Nature-based Solutions for Nutrient Removal

CONCEPT DESIGN & COST ESTIMATE: **DELTA DIABLO**

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

IN PARTNERSHIP WITH
Delta Diablo

PREPARED FOR
Bay Area Clean Water Agencies

Version 1: August 2024

INTRODUCTION

Phase I of the Nature-Based Solutions for Nutrient Reduction Study identified Delta Diablo as having high opportunity for open-water treatment wetlands and moderate potential for horizontal levees. In Phase II of the study, SFEI and Delta Diablo explored several alternatives involving these two nature-based solutions (NbS) types. This memorandum and accompanying appendix represent Phase III of the study and include the following:

- Identification of a preferred NbS alternative with concept drawings, 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, interior earthen berms' configuration, and the project's fill source significantly affect cost. Design considerations such as vegetative cover and public access also influence open-water wetlands' hydraulic capacity and nitrate-removal efficiency. If Delta Diablo pursues additional evaluations, these factors should be considered.

SELECTION OF PREFERRED OPTION

SFEI and Delta Diablo considered three options in the Phase II opportunities and constraints analysis:

- Option 1: Convert part or all of the Emergency Retention Basin in the northeast of the plant to open water treatment wetlands.
- Option 2: Convert the newly purchased property southwest of the plant to an open water treatment wetland.
- Option 3: Coordinate with BNSF Railway and Corteva Preserve to construct a horizontal levee north of the rail line.

SFEI, HDR, and Delta Diablo staff met in December 2022 to identify a preferred alternative for the Phase III analysis.

Delta Diablo should further investigate Option 1 (dual-purpose use of the Emergency Retention Basin during the dry season for nutrient removal) in light of recent studies.[1] This option may be of particular interest for polishing of blowdown. Some operational adjustments would be required, as flow diversions are currently directed to the basin 2-3 times per week during maintenance activities. A dual-purpose basin would need to be designed to preserve adequate stormwater storage capacity in the Emergency Retention Basin, especially in the context of climate change and increased precipitation intensity.

1 Kilpatrick, S.-M. 2024. Dual-purpose Equalization Basins: a Seasonal Solution for Summer Nutrient Removal and Winter Storm Events. San Francisco Estuary Institute.

Option 3 (horizontal levee north of the rail line) was determined to be infeasible due to ownership and logistical considerations. Compared to Option 2, Option 3 is likely to face greater permitting hurdles, require extensive planning and coordination with outside partners, and provide less return in terms of nitrogen reduction, according to a preliminary analysis conducted for the Phase II analysis.

In contrast, Option 2 was most feasible due to existing ownership by Delta Diablo and proximity to the north-south Calpine Energy blowdown line. The recently purchased property has not yet been slated for other uses, and an open water treatment wetland could provide several benefits for the agency. Delta Diablo staff indicated that including public access elements could increase the project's attractiveness by providing benefits to the community. The site is well suited for access given its visible location on the Pittsburg-Antioch Highway and across Arcy Lane from more sensitive plant operations. Public access could include recreational elements (e.g., trails) and educational elements (signs, access for school groups, etc.).

This memo provides additional detail and context for the development of Option 2, involving multi-benefit treatment wetlands in the recently purchased 28-acre site southwest of the main plant. The critical limitation for the implementation of NbS at Delta Diablo is the need for nitrification capacity. All NbS options assume nitrified effluent is applied to the treatment wetland for additional polishing and denitrification. Consistent with references from Appendix A, Delta Diablo is considering upgrades over the next several years involving nitrification. In this event, a portion of the total effluent stream could be routed through a constructed wetland to further reduce nutrient loading to the Sacramento/San Joaquin Delta. The costs associated with nitrification upgrades are not reflected in the costs shown in Appendix A.

Variability in dry season flow also represents a key factor in the design of any NbS strategy at Delta Diablo. Table 1 summarizes the last three years of flow characteristics. The driving variable involves the volume of Title 22 tertiary treated water routed to the adjacent power plant. A portion this flow, known as "blowdown," is routed back to Delta Diablo with concentrated nitrogen levels. During particularly hot days the demand for water at the power plant increases significantly, which affects flow rates and nutrient concentrations. Total inorganic nitrogen (TIN) levels in the returned blowdown can be three times of concentration of secondary effluent. This may represent an opportunity for higher nutrient removal rates due to higher retention times and greater removal efficiency of effluent with concentrated TIN.

Table 1. Dry-season flow statistics at Delta Diablo over the last three years.

Influent/Effluent Characteristics	Avg Flow (mgd)	Min Flow (mgd)	Max Flow (mgd)
Influent	13.4	10.9	15.9
Recycled Water Demand	7.8	2.1	12.8
Final Effluent (secondary effluent + blowdown)	7.2	2.4	12.6
Blowdown	2.1	0.2	4.3
Blowdown - percent of final effluent	35.6%	2.0%	125.8%*

* During multi-day heat waves, high demand prompts Delta Diablo to pump final effluent (secondary effluent + blowdown) back to the recycled water facility. This adjustment ensures Delta Diablo maintains consistent flow to the recycled water facility, and sometimes causes blowdown flow to exceed total effluent flow.

CONCEPT DRAWINGS

SFEI and HDR,Inc. identified two potential design concepts for a treatment wetland in the 28-acre proprety southwest of the main plant. A concept drawing for Alternative 1 (free water surface wetlands) is shown in Figure 1. Six-foot high berms are constructed around the perimeter of the 28-acre property, and the wetland is lined. Water (blowdown or plant effluent) enters the serpentine channel open water wetland in the northeast corner of Pond 1 and flows around a series of baffles to the southwest corner, where it flows into Pond 2. Pond 2 is a vegetated free-water surface wetland.

