Goleta Slough and tributary creeks not already exposed to emergent **groundwater** may become exposed with higher sea levels while collection pipes, junctions and other underground features may be subjected to shallow groundwater levels. Tidal inundation also may limit access to the WRRF with 2.5 feet sea level rise and greater. Elevated groundwater levels around the recycled water storage tank and chlorine contact basin will lead to buoyancy risks with 6.6 feet of sea level rise and potentially sooner. Extreme **coastal flooding** from storm surge may expose 50 structures under existing conditions and over 100 structures by 2080. Coastal flooding may also impact access to the WRRF from the north under existing conditions and access to the Firestone Road lift station with 6.6 feet sea level rise. The Goleta Beach outfall maintenance vault and pipe are exposed to extreme coastal storm wave run-up under existing conditions and may experience impacts of increasing severity as sea level rises.

In summary, consequences from rising groundwater, tidal inundation and flooding hazards include increased I&I and related higher pumping and treatment costs as well as floatation issues for treatment and storage facilities and exposure to erosion.

6.1.2 Fluvial Flooding

Firestone Road Pump Station and 341 other GSD structures are vulnerable to flooding from the current 100-year fluvial extents mapped by FEMA. Flood seepage through unsealed manholes and other structures will lead to increased flow rates within the collection system, potentially beyond the capacity of the collection system to convey wastewater. This could result in SSOs and regulatory action against the District. Increased flows of wastewater to the WRRF can result in higher pumping and treatment costs. Access to Firestone Road lift station and the WRRF may be limited during extreme fluvial flooding events.

6.1.3 Estuarine Flooding

The Goleta Slough modeling for this study assumes the lagoon mouth is lowered on an emergency basis ahead of significant precipitation events. If the mouth isn’t breached, the extents of and impacts from estuarine flooding would be greater than reported in this study. Under existing conditions, four GSD structures are exposed to extreme estuarine flooding in Goleta Slough. The number increases to between 39 and 69 by 2080 depending on how the mouth is managed in the future with sea level rise.

6.2 Next Steps

The following next steps will support the District to increase its resilience to sea level rise and associated flooding and erosion hazards.

6.2.1 Groundwater monitoring

The District should consider establishing groundwater monitoring wells around the plant and coordinate with other agencies around the Goleta Slough basin to establish new or track existing groundwater monitoring wells. Groundwater level monitoring will enable the District to plan and respond to rising groundwater levels to prioritize collection line maintenance, plan and design for buoyancy adaptation at the recycled water underground storage tank, chlorine contact basin and other below-grade facilities at the plant.

6.2.2 Geotechnical investigation(s)

The District should consider conducting geotechnical investigation to support buoyancy risk assessment and adaptation at the recycled water underground storage tank and chlorine contact basin. A separate geotechnical investigation could be conducted to support a feasibility study of concepts for the San Pedro Creek bank stabilization that could identify trigger point and lead times for implementation and refine the concept for the sheet pile wall component of the stabilization concepts developed in this study.

6.2.3 Agency Coordination for Goleta Slough Adaptation

The District should consider coordinating adaptation planning for the Goleta Slough area with other agencies including UCSB, SB Airport, Goleta West Sanitary District. Coordination topics include:

- Sea level rise assessments and adaptation/maintenance planning for other districts sending effluent to the District treatment plant.
- Roadway adaptation to maintain resilient access to the District plant, Airport and general area.

6.2.4 Floodproofing Firestone Road Pump Station

The District may consider design and permitting for floodproofing for the Firestone Road Pump Station to increase resilience to existing fluvial flooding and future coastal flooding with sea level rise. We recommend that future lift station flood proofing design for fluvial flood resilience includes updated hydraulic modeling of the fluvial flood event in Goleta Slough basin for existing conditions and future sea level rise and climate change driven changes in precipitation.

6.2.5 Erosion Monitoring

The District should consider monitoring coastal erosion at Goleta Beach and blufftop adaptation at Austin Road as described below:

- Monitor shoreline erosion at the District outfall access vault to support adaptation triggers for erosion protection or removal of the access vault and potentially stabilization of the outfall segment landward of the vault.
- Coordinate with Austin Road blufftop property owners regarding adaptation actions for bluff erosion. Wastewater collection infrastructure may need to be reconfigured if blufftop properties undergo managed retreat.

6.2.6 San Pedro Creek Bank Stabilization Feasibility Study

The next step to assess options for creek bank stabilization at San Pedro Creek along the District ponds is to conduct a feasibility assessment that may include a detailed biologic and topographic survey, hydraulic modeling of creek flood flows, and geotechnical investigation of the creek bank and pond berm stability.

CHAPTER 7
Acknowledgements

This report was prepared by:

James Jackson, PE (ESA)
Nathan DeRopp, EIT (ESA)
Amber Inggs, PE (ESA)
Nick Garrity, PE (ESA)
Nick Panofsky, PE (MNS)

Key contributions were made by:

Laura Romano DeFazio (District)
John Crisman (District)
Luis Astorga (District)
Steve Wagner (District)

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CHAPTER 8
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Appendix A

Goleta Slough Quantified Conceptual Modeling Memorandum

770 Paseo Camarillo
Suite 310
Camarillo, CA 93010
805.914.1500 phone
805.914.1501 fax
esassoc.com

Goleta Sanitary District Climate Adaptation Plan

Appendix A: Goleta Slough Quantified Conceptual Model

date	September 3, 2021
to	Project File
from	D. Behrens, PhD PE; Yashar Rafati, PhD
subject	QCM Modeling of the Goleta Slough Lagoon for Goleta Sanitary District Climate Adaptation Plan

This memorandum describes the quantified conceptual model used to estimate extreme water levels in Goleta Slough and results. The QCM model was run for existing and future sea level rise scenarios for the Goleta Sanitary District Climate Adaptation Plan.

1. QCM Model description and simulation cases

The Quantified Conceptual Model (QCM) was proposed as a simple framework predicting the long-term evolution of lagoon mouth and lagoon water levels (Behrens et al. 2015). This framework uses empirical data and simple parameterizations to quantify the hydrology of lagoon, coastal influences to the beach, and hydraulics of the mouth. Here, we used QCM for an 8-year simulation of Goleta Slough Lagoon considering existing conditions, as well as mid-century (2.5 feet) and late-century (6.6 feet) sea level rise scenarios (see Table 1). Due to the existing measures in lagoon management at Goleta Slough the lagoon thalweg elevation is limited to 9 feet above NAVD88 implemented by regular breaching of the lagoon. One of the challenges that we anticipated in the lagoon management under sea level rise was the cost of keeping up with the same limit of thalweg elevation. Therefore, adaptive breaching of the lagoon to the projected sea level rise was also considered in this study. Here, simulations of sea level rise scenarios are performed by assuming existing breaching (thalweg elevation limited to 9 feet above NAVD88) and adaptive breaching (thalweg elevation limited to 9 feet above NAVD88 + SLR).

