Nature-based Solutions for Nutrient Removal

CONCEPT DESIGN & COST ESTIMATE: FAIRFIELD-SUISUN SEWER DISTRICT

PREPARED BY
San Francisco Estuary Institute: Ellen Plane, Ian Wren
HDR, Inc

IN PARTNERSHIP WITH
Fairfield-Suisun Sewer District

PREPARED FOR
Bay Area Clean Water Agencies

Contents

Version 2 (September 2023)

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INTRODUCTION

Phase I of the Nature-based Solutions for Nutrient Reduction Study identified the Fairfield-Suisun Sewer District (FSSD) as having promising opportunities for horizontal levees and open-water treatment wetlands. In Phase II of the study, the San Francisco Estuary Institute (SFEI) and FSSD explored opportunities and constraints for developing these two types of nature-based solutions (NbS). This memorandum and accompanying appendix represent Phase III of the study and include the following:

- Identification of a preferred NbS alternative with concept drawings;
- Description of a possible sea level rise (SLR) adaptation pathway to expand NbS for nutrient reduction and enhance facility resilience in the context of climate change;
- Additional background information and design recommendations for peat-building wetlands: a novel strategy for wastewater facilities in the region to gradually raise subsided and low-lying baylands; and,
- A preliminary cost estimate prepared by HDR, Inc. (Appendix A).

This conceptual design and associated cost estimates remain subject to considerable refinement and uncertainty. Factors such as levee slope and height for both open water wetlands and horizontal levees, and the source of fill for the project, dramatically affect cost. Design considerations such as the degree of vegetative cover and space allocated to public access also influence open-water wetlands' hydraulic capacity and nitrate-removal efficiency. Finally, additional research is needed to assess nitrogen dynamics in a peat-building wetland and the degree to which vegetation growth and organic matter accretion rates are affected by influent water with elevated nitrate concentrations. As FSSD continues to evaluate treatment wetland options, these and other factors should be further evaluated through both desktop evaluation and in-situ experimentation and pilot projects.

Four options were identified in the Phase II opportunities and constraints analysis:

- Option 1: Convert one or more of the effluent-holding ponds in the northwest corner of the treatment plant into open-water wetlands.
- Option 2: Convert existing wet-weather equalization basins to dual-purpose equalization and open-water treatment cells.
- Option 3: Construct a horizontal levee, potentially integrated with a flood risk management (FRM) levee, along a portion of the FSSD treatment plant, with nutrient removal being the initial goal and sea-level rise resilience a longer-term goal.
- Option 4: Convert the 97-acre parcel east of the treatment plant to wastewater polishing wetlands for nutrient removal (open water treatment cells) and sea-level rise resilience (peat-building wetlands). Possible additional actions include open-water wetlands on the 40- and 18-acre parcels south of the plant and partnerships with adjacent duck clubs to build other wetlands.

The Phase II analysis identified the opportunity to combine Options 3 and 4 as an integrated strategy. Peat-building wetlands are implemented first to build elevation with organic soil accretion. In the second phase, FSSD constructs horizontal levees. In the third phase, constructed wetlands are opened to tidal action, and the horizontal levee serves as a habitat transition zone for marsh wildlife.

FSSD expressed interest in evaluating Options 1, 3, and 4. Option 2 is suboptimal compared to other options due to the loss of emergency storage capacity, especially with climate change and the increased frequency of extreme storm events. Given the large amount of available land area at FSSD, this dual-purpose wetland option has been removed from consideration.

Option 1 involves repurposing existing basins and creating a series of treatment wetlands. FSSD is looking for opportunities to pursue this project. These smaller basins represent potential pilot locations to test concepts for the more considerable nutrient reduction and peat-building wetlands under Option 4.

This memo provides additional detail and context for the development of Option 4 (multi-benefit treatment wetlands) and also provides some guidance on the integration of Options 3 and 4 as a possible adaptation pathway.

PEAT-BUILDING WETLANDS

In the context of rapid sea-level rise, many types of NbS for shoreline resilience are under consideration in our region and elsewhere. One key factor in the San Francisco Bay Area is the concept of “elevation capital” or marsh elevation relative to the tides (Lowe & Bourgeois, 2015). Low-elevation marshes are more susceptible to marsh drowning, especially as rates of sea-level rise increase. Therefore, restoring marshes with high-elevation capital early this century, before SLR acceleration, represents a vital target of the Baylands Ecosystem Goals Update (Goals Project, 2015).

Many of the San Francisco Estuary’s historical baylands are isolated from tidal influence and could be restored to tidal marsh. However, much of the restorable area is subsided, and supplies of natural and imported inorganic sediment (e.g., from navigation channel dredging and construction projects) are limited to fill them to marsh elevation (Dusterhoff et al., 2021). Therefore, leveraging the capacity for organic sediment accretion may be a valuable strategy for developing resilient marshes while providing critical ecosystem services in years to come. Wetlands with emergent marsh vegetation have some of the highest rates of net primary productivity among terrestrial ecosystems, and organic matter accumulates in these wetlands when the decomposition and export of organic matter are minimized (Miller et al. 2008).

FSSD could develop peat-building wetlands in low-elevation areas to increase elevation capital and SLR resilience in anticipation of future (planned or unplanned) restoration of tidal marshes bayward of the plant. Once restoration occurs, higher elevation land is more likely to persist as tidal marsh to attenuate waves, thus protecting future flood risk management structures and the treatment plant from erosion and flooding.

Treated wastewater would be directed through constructed wetlands, creating freshwater marshes that encourage the accumulation of peat (soil with high organic matter content) and raise ground elevation. Questions remain about the efficacy of the proposed system, as nitrate-rich waters are known to stimulate denitrification and organic carbon consumption in peatlands (Kleimeier et al. 2014). There is limited research in Mediterranean climates on the potential for elevation increase using constructed wetlands receiving nutrient-rich treated wastewater. Once FSSD’s Aeration Basin improvements are placed online (tentatively planned for late 2025), total nitrate discharged will be diminished. Additional research is needed to determine whether and how much additional upstream denitrification (for example, dedicating more space to open water versus peat building wetlands) is needed. Pilot studies can inform design.

Habitat

Constructed peat-building wetlands can provide types of freshwater marsh habitat that are largely absent from the modern landscape. Historically, extensive wet meadows and vernal pools existed in the estuarine-terrestrial transition zone of San Pablo and Suisun Bays. Much of this habitat was diked and drained for agriculture, urban development, and duck clubs. At intertidal elevations, many areas that would have accreted organic matter over time had they remained connected to tidal action have instead subsided due to oxidation, desiccation, and compaction following extensive modifications to Suisun Marsh. While freshwater peat-building wetlands would not precisely recreate these historical conditions, they would restore many ecological functions provided by the region's historical wetlands, benefiting many species once reliant on wet meadows and vernal pools. In addition, constructed wetlands enhance freshwater sources by improving water quality prior to discharge and adding inputs higher in the watershed (above tidal marsh elevation) in a part of the landscape where freshwater connections to Suisun Marsh once existed.

Greenhouse gases

In addition to the SLR adaptation benefits and nutrient removal, freshwater wetlands typically function as a sink for atmospheric carbon. At the same time, freshwater wetlands can be sources of methane (CH4), and nitrate removal in treatment wetlands can lead to elevated emissions of nitrous oxide (N2O). CH4 and N2O are both potent greenhouse gases (GHG), so the effect of treatment wetlands on the climate depends on the relative rates of carbon sequestration, greenhouse gas emissions, and alternative baseline conditions may also contribute to climate change mitigation by sequestering atmospheric carbon. One local study from the Sacramento-San Joaquin Delta suggests that converting drained agricultural peat soils to wetlands can reduce GHG emissions (Knox et al., 2015). In this case, constructed wetlands varied from year to year between being a net carbon source or a net carbon sink, and replaced agricultural lands with high baseline GHG emissions. Another study found that for a restored wetland to be a carbon sink, it needs to have at least 55% vegetation coverage (Valach et al., 2021). Carbon sequestration and GHG emission rates are influenced by various environmental and design factors such as vegetation composition and coverage, wastewater carbon-to-nitrogen ratios, and flow regime (Huang et al. 2013, Yu et al. 2023). Overall, wetlands can be either greenhouse gas sources or sinks; while they tend to sequester carbon dioxide (CO2), freshwater wetlands can be sources of methane (CH4).