Topography may be designed to promote the growth of emergent wetland vegetation (e.g., tule, cattail) in shallower areas around the edges of the wetland. This vegetated wetland will provide habitat for songbirds (e.g., song sparrow, common yellowthroat), wading birds (herons, gallinules, etc.), and other marsh species, in addition to reducing TIN. Water flows from the vegetated free-water surface wetland into a detention pond, allowing better control of water levels in the wetlands. Water then continues out to the Delta Diablo outfall at New York Slough. SFEI and HDR, Inc. did not assess options for routing treated water from the wetland to New York Slough.

A recreational/educational trail is included on the berm surrounding the wetlands for opportunities to observe wildlife and learn about nature-based wastewater treatment.

Alternative 2 also includes a serpentine channel wetland in Pond 1 but flows into unit cell open water wetlands in Pond 2 (Figure 2). Unlike the free-water surface wetlands shown in Alternative 1, which have areas of open water and vegetation that appear similar to natural marshes, unit-process open-water wetlands are shallow open-water cells designed to maximize photolysis and have no emergent vegetation. Water would flow through a series of two open water cells optimized for nutrient removal before entering the detention pond and continuing to the outfall.

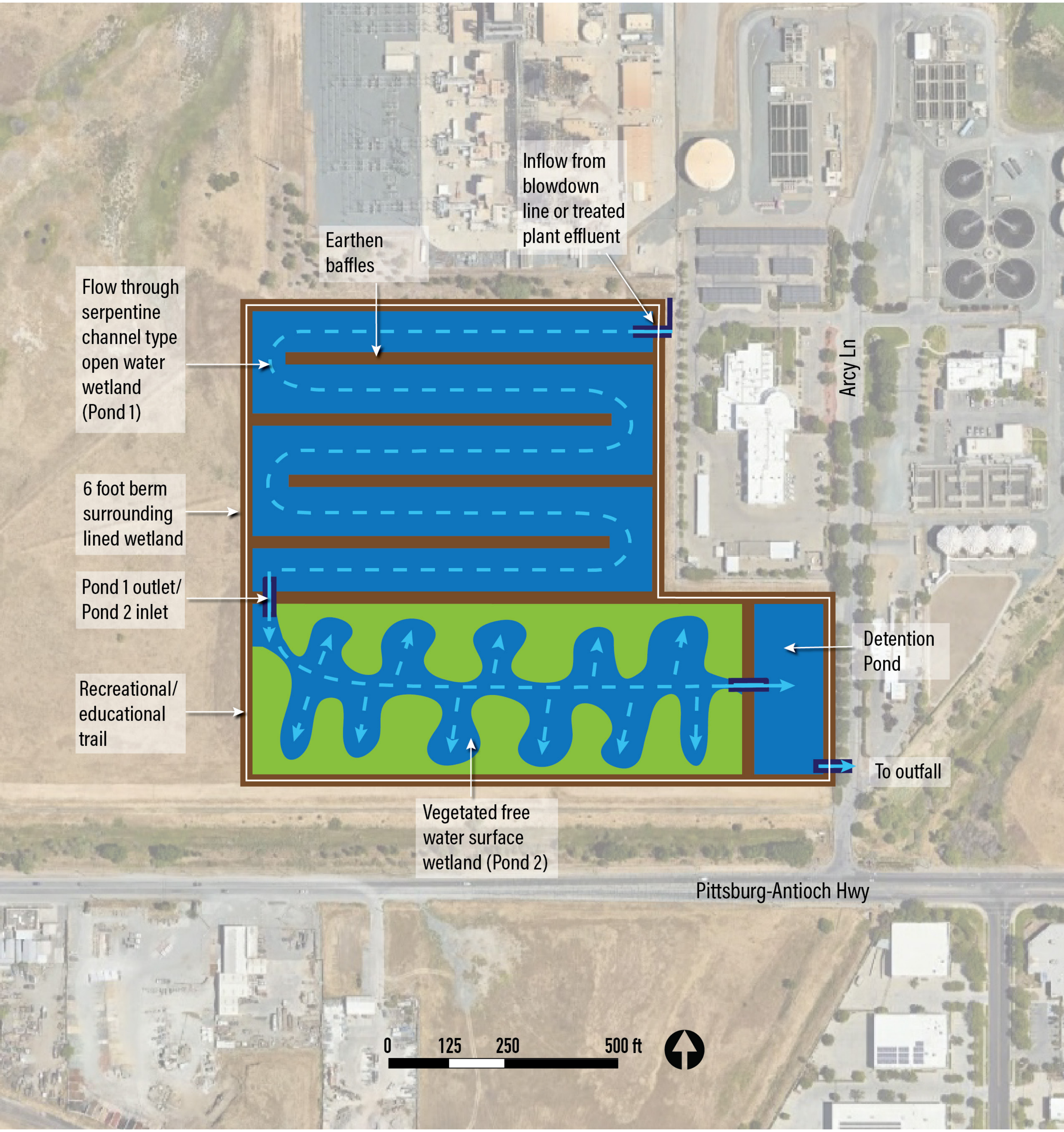

Figure 1. Alternative 1 (Free water surface wetlands)