Table 1: Quantified Conceptual Model simulation cases

Case	SLR	Breaching
1	0 feet (existing)	Existing
2	2.5 feet	Existing
3	6.6 feet	Existing
4	2.5 feet	Adaptive
5	6.6 feet	Adaptive

2. QCM Model results

Lagoon hydrology and morphology at Goleta Slough were simulated for 8 years using lagoon water level data previously provided to ESA and nearshore wave conditions (10 m water depth) provided by CDIP from 2010 to 2018. Figures 1 through 5 show the simulation results of cases 1 through 5 (see Table 1). The lowest and highest levels of ocean tides, and simulated lagoon water levels and thalweg elevations are reported in Table 2.

Case 1 is intended to be a hindcast of observations in the lagoon to understand the sensitivity of the lagoon to coastal and fluvial conditions, and to provide an understanding of the level of uncertainty in model predictions. The model hindcast for this period is described more extensively in prior work by ESA PWA (2015). Generally, the model captures the seasonality of mouth closure behavior and seasonal water levels caused by transitions between mouth open and closed periods, although at the daily or hourly scale, it does not capture all events. For Case 1 (0 feet SLR, existing breaching, Figure 1) the model predicts five long-term (order of several months to a few years) mouth closure events, which aligns with measurements of lagoon water levels. Interestingly, for this case the highest lagoon water levels and thalweg elevations occur at the end of closure events right before the onset of the breaching events. This is not uncommon in coastal lagoons in California, and results from the fact that the beach is typically highest after several months of mouth closure, meaning that the highest water levels that are often observed occur at the time that the lagoon has filled sufficiently with trapped freshwater input behind the closed beach to the level that it can overtop the beach and erode a new mouth.

The remaining cases, involving sea-level rise, reflect the two major competing effects of rising ocean tides over time due to sea level rise:

1) **Delayed closure events**: As tide levels rise, accretion in the lagoon may offset some sea-level rise, but is not likely to keep pace with accelerated late-century rates (Thorne et al. 2021), meaning that tidal marsh areas would eventually become part of the tidal prism (the intertidal volume that moves through the lagoon mouth on every tidal cycle). This greater prism means that the mouth will have faster currents, delaying the onset of seasonal closure events.

2) **Delayed breach events:** The beach berm is expected to shift vertically at the same pace as sea level rise. Since accretion in the lagoon is not expected to keep pace, this means that the lagoon will have a larger volume behind the beach, so freshwater inflows will take longer to fill the lagoon to breaching elevations. This could allow the beach more time to build, potentially further prolonging closure events.

For Case 2 (2.5 feet SLR, existing breaching, Figure 2) two long-term mouth closure events are predicted between late 2012 and early 2014 and between early 2015 and late 2015, which are concurrent with the closure events of Case 1 (Figure 1). Comparison of Case 1 (0 feet SLR) and Case 2 (2.5 feet SLR) shows that the lagoon water levels and thalweg heights are higher in Case 2 which indicates that lagoon adapts itself with SLR of 2.5 feet based on the model results. Interestingly, results of 6.6 feet SLR (Case 3) predicts the lagoon to be open during the entire simulation interval based on the existing breaching (thalweg elevation limited to 9 feet above NAVD 88) with the tidal elevations having the highest levels compared with the lagoon water levels and thalweg elevations. Moreover, for this case the peak values of lagoon water levels (13.4 feet above NAVD88) are close to those of ocean tides (14 feet above NAVD88) indicating that lagoon water levels increase with sea level rise.

In the case of adaptive breaching under 2.5 feet SLR (Case 4, Figure 4), three long-term mouth closure events were predicted by the model, where the first closure is concurrent with the closure predicted for Case 2 (between late

2012 and early 2014). As expected the maximum thalweg elevation for adaptive breaching Case 4 (11.05 feet above NAVD88) was higher than the value predicted for existing breaching Case 2 (9 feet above NAVD88). Furthermore, in Case 4 the lagoon water levels peak higher than 10 feet above NAVD at the onset of breaching events where lagoon water levels are mainly below 10 feet in Case 2. However, model prediction of maximum lagoon water levels are very close for Case 2 and Case 4 (11.15-11.2 above NAVD88). Comparison of the existing and adaptive breaching strategies under 2.5 feet SLR (Cases 2 and 4) further indicates that the adaptive breaching might be more cost-effective since the lagoon water levels are in similar ranges (peaks mainly between 8 and 10 feet above NAVD88) for both cases. Model results found to have a higher sensitivity to the breaching strategies under 6.6 feet SLR (compare Figure 3 and Figure 5). For adaptive breaching under 6.6 feet SLR (Case 5, Figure 5) model predicts a five-year mouth closure event between 2012 and 2017 which was not predicted for existing breaching (Case 3, Figure 3). Accordingly, the maximum thalweg elevation for the adaptive breaching (Figure 5) was calculated as 15.2 feet above NAVD88 which is significantly higher than the maximum thalweg elevation of 9 feet for existing breaching (Figure 3) under 6.6 feet SLR. The maximum lagoon water level under 6.6 SLR with adaptive breaching (Figure 5) was predicted as 15.2 feet above NAVD88 occurring at the end of the 5-year closure event which is higher than the maximum lagoon water level predicted for existing breaching as 13.4 feet above NAVD88 (Figure 3). For these cases model results further indicate that lagoon mouth opening can mitigate the lagoon flood level as differences between the level of ocean tides and lagoon water levels are significantly higher with adaptive breaching during the mouth closure (up to about 7.6 feet between 2012 and 2017, Figure 5) compared to those with existing breaching during the mouth opening (up to about 2.5 feet between 2012 and 2015, Figure 3).

Table 2: Ranges of modeled lagoon water levels and thalweg elevations (feet NAVD88)

Case	SLR	Breaching	Ocean Tides	Modeled Lagoon Water Levels	Modeled Thalweg Elevations
1	0 feet (existing)	Existing	-2.7 – 7.4	0.95 – 10.1	1.0 – 8.6
2	2.5 feet	Existing	0.1 – 9.9	3.5 – 11.2	3.5 – 9
3	6.6 feet	Existing	4.2 – 14.0	8.4 – 13.4	7.6 – 9
4	2.5 feet	Adaptive	0.1 – 9.9	3.5 – 11.2	3.5 – 11.0
5	6.6 feet	Adaptive	4.2 – 14.0	5.5 – 15.2	7.6 – 15.2

