NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

PHASE II SITE EVALUATIONS • JUNE 2023

- Central Contra Costa Sanitary District
- Delta Diablo
- Fairfield Suisun Sewer District
- Novato Sanitary District
- Sewerage Agency of Southern Marin
- San Jose/Santa Clara, Cities of
- South San Francisco/San Bruno, Cities of
- Union Sanitary District

BACWA
BAY AREA CLEAN WATER AGENCIES

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NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: CENTRAL SAN

BACWA BAY AREA CLEAN WATER AGENCIES

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PREPARED BY
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PREPARED FOR
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All photos in this document courtesy of the authors.

INTRODUCTION

The first phase of analysis (Phase I) of the Nature-Based Solutions for Nutrient Reduction study involved a regional-scale desktop analysis to determine which Bay Area water resource recovery facilities (WRRFs) have opportunities for implementing nature-based solutions (NbS) for nutrient reduction. In this phase (Phase II), we conducted outreach with a select group of facilities with medium to high potential for NbS, including conducting site visits and discussing opportunities and constraints with agency staff. This phase also involved additional site-scale research and analysis to refine opportunities and constraints identified at each facility. In Phase III of this study, we will narrow down to a smaller set of facilities to develop planning-level designs to enable cost estimation, identify regulatory and land use conflicts, and establish feasibility for agency-led planning.

Central Contra Costa Sanitary District (Central San) Wastewater Treatment Plant (Figures 1, 2) was one of the facilities identified as a medium-potential site for NbS. The desktop analysis identified opportunities for open water treatment wetlands in various basins and undeveloped parcels near the site and opportunities for horizontal levees along lower Walnut Creek. Initial conversations with staff at Central San refined the initial set of opportunities to two main areas for discussion: (1) potential future conversion of holding basins on the wastewater treatment plant site for dual storage/treatment use, and (2) a potential future partnership with the Lower Walnut Creek Restoration Project.

Central San was created in 1946 and currently serves almost half a million residents of Contra Costa County. The current Central San Wastewater Treatment Plant, located at 5019 Imhoff Place in Martinez, opened in 1948 and has undergone several upgrades since then. The plant's permitted capacity is 53.84 million gallons per day (mgd), with average dry weather flows of about 30 mgd and wet weather flows that can exceed 200 mgd. Treated wastewater is discharged via an outfall pipeline to Suisun Bay.

The plant recycles an annual average of 1.5 mgd, with recycled water used at the facility itself, by over 50 customer sites in nearby cities and through commercial truck fill and residential fill programs. The addition of a nitrification step is required before the implementation of NbS at Central San. Future modifications to Central San's treatment processes (e.g., advanced recycled water project opportunities and different solids handling facilities) may create sidestreams better suited for NbS than the current high volume of non-nitrified secondary effluent.

Figure 1. Site location in context

Figure 2. Site detail

SITE OVERVIEW

ECOLOGY

Historically, the tidal marsh extended inland to the Central San wastewater treatment plant and covered much of the plant footprint, including most of the storage basins (Figure 3). A perennial freshwater wetland complex was found adjacent to the tidal marsh near today's Buchanan Field Airport southwest of the Central San plant.[1] The landscape has been highly modified from its historical conditions (Figure 4). The Army Corps of Engineers constructed the trapezoidal flood control channels that Grayson and Walnut Creeks flow through in 1965 to alleviate flooding, but the lower reaches quickly started to fill with sediment. To support the persistence of existing tidal marsh species, the Lower Walnut Creek Restoration Vision recommends enhancing wildlife corridors and protecting and restoring transition zones.

Compared to historical conditions, marsh complexes adjacent to Walnut Creek receive significantly reduced freshwater input. As a result, Strategy 3 of the *Resilient Landscape Vision for Lower Walnut Creek* report suggests taking advantage of treated wastewater from Central San to create salinity gradients and maximize peat accumulation in the baylands while protecting water quality and minimizing nutrient loads. Especially given the elimination of freshwater wetlands in the Lower Walnut Creek watershed, using treated wastewater to recreate these habitats (either as freshwater wetlands or seepage slopes) could provide significant ecological benefits.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

The Central San treatment plant is located adjacent to Walnut Creek in an industrial part of Martinez near two refineries. Proximity to the nearby Buchanan Field Airport (Figure 5) means any new treatment wetlands in the site's southern portion must ensure compliance with runway safety zones due to bird strike risk. An electric transmission line runs through the site, as do several gas and petroleum pipelines.

The treatment plant is near State Route 4. There are few parks in the immediate vicinity, though recent restorations completed by the Lower Walnut Creek restoration project and an upcoming public access improvement project, led by the John Muir Trust, include public trails (north of the area shown in Figure 5).

There are not any SB535 Disadvantaged Communities nor Metropolitan Transportation Commission (MTC) Equity Priority Communities near the plant.[2,3] However, the Central San service area includes designated Disadvantaged Communities and Equity Priority Communities in and around Martinez and Concord.

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1. San Francisco Estuary Institute-Aquatic Science Center. 2016. Resilient Landscape Vision for Lower Walnut Creek: Baseline Information & Management Strategies. A SFEI-ASC Resilient Landscape Program report developed in cooperation with the Flood Control 2.0 Regional Science Advisors and Contra Costa County Flood Control and Water Conservation District, Publication #782, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

2. Equity Priority Communities are characterized by MTC as census tracts with a significant concentration of underserved populations. https://mtc.ca.gov/planning/transportation/access-equity-mobility/equity-priority-communities

3. Refer to the 2022 update of CalEPA's SB535 Disadvantaged Communities map https://experience.arcgis.com/experience/1c21c53da8de48f1b946f3402fbae55c/page/SB-535-Disadvantaged-Communities/

LAND USE & OWNERSHIP

Central San owns a significant amount of property beyond the main plant, including five large holding basins (Figure 2). Several surrounding properties, including parcels to the west and southeast of the plant, are also owned by Central San and used as buffer property or leased for industrial and commercial uses. The US Army Corps of Engineers has jurisdiction over the Walnut Creek flood control channel south of the BNSF railway, and levees east of Central San's property. The BNSF railway borders Central San property to the north (Figure 1).

FLOODING & SEA-LEVEL RISE VULNERABILITY

Central San does not have significant exposure to flooding from sea-level rise alone (Figure 6).[1] However, the plant is exposed to fluvial flooding from Walnut Creek and tributaries, and higher Bay tides can increase fluvial flood risk by reducing discharge capacity. Central San is partnering with Contra Costa County Flood Control District (CCCFCD) to raise levees on the eastern side of the plant, from the BNSF railway to the north to State Route 4 to the south, to provide federal flood risk protection for a 500-year storm plus 3 feet of freeboard. Levees on the northwest side of the Central San property have recently been raised and will soon be raised on the plant's north side. Improvements to Central San's Influent Pump Station are also underway to enhance flood resiliency.

Rising groundwater due to sea-level rise has not been evaluated and should be considered in designing any future NbS in these basins to assess the potential for groundwater seepage into the holding basins.

1. Carollo and ch2m. 2017. Central Contra Costa Sanitary District Comprehensive Wastewater Master Plan, Technical Memorandum No. TP-8: Resiliency and Vulnerabilities. Prepared on Behalf of Central Contra Costa Sanitary District.

Levees on the northwest side of the Central San property have recently been raised.

Figure 3. Historical aquatic habitats

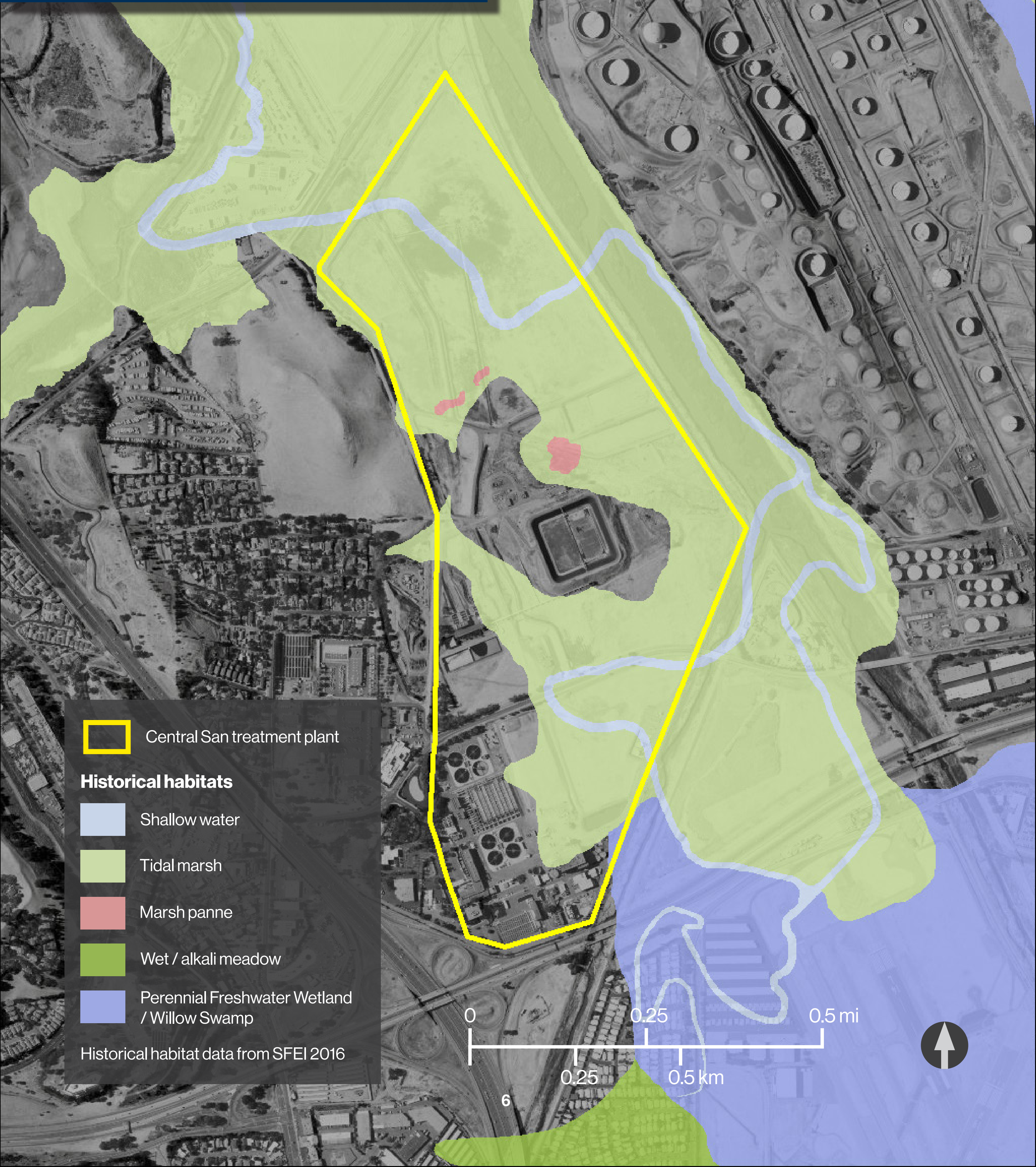


Figure 4. Modern aquatic habitats

Figure 5. Infrastructure, recreation, & disadvantaged communities

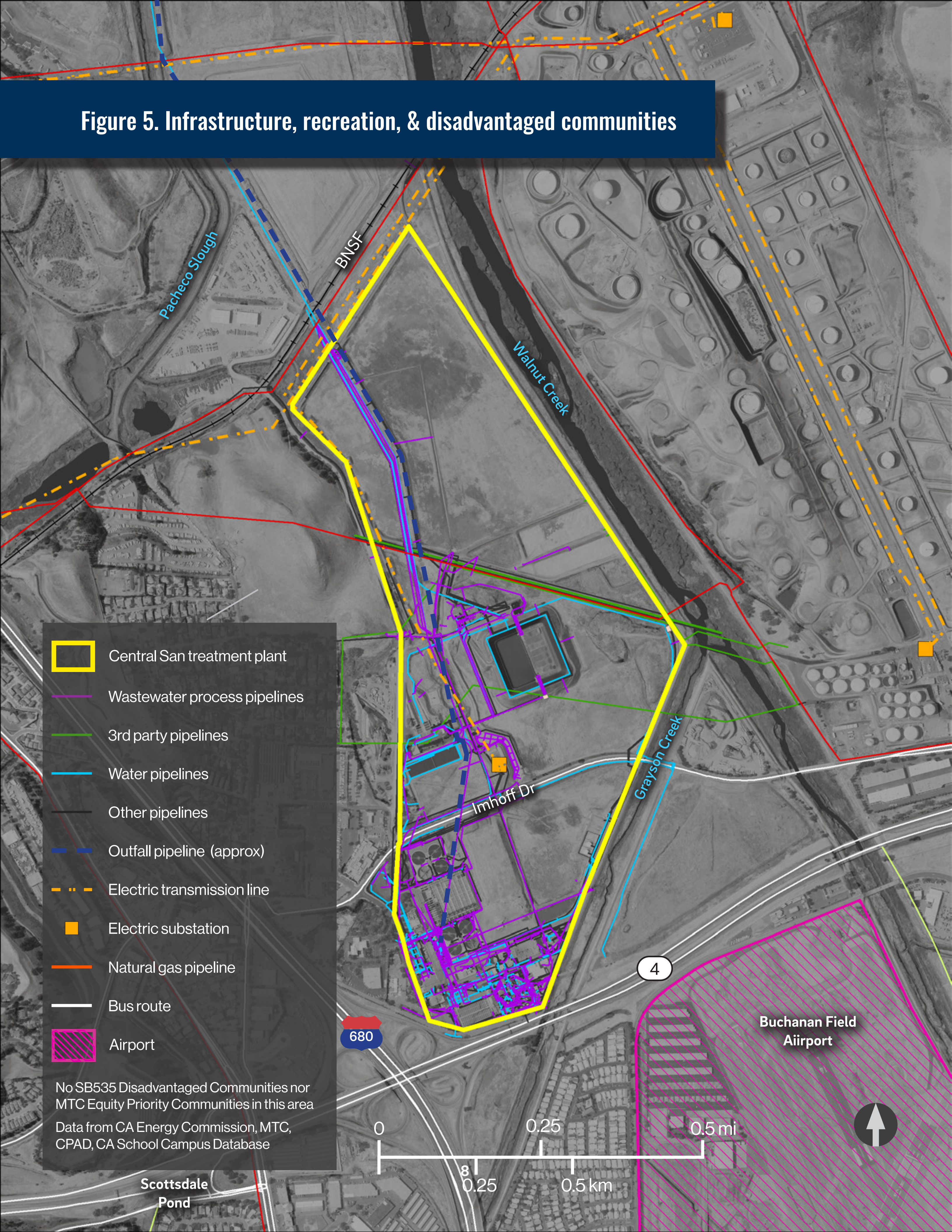
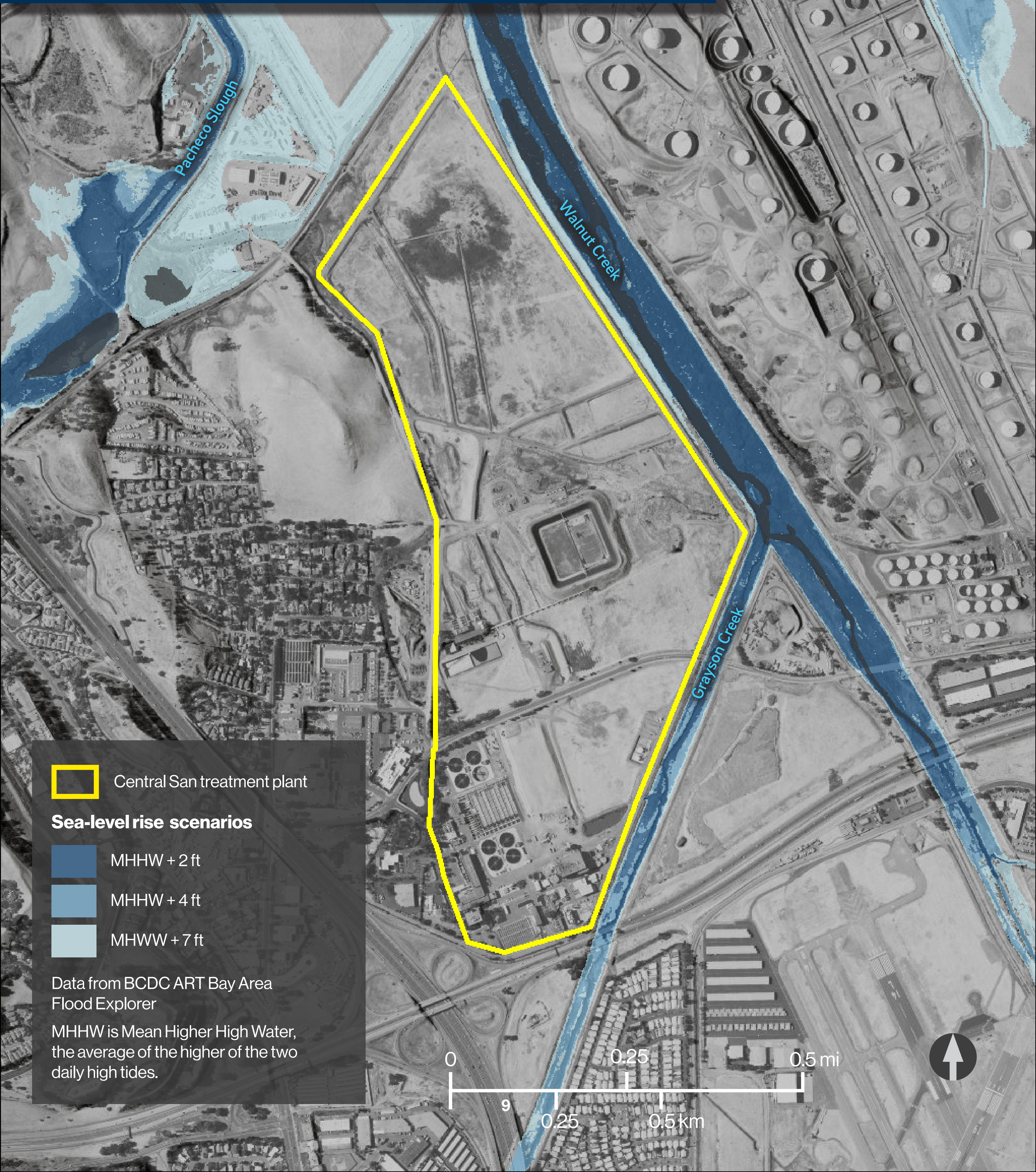


Figure 6. Sea-level rise



SITE CONSIDERATIONS

RECENT & PLANNED CHANGES AT FACILITY

Central San has discussed developing a refinery recycled water program for decades. Such a program would deliver treated wastewater to nearby refineries, which currently use large volumes of freshwater imported from the Delta. Central San recently completed an advanced recycled water pilot project, including reverse osmosis (RO) as a proof of concept for a future refinery recycled water program. In the event of program initiation, Central San will reduce its total effluent stream considerably. A resulting highly concentrated effluent could create a new opportunity and increase the value of NbS to remove nutrients from RO concentrate via horizontal levees or another form of woodchip bioreactor.

Central San is also in the process of evaluating long-term solids handling strategies. Currently, wastewater solids are dewatered and incinerated using multiple hearth furnaces. Unlike other facilities in the Bay Area, a significant portion of the nitrogen and phosphorus accumulated in biomass grown in the secondary biological treatment process is ultimately incinerated and not returned to the liquid stream. If Central San processes solids using other technologies, such as anaerobic digestion or anaerobic digestion followed by incineration or other thermal processes, more nitrogen and phosphorus may be redirected into solids handling return streams. If Central San generates a high-strength nutrient sidestream in the future, they may need to evaluate nutrient reduction alternatives.

RECENT & PLANNED CHANGES NEARBY

The Resilient Landscape Vision for Lower Walnut Creek[1] developed a series of alternative floodplain management strategies to channel dredging that would be more cost-effective and beneficial to people and wildlife. Most relevant to the development of NbS is "Strategy 3: Sustaining resilient marshes using treated wastewater." Measures suggested to achieve Strategy 3 include developing treatment wetlands in the Central San basins, and building seepage slopes. Treatment wetlands in the equalization basins would provide habitat for waterfowl and other wildlife while providing nutrient removal and water quality benefits. They would also re-create some of the historical perennial wetland habitats that existed at the site before the channelization of Walnut Creek and its tributaries. Seepage slopes would mimic the historical shallow groundwater discharge to tidal marshes at the mouth of Walnut Creek, recreating the fresh-to-brackish marsh gradient that historically existed, along with corresponding habitat diversity. Freshwater inputs can also increase organic matter accumulation, storing carbon and helping marsh elevation keep pace with sea-level rise. The Landscape Vision suggests that seepage slopes could be constructed on existing levees lacking adequate marsh migration space and habitat transition zone.

The Lower Walnut Creek Restoration Project is actively implementing several strategies outlined in the Lower Walnut Creek Vision document. The project aims to address sediment buildup in the

1. SFEI. 2016. Resilient Landscape Vision for Lower Walnut Creek: Baseline Information & Management Strategies. A SFEI report developed in cooperation with the Flood Control 2.0 Regional Science Advisors and Contra Costa County Flood Control and Water Conservation District, Publication #782, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

lower reaches of Walnut Creek with tidal restoration and floodplain expansion. Reconnecting the watershed to tidal marshes will allow more space for the creek and reduce sediment deposition in the main channel. CCCFCD took over jurisdiction of the lower reach of Walnut Creek (north of the BNSF railroad tracks) and is actively restoring two reaches as the first phase of the restoration project. Projects in the north and south reach involve restoring tidal flows to areas cut off from the Walnut Creek floodplain. Levees at the north reach (Pacheco Marsh) (Figure 1) were breached in October 2021. Restoration at the South reach is under construction and will involve the construction of a setback levee with an ecotone slope, grading of channels, and breaching and lowering existing levees. There is no plan to incorporate wastewater discharge into the ecotone levee. Future phases may tackle the restoration of the middle reach connecting the south and north reach. The project includes extensive public access elements, including a three-mile trail extension along Walnut Creek connecting with the Iron Horse Regional Trail.

OPPORTUNITIES & CONSTRAINTS

Several wet weather equalization basins at Central San present opportunities for NbS development. Conceptually, less frequently-used basins could be converted to full-time treatment wetlands, with only emergency use as wet weather holding basins. Considerations for emergency or limited use include the permitting strategy for managing mechanical failure and the flow scenarios enabling wet weather storage or bypass through potential dual-use basins. An additional consideration includes whether an NbS system may accommodate effluent of varying quality based on Central San's mode of operation. For more frequently used basins (i.e., Basin B), Central San could develop a dual-purpose management approach to allow treatment during the dry summer and full function as a holding basin during the wet season. Depending on the volume needed for equalization and the area used for NbS treatment, the basin could also be divided to allow less frequent interruptions of the treatment process. Basin A South contains contaminated soils covered with an engineered soil cap, which restricts the use of the basin only for emergencies.

Historically, extensive freshwater marshes existed in the lower Walnut Creek watershed near Central San. Re-creating freshwater marsh habitat with treated wastewater could provide valuable habitat in this landscape context. Discharge to a horizontal levee connected to a tidal marsh would mimic the historical freshwater-to-saltwater transition in the marshes of lower Walnut Creek. Depending on the design, some parts of a designed treatment wetland could support much-needed habitat for species like the California tiger salamander, western pond turtle, and a range of waterfowl and shorebirds.

A major constraint includes the complex nature of Central San's basin operational needs: storing and returning untreated and partially treated wastewater, storing and returning treated wastewater, and in some cases discharging treated effluent via the Basin B Wet Weather Structure to Walnut Creek. Implementing a multi-use concept for the basins could be challenging and difficult to implement.

ADDITIONAL CONSIDERATIONS

Other major constraints at Central San include the current lack of nitrification capacity and high flow volume, which limits the opportunity for significant nutrient load reduction. NbS concepts in the existing holding basins can evolve with expanded recycled water program plans. In the future, if and when the refinery water exchange program or other recycled water drivers reduce flows to a concentrated stream, the opportunity to contribute to nutrient load reduction with NbS may be more significant.

In 2018, engineering consultant, HDR, concluded that Central San is not a candidate for sidestream treatment since the plant incinerates solids, which does not produce a nutrient-laden sidestream.[1] Recycled water expansion may present the need to treat reverse osmosis concentrate, which may be well suited for treatment via horizontal levees or seepage slopes. In partnership with Valley Water, research at Oro Loma's horizontal levee project has shown promise for contaminant removal from RO concentrate routed through the open water treatment wetlands and horizontal levee treatment cells.[2]

An additional constraint is nearby Buchanan Field Airport. Much of the Central San plant footprint falls within the airport's Safety Zone 4, and special limitations on wetland design may apply.[3] Bird strike risk will need to be considered in the design of any new treatment wetlands at the Central San plant. Future evaluations must involve an assessment of land ownership, safety considerations, and outreach to appropriate stakeholders.

PRECEDENT

Wastewater agencies in the North Bay have for several decades been subject to several Discharge Prohibitions from the San Francisco Bay Water Quality Control Plan (Basin Plan) to protect Suisun Marsh along with sloughs and tributaries. As a result, several facilities have drastically reduced discharge volumes by maximizing water reclamation and recycling. A separate report under development for this project synthesizes existing NbS projects in the region and the regulatory circumstances surrounding their authorization.

Projects under current consideration by wastewater agencies and regulatory agencies include those to advance horizontal levees at Oro Loma Sanitary District, Palo Alto Regional Water Quality Control Plant, and West County Wastewater District. The SF Bay Regional Water Quality Control Board authorized near-shore discharges for the City of Petaluma and Mt. View Sanitary District, and the agency adopted an NPDES permit in 2022 for a new open water polishing wetland and shallow near-shore discharge for the City of San Leandro.

1. HDR. 2018. Nutrient Reduction Study Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means. Prepared on behalf of the Bay Area Clean Water Agencies. Available at https://bacwa.org/wp-content/uploads/2018/06/BACWA_Final_Nutrient_Reduction_Report.pdf

2. Reverse Osmosis Concentrate Treatment Research Results and Context for San Francisco Bay. 2020. Prepared by the University of California Berkeley, Stanford University, and San Francisco Estuary Institute on behalf of Valley Water, San Jose, CA.

3.Figure 3C, Buchanan Field Airport Safety Zones. Buchanan Field Airport Policies, 2000. https://www.contracosta.ca.gov/DocumentCenter/View/856/Buchanan-Field-Airport-Policies

REGULATORY CONSIDERATIONS

Bay Area WRRFs are subject to a myriad of regulations, some of which may inadvertently act in conflict with nutrient load reduction efforts. The regulatory landscape governs not just surface water discharges but also water reuse, biosolids management, protected species and habitats, and air emissions. Project proponents and regulators have initiated discussions over potential approaches for mitigating these barriers, recommendations for quantitative analyses of potential conflicts, and options for regulatory and permit-based strategies to maximize the multi-functional benefits associated with NbS upgrades, in the event large-scale nutrient load reductions are warranted. The final report for this regional NbS evaluation project shall synthesize the extensive regulatory considerations applicable to most WRRFs in Region 2.

Facility-specific permits, local ordinances, and site-specific plans feature requirements for each facility. Under Central San's 2017 NPDES permit (No. CA0037648), the facility hosts several holding basins with a combined capacity of 168 million gallons (mg). These holding basins temporarily store peak wet weather flows when primary treated wastewater exceeds secondary treatment capacity. When flows subside, Central San routes stored wastewater back to the headworks for complete primary and secondary treatment. Alternatives 1 and 2, presented below, involve the modification of existing basins. Regulatory agencies generally exclude existing elements of a wastewater treatment train, including equalization ponds or retention basins, from waters of the U.S., thus minimizing wetlands-related mitigation considerations.

For regulatory purposes, the San Francisco Bay Regional Water Quality Control Board recently provided guidance and continues establishing a precedent for permitting discharges of treated effluent from NbS projects in the region.[1] On-going consultations with other regulatory agencies for similar projects also serve to continually inform opportunities and constraints regarding mitigation and monitoring requirements, desired treatment performance, and the appropriate quantification of ancillary benefits, including habitat enhancement and water reclamation, and community benefits.

Central San anticipates retaining the existing outfall pipeline under any future scenario. Further NbS evaluations must consider designing and permitting multiple discharges to minimize regulatory compliance risks and streamline monitoring and reporting efforts. The ancillary benefits of pursuing any option presented here include, at a minimum, additional reductions in dry weather discharges to Suisun Bay and the enhancement of habitat quality and quantity. Other potential benefits include recreation and education opportunities, demonstrating novel NbS strategies, and enhancing habitat quality and quantity within a highly disturbed landscape.

Pending refinement of these concepts, this memorandum aims to quantify these and other likely benefits and impacts. Quantifying such benefits enables regulatory agencies to weigh the net environmental benefits associated with a project.

1. "NPDES Permitting for Nature-based Solutions," 2022, San Francisco Bay Regional Water Quality Control Board.

Figure 7. Conceptual design options

Option 1: Convert basins C, D, or both to open water treatment wetlands

Option 2: Convert Basin A North into a serpentine channel-type open water wetland

(1 mile north) Option 3: Coordinate with the Lower Walnut Creek Restoration Project Phase II (Middle Reach) on a horizontal levee

CONCEPTUAL DESIGN OPTIONS

To date, three main nature-based options for a multi-benefit nutrient load management strategy at Central San have been identified (Figure 7). These represent standalone options or modular elements of a larger plan. All options are contingent upon developing a suitable effluent stream, such as nitrified secondary or RO concentrate. NbS systems generally achieve higher total nitrogen removal when nitrate is the dominant nitrogen species.

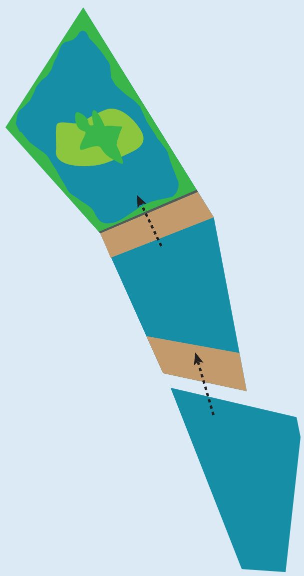
These options are consistent with regional plans, such as the Baylands Habitat Goals Project, which recognizes the importance of transition zones and the role of converting diked wetlands and constructed levees to horizontal levees or establishing brackish marsh conditions using treated wastewater effluent.[1]

1. Goals Project. 2015. The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015 prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

OPTION 1

Convert Basin C, Basin D, or both to open water treatment wetlands. Basin B is the largest basin with the highest nutrient reduction capacity but is also the most frequently used for wet weather storage and storage during regular maintenance and inspection events. Therefore, it is likely to be maintained in its current function as a holding basin. Basins C and D are less frequently used but have a smaller volume. Multiple designs are possible for Basins C and D. One or both basins could be developed as open-water treatment cells optimized for nutrient reduction, or the basins could be designed as a treatment train, with a combination of open-water treatment cells and vegetated treatment wetlands, to maximize nutrient reduction and wildlife habitat benefits.

This option would create 19 acres of open water wetlands, which could receive at least 1.6 mgd based on conservative assumptions intended to remove 90% of nitrate loads. Optimization strategies to increase denitrification or reduce retention time could yield higher load reductions. Constraints associated with this alternative include the presence of multiple pipelines below the basins (i.e., sewer, recycled water, and petroleum). Refer to Table 1 for a comparison of estimated nutrient load reduction benefits and associated co-benefits.



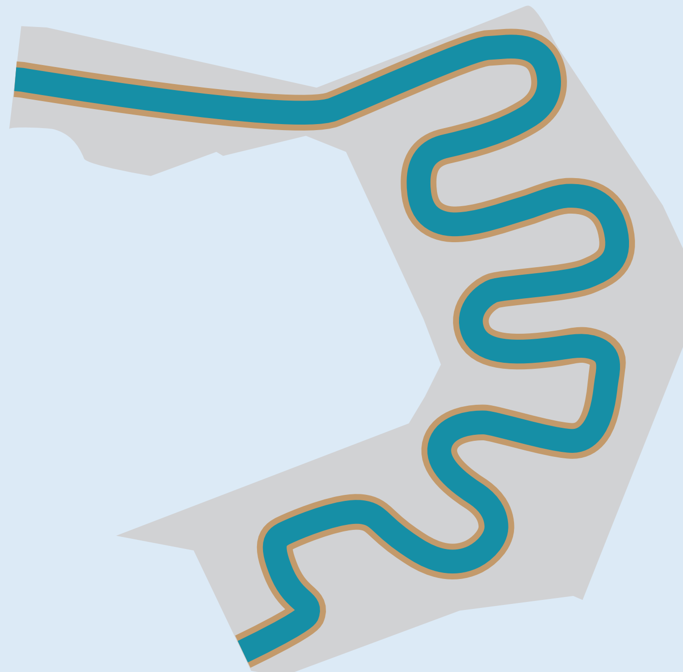
Example concept sketch demonstrating option 1 (Basins C & D). In this example, plant effluent is routed first to a shallow open water treatment cell optimized for denitrification. Water then flows through a woodchip seepage slope into a second open water treatment cell, then through a second woodchip seepage slope into a vegetated open water wetland optimized for habitat benefits.

OPTION 2

Convert Basin A North into an open water wetland. Basin A North is also infrequently used and could be converted for NbS. Unlike Basins B, C, and D, Basin A North has uneven topography that must be regraded if repurposed. Multiple designs are possible for an open water wetland in Basin A North. Given its unusual shape, one option involved the construction of a serpentine-channel wetland to enhance detention time, settling, and flow storage volume, which favors microbially-mediated denitrification.

Woodchip seepage slopes could be included to enhance nutrient removal further. The design could be expanded to Basin A South, but this is unlikely to be viable given soil contamination constraints.

This alternative involves creating 37 acres of open water treatment wetlands and winding channels, which could receive, at a minimum, 3.2 mgd, based on conservative assumptions. As with Option 1, optimization strategies to increase denitrification or reduce retention time could yield more significant load reductions. Constraints associated with this alternative include gas and petroleum pipelines beneath the basin's northern portion, and Central San uses this basin to manage the draining of recycled water infrastructure.

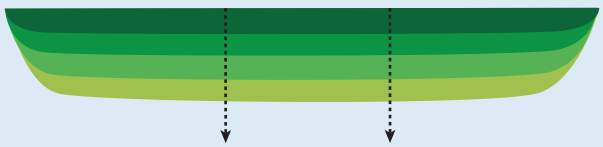


Example concept sketch demonstrating option 2 in Basin A North. In this example, plant effluent is routed through a serpentine-style open water wetland with woodchip sides optimized for nutrient removal. The serpentine-style channel minimizes the opportunity for hydraulic short-circuiting. The remainder of the basin could be reserved for emergency storage.

Basin A North

OPTION 3

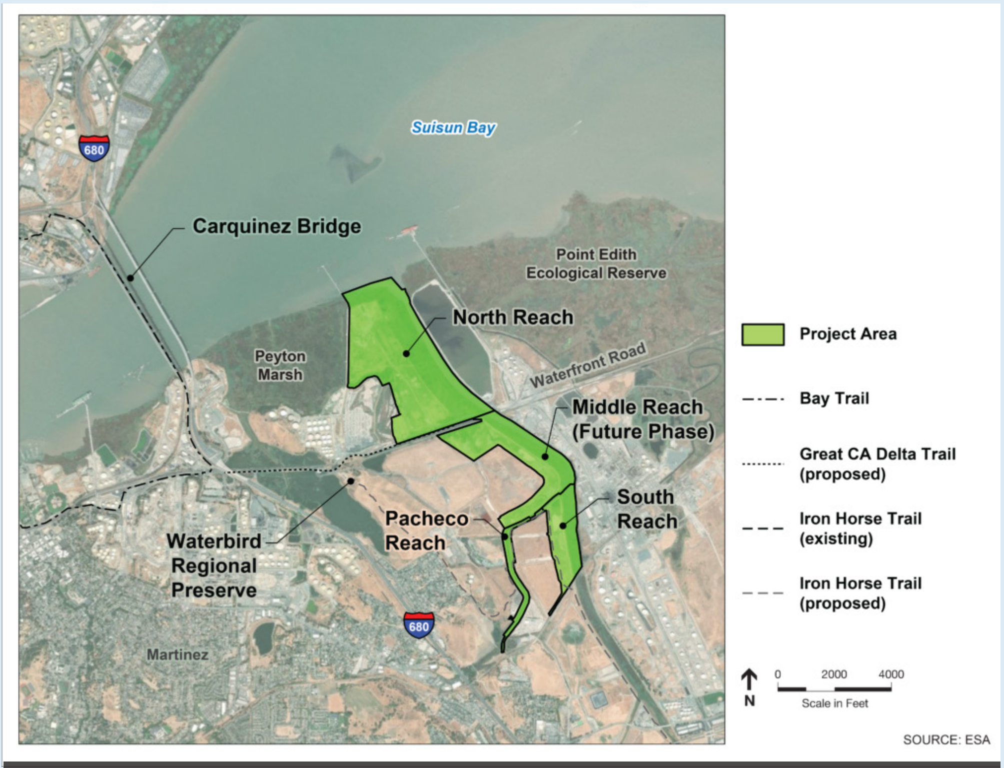
This option would involve a close partnership with Lower Walnut Creek Restoration Project to incorporate a treated wastewater seepage slope into ecotone slope(s) constructed during future phases of the restoration project. Phase II (the middle reach of the project area) is planned for future implementation. Early coordination with project proponents and the design team early in the planning process is necessary to establish a governance, funding, and maintenance roadmap.



Example concept sketch demonstrating option 3.
A horizontal levee could be integrated into the future design of the Lower Walnut Creek Restoration Project's Middle Reach. Treated wastewater would flow through a seepage slope designed to remove nutrients and other contaminants before discharging to a tidal marsh and flowing out to Pacheco Slough or Walnut Creek. The seepage slope would be integrated into the design of the habitat ecotone at the back of the newly restored tidal marsh. Location and other details must be determined in collaboration with restoration partners.

The Lower Walnut Creek Restoration Vision suggested that horizontal levees could be constructed in other reaches where steep levees limit the habitat transition zone. However, given recent flood-risk management levee upgrades closer to the plant and the floodplain widening pursued by the Lower Walnut Creek Restoration Project, the Middle Reach is likely the best location for a horizontal levee in the area. Compared to farther upstream and nearer the treatment plant, adequate space exists for a broad, gently sloping levee that would not infringe upon the main channel and could be constructed in an area not currently wetland habitat. Including treated wastewater in the design of the ecotone slope for the restoration project could increase the diversity and complexity of transition zone habitats available in the area. Irrigated slopes would create a salinity gradient and allow a broader range of vegetation types more representative of the mosaic of wetland types that historically existed in the lower Walnut Creek watershed.

This alternative involves routing approximately one mgd through an approximately 0.4-mile horizontal levee. This volume represents a minimum amount based on lessons learned from the horizontal levee pilot project at Oro Loma Sanitary District. Applying higher-strength effluent, such as reverse osmosis concentrate, would increase such a system's TIN load removal rate and overall efficiency.



The Middle Reach of the Walnut Creek Restoration Project will be completed in a future phase.

COMPARING OPTIONS

Table 1 lists goals of implementing NbS, and the relative contribution of each option toward meeting those goals. This allows for a high-level comparison of options. Further feasibility analysis is needed to determine the most appropriate options.

Table 1. Comparison of each option's relative contribution to achieving goals of NbS implementation.

● = Achieves. ◑ = Partially or possibly achieves. ○ = Does not achieve.

For TIN removal, 'Achieves' is>30% removal, 'Partially achieves' is 5-20% removal, and "Does not achieve is <5% removal.