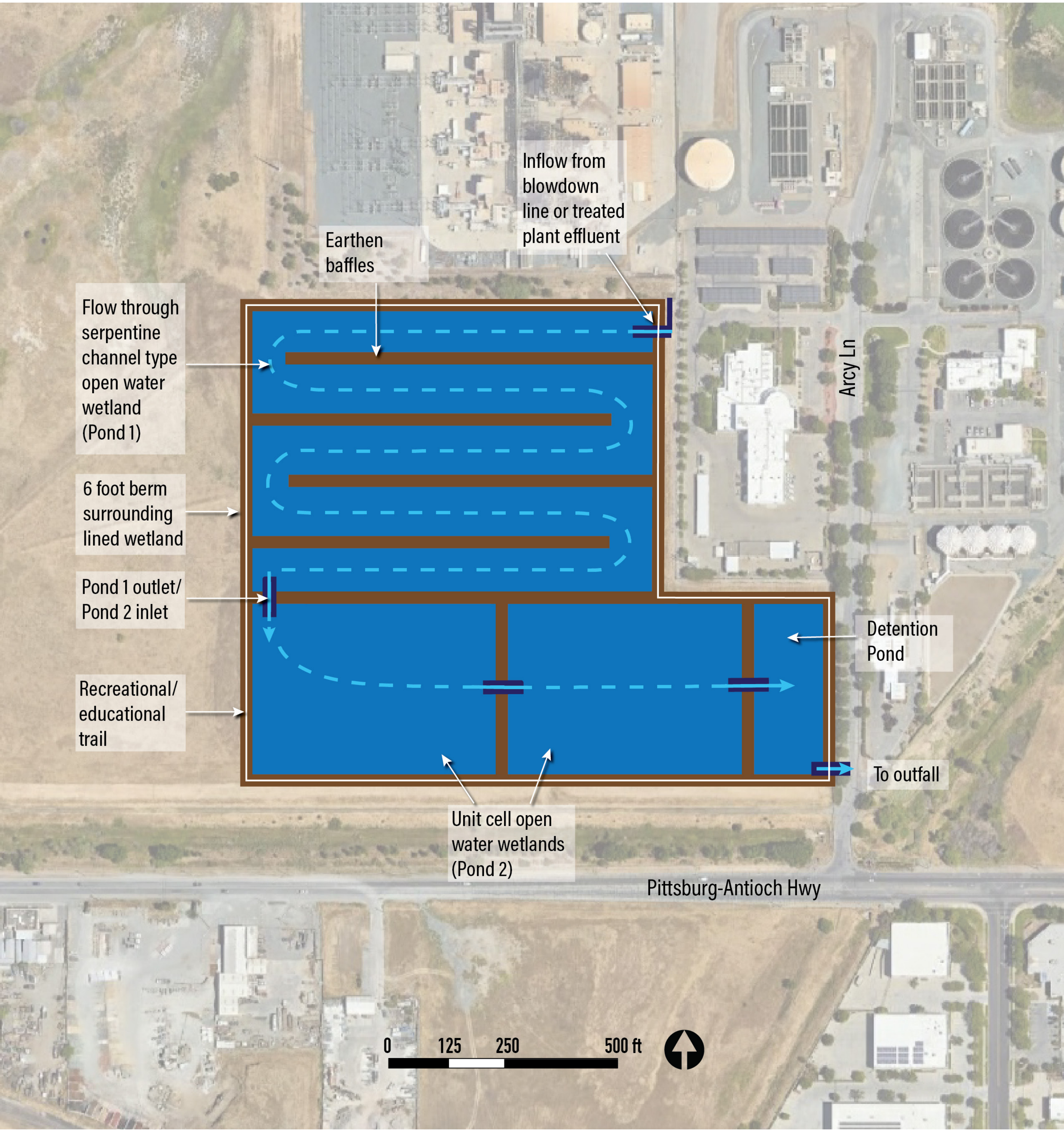

Figure 2. Alternative 2 (Unit cell open water wetlands)

ESTIMATED PERFORMANCE SUMMARY

Appendix A discusses the assumptions for the performance of a treatment wetland for managing TIN levels. Alternatives 1 and 2 both involve constructing a 27-acre open water treatment wetland designed to handle about 3.7 million gallons per day (mgd), aiming to reduce TIN loads by approximately 320 pounds per day (145 kg/day), an approximately 15% reduction in TIN loads.

The key assumption in this analysis is that dry season TIN concentrations are 15 mg/L. In reality, TIN concentrations spike higher during the dry season due to specific blowdown characteristics, and the hydraulic constraints are less severe, which should lead to even higher TIN reduction values than initially estimated.

Therefore, while the planned wetland has a designed capacity based on certain assumptions, actual conditions might show improved performance due to higher than expected TIN concentrations in dry seasons. It will be important to validate these assumptions with real-world data and possibly adjust the design or management strategies accordingly.

PRELIMINARY COST ESTIMATE

HDR has prepared high-level cost estimates for Alternatives 1 and 2. The planning-level cost estimates for Alternative 1, in 2023 dollars, range from $13.6 Mil - $17.8 Mil, based on fill quality, and from $13.2 to $22.5 Mil for Alternative 2. Appendix A contains more details on the high-level cost estimates.

NEXT STEPS

The next steps for implementation involve determining project goals and objectives, selecting a preferred design, refining cost estimates, and initiating early conversations with permitting agencies. Effective nutrient removal requires implementing nitrification before discharging into the treatment wetlands; therefore, it is crucial to coordinate the planning of wetland construction with nitrification upgrades. Additionally, we recommend early coordination with the mosquito abatement district, before advancing further in the design development process.

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Appendix A

Bay Area Clean Water Agencies
Nature-based Solutions Study

Delta Diablo: Nature-based Solutions Evaluation for Nutrient Management

Individual Plant Report

Antioch, CA
June 6, 2023
March 4, 2024
June 28, 2024
July 27, 2024
FINAL Report

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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 the Delta Diablo 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 Delta Diablo 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.

2 Methods

The methods section includes a brief description on Delta Diablo WWTP and the potential siting locations, details on the cost estimating approach, and the approach for total inorganic nitrogen (TIN) load reduction with NbS technologies. TIN equals the sum of ammonium, nitrite, and nitrate.

2.1 Delta Diablo Wastewater Treatment Plant

The Delta Diablo WWTP discharges to New York Slough (a tributary to the San Joaquin River which feeds into Suisun Bay). It is located at 2500 Pittsburg-Antioch Highway, Antioch, CA 94509, and it serves about 57,700 service connections throughout Pittsburg, Antioch, and the unincorporated community of Bay Point. The plant has an average dry weather flow (ADWF) permitted capacity of 19.5 million gallons per day (mgd).