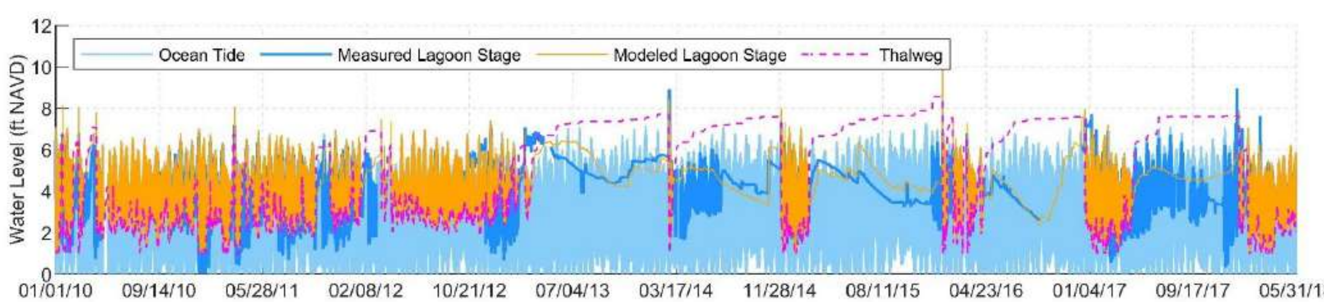

Figure 1: QCM model results of Case 1 (0 feet SLR, existing breaching)

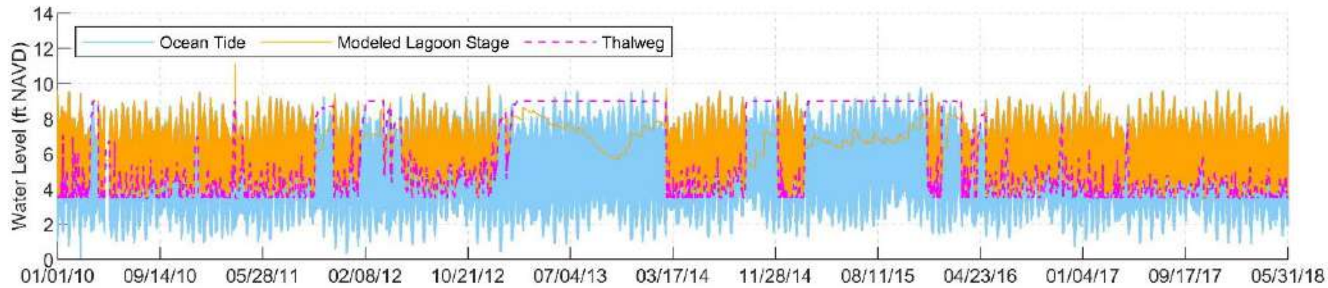

Figure 2: QCM model results of Case 2 (2.5 feet SLR, existing breaching)

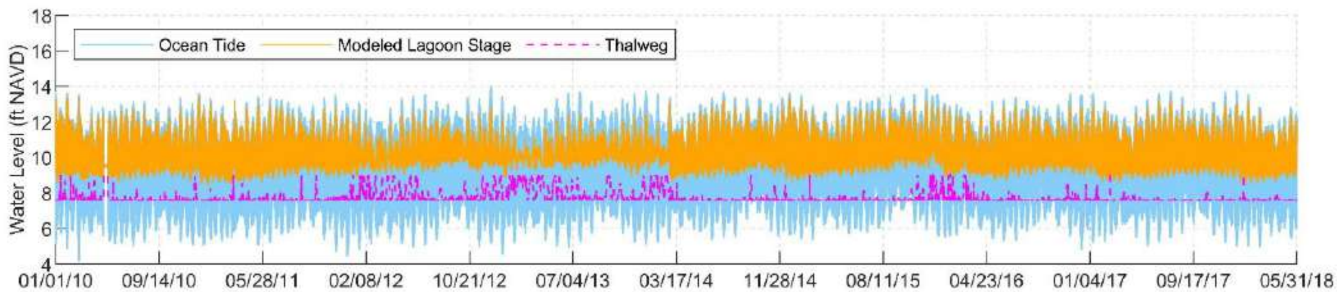

Figure 3: QCM model results of Case 3 (6.6 feet SLR, existing breaching)

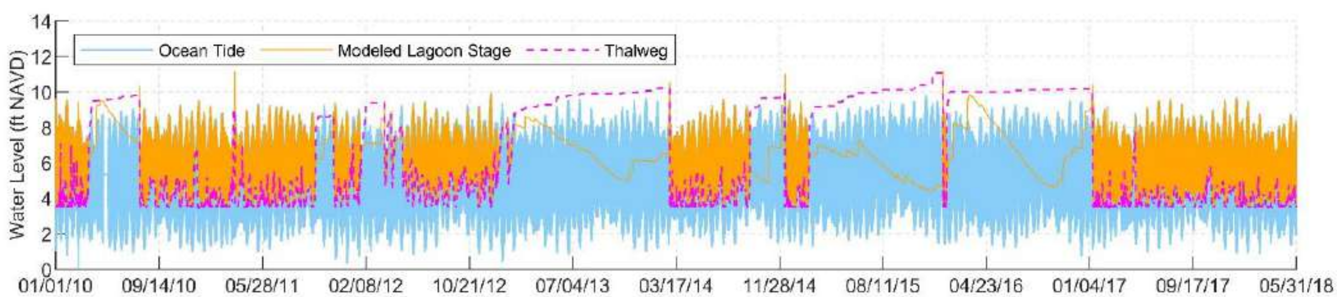

Figure 4: QCM model results of Case 4 (2.5 feet SLR, adaptive breaching)

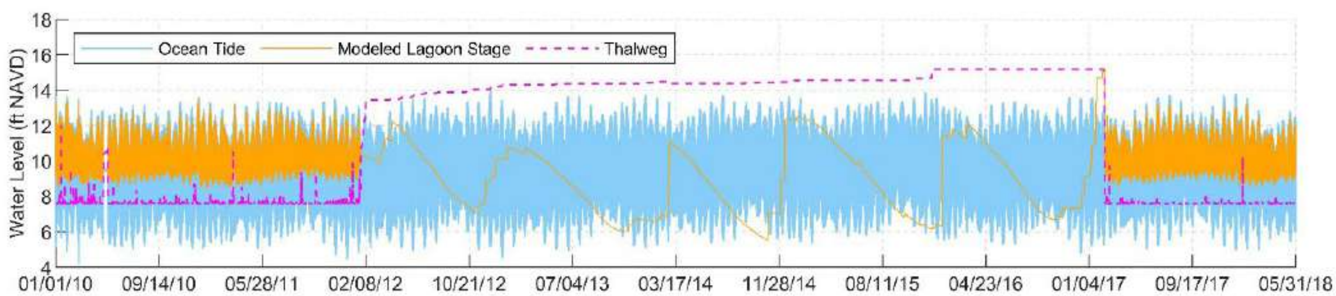

Figure 5: QCM model results of Case 5 (6.6 feet SLR, adaptive breaching)