CH4 and N2O emissions are a tradeoff with the benefits treatment wetlands can provide for carbon sequestration, vertical accretion, and nutrient removal. The relative rates of these different processes depend on various factors, which can be interrelated. For instance, enriched nutrient concentrations stimulate plant growth and CO2 uptake, which is the driver of carbon sequestration and vertical accretion, but can also lead to higher methane and N2O emissions. Pilot studies can monitor these fluxes, and test possible design variables. Through this testing process tradeoffs among these processes can be optimized to achieve desired outcomes in peat building and GHG mitigation objectives.

One design consideration to test in a pilot study is how much nitrogen removal to target in the unit cell open water treatment wetland prior to inflow into the peat building wetland. Removing more nitrogen prior to flow into the peat-building wetland would reduce GHG emissions but possibly also reduce accretion rates. A pilot study at the Fairfield -Suisun Sewer District could provide critical information for the region on the GHG fluxes of peat-building wetlands, particularly peat-building wetlands supplied by treated wastewater.

Lessons learned from nearby wetlands

While yet to be tested with treated wastewater and in the context of Suisun Bay, the utility of peat-building with freshwater marshes for subsidence reversal has been proven in the nearby Sacramento-San Joaquin Delta, where subsidence is a major concern. Subsidence reversal pilot projects have tested the ability of peat-building wetlands to reduce soil loss and greenhouse gas emissions while increasing the likelihood of future success in tidal wetland restoration. In the case of these Delta wetlands, the GHG benefit is due to the halting of subsidence-related emissions, a factor that does not apply at the FSSD site. Results from some of these pilot studies are summarized below:

At Twitchell Island, subsidence reversal wetlands were established in 1997. Permanent shallow flooding created anaerobic conditions with high biomass accretion rates. Multiple conditions (water depths, residence times) were tested, and vegetated areas with low flows and long residence times were found to increase elevation gains most; short-term accretion rates as high as 7-9 cm/year were observed, with average accretion rates 4 cm/year (Miller et al., 2008). Dominant species of emergent vegetation are tule (*Schoenoplectus acutus*) and cattail (*Typha* spp.). West Pond at Twitchell Island was designed with more homogenous bathymetry, and with denser vegetation and no open water it has demonstrated more robust accretion over time. A more recent analysis of accretion rates found that soil accretion has been 1.65 cm/yr in West Pond (Arias-Ortiz et al. 2021).

Mayberry Wetland on Sherman Island was restored from pastureland in 2010. The site is dominated by tule (*Schoenoplectus acutus*) and cattail (*Typha* spp.), with some reeds (*Phragmites* spp) also present (Arias-Ortiz et al., 2021). The site is divided into seven wetland units where water levels can be independently managed. Water depths range from 2 cm to 2 m. Due to the heterogeneous bathymetry, the site is a mix of vegetation and open water (Angell et al., 2013). Mayberry wetland took about a year to become established with vegetation and about five years to achieve 50% coverage (Valach et al., 2021). Overall soil accretion rates at Mayberry were 0.55 cm/yr (Arias-Ortiz et al., 2021).

The CA Department of Water Resources (DWR) manages the Sherman and Twitchell Island subsidence reversal wetlands. SFEI and FSSD staff met with David Julian and Michelle Jesperson of DWR on February 2, 2023. Design recommendations based on this conversation included:

- Water depths can be kept low during the first few years to allow passive (unplanted) vegetation establishment, and then water depth can be increased to enhance accretion rates. Water depths of one to three feet are ideal for tule growth (the dominant species at the DWR wetlands). When the water is too deep, emergent vegetation will not grow.
- Planting can allow for faster vegetation establishment if budgets allow; however, passive vegetation colonization has also worked. Planting may help stave off issues with invasive plants colonizing before native vegetation is established.
- Drought has been a significant management challenge. Ensuring a consistent water supply will increase ease of management.
- Islands built for habitat/nesting are hard to access and can become weedy; maintenance and access should be considered during the design process.
- Beavers can block up water control structures. Water control structure design can include full pipes rather than half pipes to reduce potential blockage.

- Early coordination with mosquito abatement districts is important. Mosquito mitigation measures can include ponds and open water for mosquito fish habitat.
- It is beneficial to have more than one inlet for redundancy; if there are issues with one of the inlets, then water can still be delivered.

CONCEPT DRAWING

A concept design for the potential complex of FSSD treatment wetlands is shown in Figure 1. An existing pipeline extends northwest from the treatment plant to the existing FSSD discharge location at Ledgewood Creek (not shown). Under the proposed concept, flow is diverted from this outfall line through a series of unit cell open water wetlands, designed to optimize nutrient removal. The unit cell wetlands are shallow open-water cells designed to maximize photolysis and have no emergent vegetation. These cells would be lined and surrounded by 38" high earthen berms. Cross-berms with notched weirs are included to prevent hydraulic short-circuiting. After passing through the unit cell open water wetlands, water flows into the peat building wetland, where water levels are kept at 1-3 feet to maximize vegetation growth and accretion of organic material. Flow diffuses through this wetland, eventually exiting at the southeast corner and continuing to the existing FSSD Boynton Slough discharge location. Additional research is needed to inform the optimal ratios of open water and peat-building wetlands to remove nutrients and foster peat formation and maintenance.

A pilot project in the former recycled water basins in the northwest of the plant could be designed to test water retention times, water depths, density of plantings, etc. to determine the most optimal design before developing the larger nutrient removal and peat-building wetland. Monitoring efforts could track soil accretion rates, greenhouse gas fluxes, and nutrient removal rates in the pilot cells to allow comparison of tradeoffs between design parameters. The three basins could be used to test different design conditions for the peat-building wetland, or one could be used as a pilot for the open water treatment wetland. Alternatively, the basins could be subdivided into even more cells if it is deemed desirable to test a wider range of conditions.

Space is reserved west of the peat-building wetland to add a flood risk management levee and accompanying horizontal levee if needed in future SLR scenarios. There is potential to expand the wetlands and pursue a similar strategy on the property south of the treatment plant, including a second peat-building wetland and space for a horizontal levee.

Public access represents a critical element of NbS development at FSSD. Space is identified for a visitor center in the northeast corner of the unit cell open water wetlands. An extensive trail system around the constructed wetlands includes raised boardwalk trails. Additional consideration during the upcoming concept design development phase can also be given to potentially incorporating stormwater flows from the approximately 500-acre industrial park area north of the proposed wetland area.