Delta Diablo WWTP currently treats all of the raw influent flow to at least secondary treatment standards. A portion of the secondary treated flow is diverted to their recycled water facility (RWF) which includes flocculation/clarification/filtration/disinfection to meet tertiary level standards. The RWF effluent is conveyed to either a nearby power plant (majority of flow) or other non-potable recycled water applications (e.g., landscape irrigation). A portion of the flow conveyed to the nearby power plant is returned to Delta Diablo WWTP as blowdown and disinfected prior to Bay discharge.

Delta Diablo WWTP does not currently remove ammonia and/or TIN beyond biological assimilation. Most NbS technologies are based on the removal and/or oxidation of ammonium to nitrate upstream of the NbS technology. Note: Delta Diablo WWTP is in the midst of selecting and designing treatment plant upgrades that are considering ammonium and TIN load reduction. Such upgrades should be designed and constructed within the next 10 or so years. This NbS evaluation assumes ammonium removal upstream of the NbS technology. The costs associated with ammonium removal upstream is excluded from this evaluation as Delta Diablo WWTP is in the process of selecting such an alternative.

Delta Diablo recently purchased 28 vacant acres in a neighboring parcel southwest of the existing plant. A general layout is provided in Figure 2. The new acreage is being proposed for the two alternatives under consideration.

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

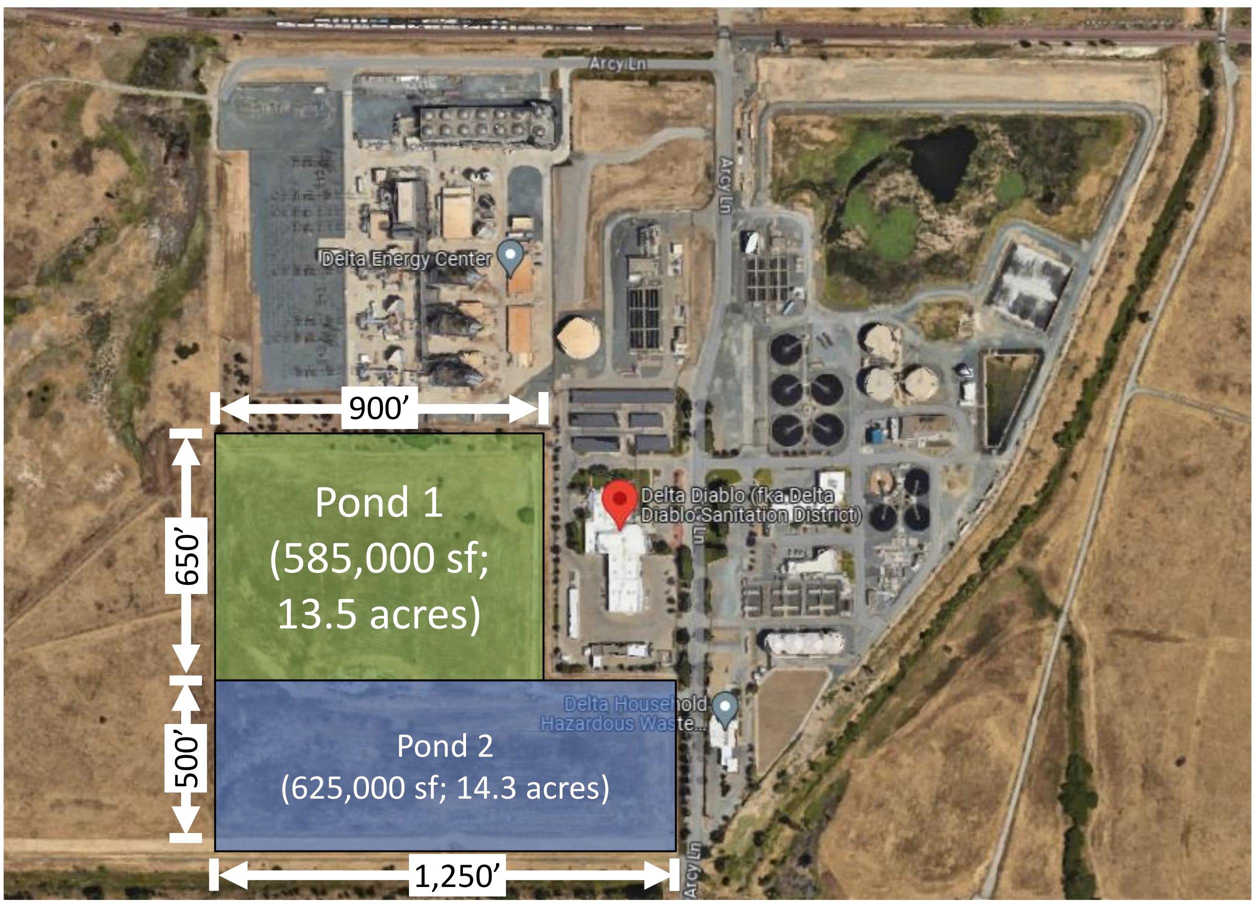

Figure 1. Delta Diablo: Newly Acquired Property under Consideration for NbS Alternatives

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 are provided in Appendix A.

2.2.2 Carbon Source for TIN Load Reduction

The polishing of TIN 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 Delta Diablo, two different NbS alternatives were evaluated for the same area (Ponds 1 and 2 as presented in Figure 1):

- Free water surface treatment wetlands
- Unit cell wetlands

Estimating the TIN load reduction polishing for the unit cell 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 Delta Diablo, 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 and the 59.4 k value is thus left as is (i.e., not increased to account for likely warmer temperatures).