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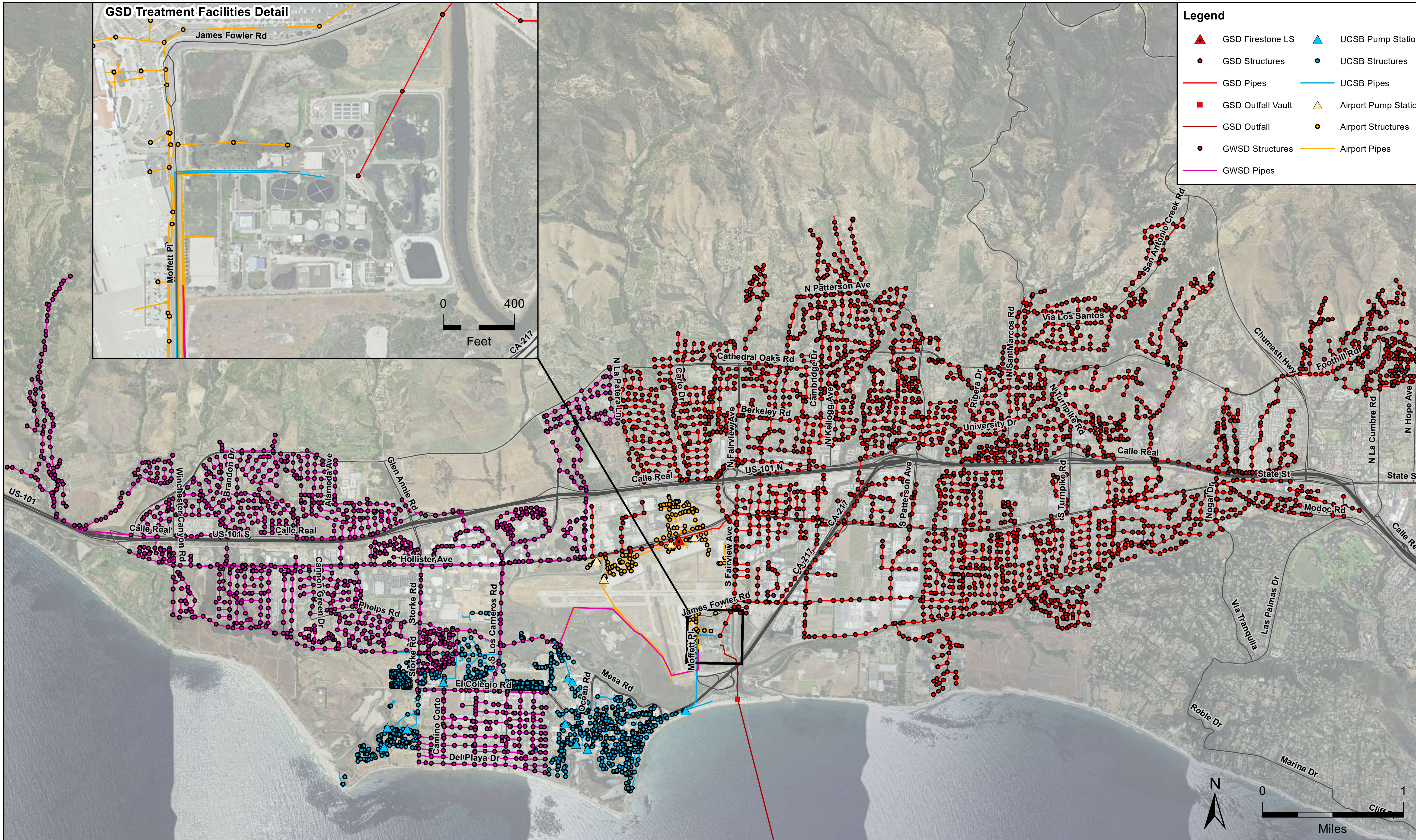
Appendix B
Wastewater Assets Map



SOURCE: ESA/SB County, USGS, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

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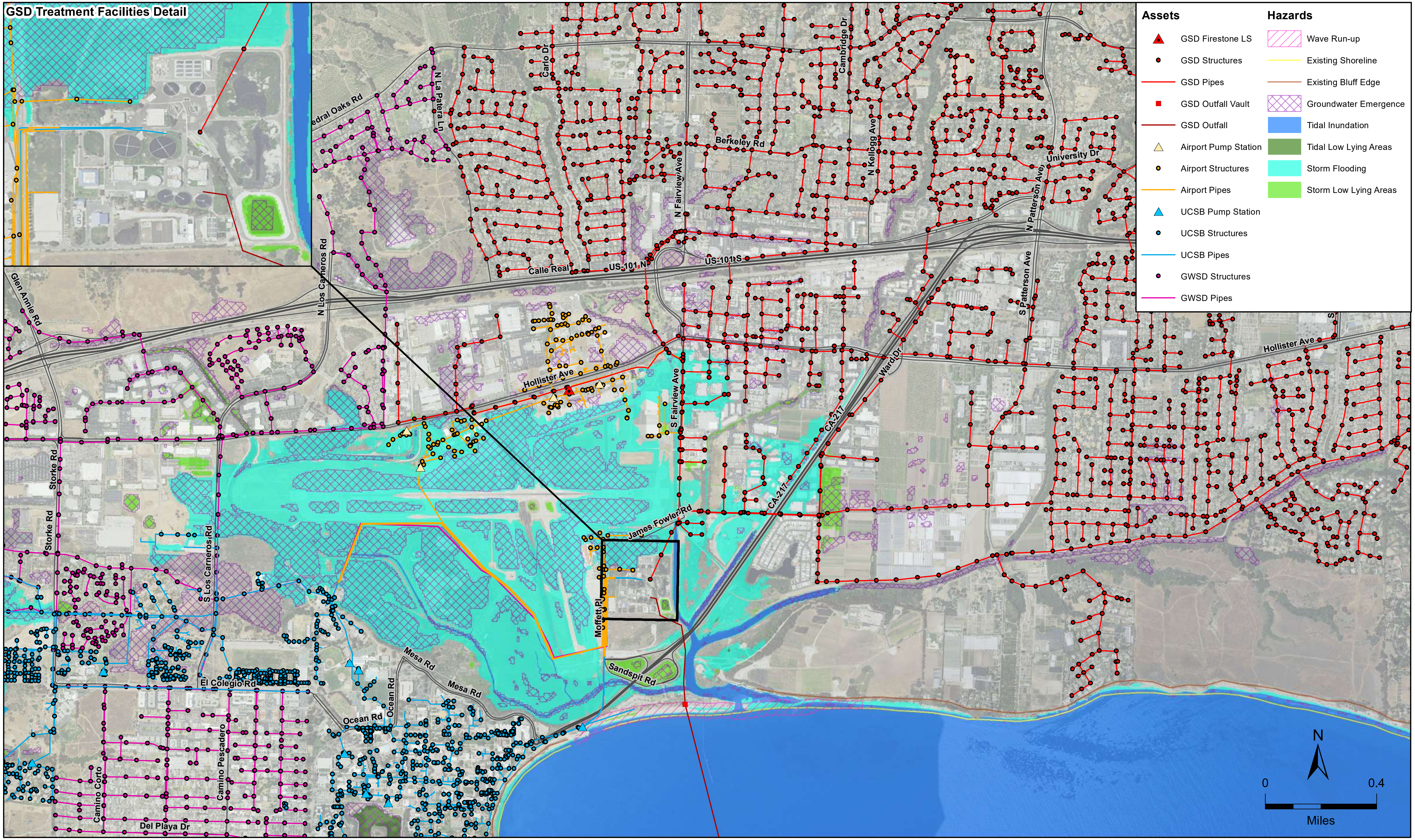
Figure B1