	Option 1. (Convert basins C&D to open water treatment wetlands)[1]	**Option 2.** (Convert Basin A North into an open water treatment wetland)	**Option 3.** (Partnership with CCCFCD on a horizontal levee)[2]
Goal 1: Reduces nutrient loads to the Bay and improves overall water quality.			
Reduces TIN *Estimated dry-season reduction (kg d^{-1} / % reduction of daily TIN load)*	◑ *160 kg d^{-1} / 5%*[3]	◑ *320 kg d^{-1} potential / 10%*	○ *76 kg d^{-1} / 2%*
Reduces Flow	1.6 mgd / 5%[4]	3.2 mgd / 10%	1.0 mgd / 3%
Reduces CECs	◑	◑	○
Goal 2: Reduces flood risk for the plant and/or associated infrastructure.			
Attenuates waves and provides erosion resistance	○	○	◑ *For area adjacent to restoration site but not plant/ associated infrastructure*
Facilitates marsh accretion	○	○	●
Goal 3: Create and/or enhance habitat			
Provides marsh-upland transition zone habitat and marsh migration space	○	○	●
Provides high tide refuge habitat for wildlife	○	○	●
Increases habitat complexity	◑	◑	●
Provides freshwater pond/marsh habitat	●	●	●
Goal 4: Enhances recreational opportunities.			
Provides opportunity for public trails and wildlife viewing	○	○	◑ *Dependent on Lower Walnut Creek Restoration Project plans*
Goal 5: Provides additional co-benefits.			
Reduces use of potable water for irrigation	○	○	○
Supports goals of partner organizations (e.g. facilitates neighboring restoration projects)	N/A	N/A	◑ *TBD if this fits with the Middle Reach plans envisioned by Lower Walnut Creek Project*

1. Options 1 & 2 assume treatment of nitrified effluent based on the 5-year average of dry weather TIN concentrations and creation of an unvegetated open water treatment wetland requiring 11.2 acres per MGD and shallow water depth of 0.3 meters to achieve 90% removal of nitrate (A90). Concentrated waste streams or higher flow-through may increase load removal rates. Jasper, J.T., Jones, Z.L., Sharp, J.O. and Sedlak, D.L., 2014. Nitrate removal in shallow, open-water treatment wetlands. Environmental science & technology, 48(19), pp.11512-11520.

2. Assumptions: horizontal levee with length: 580 meters, height: 3.1 meters, 10:1 slope, bed temperature of 20° C, 24-hr retention time, and woodchip media depth of 0.5 meters. Addy, K., Gold, A.J., Christianson, L.E., David, M.B., Schipper, L.A. and Ratigan, N.A., 2016. Denitrifying bioreactors for nitrate removal: A meta-analysis. Journal of Environmental Quality, 45(3), pp.873-881.

3. Conservatively estimated TIN reductions, as absolute daily reductions and percentage of average dry season daily load (~3,600 kg N d-1)

4. Conservatively estimated flow reductions compared with average dry weather discharges (31.9 mgd)

NEXT STEPS

Key factors influencing the formulation of an NbS project for nutrient management at Central San include, but are not limited to:

- The status of recycled water projects and the potential creation of a concentrated effluent stream from RO concentrate or another process.
- Interest and ability to coordinate with the Lower Walnut Creek Restoration Project to incorporate a treated wastewater seepage slope into ecotone slope(s) constructed during future phases of the restoration project.
- Interest in pursuing an early-actor nutrient reduction program.
- Whether retrofits to the existing basin can support a treatment cell optimized for nutrient removal.
- Whether grant funding is available for planning design and permitting consultations.
- Less control over nutrient reduction performance with NbS options compared to other nutrient reduction alternatives.
- Costs and strategies for producing nitrified effluent required for NbS options.
- Costs and benefits of Nbs projects compared to other nutrient reduction project alternatives.
- Risks associated with unintended release(s) of accumulated organic and inorganic constituents (e.g. toxicity from heavy metals).

Central San's executive staff or board of directors have not decided on which long-term strategy(ies) would be used to reduce total inorganic nitrogen load to the Bay, including NbS, conventional treatment, innovative treatment technologies, large-scale recycled water projects, etc. While NbS remains a candidate strategy, it is considered as a preliminary concept and the above key factors could significantly influence its feasibility.

If the facility is selected for consideration under Phase 3 of this project, it is recommended that additional planning and outreach efforts be performed within the agency and that funding opportunities are explored at the regional (e.g., Measure AA), state (upcoming climate and water resilience programs), and federal levels (e.g., coastal resilience funding under the Bipartisan Infrastructure Law).

NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: DELTA DIABLO

BACWA BAY AREA CLEAN WATER AGENCIES

SFEI | AQUATIC SCIENCE CENTER

PREPARED BY
San Francisco Estuary Institute

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INTRODUCTION

The first phase of analysis (Phase I) of the Nature-Based Solutions for Nutrient Reduction study involved a regional-scale desktop analysis in determining which Bay Area water resource recovery facilities (WRRFs) have opportunities for implementing nature-based solutions (NbS) for nutrient reduction. In this phase (Phase II), we conducted outreach with a select group of facilities with high potential for NbS, including conducting site visits and discussing opportunities and constraints with agency staff. This phase also involved additional site-scale research and analysis in refining opportunities and constraints identified at each facility. In Phase III of this study, we will develop planning-level designs to enable cost estimation, identify regulatory and land use conflicts, and establish feasibility for agency-led planning. In coordination with key stakeholders, Delta Diablo was selected for the Phase III analysis based on opportunity and interest in pursuing the evaluation.

Delta Diablo (Figure 1) was one of the facilities identified as a high-potential site for NbS. The desktop analysis identified opportunities for open water treatment wetlands in undeveloped parcels near the site, including one recently purchased by Delta Diablo (Figure 2), and opportunities for horizontal levees adjacent to the plant to the east and north. Initial conversations with staff at Delta Diablo refined the initial set of options to three main areas: the recent land acquisition, the existing 16 million-gallon emergency retention basin, and a possible partnership to allow the construction of a horizontal levee outside the plant boundary.

Delta Diablo was created in 1955 and currently serves over 215,000 customers in Antioch, Pittsburg, and Bay Point. The Delta Diablo Wastewater Treatment Plant, located at 2500 Pittsburg-Antioch Hwy in Antioch, opened in 1982 and has undergone several upgrades since then. The plant's capacity is 19.5 million gallons per day (mgd), with an average flow of about 12.4 mgd. The agency discharges non-nitrified treated wastewater via a deepwater outfall to New York Slough.

The plant recycles about six mgd of water, 90% of which is distributed to two nearby power plants for cooling and subsequent discharge. Other uses of recycled water include landscape irrigation at parks and golf courses and commercial use for dust control. Cooling towers at the power plants generate a concentrated waste stream (blowdown) for return to the treatment plant, where chlorination and dechlorination occur before discharge to New York Slough. An opportunity may exist to nitrify the blowdown before polishing it in an NbS system. NbS systems generally achieve higher total nitrogen removal when nitrate is the dominant nitrogen species.

Figure 1. Site in context

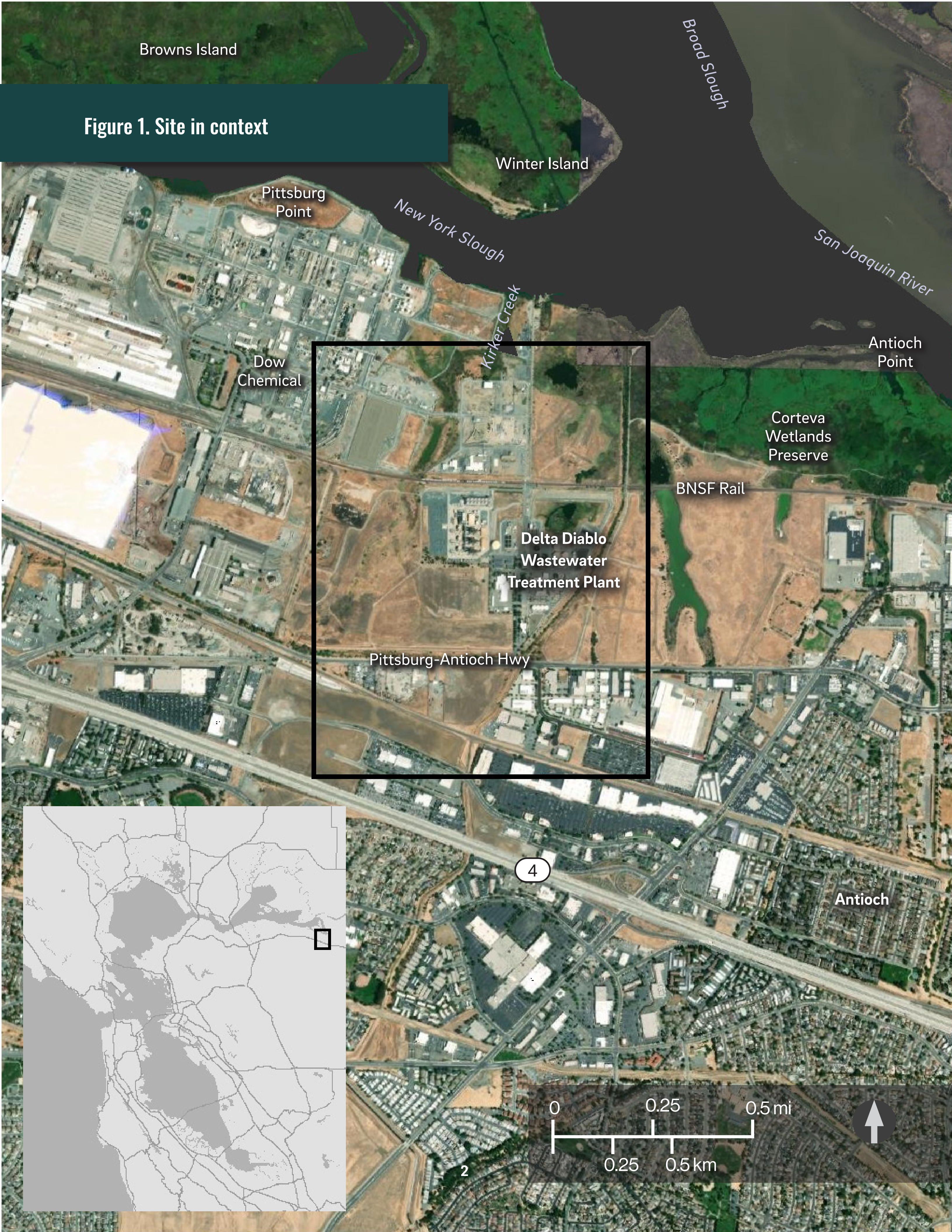

Figure 2. Site detail

SITE OVERVIEW

ECOLOGY

Before development, the area now occupied by Delta Diablo was primarily grassland (Figure 3). The northeast part of the plant site was historically a tidal marsh that extended northward to connect to the brackish marshes of the San Joaquin River (Figure 4). Today, this lower-elevation part of the plant site is an emergency storage basin. To the northeast are the tidal wetlands of the Corteva Wetlands Preserve.

South of the tidal wetlands is protected uplands and pond habitat. Habitat types in this area remain similar to historical habitats, though the upland regions have been disconnected from tidal marshes by the BNSF rail line, interrupting the natural wetland-upland transition zone. Channelization of creeks occurred decades ago to drain wetlands and convey floodwaters to the Bay. This process reduced the freshwater-saltwater gradient historically formed by extensive lagoons and wet meadows along San Pablo Bay into the Delta. None of the historical wet meadow habitat persists, though some freshwater emergent wetland habitat is present northeast of the Delta Diablo plant.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

Land use around Delta Diablo includes heavy industry, open space, and commercial. The facility is within the industrial corridor featuring chemical manufacturers and power plants between Pittsburg and Antioch. The Corteva Wetlands (formerly Dow Wetlands Preserve) is east of the plant. Corteva Agriscience owns Corteva Wetlands, which is open to the public.

The BNSF rail line runs east-west along the northern border of the plant, with a natural gas pipeline parallel to the tracks (Figure 5). West of Delta Diablo is the Delta Energy Center, an 880-megawatt natural gas plant and one of the two power plants receiving treated effluent for cooling.

The Metropolitan Transportation Commission (MTC) designated the census tract containing Delta Diablo as an Equity Priority Community.[1] CalEPA has also established this area as a Disadvantaged Community, under SB 535, based on pollution burden and population characteristics.[2]

LAND USE & OWNERSHIP

Corteva Agriscience owns much of the surrounding land, including Delta Energy Center to the west, Corteva Wetlands Preserve to the east, and the parcel directly north of the plant. Delta Diablo recently acquired a 28.1-acre property south of the administration building from Dow (Figure 1). That property is undeveloped, and Delta Diablo is exploring possible uses for the new land. One proposed option is to use the area for biosolids storage.

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1. Equity Priority Communities are characterized by MTC as census tracts with a significant concentration of underserved populations. https://mtc.ca.gov/planning/transportation/access-equity-mobility/equity-priority-communities

2. Refer to the 2022 update of CalEPA's SB535 Disadvantaged Communities map https://experience.arcgis.com/experience/1c21c53da8de48f1b946f3402fbae55c/page/SB-535-Disadvantaged-Communities/

FLOODING & SEA-LEVEL RISE VULNERABILITY

The existing basin represents the low point of the Delta Diablo facility, at approximately 12 ft above sea level. The site slopes upward to the south to an elevation of approximately 30 ft. The primary operations area of the Delta Diablo plant is high enough in elevation to be outside the flood zone at 7 feet above today's high tides (Figure 6). An embankment surrounds the low-lying pond in the site's northeast corner and also along the railroad track to the north. In the future, operational challenges are possible if higher water levels impact outfall operation at New York Slough.

Another factor to consider is rising groundwater. The lowest-lying part of the site is the holding basin in the northeast of the plant site, which was historically a tidal marsh before the construction of the rail line. Rising groundwater levels may cause seepage as sea levels rise and affect capacity in the holding basin. The basin serves a dual purpose as an emergency storage and stormwater detention basin for the plant. Any NbS implemented there must include design elements to manage stormwater, provide emergency effluent storage, account for rising groundwater, and ensure no increase in flood risk to the plant.

View over the emergency retention basin to the Delta Energy Center.

Figure 3. Historical bayland habitats

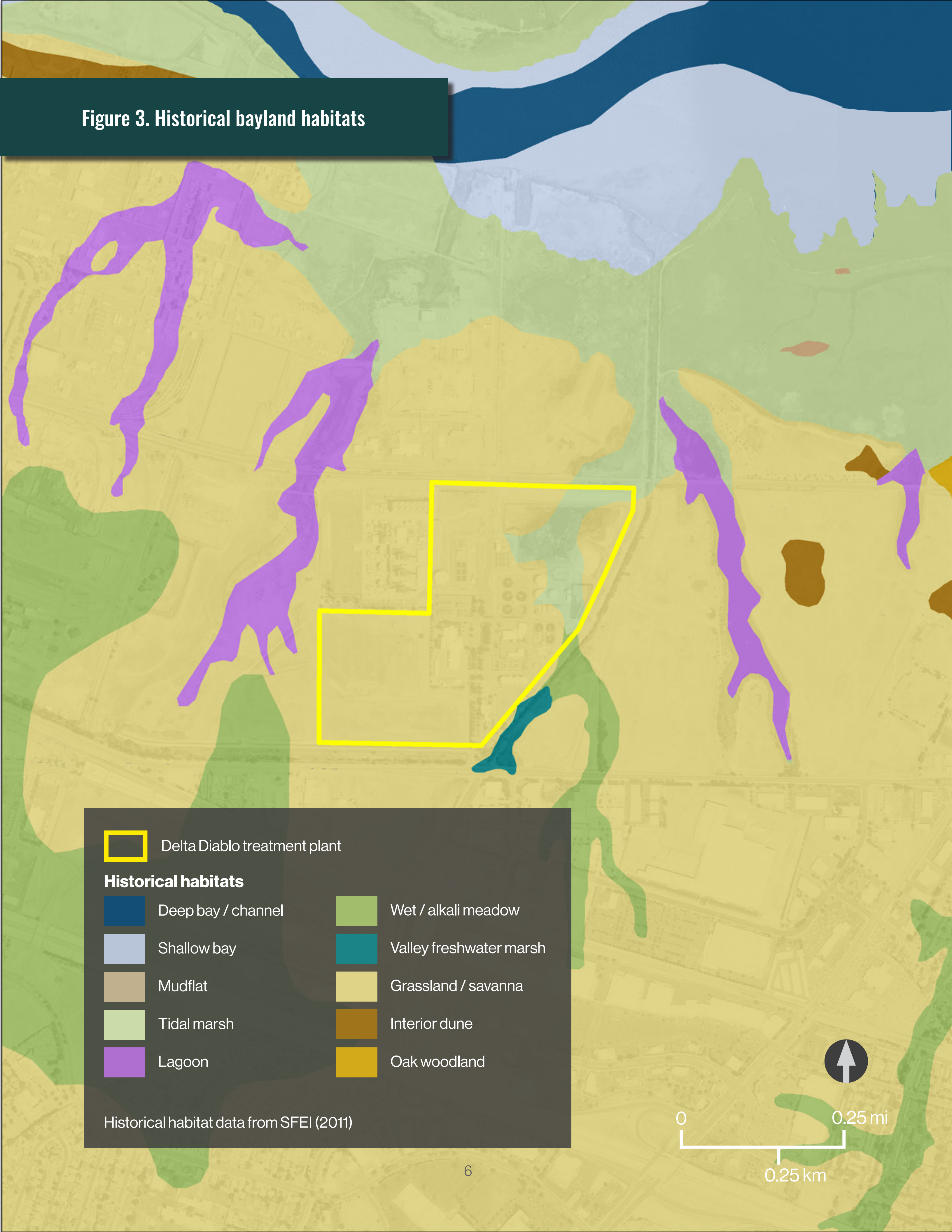


Figure 4. Modern bayland habitats

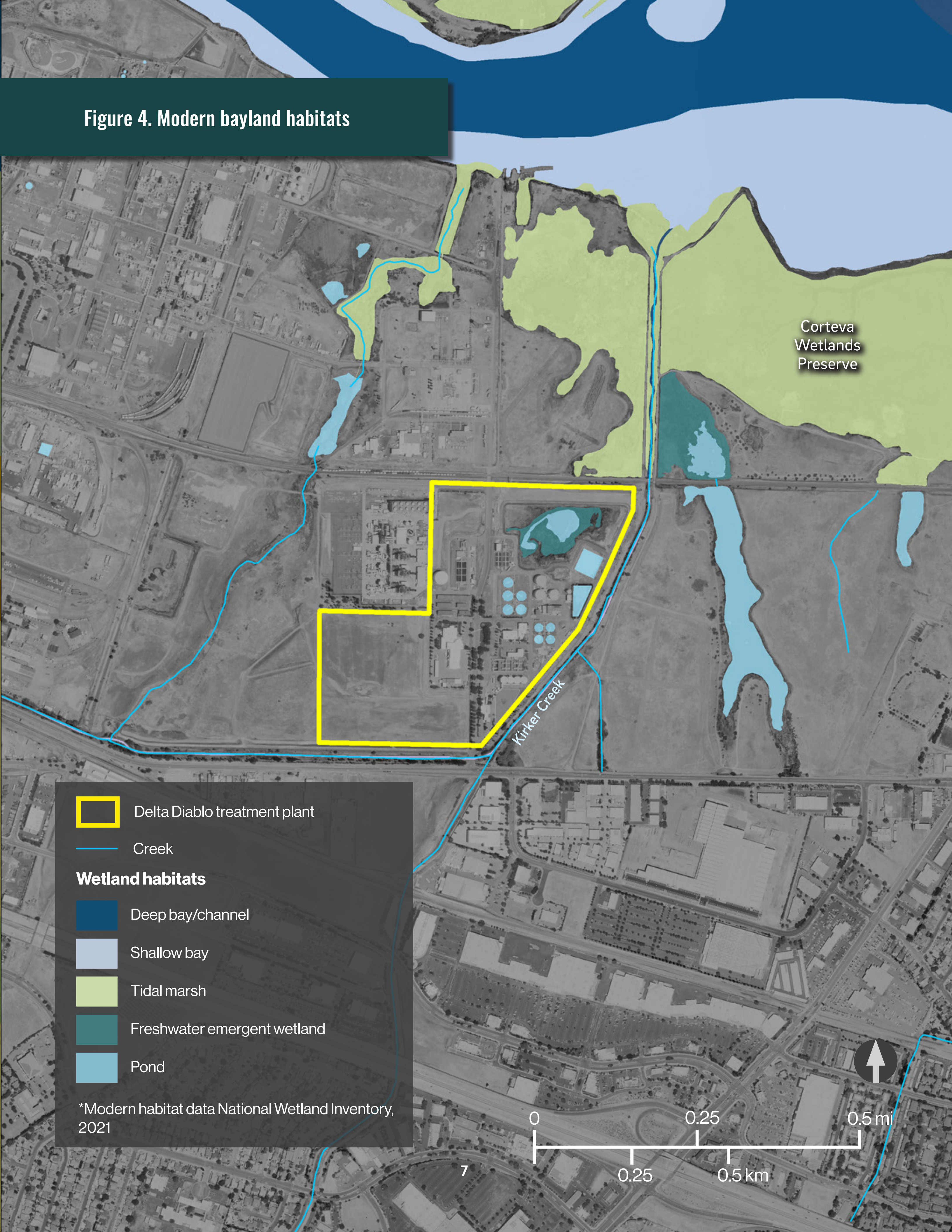


Figure 5. Infrastructure, recreation, & disadvantaged communities

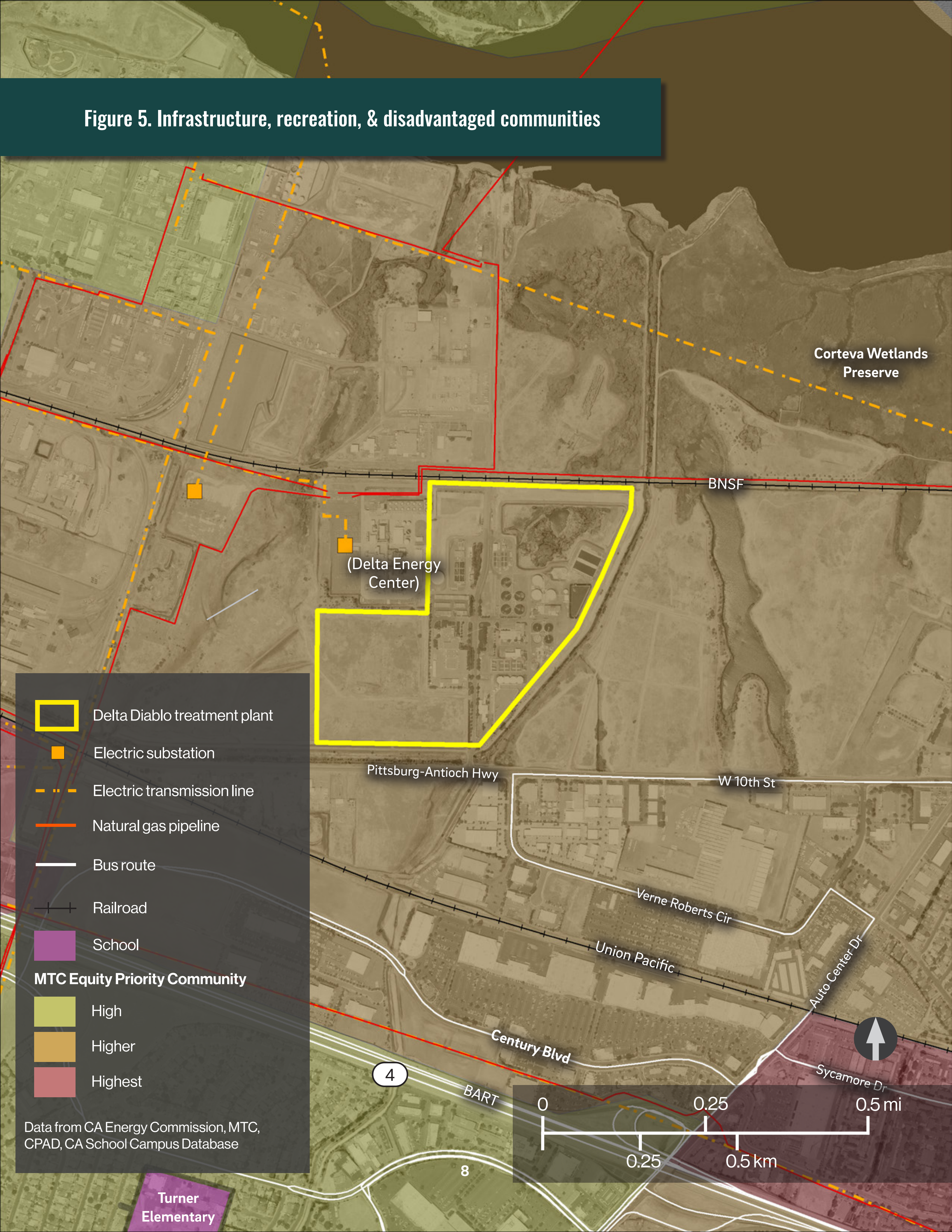
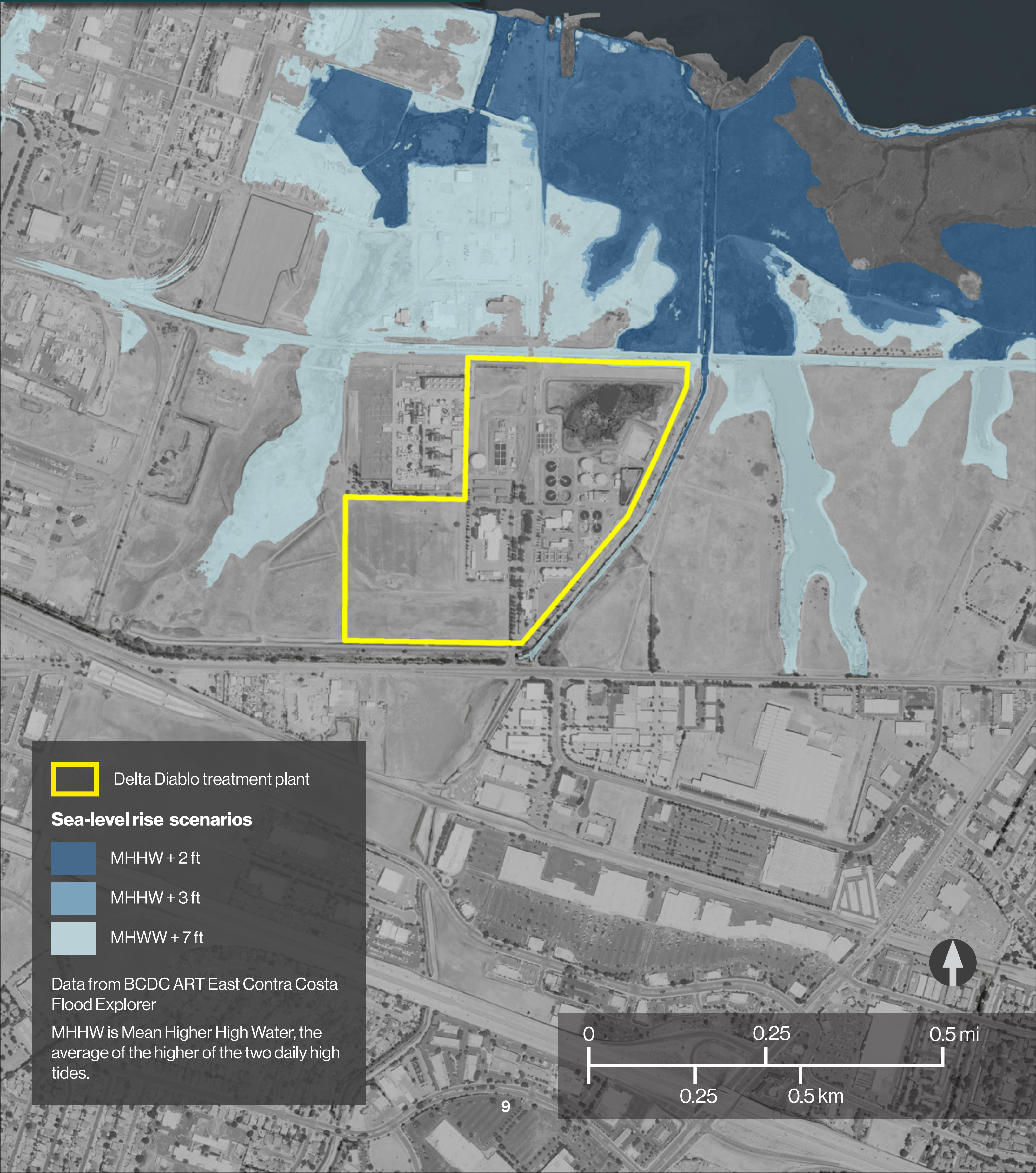


Figure 6. Sea-level rise



SITE CONSIDERATIONS

RECENT & PLANNED CHANGES AT FACILITY

The City of Antioch is constructing the Antioch Brackish Water Desalination Plant at the existing Antioch Water Treatment Plant to improve water supply reliability for its customers. Desalination concentrate, the byproduct of the reverse osmosis treatment process, will be conveyed via pipeline to Delta Diablo, which will be blended with effluent from the treatment plant and discharged via Delta Diablo's existing outfall.

We identified no other active projects believed to influence the implementation of NbS at Delta Diablo.

OPPORTUNITIES & CONSTRAINTS

The site's existing conditions and landscape context could support the construction of a horizontal levee or constructed wetland to support multiple benefits: namely water quality improvement and habitat enhancement. Designation of the facility and surrounding lands as a Disadvantaged Community and Equity Priority Community indicates a need to mitigate the surrounding industrial corridor's air and water quality impacts. Such designations suggest funding support through grants, forgivable loans, or revolving funds.

The approximately 9-acre basin called the Emergency Retention Basin, or ERB, in the northeast corner of the plant site presents opportunities to implement NbS. The basin receives stormwater from the treatment plant, which is routed to the tower pump station for treatment through the plant. Process drains from the Recycled Water Facility also contribute a small amount of stormwater to the ERB during storm events. Staff indicates large multi-day storms fill the ERB to approximately 25% capacity. Effluent is diverted to the ERB on occasion to address water quality concerns or power outages. The ERB also receives the entire effluent flow for approximately one hour, three times per week, when Delta Diablo flushes lines or calibrates their sodium bisulfite meters. Two smaller basins adjoining the ERB serve flow equalization purposes to ensure a consistent supply of recycled water to power plants for cooling water.

The ERB is used for a few hours per week to hold treated wastewater and serves as an emergency basin where Delta Diablo can divert effluent that does not meet discharge requirements. Staff has indicated that excess capacity exists in the basin and that only a portion of the holding basin is required to fulfill operational needs. This feature supports wetland vegetation and bird habitat. A potential NbS design could preserve existing habitat by including multiple cells or treatment types, focusing on various benefits, including habitat provision and nutrient reduction.

Freshwater wetland habitat was historically more widespread in this area, and the expansion of wetlands could improve habitat connectivity due to the proximity to freshwater wetlands at the Corteva Wetlands Preserve. A horizontal levee could recreate a more gradual freshwater-brackish wetland gradient to mimic historical conditions before the creation of stormwater channels. Constraints to consider in designing NbS to benefit wildlife include (1) water quality concerns, especially to sensitive species attracted to the wetland; (2) risk of supporting invasive species such as bullfrogs; and (3) management and maintenance challenges.

Existing recycled water partnerships with two power plants present opportunities for NbS treatment. Compared to the secondary effluent sent to the power plants, blowdown returned to Delta Diablo from the power plants is lower in volume and higher in nutrient concentration. Emerging science has demonstrated the effectiveness of routing reverse osmosis concentrate through the Oro Loma horizontal levee.[1] A confined horizontal levee or other optimized subsurface treatment wetland system may remove a more significant portion of the nutrient load in a smaller area by treating blowdown and other concentrated waste streams rather than stand-alone secondary-treated effluent.

One constraint to overcome is the lack of nitrification capacity in the existing treatment process. Nitrification is strongly recommended as a precursor to treatment through NbS systems due to concerns over ammonia toxicity and reduced nutrient removal capacity associated with an ammonia-dominant nitrogen load. Delta Diablo faces difficulty implementing any form of NbS before the expansion of nitrification capacity at the plant.

In 2018, the engineering consultancy, HDR, concluded that Delta Diablo is a candidate for sidestream treatment since the plant anaerobically digests its biosolids and dewaters to produce a nutrient-laden sidestream.[2] Recycled water expansion may present the need to treat reverse osmosis (RO) concentrate. Treatment of a nitrified sidestream, industrial blowdown, or RO concentrate may be well suited for treatment via open-water wetlands, horizontal levees, or seepage slopes. Research at Oro Loma's horizontal levee project, in partnership with Valley Water, has shown promise for contaminant removal from RO concentrate routed through the open water treatment wetlands and horizontal levee treatment cells.[3]

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1. Cecchetti, A. R., A. N. Stiegler, K. E. Graham, and D. L. Sedlak. 2020. The horizontal levee: a multi-benefit nature-based treatment system that improves water quality and protects coastal levees from the effects of sea level rise. Water Research X 7:100052.

2. HDR. 2018. Nutrient Reduction Study Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means. Prepared on behalf of the Bay Area Clean Water Agencies. Available at https://bacwa.org/wp-content/uploads/2018/06/BACWA_Final_Nutrient_Reduction_Report.pdf

3. Reverse Osmosis Concentrate Treatment Research Results and Context for San Francisco Bay. 2020. Prepared by the University of California Berkeley, Stanford University, and San Francisco Estuary Institute on behalf of Valley Water, San Jose, CA.

ADDITIONAL CONSIDERATIONS

PRECEDENT

Wastewater agencies in the North Bay have for several decades been subject to several Discharge Prohibitions from the San Francisco Bay Water Quality Control Plan (Basin Plan) to protect Suisun Marsh along with sloughs and tributaries. As a result, several facilities have drastically reduced discharge volumes by maximizing water reclamation and recycling. A separate report under development for this project synthesizes existing NbS projects in the region and the regulatory circumstances surrounding their authorization.

Projects under current consideration by wastewater agencies and regulatory agencies include those to advance horizontal levees at Oro Loma Sanitary District, Palo Alto Regional Water Quality Control Plant, and West County Wastewater District. The SF Bay Regional Water Quality Control Board authorized near-shore discharges for the City of Petaluma and Mt. View Sanitary District, and the agency adopted an NPDES permit in 2022 for a new open water polishing wetland and shallow near-shore discharge for the City of San Leandro.

REGULATORY CONSIDERATIONS

Bay Area WRRFs are subject to myriad regulations, some of which may inadvertently act in conflict with nutrient load reduction efforts. The regulatory landscape governs not just surface water discharges, but also water reuse, biosolids management, protected species and habitats, and air emissions. Project proponents and regulators have initiated discussions over potential approaches for mitigating these barriers; recommendations for quantitative analyses of potential conflicts; and options for regulatory and permit-based approaches to maximize the multi-functional benefits associated with NbS upgrades in the event of requirements to achieve significant nutrient load reductions. The final report for this regional NbS evaluation project shall feature a synthesis of the extensive regulatory considerations applicable to most WRRFs in Region 2.

Facility-specific permits, local ordinances, and site-specific plans feature requirements for each facility. Under Delta Diablo's 2019 NPDES permit (No. CA0038547), the facility hosts two (2) equalization basins and a larger (16 MG) emergency retention basin. Alternative 1, discussed below, considers the modification of the Emergency Retention Basin. Regulatory agencies generally exclude existing elements of a wastewater treatment train, including equalization ponds, from waters of the U.S., thus minimizing wetlands-related mitigation considerations.

For regulatory purposes, the San Francisco Bay Regional Water Quality Control Board recently provided guidance and continues to establish a precedent for permitting discharges of treated effluent from NbS projects in the region.[1] On-going consultations with other regulatory agencies for similar projects also serve to continually inform opportunities and constraints

1. "NPDES Permitting for Nature-based Solutions," 2022, San Francisco Bay Regional Water Quality Control Board.

regarding mitigation and monitoring requirements, desired treatment performance, and the appropriate quantification of ancillary benefits, including habitat enhancement, water reclamation, and community benefits.

The ancillary benefits of pursuing any option presented here include, at a minimum, additional reductions in dry weather discharges to New York Slough and the enhancement of habitat quality and quantity. Other potential benefits include recreation and education opportunities, demonstration of novel NbS strategies, and water quality improvement within a designated Disadvantaged Community. Pending refinement of these concepts, this memorandum aims to quantify these and other likely benefits and impacts. Quantifying such benefits enables regulatory agencies to weigh the net environmental benefits associated with a project.

Emergency Retention Basin

Figure 7. Conceptual design options

Option 1: Convert part or all of the Emergency Retention Basin to open water wetlands.

Option 2: Convert the newly purchased property southwest of the plant to an open water wetland.

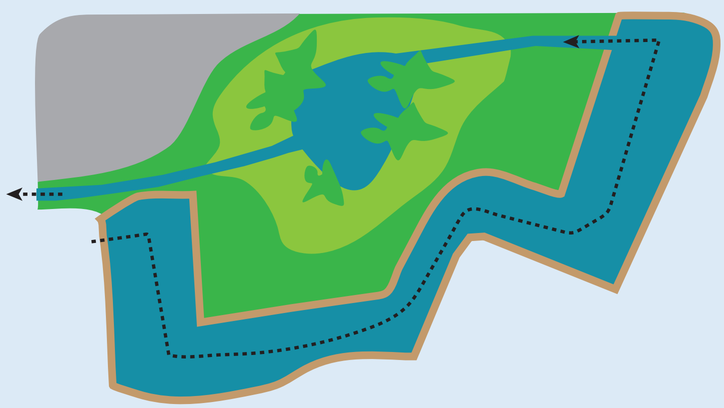
Option 3: Coordinate with BNSF and Corteva Preserve to construct a horizontal levee north of the rail line.

CONCEPTUAL DESIGN OPTIONS

To date, this project identified three main nature-based options for a multi-benefit nutrient load management strategy for Delta Diablo (Figure 7). These could be standalone options or combined as elements of a larger strategy. Options 1 and 2 are located on Delta Diablo property, while Option 3 involves a footprint outside the treatment plant. Implementation of any of these options is contingent upon a nitrification upgrade. These options could be suitable for treating either blowdown or plant effluent.

OPTION 1

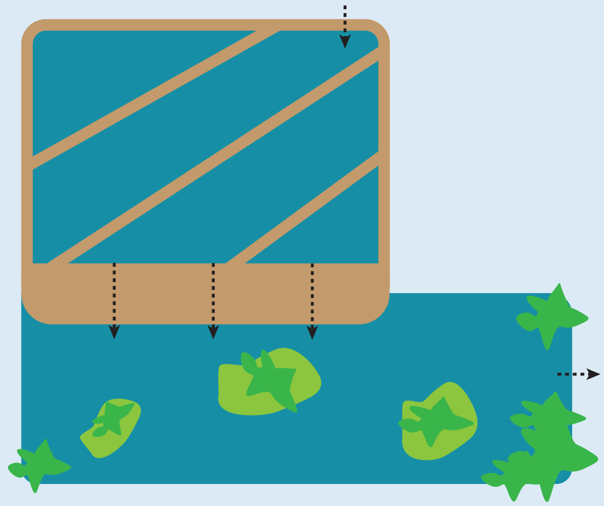
Convert part or all of the Emergency Storage Basin (ERB) in the northeast of the plant to open-water treatment wetlands. The basin could be segmented to allow the integration of multiple open-water wetland types in sequence, each segment designed to maximize a different benefit (e.g., nutrient load reduction and wildlife habitat). Numerous designs are possible and could include various types of vegetated and unvegetated wetlands. An engineered shallow open-water treatment cell could be formed to maximize the removal of nutrients and contaminants of emerging concern. Regardless of the design option, basin capacity must be maintained to ensure adequate storage capacity for plant effluent and stormwater management. Cells could be designed to be drained down in case additional emergency storage is needed.



Example concept sketch demonstrating option 1.
In this example, plant effluent is first routed through an open water treatment cell optimized for denitrification, then to a vegetated open water wetland optimized for habitat benefits. A third section of the basin (upper left) is reserved as an emergency holding basin.

OPTION 2

Convert the newly purchased property southwest of the plant (south of the administration building) to a treatment wetland. Depending on project goals, this option could also include multiple open-water wetland types to maximize various benefits. The large size of the parcel opens up a more comprehensive range of design opportunities than are available within the existing constraints of the holding basin (Option 1). However, this alternative requires the construction of a new basin and associated conveyance, along with additional pumping capacity, representing significant capital costs.



Example concept sketch demonstrating option 2.
In this example, plant effluent is routed first to an open water treatment cell optimized for denitrification, with woodchip baffles to minimize hydraulic short-circuiting. Water then flows through a woodchip seepage slope (providing a carbon source for denitrification) and into a vegetated open water wetland optimized for habitat benefits.