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. The likely NbS feed source would be either secondary clarifier effluent, blowdown, and/or final effluent (represents a blend of blowdown and secondary clarifier effluent). Regardless, the NbS feed water quality should be of similar or higher quality than those facilities listed in Table 1 due to the pending upgrades (if secondary clarifier effluent feeds the NbS) and/or the RWF (if final effluent feed stream feeds the NbS). For comparative purposes, 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 the NbS alternatives considered at Delta Diablo.

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)

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3 Results

The plant currently provides secondary treatment and thus does not remove nitrogen loads (beyond biological assimilation). Delta Diablo is in the process of expanding and upgrading the secondary treatment process in anticipation of TIN removal requirements. The upgrades are based on concerns over aging infrastructure (specifically their biotowers) and the flexibility to remove nutrients. The design and construction are anticipated to be completed in two phases over the next six to twelve years. This evaluation is based on implementation of such upgrades that will produce a fully nitrified with partial TIN load reduction (i.e., secondary clarifier effluent of 15 mg N/L).

SFEI/HDR engaged with Delta Diablo and reached consensus on the most attractive potential NbS solutions. The concept is based on using either i) a free water surface treatment wetland or ii) a unit cell treatment wetland in the recently purchased 27 vacant acres as previously discussed. This newly acquired land is where the proposed NbS technologies could be installed.

HDR was tasked with providing layouts and planning-level cost estimates for two (2) alternatives which have been designated Alternatives 1 and 2. As previously noted, the treatment alternatives rely on the use of newly purchased acreage on the property southwest of the plant as presented in Figure 2. With this area identified by the SFEI, HDR proceeded to evaluate two alternatives for creating a Free Water Surface Treatment wetland (Alternative 1) or a Unit Cell Wetland (Alternative 2).

Alternative 1 calls for construction of two (2) new treatment ponds situated on the newly purchased acreage (using 27 out of 28 acres). The northern pond or “Pond 1” would have earthen baffles to foster oxygenation and mixing of the effluent feed. While oxygenation might stifle some biological denitrification, the benefits outweigh the means to control odors and any potential water stagnation.

Pond 1 would be created by installing a 6-foot-high earthen berm around the perimeter of the field and lining it. After Pond 1, treated water would flow into the southern pond or “Pond 2” in the northwest corner. Pond 2 would include a central flow path with several benched branches to allow for wetland transition zones. Pond 2 would also feature a detention pond to ensure a consistent water level and to allow for greater nutrient removal by the wetland elements. Effluent from Pond 2 will be brought out to the drainage ditch on the east side of Arcy Lane and ultimately discharged to the New York Slough.

Alternative 2 keeps the current layout for Pond 1 and instead of a benched wetland at Pond 2, there would be two-unit cell wetlands working in sequence to ultimately discharge back out to the New York Slough.

A summary of the planning-level cost estimates, footprint, anticipated feed flow, and potential nitrogen load reduction is provided in Table 2. For the allocated 27 acres, it is anticipated that nearly 4 mgd of feed flow could be treated at the ponds (translates to upwards of approximately 150 to 450 kg N/d (320 to 960 lb N/d) removed daily). A range is provided to account for the various potential feed sources (secondary clarifier effluent, blowdown, and/or final effluent). As previously noted, this feed flow is predicated on Delta Diablo moving forward with nutrient removal as part of their upcoming plant upgrades. The inability to treat more flow/load is predicated on the relatively small footprint available as NbS alternatives typically require more footprint than mechanical-based solutions. The free water surface alternative would have less hydraulic constraints than a unit cell system. However, free water surface systems are more prone to short-circuiting which can impact TIN load reduction performance.

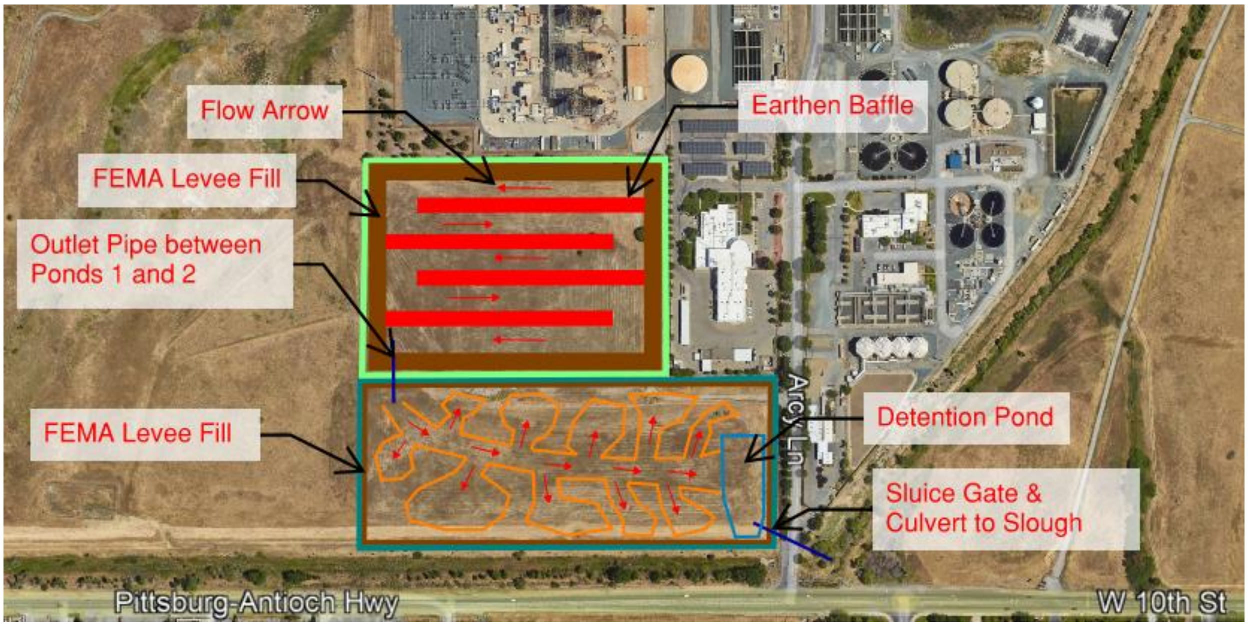

Figure 2. Delta Diablo: Proposed Layout for Alternative 1

The planning-level cost estimates in 2023 dollars for Alternatives 1 and 2 are $ 17.8 Mil and $18.6 Mil, respectively. These values are based on the conservative “high” fill cost. The values for the different fill qualities are provided in Appendix A (range from $13.6 Mil - $17.8 Mil for free water surface wetlands and $10.9 Mil - $18.6 Mil for unit cell wetlands) and are labelled for High, middle, and low-cost fill.