Existing Assets Map

Appendix C
Coastal Hazards Asset Exposure Maps

ESA



SOURCE: ESA/SB County, USGS, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

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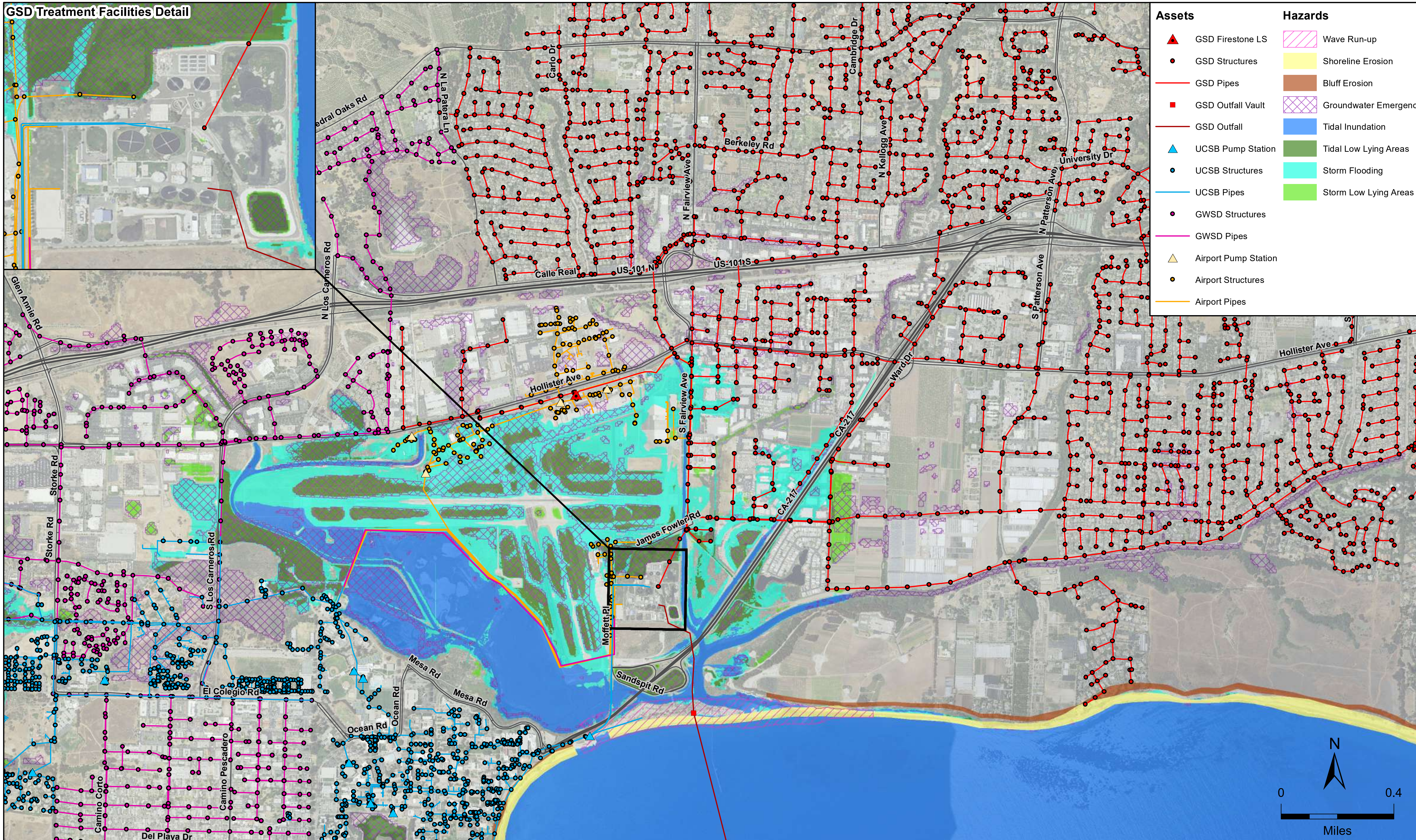
Figure C1

Coastal Hazard Exposure Map (Existing Conditions, 0 ft Sea Level Rise)



SOURCE: ESA/SB County, USGS, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