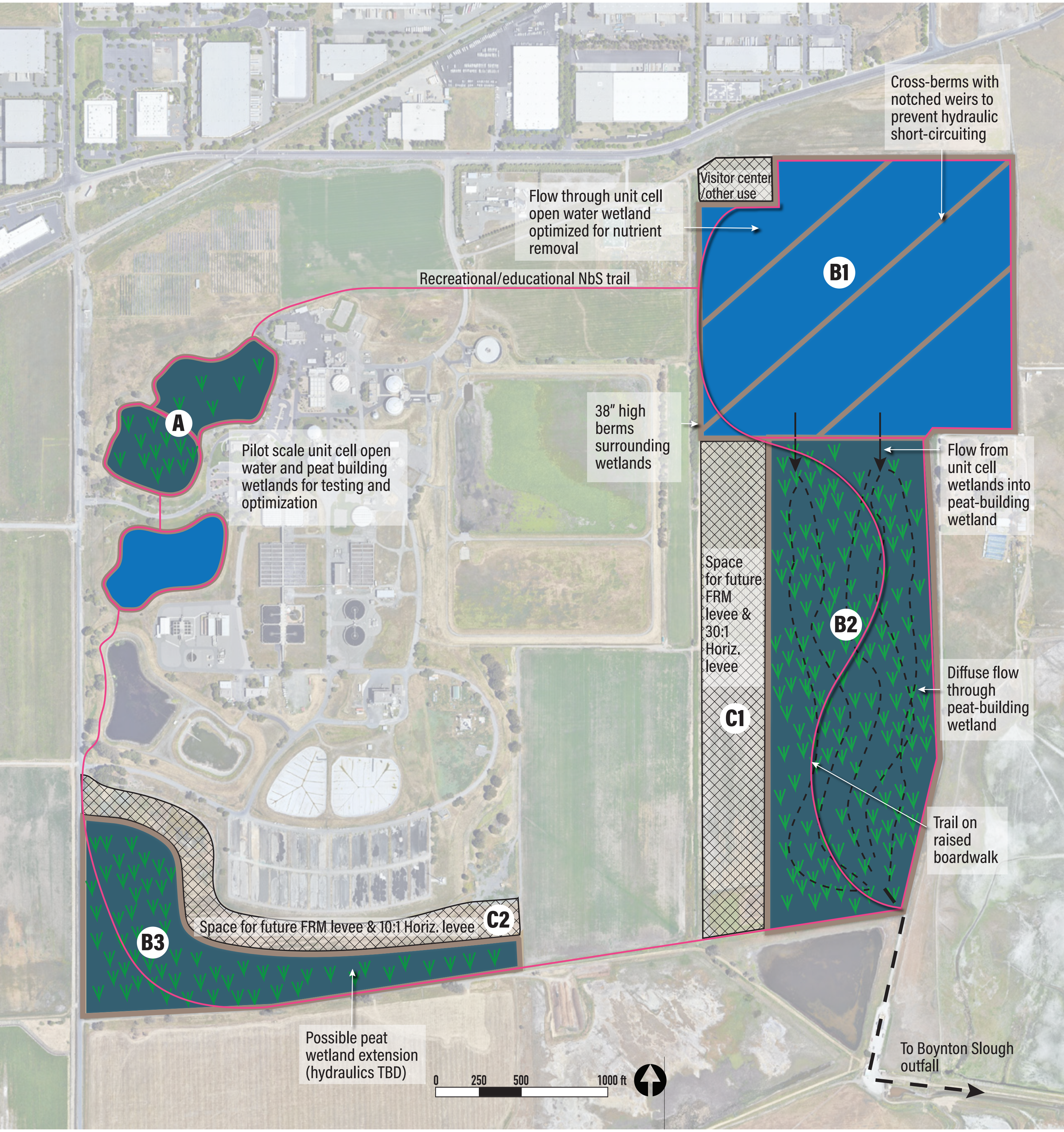

Figure 1. Concept drawing for open water wetland complex at FSSD. Circled letter labels correspond to the phases of the adaptation pathway shown in Figure 2.

ADAPTATION PATHWAY

FSSD is interested in developing a phased strategy to maximize the wastewater treatment plant's resilience to sea-level rise. Figure 2 illustrates one possible adaptation pathway for the constructed wetlands proposed in the concept above. Under this adaptation pathway, the first step is planning, designing, and constructing open-water treatment wetlands. Once constructed, these wetlands will remove nutrients and contaminants of emerging concern from treated wastewater, and peat-building wetlands will accrete organic material over time, increasing elevation capital.

While the peat-building wetlands are accreting gradually, planning for the following stages of facility flood protection, including additional wetland development, is underway. A flood protection plan will determine the type and scale of flood risk management infrastructure needed to protect plant facilities. As part of this plan development process, critical sea-level rise thresholds will determine when action is needed to construct any "gray" flood risk management infrastructure and associated "green" infrastructure elements (e.g., horizontal levees). Once FSSD constructed the flood risk management infrastructure and horizontal levees, treated wastewater can be redirected to seep through the horizontal levee into the peat-building wetlands, providing additional treatment benefits and expanding the freshwater wetland habitat area.

During the coming decades, plans may evolve regarding restoring diked baylands bayward of FSSD to tidal wetlands. Whether planned or unplanned, SLR will likely cause overtopping or failure of the non-engineered berms surrounding the diked baylands, followed by passive restoration to tidal marsh. When this occurs on adjacent properties, FSSD can breach or lower the berms surrounding peat-building wetlands and allow natural tidal flows to enter the site. Wetlands will undergo a transition from freshwater wetlands to brackish tidal wetlands. With treated wastewater continuing to seep through the horizontal levee and discharge to the marsh, a salinity gradient of freshwater to brackish wetlands will provide a valuable range of wetland habitat. Due to continued freshwater inputs, the wetlands will likely continue to sustain high organic matter accretion rates and persist as SLR rates increase. Functional tidal wetlands and a horizontal levee bayward of the plant and its associated flood risk management infrastructure would increase plant resilience by attenuating waves and reducing erosion for potentially the next century and beyond.

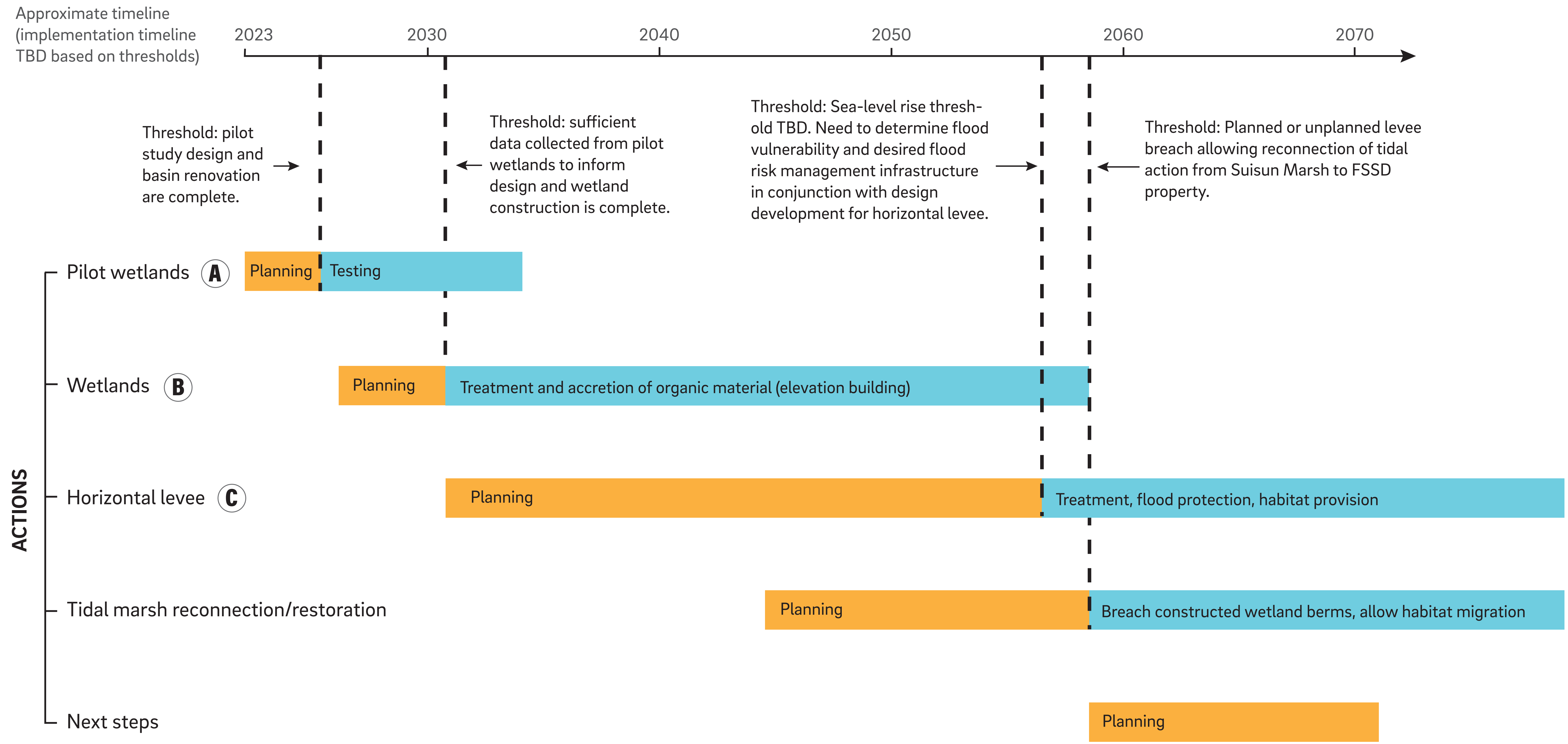

Figure 2. Possible adaptation pathway for FSSD wetlands. Circled letter labels correspond to locations shown in Figure 1.