Rather than feeding Delta Diablo secondary clarifier effluent to either NbS alternatives, it should be further evaluated whether feed blowdown from the neighboring power plant and/or final effluent is more practical. Delta Diablo has an agreement with the neighboring power plant that Delta Diablo provides Title 22 tertiary treated water to the power plants which is subsequently returned as blowdown upstream of disinfection. The blowdown and/or final effluent should have a higher strength in terms of TIN levels which might translate to higher load reductions because hydraulic constraints would be reduced.

Some examples of what a treatment wetland and horizontal levee could look like are provided in Figure 3 and Figure 4.

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

Table 2. Delta Diablo: Summary of the Alternatives

Alternative	Technology Description	Footprint, Acres	Feed Flow, mgd	Potential TIN Load Reduction, kg N/d*,**	Construction Cost, $ Mil	Comment
1	Free Water Surface Wetlands	27	Treat up to approximately 3.7 mgd (represents about 30 percent of current dry season raw influent flow).	If secondary clarifier effluent: upwards of 150 kg N/d (320 lb N/d). Based on a feed flow that has been nitrified and partially denitrified (approx. 15 mg N/L). If blowdown: upwards of 450 kg N/d (960 lb N/d). Assumes that the blowdown has a feed concentration approximately 3 times the power plant feed (i.e., from approximately 15 mg N/L to 45 mg N/L). If final effluent: somewhere between secondary clarifier effluent and blowdown (dependent on the feedwater ratio of secondary clarifier effluent and blowdown).	$17.8 Mil for High Quality Fill $14.4 Mil for Medium Quality Fill $13.6 Mil for Low Quality Fill	• 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. Note: a free water surface wetlands should have less stringent hydraulic constraints compared to a unit cell wetland so this is considered less of a constraint. • On-site fill might be an option to reduce and/or eliminate cost; however, there are concerns over availability at Delta Diablo, as well as potential fill quality (on-site bay mud quality). For planning-level purposes, it was assumed that off-site fill would be required. • Free water surface water wetlands are known to be susceptible to short-circuiting. The design would need to consider such short-circuiting as such issues could impact TIN load reduction performance. • Both alternatives should consider whether the feed water would be secondary clarifier effluent, blowdown, and/or final effluent. It would likely be blowdown and/or final effluent as there is there are concerns over having sufficient secondary effluent flow during peak recycled water demand. If final effluent, the extent of nutrient reduction would be dependent on the feedwater ratio of secondary clarifier effluent and blowdown.
2	Unit Cell Wetlands	27	Treat up to approximately 3.7 mgd (represents about 30 percent of current dry season raw influent flow). More challenging to push the flow through the process compared to the free water surface wetlands.	If secondary clarifier effluent: upwards of 150 kg N/d (320 lb N/d). Based on a feed flow that has been nitrified and partially denitrified (approx. 15 mg N/L). If blowdown: upwards of 450 kg N/d (960 lb N/d). Assumes that the blowdown has a feed concentration approximately 3 times the power plant feed (i.e., from approximately 15 mg N/L to 45 mg N/L). If final effluent: somewhere between secondary clarifier effluent and blowdown (dependent on the feedwater ratio of secondary clarifier effluent and blowdown).	$18.6 Mil for High Quality Fill $11.7 Mil for Medium Quality Fill $10.9 Mil for Low Quality Fill	• Marginally more expensive than the free water surface wetlands as it requires more earthen fill (plus higher quality) for Pond 2. • 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 over availability at Delta Diablo, as well as potential fill quality (on-site bay mud quality). For planning-level purposes, it was assumed that off-site fill would be required. • Both alternatives should consider whether the feed water would be secondary clarifier effluent, blowdown, and/or final effluent. It would likely be blowdown and/or final effluent as there is there are concerns over having sufficient secondary effluent flow during peak recycled water demand. If final effluent, the extent of nutrient reduction would be dependent on the feedwater ratio of secondary clarifier effluent and blowdown.

* Delta Diablo WWTP discharge currently averages approximately 1,200 kg TIN/d

** Note: the hydraulics govern the loading rates. As such, the potential load reduction would increase from secondary clarifier effluent to blowdown due to higher feed concentrations.