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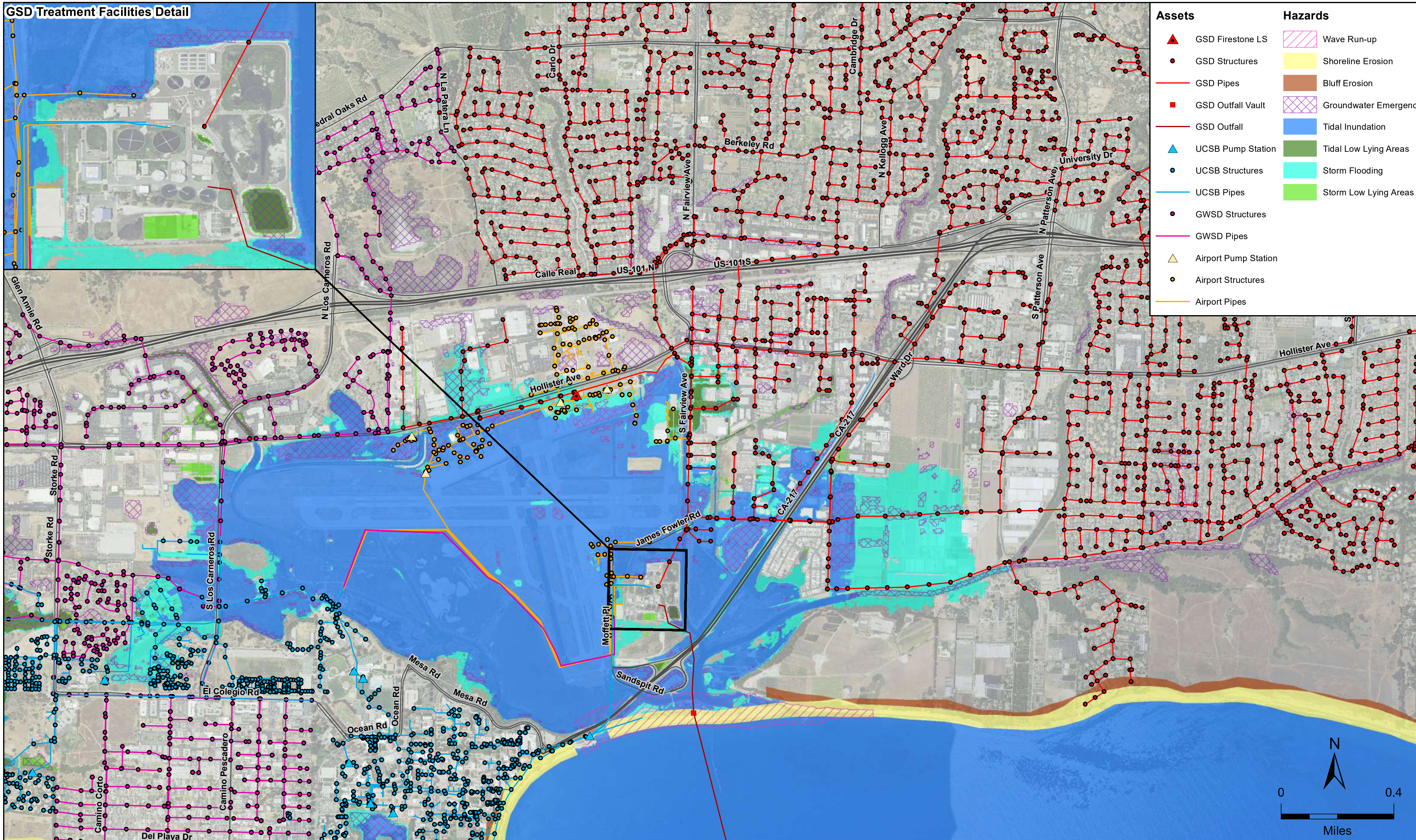
Figure C2

Coastal Hazard Exposure Map (2.5 ft Sea Level Rrise)



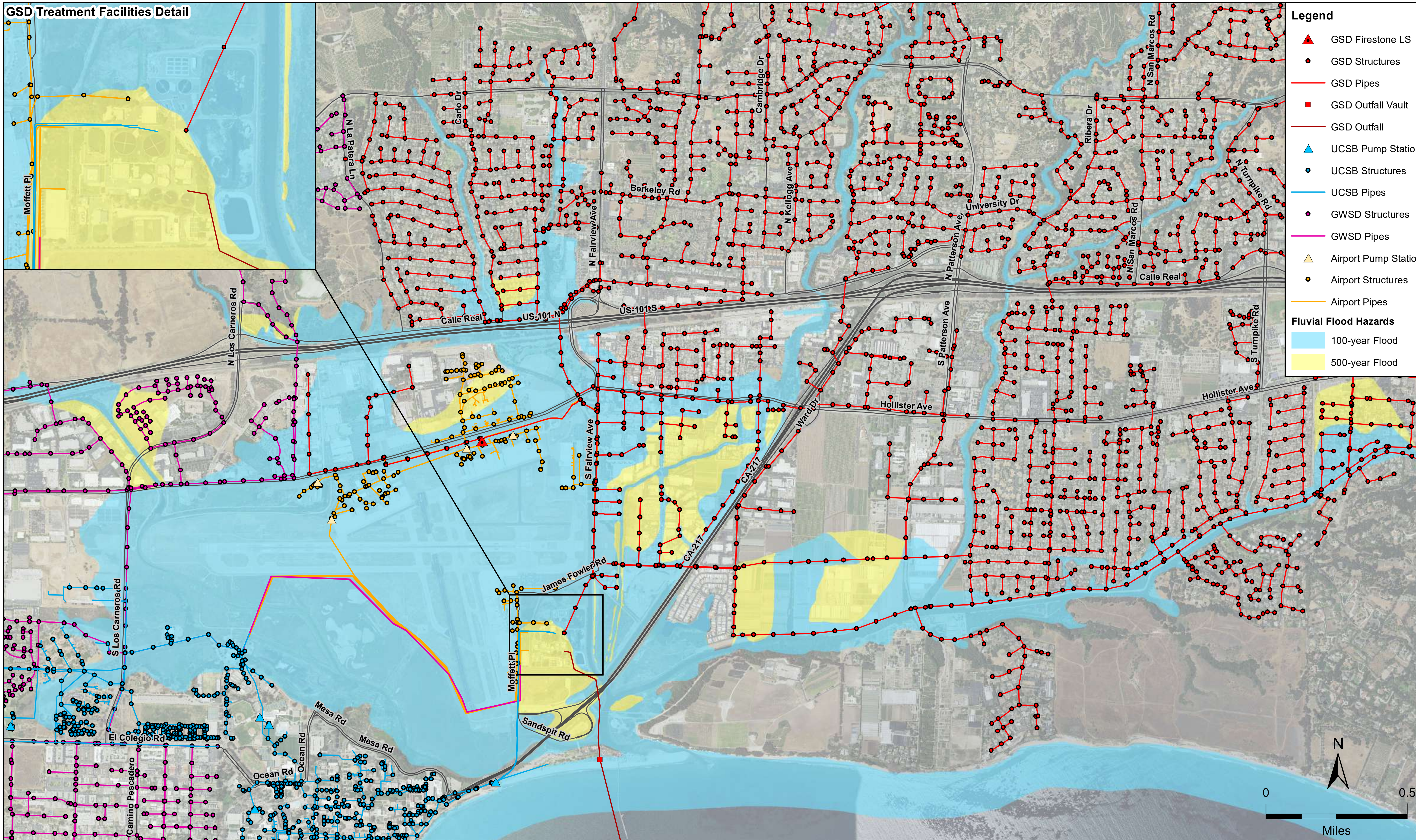
SOURCE: ESA/SB County, USGS, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

Goleta Sanitary District Climate Adaptation Plan . D202100303.00

Figure C3

Coastal Hazard Exposure Map (6.6 ft Sea Level Rise)