Recently acquired property at Delta Diablo.

OPTION 3

Example concept sketch demonstrating option 3.
Plant effluent is routed to a horizontal levee north of the plant, where it flows through a seepage slope designed to remove nutrients and other contaminants.

Looking north from Delta Diablo across BNSF tracks.

Construct a horizontal levee north of the BNSF tracks. A seepage slope could remove nutrients and contaminants of emerging concern from treated wastewater while providing additional benefits, including wildlife habitat and flood reduction. A horizontal levee in this location could expand freshwater and brackish marsh habitat at the Corteva Wetlands and help protect critical infrastructure from future sea-level rise by attenuating waves before they reach the rail embankment.

Because there is already upland habitat adjacent to the marsh, transition zone and high tide refuge habitat for tidal marsh wildlife are already available. However, reintroducing freshwater to the back of the marsh could increase the diversity and complexity of transition zone habitats by creating a salinity gradient and allowing a more comprehensive range of vegetation types to establish. Implementation of this option would require close coordination with BNSF and Corteva. This option would require placing fill in existing wetlands, and early coordination would be needed with regulatory agencies to weigh the short-term impacts versus long-term benefits of this action for habitats and species.

COMPARING OPTIONS

Table 1 lists goals of implementing NbS, and the relative contribution of each option toward meeting those goals. This allows for a high-level comparison of options. Further feasibility analysis will be conducted in collaboration with Delta Diablo staff to determine which options are most appropriate to pursue.

Table 1. Comparison of each option's relative contribution to achieving goals of NbS implementation.

● = Achieves. ◑ = Partially or possibly achieves. ○ = Does not achieve.

For TIN removal, 'Achieves' is>30% removal, 'Partially achieves' is 5-20% removal, and "Does not achieve is <5% removal.

	Option 1. (9-acre open water wetland in emergency storage basin)[1]	**Option 2.** (28-ac open water wetland at newly acquired parcel**)**	**Option 3.** (170-meter horizontal levee)[2]
Goal 1: Reduces nutrient loads to the Bay and improves overall water quality.			
Reduces TIN *Estimated dry-season reduction (kg d^{-1} / % reduction of daily TIN load)*	◑ *140 kg d^{-1} / 11%*	● *420 kg d^{-1} / 35%*	○ *22 kg d^{-1} / 2%*
Reduces contaminants of emerging concern	◑	●	○
Goal 2: Reduces flood risk for the plant and/or associated infrastructure.			
Attenuates waves and provides erosion resistance	○	○	●
Facilitates marsh accretion	○	○	●
Goal 3: Create and/or enhance habitat			
Provides marsh-upland transition zone habitat and marsh migration space	○	○	●
Provides high tide refuge habitat for tidal marsh wildlife	○	○	●
Increases habitat complexity	●	●	●
Provides freshwater pond/marsh habitat	●	●	●
Goal 4: Enhances recreational opportunities.			
Provides opportunity for public trails and wildlife viewing	○	◑	◑
Goal 5: Provides additional co-benefits.			
Reduces use of potable water for irrigation	○	○	○
Supports goals of partner organizations (e.g. facilitates neighboring restoration projects)	N/A	N/A	N/A

1. Options 1 & 2 assume treatment of nitrified effluent based on the 5-year average of existing dry weather TIN concentrations and creation of an unvegetated open water treatment wetland requiring 11.2 acres per mgd and shallow water depth of 0.3 meters to achieve 90% removal of nitrate (A90). Design-specific nitrate removal estimates available upon request. Jasper, J.T., Jones, Z.L., Sharp, J.O. and Sedlak, D.L., 2014. Nitrate removal in shallow, open-water treatment wetlands. Environmental science & technology, 48(19), pp.11512-11520.

2. Assumptions: horizontal levee with length: 170 meters, height: 3.1 meters, 10:1 slope, bed temperature of 20° C, 24-hr retention time, and woodchip media depth of 0.5 meters. Addy, K., Gold, A.J., Christianson, L.E., David, M.B., Schipper, L.A. and Ratigan, N.A., 2016. Denitrifying bioreactors for nitrate removal: A meta- analysis. Journal of Environmental Quality, 45(3), pp.873-881.

NEXT STEPS

Under Phase III of this project, SFEI and the engineering firm, HDR, shall produce cost estimates and planning-level designs to better inform implementation and overall viability. Key factors influencing the formulation of an NbS project for nutrient management at Delta Diablo include the interest in pursuing an early-actor nutrient reduction program; whether retrofits to the existing basin can support a treatment cell optimized for nutrient removal if sidestream concentrate or industrial blowdown is suitable for isolated treatment via NbS; and whether grant funding is made available for planning level designs and permitting consultations.

Delta Diablo's executive staff or Board of Directors have not evaluated NbS or considered the options presented herein. That said, Delta Diablo represents a strong candidate for moving forward to the design and advanced planning phase. SFEI recommends pursuing planning and outreach efforts while exploring funding opportunities at the regional (e.g., Measure AA), state (upcoming climate and water resilience programs), and federal levels (e.g., coastal resilience funding under the Bipartisan Infrastructure Law).

Site visit at Delta Diablo, October 19, 2021.

NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: FAIRFIELD-SUISUN SEWER DISTRICT

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All photos in this document courtesy of the authors.

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Fairfield-Suisun Wastewater Treatment Plant (Figures 1, 2) was one of the facilities identified as a high-potential site for NbS. The desktop analysis identified one opportunity for a horizontal levee south of the plant, and extensive opportunity for open water treatment wetlands in the undeveloped agricultural lands surrounding the plant.

Fairfield-Suisun Sewer District (FSSD) was created in 1951 and currently serves about 147,000 customers in Fairfield, Suisun City, and Travis Air Force Base. The current Fairfield-Suisun Wastewater Treatment Plant, located at 1010 Chadbourne Rd in Fairfield, was completed in 1974 and has undergone several expansions since then. Dry weather permitted capacity is 23.7 mgd and actual average dry weather flows are about 11 mgd. Treated wastewater is discharged to Boynton Slough to the south and Ledgewood Creek to the north.

The FSSD treatment plant recycles about 10% of flows for irrigation of nearby agricultural lands. With full nitrification capability, Fairfield-Suisun Sewer District is well-situated to expand the provision of recycled water and/or implement other types of nature-based solutions like treatment wetlands or horizontal levees, especially given the abundance of open space near the plant and along existing discharge pathways. Existing available land on FSSD property is likely sufficient for NbS, and partnerships or purchases would need to be explored for NbS to expand onto adjacent privately owned land.

Figure 1. Site in context

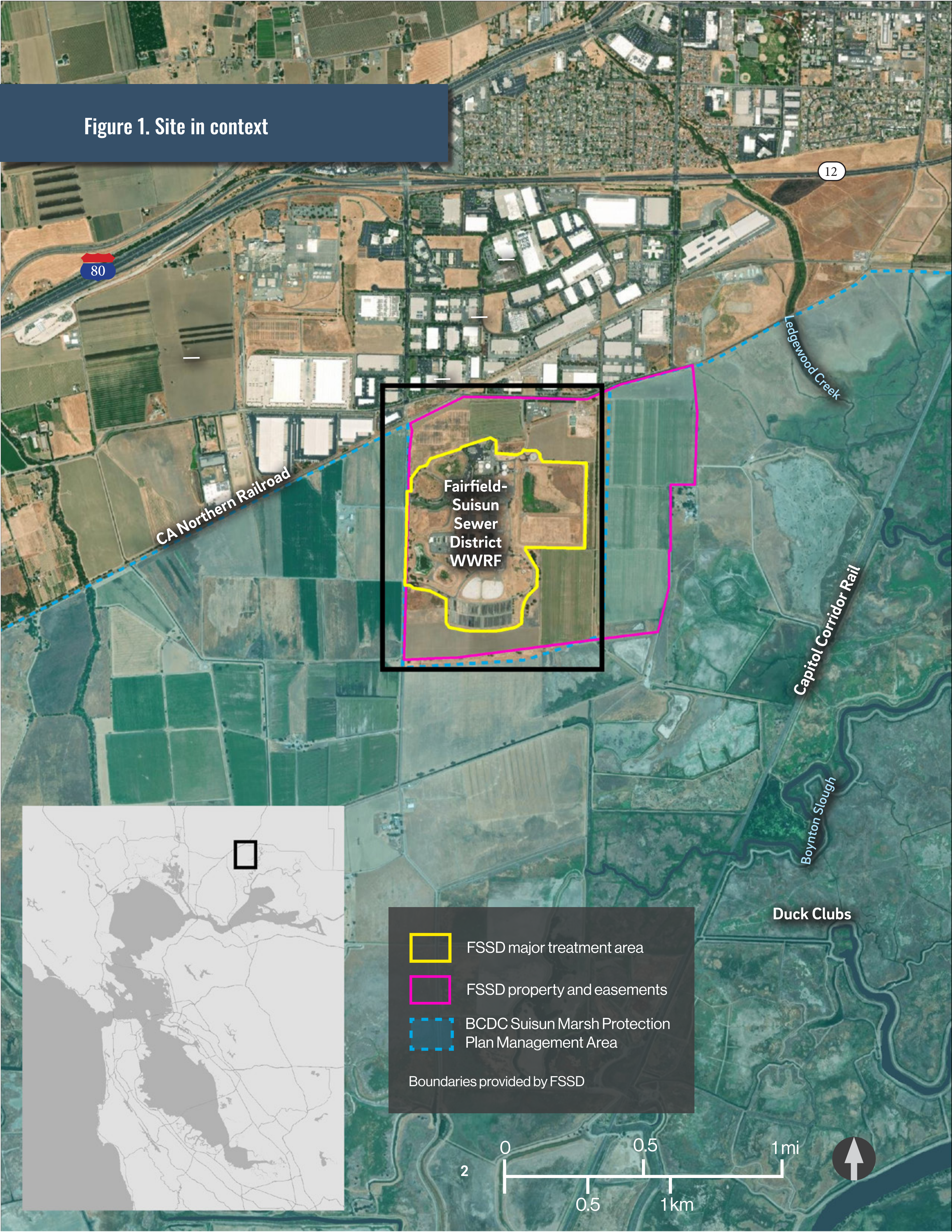


Figure 2. Site detail

Facility information provided by FSSD

SITE OVERVIEW

ECOLOGY

Historical ecology mapping shows the extensive Suisun Marsh complex south of the FSSD wastewater treatment plant (Figure 3). Tidal marsh habitat was much more widespread in the area prior to reclamation, which began starting in the 1850s, and little of the original marsh remains today (Figure 4). Though some of the marsh was converted for agricultural and other uses, today most of the historical marsh plain of Suisun Marsh (about 80%) is managed as private duck clubs. Duck club properties are optimized for the type of shallow, open water habitat that game birds prefer and have subsided below sea level. The remaining tidal areas of Suisun Marsh still provide essential habitat for fish and other species, and both the duck clubs and tidal marsh provide important stopover habitat for migratory waterbirds. Sloughs like Boynton Slough, where flows from FSSD are discharged, provide connections to the rest of the San Francisco Estuary. Unlike many other facilities, the FSSD plant is not constructed within the footprint of historical tidal marsh. Instead, it is located in the wetland-upland transition zone just above today's tidal elevations.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

The Fairfield-Suisun Wastewater Treatment Plant is located near several major transportation corridors. I-80 and the CA Northern rail line run to the north of the site and an Amtrak line (Capitol Corridor) runs to the south of the site (Figure 5). Most land near the plant is under private ownership. The exception is the Grey Goose Unit of the Grizzly Island Wildlife Area to the south of the treatment plant, managed by the California Department of Fish and Wildlife and accessible only by boat.

The wastewater plant is located within a census tract designated as an Equity Priority Community (EPC) by MTC, the Metropolitan Transportation Commission. EPCs are defined by the MTC as census tracts that have a significant concentration of underserved populations, such as households with low incomes and people of color. EPCs are designated for more significant future investment in services, housing, and transportation. Parts of the City of Fairfield and the City of Suisun City, northeast of the wastewater plant, are also designated as EPCs and Priority Development Areas (PDAs) by MTC. PDAs are places near public transit planned for more housing and amenities. The census tract the wastewater plant falls within is considered a disadvantaged community for the purposes of California SB 535.

LAND USE & OWNERSHIP

FSSD owns the oat and alfalfa fields directly east of the plant and the agricultural parcels to the south. Much of the surrounding land is under private ownership. To the west are privately held agricultural fields, to the south are privately held cattle ranching pastures, and to the east are privately held duck hunting clubs. Most FSSD property is excluded from BCDC's Suisun Marsh Protection Plan Management Area, though the fields east of the plant are within the boundary (Figure 1).

FLOODING & SEA-LEVEL RISE VULNERABILITY

The FSSD main treatment plant is expected to experience impacts of SLR in the long term (i.e. 2100 and beyond). However, SLR is already impacting plant operations. According to FSSD staff, under today's conditions, there is reduced outfall capacity at Boynton Slough during high tide events, requiring the use of the Ledgewood Creek outfall to maintain adequate flow through the plant during wet weather events. The combined impacts of higher tides and more extreme storm events in the future are likely to exacerbate these impacts. Figure 6 shows predicted flooding under multiple sea-level rise scenarios, based on data from the ART Bay Area Flood Explorer. With higher amounts of sea-level rise (7 ft above today's MHHW), water levels will start to encroach closer to the plant itself. The lowest-lying part of the site is the field in the southeast corner. Impacts of groundwater rise due to rising sea levels should also be considered, particularly for basins subject to seepage and any belowground infrastructure.

Agricultural fields east of the FSSD plant

Figure 3. Historical bayland habitats

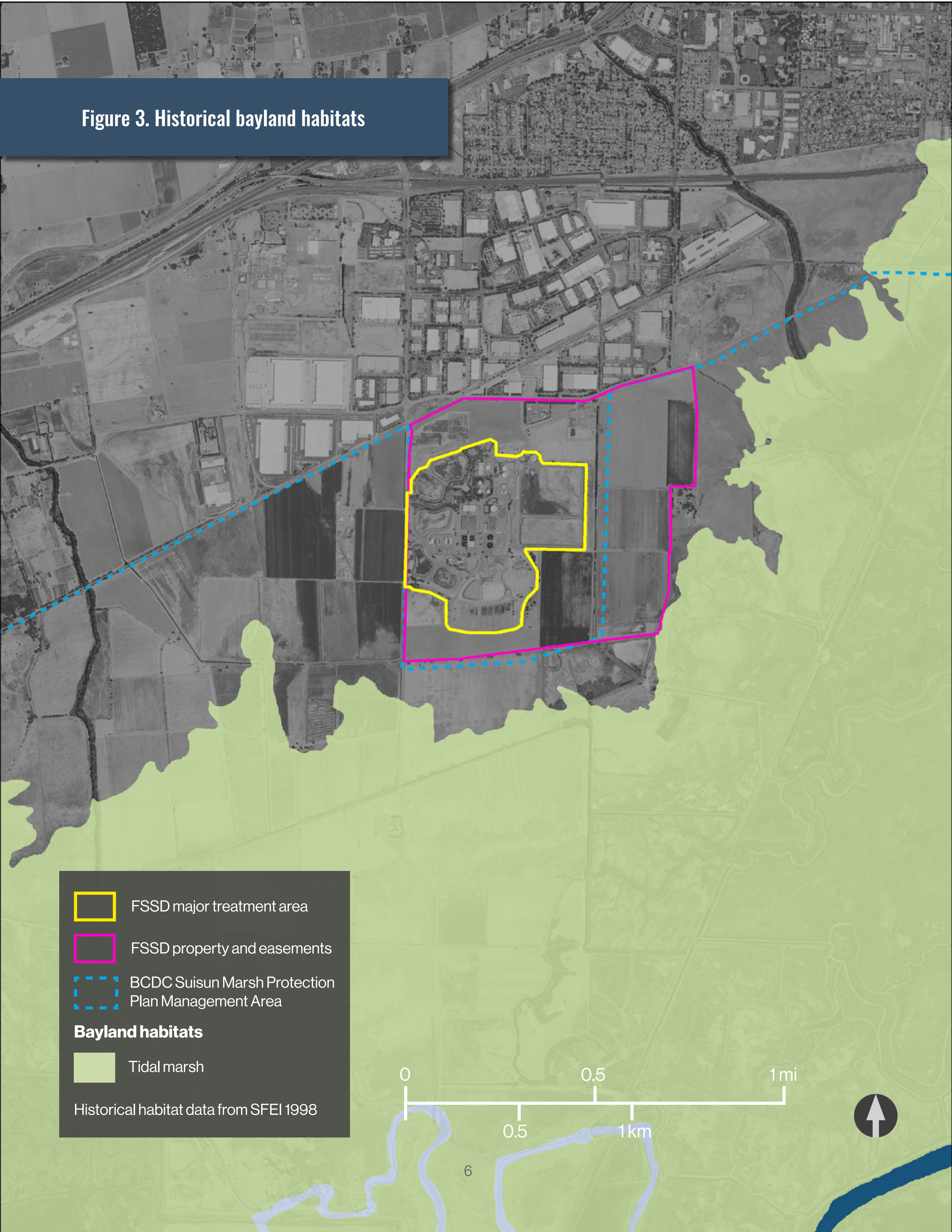


Figure 4. Modern bayland habitats

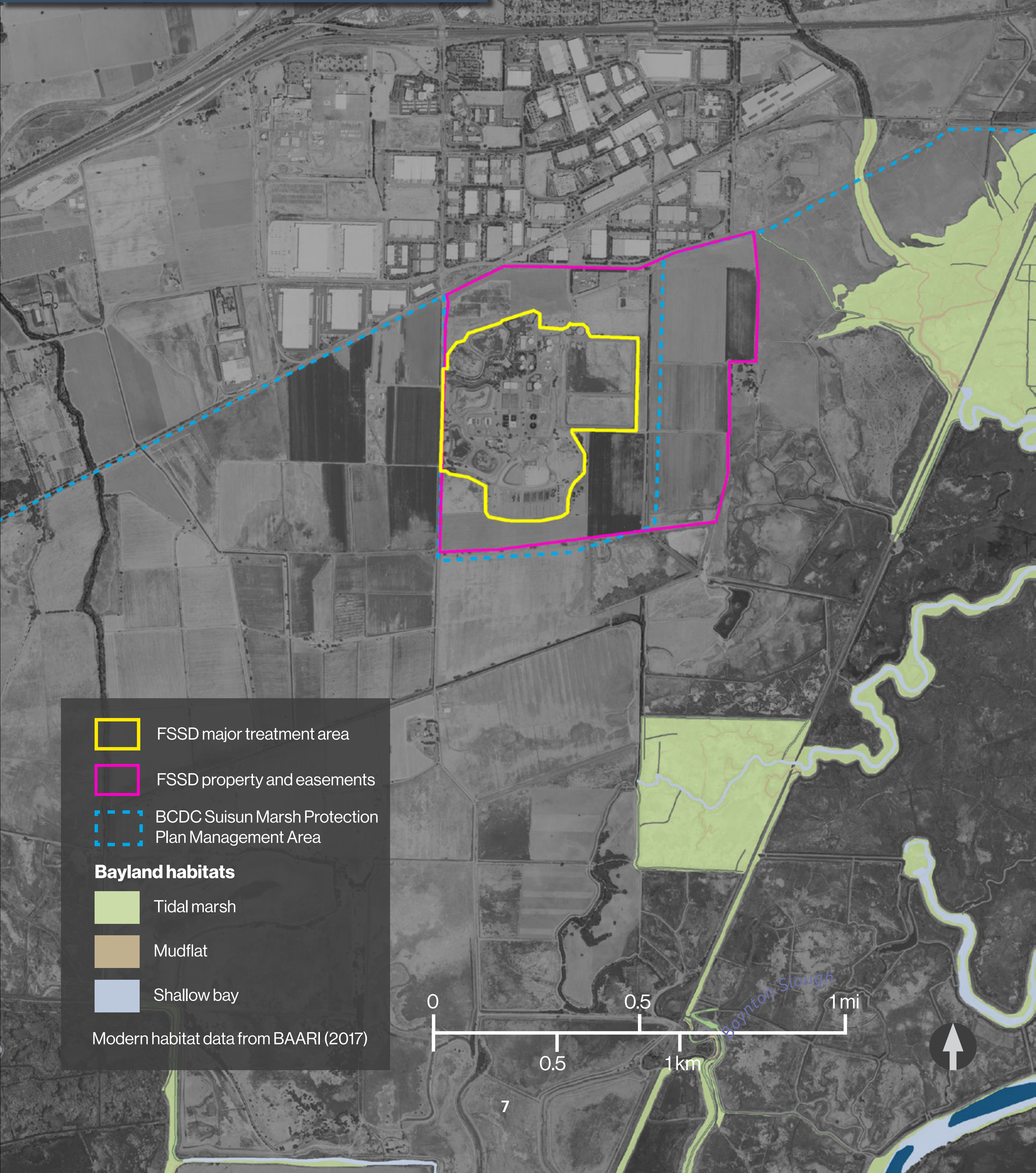


Figure 5. Infrastructure, recreation, & disadvantaged communities

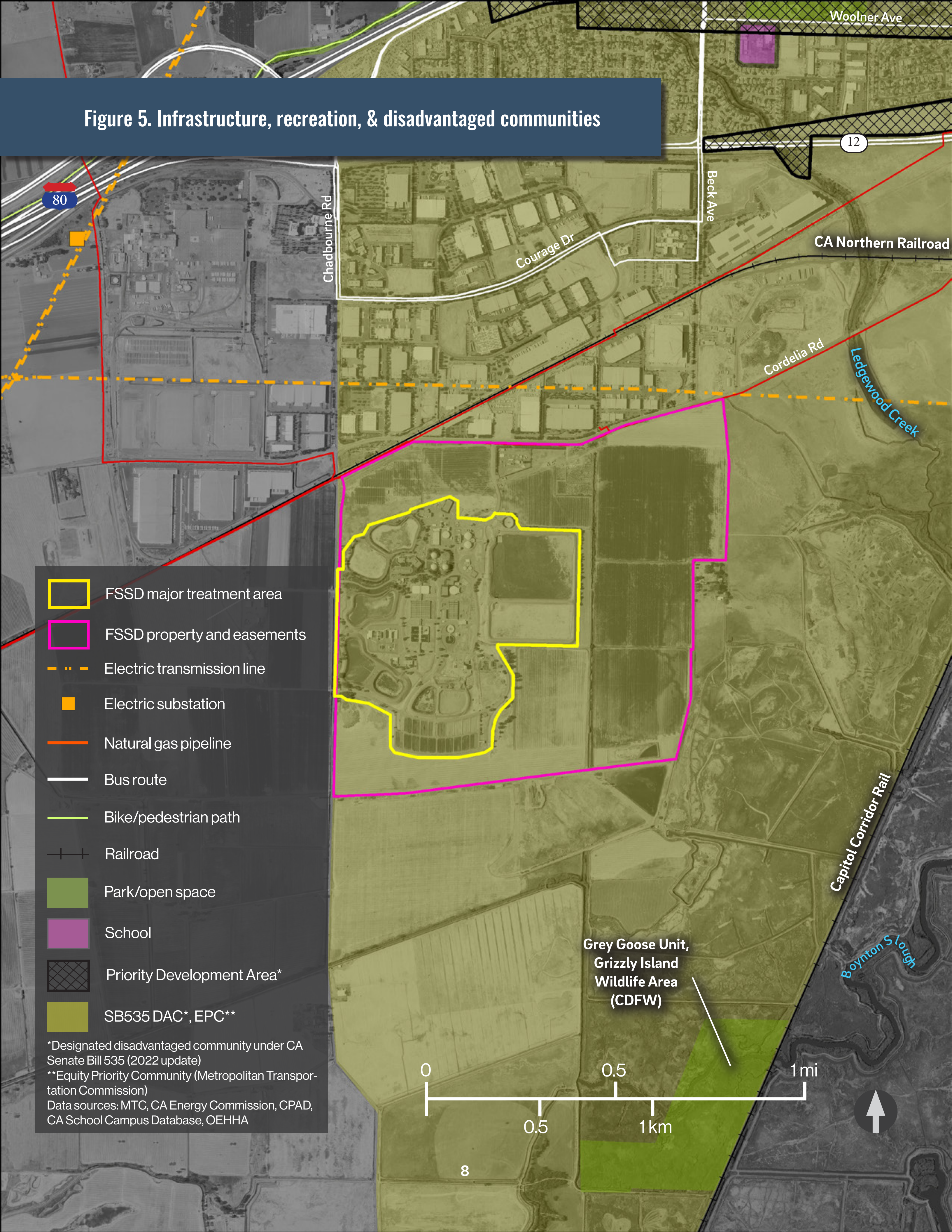
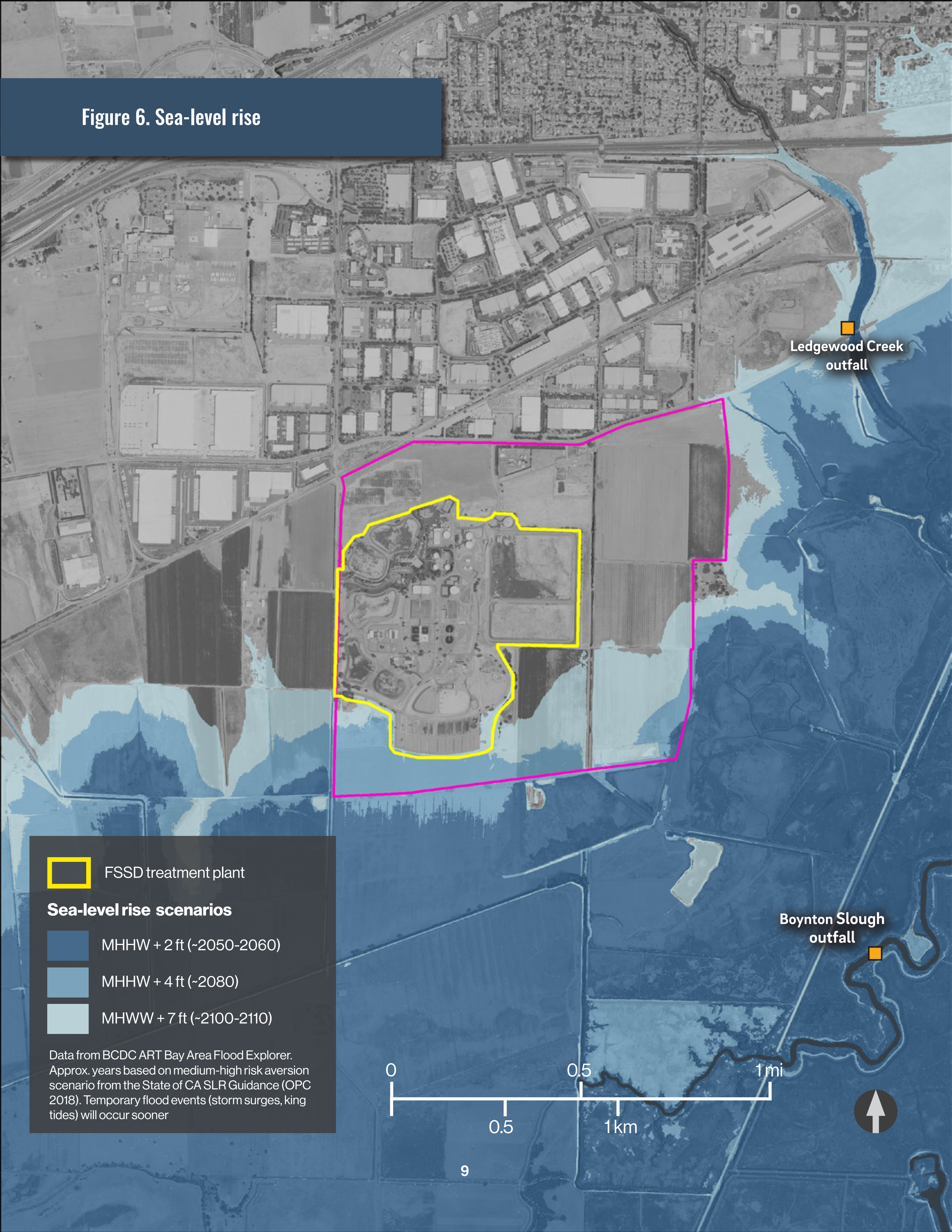


Figure 6. Sea-level rise



RECENT & PLANNED CHANGES AT FSSD

In the last decade, FSSD has formed public-private partnerships and made lease agreements with companies promoting resource recovery innovation. More recently, the District embarked on a master planning process focused on sustainability and green infrastructure.

One partnership involves the Lystek Organic Material Recovery Center, which operates on District property and transforms organic materials diverted away from landfills into an organically-based, bio-fertilizer product called LysteGro. The result generates economic and environmental benefits while supporting the evolution toward a circular economy. More recently, FSSD is proposing to lease land to Aries Fairfield LLC to allow the construction and operation of a biomass processing facility that would assist the District in the processing and reduction of biomass (wet biosolids and wood waste) to produce renewable thermal energy, renewable electricity, and carbon products.

Currently, FSSD is developing a Resilient & Green Plant-wide Master Plan to identify a diversity of projects that promote sustainability, equity, and climate resilience. The types of projects the District proposes to consider during Master Plan development include, but are not limited to:

1. Native plant restoration to sequester carbon. Including ice plant removal, tree planting, ephemeral channel habitat restoration, and lawn replacement;
2. Green stormwater infrastructure showcased in parking lots;
3. Maximizing on-site recycled water use and/or capture of roof runoff from buildings. With potential reuse opportunities to consider including flushing toilets, irrigation, and vehicle washing;
4. Freshwater wetland restoration in Final Effluent Holding Reservoirs;
5. Developing new spaces and trails for community access;
6. Ecotone / Horizontal Levee creation potentially linked to nitrogen management of effluent, climate adaptation, and habitat connectivity benefits; and a
7. Community-Supported Anaerobic Digestion Project.

The options discussed in this memo are consistent with these Master Plan proposals, particularly the proposals to develop wetland restoration horizontal/ecotone levee projects.

RECENT & PLANNED CHANGES NEARBY

Plans are in development for a new Pacific Flyway Center to be located along I-680 in Cordelia, only a few miles away from the Fairfield-Suisun Sewer District. The Flyway Center's goal is to "inspire conservation of the Pacific Flyway" and it is anticipated to include an education center as well as trails through constructed wetlands on former agricultural land. There may be a partnership opportunity for FSSD to provide recycled water to future managed wetlands created at the Flyway Center. These wetlands could achieve multiple benefits, including nutrient reduction as well as habitat for waterfowl and public recreation and education opportunities.

FSSD is also collaborating with nearby cities and communities to develop nature-based climate adaptation solutions that benefit diverse stakeholders, making both public infrastructure and private properties more resilient in the future. One example is the Kellogg Resiliency project which aims to create a nature-based solution to protect people, optimize infrastructure, and safeguard a stable and biodiverse future at a low-lying pump station in Suisun City vulnerable to sea level rise, flooding, and fire.

OPPORTUNITIES & CONSTRAINTS

Conversations with FSSD staff illuminated opportunities and constraints for implementation of NbS at FSSD beyond what was identified through the desktop analysis. In particular, opportunities to use underutilized existing basins and vacant land at the FSSD plant were identified. These areas include the final effluent holding ponds in the northwest corner of the site, the southern wet weather equalization/summer maintenance storage pond on the east side of the site and the dry-farmed area in the southwest corner of the site. The use of existing basins may be particularly attractive due to reduced construction costs.

There may also be opportunities to explore partnerships with surrounding agricultural lands and duck clubs as NbS sites. Some associations exist with local duck clubs, as FSSD discharges some treated wastewater to the duck clubs during the winter months. Higher-elevation agricultural areas may be more attractive than duck clubs as long-term NbS locations. They are less vulnerable to sea-level rise and less valuable as future tidal marsh restoration sites. Developing an open-water wetland as an essential element of a nutrient management strategy on subsided duck club land could mean it needs to be protected from sea-level rise in perpetuity. However, a temporary freshwater wetland could be designed intentionally to facilitate future tidal restoration. Treated wastewater could be used to create a freshwater marsh to build up organic matter (peat). This would increase the elevation of the duck clubs in advance of tidal restoration, increasing resilience of the marsh and the FSSD plant to future sea-level rise. Subsidence-reversal wetlands like this are being tested at Sherman and Twitchell Islands. The wetland would also sequester carbon and could be eligible for saleable carbon credits. Cost-benefit analysis specific to the site would need to be undertaken to determine the financial viability of pursuing the carbon offsets validation/verification process. There would also be an opportunity to use the site for research on carbon capture specific to treatment wetlands.

Given the lack of public land and parks in the vicinity of the FSSD, there is a significant opportunity to establish publicly-accessible NbS to serve as a public open space with educational and recreational value. For example, the prominent location of the existing effluent holding ponds at the northwest border of the treatment plant site present good opportunities for public access.

ADDITIONAL CONSIDERATIONS

PRECEDENT

Wastewater agencies in the North Bay have for several decades been subject to several Discharge Prohibitions from the San Francisco Bay Water Quality Control Plan (Basin Plan) to protect Suisun Bay along with sloughs and tributaries. This has resulted in efforts to maximize water reclamation and recycling in the area, though FSSD is permitted to discharge to Boynton Slough to the south and Ledgewood Creek to the north, under certain criteria. A separate report under development for this project synthesizes existing NbS projects in the region and the regulatory circumstances surrounding their authorization.

Projects under current consideration by wastewater agencies and regulatory agencies include those to advance horizontal levees at Oro Loma Sanitary District, Palo Alto Regional Water Quality Control Plant, and West County Wastewater District. Open water wetlands were authorized for near shore discharge for the City of Petaluma and Mt. View Sanitary District, and a 2022 NPDES permit was adopted for a new open water polishing wetland for the City of San Leandro.

REGULATORY CONSIDERATIONS

Bay Area WRRFs are subject to myriad regulations, some of which may inadvertently act in conflict with nutrient load reduction efforts. The regulatory landscape governs not just surface water discharges, but also water reuse, biosolids management, protected species and habitats, and air emissions. Project proponents and regulators have initiated discussions over potential approaches for mitigating these barriers, recommendations for quantitative analyses of potential conflicts, and options for regulatory and permit-based approaches to maximize the multi-functional benefits associated with NbS upgrades, in the event large-scale nutrient load reductions are warranted. The final report for this regional NbS evaluation project shall feature a synthesis of the extensive regulatory considerations applicable to most WRRFs in Region 2.

Facility-specific permits, local ordinances, and site-specific plans feature requirements for each facility. In general, FSSD faces significantly fewer regulatory hurdles, compared with other WRRFs in the region located closer to San Francisco Bay and the urban core of the region. Factors contributing to this conclusion include the fact that FSSD owns much of the land surrounding the facility, an existing NPDES permit allows for shallow water discharges already, and several of the design options presented involve retrofitting of existing basins. Regulatory agencies generally exclude existing elements of a wastewater treatment train, including equalization ponds, from waters of the U.S., thus minimizing wetlands-related mitigation considerations.

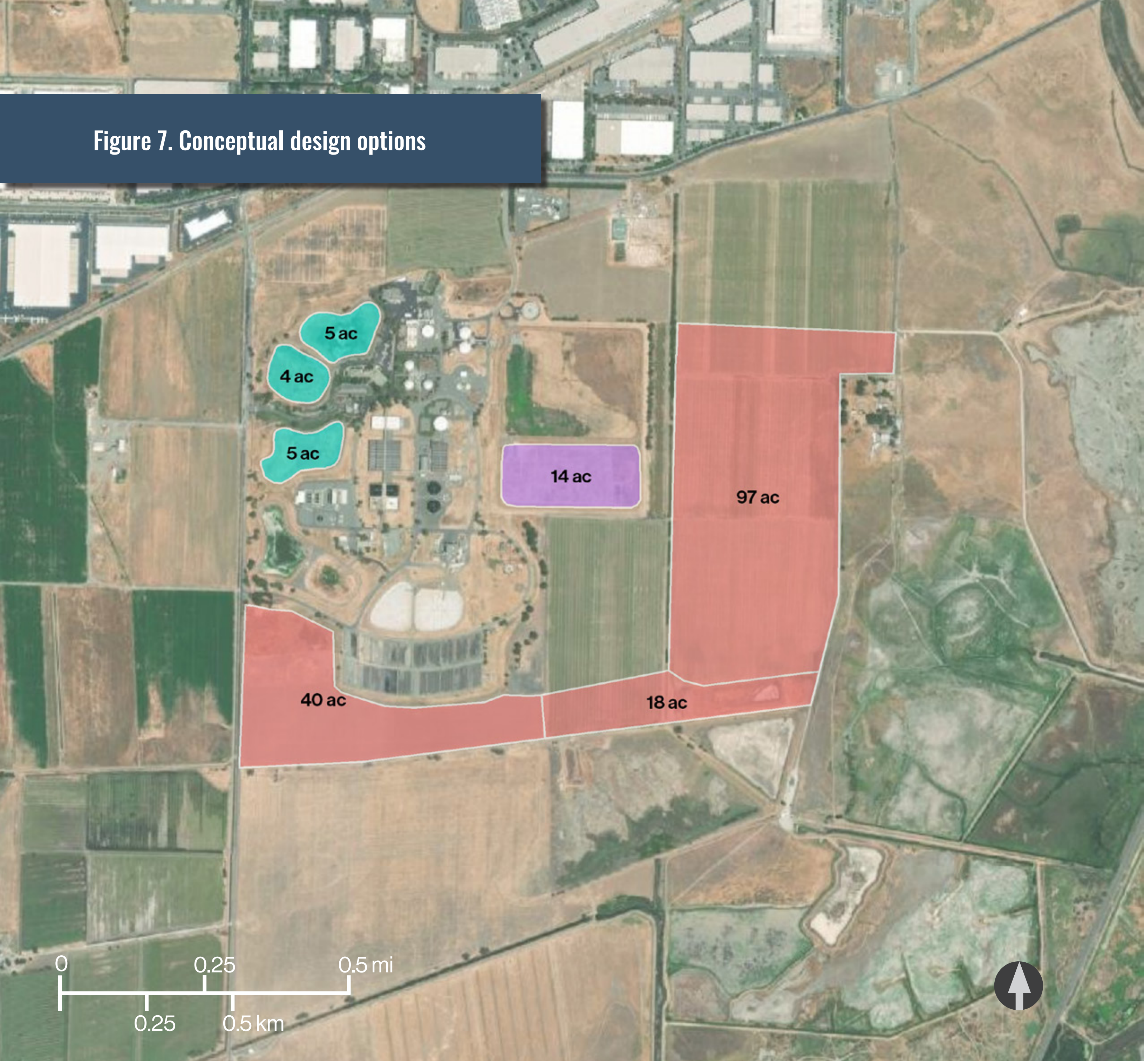
For regulatory purposes, the San Francisco Bay Regional Water Quality Control Board recently provided guidance and continues to establish precedent for permitting discharges of treated effluent from NbS projects in the region.[1] On-going consultations with other regulatory agencies for similar projects also serve to continually inform opportunities and constraints, in terms of mitigation and monitoring requirements, desired treatment performance, and the appropriate quantification of ancillary benefits, including habitat enhancement, water reclamation, and community benefits.

The ancillary benefits of pursuing any option presented here include, at a minimum, additional reductions in dry weather discharges to Suisun Marsh and the enhancement of habitat quality and quantity. Other potential benefits include recreation and education opportunities, demonstration of novel NbS strategies, and sea-level rise adaptation and resilience of FSSD and surrounding areas. Pending refinement of these concepts, this memorandum aims to quantify these and other likely benefits and impacts. Quantification of such benefits enables regulatory agencies to weigh the net environmental benefits associated with a project.

1 "NPDES Permitting for Nature-based Solutions," 2022, San Francisco Bay Regional Water Quality Control Board.

Final effluent holding reservoir

Figure 7. Conceptual design options



Option 1: Convert former final effluent ponds into train of open water wetlands optimized for various purposes

Option 2: Dual-purpose wet-weather equalization / open water treatment cell with seepage slope sides

Option 3: Construct perimeter horizontal levee in phases. Eventually reconnect to restored tidal marsh (Option 4)

Option 4: Convert the 97-acre parcel to a multi-benefit wastewater polishing wetland. Future phases may include construction of polishing wetlands in the parcels the south of the plant and partnerships with duck clubs to construct temporary freshwater wetlands to build peat (elevation) and prepare for future tidal restoration.