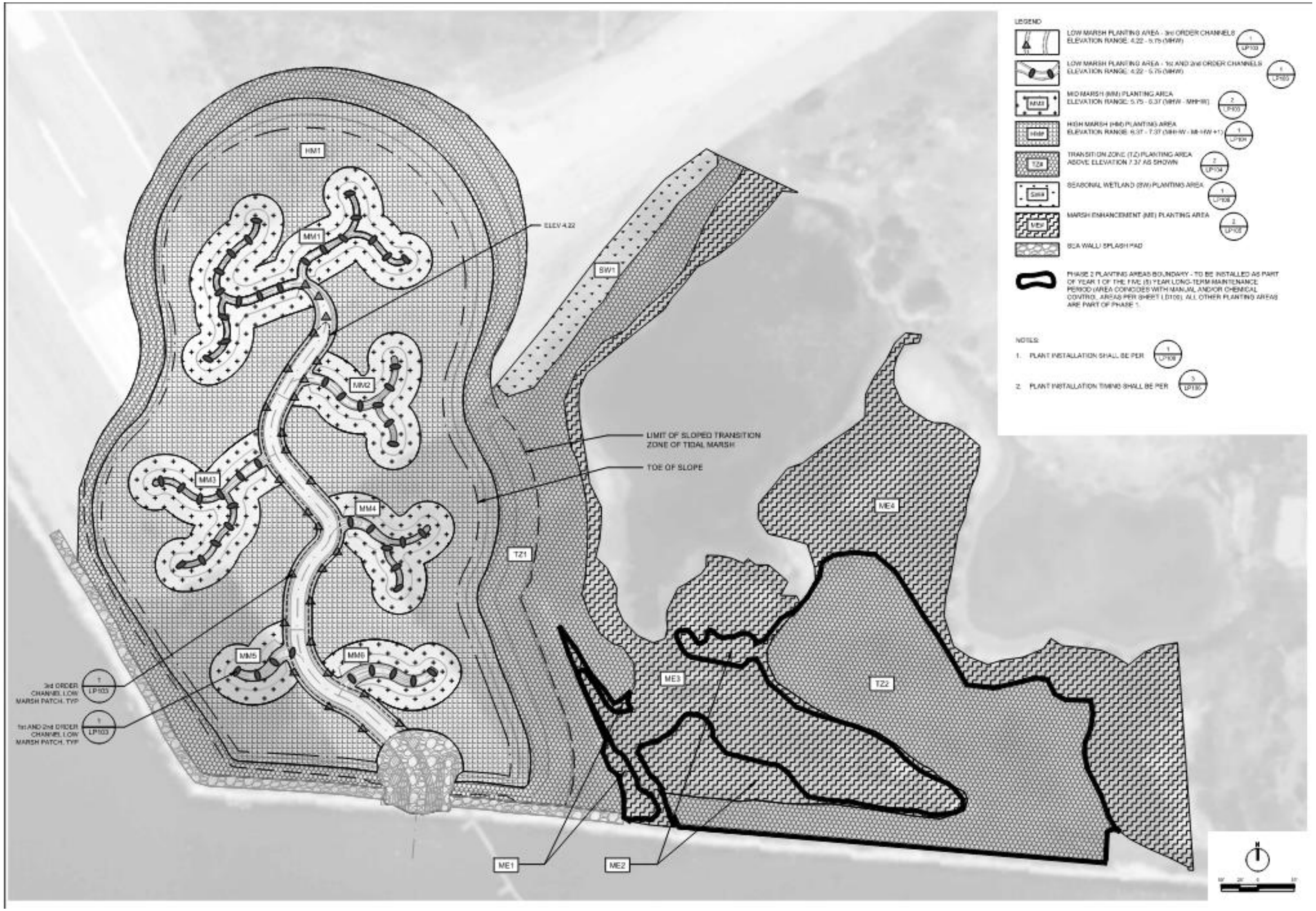

Figure 3. Plan View of a Proposed Wetland Plan View with Planting

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

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Appendix A. Quantities and Take-Offs

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Delta Diablo NbS Treatment
Free Water Wetlands
Updated: 02/22/24

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			$ 330,000
Demoliton	Clearing/Grubbing	27	Ac	$ 5,440	Ac		Hand Calc	$ 150,000
Civil	**"FEMA" Levee Fill for Pond 1 (High Quality)**							
Civil	Fill Purchase	20,721	CY	$ 133	CY	Assumes high quality fill is 2X middle quality.	Hand Calc	$ 2,760,000
Civil	Fill Haul	20,721	CY	$ 19	CY	Assumes high quality fill is 2X middle quality.	Hand Calc	$ 390,000
Civil	Fill Placement	20,721	CY	$ 63	CY	Assumes high quality fill is 2X middle quality.	Hand Calc	$ 1,300,000
							Subtotal	**$ 4,450,000**
	"FEMA" Levee Fill for Pond 1 (Middle Quality)							
Civil	Fill Purchase	20,721	CY	$ 67	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 1,380,000
Civil	Fill Haul	20,721	CY	$ 10	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 200,000
Civil	Fill Placement	20,721	CY	$ 31	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 650,000
							Subtotal	**$ 2,230,000**
	"FEMA" Levee Fill for Pond 1 (Low Qaulity)							
Civil	Fill Purchase	20,721	CY	$ 50	CY	Assumes low quality fill is 0.75X middle quality.	Hand Calc	$ 1,040,000
Civil	Fill Haul	20,721	CY	$ 7	CY	Assumes low quality fill is 0.75X middle quality.	Hand Calc	$ 150,000
Civil	Fill Placement	20,721	CY	$ 23	CY	Assumes low quality fill is 0.75X middle quality.	Hand Calc	$ 490,000
							Subtotal	**$ 1,680,000**
Civil	Compact Clay Purchase	22,144	CY	$ 67	CY	Potentially needed to "seal" both ponds. Assumed 6" deep and is the total area of both ponds.	Hand Calc	$ 1,480,000
Civil	Compact Clay Haul	22,144	CY	$ 10	CY	Potentially needed to "seal" both ponds. Assumed 6" deep and is the total area of both ponds.	Hand Calc	$ 210,000
Civil	Compact Clay Placement	22,144	CY	$ 31	CY	Potentially needed to "seal" both ponds. Assumed 6" deep and is the total area of both ponds.	Hand Calc	$ 690,000
Civil	**Specified Earthen Fill for Pond 2**							
Civil	Excavation	44,954	CY	$ 25	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 1,120,000
Civil	Fill Purchase	14,220	CY	$ 133	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 1,900,000
Civil	Fill Haul	14,220	CY	$ 19	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 270,000
Civil	Fill Placement	14,220	CY	$ 63	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 890,000
Misc	**Miscellaneous**							
Misc	Native plantings	14	Ac	$ 5,000		Total Acreage		$ 70,000
Misc	8" Pipe	450	LF	$ 40	LF	Estimated. Would depend on final layout		$ 20,000
							Subtotal	**$ 6,650,000**