Appendix D
Fluvial Flooding Asset Exposure Map



SOURCE: FEMA, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

Goleta Sanitary District Climate Adaptation Plan . D202100303.00

Figure D1

Fluvial Flood Hazard Exposure Map - Existing Conditions

Appendix E

Estuarine Flooding Asset Exposure Map

ESA

SOURCE: ESA, NAIP, GSD, Santa Barbara Airport, UCSB, GWSD

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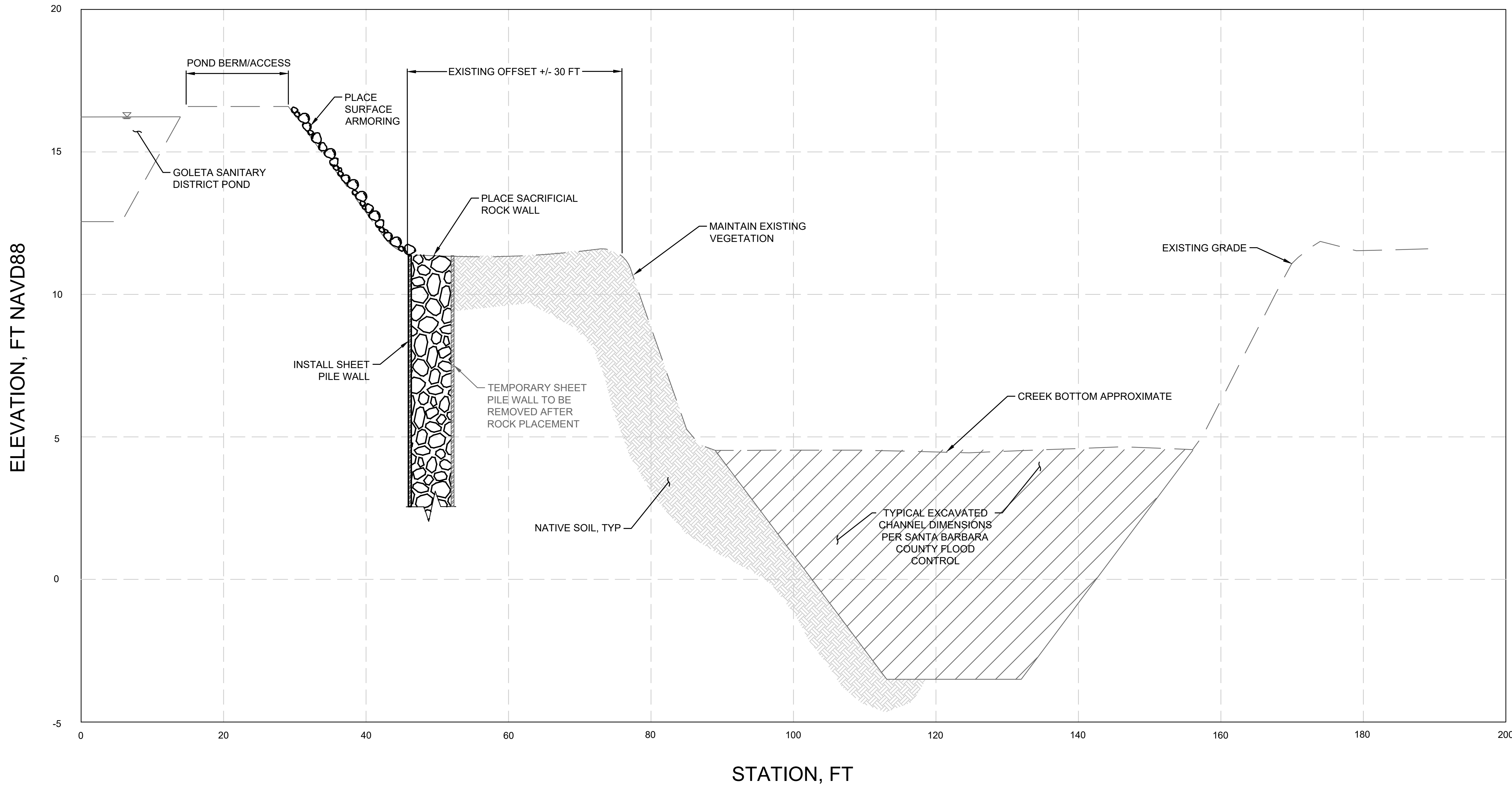
Figure E1

Estuarine Flooding Hazard Exposure Map

Appendix F

San Pedro Creek Bank Stabilization Concept 1: Sacrificial Rock Wall

ESA



NOT TO SCALE

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Goleta Sanitary District Climate Adaptation Plan . D202100303.00

ESA

Figure F
San Pedro Creek Bank Stabilization
Sacrificial Rock Wall Concept

OPINION OF PROBABLE CONSTRUCTION COST

Project: Goleta Sanitary District Climate Adaptation Plan

Prepared By/Checked By: NAB/NEP

Date Prepared: 4/1/2022

Facility: San Pedro Creek Bank Stabilization - Rock Wall Protection

MNS Proj. No. GOLSD.210163

Estimate Type:

- [x] Conceptual
- [ ] Preliminary (w/o plans)
- [ ] Design Development @
- [ ] Construction
- [ ] Change Order

_______ % complete

Item No.	Description	Qty.	Units	Materials $/Unit	Materials Total	Installation $/Unit	Installation Total	Sub-Contractor $/Unit	Sub-Contractor Total	Total
1	Mobilization/Demobilization	1	LS	$0	$0	$150,000	$150,000			$150,000
2	Access Road Improvements	1	LS	$25,000	$25,000	$25,000	$25,000			$50,000
3	Clear and Grub Vegetation	1,160	LF	$25	$29,000	$25	$29,000			$58,000
4	Rock Armor Surface Stabilization, 6" Thickness, Top of Bank (B)	430	CY	$45	$19,350	$40	$17,200			$36,550
5	Sheet Pile Wall, 20' Depth (C)	46,400	SF	$36	$1,670,400	$21	$974,400			$2,644,800
6	Excavate, Dry, Transport, Dispose of Bank Material, Between Sheet Piles	1,718	CY	$20	$34,360	$25	$42,950			$77,310
7	Rock Wall Stabilization (A)	1,718	CY	$42	$72,156	$20	$34,360			$106,516
	Subtotals				$1,850,266		$1,272,910		$0	$3,123,176
	Division 1 Costs	@	2.00%		$37,005		$25,458		$0	$62,464
	Subtotals				$1,887,271		$1,298,368		$0	$3,185,640
	Taxes - Materials Costs	@	7.75%		$143,396					$143,396
	Subtotals				$2,030,667		$1,298,368		$0	$3,329,035
	Contractor OH&P	@	15.00%		$277,540				$0	$277,540
	Subtotals				$2,308,207		$1,298,368		$0	$3,606,575
	Estimate Contingency	@	30.00%							$1,081,973
	Subtotals									$4,688,548
	Total Estimate									**$4,690,000**

(A) Caltrans 60 Pound Class II Rock. 2' Thickness.