PRELIMINARY COST ESTIMATE

SFEI contracted with the engineering firm HDR to develop planning-level cost estimates and potential TIN load reductions for various alternatives. Details are provided in Appendix A to this memorandum and summarized in Table 1. A summary of options, which can be thought of as modules contributing to future alternatives, are described below:

- **Unit Cell Wetland:** The northeast location ("B1" in Figure 1), was considered for the purposes of the cost estimate to be a 68-acre unit-cell open water wetland, which can take various forms but is generally unvegetated shallow open water systems optimized for denitrification.
- **Peat Building Wetland:** A 64-acre constructed wetland ("B2" in Figure 1). The sizing and nutrient reduction potential of this area is subject to change based on pilot study findings on nutrient removal and peat accumulation rates.
- **Extended Peat Building Wetland**: A 31-acre peat-building wetland ("B3" in Figure 1). Similar to Option B, the nutrient reduction and overall size are subject to change based on management priorities concerning nutrient load reduction versus peat building.
- **30:1 Horizontal Levee:** A 2,700-foot-long horizontal levee at a 30:1 slope, for a total width of 270 feet, located along the western perimeter of the peat building wetlands ("C1" in Figure 1).
- **10:1 Horizontal Levee:** A 3,000-foot-long horizontal levee at a 10:1 slope, for a width of 70 feet, located along the western perimeter of the peat building wetlands ("C2" in Figure 1).

Table 1. Planning level cost estimates for various nature-based solutions considered in Appendix A.

Option	Footprint Size (acres)	Construction Cost ($ Milions)
Unit Cell Wetland (B1 - Figure 1)	68	$35 Mil
Peat Building wetland (B2 - Figure 1)	64	$34 Mil
Extended Peat Building Wetland (B3 - Figure 1)	31	$19 Mil
30:1 Horizontal Levee (C1 - Figure 1)	17	$11 - 26 Mil
10:1 Horizontal Levee (C2 - Figure 1)	7	$6-12 Mil

In terms of planning-level estimates for construction cost, Option A (unit-cell wetlands) are estimated at roughly $35 million. The total cost for the peat building wetlands (Options B and C) amounts to approximately $50 million. For the larger 30:1 horizontal levee on the eastern side (Option D), the cost range spans from about $11 million to $26 million, while Option E, the smaller horizontal levee on the southern side (10:1 slope) ranges from approximately $5 million to $12 million. Variations in the costs of the horizontal levees are driven by differences in fill qualities.

These estimates are based on the assumption of importing fill to create perimeter and interior berms. However, site-specific analyses will determine whether on-site sources can be utilized for this purpose, potentially reducing costs.

NEXT STEPS

FSSD has already secured funding from the Environmental Protection Agency's Water Quality Improvement Fund for project planning and design (up to 30% design) for a community treatment wetland. This work will focus on developing open-water wetlands in the 97-acre parcel east of the plant. FSSD is also exploring funding options for a peat-building wetland pilot study in the existing recycled water basins.

The next steps for implementation include prioritizing with community input which elements to include in the three treatment wetland concept design alternatives, selecting a preferred alternative, estimating costs, and starting early conversations with permitting agencies. In particular, early coordination with the mosquito abatement district is recommended before the design development process has progressed much further.

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Appendix A

Bay Area Clean Water Agencies
Nature-based Solutions (NbS) Study

Fairfield-Suisun Sewer District NbS Evaluation for Nutrient Management

September 13, 2023
FINAL Report

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Contents

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1 Overview

HDR was retained by San Francisco Estuary Institute (SFEI) to support a high-level analysis on the feasibility and layouts for Nature-based solutions (NbS) at Fairfield-Suisun Sewer District (FSSD) Wastewater Treatment Plant (WWTP). This effort supports the on-going NbS efforts under the Second Nutrient Watershed Permit (R2-2019-0017) to evaluate nutrient management strategies at treatment plants across the Bay Area.

Several alternatives and layouts were reviewed for the FSSD WWTP, as well as a planning level cost estimate to implement each of the listed NbS projects. The cost estimates were based off a blend of previous HDR projects and engineering judgment based on geographic location. The quantities calculations are provided in Appendix A.

This technical memorandum reviews the potential for NbS solutions at the FSSD WWTP.

2 Methods

The methods section includes a brief description for the siting locations at FSSD WWTP, details on the cost estimating approach, and the approach for total inorganic nitrogen (TIN) load reduction with NbS technologies.

2.1 Fairfield-Suisun Sewer District

FSSD owns and operates the WWTP located in Fairfield, CA and discharges treated effluent to Boynton Slough, Duck Pond 1, Duck Pond 2, and Ledgewood Creek. The plant has an average dry weather flow (ADWF) permitted capacity of 23.7 million gallons per day (mgd).

The FSSD WWTP currently fully nitrifies (i.e., reliably biologically converts ammonia to nitrite/nitrate). A portion of the produced nitrite/nitrate is denitrified (i.e., biologically reduces formed nitrite/nitrate to nitrogen gas). Such biological processes are fundamental to any NbS technology as NbS technologies are typically designed to remove nitrite/nitrate with limited treatment of ammonia. Following biological treatment, FSSD WWTP filters the water prior to disinfection.

HDR was provided with the total property space as well as the location of agricultural fields around the plant that are owned by FSSD and leased to farmers. An aerial view of the treatment plant property is provided in Figure 1. The largest section of space for different practices was located on the eastern side of the plant. In this space, HDR was asked to review three separate alternatives including: a unit cell wetlands, a peat building wetlands, an extended peat building wetlands, and a horizontal levee. Additional space is offered at the southern portion of the WWTP considered an extended peat building wetlands, as well as a horizontal levee.

There are two separate segments of potential future horizontal levee, one on the eastern edge of the plant property and one along the southern boundary along the edge of the drying beds. An aerial view that includes such layouts is provided in Figure 2. The east section of levee would include an horizontal levee segment with a slope of 30:1 while the southern section would include an horizontal levee segment with a 10:1 slope.

Figure 1. FSSD: Property and Easements

Figure 2. FSSD: Horizontal Levee with a 30:1 Slope Horizontal Levee on the East side and a 10:1 Slope on the South

Note: FEMA Levee Fill included for illustrative purposes (i.e., not required for TIN load reduction)

2.2 Cost Estimate Basis

The cost estimate prepared for these projects combines historical unit pricing in Northern California (emphasis on the Bay Area) escalated to an equivalent present cost and task-based estimates. Task-based estimating is based on the following variables:

- Construction method,
- Equipment,
- Labor classifications,
- Material pricing appropriate for the scope of work,
- Site conditions, and
- Level of design detail

The basis of historical unit pricing was primarily derived from the Caltrans Contract Cost Database, available online at: EM 1110-2-1304, Civil Works Construction Cost Index System (CWCCIS), Tables 1-4, 30 September 2022 (oclc.org)

These tables provide historical information for inflation and the cost data herein is considered appropriate for such planning-level cost estimates. All cost values are in 2023 dollars except for the horizontal levee which is in 2050 dollars.

2.2.1 Key Variables Governing the Estimates: Slope and Fill

The key drivers for cost in each of the alternatives are fill and slope. The slope governs the overall footprint, whereas fill represents the primary quantity that makes up the cost for each alternative. Slope selection is typically governed by available land and desired outcomes (e.g., ecological benefits). Fill constitutes the largest portion of cost. As such, the quality of fill can have a profound impact on overall costs. To account for this, HDR has provided a “High”, “Medium”, and “Low” pricing for fill.

The calculations that informed quantities for each alternative were calculated based on the current conceptual design with assumptions made for the extent of impact to existing features, foundation over-excavation and stabilization, dewatering, and other items necessary to quantify the work. Details on quantities for each alternative is provided in Appendix A.