Delta Diablo NbS Treatment
Free Water Wetlands
Updated: 02/22/24

								Free Water Wetlands (High)
General	Mobilization/Demobilization	1	LS	From Total	LS	10% of Total Cost		$ 1,158,000
							Base Total	**$ 12,738,000**
							Contingency (30%)	$ 3,820,000
							Contractor Profit (8%)	$ 1,020,000
							Insurance and Bonds (2%)	$ 250,000
							Total:	**$ 17,828,000**
								Free Water Wetlands (Medium)
General	Mobilization/Demobilization	1	LS	From Total	LS	10% of Total Cost		$ 936,000
							Base Total	**$ 10,296,000**
							Contingency (30%)	$ 3,090,000
							Contractor Profit (8%)	$ 820,000
							Insurance and Bonds (2%)	$ 210,000
							Total:	**$ 14,416,000**
								Free Water Wetlands (Low)
General	Mobilization/Demobilization	1	LS	From Total	LS	10% of Total Cost		$ 881,000
							Base Total	**$ 9,691,000**
							Contingency (30%)	$ 2,910,000
							Contractor Profit (8%)	$ 780,000
							Insurance and Bonds (2%)	$ 190,000
							Total:	**$ 13,571,000**

Delta Diablo NbS Treatment
Unit Cell Wetlands
Updated: 02/22/24

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			$ 330,000
Demoliton	Clearing/Grubbing	27	Ac	$ 5,440	Ac		Hand Calc	$ 150,000
Civil	**Earthen Levee Fill for Pond 1 (High)**							
Civil	Fill Purchase	20,721	CY	$ 133	CY	Assumes high quality fill is 2X middle quality.	Hand Calc	$ 2,760,000
Civil	Fill Haul	20,721	CY	$ 19	CY	Assumes high quality fill is 2X middle quality.	Hand Calc	$ 390,000
Civil	Fill Placement	20,721	CY	$ 63	CY	Assumes high quality fill is 2X middle quality.	Hand Calc	$ 1,300,000
							Subtotal	**$ 4,450,000**
Civil	**Earthen Levee Fill for Pond 1 (Middle)**							
Civil	Fill Purchase	20,721	CY	$ 67	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 1,380,000
Civil	Fill Haul	20,721	CY	$ 10	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 200,000
Civil	Fill Placement	20,721	CY	$ 31	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 650,000
							Subtotal	**$ 2,230,000**
Civil	**Earthen Levee Fill for Pond 1 (Low)**							
Civil	Fill Purchase	20,721	CY	$ 50	CY	Assumes low quality fill is 0.75X middle quality.	Hand Calc	$ 1,040,000
Civil	Fill Haul	20,721	CY	$ 7	CY	Assumes low quality fill is 0.75X middle quality.	Hand Calc	$ 150,000
Civil	Fill Placement	20,721	CY	$ 23	CY	Assumes low quality fill is 0.75X middle quality.	Hand Calc	$ 490,000
							Subtotal	**$ 1,680,000**
Civil	Compact Clay Purchase	22,144	CY	$ 67	CY	Potentially needed to "seal" both ponds. Assumed 6" deep and is the total area of both ponds.	Hand Calc	$ 1,480,000
Civil	Compact Clay Haul	22,144	CY	$ 10	CY	Potentially needed to "seal" both ponds. Assumed 6" deep and is the total area of both ponds.	Hand Calc	$ 210,000
Civil	Compact Clay Placement	22,144	CY	$ 31	CY	Potentially needed to "seal" both ponds. Assumed 6" deep and is the total area of both ponds.	Hand Calc	$ 690,000
Civil	**Specified Earthen Fill for Pond 2**							
Civil	Excavation	83,282	CY	$ 25	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 2,080,000
Civil	Fill Purchase	3,144	CY	$ 67	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 210,000
Civil	Fill Haul	3,144	CY	$ 10	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 30,000
Civil	Fill Placement	3,144	CY	$ 31	CY	Based on engineer's best judgment from projects requiring fill around the Bay Area.	Hand Calc	$ 100,000
Misc	**Miscellaneous**							
Misc	Native plantings	14	Ac	$ 5,000		Total Acreage		$ 70,000
Misc	8" Pipe	450	LF	$ 40	LF	Estimated. Would depend on final layout		$ 20,000
							Subtotal	**$ 4,890,000**

Delta Diablo NbS Treatment
Unit Cell Wetlands
Updated: 02/22/24

									Unit Cell Wetlands (High)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	1,211,000
							Base Total	**$**	**13,321,000**
							Contingency (30%)	$	4,000,000
							Contractor Profit (8%)	$	1,070,000
							Insurance and Bonds (2%)	$	270,000
							Total:	**$**	**18,661,000**
									Unit Cell Wetlands (Medium)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	760,000
							Base Total	**$**	**8,360,000**
							Contingency (30%)	$	2,510,000
							Contractor Profit (8%)	$	670,000
							Insurance and Bonds (2%)	$	170,000
							Total:	**$**	**11,710,000**
									Unit Cell Wetlands (Low)
General	Mobilization/Demobilization	1	LS	From Total	LS	Estimate about 10% of the total		$	705,000
							Base Total	**$**	**7,755,000**
							Contingency (30%)	$	2,330,000
							Contractor Profit (8%)	$	620,000
							Insurance and Bonds (2%)	$	160,000
							Total:	**$**	**10,865,000**