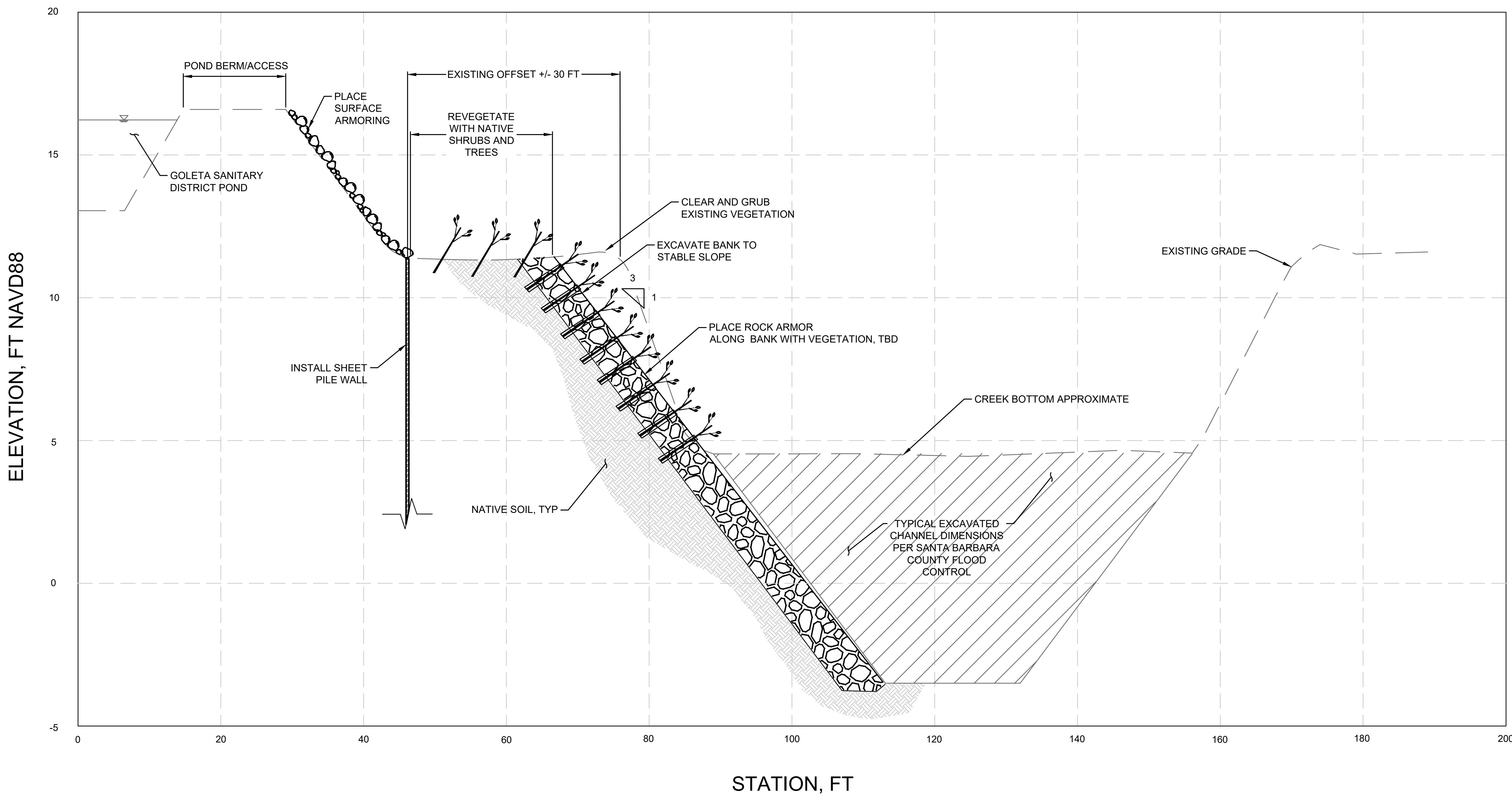
(B) Caltrans 10 Pound Class II Rock. 6" Thickness.

(C) Type Nucor NZ 19 Sheeting

Appendix G

San Pedro Creek Bank Stabilization Concept 2: Vegetated Rock Slope Protection

ESA



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Goleta Sanitary District Climate Adaptation Plan . D202100303.00

ESA

Figure G
San Pedro Creek Bank Stabilization
Vegetated Rock Slope Protection Concept

OPINION OF PROBABLE CONSTRUCTION COST

MNS ENGINEERS INC

Project: Goleta Sanitary District Climate Adaptation Plan

Prepared By/Checked By: NAB/NEP

Date Prepared: 4/1/2022

Facility: San Pedro Creek Bank Stabilization - Rock Slope Protection

MNS Proj. No. GOLSD.210163

Estimate Type:

- [x] Conceptual
- [ ] Preliminary (w/o plans)
- [ ] Design Development @
- [ ] Construction
- [ ] Change Order

_______ % complete

Item No.	Description	Qty.	Units	Materials $/Unit	Materials Total	Installation $/Unit	Installation Total	Sub-Contractor $/Unit	Sub-Contractor Total	Total
1	Mobilization/Demobilization	1	LS	$0	$0	$150,000	$150,000			$150,000
2	Access Road Improvements	1	LS	$25,000	$25,000	$25,000	$25,000			$50,000
3	Clear and Grub Vegetation	1,160	LF	$50	$58,000	$100	$116,000			$174,000
4	Rock Armor Surface Stabilization, 6" Thickness, Top of Bank (B)	430	CY	$45	$19,350	$40	$17,200			$36,550
5	Sheet Pile Wall, 20' Depth (F)	23,200	SF	$36	$835,200	$21	$487,200			$1,322,400
6	Excavate, Dry, Transport and Dispose of Bank Material, Toe of Bank	4,468	CY	$20	$89,360	$25	$111,700			$201,060
7	Rock Armor Surface Stabilization, Toe of Bank (A)	4,468	CY	$42	$187,656	$25	$111,700			$299,356
8	Vegetated Errosion Control (C)	1	LS	$20,000	$20,000	$25,000	$25,000			$45,000
9	Irrigation System and Irrigation System Maintenance (D)	1	LS	$40,000	$40,000	$45,000	$45,000			$85,000
	Subtotals				$1,234,566		$1,043,800		$0	$2,278,366
	Division 1 Costs	@	2.00%		$24,691		$20,876		$0	$45,567
	Subtotals				$1,259,257		$1,064,676		$0	$2,323,933
	Taxes - Materials Costs	@	7.75%		$95,679					$95,679
	Subtotals				$1,354,936		$1,064,676		$0	$2,419,612
	Contractor OH&P	@	15.00%		$185,185				$0	$185,185
	Subtotals				$1,540,121		$1,064,676		$0	$2,604,797
	Estimate Contingency	@	30.00%							$781,439
	Subtotals									$3,386,236
	Total Estimate									**$3,390,000**

(A) Caltrans 60 Pound Class II Rock. 2' Thickness.

(B) Caltrans 10 Pound Class II Rock. 6" Thickness.

(C) Willows, Pole Planting, 4' On Center, 1500 Willow Poles

(D) Temporary Irrigation System, 5 Year Duration Operating During Summers

(E) 5 Year Maintenance Duration, Does Not Include Water Cost

(F) Type Nucor NZ 19 Sheeting