2.2.2 Carbon Source for TIN Load Reduction

The polishing of total inorganic nitrogen (TIN = ammonia + nitrite + nitrate) that is fed to any of the NbS alternatives requires a carbon source to facilitate the biological denitrification process (i.e., reduction of nitrite/nitrate to nitrogen gas). In most NbS scenarios, a natural carbon source, such as wood chips, are incorporated into the design. Horizontal levees can have a woodchip layer; woodchip-filled seepage slopes can be situated where the treatment plant discharges to an open water wetland; and unit-cell treatment wetlands can incorporate horizontal-flow woodchip bioreactors in one or several open water treatment cells. Wood chips were selected as they are relatively easy to obtain, are safe, and they have a relatively long replacement horizon (decadal timescales). The addition of an external carbon source does not necessarily enhance the nitrogen loading rate criteria; rather, it improves the nitrogen removal performance within the NbS.

As noted in the previous section, details on the carbon source quantity and unit cost are provided in Appendix A.

2.3 Total Inorganic Nitrogen Polishing

The extent of TIN load reduction varies by NbS alternative. For FSSD, three different NbS alternatives were evaluated:

- Unit cell wetlands,
- Peat building wetlands, and
- Horizontal levee

Estimating the TIN load reduction polishing for the unit cell and peat building wetlands is predicated on a tanks-in-series model based on available literature (Crites et al, 2014; Kadlek and Wallace, 2008; Wren, 2019). The tanks-in-series model is as follows:

$$\frac{Nitrate\ Concentration\ as\ N\ Exiting\ Wetland}{Nitrate\ Concentration\ as\ N\ Entering\ Wetland} = \left(1 + \frac{kA}{NQ}\right)^{-N}$$

where:

k = areal removal rate (m per yr)

A = wetland area (m^2)

Q = influent flow rate (m^3 per year)

N = number of tanks-in-series

As previously discussed in the BACWA NbS Scoping and Evaluation Plan (Wren, 2019), research at the nearby Town of Discovery Bay's wastewater treatment plant revealed that k is equal to 59.4 (at 20 degrees C) (Wren, 2019). Given the proximity to FSSD, using a similar value is deemed reasonable and used for this analysis. A more detailed evaluation is recommended to verify the k value. Given that the TIN load reduction is currently focused on dry season reductions (i.e., May through September), the 20 degrees C value is considered a conservative estimate and the 59.4 k value is thus left as is (i.e., not increased to account for likely warmer temperatures).

There is less available literature available on TIN load reduction across a horizontal levee. The available information is predominantly from the Bay Area's horizontal levee demonstration facility at Oro Loma/Castro Valley Sanitary District (OLSD). Recent empirical performance data at OLSD's horizontal levee suggests that 2.15 acres is required for every mgd to achieve 90 percent nitrate reduction across a horizontal levee (ranged from 0.6 to 6.7 acres/mgd; Cecchetti et al., 2020). Similar to the k value for the tanks-in-series model, the OLSD horizontal levee is located relatively nearby in the Bay Area and thus seems reasonable to use for this planning level analysis.

Besides having the capacity to polish TIN loads, NbS systems must be able to accommodate the hydraulic loading rate. A literature review was performed that yielded the information presented in Table 1. Those listed in Table 1 are more representative of unit cell wetlands and peat building wetlands. Given that FSSD provides biological treatment (with nitrification/denitrification) and filtration to produce a high quality product water, the Prado Wetlands hydraulic loading rate in Table 1 is deemed a conservative hydraulic loading rate (0.41 ft/d; 0.13 mgd/acre) for evaluating the unit cell and peat building wetlands for this analysis.

As for the horizontal levee, the on-going demonstration at the City of Palo Alto is taking a cautious approach and applying feed at just under 0.001 ft/d (330 gpd/acre) compared to 0.04 ft/d (0.012 mgd/acre) at the OLSD horizontal levee. Given the anticipated high quality feed water from FSSD the hydraulic loading rate from the OLSD horizontal levee was assumed for this effort. Given the subsurface nature of horizontal levees, determining site specific hydraulic conductivities would be required.

Table 1. Literature Review of NbS Hydraulic Loading Rates (Adapted from Jasper et al., 2013)

Wetland Name	Location (Year Started)	Size	Flow	Hydraulic Loading rate	Comment
Easterly	Orlando, FL (1987)	1,170 ac	21 mgd	0.06 ft/d (0.02 mgd/acre)	Wildlife habitat; nutrient polishing of treated wastewater. Florida Department of Environmental Protection (2012)
Prado	Riverside, CA (1992)	494 ac	66 mgd	0.41 ft/d (0.13 mgd/acre)	Wildlife habitat; nitrate polishing from effluent-dominated Santa Ana River prior to aquifer recharge. Orange County Water District (2012)
George W Shannon	Tarrant County, TX (2002)	445 ac	106 mgd	0.73 ft/d (0.24 mgd/acre)	Wildlife habitat; nutrient and solids polishing from effluent-dominated Trinity River. Tarrant Regional Water District (2012)

3 Results

SFEI/HDR engaged with FSSD and reached consensus on the most attractive potential NbS solution(s). HDR was tasked with providing layouts and planning-level cost estimates for three (3) alternatives that include a:

1) Unit Cell Wetland,
2) Peat Building Wetlands (as is plus with an extension), and
3) Horizontal Levee (with a wood chip bioreactor). Note: each horizontal levee includes costs for low-, medium-, and high-quality fill as this will significantly impact costs

The proposed unit cell wetlands, peat building wetlands, and peat building wetlands extension would add approximately 163 acres of treatment area to the facility. A layout of the FSSD WWTP with a layout of such features is provided in Figure 3.

The projects would likely be phased at the FSSD WWTP. The initial project would likely include the unit cell wetlands, followed by the peat building wetlands and extended peat building wetlands. These initial projects would all be hydraulically connected. The subsequent phasing would include horizontal levee around year 2050. It is recommended that FSSD WWTP consider a FEMA Fill Levee as a strategy to address flood control concerns prior to the horizontal levee(s). While the FEMA Fill Levee would not receive any water from the extend peat building wetlands, it would assist with addressing flood control concerns. It is unclear at this stage of planning as to whether the horizontal levee(s) would receive FSSD WWTP effluent OR effluent from either the unit cell or peat building wetlands.

A summary of the planning-level cost estimates, footprint, anticipated feed flow as stand-alone concepts, and potential TIN load reduction for each alternative is provided in Table 2. The extent of TIN load reduction is predicated on the type and scale of the listed NbS concept as described in Section 2.3.

It is anticipated that the unit cell and peat building wetlands (except the extended peat building wetland) could individually treat a majority (approximately 9 mgd) of the existing FSSD WWTP average effluent (approximately 13 mgd). FSSD WWTP currently discharges approximately 2,470 lb TIN/d on average. The anticipated load reduction for the unit cell and peat building wetlands are each on the order of 1,000 – 1,100 lb TIN/d. In contrast, the extended peat building wetland can accommodate approximately 4 mgd of the plant effluent and as such less TIN load reduction (on the order of 500 lb TIN/d on average) The extended peat building wetlands has a smaller footprint that the unit cell and peat building wetlands.

The horizontal levee concepts (East and South) both have marginal TIN load reductions (<100 lb N/d in both cases). The analysis suggests that horizontal levees in this case are limited by hydraulics (0.012 mgd/acre; primarily due to clogging). On-going research at the OLSD horizontal levee is focused on how to address hydraulic limitations. Note: if the horizontal levee received water that had already passed through a unit cell and/or peat building wetland, the likelihood of clogging would decrease and thereby improve the hydraulic conductivity. Site specific measurements would be required to verify such a claim.