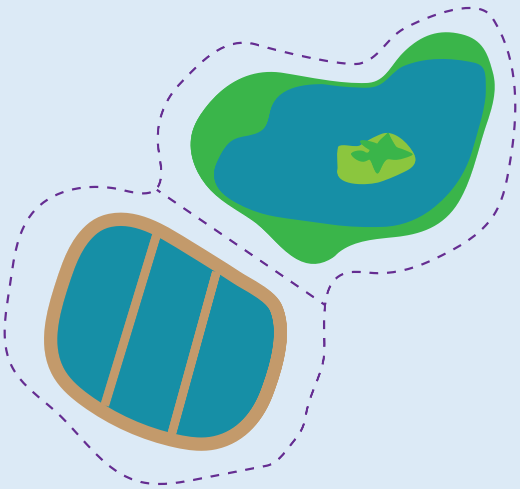
CONCEPTUAL DESIGN OPTIONS

Four main nature-based options for a multi-benefit nutrient load management strategy at FSSD have been identified (Figure 7). These could be standalone options or could be combined as elements of a larger strategy. Given interest in multibenefit NbS solutions at FSSD, some of the options could be optimized for wildlife habitat and recreation while others are optimized for nutrient removal.

Options presented in this report reflect land ownership constraints, based on consultation with District staff. FSSD holds a considerable amount of land and wet weather storage ponds at its facility. However, FSSD does not own the duck ponds to the southeast, and FSSD leases the agricultural parcels to the east of existing wet weather storage areas for active use. Additional considerations that have not received full consideration include implementation costs, regulatory constraints, and competing demands for space and existing wet weather storage capacity at the facility.

OPTION 1

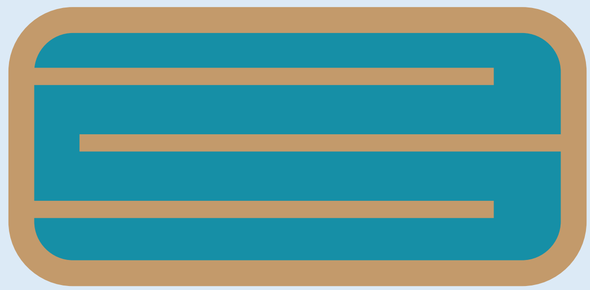
Convert one or more of the effluent holding ponds in the northwest area of the plant to a train of ponds or segmented sections optimized separately for ecological enhancement and nutrient removal. These holding ponds are currently underutilized and could be repurposed to achieve multiple benefits. The train of ponds could provide a valuable recreational opportunity in an underserved area with minimal access to parks. This could include wildlife viewing opportunities as well as educational components including signage describing the design and purpose of each pond. The series could include 1-2 unvegetated ponds optimized for nutrient and contaminants of emerging concern (CEC) removal and 1-2 vegetated ponds optimized for waterbird habitat.



Example concept sketch demonstrating Option 1. The open water treatment cell on the left is optimized for denitrification - with woodchip seepage slopes and baffles to minimize hydraulic short-circuiting. The pond on the right is a vegetated open water wetland with a habitat island. A trail with educational signage (purple dotted line) surrounds the two ponds.

OPTION 2

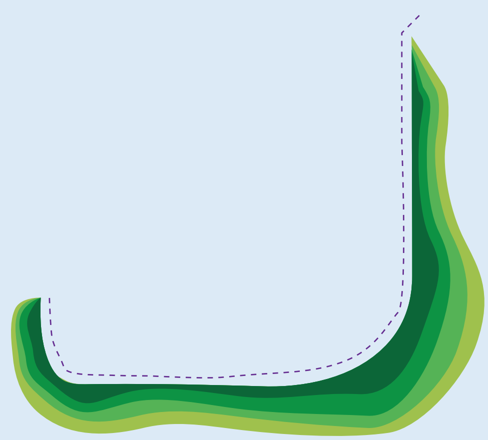
Use the southern wet weather equalization lagoon to the east of the site for both wet weather storage and dry weather polishing. The dual-purpose basin would be designed and optimized for nutrient removal when not in use for stormwater equalization. One potential design to explore is an open water treatment cell with seepage slope sides. This basin is currently used for equalization about once per year during peak flows when the northern basin is full. Continued capacity would need to be ensured if the basin was redesigned for dual purposes. When needed, the basin would be drained to ensure adequate equalization capacity. There are design and maintenance challenges to overcome with dual-use systems (e.g. impacts of raw sewage fouling on the biomat where denitrification occurs, need to drain in advance of major storm events, etc.). Given the large amount of open space and alternative options available at FSSD, this option is worth consideration but less likely to be implemented.



Example concept sketch demonstrating option 2.
Convert the southern equalization lagoon to a dual-purpose storage and nutrient removal basin. One option is conversion to a shallow open water treatment cell, routing treated effluent through woodchip seepage slopes.

OPTION 3

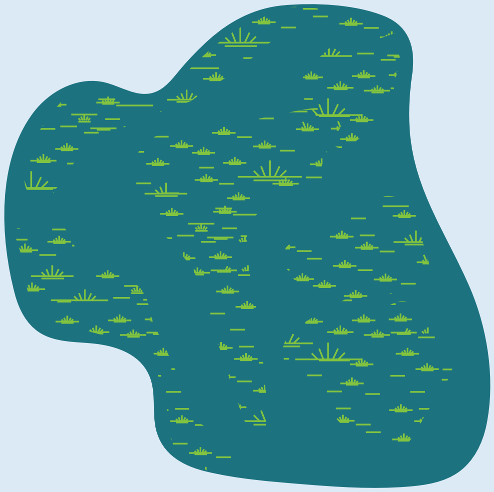
Build a horizontal levee around the treatment plant on the farmed parcels to the south and east. The levee could be developed in phases, with the first phase on the parcels to the east or south of the plant, and later phases completing the ring with a levee on the edge of the southeast parcel. Initially, the purpose of the horizontal levee would be nutrient removal, with additional co-benefits if tidal marsh is restored bayward of the levee. The horizontal levee could be designed to include trails for public access, recreation, and education. Figure 7 shows the parcels where the horizontal levee could be constructed. The actual construction footprint would be smaller than these parcels and can be determined in later design stages. The design would need to be integrated with the design of future flood risk management infrastructure needed to protect the plant.



Example concept sketch demonstrating option 3.
A horizontal levee/seepage slope is located to the south and east of the plant. An option includes adding recreational access at the top of the flood levee behind the seepage slope for public access and educational/wildlife viewing opportunities.

OPTION 4

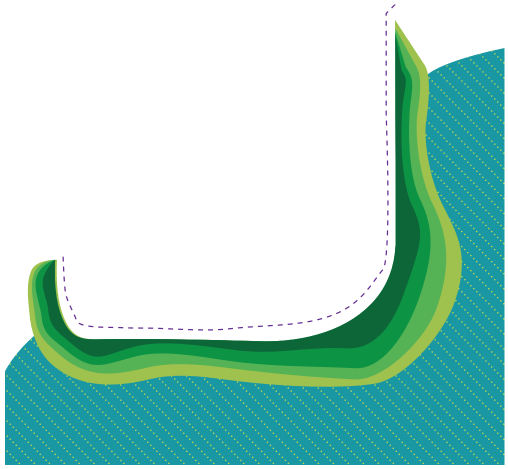
Convert the 97-acre agricultural parcel to the east of the treatment plant to a treatment wetland for wastewater polishing, education, and possible recreation. Other areas potentially suitable for conversion to freshwater marsh include the 40- and 18-acre parcels south of the plant and nearby duck clubs. Based on management priorities, the area could serve long-term wastewater treatment purposes or be encouraged to build a peat layer to increase land elevation and sea-level rise resilience. As maintenance of perimeter dikes becomes more challenging with sea-level rise, strategic breaches may connect the area to tidal influence via Suisun Marsh sloughs. Eventually, the marsh could migrate upland toward a horizontal levee, if incorporated with Option 3, and freshwater flowing through the horizontal levee could be discharged in a diffuse manner to the tidal marsh. This option would enhance the connectivity of the landscape to Suisun Marsh and increase the resilience of the wastewater plant and surrounding lands to sea-level rise.



Example concept sketch demonstrating option 4. Treated wastewater is used to create a temporary freshwater wetland to build up organic matter for increasing elevation and resilience to sea-level rise.

INTEGRATION OF OPTIONS 3 & 4

Options 3 and 4 can be combined into a phased adaptation pathway for nutrient removal and sea-level rise adaptation. In the first phase, a freshwater wetland is created in adjacent parcels and possibly nearby duck clubs, which are low-lying and could be managed to build elevation with organic material over time. In the second phase, horizontal levees are constructed around the plant and employed for nutrient removal. In the third phase, the freshwater wetland is opened up to tidal action and a broad fresh-to-brackish wetland complex is allowed to develop, connecting to the toe of the horizontal levee slopes. In addition to nutrient removal, the horizontal levee provides co-benefits including flood protection for the treatment plant, a habitat salinity gradient, and transitional habitat for marsh species.



Example concept sketch demonstrating the integration of options 3 and 4. In the long term, sea-level rise may make continued maintenance of dikes surrounding the proposed polishing wetland infeasible, and tidal restoration may be pursued. At this point, tidal marsh could move inland and upland and connect to the toe of the horizontal levee.

COMPARING OPTIONS

Table 1 lists goals of implementing NbS, and the relative contribution of each option toward meeting those goals. This allows for a high-level comparison of options. Further feasibility analysis will be conducted in collaboration with FSSD staff to determine which options are most appropriate to pursue.

Table 1. Comparison of each option's relative contribution to achieving goals of NbS implementation.

● = Achieves. ◑ = Partially achieves. ○ = Does not achieve.

For TIN removal, 'Achieves' is>30% removal, 'Partially achieves' is 5-20% removal, and "Does not achieve is <5% removal.

	Option 1. Convert former final effluent ponds into train of wetlands optimized for various purposes (14-ac total)[1]	**Option 2.** Dual purpose wet weather equalization / open water treatment cell with seepage slope sides (155-ac total)	**Option 3.** 2.4-km horizontal levee along the interior portions of the three potential freshwater wetland cells[2]	**Option 4.** Convert the 97-acre parcel to a multi-benefit wastewater polishing wetland
Goal 1: Reduces nutrient loads to the Bay and improves overall water quality.				
Reduces TIN *Estimated dry-season reduction (kg d-1 / % reduction of daily TIN load)*	● *100 kg d-1 / 10%*	● *1,200 kg d-1 potential / 100%*	◑ *310 kg d-1 / 30%*	● *730 kg d-1 / 70%*
Reduces CECs	●	●	●	●
Goal 2: Reduces flood risk for the plant and/or associated infrastructure.				
Attenuates waves and provides erosion resistance	○	○	●	●
Facilitates marsh accretion	○	○	○	●
Goal 3: Create and/or enhance habitat				
Provides marsh-upland transition zone habitat and marsh migration space	○	○	●	○
Provides high tide refuge habitat for wildlife	○	○	●	○
Increases habitat complexity	●	◑	●	●
Provides freshwater pond/marsh habitat	●	◑	●	●
Goal 4: Enhances recreational opportunities.				
Provides opportunity for public trails and wildlife viewing	●	○	●	●
Goal 5: Provides additional co-benefits.				
Reduces use of potable water for irrigation	○	○	○	○
Supports goals of partner organizations (e.g. facilitates neighboring restoration projects)	N/A	N/A	N/A	N/A

1. Options 1, 2, and 4 assume treatment of nitrified effluent based on dry weather TIN concentrations and creation of an unvegetated open water treatment wetland requiring 11.2 acres per MGD and shallow water depth of 0.3 meters to achieve 90% removal of nitrate (A90) (Jasper et al 2014). Design-specific nitrate removal estimates available upon request.

2. Assumptions: horizontal levee with length: 2.4 kilometers, height: 3.1 meters, 10:1 slope, bed temperature of 20° C, 24-hr retention time, and woodchip media depth of 0.5 meters. Nitrate removal rates based on Addy et al 2016.

NEXT STEPS

In the event this facility is selected for consideration under Phase 3 of this project, cost estimates and planning-level designs shall be produced to better inform implementation options and overall viability. FSSD has demonstrated a keen interest in pursuing nature-based treatment and wider green infrastructure-based projects at their WRRF and represents a strong candidate for moving forward to the design and advanced planning phase. Currently, FSSD is coordinating with partnering agencies to fund design and permitting processes in parallel with this evaluation project.

Wet weather equalization lagoons (southern lagoon is on the right side).

NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: NOVATO SANITARY DISTRICT

BACWA
BAY AREA
CLEAN WATER
AGENCIES

SFEI | AQUATIC SCIENCE CENTER

PREPARED BY
San Francisco Estuary Institute

PREPARED FOR
Bay Area Clean Water Agencies

AUTHORS
Ellen Plane
Ian Wren

CONTENTS

Version 2 (April 2023).

All photos in this document courtesy of the authors.

INTRODUCTION

The first phase of analysis (Phase I) of the Nature-Based Solutions for Nutrient Reduction study involved a regional-scale desktop analysis in determining which Bay Area water resource recovery facilities (WRRFs) have opportunities for implementing nature-based solutions (NbS) for nutrient reduction. In this phase (Phase II), we conducted outreach with a select group of facilities with high potential for NbS, including conducting site visits and discussing opportunities and constraints with agency staff. This phase also involved additional site-scale research and analysis in refining opportunities and constraints identified at each facility. In Phase III of this study, we will narrow to a smaller set of facilities to develop planning-level designs to enable cost estimation, identify regulatory and land use conflicts, and establish feasibility for agency-led planning.

Novato Wastewater Treatment Plant, located near Novato Creek in Marin County (Figure 1), was one of the facilities identified as a high-potential site for NbS. With a relatively small nutrient contribution, a critical ancillary driver for implementing NbS would be supporting the adjacent restoration and flood risk reduction projects. The desktop analysis identified opportunities for horizontal levees along the inland edge of Deer Island Basin, near the Novato treatment plant. A partnership with the Deer Island Basin Complex Tidal Wetland Restoration Project (Deer Island Basin Restoration Project), led by the Marin County Flood Control and Water Conservation District, presents a valuable opportunity to beneficially use wastewater for habitat restoration.

Novato Sanitary District (NSD) was chartered in 1925 and currently serves about 60,000 people. The current Novato Wastewater Treatment Plant (Figure 2), located at 500 Davidson Street in Novato, was completed in 2011. Dry weather permitted capacity is 7.0 million gallons per day (mgd), and average dry weather flows are about 3.3 mgd, based on historical averages.

Treated wastewater is pumped to San Pablo Bay. NSD plans to relocate its outfall towards the newly restored tidal marsh following the completion of the Bel Marin Keys Unit V wetland restoration project.

The NSD plant continues to expand the production of recycled water. Disinfected tertiary recycled water is provided to the North Marin Water District (NMWD), and the volume recycled to NMWD will likely increase in the coming years. NSD reclaims the majority of its dry-season flows. Water is kept in storage ponds before use for irrigation, and the plant also uses some water in a wildlife pond. NSD is well-situated to implement other types of nature-based solutions like treatment wetlands or horizontal levees, especially given the area's widespread ecological restoration and flood protection efforts. The 2011 upgrade included raising the plant's elevation to reduce flood risk. Continued collaboration with the Deer Island Basin Restoration Project could enhance the resilience of the plant to future flooding.

Figure 1. Site in context

Figure 2. Site detail

SITE OVERVIEW

ECOLOGY

Historical ecology mapping shows extensive tidal marsh near the plant before diking and draining (Figure 3). Much of the NSD plant was part of a large tidal marsh complex along Novato Creek, with some of the plant footprint in the wetland-upland transition zone. Levees were constructed in the late 1800s to convey floodwaters in Novato Creek more quickly to San Pablo Bay, and tidal marshes were drained for development and agriculture. Changes to the watershed and baylands resulted in the aggradation of sediment in Lower Novato Creek, which now must be dredged periodically to reduce flood risk in the watershed. The Novato Creek Baylands Historical Ecology Study extensively analyzes historical ecology and geomorphology in lower Novato Creek.[1]

Today, much of the historical baylands along Novato Creek are used for agriculture and stormwater basins. Other significant features include the residential development at Bel Marin Keys, Highway 37, and the recently restored Hamilton wetlands. Despite massive reductions in tidal habitat in the area compared to historical conditions, narrow bands of marsh along Novato Creek between constructed levees (Figure 4) provides valuable habitat for marsh species. Waterbirds use the wastewater and stormwater ponds in the area. The Baylands Ecosystem Habitat Goals Update suggests restoring a mosaic of tidal, seasonal, and riparian wetlands in the Lower Novato Creek watershed and notes that treated wastewater could be an essential resource for discharge to horizontal levees and establishment of brackish marshes.[2] In the future, large-scale habitat improvements in the Deer Island Basin and Bel Marin Keys Unit V will join the recent Hamilton Wetlands project to restore historical ecosystem functions and improve habitat quality in the Novato baylands.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

Notably, the NSD plant is adjacent to large swaths of protected open space (Figure 5). Proximity to basins and ponds managed by the Marin County Flood Control District and CA Department of Fish and Wildlife (CDFW) means possible partnerships on future restoration efforts. Electric transmission lines run south and west of the site, as does the SMART rail line. There are no SB535 Disadvantaged Communities or MTC Equity Priority Communities near the NSD plant. The plant is near two major freeways, Interstate 101 and State Highway 37 (see context map in Figure 1). NSD's infrastructure, especially the bell-and-spigot force main running through the Deer Island basin, is a crucial consideration for the feasibility of restoration designs.

LAND USE & OWNERSHIP

Much of the land in the area is publicly owned by agencies, including NSD, the City of Novato, and various Marin County districts. Marin County Flood Control and Water Conservation District owns Deer

1. SFEI. 2015. Novato Creek Baylands Historical Ecology Study. A Report of SFEI-ASC's Resilient Landscapes Program, Publication #740, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

2. Goals Project. 2015. The Baylands and Climate Change: What We Can Do. The 2015 Science Update to the Baylands Ecosystem Habitat Goals Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

Island Basin. In addition to the main plant footprint, NSD owns two approximately 7-acre parcels: one to the east of the plant and one to the northwest. Private properties in residential neighborhoods are relatively close to the NSD plant to both the east and west.

FLOODING & SEA-LEVEL RISE VULNERABILITY

Built on a historical tidal marsh, the area around the NSD plant is low-lying and vulnerable to flooding. The 2011 plant upgrade included major retrofits for flood protection, including raising the plant's elevation. However, according to Marin County's BayWave Vulnerability Assessment, the NSD plant is vulnerable just before 3 feet of sea-level rise, and storm surges have the potential to cause flooding at the plant sooner. The BayWave assessment concluded that the wet weather equalization basins would first be impacted, followed by the UV Disinfection and Final Effluent Processing facilities. The low floodwall bordering the property could be raised to provide additional protection for these facilities at the plant itself. However, due to subsidence of surrounding areas following the diking and draining of the tidal marsh, the area around the NSD plant is vulnerable to sea-level rise. Restoration of tidal marsh in this area can help raise elevations and protect the site from future flooding by reducing wave action reaching the plant.

Figure 6 shows predicted flooding under multiple sea-level rise scenarios based on ART Bay Area Flood Explorer data. This map only accounts for overland flooding from sea level rise. Sea-level rise can also cause a rise in groundwater levels, so even if NSD raised floodwalls to prevent overland flooding, the NSD plant and collection system might also be affected by flooding from below. This phenomenon is of particular concern for any belowground facilities subject to seepage.

Floodwall and Deer Island basin from the NSD plant.

Figure 3. Historical bayland habitats

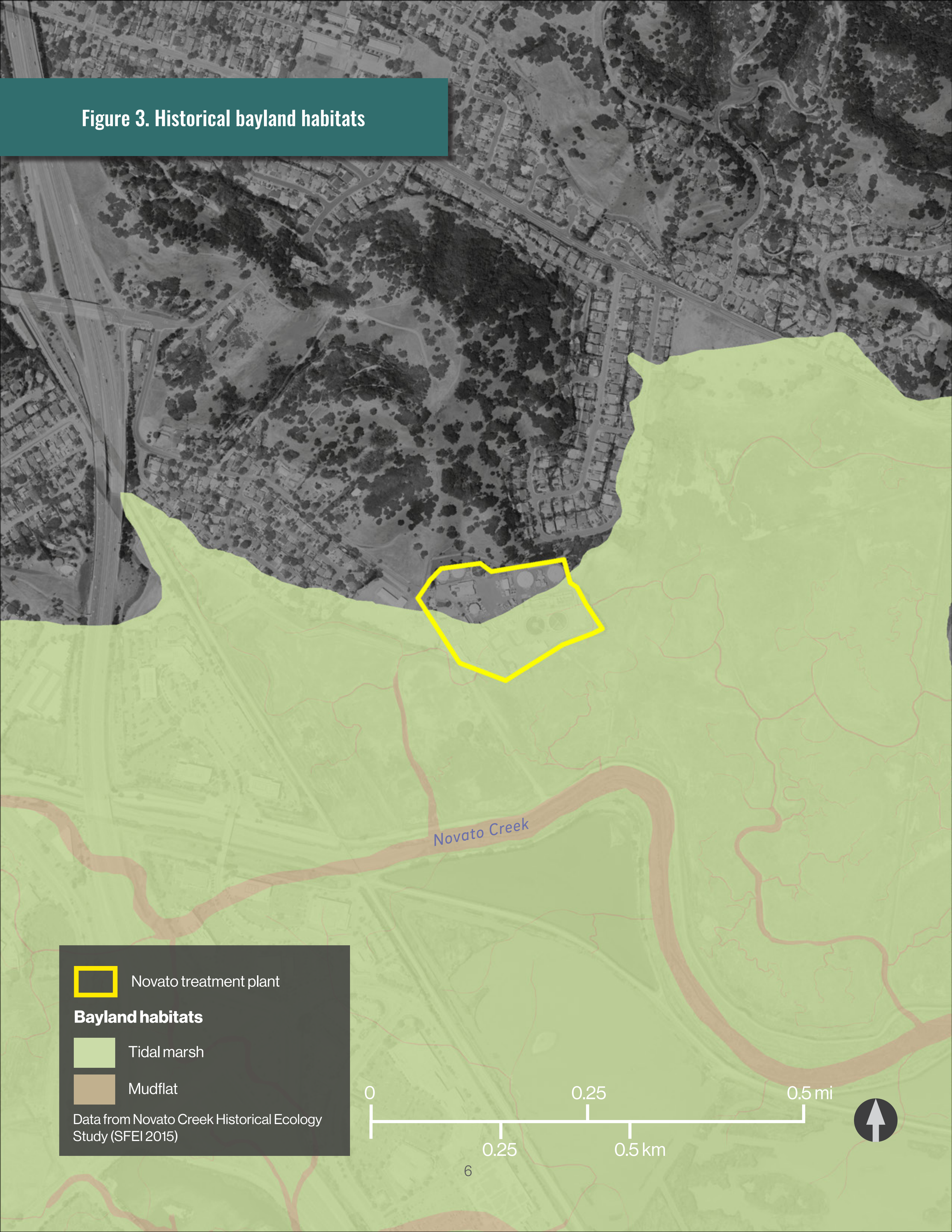
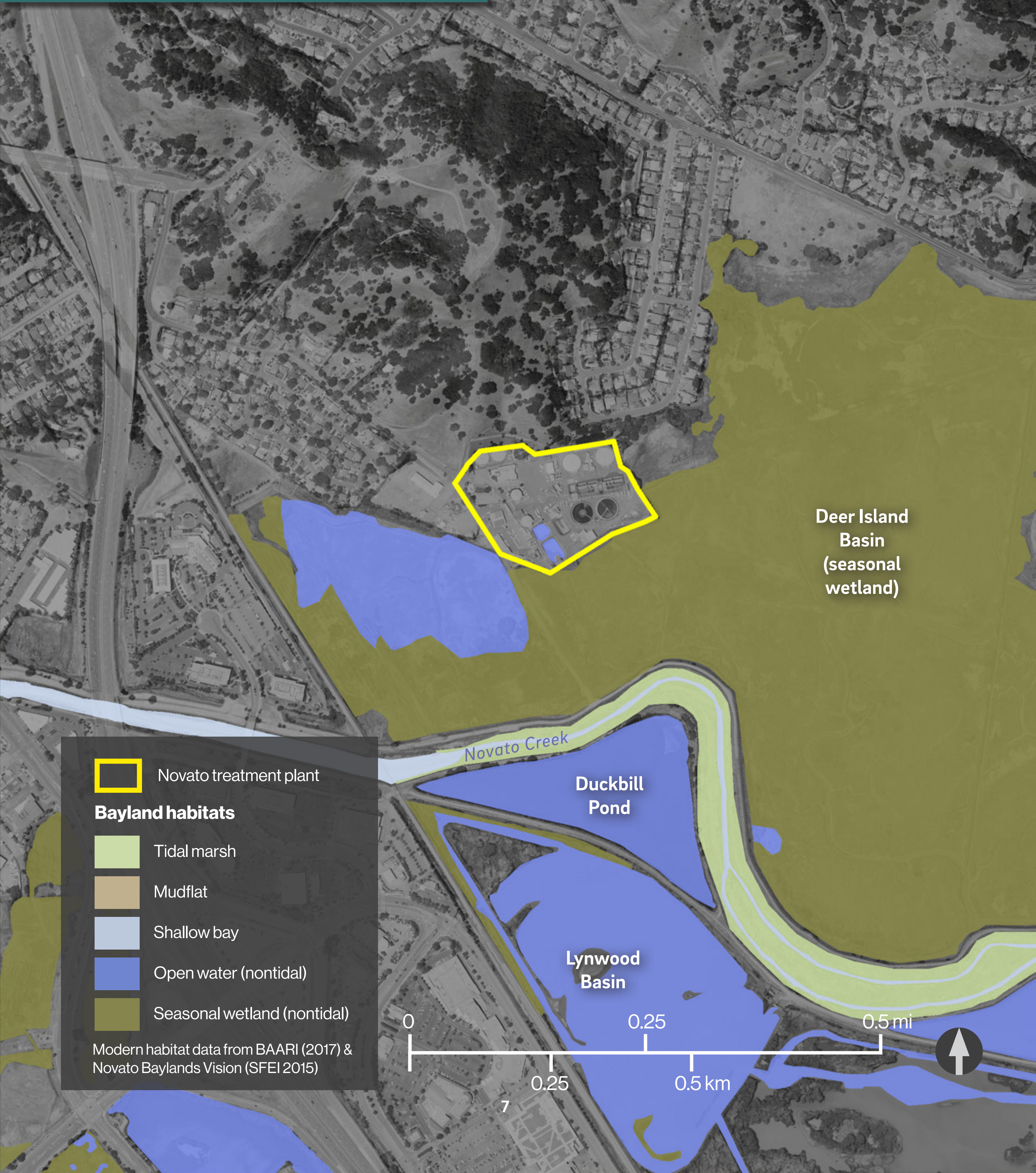


Figure 4. Modern bayland habitats



Modern habitat data from BAARI (2017) & Novato Baylands Vision (SFEI 2015)

Figure 5. Infrastructure, recreation, & disadvantaged communities

Figure 6. Sea-level rise

SITE CONSIDERATIONS

RECENT & PLANNED CHANGES AT FACILITY

Most relevant to the development of future NbS at the NSD plant is the planned change of discharge point from the existing shallow San Pablo Bay location inland to the Bel Marin Keys tidal marsh restoration. This relocation supports the Bel Marin Keys restoration by creating a brackish marsh gradient at the back of the restored area.

According to NSD's 2020 NPDES permit (CA0037958), the plant intends to move its discharge approximately 1.2 miles inland from the current outfall 950 feet offshore in San Pablo Bay. The diffuser is submerged at the 1 foot above mean lower low water tidal elevation. At lower tidal elevations, the outfall is exposed, and the distance from the diffuser to the San Pablo Bay water line can range from 1,000 to 3,500 feet. The State Coastal Conservancy intends to create approximately 1,750 acres of brackish and tidal marsh from existing farmland and former diked marshland. The restoration project will involve breaching a bayfront levee at the Bel Marin Keys shoreline and allowing tidal waters to inundate the area. The marsh will become part of San Pablo Bay, and the new shoreline will move landward by approximately 5,000 feet. The nearshore discharge location will provide freshwater to the new brackish marsh. If the restoration project receives all necessary permits and funding, NSD's treated effluent will flow to the marsh year-round to support the brackish marsh habitat.

NSD also intends to reduce its discharge volume and nutrient load by increasing recycled water capacity - shifting away from pastureland irrigation toward providing tertiary-treated recycled water. This shift is partly driven by plans from the Marin County Flood Control and Water Conservation District to implement tidal wetland restoration projects on NSD's leased pasture irrigation lands. About half of the plant's dry weather flow is now recycled through a collaboration with North Marin Water District for distribution to parks, golf courses, etc.

RECENT & PLANNED CHANGES NEARBY

Bel Marin Keys Unit V: The California State Coastal Conservancy is restoring the Bel Marin Keys Unit V property to various habitat types, including tidal wetlands, seasonal wetlands, and upland transition zone. The project involves constructing a sinuous setback levee to protect the Bel Marin Keys Development, placing material to increase ground elevation, and establishing tidal channel networks to connect to the Bay when the current levees are breached. Novato Sanitary District is coordinating with the restoration, and the new outfall will be set back in conjunction with the restoration to provide treated effluent to the site, supporting the development of brackish marsh habitat. Phase I of construction is complete. Project updates can be found on the State Coastal Conservancy website.

Deer Island Basin Restoration: Marin County Flood Control District is in the process of restoring the Deer Island Basin to tidal marsh. Historical landscape modifications, including diking and draining of tidal marsh, have exacerbated flood risk in the Novato Creek watershed. The project will expand the floodplain to reduce flood risk in the City of Novato and along SR 37 and increase the area's resiliency to sea-level rise. Phase I will restore Duck Bill and Heron's

Beak Ponds to tidal action. Later phases will restore Deer Island Basin to tidal marsh, including constructing ecotone levees. Full restoration of the Basin will eventually require rerouting NSD's sewer force main, introducing opportunities for incorporating wastewater discharge into a horizontal levee along the back of the newly created marsh. More information about the project is available via the Marin Watershed Program. The conceptual basis for this project, which also describes incorporating wastewater discharge into future horizontal levees, is outlined in the Novato Creek Baylands Vision.[1]

State Highway 37: Planning is underway to address traffic congestion, periodic flooding, and sea-level rise adaptation for the State Highway 37 corridor, including the segment from Highway 101 to the Petaluma River, which traverses the Novato baylands. The baylands conservation community is engaged with the process to help co-develop roadway improvement designs to allow restorations in the Novato Baylands, as envisioned.

OPPORTUNITIES & CONSTRAINTS

Given the open space and restoration plans underway, the largest opportunities lie in partnerships that could use treated wastewater as a valuable resource in restoration projects. Given NSD's existing nitrification and partial denitrification capacity, NbS would be largely targeted toward other benefits beyond nutrient reduction: habitat provision and sea-level rise adaptation. A partnership with the Deer Island Basin Restoration Project could be a win-win for both NSD and the restoration project. Wastewater could help build elevation in the basin before tidal restoration or create a fresh-to-brackish marsh gradient on a horizontal levee. Both options would increase the plant's and neighboring communities' resilience to sea-level rise.

A residential community is located directly to the northeast of the plant. Public outreach and education efforts may be required to prepare the community and help inform new projects at NSD. Partnerships with the restoration project may present new opportunities for recreation, including wildlife viewing.

Sea-level rise vulnerability introduced by the diking, draining, and subsidence of former baylands along Novato Creek presents a constraint to developing open-water wetlands in the Deer Island Basin, but it also presents opportunities to make use of wastewater in the design of restoration plans that can help reduce flood risk for the plant and adjacent areas.

1. SFEI. 2015. Novato Creek Baylands Vision: Integrating ecological functions and flood protection within a climate-resilient landscape. A SFEI-ASC Resilient Landscape Program report developed in cooperation with the Flood Control 2.0 project Regional Science Advisors and Marin County Department of Public Works, Publication #764, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

ADDITIONAL CONSIDERATIONS

PRECEDENT

Wastewater agencies in the North Bay have for several decades been subject to several Discharge Prohibitions from the San Francisco Bay Water Quality Control Plan (Basin Plan) to protect Suisun Marsh along with sloughs and tributaries. As a result, the North SF Bay dischargers have drastically reduced discharge volumes by maximizing water reclamation and recycling.

Many North Bay dischargers, including NSD, have relied on land application and wastewater recycling to minimize dry season discharges, representing a form of NbS for beneficial uses. As a result, dry season nutrient loads remain low. Under their NPDES Permit, NSD may discharge year-round due to the Marin County Flood Control and Water Conservation District's proposal to implement tidal wetland restoration projects on pasture irrigation lands previously used for land application of secondary-treated effluent. This permit element assumes relocation of the existing discharge location for beneficial use based on analyses involving modeling studies and Antidegradation Analyses.

Other projects under current consideration by the region's wastewater agencies and regulatory agencies include those to advance horizontal levees at Oro Loma Sanitary District, Palo Alto Regional Water Quality Control Plant, and West County Wastewater District. The SF Bay Regional Water Quality Control Board authorized near-shore discharges for the City of Petaluma and Mt. View Sanitary District, and the agency adopted an NPDES permit in 2022 for a new open water polishing wetland and shallow near-shore discharge for the City of San Leandro.

The three NbS alternatives presented here involve conversion of existing seasonal wetlands. Few examples of treatment wetlands in the region involve wetland fill or habitat conversion. US EPA, Region 9, recently commissioned a report by the Southern California Coastal Water Research Project (SCCWRP) that evaluates options for wetland habitat type conversion, with respect to ecological concerns and possible regulatory pathways.[1] This report may offer options for quantifying the benefits of projects involving beneficial fill and converting seasonal wetland habitat to tidal habitat intended to boost shoreline and habitat resilience. A project at the Oro Loma Sanitary District, referred to as the First Mile horizontal levee project, evaluates similar issues and may offer useful insights resulting from project deliverables examining regulatory options for a project with similar constraints as those presented here.

1. Stein, E.D., Brown, J.S., Siu, J.D. 2022. Aquatic Resource Type Conversion Evaluation Framework Version 2.0. Technical Report 1110. Prepared on behalf of U.S. EPA Region 9. Available at https://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1110_ConversionFramework.pdf

REGULATORY CONSIDERATIONS

Bay Area WRRFs are subject to myriad regulations, some of which may inadvertently act in conflict with nutrient load reduction efforts. The regulatory landscape governs not just surface water discharges but also water reuse, biosolids management, protected species and habitats, and air emissions. Project proponents and regulators have initiated discussions over potential approaches for mitigating these barriers, recommendations for quantitative analyses of potential conflicts, and options for regulatory and permit-based strategies to maximize the multi-functional benefits associated with NbS upgrades, in the event large-scale nutrient load reductions are warranted. The final report for this regional NbS evaluation project shall synthesize the extensive regulatory considerations applicable to most WRRFs in Region 2.

Facility-specific permits, local ordinances, and site-specific plans feature requirements for each facility. Under NSD's 2020 NPDES permit (No. CA0037958), the facility includes a recycled water treatment system, enabling the production of up to 1.7 mgd of disinfected tertiary recycled water for the North Marin Water District for subsequent distribution to landscape irrigation and other customers. NSD maintains two storage ponds with a combined storage capacity of 180 million gallons and an irrigation pump station. The permit provisionally authorizes the relocation of the existing outfall to a point approximately 1.2 miles inland to support construction and habitat restoration efforts. The alternatives presented here involve modification of the discharge points, likely requiring additional consideration under the next iteration of NSD's NPDES Permit. Discharge via the horizontal levees considered under Options 1 & 2 represents a more diffuse discharge scenario that offers fewer regulatory hurdles than discharge directly to an open water system (Option 3).

For regulatory purposes, the San Francisco Bay Regional Water Quality Control Board recently provided guidance and continues establishing a precedent for permitting discharges of treated effluent from NbS projects in the region.[1] On-going consultations with other regulatory agencies for similar projects also serve to continually inform opportunities and constraints regarding mitigation and monitoring requirements, desired treatment performance, and the appropriate quantification of ancillary benefits, including habitat enhancement and water reclamation, and community benefits.

The ancillary benefits of pursuing any option presented here include, at a minimum, reductions in dry weather discharges to San Pablo Bay, future flood risk reduction, and the enhancement of habitat quality and quantity. Other potential benefits include recreation and education opportunities, demonstrating novel NbS strategies, and enhancing bayland habitat quality and quantity within a disturbed landscape.

Pending refinement of these concepts, this memorandum aims to quantify these and other likely benefits and impacts. Quantifying such benefits enables regulatory agencies to weigh the net environmental benefits associated with a project.

1. "NPDES Permitting for Nature-based Solutions," 2022, San Francisco Bay Regional Water Quality Control Board.

Figure 7. Conceptual design options

Option 1: Coordinate with Deer Island Restoration on horizontal levee in front of treatment plant

Option 2: Coordinate with Deer Island Restoration on horizontal levee at back of north basin (may not extend this full length)

Option 3: Coordinate with Deer Island Restoration on temporary freshwater marsh to build elevation (peat) prior to tidal restoration

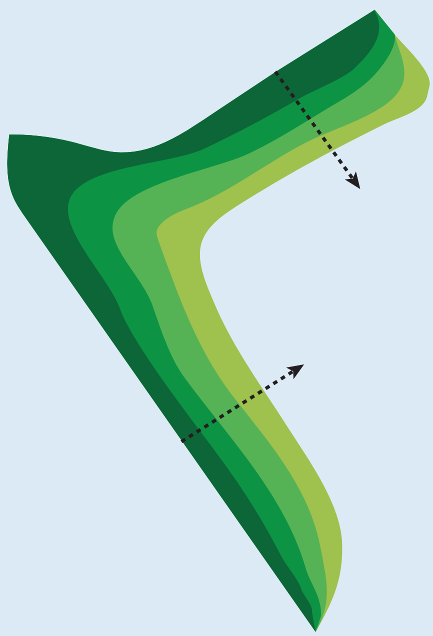
CONCEPTUAL DESIGN OPTIONS

Figure 7 outlines the three main options for a multi-benefit NbS project at NSD. These options involve a footprint outside the treatment plant in the Deer Island Basin and require ongoing coordination with restoration partners. These options are not mutually exclusive and may be possible to implement in sequence as part of a combined strategy.

OPTION 1

A horizontal levee would be constructed in front of the treatment plant. Ecotone levees are already planned as part of the long-term strategy for the Deer Island Basin restoration project. With planning and coordination, these levees could incorporate a subsurface (or surface) discharge to polish wastewater and create a fresh-to-brackish marsh gradient at the back of the Deer Island basin, providing important habitat for marsh species. The idea of incorporating wastewater seepage slopes as a part of this restoration project was suggested in the 2015 Novato Creek Baylands Vision and explored in detail in conceptual designs prepared by ESA in a 2018 memo provided to NSD. ESA suggested several locations for horizontal levees. One of those locations, at the back of the western Deer Island basin (west of the NSD treatment plant), is not planned for tidal reconnection in the most recent plans for the Deer Island Basin restoration (R. Leventhal and M. Lindley, pers. comm.).

Figure 7 shows the other possible horizontal levee alignments suggested in ESA's 2018 memo. One option places a levee at the front of NSD's plant and another at the back of the Deer Island Basin. The smaller horizontal levee in front of the plant (~500 meters long) could be constructed as part of Phase I of the Deer Island Basin restoration, which will restore the basin south of the force main to tidal marsh. A timeline for restoration has not been established, and feasibility is undetermined based on the cost of protecting the force main. A horizontal levee in this location could provide flood control benefits for the NSD plant by reducing wave action reaching the plant's floodwall.

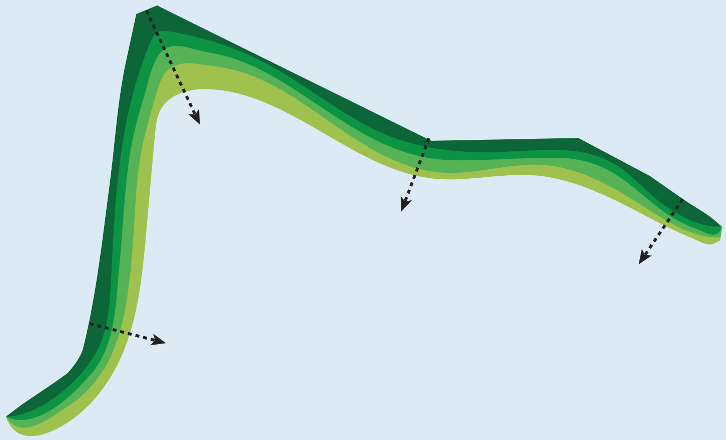


Example concept sketch demonstrating option 1. A seepage slope is integrated into the planned ecotone levee for the south Deer Island Basin restoration, directly in front of the NSD plant (see Figure 7 for location).