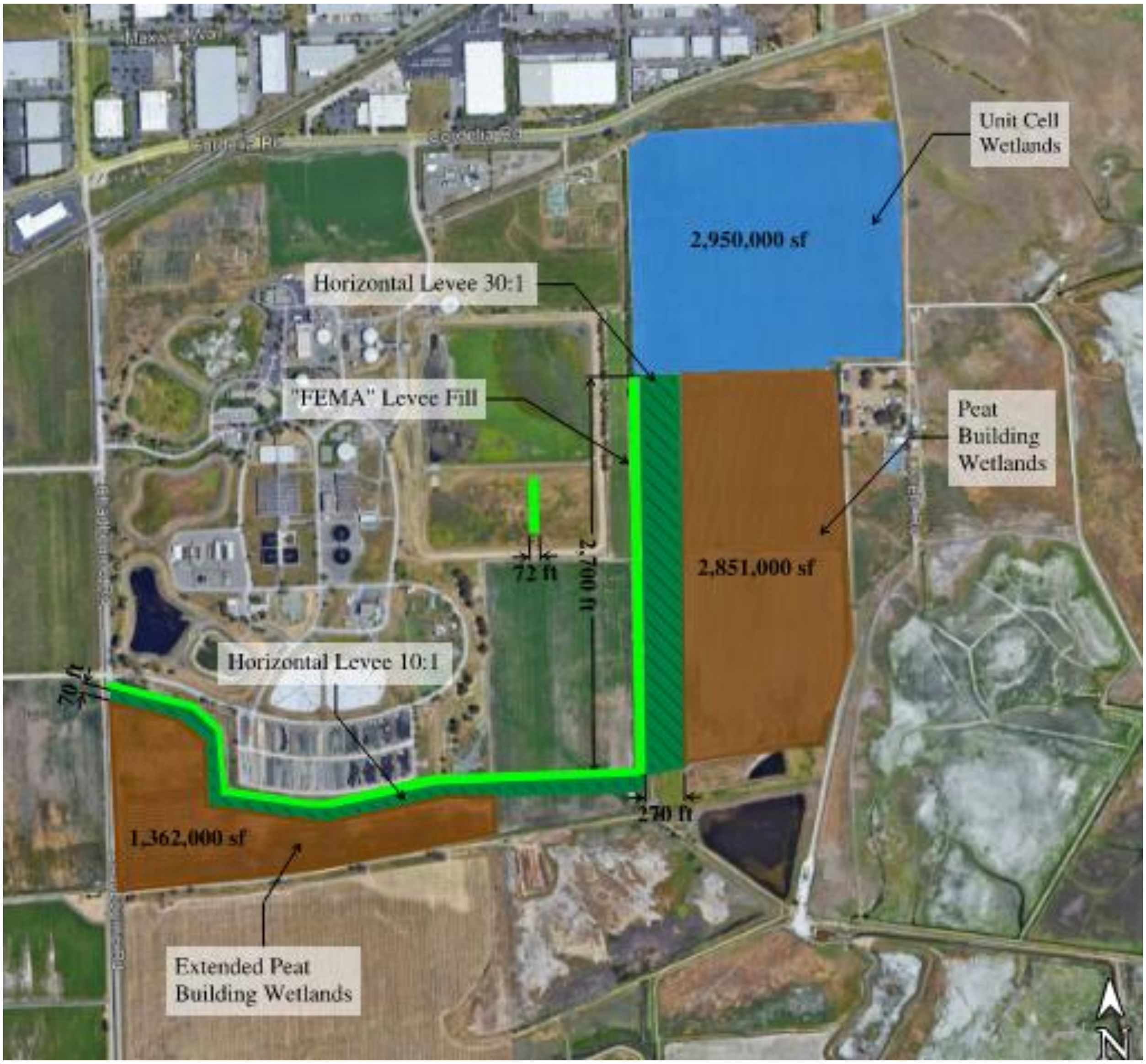

Figure 3. FSSD: Layouts for All Three NbS Alternatives
Note: FEMA Levee Fill included for illustrative purposes (i.e., not required for TIN load reduction)

The planning level costs for Unit Cell Wetlands is approximately $35 Mil, whereby the peak building wetlands are a combined total cost of approximately $50 Mil for both. As for the horizontal levee, the larger of the two (eastern side at 30:1 slope) ranges from approximately $11 to $26 Mil. The smaller horizontal levee on the southern side (10:1 slope) ranges in cost from approximately $5 Mil to $12 Mil. The wide range in costs for the horizontal levees is predicated on differing fill qualities.

Some examples of the pilot-scale unit-cell wetlands at Discovery Bay and engineering drawings for a horizontal levee are provided in Figure 4 and Figure 5, respectively.

Details on the quantities that informed the planning-level cost estimates is provided in Appendix A.

Table 2. Fairfield-Suisun Sewer District: Summary of the Alternatives

Technology Description	Footprint, Acres	Feed Flow, mgd	Potential TIN Load Reduction, lb N/d *	Construction Cost, $ Mil	Comments
Unit Cell Wetlands					
Unit Cell Wetlands	**68**	**Treat up to approximately 9 mgd (represents about 75 percent of current dry season discharge flow)**	**Upwards of 1,100 lb N/d [1]**	**$ 35.1 Mil**	• Need to verify that the wetlands can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Note: based on the hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre) the system would be nearing hydraulic limitations. • **On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns associated with on-site bay mud quality for such an application. For planning-level purposes, it was assumed that off-site fill would be required.**
Peat Building Wetlands					
Peat Building Wetlands	**64**	**Treat up to approximately 9 mgd (represents about 75 percent of current dry season discharge flow)**	**Upwards of 1,000 lb N/d [1]**	**$ 33.6 Mil**	• Need to verify that the wetlands can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Note: based on the hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre) the system would be nearing hydraulic limitations. • **On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns associated with on-site bay mud quality for such an application. For planning-level purposes, it was assumed that off-site fill would be required.**
Extended Peat Building Wetlands	**31**	**Treat up to approximately 4 mgd (represents about 30 percent of the current dry season discharge flow)**	**Upwards of 500 lb N/d [1]**	**$ 18.5 Mil**	• Need to verify that the wetlands can accommodate the hydraulic loading (site specific) and minimize short-circuiting. Note: based on the hydraulic loading rate of 0.41 ft/d (0.13 mgd/acre) the system would be nearing hydraulic limitations. • **On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns associated with on-site bay mud quality for such an application. For planning-level purposes, it was assumed that off-site fill would be required.**
Horizontal Levee East Slope (Varying Fill Quality)					
Horizontal Levee – East Side (30:1 Slope)	**17**	**More challenging to push the flow through the process compared to unit cell and peat building wetlands (<1 mgd)**	**<100 lb N/d [1]**	**$ 11.2 Mil [2] $ 14.4 Mil [3] $ 26.4 Mil [4]**	• Fill quality significantly impacts cost (refer to Appendix A for detailed cost breakdown). The process appears to be hydraulically limited using the hydraulic loading rates from OLSD horizontal levee (0.04 ft/d; 0.012 mgd/acre). The hydraulic loading criterion needs to be verified as the hydraulic limitations outweigh TIN load reduction potential. • **Opportunity to reduce this cost $3-$7 Mil (low- to high-quality fill, respectively) if we use on-site fill (detailed evaluation required to confirm suitability).** Potential savings shown in Appendix A. For planning-level purposes, the analysis assumed off-site fill would be required.
Horizontal Levee South Slope (Varying Fill Quality)					
Horizontal Levee – South Side (10:1 Slope)	**7**	**More challenging to push the flow through the process compared to unit cell and peat building wetlands (<1 mgd)**	**<100 lb N/d [1]**	**$ 5.4 Mil [2] $ 6.7 Mil [3] $ 11.7 Mil [4]**	• Fill quality significantly impacts cost (refer to Appendix A for detailed cost breakdown). The process appears to be hydraulically limited using the hydraulic loading rates from OLSD horizontal levee (0.04 ft/d; 0.012 mgd/acre). The hydraulic loading criterion needs to be verified as the hydraulic limitations outweigh TIN load reduction potential. • **Opportunity to reduce this cost $1-$3 Mil (low- to high-quality fill, respectively) if we use on-site fill (detailed evaluation required to confirm suitability).** Potential savings shown in Appendix A. For planning-level purposes, the analysis assumed that off-site fill would be required.