OPTION 2

A more extensive horizontal levee could be constructed when the northern portion of the Deer Island Basin is eventually restored. The horizontal levee at the back of Deer Island Basin need not extend the full length/area shown in Figure 7 (~1,750 meters long). The 2018 conceptual designs by ESA identified the corner in the northernmost part of the basin as the most logical location for a seepage slope, as it could be built on an existing slope with only minor grading required (no new levee). ESA suggested that this design could use existing alluvial soils rather than constructing a new underground treatment zone. Recent plans for the Deer Island Basin restoration include ecotone levees along the entire back of the Deer Island basin. Including horizontal levee segments along this ecotone levee could provide wastewater polishing benefits (reducing contaminants of emerging concern and nutrients) and habitat benefits (providing a freshwater source and increasing habitat complexity).

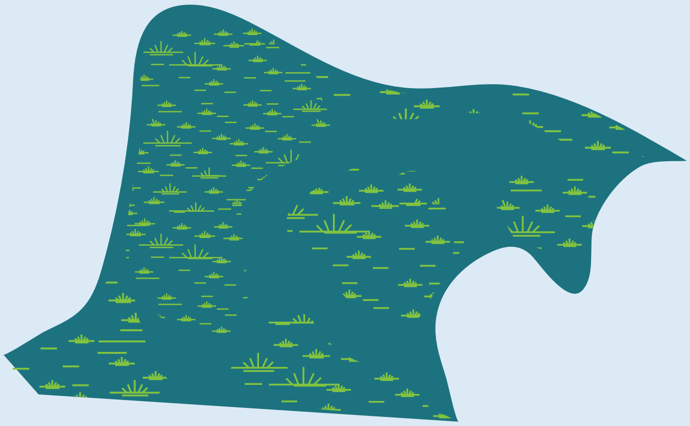
If regulators approve, discharge from NSD directly to the newly restored Deer Island Basin could allow the decommissioning of the force main leading to the existing outfall. Further coordination would be required with relevant agencies, including the Coastal Conservancy, which is leading the Bel Marin Keys Restoration. Discharging closer to the plant directly into the Deer Island Basin would reduce costs for maintaining the force main.



Example concept sketch demonstrating option 2.
A seepage slope is integrated into the planned ecotone levee for the north Deer Island Basin restoration (see Figure 7 for location). Seepage slopes may be optimized for certain segments of the levee, rather than extending for the full length.

Looking over the Deer Island Basin from the NSD treatment plant.

OPTION 3



Example concept sketch demonstrating option 3.
Treated wastewater is used to create a temporary freshwater wetland to build up organic matter for increasing elevation and resilience to sea-level rise.

A freshwater marsh could be designed to build up peat (increase elevation) in the Deer Island Basin prior to tidal restoration. Restoration in the northern portion of the Deer Island Basin is currently precluded by the presence of the force main. NSD requires maintenance access to the force main, so restoring tidal flows over the main is infeasible if it remains in its current condition. Three scenarios that would allow complete restoration of the basin include: (1) replacing the force main and secondary lines, (2) rerouting the line, or (3) shortening it to discharge directly into Deer Island Basin. However, none of these options are likely to occur soon.

Deer Island Basin is subsided below typical marsh elevation, at elevations ranging from mean lower low water to mean sea level. The Baylands Ecosystem Habitat Goals Update includes a goal of restoring the baylands to full tidal action before 2030.[1] This goal stems from the belief that restoring subsided diked baylands, like the Deer Island Basin, as soon as possible gives them a better chance of accreting organic sediment, reaching tidal marsh elevation, and keeping pace with sea-level rise as rates increase toward the end of the century. However, it is unlikely the northern Deer Island Basin will be restored before 2030, and it may occur significantly later than that when the elevation difference relative to sea level is even more significant.

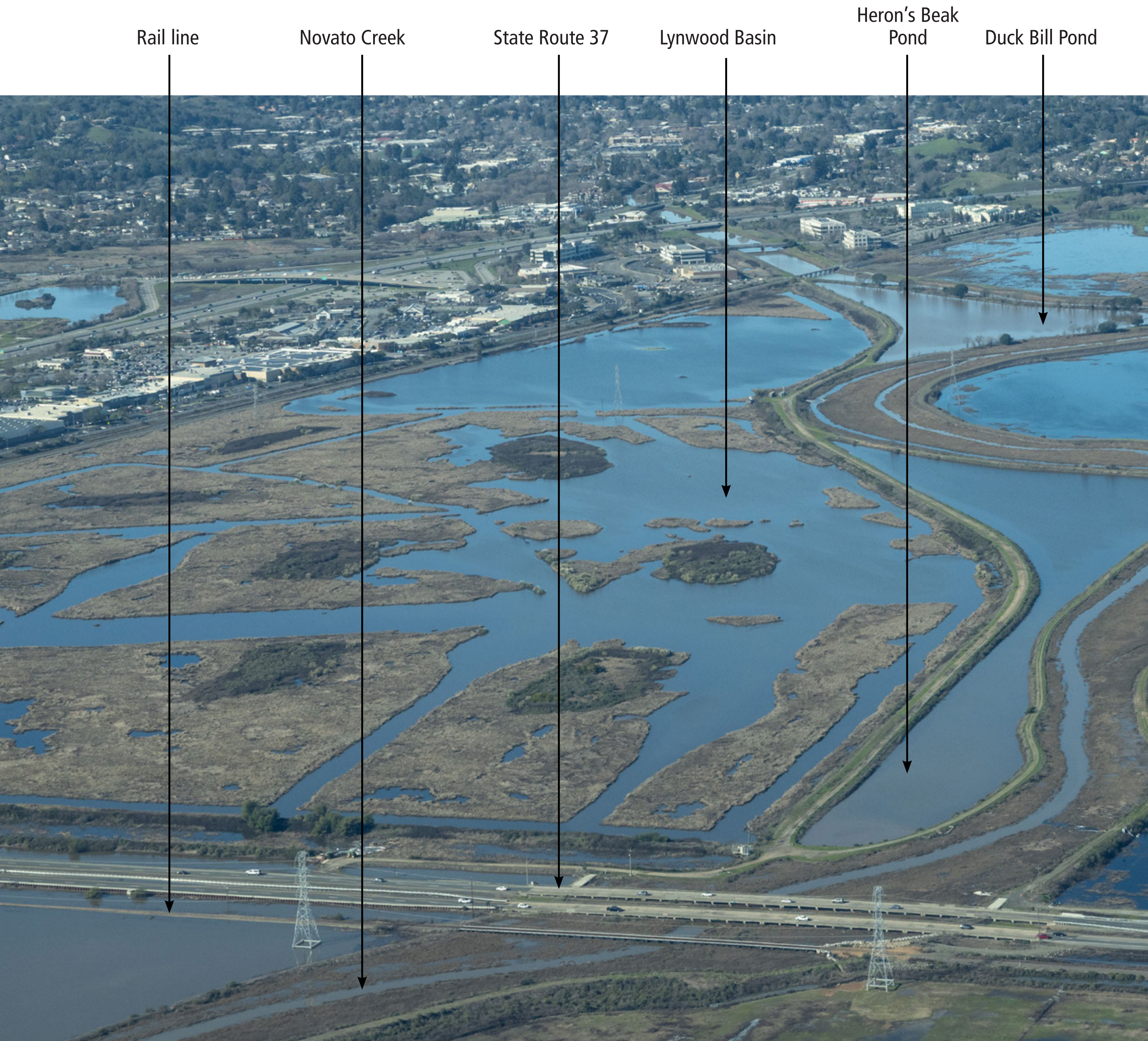
To address this elevation challenge, a temporary freshwater wetland could be designed intentionally to facilitate future tidal restoration in the northern part of the Deer Island Basin. Treated wastewater from NSD could create a freshwater marsh in a portion of the 94-acre basin to build up organic matter (peat). The basin is already inundated with stormwater for part of the year (see photo on next page), but water levels could be managed year-round to maximize wetland vegetation and organic matter accretion. This would increase the elevation of the basin in advance of tidal restoration, thereby improving the resilience of the marsh and NSD's plant to future sea-level rise.

Subsidence-reversal wetlands have been successful at Sherman and Twitchell Islands in the Sacramento-San Joaquin Delta. This type of treatment wetland would also sequester carbon and could be eligible for saleable carbon credits. Cost-benefit analysis specific to the site would need to be undertaken to determine the financial viability of pursuing the carbon offsets validation/verification process. There may also be opportunity to use the site for research on carbon capture specific to treatment wetlands.

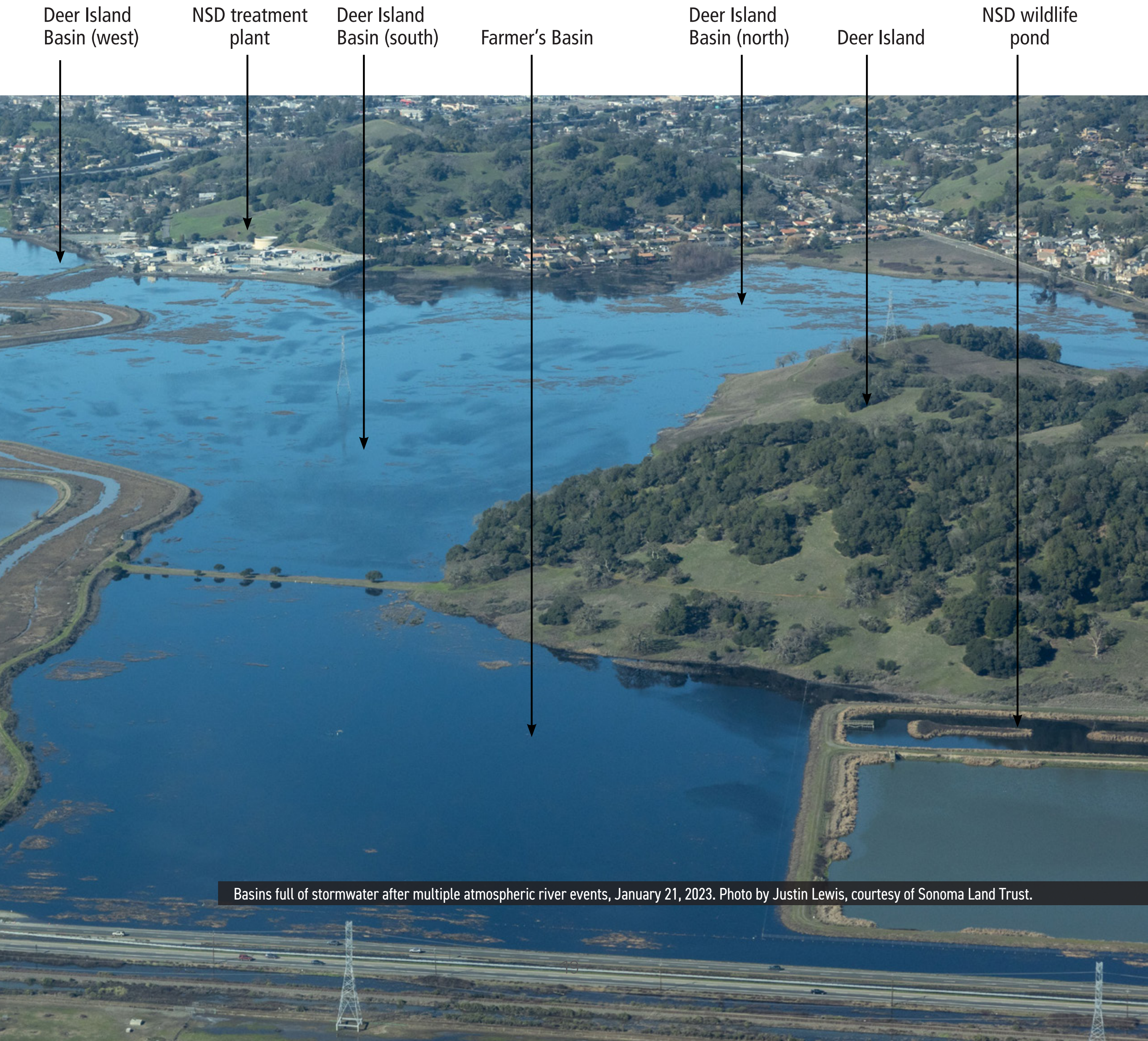
1. Goals Project. 2015. The Baylands and Climate Change: What We Can Do. The 2015 Science Update to the Baylands Ecosystem Habitat Goals Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

INTEGRATION OF OPTIONS 1 & 2

Options 1 and 2 may be integrated into a sequence of actions, beginning with implementing the smaller horizontal levee in front of the treatment plant. Construction of the seepage slope could occur with the restoration of the southern portion of the Deer Island Basin, which includes a planned ecotone levee in that location. Next (or concurrently), a freshwater wetland could be implemented in the northern portion of the Deer Island Basin to increase elevation before tidal restoration. Seepage slopes could be constructed strategically in the planned ecotone levee at the back of the northern Deer Island Basin. Eventually, once the force main is rebuilt, rerouted, or shortened, the north portion of the basin could be restored to tidal marsh. The horizontal levees would then serve as transition zone habitat at the back of the marsh.



Based on rough estimates of treatment capacity, the horizontal levees represented in Options 1 and 2, which total approximately 1.7 km in length, could conservatively receive about 3 mgd of flow and remove essentially all nutrients from that flow. Recent data indicates NSD's annual average flow is approximately 3.5 mgd. Dry weather flows in recent years average 2.3 mgd, based on agency communications. As a result, the horizontal levees identified under Options 1 and 2 could receive and treat all dry weather flow.



Basins full of stormwater after multiple atmospheric river events, January 21, 2023. Photo by Justin Lewis, courtesy of Sonoma Land Trust.

COMPARING OPTIONS

Table 1 lists the goals of implementing NbS to achieve multiple benefits and the relative contribution of each option toward meeting those goals. This comparison allows for a high-level comparison of alternatives. Further feasibility analysis is necessary to determine the most appropriate options. Factors that have not received full consideration include implementation costs and regulatory constraints.

Table 1. Comparison of each option's relative contribution to achieving goals of NbS implementation.

● = Achieves. ◑ = Partially achieves. ○ = Does not achieve.

For TIN removal, 'Achieves' is>30% removal, 'Partially achieves' is 5-20% removal, and "Does not achieve is <5% removal.

	Option 1. (Horizontal levee in front of NSD plant) (475 m length)[1]	**Option 2.** (Horizontal levee at the back of northern Deer Island Basin) (1.7 km length)	**Option 3.** (Vegetated freshwater wetland to build elevation)
Goal 1: Reduces nutrient loads to the Bay and improves overall water quality.			
Reduces TIN *Estimated dry-season reduction (kg d-1 / % reduction of daily TIN load)*	● *60 kg d^{-1} potential / 95%*[2]	● *225 kg d^{-1} / >100%*	● *50 kg d^{-1} / 92%*[3]
Reduces CECs	●	●	●
Goal 2: Reduces flood risk for the plant and/or associated infrastructure.			
Attenuates waves and provides erosion resistance	●	●	● *More likely to reach marsh elevation (more wave attenuation) when restored in future*
Facilitates marsh accretion	●	●	●
Goal 3: Create and/or enhance habitat			
Provides marsh-upland transition zone habitat and marsh migration space	●	●	○
Provides high tide refuge habitat for wildlife	●	●	○
Increases habitat complexity	●	●	●
Provides freshwater pond/marsh habitat	●	●	●
Goal 4: Enhances recreational opportunities.			
Provides opportunity for public trails and wildlife viewing	◑ *Depends on Deer Island Basin Restoration*	◑ *Depends on Deer Island Basin Restoration*	◑ *Depends on Deer Island Basin Restoration*
Goal 5: Provides additional co-benefits.			
Reduces use of potable water for irrigation	○	○	○
Supports goals of partner organizations (e.g. facilitates neighboring restoration projects)	●	●	●

1. Assumptions: horizontal levee with length: 472 meters (Option 1) and 1,725 meters (Option 2), height: 3.1 meters, 10:1 slope, bed temperature of 20° C, 24-hr retention time, and woodchip media depth of 0.5 meters. Addy, K., Gold, A.J., Christianson, L.E., David, M.B., Schipper, L.A. and Ratigan, N.A., 2016. Denitrifying bioreactors for nitrate removal: A meta- analysis. Journal of Environmental Quality, 45(3), pp.873-881.

2. Conservatively estimated TIN reductions, as absolute daily reductions and percentage of average dry season daily load (~60 kg N d-1)

3. Assumes only 15% of the 94-ac basin receiving treated effluent for freshwater marsh formation, or an equivalent flow distributed throughout a larger area.

NEXT STEPS

As part of the 2020 NPDES renewal process, NSD undertook significant analyses and regulatory outreach to facilitate the relocation of their outfall pipe. That level of engagement demonstrates that internal and external support may exist for an NbS alternative at the plant. Initial discussions indicate Marin County is open for a partnership on the Deer Island Basin Restoration Project, offering options for horizontal levees and open water treatment.

Nutrient reduction is not a significant driver for this project, given the relatively low nutrient loads from NSD. Instead, NSD's engagement on the Deer Island project could be a novel partnership with a habitat and flood risk reduction project that will yield several benefits to the area. SFEI recommends pursuing planning and outreach efforts with Marin County, in parallel with conversations with the Coastal Conservancy regarding future phases of the Bel Marin Keys project. We also recommend exploring funding opportunities at the regional (e.g., Measure AA), state (upcoming climate and water resilience programs), and federal levels (e.g., coastal resilience funding under the Bipartisan Infrastructure Law).

Site visit at Novato Sanitary District, November 18, 2021.

NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: SEWERAGE AGENCY OF SOUTHERN MARIN

BACWA BAY AREA CLEAN WATER AGENCIES

SFEI | AQUATIC SCIENCE CENTER

PREPARED BY
San Francisco Estuary Institute

PREPARED FOR
Bay Area Clean Water Agencies

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CONTENTS

Version 3 (May 2023).

All photos in this document courtesy of the authors.

INTRODUCTION

The first phase of analysis (Phase I) of the Nature-Based Solutions for Nutrient Reduction study was a regional-scale desktop analysis to determine which Bay Area water resource recovery facilities (WRRFs) have opportunities for implementing nature-based solutions (NbS) for nutrient reduction. In this phase (Phase II), we conducted outreach with a select group of facilities with high potential for NbS, including conducting site visits and discussing opportunities and constraints with agency staff. This phase also involved some additional site-scale research and analysis to refine opportunities and constraints identified at each facility. In Phase III of this study we will narrow down to a smaller set of facilities to develop planning-level designs to enable cost estimation, identification of regulatory and land use conflicts, and establish feasibility for agency-led planning.

The Sewerage Agency of Southern Marin (SASM) in Mill Valley (Figure 1) was one of the facilities identified as a high-potential site for NbS. The desktop analysis identified opportunities for horizontal levees along the inland edge of Bothin Marsh, near the SASM plant. Through conversations with SASM representatives, other opportunities even nearer to the plant emerged, including the potential to dual-purpose the existing North and South Equalization Basins as open water treatment wetlands or construct a small horizontal levee along the bayward side of the plant's flood protection levee. These opportunities had been missed in the GIS analysis because the National Land Cover Database incorrectly classifies the equalization basins and adjacent marsh as "developed."

SASM is a joint powers authority (JPA) formed in 1979 to consolidate wastewater treatment services for southern Marin residents. The JPA serves about 29,000 people through six southern Marin County member agencies. Each member agency has its own sewer system that directs flows to the SASM treatment plant, located at 450 Sycamore Ave in the city of Mill Valley (Figure 2). Dry weather permitted capacity is 3.6 mgd and actual average dry weather flows are about 2.0 mgd. Treated wastewater is discharged via a deepwater outfall off the shore of Tiburon.

The SASM plant has a small tertiary treatment facility for reclaimed water, which is used to irrigate the fields at Bayfront Park and the landscaping at the treatment plant. SASM is well-situated to implement other types of nature-based solutions like treatment wetlands or horizontal levees as the plant already performs partial nitrification. This enhances SASM's ability to remove nitrogen from the waste stream via NbS. The site is low-lying and vulnerable to sea level rise, and any future NbS that are implemented should be designed to improve flood resilience at the plant, in conjunction with planned flood control improvements envisioned in their current Master Plan.

Figure 1. Site in context

Figure 2. Site detail

SITE OVERVIEW

ECOLOGY

Historical ecology mapping shows an extensive marsh complex in the vicinity of the plant prior to development in the late 1800s and early 1900s (Figure 3). The SASM site and the area along both sides of the mouth of Arroyo Corte Madera del Presidio were historically part of Mill Valley Marsh. The tidelands in this area have been heavily impacted by human interventions. Baye and Collins (2018) provide a thorough accounting of the history and ecology of Bothin Marsh.[1] In the mid-20th century, much of the historical tidal marsh was filled and developed, and the area that is now North Bothin Marsh was diked and filled for a planned development that never came to be. Marsh vegetation established in the filled area, sheltered from wave action by constructed berms. Bothin Marsh was protected as open space in the 1970s. Today, tidal marsh habitat persists, though it is a fragment of its former extent (Figure 4)). Lack of high marsh and underdeveloped channel networks limit biodiversity in Bothin Marsh, though it is home to some special-status species including the endangered Ridgway's rail and salt marsh harvest mouse, and a large population of the rare plant Point Reyes bird's beak. The marsh also provides important food-rich habitat for native fish and migrating waterbirds, as well as providing additional food resources for terrestrial wildlife. Sea-level rise (SLR) threatens the longevity of marsh habitat, especially due to the added challenges of poor drainage, limited sediment supply, and lack of available migration space.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

SASM is located in a visible and accessible location near multiple community assets (Figure 5). The SASM site sits between two schools (Tamalpais High School to the south and Mill Valley Middle School to the north), near several parks (Bayfront Park, Sycamore Park, Enchanted Hills Park, Bothin Marsh Open Space Preserve), and along a popular biking/walking/wildlife viewing trail (the Bay Trail connection between Mill Valley and Sausalito). A north-south electric transmission line runs to the east of the site. There are no SB535 Disadvantaged Communities nor MTC Equity Priority Communities located in the vicinity of SASM. An assisted living facility is located southwest of the site across Arroyo Corte Madera del Presidio.

LAND USE & OWNERSHIP

The City of Mill Valley owns much of the land surrounding SASM, including Mill Valley Marsh (marsh adjacent to and south of the SASM plant), Alto Marsh (triangular marsh just south of Arroyo Corte Madera del Presidio), and Bayfront Park (the complex of recreational facilities east of the Bay Trail with soccer fields, a dog park, and a skate park). The paved area adjacent to the SASM plant to the west is used as a City maintenance yard. West of the maintenance yard is the Mt. Tamalpais United Methodist Church. The Bothin Marsh Open Space Preserve (Marin County Open Space District) lies to the south of the City property.

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1 Collins, L., & Baye, P. (2018). Bothin Marsh Geomorphology, Ecology, and Conservation Options. Prepared for the Marin County Open Space District, San Rafael CA.

FLOODING & SEA-LEVEL RISE VULNERABILITY

Built on artificial fill in historical wetlands, SASM and surrounding developed areas are low-lying and vulnerable to flooding. Levees protect the site from high water levels (the photo below is taken from the levee surrounding the equalization basins). The SASM site is already at risk of flooding today. According to the flood study conducted as part of the plant's 2014 master plan, the floors of some of the SASM buildings are just 2 inches above the FEMA 100-year flood elevation. The master plan suggests constructing a berm around the north and west side of the site to protect from today's 100-year flood, and adding flood walls and flood gates to protect from sea-level rise over the coming century.

According to the Adapting to Rising Tides Shoreline Flood Explorer maps, the SASM site would be flooded on a daily basis with about 4 feet of sea-level rise, though storm surges will start to cause intermittent flooding sooner. Figure 6 shows predicted flooding under multiple sea-level rise scenarios, based on data from the ART Bay Area Flood Explorer. As sea-level rise causes the overlying groundwater to push upward, the SASM plant may also be affected by flooding from below. Groundwater seepage has been an issue in the northern equalization basin in the past, and a plastic membrane was added to reduce seepage into the pond. Increasing groundwater levels over the long term could exacerbate seepage issues and affect other infrastructure at the plant.

Looking west at the southern end of the equalization basins.

Figure 3. Historical bayland habitats

Figure 4. Modern bayland habitats

Figure 5. Infrastructure, recreation, & disadvantaged communities

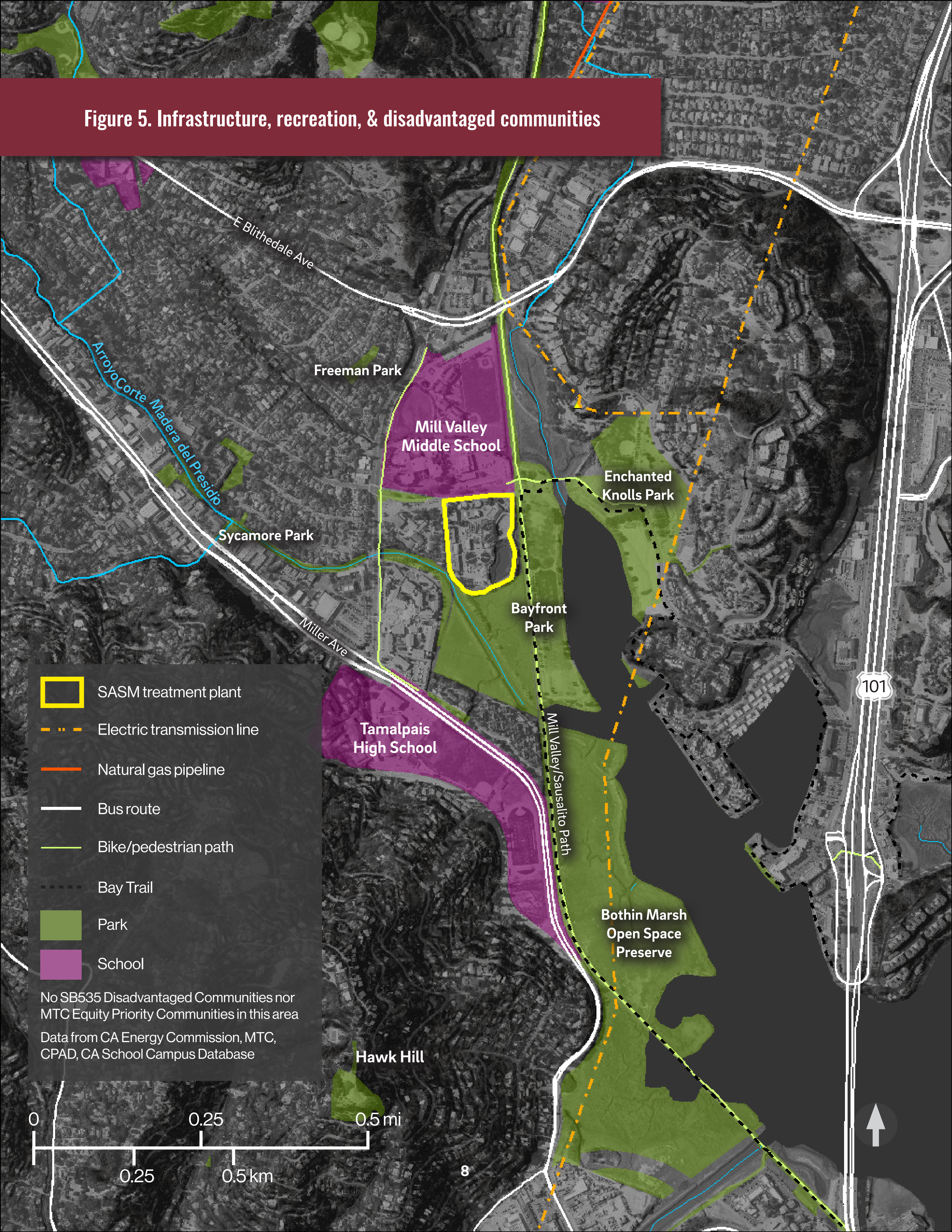
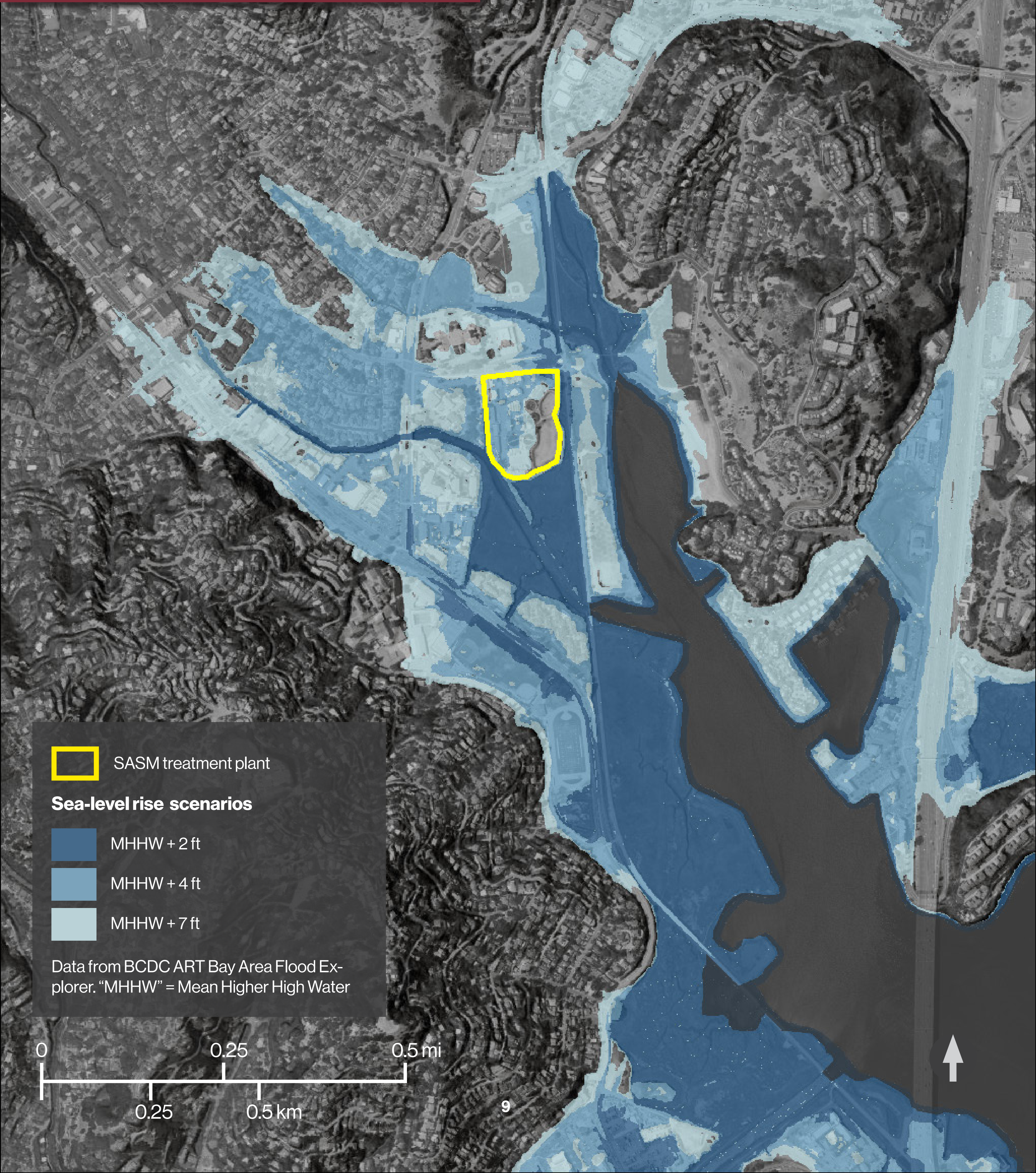


Figure 6. Sea-level rise



SITE CONSIDERATIONS

RECENT & PLANNED CHANGES AT FACILITY

From 1995 to 2017, the South Equalization Basin was used year round: in the winter to meet wet weather equalization needs and during dry weather for wildlife habitat. The South Equalization Basin held treated wastewater to a depth of about four feet and the pond was drained whenever statistical projections indicated that the basin would be needed to store excess plant influent. In 1995, it was estimated that though the dual-use management scheme increased vegetation in the South Equalization Basin, the basin could still provide 95% of the total storage volume for use during wet-weather events. However, sediment and vegetation accumulated in excess of the 1995 expectations, resulting in insufficient equalization storage capacity to meet current conditions.

The North and South Equalization Basins only serve a wet weather equalization function at this time due to loss of storage capacity and soil contamination (heavy metals). SASM may consider remediation of the south basin or another strategy to enable the dual use of the pond for dry weather habitat enhancement and nutrient load management, and equalization storage based on wet weather projections. Refer to the 2018 *South Equalization Basin Management Report* and 2014 *SASM Master Plan* for additional details.

RECENT & PLANNED CHANGES NEARBY

A collaborative group led by One Tam (a partnership of the National Park Service, CA State Parks, Marin Municipal Water District, Marin County Parks, and the Golden Gate National Parks Conservancy) is in the process of developing adaptation strategies for Bothin Marsh with their Bothin Marsh Evolving Shorelines project.[1] The proposed adaptation strategies were developed based on a vision developed in collaboration with community members, and the next step will be to evaluate the feasibility of adaptation strategies. Two main goals of the project are to improve the trail network and the resilience of marsh habitats to sea-level rise.

Conceptual adaptation strategies have been developed for multiple timeframes, ranging from near-term trail resurfacing and tidal channel improvements to long-term trail realignment and landscape transition. One “potential design element” relevant to nature-based nutrient reduction and adaptation planning at SASM is the use of ecotone slopes as transitional habitat and high-tide refuge for species at the back of Bothin Marsh. The Initial Planning Memo for the project describes the benefits of applying treated wastewater on ecotone slopes.

Opportunity locations for ecotone slopes shown in the Evolving Shorelines memo include the Bay Trail frontage along the back of both North Bothin and South Bothin marshes, similar to the opportunity locations identified in the desktop analysis. Distance from the wastewater plant and a creek crossing at Arroyo Corte Madera del Presidio are potential constraints to incoprorating wastewater discharge into the design of future ecotone slopes. Implementing a horizontal levee nutrient reduction strategy here would require close coordination with trail updates as sea-level rise progresses.

1 WRT, & ESA. (2020). Bothin Marsh Open Space Preserve: Evolving Shorelines. Initial Planning Memo. One Tam.

OPPORTUNITIES & CONSTRAINTS

A site visit and conversation with Mark Grushayev, the SASM Plant Director (February 24, 2021), illuminated opportunities that were not identified by the GIS model, including potential opportunities at the plant itself. In particular, SASM staff are interested in pursuing design ideas to dual-purpose the equalization basins, so they can function as a nature-based nutrient reduction system most of the time and retain their wet weather storage function as needed. This type of NbS may also be a valuable upgrade to consider for other facilities with wet weather equalization basins that are only used a few times per year.

The SASM equalization basins are used approximately once per year during large storm events and are usually full for less than a day. The frequency and duration of use is likely to be affected by shifting precipitation patterns with climate change. Models predict that extreme rainfall events will double in frequency by the end of the 21st century compared to the end of the 20th century (cal-adapt.org).[2] Untreated water is stored in the basins prior to being routed to the plant for treatment. The northern basin is used more frequently; an overflow pipe routes flows to the southern basin when the northern basin is full. The southern basin has been used only a couple of times in the last eight years. Despite recent upgrades, it is likely the basins are not large enough to contain flows from a 50-year rainfall event (7.2" in 24 hours) (NOAA Precipitation Frequency Data Server).

Transitional and high-tide refuge habitat is very limited in the Mill Valley marsh complex today. Given the plant's adjacency to tidal marsh and the need for this important habitat type as sea levels rise, opportunity exists to connect nutrient reduction and flood risk management strategies by constructing a small horizontal levee connecting the plant's levee to the marsh. Regulatory agencies are recognizing that fill placement for projects with future habitat benefit are needed (e.g. BCDC's Fill for Habitat amendment), but the feasibility of permitting a project such as this with wastewater discharge incorporated is not known. A horizontal levee here could reduce flood risk for the plant by reducing impacts on the levee. Alternatively, a partnership could be formed with the Bothin Marsh Open Space Preserve to irrigate ecotone slopes with nitrified water from SASM, rather than constructing them as designed horizontal levee systems with subsurface flow. Coordination with the ongoing Bothin Marsh Evolving Shorelines effort could enhance opportunities for both SASM and the Preserve.

Contaminated soils at the base of the South Equalization Basin presents a constraint to NbS implementation. Prior to utilization of the basins for open water treatment wetlands, the basin must either be remediated or lined to inhibit the mobilization of heavy metals to waters intended for discharge to San Francisco Bay. Sea level rise and rising groundwater pose additional constraints that must be factored into the design of NbS systems at SASM. For example, the basins may need to be lined to prevent groundwater intrusion, and existing levee crest heights may need to be raised to prevent flooding from Richardson Bay. Finally, public perception of NbS may be an important constraint to overcome, especially due to the proximity of recreational facilities parks and trails. Especially with a horizontal levee system outside the plant's levee, an educational campaign would needed to explain the multiple benefits of this type of NbS. This represents an opportunity to engage members of the public and students from the adjacent Mill Valley Middle School to participate in an educational program regarding nature-based adaptation and wastewater treatment.

2 2-day rainfall totals over 1.7", for 2070-2099 relative to 1961-1990. Cal-Adapt

ADDITIONAL CONSIDERATIONS

ASSUMPTIONS

Site-specific assumptions inform the alternatives evaluation process and include project objectives, geographic and ecological constraints, land use, ownership, and political or funding realities. The following represent the base set of assumptions for the near-term alternative evaluation process with SASM:

- The project should not compromise the primary wastewater treatment plant needs and regulatory requirements. This includes ensuring that wet weather storage capacity is retained in the North and South Equalization Basins. The 2014 *SASM Master Plan* recommended expanding equalization basin capacity.
- The project should yield multiple benefits, including nutrient load reduction, enhanced wildlife habitat and environmental education.
- The alternatives evaluation process assumes little change in the surrounding land use and economy, and population growth consistent with planning projections, which are ~5% between 2014 and 2035. This amount of growth would increase the average dry weather flow from the plant in 2035 to 2.35 million gallons per day (mgd).
- The project should be designed to accommodate changing climate conditions. This includes designing for projected sea-level rise (1.9 ft by 2050 and 6.9 ft by 2100)[1] and increased intensity of preciptation events.

PRECEDENT

Open water treatment wetlands and horizontal levees have been implemented or are under consideration at several Bay Area WRRFs. In recent years, SASM operated its South Equalization Basin in dual purpose mode, which demonstrates the ability to manage one or both of the basins in both the dry and wet weather seasons. Already employed at the Oro Loma treatment plant, this strategy is gaining interest in the region and would demonstrate feasibility of enhancing existing wastewater retention basins to serve multiple purposes.

Currently, the San Leandro Water Pollution Control Plant is designing a project to repurpose a basin for nutrient load management and near-shore discharge. That project incorporates unit-cell open water treatment wetlands and woodchip bioreactors along the perimeter of the basin to enhance denitrifications and nutrient removal.

REGULATORY CONSIDERATIONS

The level of regulatory engagement and required permits depends on the scope of the project. If limited to repurposing the Equalization Basins, the permitting process is eased, since the basin is a part of SASM's treatment train and thus not a water of the United States. Activities in Bothin Marsh or on the outboard side of SASM's levee introduce significant regulatory requirements from multiple agencies and are likely viable only if SASM succeeds in partnering with multiple local and regional agencies or stakeholders.

1. These are the recommended projections to use for medium-high risk aversion planning purposes. CNRA-OPC. (2018). State of California Sea Level Rise Guidance, 2018 Update. California Natural Resources Agency and Ocean Protection Council. Sacramento, CA, USA, 84.


View over Mill Valley Marsh from the levee around the South Equalization Basin

Option 1: Coordinate with Bothin Marsh Evolving Shorelines project on a horizontal levee at North Bothin Marsh.

Option 2: Construct a horizontal levee between the South Equalization Basin and Mill Valley Marsh.

Option 3: Retrofit one or both equalization basins as dual-purpose treatment wetlands / wet weather equalization basins.

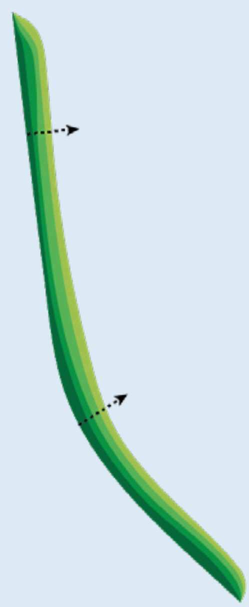
CONCEPTUAL DESIGN OPTIONS

To date, this project identified three main nature-based options for a multi-benefit nutrient load management strategy for SASM (Figure 7). These could be standalone options or could be combined as elements of a larger strategy. Option 3 represents the most viable stand-alone alternative, involving conversion of the North and/or South Equalization Basins to some form of open water treatment wetland. Options 1 and 2 involve a footprint outside the treatment plant and would require additional partnerships and regulatory processes.

The next step in this process involves additional engagement with SASM to identify the preferred alternative and appropriate near-term planning efforts.

OPTION 1

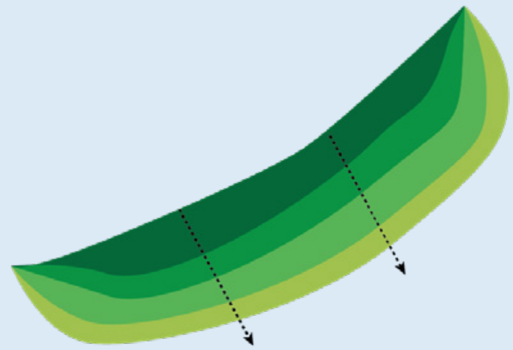
Option 1 requires partnership with the Bothin Marsh Evolving Shorelines project and the Bothin Marsh Open Space Preserve to route treated effluent to a horizontal levee at the back of North Bothin Marsh. The levee could be constructed as part of a habitat resilience and flood protection effort, making it lower risk and lower cost for SASM. The horizontal levee would be integrated with Bay Trail and habitat adaptation planning for Bothin Marsh. Water would need to be piped from the SASM plant along the Bay Trail and across the bridge at Arroyo Corte Madera del Presidio to the horizontal levee site. It would then seep through a subsurface layer in the horizontal levee and discharge to North Bothin Marsh.



Example concept sketch demonstrating Option 1. Treated wastewater from SASM is polished in a horizontal levee seepage slope integrated into an ecotone levee at the back of Bothin Marsh.

OPTION 2

Option 2 involves constructing a horizontal levee connecting the levee around the North and South Equalization Basins to the marsh. Treated effluent would be routed to a subsurface seepage slope in the horizontal levee and discharge directly to the adjacent marsh, creating a valuable fresh-to-salt marsh habitat gradient. This option could be integrated with Option 3 to create a combined wastewater polishing system, with water first treated in an open water wetland and then discharged through the horizontal levee seepage slope.

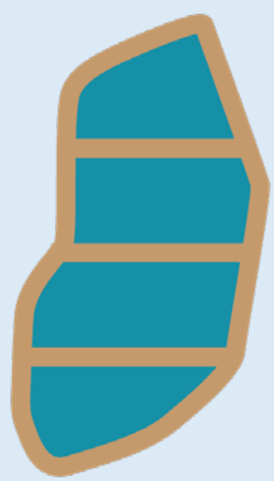


Example concept sketch demonstrating option 2. Construct a horizontal levee adjacent to the southern equalization basin at the back of Mill Valley Marsh.

OPTION 3

Alternative 3 involves retrofitting one or both of the equalization basins to a dual-purpose nature-based nutrient reduction system and wet weather equalization basin. The sides of the basin could be constructed as woodchip-based seepage slopes to promote denitrification. Flows from the slopes could be routed to the center of the basin, serving as a shallow 'unit-cell open water treatment wetland' similar to the recent proposed design at the San Leandro plant and demonstrated at other sites.

Multiple designs for the treatment wetland could be pursued, based on a set of limiting factors. For instance, does existing contamination require a toxics evaluation and remendiation plan or could the basin be lined, consistent with the San Leandro project, to inhibit contaminant migration? When major storms are expected, rapid draining of the treatment wetland would provide equalization storage capacity.



Example concept sketch demonstrating option 3. One option for this basin is conversion to a shallow open water treatment cell with effluent routed through woodchip seepage slopes. Woodchip baffles may be included to minimize hydraulic short-circuiting.

COMPARING OPTIONS

Table 1 lists a range of factors to consider when comparing the relative contributions of each option toward achieving habitat, nutrient reduction, flood risk management, and recreational goals.

Table 1. Comparison of each option's relative contribution to achieving goals of NbS implementation.

	Option 1 (Bothin Marsh horizontal levee)	Option 2 (SASM horizontal levee)	Option 3 (Equalization basin retrofit)
Habitat Interactions	Pros: Potential to contribute to habitat adaptation strategy for Bothin Marsh. Provision of high tide refuge, transition zone, fresh-to-brackish-to-salt marsh habitat gradient. Cons: Requires placement of fill in existing marsh. Will be permitting hurdles to discharge to Bothin Marsh.	Pros: Provision of high tide refuge, transition zone, fresh-to-brackish-to-salt marsh habitat gradient. Cons: Requires placement of fill in existing marsh. Will be permitting hurdles to discharge to Mill Valley marsh.	Pros: Provides habitat for waterbirds, freshwater invertebrates, etc. Vegetated marsh would provide more benefits. Can be designed for ecosystem function as well as for nutrient reduction. Cons: Vegetated wetlands require more management. Potential for invasive species.
Nutrient Reduction Capacity	As a stand-alone feature, this 0.7-km length of levee could receive up to ~1.2 mgd of flow and reduce dry season total inorganic nitrogen (TIN) loads from SASM by ~50%. An irrigation-only strategy would reduce this amount significantly.	As a stand-alone feature, this 0.15-km length of levee could receive up to ~0.3 mgd of flow and reduce dry season total inorganic nitrogen (TIN) loads from SASM by ~10%. An irrigation-only strategy would reduce this amount significantly.	Preliminary estimates suggest dry season TIN load could be reduced by ~7-20%, depending on the level of nutrient optimization and retention time through the equalization basins and adjacent seepage slopes.
Flood Risk Management	Could be built in conjunction with future trail upgrades and contribute to protection of the Bay Trail and areas behind (e.g. road and school) by reducing the height of waves reaching the trail.	Could contribute to protection of the SASM plant by reducing wave-driven erosion of the levee around the equalization basins, though waves are relatively small in this sheltered area.	This option does not contribute to flood risk management for SASM or the surrounding community.
Recreation	A horizontal levee in this location could enhance recreational access as sea level rise progresses and trails along Richardson Bay become inundated with greater frequency.	This alignment along an existing levee adjacent to the SASM plant would not enhance recreational access but could contribute to wildlife viewing and provide an environmental education resource. Opportunity to explore re-enabling public access.	Reintroducing year-round flow to the site and perhaps re-enabling public access would most likely increase bird populations and wildlife viewing opportunities that were lost when the basins were drained and access was limited.

NEXT STEPS

To identify and describe more detailed alternatives, including a preferred alternative, SFEI will engage with SASM and a select number of stakeholders where appropriate. Currently, SASM has not considered projects outside the footprint of their plant and communication with agencies involved in the Bothin Marsh Evolving Shorelines project will be needed to refine Concept Options 1 and 2.

Integral to the alternatives evaluation process is the compilation of data available for the North and South Equalization Basins and any other relevant information regarding SASM's treatment process and recent upgrades as a result of implementing options of their 2014 Master Plan.

Site visit with SASM representatives, February 2021.

NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: SAN JOSE-SANTA CLARA

PREPARED BY
San Francisco Estuary Institute

PREPARED FOR
Bay Area Clean Water Agencies

AUTHORS
Ellen Plane
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CONTENTS

Version 2 (June 2023).

All photos in this document courtesy of the authors.

INTRODUCTION

The first phase of analysis (Phase I) of the Nature-Based Solutions for Nutrient Reduction study was a regional-scale desktop analysis to determine which Bay Area water resource recovery facilities (WRRFs) have opportunities for implementing nature-based solutions (NbS) for nutrient reduction. In this phase (Phase II), we conducted outreach with a select group of facilities with high potential for NbS, including conducting site visits and discussing opportunities and constraints with agency staff. This phase also involved additional site-scale research and analysis to refine opportunities and constraints identified at each facility. Phase III of this study involves developing planning-level designs to enable cost estimation, identifying regulatory and land use conflicts, and establishing feasibility for agency-led planning for a small group of agencies, including the San José-Santa Clara Regional Wastewater Facility (SJSC).

The desktop analysis for SJSC identified opportunities for open water treatment wetlands in some of the former sludge lagoons adjacent to the plant and opportunities for horizontal levees along the back of Pond A18, as well as some areas deemed infeasible due to conflicts with a burrowing owl habitat protection area and other constraints. Initial conversations with staff at SJSC refined the initial set of opportunities to two main areas: the former sludge lagoons currently being cleared and consolidated and a potential partnership with other agencies to develop a project for Pond A18.

The SJSC facility was constructed in 1956. The facility has undergone several major upgrades since then and now serves over 1.4 million residents in eight cities. It is the largest advanced wastewater treatment facility in the western US, with a capacity of 167 mgd and average flows of about 110 mgd. In recent years, the plant has discharged about 79 mgd during the dry season. Treated wastewater is discharged via an outfall pipeline to Artesian Slough, which flows to Lower South San Francisco Bay. Discharges to Artesian Slough have long raised questions regarding habitat conversion and water quality impacts on the surrounding area. The SJSC has recently optimized operations to reduce nutrient loading to Lower San Francisco Bay and is exploring other alternatives, including nature-based solutions, to improve water quality in consideration of potential regulatory action concerning nutrient management.

Extensive recycled water programs operate at the SJSC facility and the nearby Silicon Valley Advanced Water Purification Center. South Bay Water Recycling manages the distribution of recycled water through an extensive purple pipe system, delivering an average of 11 mgd of recycled water to commercial customers. Staff at the SJSC facility are interested in exploring nutrient removal alternatives, and the plant may be well-suited for NBS implementation due to the availability of nitrified effluent and the large footprint of the sludge lagoons now being consolidated and converted for other uses.

Figure 1. Site in context

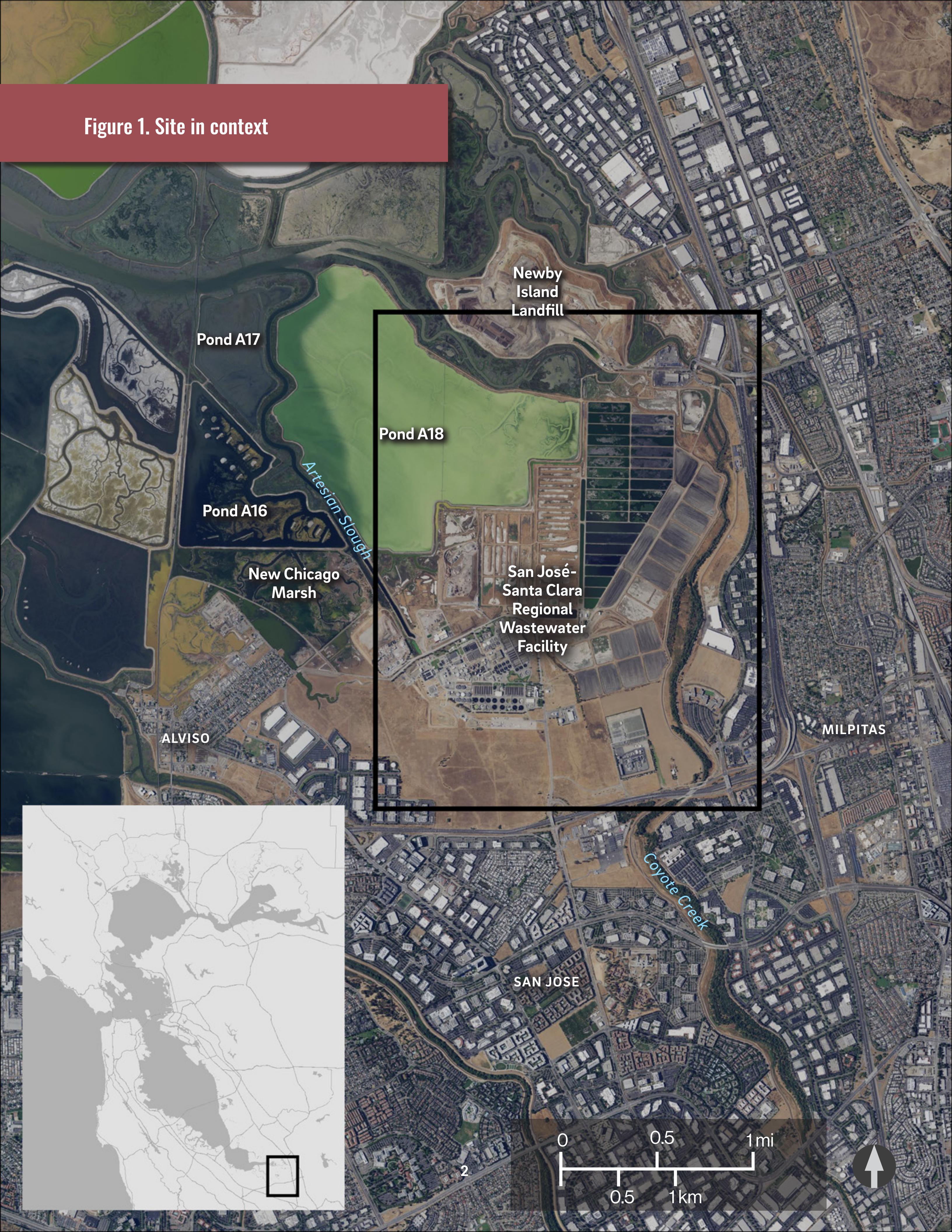


Figure 2. Site detail

SITE OVERVIEW

ECOLOGY

The SJSC facility is built on historical wetlands. Most of the plant footprint is on a historical tidal marsh and adjacent wet meadows. Before extensive salt pond creation in the Lower South Bay in the early-mid 1900s, freshwater entered the Baylands directly from streams like Coyote Creek and diffusely from groundwater and surface runoff. These freshwater inputs created salinity gradients that were an important component of the Baylands ecosystem, increasing the physical and ecological diversity of the landscape. Figure 3 shows the extensive freshwater wet meadow that ringed the tidal marshes of Lower South San Francisco Bay before development.

Today, the volume, timing, and type of freshwater inputs have been greatly altered by urban development, the construction of stormwater drainage channels, and the creation of salt evaporation ponds. The once-broad floodplain of Coyote Creek has been narrowed and channelized to allow for development. Tidal marsh still remains in the channel margins between the former salt ponds (Figure 4), but is much more limited, compared to its historical extent. Restoration of salt ponds in the area by the South Bay Salt Pond Restoration Project is gradually increasing the area of tidal marsh while continuing to provide managed pond habitat for waterbirds.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

The SJSC facility is located near several major transportation corridors (Figure 5). I-880 runs north-south and CA-237 east-west just south of the site. Much of the land surrounding the site is owned and managed by public entities. Pond A18 and the Coyote Creek corridor to the east are owned by the City of San Jose. The US Fish and Wildlife Service manages the former salt ponds and tidal marshes bayward of Pond A18 as part of the Don Edward National Wildlife Refuge. Several large active landfills are in the vicinity of the facility, including the Newby Island Landfill and the Zanker Road landfills. The undeveloped area south of the facility is a protected area for burrowing owls.

The SJSC Plant is not located within a census tract designated as an Equity Priority Community (EPC) by MTC, the Metropolitan Transportation Commission, nor is it within a state SB 535 Disadvantaged Community. Several areas nearby are designated as Priority Development Areas (PDAs) by MTC. PDAs are places near public transit planned for more housing and amenities.

LAND USE & OWNERSHIP

According to SJSC's 2013 Plant Master Plan, the existing operations footprint currently includes the wastewater treatment operations area, the residual solids management area, and the legacy biosolids lagoons, which together comprise a total land area of approximately 950 acres. According to the Plan, SJSC intends to transition to mechanical solids dewatering, relocate a significant component of the solids handling processes to the legacy biosolids lagoons, and reduce the operations footprint to approximately 440 acres. The alternatives presented here are limited to areas within the plant footprint and do not include the lagoon ponds or drying beds. Some additional acreage (exact acres unknown) in the active lagoon areas may be available for conversion to alternative uses after ~2030, as decommissioning of active lagoons and drying beds gradually progresses over the next 5+ years.

FLOODING & SEA-LEVEL RISE VULNERABILITY

Coastal flood exposure due to sea-level rise for the SJSC facility is shown in Figure 6. This flood exposure map will look significantly different after construction is completed on Phase I of the South San Francisco Bay Shoreline Study. The protection of high-value infrastructure at the SJSC facility is one of the key reasons for the construction of the levee. The levee crest height accounts for 2.59 feet of SLR, the US Army Corps of Engineers (USACE)'s "high" scenario projected for 2067.[1] See *Recent & Planned Changes Nearby* for more information about the South San Francisco Bay Shoreline Study. Levees along Coyote Creek, to the east of the treatment plant, are owned and maintained by Valley Water and provide protection from riverine flooding. Impacts of groundwater rise due to rising sea levels may not be ameliorated by levee construction, and are important to consider, particularly for basins subject to seepage and any belowground infrastructure.

1. USACE. 2015. South San Francisco Bay Shoreline Phase I Study: Final Integrated Document (Final Interim Feasibility Study with Enivronmental Impact Statement / Environmental Impact Report). Prepared by HDR Engineering, Inc. for the U.S. Army Corps of Engineers.

Artesian Slough.

Figure 3. Historical bayland habitats

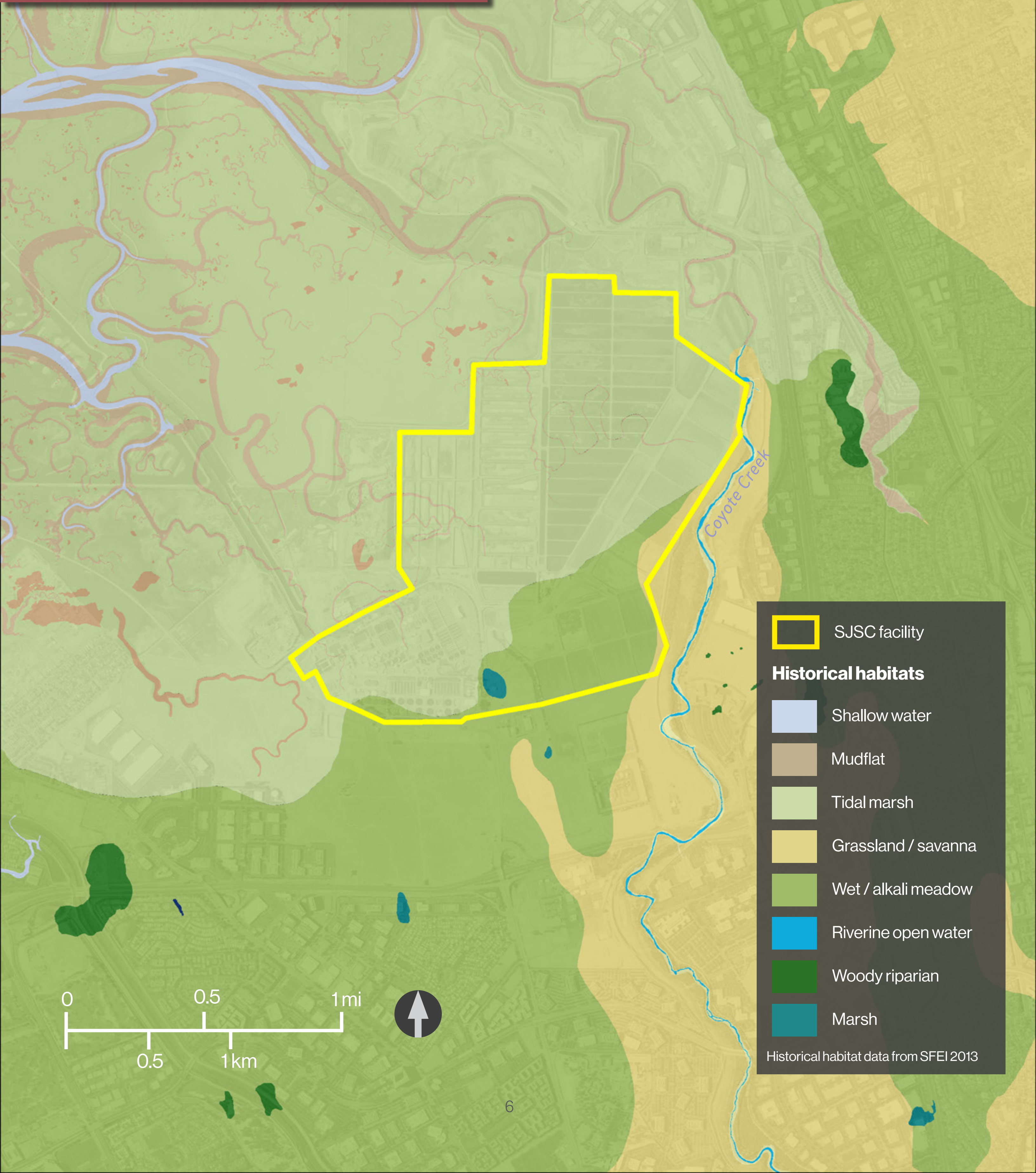


Figure 4. Modern bayland habitats

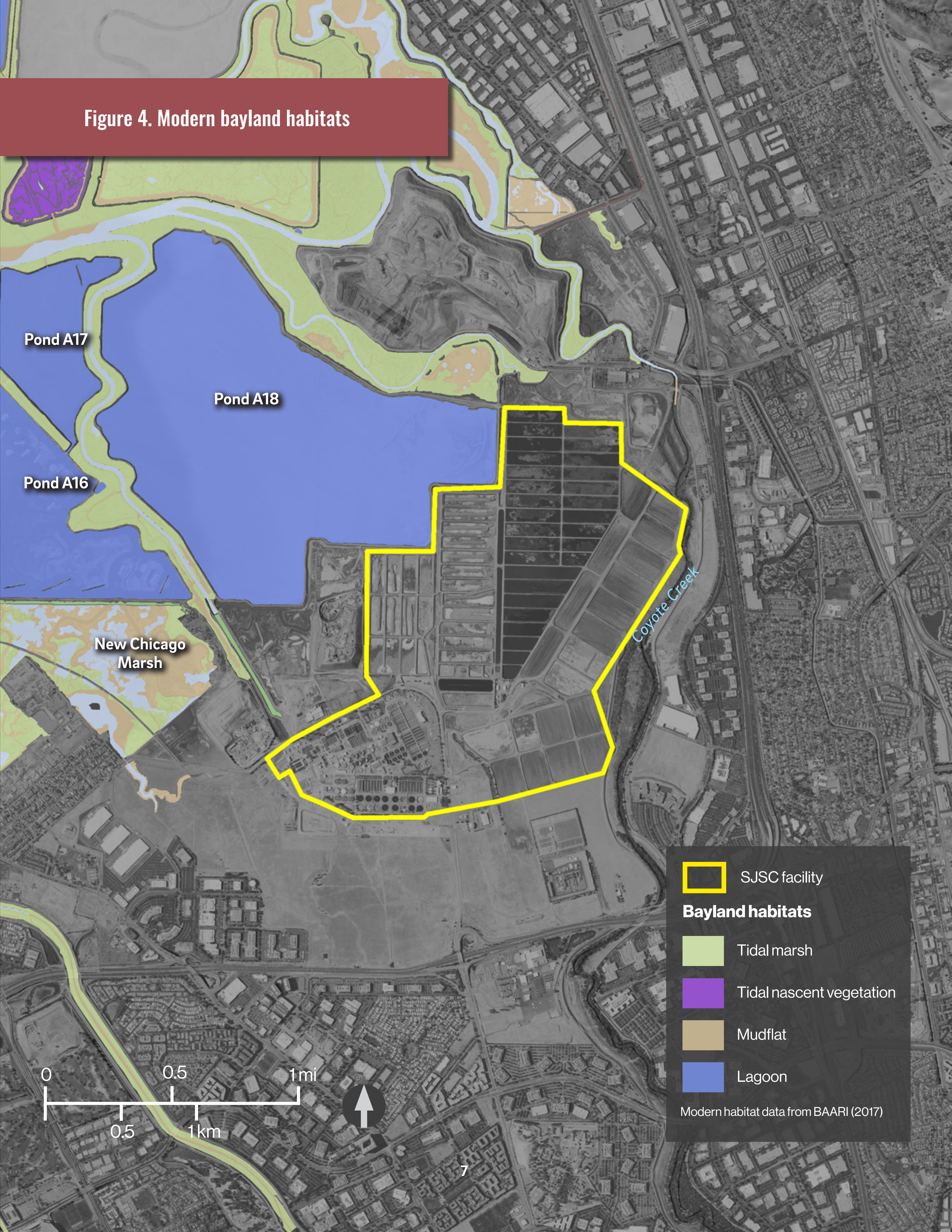
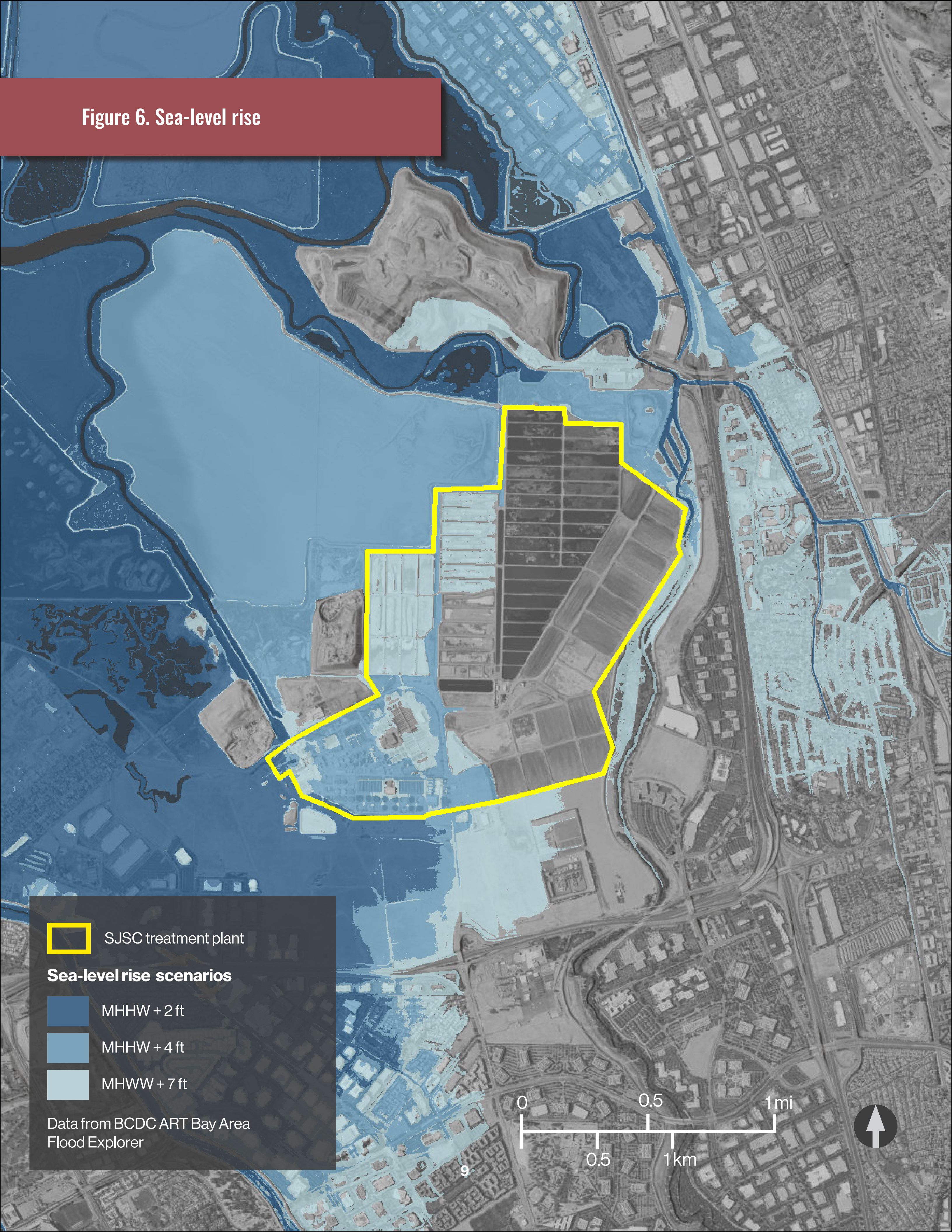


Figure 5. Infrastructure, recreation, & disadvantaged communities

Figure 6. Sea-level rise



SITE CONSIDERATIONS

RECENT & PLANNED CHANGES AT FACILITY

The plant is currently undergoing upgrades according to its 2013 Plant Master Plan.[1] Staff are also working to develop a conservation easement to protect burrowing owl habitat south of the plant. Most relevant to the development of NbS, activities are underway in the undeveloped area to the northeast of the plant to consolidate material in former biosolid drying lagoons due to concerns over contamination (metals in particular). Dried biosolids are being removed from lagoons and placed in two basins, where they will eventually be capped. The base of these basins lies about five feet above mean sea level, and they will be filled to 12ft above mean sea level. After completion of the remediation effort, a wetland mitigation project will also be developed to replace the low-quality wetland habitat that existed in the sludge lagoons and was disturbed by the consolidation project. This mitigation wetland will likely be developed on top of the consolidated and capped biosolids.

The alignment of the future flood risk management levee is planned to cut across several lagoons in the northeast part of the site. Following construction of the levee, these lagoons will be connected to Pond A18. The fill material in the berms was tested and determined to be clean enough to allow this plan to proceed. There have been discussions about the beneficial reuse of the material to construct the planned ecotone levee.

RECENT & PLANNED CHANGES NEARBY

Much of the south San Francisco Bay shoreline is currently protected by unengineered berms surrounding former salt production ponds. The **South San Francisco Bay Shoreline Project** aims to construct an engineered, FEMA-certified shoreline levee to protect South Bay communities from coastal flooding and sea-level rise. The project is led by the US Army Corps of Engineers in partnership with Valley Water and the State Coastal Conservancy. Phase I covers the Alviso area and will involve the construction of 4 miles of levee, including along the back of pond A18 to protect the SJSC facility. Construction of the levee will allow for the berms surrounding the salt ponds bayward of the new levee to be breached and the ponds restored to tidal marsh, per the plans of the South San Francisco Bay Shoreline Project.[2] Ecotone levees will be included to allow for development of high marsh and transitional habitat at the back of newly restored marshes. The feasibility study for Phase I was completed in 2015 and construction on reaches 1-3 (west of Artesian Slough) began in December 2021.

The **South Bay Salt Pond Restoration Project** (SBSPRP), a collaborative project between regional, state, and federal agencies, represents the largest tidal wetland restoration project on the West Coast. When complete, the project will restore 15,100 acres of industrial salt ponds to a rich mosaic of tidal wetlands and other habitats. As part of this effort, the SBSPRP plans to restore

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1. San Jose Santa Clara Water Pollution Control Plant Plant Master Plan. 2013. Available at https://www.sanjoseca.gov/your-government/environment/water-utilities/regional-wastewater-facility/capital-improvement-program/plant-master-plan
2. South San Francisco Bay Shoreline Phase I Study, Final Integrated Document, Final Interim Feasibility Study with Environmental Impact Statement / Environmental Impact Report. 2015. Prepared for U.S. Army Corps of Engineers by HDR Engineering, Inc. Available at www.spn.usace.army.mil

the salt ponds in the Alviso complex directly bayward of the Sunnyvale-San Jose shoreline. Some of the ponds will be restored to tidal marsh and other, deeper ponds will continue to be managed as open water habitat for waterbirds, with restoration decisions guided by the SBSPRP's adaptive management plan and local riverine and coastal hydrology. The SBSPRP coordinates closely with the US Fish and Wildlife Service, which manages the ponds in the Alviso complex as part of the Don Edwards National Wildlife Refuge. Pond A18 is not part of the Refuge nor the SBSPRP and is owned by the City of San Jose. However, it is planned to be breached and restored to tidal marsh in association with the construction of the shoreline levee under the South San Francisco Bay Shoreline Project. Based on a staff report recommending Measure AA funding for this project, breaching of pond A18 is planned to occur between 2024 and 2027.[1]

OPPORTUNITIES & CONSTRAINTS

Following conversations with staff at SJSC, it was determined that the greatest opportunities for NbS likely lie in the former sludge lagoon area and potentially in or adjacent to Pond A18. Currently, there are no specific land use plans in place for the consolidated and capped area or for the former biosolid drying lagoons. However, opportunities may exist to integrate planning for NbS with those for mitigation for activities associated with the sludge lagoon consolidation work.

Discussions with SJSC included consideration of pond A18 as a long-term nutrient management alternative. However, future plans for pond A18 include a change of ownership from the City and breaching of the pond, which is in conflict with future uses involving open water wetlands or extensive seepage slopes around the pond, for instance. The 856-acre Pond A18 was diked for salt production in the 1950s and was purchased by the City of San Jose in 2003.[2, 3] Currently, Pond A18 is believed to serve a nutrient cycling function, given its proximity to Artesian Slough and gate operations, which enable a high retention time that promotes denitrification. Nutrient cycling functions will change when the shoreline levee is completed and Pond A18 is breached and fully reconnected to San Francisco Bay. The fate of pond A18 is critical to understanding the range of NbS alternatives for the facility, as well as the nutrient transport and fate in the Lower South San Francisco Bay.

Other opportunities involve the fact that the SJSC facility and Valley Water maintain a water recycling partnership to generate treated water suitable for potable uses. And for the last two years, Valley Water has collaborated with the Oro Loma Sanitary District to evaluate the feasibility of treating reverse osmosis concentrate through horizontal levees or other seepage slopes. Preliminary findings indicate high removal rates of nitrogen and other contaminants from wastewater. Valley Water currently partners with SJSC to provide treated effluent to the Silicon

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1. San Francisco Bay Restoration Authority. June 7, 2019. Staff Recommendation: South San Francisoc Bay Shoreline Project Project No.: RA-006. Available at https://www.sfbayrestore.org/sites/default/files/2020-02/item_11_south_sf_bay_shoreline_new_site.pdf
2. Collins. J.N. and R.M. Grossinger. 2004. Synthesis of scientific knowledge concerning estuarine landscapes and related habitats of the South Bay Ecosystem. Technical report of the South Bay Salt Pond Restoration Project. San Francisco Estuary Institute, Oakland CA.
3. Memorandum providing the City of San José's Transportation and Environment Committee a Shoreline Levee Update. September 24, 2017. Available at http://sanjose.granicus.com/MetaViewer.php?meta_id=665088

Valley Advanced Water Purification Center, near the SJSC. If this partnership evolves, nature-based treatment of reverse osmosis concentrate (ROC) represents a highly advantageous strategy for removing nitrogen from a concentrated waste stream prior to discharge to SF Bay. In the next year, researchers will release findings which could influence feasibility assessments of expanding recycled water production in San José.

Other opportunities include the use of additional lagoon areas or other buffer lands for NbS alternatives, which are not considered here. Future iterations or refinements should consider whether all potentially available lands have been considered for NbS.

Constrains to developing NbS alternatives at the SJSC facility involve land ownership, contamination of lands at the lagoons and drying beds, as well as the presence of a bomb disposal area adjacent to areas under consideration for NbS.

Currently, wastewater agencies cannot plan around a certain nutrient load cap or reduction objective. This regulatory uncertainty limits the ability to know whether NbS represents a viable nutrient management alternative. If significant (>25%) reductions are needed in the longer term, the facility must evaluate the range of nutrient load alternatives available, including optimization and upgrades, NbS, and wastewater recycling. For the SJSC facility, all options are available, and NbS could play a supporting role to treat either tertiary treated effluent or concentrated discharges.

As regulatory clarity emerges regarding the scale of nutrient load management scenarios, additional load management scenarios will emerge, which will inform an evaluation of the constraints. At this point, however, none of the known constraints represent a fatal blow to NbS deployment at the SJSC facility.

PRECEDENT

Wastewater agencies in the northern and southern reaches of San Francisco Bay have for several decades been subject to several Discharge Prohibitions from the San Francisco Bay Water Quality Control Plan (Basin Plan) to protect Suisun Bay and the Lower South Bay. This has resulted in efforts to maximize water reclamation and recycling in the North Bay, while enhanced treatment has occurred at the Lower South Bay WRRFS, of which the SJSC facility is the largest. Wastewater dischargers to the Lower South Bay have not adopted NbS at scale to date, yet all are considering the possibilities as they tackle issues related to aging infrastructure and future water quality regulations.

Projects under current consideration by wastewater agencies and regulatory agencies include those to advance horizontal levees at Oro Loma Sanitary District, Palo Alto Regional Water Quality Control Plant, and West County Wastewater District. Open water wetlands were authorized for near-shore discharge for the City of Petaluma and Mt. View Sanitary District, and a 2022 NPDES permit was adopted for a new open water polishing wetland for the City of San Leandro.

REGULATORY CONSIDERATIONS

Bay Area WRRFs are subject to myriad regulations, some of which may inadvertently act in conflict with nutrient load reduction efforts. The regulatory landscape governs not just surface water discharges but also water reuse, biosolids management, protected species and habitats, and air emissions. Project proponents and regulators have initiated discussions over potential approaches for mitigating these barriers, recommendations for quantitative analyses of potential conflicts, and options for regulatory and permit-based approaches to maximize the multi-functional benefits associated with NbS upgrades, in the event large-scale nutrient load reductions are warranted. The final report for this regional NbS evaluation project shall feature a synthesis of the extensive regulatory considerations applicable to most WRRFs in Region 2.

Facility-specific permits, local ordinances, and site-specific plans feature requirements for each facility. In general, the SJSC facility faces fewer likely regulatory hurdles, compared with other WRRFs in the region located closer to Central San Francisco Bay. Factors contributing to this conclusion include the fact that the City of San José owns much of the land surrounding the facility, an existing NPDES permit allows for shallow water discharges already, and several of the design options presented involve retrofitting of existing basins. Regulatory agencies generally exclude existing elements of a wastewater treatment train from waters of the U.S., thus potentially minimizing wetlands-related mitigation considerations.

For regulatory purposes, the San Francisco Bay Regional Water Quality Control Board recently provided guidance and continues to establish precedent for permitting discharges of treated effluent from NbS projects in the region.[1] On-going consultations with other regulatory agencies for similar projects also serve to continually inform opportunities and constraints, in terms of mitigation and monitoring requirements, desired treatment performance, and the appropriate quantification of ancillary benefits, including habitat enhancement, water reclamation, and community benefits.

The ancillary benefits of pursuing any option presented here include, at a minimum, additional reductions in dry weather discharges to Lower South San Francisco Bay and the enhancement of habitat quality and quantity. Other potential benefits include recreation and education opportunities, demonstration of novel NbS strategies, and potential sea-level rise adaptation and resilience of the SJSC facility and surrounding areas. Pending refinement of these concepts, this memorandum aims to quantify these and other likely benefits and impacts. Quantification of such benefits enables regulatory agencies to weigh the net environmental benefits associated with a project.

1. "NPDES Permitting for Nature-based Solutions," 2022, San Francisco Bay Regional Water Quality Control Board.

Figure 7. Conceptual design options

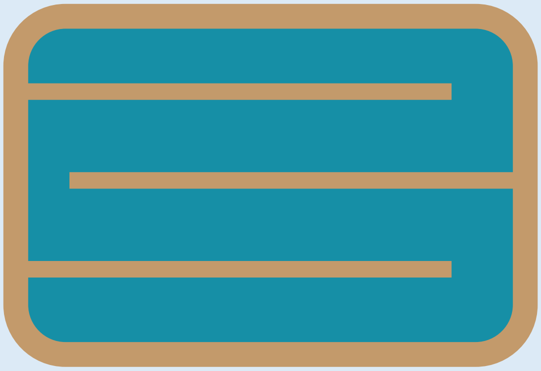
- Option 1: Lined open water treatment wetland over consolidated fill area
- Option 2: Open water treatment wetland in former sludge lagoons
- Option 3: Incorporate seepage slope into future ecotone levee at the back of Pond A18

CONCEPTUAL DESIGN OPTIONS

Three main nature-based options for a multi-benefit nutrient load management strategy at SJSC have been identified (Figure 7). These could represent standalone options or combined as elements of a larger strategy. Given volumes of nitrified effluent and potentially large areas of available space, multiple options may be pursued.