* FSSD WWTP effluent currently averages approximately 2,470 lb TIN/d. After aeration basin upgrades, effluent will be ~1,760 lb TIN/d. The TIN load reduction calculations shown here do not account for the upgrade.
1 Based on current flows of approximately 13 mgd that average an effluent TIN concentration of approximately 21 mg N/L
2 Based on low quality fill
3 Based on medium quality fill
4 Based on high quality fill

Figure 4. Picture of Discovery Bay Open-Water Wetland Cell Located in Discovery Bay, CA) (Jasper et al., 2013)

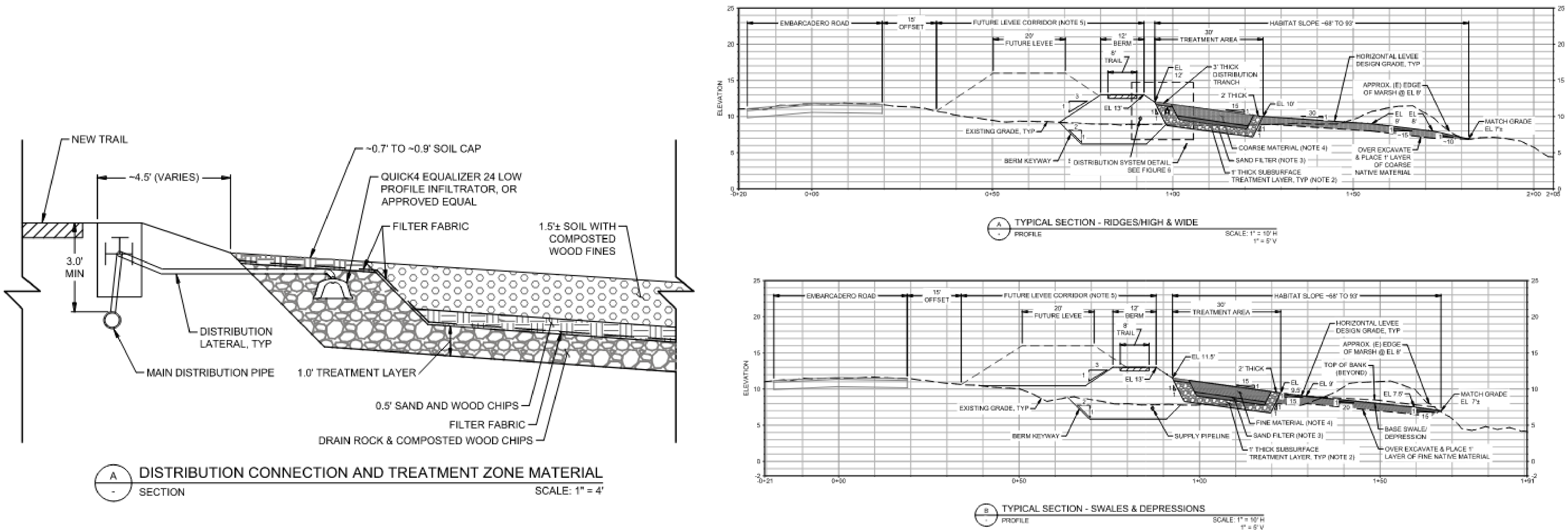

Figure 5. Representative Horizontal Levee Overview (Left-Hand Side) and Typical Sections (Right-Hand Side) (Source: Palo Alto Horizontal Levee Demonstration: https://www.sfestuary.org/truw-pahlp/)

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Appendix A. Quantities and Take-Offs

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FSSD NbS Treatment
Various NbS Solutions Captured in the Calcs Below
Updated: 9/13/23

Component/ Discipline	Item to be Quantified	Quantity	Unit	Price	Unit	Notes	Calculation Method Used	Total
General	Stormwater Pollution Prevention Plan/ Erosion/ Stormwater Control	24	Month	$ 13,601	Month		Hand Calc	$ 330,000
Civil	**Eco-Tone 30:1 (High)**							
Civil	Eco-Tone Fill Purchase	135,000	CY	$ 33	CY	Opportunity to eliminate and/or reduce this cost if we use on-site fill (would require a detailed evaluation to confirm suitability). For planning-level purposes, it was assumed that off-site fill would be required.	Hand Calc	$ 4,500,000
Civil	Eco-Tone Fill Haul	135,000	CY	$ 19	CY		Hand Calc	$ 2,570,000
Civil	Eco-Tone Fill Placement	135,000	CY	$ 63	CY		Hand Calc	$ 8,450,000
Civil	**Subsurface Seepage Zone**							
Civil	Wood Chip Bioreactor	6,800	CY	$ 10	CY			$ 70,000
Misc	Native plantings	1	Acre	$ 5,000	Acre		Hand Calc	$ 3,000
Misc	8" Pipe	10,500	LF	$ 40	LF	From San Jose levee piping plan (for planning level purposes)	Hand Calc	$ 420,000
							Subtotal	**$ 15,590,000**
Civil	**Eco-Tone 30:1 (Medium)**							
Civil	Eco-Tone Fill Purchase	135,000	CY	$ 17	CY	Opportunity to eliminate and/or reduce this cost if we use on-site fill (would require a detailed evaluation to confirm suitability). For planning-level purposes, it was assumed that off-site fill would be required.	Hand Calc	$ 2,250,000
Civil	Eco-Tone Fill Haul	135,000	CY	$ 10	CY		Hand Calc	$ 1,290,000
Civil	Eco-Tone Fill Placement	135,000	CY	$ 31	CY		Hand Calc	$ 4,220,000
Civil	**Subsurface Seepage Zone**							
Civil	Wood Chip Bioreactor	6,800	CY	10	CY			$ 70,000
Misc	Native plantings	1	Acre	5,000	Acre		Hand Calc	$ 3,000
Misc	8" Pipe	10,500	LF	40	LF	From San Jose levee piping plan (for planning level purposes)	Hand Calc	$ 420,000
							Subtotal	**$ 8,250,000**
Civil	**Eco-Tone 30:1 (Low)**							
Civil	Eco-Tone Fill Purchase	135,000	CY	$ 12	CY	Opportunity to eliminate and/or reduce this cost if we use on-site fill (would require a detailed evaluation to confirm suitability). For planning-level purposes, it was assumed that off-site fill would be required.	Hand Calc	$ 1,690,000
Civil	Eco-Tone Fill Haul	135,000	CY	$ 7	CY		Hand Calc	$ 960,000
Civil	Eco-Tone Fill Placement	135,000	CY	$ 23	CY		Hand Calc	$ 3,170,000
Civil	**Subsurface Seepage Zone**							
Civil	Wood Chip Bioreactor	6,800	CY	10	CY			$ 70,000
Misc	Native plantings	1	Acre	5,000	Acre		Hand Calc	$ 3,000
Misc	8" Pipe	10,500	LF	40	LF	From San Jose levee piping plan (for planning level purposes)	Hand Calc	$ 420,000
							Subtotal	**$ 6,310,000**

Civil	**Eco-Tone 10:1 (High)**							
Civil	Eco-Tone Fill Purchase	53,422	CY	$ 33	CY	Opportunity to eliminate and/or reduce this cost if we use on-site fill (would require a detailed evaluation to confirm suitability). For planning-level purposes, it was assumed that off-site fill would be required.	Hand Calc	$ 1,780,000
Civil	Eco-Tone Fill Haul	53,422	CY	$ 19	CY		Hand Calc	$ 1,020,000
Civil	Eco-Tone Fill Placement	53,422	CY	$ 63	CY		Hand Calc	$ 3,340,000
Civil	**Subsurface Seepage Zone**							
Civil	Wood Chip Bioreactor	6,800	CY	10	CY			$ 70,000
Misc	Native plantings	1	Acre	5,000	Acre		Hand Calc	$ 3,000
Misc	8" Pipe	10,500	LF	40	LF	From San Jose levee piping plan (for planning level purposes)	Hand Calc	$ 420,000
							Subtotal	**$ 6,630,000**
Civil	**Eco-Tone 10:1 (Medium)**							
Civil	Eco-Tone Fill Purchase	53,422	CY	$ 17	CY	Opportunity to eliminate and/or reduce this cost if we use on-site fill (would require a detailed evaluation to confirm suitability). For planning-level purposes, it was assumed that off-site fill would be required.	Hand Calc	$ 890,000
Civil	Eco-Tone Fill Haul	53,422	CY	$ 10	CY		Hand Calc	$ 510,000
Civil	Eco-Tone Fill Placement	53,422	CY	$ 31	CY		Hand Calc	$ 1,670,000
Civil	**Subsurface Seepage Zone**							
Civil	Wood Chip Bioreactor	6,800	CY	10	CY			$ 70,000
Misc	Native plantings	1	Acre	5,000	Acre		Hand Calc	$ 3,000
Misc	8" Pipe	10,500	LF	40	LF	From San Jose levee piping plan (for planning level purposes)	Hand Calc	$ 420,000
							Subtotal	**$ 3,560,000**
Civil	**Eco-Tone 10:1 (Low)**							
Civil	Eco-Tone Fill Purchase	53,422	CY	$ 12	CY	Opportunity to eliminate and/or reduce this cost if we use on-site fill (would require a detailed evaluation to confirm suitability). For planning-level purposes, it was assumed that off-site fill would be required.	Hand Calc	$ 670,000
Civil	Eco-Tone Fill Haul	53,422	CY	$ 7	CY		Hand Calc	$ 380,000
Civil	Eco-Tone Fill Placement	53,422	CY	$ 23	CY		Hand Calc	$ 1,250,000
Civil	**Subsurface Seepage Zone**							
Civil	Wood Chip Bioreactor	6,800	CY	10	CY			$ 70,000
Misc	Native plantings	1	Acre	5,000	Acre		Hand Calc	$ 3,000
Misc	8" Pipe	10,500	LF	40	LF	From San Jose levee piping plan (for planning level purposes)	Hand Calc	$ 420,000
							Subtotal	**$ 2,790,000**