OPTION 1

When the biosolids consolidation project is complete in the 26-acre basin south of the future levee (Figure 7), base elevations will be approximately 12 to 13 ft MSL, about 4 feet below the top of the surrounding berms.[1] An open water treatment wetland could be constructed on top of the consolidated and capped fill. The basin would be designed and optimized for nutrient removal. One potential design to explore is an open water treatment cell with seepage slope sides, potentially also including woodchip baffles to minimize hydraulic short-circuiting. These slopes could be optimized to receive ROC or other concentrated discharges. This basin will be capped once it has been filled to the target elevation with dried biosolids, with the open water treatment cell constructed on top of the cap.

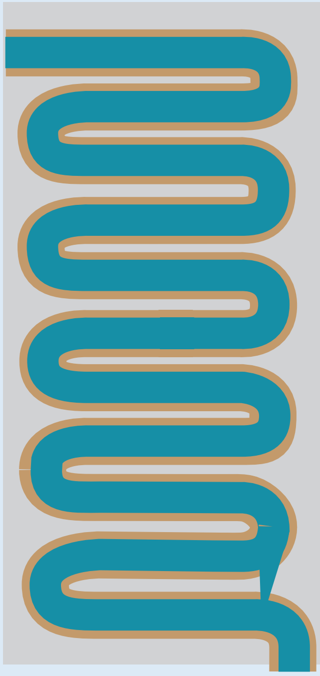


Example concept sketch demonstrating option 1: construct a lined open water treatment wetland over consolidated fill area. One option for this area is conversion to a shallow open water treatment cell with effluent routed through woodchip seepage slopes. Woodchip baffles may be included to minimize hydraulic short-circuiting.

1. Cornerstone Earth Group. Dec 12, 2019. Memorandum to City of San Jose Environmental Services Division. Subject: Draft Narrative for Legacy Lagoon Closure.

OPTION 2

Once biosolids are removed from the drying basins and placed in the consolidated fill area, the elevation of the former drying basins will be approximately 2 to 3 feet above MSL and the existing berms will be left in place.[1] Following the consolidation project these basins will be decommissioned and become available for other uses. One potential use is conversion to open water treatment cells. A variety of potential designs could be employed. For the larger 62-acre area shown in Figure 7, a serpentine-style treatment wetland could be created, taking advantage of the existing berms between the basins to create structure, control flow direction, and minimize hydraulic short-circuiting. For smaller areas (e.g. the 19-acre area in Figure 7), open water treatment cells with seepage slope sides may be more suitable, potentially taking advantage of existing berms to create the woodchip slopes.



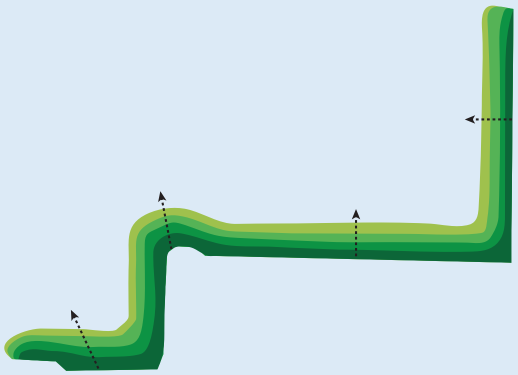
Example concept sketch demonstrating option 2. In one basin, a shallow open water treatment cell is constructed, with effluent routed through woodchip seepage slopes. In the larger basin, plant effluent is routed through a serpentine-style open water wetland with woodchip sides optimized for nutrient removal. The serpentine-style channel minimizes opportunity for hydraulic short-circuiting.

1. Cornerstone Earth Group. Dec 12, 2019. Memorandum to City of San Jose Environmental Services Division. Subject: Draft Narrative for Legacy Lagoon Closure.

OPTION 3

This option would involve working closely with the South San Francisco Bay Shoreline Project (USACE, State Coastal Conservancy, and Valley Water) to incorporate a treated wastewater seepage slope into the ecotone slope planned for the southern shoreline of Pond A18. Coordination with project proponents and the design team as soon as possible would be necessary to establish a roadmap for governance, funding, and maintenance.

The South San Francisco Bay Shoreline Project plans to construct a 30:1 ecotone levee at the back of Pond A18 (bayward of the new flood risk management levee) to provide transitional habitat, including high marsh and marsh-upland transition zone.[1] The ecotone levee will be planted with native transition zone plants and will provide high tide refugia for marsh species once the existing dikes around Pond A18 are breached and tidal marsh is allowed to establish within the pond.



Example concept sketch demonstrating option 3. A horizontal levee could be integrated into the South San Francisco Bay Shoreline Project's planned ecotone levee. Treated wastewater would flow through a seepage slope designed to remove nutrients and other contaminants before discharging to Pond A18. The seepage slope would be integrated into the design of the habitat ecotone at the back of the newly restored tidal marsh in Pond A18. While the sketch shows an seepage slope along the full length of the ecotone levee, it could be constructed for just part of the length.

The current ecotone levee design does not include a wastewater seepage slope. However, the addition of a freshwater source at the back of the marsh in this area could be a valuable addition from a habitat perspective in addition to providing nutrient reduction benefits. Wet meadows were historically widespread at the back of tidal marsh in this area (Figure 3), and the addition of freshwater flow to the ecotone slope could recreate some of the historical fresh-brackish-salt marsh habitat gradients that historically existed. In addition, brackish marshes accumulate organic matter faster than salt marshes and thus can grow vertically faster with less inorganic sediment. This is a boon in the context of climate change; marshes with high primary productivity may be able to accrete more organic matter and be more resilient to rising sea levels.[2]

Given that Phase I of the South San Francisco Bay Shoreline Project is well underway, it may be difficult to align stakeholders to redirect design and construction. Ecotone levees require special subsurface design considerations that have not been accounted for in existing planning. However, incorporating a seepage slope in this location would provide a valuable opportunity to achieve multiple benefits if these hurdles can be overcome.

In the event a seepage slope is not feasible along the proposed levee, the existing partnership between Valley Water and SJSC could be leveraged to identify other areas where seepage slopes could treat ROC. Options 1 and 2 could be modified to incorporate seepage slopes optimized for nitrate removal.

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1. USACE. 2015. South San Francisco Bay Shoreline Phase I Study: Final Integrated Document (Final Interim Feasibility Study with Enivronmental Impact Statement / Environmental Impact Report). Prepared by HDR Engineering, Inc. for the U.S. Army Corps of Engineers.
2. Schile, L.M., Callaway, J.C., Morris, J.T., Stralberg, D., Parker, V.T., Kelly, M., 2014. Modeling Tidal Marsh Distribution with Sea-Level Rise: Evaluating the Role of Vegetation, Sediment, and Upland Habitat in Marsh Resiliency. PLOS ONE 9, e88760. https://doi.org/10.1371/journal.pone.0088760

COMPARING OPTIONS

Table 1 lists the goals of implementing NbS to achieve multiple benefits and the relative contribution of each option toward meeting those goals. This allows for a high-level comparison of options. Further feasibility analysis will be conducted by SJSC staff to determine which options are most appropriate to pursue. Factors that have not received full consideration include implementation costs, regulatory constraints, and competing demands for space and existing wet weather storage capacity at the facility.

Table 1. Comparison of each option's relative contribution to achieving goals of NbS implementation.

● = Achieves. ◑ = Partiallyor possibly achieves. ○ = Does not achieve.

For TIN removal, 'Achieves' is>30% removal, 'Partially achieves' is 5-20% removal, and "Does not achieve is <5% removal.

	Option 1 (Open water treatment wetland over consolidated fill area (26-ac total)	**Option 2** (Open water treatment wetland in former sludge lagoons) (81-ac total)	**Option 3** (3.1-km horizontal levee along the back of Pond A18
Goal 1: Reduces nutrient loads to the Bay and improves overall water quality.			
Reduces TIN *Estimated dry-season reduction (kg d^{-1} / % reduction of daily TIN load)*	○ 120 kg d-1 / 3%	◑ 380 kg d-1 potential / 9%	◑ 400 kg d-1 / 9%
Goal 2: Reduces flood risk for the plant and/or associated infrastructure.			
Attenuates waves and provides erosion resistance	○	○	Already provided by planned ecotone levee
Facilitates marsh accretion	○	○	●
Goal 3: Create and/or enhance habitat			
Provides marsh-upland transition zone habitat and marsh migration space	○	○	Already provided by planned ecotone levee
Provides high tide refuge habitat for wildlife	○	○	Already provided by planned ecotone levee
Increases habitat complexity	◑	◑	●
Provides freshwater pond/ marsh habitat	◑	◑	●
Goal 4: Enhances recreational opportunities.			
Provides opportunity for public trails and wildlife viewing	○	○	Already proposed as part of South San Francisco Shoreline Project Phase I
Goal 5: Provides additional co-benefits.			
Reduces use of potable water for irrigation	○	○	○
Supports goals of partner organizations *(e.g. facilitates neighboring restoration projects)*	○	○	◑

In terms of nitrogen removal, the estimates provided in the first row represent a conservative estimate, assuming 11.2-acres of shallow open water wetland can remove 90% of the nitrate from one mgd of nitrified effluent. SJSC owns a significant amount of buffer lands and ponds being considered for other uses. Figure 8 illustrates the proportion of nitrate removal expected, based on wetland acreage and water temperature.

From literature-based decay rates, it is possible to estimate nitrogen removal in relation to temperature and wetland extent and volume. In San José, an average summer-time water temperature of 20 degrees celcius (68 degrees fahrenheit) is assumed. If Options 1 and 2 were combined, for a total of 87-acres of open water wetland, and all dry weather flow was routed through this system (~79mgd), approximately 25% of nitrate removal could be expected during the summer months. Figure 8 shows how the proportion of nitrate removed increases with wetland extent.

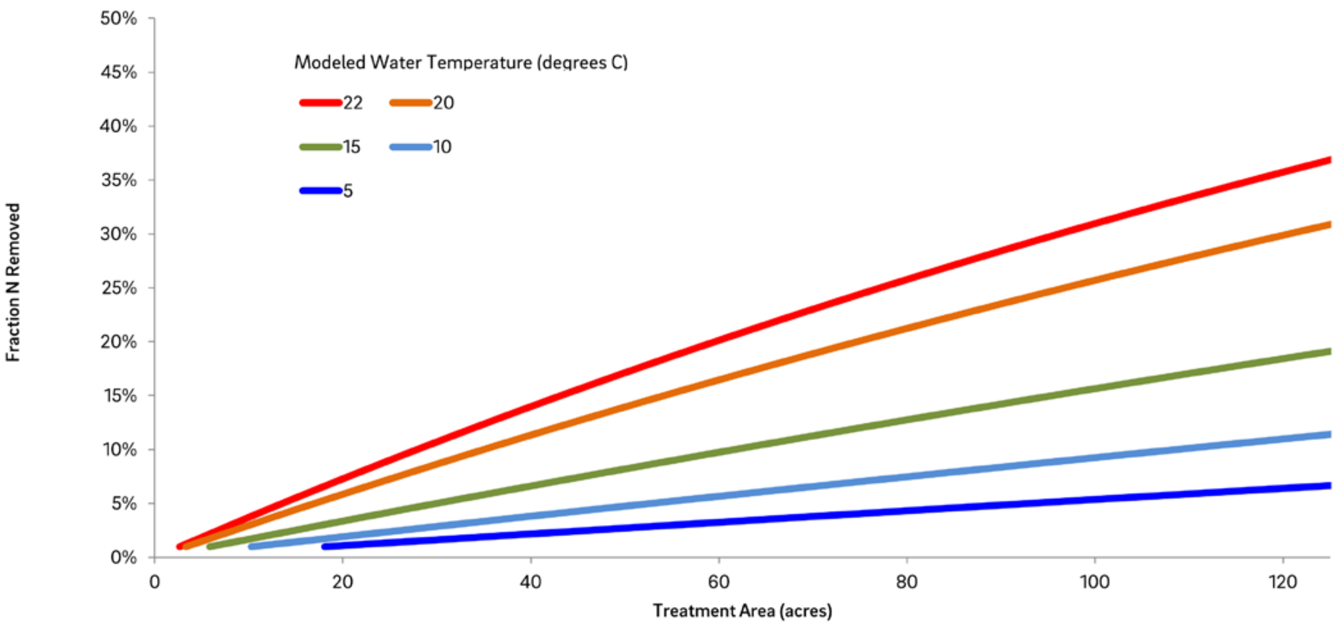


Figure 8. Depiction of the amount of open water treatment wetlands needed to treat San Jose's dry weather flow of ~79 mgd, and the corresponding percentage of nitrate removed.

NEXT STEPS

In Phase 3 of this project, cost estimates and planning-level designs shall be produced to better inform implementation options and overall viability. SJSC has demonstrated some interest in converting former sludge handling ponds for nature-based treatment and additional buffer lands may be available for additional nature-based treatment. The fact that SJSC already nitrifies its effluent and maintains significant acreage for open water wetlands or seepage slopes makes them a strong candidate for moving forward to the design and advanced planning phase.

The alternatives presented here do not reflect a scenario in which Valley Water and SJSC increase recycled water production and require options for the treatment of ROC. In the next year, researchers will release findings that could influence feasibility assessments of expanding recycled water production in San José. Based on discussions regarding nutrient load management and recycled water for direct or indirect potable reuse, nature-based treatment could play a vital role in treating ROC prior to discharge to San Francisco Bay.

Looking northeast over Pond A18 during site visit on February 10, 2022.

NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: SOUTH SAN FRANCISCO / SAN BRUNO

PREPARED BY
San Francisco Estuary Institute

PREPARED FOR
Bay Area Clean Water Agencies

AUTHORS
Ellen Plane
Ian Wren

CONTENTS

Version 1 (May 2023).

All photos in this document courtesy of the authors.

INTRODUCTION

The first phase of analysis (Phase I) of the Nature-Based Solutions for Nutrient Reduction study involved a regional-scale desktop analysis to determine which Bay Area water resource recovery facilities (WRRFs) have opportunities for implementing nature-based solutions (NbS) for nutrient reduction. In this phase (Phase II), we conducted outreach with a select group of facilities with high potential for NbS, including conducting site visits and discussing opportunities and constraints with agency staff. This phase also involved additional site-scale research and analysis in refining opportunities and constraints identified at each facility. In Phase III of this study, we will develop planning-level designs to enable cost estimation, identify regulatory and land use conflicts, and establish feasibility for agency-led planning.

South San Francisco-San Bruno Water Quality Control Plant (WQCP) was one of the facilities identified as a high-potential site for NbS. In this highly developed area just north of the San Francisco International Airport (Figure 1), the desktop analysis identified few opportunities for open water treatment wetlands or horizontal levees adjacent to the plant. However, staff at the plant were interested in continuing to develop ideas for NbS, and through these conversations, a few opportunities were identified for potential treatment wetlands and/or a horizontal levee near the plant, including east of the plant where former naval wharves are currently underutilized and in disrepair (Figure 2).

The South San Francisco-San Bruno WQCP currently serves about 120,000 people in South San Francisco, San Bruno, and Colma. The WQCP was constructed in 1951 and has undergone several upgrades since then. The WQCP treats average dry weather flows of about 7 mgd (permitted capacity 13 MGD) and wet weather flows up to 60 mgd. Treated wastewater is discharged via a pipeline to a shared outfall northeast of the Oyster Point Marina. Other facilities discharging to this outfall are San Francisco International Airport, Burlingame, and Millbrae, which form a joint powers authority referred to as the North Bayside System Unit (NBSU).

In 2023 the WQCP completed a comprehensive capital improvement project increasing secondary treatment capacity from 30 MGD to 40 MGD, helping to further minimize blending with primary effluent during wet weather events. Currently, the WQCP does not nitrify any portion of effluent nor produce recycled water. The addition of a nitrification step would be required to implement NbS at South San Francisco-San Bruno. Early conversations with plant staff indicate that there could be potential to convert a nearby parking lot to develop a nitrification step.

Figure 1. Site in context

Figure 2. Site detail

SITE OVERVIEW

ECOLOGY

The WQCP is located on a peninsula at the mouth of Colma Creek. The northern part of the plant is constructed on artificial fill over historical tidal flats and tidal channels (Figure 3), while the southern portion is constructed on a historical upland (a former island in the marsh). Prior to development, the mouth of Colma Creek was home to a broad complex of tidal marshes, tidal flats, and channel networks. Highly constrained by development, today, the banks have been hardened and only remnants of the historical tidal marsh remain (Figure 4).

In the early 2000s, the Colma Creek marsh complex was a major habitat area for Ridgway's rail. At that point, the invasion of introduced Spartina alterniflora (smooth cordgrass) was in full swing in the Bay, and the Colma Creek complex was one of the epicenters. Invasive Spartina spread into the mudflats and increased marsh habitat area. As in other parts of the Bay, Ridgway's rail benefited from the invasion, as rails prefer the dense cover provided by the invasive and hybrid Spartina. After San Francisco Estuary Invasive Spartina Project staff removed the invasive Spartina, the marsh eroded, and the proportion of mudflat increased, and so the rail population dwindled in the Colma Creek complex. Today a band of planted native Spartina foliosa survives but there is very minimal marsh cover sufficient to support a rail population.

The remaining pockets of marsh along the San Francisco peninsula (including those at Colma Creek) continue to provide some important benefits. Marshes at Colma Creek are one of the last habitat patches in the region for species migrating north along the peninsula, and anecdotal evidence suggests that this results in wildlife concentrating in this area. The 2015 Baylands Goals Update[1] focuses on these two goals for this shoreline segment: (1) to enhance and protect habitat patches; (2) to use these marsh patches as opportunities to promote public awareness of climate change and the baylands.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

The WQCP is located adjacent to the San Francisco International Airport, in a highly developed commercial and industrial area of South San Francisco (Figure 5). The plant is located east of Interstate 101. A peninsula across the water from the WQCP serves as a storage yard for SamTrans buses. The Bay Trail is close to the site, both to the south and the north, and a pedestrian bridge crosses Colma Creek near the northwest corner of the WQCP. The WQCP is located in a census tract designated by the Metropolitan Transportation Commission as an "Equity Priority Community," a historically underserved area identified for future investment and community engagement. An area southwest of the WQCP along the Caltrain line is designated as a priority area for future development.

1. Goals Project. 2015. The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015, prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

LAND USE & OWNERSHIP

The City of South San Francisco owns the treatment plant and adjacent properties, including the former naval wharves. The City utilizes some of the abandoned navel wharves for storage. The City leases the remaining nearby land to Park SFO, which operates two parking garages directly south of the WQCP.[2] The City also owns the adjacent Bay Trail parking area. Other neighbors are privately owned businesses, including Costco, Peninsula Truck Rental, and Shell Oil.

FLOODING & SEA-LEVEL RISE VULNERABILITY

Mapping from BCDC's ART Bay Area Flood Explorer shows that the WQCP is exposed to coastal flooding at 48" above today's mean high tide (Figure 6). Flooding could result in sewer backups, the release of untreated effluent, and impacts to human health and the environment. The WQCP is particularly vulnerable because some electrical and pumping infrastructure is located belowground. Rising groundwater tables due to sea-level rise could pose risks to underground infrastructure, and pumping may be required in the future to maintain dry conditions. Groundwater at the site is currently located 3-6 feet below the ground surface during the winter wet season.[3]

More in-depth coastal flood risk assessments are provided in the San Mateo County Sea Level Rise Vulnerability Assessment (SSF-San Bruno WQCP Asset Vulnerability Profile) and the recent study completed by the US Army Corps of Engineers, which included detailed flood modeling for the site.[1]

Former naval wharves.

2. USACE. 2022. Lower Colma Creek Continuing Authorities Program Section 103 Project: Draft Detailed Project Report and Environmental Assessment
3. May CL, Mohan A, Plane E, Ramirez-Lopez D, Mak M, Luchinsky L, Hale T, Hill K. 2022. Shallow Groundwater Response to Sea-Level Rise: Alameda, Marin, San Francisco, and San Mateo Counties. Prepared by Pathways Climate Institute and San Francisco Estuary Institute. doi.org/10.13140/ RG.2.2.16973.72164

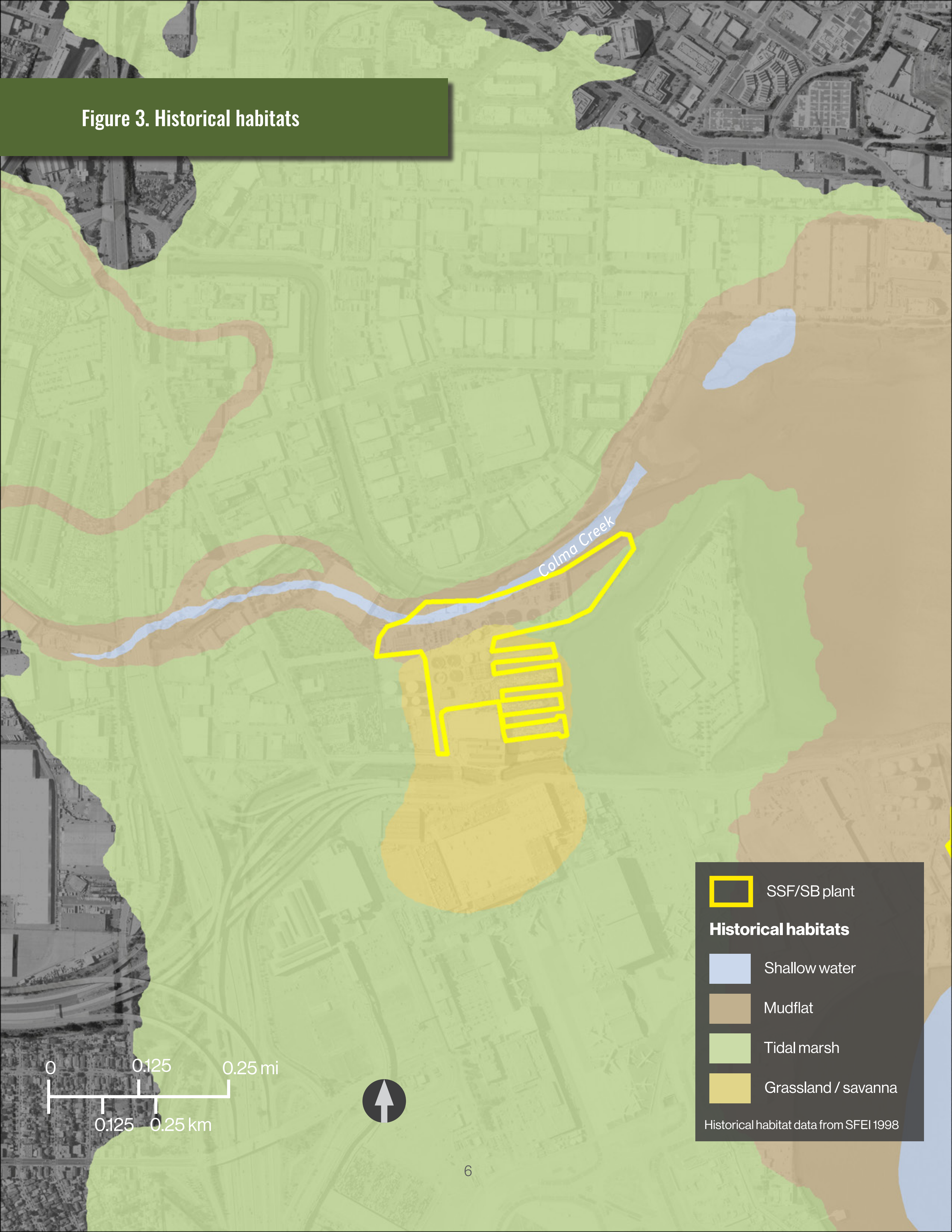
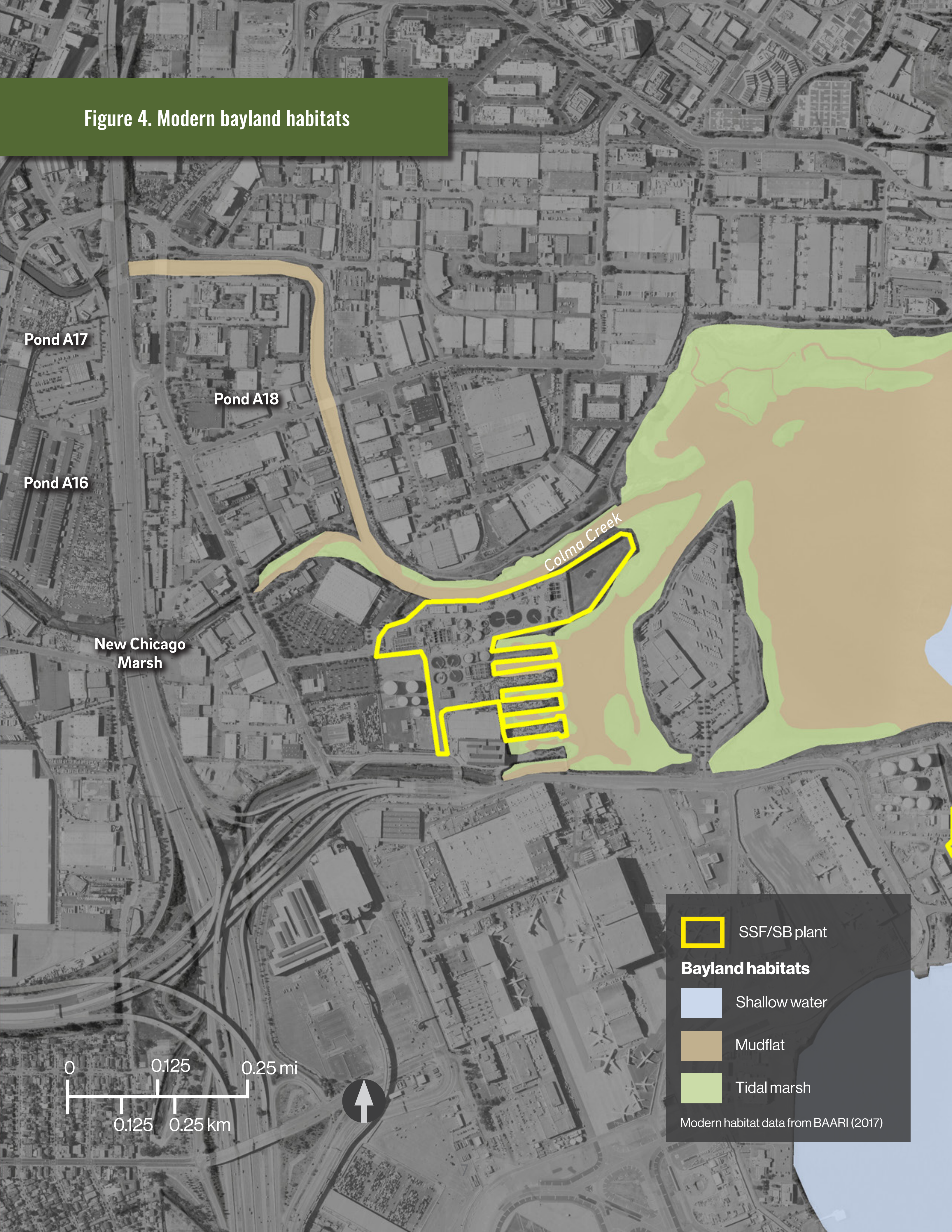


Figure 3. Historical habitats
Colma Creek
SSF/SB plant
Historical habitats
Shallow water
Mudflat
Tidal marsh
Grassland / savanna
Historical habitat data from SFEI 1998
0
0.125
0.25 mi
0.125
0.25 km

Figure 4. Modern bayland habitats



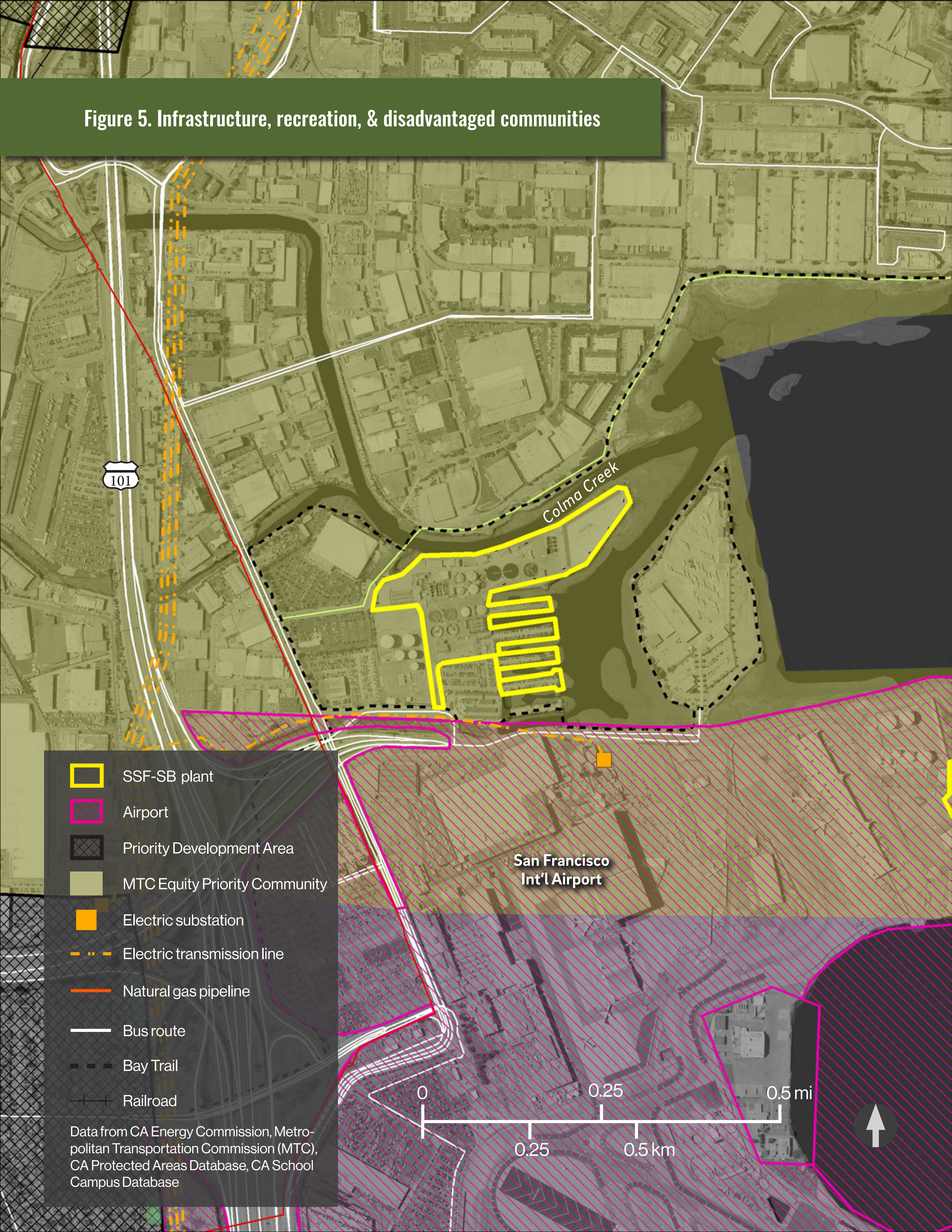
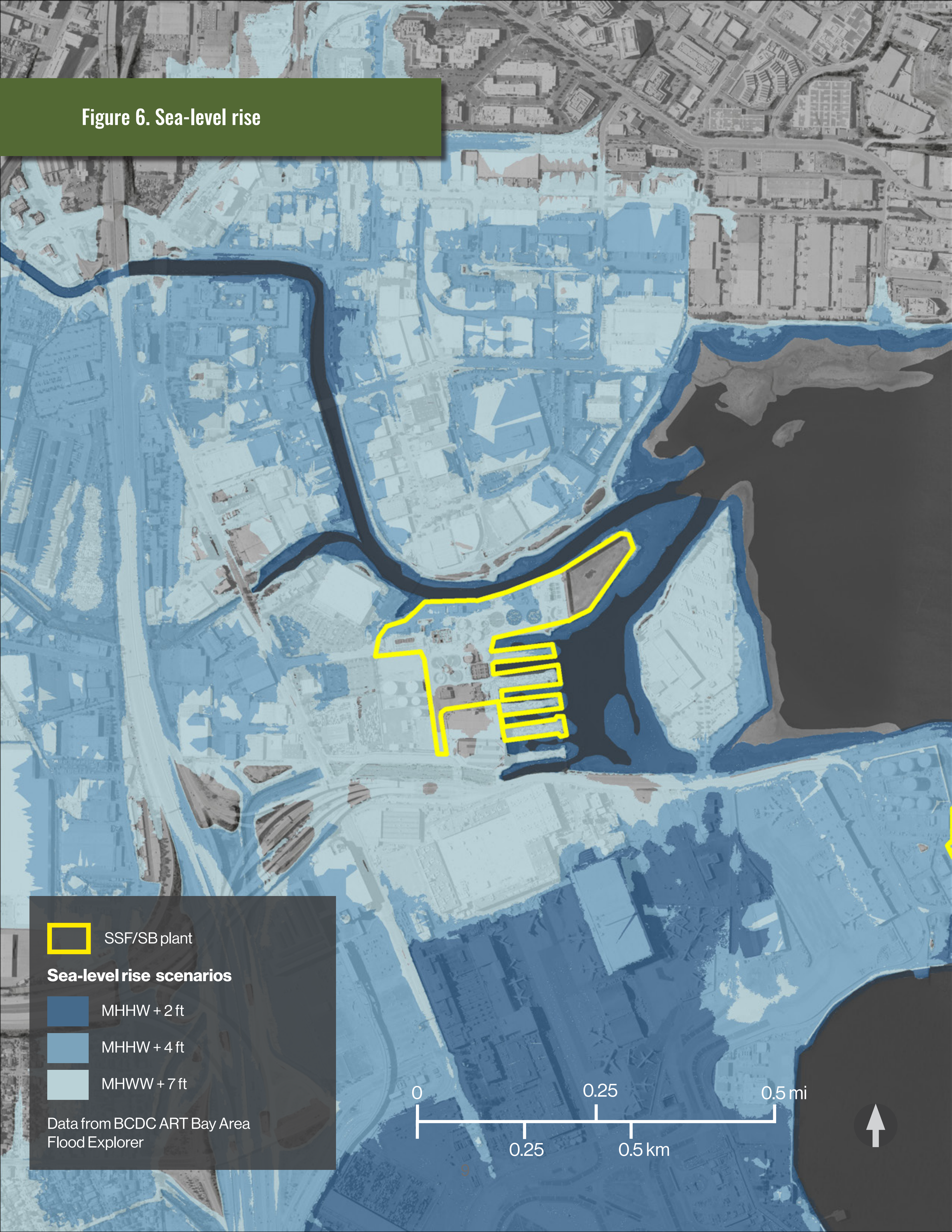


Figure 5. Infrastructure, recreation, & disadvantaged communities
101
Colma Creek
San Francisco Int'l Airport
SSF-SB plant
Airport
Priority Development Area
MTC Equity Priority Community
Electric substation
Electric transmission line
Natural gas pipeline
Bus route
Bay Trail
Railroad
Data from CA Energy Commission, Metropolitan Transportation Commission (MTC), CA Protected Areas Database, CA School Campus Database
0
0.25
0.5 mi
0.25
0.5 km

Figure 6. Sea-level rise



SITE CONSIDERATIONS

RECENT & PLANNED CHANGES AT FACILITY

Since construction in 1951, the plant has undergone upgrades approximately every ten years. The current upgrade began in 2018, including adding a fourth secondary clarifier, expanding secondary treatment capacity and expanding digester capacity.

South San Francisco has partnered with the US Army Corps of Engineers to complete a flood reduction study for the wastewater treatment plant and associated facilities. The Lower Colma Creek Continuing Authorities Program (CAP) 103 project released a draft report in 2022.[1] The project's main purpose was to identify options for reducing coastal flood risk at the WQCP and associated facilities. Several alternative plans were explored, including sheet pile floodwalls, floodproofing buildings, and elevating the subterranean electrical system. An alternative plan has been tentatively selected, involving building a new 2,000-foot-long sheet pile floodwall at the low points on the plant perimeter, and a ring floodwall at Pump Station Number No. 4. The alignment of the proposed floodwall is shown in Figure 7. This project's design and implementation phase is expected to start in 2023.

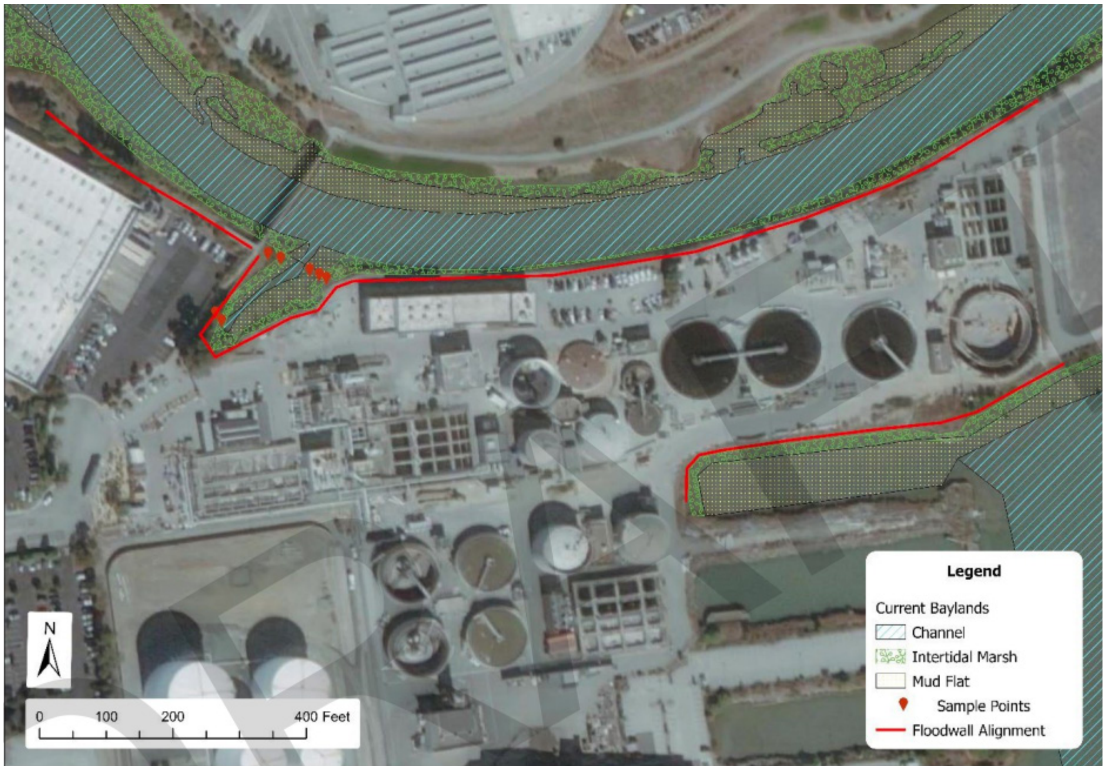


Figure 7. Floodwall alignment from USACE 2022 (Draft).

1. USACE. 2022. Lower Colma Creek Continuing Authorities Program Section 103 Project: Draft Detailed Project Report and Environmental Assessment

RECENT & PLANNED CHANGES NEARBY

Beginning with the 2018 Resilient By Design Challenge, work has been underway to reimagine the Colma Creek corridor as a recreational resource and community asset. Goals include reducing flood risk, restoring critical marsh habitat, enhancing access to the creek, and building environmental awareness and stewardship opportunities. The design firm Hassell is leading the project and has received several grants to continue work on the project since the Resilient By Design Challenge. The latest was a San Francisco Bay Restoration Authority (Measure AA) grant to the City of South San Francisco for community engagement, design and engineering, and permitting and CEQA plan for the "Colma Creek Restoration and Adaptation Project." The design work is slated to be completed in 2023, with implementation to follow. Several community engagement events, including native plant restoration efforts, have already taken place.

OPPORTUNITIES & CONSTRAINTS

One opportunity for NBS explored at other treatment plants is to create dual-purpose equalization basins that can be used for nutrient removal most of the time and drained to increase storage capacity during emergency wet weather events. Though South San Francisco does have a lined 7 million gallon wet weather equalization basin, it is likely not a viable opportunity for NBS due to its frequent use. The basin is used several times per year during wet weather to comply with mandates and regulations.

The plant's physical location near the outlet of Colma Creek to San Francisco Bay indicates that it may be a logical area to supplement freshwater flows and enhance the brackish marsh habitat using NbS. However, the highly developed area around the plant means there are limited opportunities to develop open-water wetlands or a seepage slope. In particular, there is very limited space between plant facilities and the south bank of Colma Creek.

The most likely area where a seepage slope or other NbS system could be developed is east of the plant, where former naval wharves extend into an inlet of San Francisco Bay. The existing material in the wharves creates some natural topography in the area which could be taken advantage of to create treatment ponds, or the material could be repurposed into a new configuration. The quality of the fill material is unknown and would need to be assessed to determine whether it is suitable for use in an NbS project.

Other than the limited available space for construction at the site, another constraint is the lack of nitrification capacity at the plant. There is currently no ammonia limit for the plant, so a nitrification step has not been incorporated into the treatment train. Nitrification capacity would need to be expanded before or in conjunction with implementing NbS. The 2018 Optimization and Upgrade report, prepared by HDR pursuant to the first SF Bay Nutrient Watershed Permit, indicated limited opportunities to upgrade existing infrastructure for nitrification and recommended sidestream treatment for partial nitrogen removal.[1]

Finally, the WQCP's close proximity to SFO may mean additional coordination with the US Department of Agriculture's (USDA) Airport Wildlife Hazards Program to ensure the addition of any new NbS does not increase the risk of a bird strike at the airport.

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1. *Nutrient Reduction Study Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means.* 2018. Prepared by HDR Inc. on behalf of the Bay Area Clean Water Agencies.

ADDITIONAL CONSIDERATIONS

PRECEDENT

Wastewater agencies in the northern and southern reaches of San Francisco Bay have for several decades been subject to several Discharge Prohibitions from the San Francisco Bay Water Quality Control Plan (Basin Plan) to protect Suisun Marsh and the Lower South Bay. This has resulted in efforts to maximize water reclamation and recycling in the North Bay, while enhanced treatment has occurred at the Lower South Bay WRRFs. Regulators have not required tertiary treatment, nutrient load reductions, or reclamation requirements. Central and South Bay dischargers have not adopted NbS at scale, yet all are considering the possibilities as they tackle issues related to aging infrastructure and future water quality regulations.

Projects under current consideration by wastewater agencies and regulatory agencies include those to advance horizontal levees at Oro Loma Sanitary District, Palo Alto Regional Water Quality Control Plant, and West County Wastewater District. Open water wetlands were authorized for near-shore discharge for the City of Petaluma and Mt. View Sanitary District, and a 2022 NPDES permit was adopted for a new open water polishing wetland for the City of San Leandro.

REGULATORY CONSIDERATIONS

Bay Area WRRFs are subject to myriad regulations, some of which may inadvertently act in conflict with nutrient load reduction efforts. The regulatory landscape governs not just surface water discharges but also water reuse, biosolids management, protected species and habitats, and air emissions. Project proponents and regulators have initiated discussions over potential approaches for mitigating these barriers, recommendations for quantitative analyses of potential conflicts, and options for regulatory and permit-based approaches to maximize the multi-functional benefits associated with NbS upgrades in the event large-scale nutrient load reductions are warranted. The final report for this regional NbS evaluation project shall synthesize the extensive regulatory considerations applicable to most WRRFs in Region 2.

Facility-specific permits, local ordinances, and site-specific plans feature requirements for each facility. Based upon site inspections and South San Francisco – San Bruno's 2019 NPDES permit (No. CA0038130), the facility maintains a limited capacity to convert existing treatment elements to an NbS solution, given the built-out nature of the site and surrounding area. Options 1 and 2, discussed below, involve fill and habitat conversion of areas likely considered waters of the U.S., thus likely triggering wetlands-related mitigation and monitoring requirements.

In 2019-2020, 2022 the California Water Environment Association (CWEA) awarded the South San Francisco – San Bruno Water Quality Control Plant as Medium Plant of the Year. This demonstrates excellence in innovation and compliance. To encourage strict compliance while urging NbS deployment, the Water Board may offer regulatory incentives which enable ramp up and testing periods that minimize the consequences of failure to meet strict effluent standards. For regulatory purposes, the San Francisco Bay Regional Water Quality Control Board recently provided guidance and continues to establish a precedent for permitting discharges of treated effluent from NbS projects in the region. On-going consultations with other regulatory agencies for similar projects also continually inform opportunities and constraints regarding mitigation and monitoring requirements, desired treatment performance, and the appropriate quantification of ancillary benefits, including habitat enhancement, water reclamation, and community benefits.

The ancillary benefits of pursuing any option presented here include, at a minimum, additional reductions in dry weather discharges to South San Francisco Bay and the enhancement of habitat quality and quantity. Other potential benefits include recreation and education opportunities, demonstration of novel NbS strategies, and potential sea-level rise adaptation and resilience demonstration for the South SF / San Bruno Facility and surrounding areas. Pending the advancement of the concepts presented here, future work may involve measuring the likely benefits and impacts of an NbS project. Quantifying such benefits enables regulatory agencies to weigh the net environmental benefits associated with a project.

Site visit at SSF / San Bruno Water Quality Control Plant, January 2022.

Figure 8. Conceptual design options

Option 1: Two open water wetlands with seepage slope sides

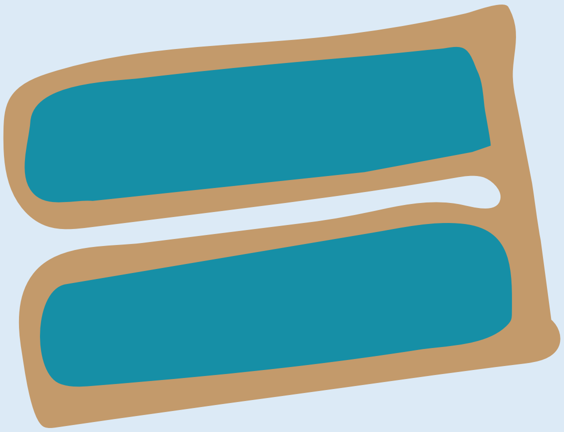
Option 2: Horizontal levee and restored tidal marsh

CONCEPTUAL DESIGN OPTIONS

To date, two main nature-based options for a multi-benefit nutrient load management strategy at the WQCP have been identified (Figure 8). Given that public access is restricted, these options will likely optimize for nutrient removal and ecological benefits rather than recreational opportunities. The 3-acre area could be expanded to include more of the former naval wharves, depending on the use priorities of the City of South San Francisco.

OPTION 1

Convert the space between the former naval wharves adjacent to the WQCP to open water treatment wetlands. Utilize existing topography and material to create woodchip seepage slopes on all four sides of each open water wetland. Optimize the design for nutrient removal. This option would require the addition of a nitrification step prior to implementation. Permitting may be challenging because the new treatment ponds would be located in the existing intertidal zone.

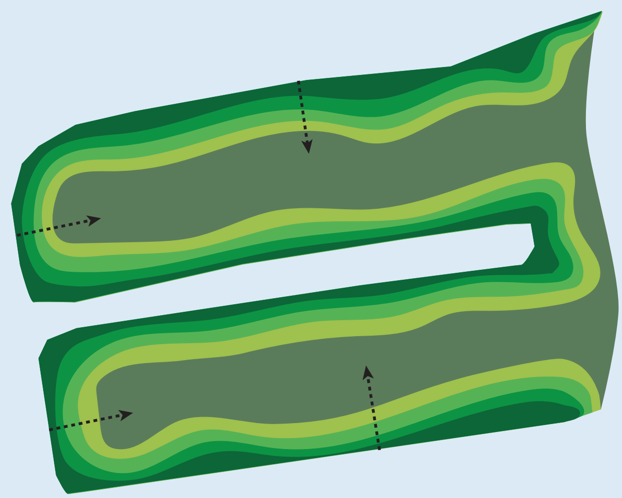


Example concept sketch demonstrating Option 1.
The open-water treatment cells are optimized for denitrification and include a woodchip seepage slope. Treated wastewater could be directed to either cell or flow through both cells before discharge.

OPTION 2

Create a new horizontal levee at the back of a restored tidal marsh. Along the eastern perimeter of the plant, five former Navy wharves are now used as parking lots and storage areas. A horizontal levee around the inland edge of the wharves could include a seepage slope optimized for nutrient removal and wastewater polishing. The finger-like structures of the wharves offer about 600 meters of linear length (in the area identified in Figure 8) and up to 1,700 meters of linear length (across all five wharves) to convert to horizontal levees within a small footprint. Bayward of the horizontal levee, tidal marsh development may be facilitated with sediment placement, if deemed appropriate by regulatory agencies.

This option would provide much-needed tidal marsh and transition zone habitat in an area where nearly all marsh habitat has been lost. The site may be suitable for marsh restoration as it is protected (not exposed to high wave energy). Construction of a horizontal levee would provide valuable transition zone habitat for marsh species, including a rare opportunity to create a freshwater to brackish marsh habitat gradient.



Example concept sketch demonstrating option 2. Fill material in the former naval wharves is repurposed (if the material is appropriate) to create a horizontal levee seepage slope around the inland edge. Treated wastewater is routed through a subsurface polishing layer and discharges to the Bay. Here, the horizontal levee is shown in the area identified in Figure 8; however, a more expansive project could be undertaken utilizing all five former naval wharves.

There has been much interest in marsh restoration along the Colma Creek corridor; however, the constrained nature of that channel has limited opportunity for the restoration of larger marsh patches. This site may be a more logical location for restoring a larger patch of tidal marsh than areas within the channel itself. Previous efforts, including the Resilient South City proposal in the Resilient By Design Challenge, have envisioned a restored marsh near the former naval wharves. Restoration of tidal marsh in this area could expand habitat in the vicinity of nearby restorations pursued through the Colma Creek Restoration and Adaptation Project, increasing habitat value for marsh species along this shoreline segment by increasing patch size/decreasing distance between patches. This option could also enhance the WQCP's flood resilience by protecting the new floodwall from wave erosion. Permitting a horizontal levee and marsh restoration project may be more feasible in this intertidal area than open water treatment cells; however, further research and conversation with regulatory agencies are needed.

COMPARING OPTIONS

Table 1 lists the goals of implementing NbS at the South San Francisco-San Bruno WQCP and the relative contribution of each option toward meeting those goals. This allows for a high-level comparison of options. Further feasibility analysis may be conducted in collaboration with WQCP staff and design consulting engineers to determine the most appropriate options. Options presented in this report reflect land ownership constraints based on consultation with WQCP staff. Additional considerations that have not received full consideration include implementation costs, regulatory constraints, and competing demands for space at the facility.

Table 1. Comparison of each option's relative contribution to achieving goals of NbS implementation.

● = Achieves. ◑ = Partially or possibly achieves. ○ = Does not achieve.

For TIN removal, 'Achieves' is>30% removal, 'Partially achieves' is 5-20% removal, and "Does not achieve is <5% removal.

	Option 1 (Two open water wetlands with seepage slope sides) (3 ac)[1]	**Option 2** (Horizontal levee with marsh restoration) (1,700 meters - all five wharves)[2]
Goal 1: Reduces nutrient loads to the Bay and improves overall water quality.		
Reduces TIN *Estimated dry-season reduction (kg d-1 / % reduction of daily TIN load)*	○ about 20 kg d^{-1} / 3%[3]	◑ about 221 kg d^{-1} potential / 23%
Goal 2: Reduces flood risk for the plant and/or associated infrastructure.		
Attenuates waves and provides erosion resistance	○	●
Facilitates marsh accretion	○	●
Goal 3: Create and/or enhance habitat		
Provides marsh-upland transition zone habitat and marsh migration space	○	●
Provides high tide refuge habitat for wildlife	○	●
Increases habitat complexity	◑	●
Provides freshwater pond/marsh habitat	●	●
Goal 4: Enhances recreational opportunities.		
Provides opportunity for public trails and wildlife viewing	○	○
Goal 5: Provides additional co-benefits.		
Reduces use of potable water for irrigation	○	○
Supports goals of partner organizations (e.g. facilitates neighboring restoration projects)	○	●

1. Option 1 assumes treatment of nitrified effluent based on the 5-year average of dry weather TIN concentrations and creation of an unvegetated open water treatment wetland requiring 11.2 acres per MGD and shallow water depth of 0.3 meters to achieve 90% removal of nitrate (A90). Concentrated waste streams or higher flow-through may increase load removal rates. Jasper, J.T., Jones, Z.L., Sharp, J.O. and Sedlak, D.L., 2014. Nitrate removal in shallow, open-water treatment wetlands. Environmental science & technology, 48(19), pp.11512-11520.
2. Assumptions: horizontal levee with length: 580 meters, height: 3.1 meters, 10:1 slope, bed temperature of 20° C, 24-hr retention time, and woodchip media depth of 0.5 meters. Addy, K., Gold, A.J., Christianson, L.E., David, M.B., Schipper, L.A. and Ratigan, N.A., 2016. Denitrifying bioreactors for nitrate removal: A meta-analysis. Journal of Environmental Quality, 45(3), pp.873-881.
3. Conservatively estimated TIN reductions, as absolute daily reductions and percentage of average dry season daily load (~950 kg N d-1) .

NEXT STEPS

Option 2 identified in this report involves the conversion of bermed wharf structures into horizontal levees that could extend as long as 1,700 meters and reduce nitrogen loading from the WQCP by up to ~20%. This alternative involves Bay fill yet remains consistent with identified habitat restoration goals for the Colma Creek area. SFEI will engage with staff to evaluate the interest in exploring this alternative more fully.

Neither executive staff nor the board of directors have decided regarding the interest or ability to pursue NbS or weighed in on the options presented herein. However, Option 2 represents a potentially viable novel approach to achieving multiple water quality and habitat-related benefits. SFEI recommends pursuing planning and outreach efforts while exploring funding opportunities at the regional (e.g., Measure AA), state (upcoming climate and water resilience programs), and federal levels (e.g., coastal resilience funding under the Bipartisan Infrastructure Law).

Pedestrian bridge over Colma Creek, from SSF / San Bruno facility.

NATURE-BASED SOLUTIONS FOR NUTRIENT REMOVAL

SITE EVALUATION: UNION SANITARY DISTRICT

PREPARED BY
San Francisco Estuary Institute

PREPARED FOR
Bay Area Clean Water Agencies

AUTHORS
Ellen Plane
Ian Wren

CONTENTS

Version 1 (May 2023).

All photos in this document courtesy of the authors.

INTRODUCTION

The first phase of analysis (Phase I) of the Nature-Based Solutions for Nutrient Reduction study involved a regional-scale desktop analysis in determining which Bay Area water resource recovery facilities (WRRFs) have opportunities for implementing nature-based solutions (NbS) for nutrient reduction. In this phase (Phase II), we conducted outreach with a select group of facilities with high potential for NbS, including conducting site visits and discussing opportunities and constraints with agency staff. This phase also involved additional site-scale research and analysis to refine opportunities and constraints identified at each facility. Phase III of this study involves narrowing the list of facilities to develop planning-level designs to enable cost estimation, identify regulatory and land use conflicts, and establish feasibility for agency-led planning.

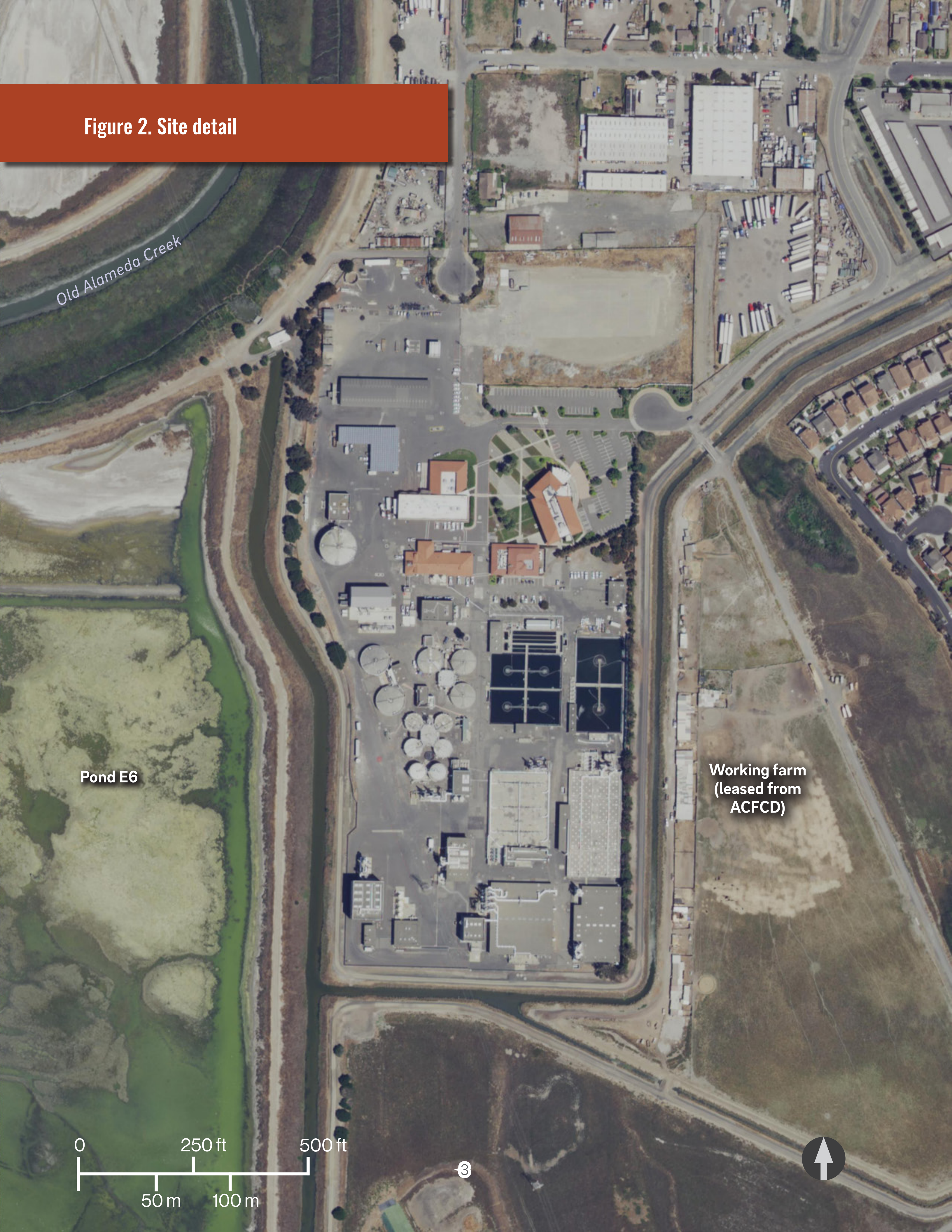
Union Sanitary District (USD) was one of the facilities identified as a high-potential site for NbS. The desktop analysis identified numerous opportunities, including open water treatment wetlands in undeveloped parcels near the site, and extensive opportunity for horizontal levees between developed areas and the Eden Landing Ecological Reserve (Figure 1). Initial conversations with staff at USD refined the initial set of opportunities to three main areas: undeveloped land managed by Alameda County Flood Control District to the north and south of the plant and a possible horizontal levee between the plant and the Eden Landing ponds.

Union Sanitary District was founded in 1918 and serves over 350,000 people in Fremont, Newark, and Union City. The Alvarado Wastewater Treatment Plant (Figure 2) is located at 5072 Benson Rd in Union City.. The plant's permitted capacity is 33 mgd, with average flows of about 23.2 mgd. Treated wastewater is discharged to San Francisco Bay via the East Bay Dischargers Authority (EBDA) deepwater outfall.

Historically, USD supplied treated wastewater to Hayward Marsh, supporting freshwater and brackish marsh habitat there. Partnerships will be key, given the limited available space within the plant footprint. High sea-level rise risk at this facility may mean pursuing a horizontal levee strategy with future levee upgrades. However, timelines must be aligned with restoration of the Eden Landing ponds adjacent to the facility, which the California Department of Fish and Wildlife and the South Bay Salt Ponds Restoration Project manages.

Figure 1. Site in context

Figure 2. Site detail



SITE OVERVIEW

ECOLOGY

Historical ecology mapping shows an extensive marsh complex in the location of the current USD treatment plant (Figure 3). The northern part of the plant was historically grassland along Alameda Creek. The southern part of the plant site was tidal marsh and mudflat, with marsh extending far inland from the current plant footprint into what today are the neighborhoods of Union City. The tidal marsh of the Eden Landing salt ponds bayward of the treatment plant was converted to artificial salt ponds between 1897-1931.[1]

Land behind the salt ponds was drained and/or filled and used for grazing, then later developed. Historically, flows from Alameda Creek created a large zone of brackish tidal marsh and significant riparian habitat.[2] The Alameda Creek estuary is highly altered, with most flows directed through the Alameda Creek Flood Control Channel (Old Alameda Creek, adjacent to the treatment plant, is the historical flow route) (Figure 4).

Today the Alameda Creek Flood Control Channel receives little tidal influence and freshwater and sediment is directed straight to the Bay, bypassing the baylands. There is some diked marsh habitat in the basin to the south and east of the treatment plant. Today the former salt ponds are managed ponds as important habitat for migratory shorebirds and waterfowl. According to the 2015 Baylands Goals Update, transition zone habitat creation in this segment is a priority. The Baylands Goals suggest constructing a horizontal levee, supported by effluent from USD, before the tidal restoration of the Eden Landing ponds. Inactive salt ponds, salt pond beaches, and levees currently provide habitat for snowy plover.

INFRASTRUCTURE, RECREATION, AND COMMUNITIES

Alvarado Treatment Plant is located between the Eden Landing Ecological Reserve (California Department of Fish and Wildlife) to the west and Union City to the east (Figure 5). Residential neighborhoods lie east of the plant. Northwest of the plant is the Old Alameda Creek flood control channel, managed by the Alameda County Flood Control and Water Conservation District. An electric transmission line runs through the treatment plant site. 0.5 miles south of the plant is the Turk Island Landfill.

1. Stanford, B.; Grossinger, R. M.; Beagle, J.; Askevold, R. A.; Leidy, R. A.; Beller, E. E.; Salomon, M.; Striplen, C. J.; Whipple, A. 2013. Alameda Creek Watershed Historical Ecology Study. San Francisco Estuary Institute: Richmond, CA.
2. Goals Project. 2015. The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update. California State Coastal Conservancy: Oakland, CA.

LAND USE & OWNERSHIP

Much of the surrounding vacant land is owned by the Alameda County Flood Control District. The diked areas to the east and south of the treatment plant are owned by the Flood Control District and are currently leased to private entities. A working farm is located east of the plant on leased land, and south of the plant is a model airplane field and a former duck club. The Old Alameda Creek channel is under the jurisdiction of the State Lands Commission. The Eden Landing ponds to the west of the site are owned and managed by the California Department of Fish and Wildlife.

FLOODING & SEA-LEVEL RISE VULNERABILITY

Without additional improvements to the surrounding levees, the Alvarado Treatment Plant is vulnerable to sea level rise (SLR). At just two feet above today's MHHW, much of the plant is exposed to flooding due to levee overtopping to the south and east (ART Bay Area Flood Explorer; Figure 6). A 2013 SLR vulnerability assessment was conducted to determine the EBDA and USD assets that are at risk of damage from flooding.[1] That vulnerability assessment has recently been updated to account for more recent sea-level rise projections and provide a more thorough analysis of possible short and long-term adaptation measures.[2] Several pump stations and lift stations, twin force mains, and the treatment plant itself are assets listed in both assessments as exposed to the effects of SLR.

Flooding is possible at the wastewater treatment plant due to coastal overtopping of the flood control channel levees and fluvial overtopping of Old Alameda Creek or other flood control channels. Stormwater at the site drains to a pump station, and there have been no flooding issues in recent memory (at least 8 years). Groundwater is very shallow at Alvarado Treatment Plant today.[3,4] Because water tables have historically been high, facilities have been designed accordingly. However, changes in groundwater levels and salinity due to sea-level rise are possible and should be considered in the design of future projects at the site (ESA 2022).

Potential short-term adaptation strategies identified in the 2022 ESA study include retrofitting existing infrastructure (e.g., elevating, floodproofing). Potential long-term adaptation strategies for Alvarado Treatment Plant identified in the draft 2022 ESA study include enhancing existing levees and floodwalls, elevating roads, adjusting operations to allow for intermittent flooding, and pursuing possible regional coordination on the construction of a horizontal levee at the back of Pond E6.

1. ESA PWA. 2013. Union Sanitary District: Preliminary Study of the Effect of Sea Level Rise on District Infrastructure.
2. ESA. 2022. Sea-level rise vulnerability assessment and adaptation plan study for Union Sanitary District infrastructure. Prepared by ESA, Woodard & Curran, and SFEI for Union Sanitary District.
3. Befus, K. M., P. L. Barnard, D. J. Hoover, J. A. Finzi Hart, and C. I. Voss. 2020. Increasing threat of coastal groundwater hazards from sea-level rise in California. Nature Climate Change.
4. May, C.L., Mohan, A., Plane, E., Ramirez-Lopez, D., Mak, M., Luchinsky, L., Hale, T., and K. Hill. 2022. Shallow Groundwater Response to Sea-Level Rise: Alameda, Marin, San Francisco, and San Mateo Counties. Prepared by Pathways Climate Institute and San Francisco Estuary Institute. doi.org/10.13140/ RG.2.2.16973.72164

Figure 3. Historical habitats

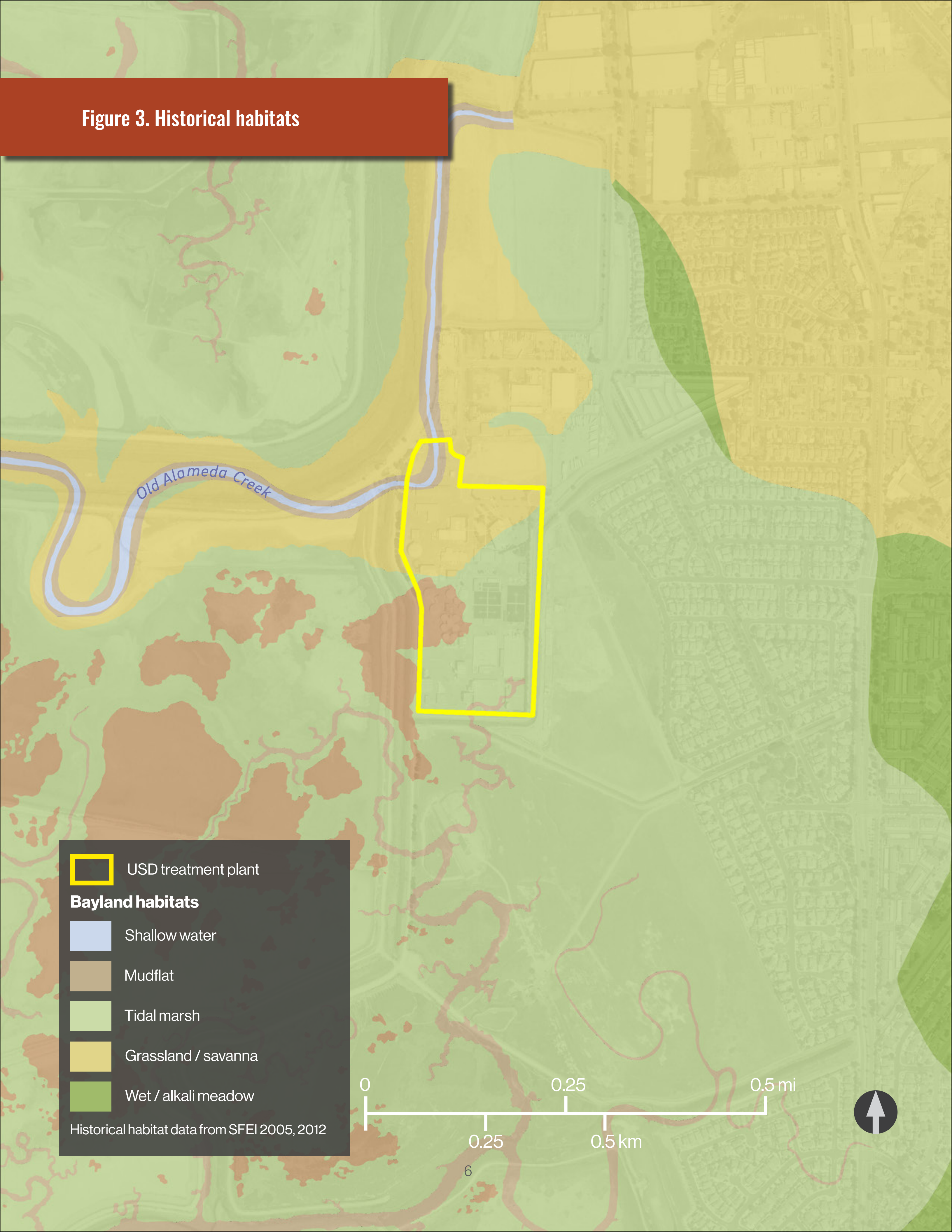


Figure 4. Modern bayland habitats

Figure 5. Infrastructure, recreation, & disadvantaged communities

Figure 6. Sea-level rise

SITE CONSIDERATIONS

RECENT & PLANNED CHANGES AT FACILITY

USD recently ceased discharge to Hayward Marsh at the request of the property manager, EBRPD. It is a constructed wetland that received effluent from the facility to support fresh and brackish marsh habitat since 1985. The reason for the closure included operations and maintenance challenges for the East Bay Regional Park District (EBRPD), which managed the site. Currently, there are no plans to resume discharges to Hayward Marsh. EBRPD is in the planning phase for tidal restoration of Hayward Marsh.

The plant is undergoing a major upgrade over the next 7-10 years, resulting in a 50% reduction in nutrient loads to the Bay. The upgrade includes nitrification and denitrification facilities, optimization of existing aeration basins, and constructing deeper secondary clarifiers. The project will also reduce total suspended solids and is being designed in a modular fashion to allow for future upgrades as regulations change.

To account for future sea-level rise, finished floor elevations for new facilities will be raised above the elevations required by the Federal Emergency Management Agency to 12 feet.

RECENT & PLANNED CHANGES NEARBY

There are plans to restore the former salt ponds bayward of the Alvarado Treatment Plant at the Eden Landing Ecological Reserve through the South Bay Salt Ponds Restoration Project (SBSPRP). The proposed design for Stage A of Phase 2 restoration at Eden Landing involves maintaining the Inland Ponds (Ponds E6, E5, and E6C, directly bayward of the treatment plant) as managed ponds. The ponds would be enhanced, including new and repaired water control structures. The levee at the back of the Inland Ponds would also be improved, including constructing a new habitat transition zone/slope. These improvements are likely to benefit the goals of the SBSPRP and reduce flood risk at Alvarado Treatment Plant.

USD and SBSPRP staff have previously discussed the possibility of incorporating treated wastewater into the restoration of the Eden Landing ponds. Wastewater could irrigate constructed habitat transition zones, and a future horizontal levee could integrate a subsurface treatment zone. Pond E6 will be maintained as a managed pond for the foreseeable future. Future projects may involve constructing a horizontal levee along a portion of the pond, which requires collaboration between USD, SBSPRP, and CDFW during future planning to eventually restore Pond E6 to tidal marsh.

OPPORTUNITIES & CONSTRAINTS

Plant upgrades involving nitrification and denitrification facilities mean USD does not face a strong nutrient reduction driver in the near term. Future changes in nutrient limits could increase the need to consider NbS as a nutrient reduction strategy. However, flood protection may represent a stronger driver for NbS implementation at USD.

The greatest long-term opportunity for USD lies in collaboration with the South Bay Salt Ponds Restoration Project and other public partners. Though the USD plant footprint is constrained, a large amount of publicly managed open space surrounds the plant, and partnerships are key to developing NbS in this area.

Future collaboration on the restoration of the Eden Landing ponds represents an opportunity for multi-benefit solutions to enhance water quality, habitat quality, recreational value, and flood protection at the plant. Restoration of tidal marsh in the ponds requires levee upgrades, potentially presenting a cost-sharing opportunity. Future construction of an ecotone levee directly adjacent to the plant provides an opportunity to design the slope as a horizontal levee for water quality improvement. Even if subsurface seepage elements are not included in the design, wastewater could be used for irrigation, and the slope would provide habitat and flood protection benefits for USD.

This project's Phase 1 desktop analysis identified opportunities for open water treatment wetlands in the diked areas east and south of the plant. These areas are largely undeveloped, will likely remain protected by a future shoreline levee, and are under public ownership by the Alameda County Flood Control District. However, an initial investigation conducted by USD found high-quality seasonal wetland habitat across much of the area, including pickleweed marsh inhabited by salt marsh harvest mouse. Conversion of the area to alternative uses would likely trigger cost-prohibitive habitat mitigation requirements. Given the lack of a nutrient reduction driver at USD and the constraints present at these sites, USD is unlikely to pursue an NBS opportunity in that area.

The low elevation of the plant and corresponding flood risk from fluvial and coastal sources is one constraint to the development of NbS, though it may also present opportunities for multibenefit projects that reduce nutrient loads while improving flood resilience at the plant. Developing any new NbS at USD should be closely coordinated with flood protection upgrades to ensure the longevity of any newly constructed infrastructure.

ADDITIONAL CONSIDERATIONS

PRECEDENT

In cooperation with EBRPD, USD discharged secondary treated effluent to the Hayward Marsh between 1985 and 2019. As one of the longest-running treatment wetlands in the West Coast, USD gained valuable insights into the maintenance, design, and governance of operating a large-scale treatment wetland subject to complementary but sometimes competing interests. Hayward Marsh is slated for habitat restoration and will no longer serve as a treatment wetland, though both USD and EBRPD remain open to cooperation on future multi-benefit shoreline strategies, including treatment wetlands.

Hayward Marsh represented one of the early treatment wetlands along the West Coast, developed soon after open water wetlands at Mt. View Sanitary District. Wastewater agencies in the northern and southern reaches of San Francisco Bay have for several decades been subject to several Discharge Prohibitions from the San Francisco Bay Water Quality Control Plan (Basin Plan) to protect Suisun Marsh and the Lower South Bay. This has resulted in efforts to maximize water reclamation and recycling in the North Bay, while enhanced treatment has occurred at the Lower South Bay WRRFS.

Several other agencies that discharge via EBDA's joint outfall have developed NbS, such as Oro Loma Sanitary District, or are in the planning process - including the Cities of San Leandro and Hayward. Projects under current consideration by wastewater agencies and regulatory agencies include those to advance horizontal levees at Oro Loma Sanitary District, Palo Alto Regional Water Quality Control Plant, and West County Wastewater District. Open water wetlands were authorized for near-shore discharge for the City of Petaluma and Mt. View Sanitary District, and a 2022 NPDES permit was adopted for a new open water polishing wetland for the City of San Leandro.

REGULATORY CONSIDERATIONS

Bay Area WRRFs are subject to myriad regulations, some of which may inadvertently act in conflict with nutrient load reduction efforts. The regulatory landscape governs not just surface water discharges but also water reuse, biosolids management, protected species and habitats, and air emissions. Project proponents and regulators have initiated discussions over potential approaches for mitigating these barriers, recommendations for quantitative analyses of potential conflicts, and options for regulatory and permit-based strategies to maximize the multi-functional benefits associated with NbS upgrades, in the event large-scale nutrient load reductions are warranted. The final report for this regional NbS evaluation project shall synthesize the extensive regulatory considerations applicable to most WRRFs in Region 2.

Facility-specific permits, local ordinances, and site-specific plans feature requirements for each facility. The conceptual alternative below involves coordination with the SBSPRP to implement a horizontal levee along the perimeter of Pond E6. This likely triggers water quality and wetland fill-related concerns subject to oversight by the San Francisco Bay Regional Water Quality Control Board (Regional Board), SF Bay Conservation and Development Commission, California Department of Fish and Wildlife, US Fish and Wildlife, and Army Corps of Engineers. Critical considerations include the extent of mitigation required to account for beneficial fill of Pond E6 and whether nearby areas can be incorporated as mitigation areas for the project.

The Regional Board recently provided guidance and continues establishing a precedent for permitting discharges of treated effluent from NbS projects in the region.[1] On-going consultations with other regulatory agencies for similar projects also serve to continually inform opportunities and constraints regarding mitigation and monitoring requirements, desired treatment performance, and the appropriate quantification of ancillary benefits, including habitat enhancement and water reclamation, and community benefits.

1. "NPDES Permitting for Nature-based Solutions," 2022, San Francisco Bay Regional Water Quality Control Board.

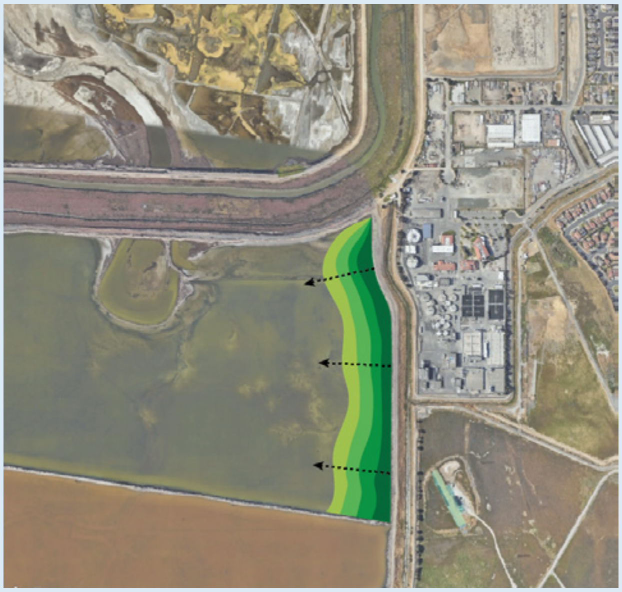
Pond E6, looking south. The berm protecting the Alvarado Treatment Plant is on the left side of the photo.

CONCEPTUAL DESIGN OPTIONS

To date, one main option for a multi-benefit NbS project at USD has been identified. This option involves a footprint outside the treatment plant and would require coordination with partner agencies.

CONCEPT

Coordinate with the SBSPRP and CDFW to construct a horizontal levee at the back of Pond E6. The horizontal levee would provide nutrient load reduction and transition zone habitat while reducing wave action reaching the levee. Timing of implementation requires close coordination with SBSPRP on the restoration of Pond E6 to tidal marsh, which depends on their adaptive management process. Pond E6 is currently planned to be maintained as a managed pond, with no plans in place to restore it to tidal marsh.



Example concept sketch. A 2,400 foot long horizontal levee at the back of Pond E6 has been identified as a potential NBS option for USD. However it cannot be pursued until Pond E6 is restored to tidal marsh, and the timing of that restoration is uncertain and dependent on the adaptive management plan of the South Bay Salt Pond Restoration Project.

ESA calculated in 2022 that a 2,400 foot long horizontal levee at the back of Pond E6 would only treat about 1% of the plant's daily average 25 MGD capacity, which approximates the estimates used for this project.[1] The primary purpose of the horizontal levee would therefore be to provide flood reduction and habitat benefits. Historically there were many more connections from riparian areas and freshwater marshes to the back of tidal marshes, including in the vicinity of USD. Seeping treated wastewater through the levee would recreate some of the fresh-brackish-salt marsh habitat gradient that historically existed in this area.

1. ESA. 2022. Sea-level rise vulnerability assessment and adaptation plan study for Union Sanitary District infrastructure. Prepared by ESA, Woodard & Curran, and SFEI for Union Sanitary District.

NEXT STEPS

Given the lack of a nutrient driver for NbS implementation at USD, the regulatory constraints involved with developing NbS in the seasonal wetlands east and south of the plant, and the timeline of restoration for Pond E6, it is unlikely that NbS will be implemented at USD in the near future. This memo lays out opportunities and constraints for future development of NbS, targeted for flood protection, habitat, and recreational access. USD's role in developing future NbS is likely to be in supporting the goals of partner organizations and furthering flood risk reduction goals for the treatment plant and associated infrastructure.

Site visit at USD, May 13, 2022.