Civil	**Peat Building Wetland**							
Demoliton	Clearing/Grubbing	64	Ac	$ 5,440	Ac		Hand Calc	$ 350,000
Civil	**Peat Building Wetland Berm**							
Civil	Fill Purchase	23,611	CY	$ 67	CY	On-site fill might be an option to reduce and/or elimindate cost; however, there are concerns associated with on-site bay mud quality for such an application.	Hand Calc	$ 1,570,000
Civil	Fill Haul	23,611	CY	$ 10	CY		Hand Calc	$ 220,000
Civil	Fill Placement	23,611	CY	$ 31	CY		Hand Calc	$ 740,000
Civil	**Peat Building Wetland Fill (Wetlands Interior)**							
Civil	Peat Building Fill	64	Ac	$ 288,000	Ac	Using total line price for other unit cell wetlands pricing and dividing by area to scale it per acre. Note 1: the sample unit cell wetland was 27 acres which is within the same magnitude as FSSD and thus deemed reasonable. Note: the most conservative high quality fill was used (unit cost ranged from $263,000 - $288,000 depending on fill quality). The unit cost per acre includes a compact clay liner, specified earther fill (purchase, haul, and placement), miscellaneous excavation (purchase, haul, placement), plantings, miscellaneous 8" pipes, and mobilization/demo.	Hand Calc	$ 18,390,000
							Subtotal	**$ 21,270,000**
Civil	**Extended Peat Building Wetland**							
Demoliton	Clearing/Grubbing	31	Ac	$ 5,440	Ac		Hand Calc	$ 170,000
Civil	**Extended Peat Building Wetland Berm**							
Civil	Fill Purchase	23,538	CY	$ 67	CY	On-site fill might be an option to reduce and/or elimindate cost; however, there are concerns associated with on-site bay mud quality for such an application.	Hand Calc	$ 1,570,000
Civil	Fill Haul	23,538	CY	$ 10	CY		Hand Calc	$ 220,000
Civil	Fill Placement	23,538	CY	$ 31	CY		Hand Calc	$ 740,000
Civil	**Peat Building Wetland Fill (Wetlands Interior)**							
Civil	Peat Building Fill	31	Ac	$ 288,000	Ac	Using total line price for other unit cell wetlands pricing and dividing by area to scale it per acre. Note 1: the sample unit cell wetland was 27 acres which is within the same magnitude as FSSD and thus deemed reasonable. Note: the most conservative high quality fill was used (unit cost ranged from $263,000 - $288,000 depending on fill quality). The unit cost per acre includes a compact clay liner, specified earther fill (purchase, haul, and placement), miscellaneous excavation (purchase, haul, placement), plantings, miscellaneous 8" pipes, and mobilization/demo.	Hand Calc	$ 8,810,000
							Subtotal	**$ 11,510,000**

	Unit Cell Wetlands							
Demoliton	Clearing/Grubbing	68	Ac	$ 5,440	Ac		Hand Calc	$ 370,000
Civil	**Unit Cell Wetlands Berm**							
Civil	Fill Purchase	22,144	CY	$ 67	CY	On-site fill might be an option to reduce and/or elimindate cost; however, there are concerns associated with on-site bay mud quality for such an application.	Hand Calc	$ 1,480,000
Civil	Fill Haul	22,144	CY	$ 10	CY		Hand Calc	$ 210,000
Civil	Fill Placement	22,144	CY	$ 31	CY		Hand Calc	$ 690,000
Civil	**Unit Cell Wetlands Fill (Wetlands Interior)**							
Civil	Wetlands Fill	68	Ac	$ 288,000	Ac	Using total line price for other unit cell wetlands pricing and dividing by area to scale it per acre. Note 1: the sample unit cell wetland was 27 acres which is within the same magnitude as FSSD and thus deemed reasonable. Note: the most conservative high quality fill was used (unit cost ranged from $263,000 - $288,000 depending on fill quality). The unit cost per acre includes a compact clay liner, specified earther fill (purchase, haul, and placement), miscellaneous excavation (purchase, haul, placement), plantings, miscellaneous 8" pipes, and mobilization/demo.	Hand Calc	$ 19,500,000
							Subtotal	**$ 22,250,000**
Misc	**Miscellaneous**							
Misc	Native plantings	33	Acre	$ 5,000	Acre		Hand Calc	$ 170,000
Misc	8" Pipe	450	LF	$ 40	LF			$ 20,000
								Unit Cell Wetlands
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$ 2,277,000
							Base Total	$ 25,047,000
							Contingency (30%)	$ 7,510,000
							Contractor Profit (8%)	$ 2,000,000
							Insurance and Bonds (2%)	$ 500,000
							Total:	**$ 35,057,000**
								Peat Bog
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$ 2,179,000
							Base Total	$ 23,969,000
							Contingency (30%)	$ 7,190,000
							Contractor Profit (8%)	$ 1,920,000
							Insurance and Bonds (2%)	$ 480,000
							Total:	**$ 33,559,000**
								Extended Peat Bog
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$ 1,203,000
							Base Total	$ 13,233,000
							Contingency (30%)	$ 3,970,000
							Contractor Profit (8%)	$ 1,060,000
							Insurance and Bonds (2%)	$ 260,000
							Total:	**$ 18,523,000**

									30:1 Eco-Tone Cost (High)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	1,611,000
							Base Total	$	17,721,000
							Contingency (30%)	$	5,320,000
							Contractor Profit (8%)	$	1,420,000
							Insurance and Bonds (2%)	$	350,000
							Total:	**$**	**26,422,000**
									30:1 Eco-Tone Cost (Medium)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	877,000
							Base Total	$	9,647,000
							Contingency (30%)	$	2,890,000
							Contractor Profit (8%)	$	770,000
							Insurance and Bonds (2%)	$	190,000
							Total:	**$**	**14,374,000**
									30:1 Eco-Tone Cost (Low)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	683,000
							Base Total	$	7,513,000
							Contingency (30%)	$	2,250,000
							Contractor Profit (8%)	$	600,000
							Insurance and Bonds (2%)	$	150,000
							Total:	**$**	**11,196,000**
									10:1 Eco-Tone Cost (High)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	715,000
							Base Total	$	7,865,000
							Contingency (30%)	$	2,360,000
							Contractor Profit (8%)	$	630,000
							Insurance and Bonds (2%)	$	160,000
							Total:	**$**	**11,730,000**
									10:1 Eco-Tone Cost (Medium)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	408,000
							Base Total	$	4,488,000
							Contingency (30%)	$	1,350,000
							Contractor Profit (8%)	$	360,000
							Insurance and Bonds (2%)	$	90,000
							Total:	**$**	**6,696,000**
									10:1 Eco-Tone Cost (Low)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	331,000
							Base Total	$	3,641,000
							Contingency (30%)	$	1,090,000
							Contractor Profit (8%)	$	290,000
							Insurance and Bonds (2%)	$	70,000
							Total:	**$**	**5,422,000**