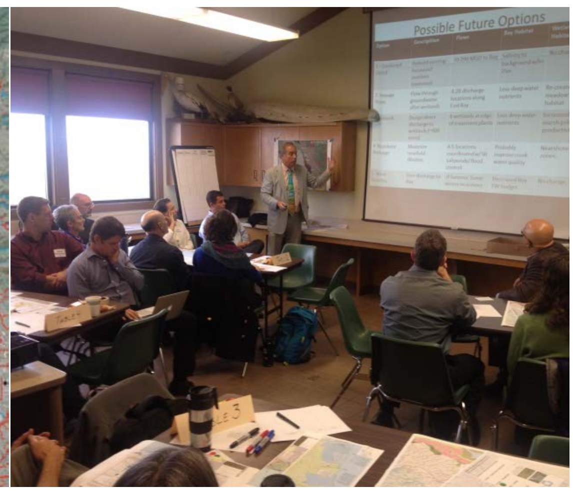
EAST BAY DISCHARGERS AUTHORITY

SEA LEVEL RISE ADAPTATION PLANNING PROJECT

Decentralized Wastewater Discharges and Multiple Benefit Natural Infrastructure: Preliminary Analysis and Next Steps



AUGUST 2015

Coastal Conservancy
Climate Ready
Helping California communities meet the challenge of a changing climate

EBDA EAST BAY DISCHARGERS AUTHORITY

SFEI AQUATIC SCIENCE CENTER

MBA Consultants

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EBDA Climate Ready Grant Project

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Many others played important roles, including participating in project management meetings, and providing advice and counsel on project concept, scope of work, and implementation, but in particular we want to acknowledge Andy Gunther of the Bay Area Ecosystems Climate Change Collaborative, Marc Holmes of the Bay Institute, and John Bourgeois of the South Bay Salt Pond Restoration Project. In addition, Bob Gearheart of Humboldt State University, and Alex Horne and David Sedlak of University of California, Berkeley provided technical and scientific advice and review. Finally, the Coastal Conservancy was an essential partner, providing the project funding, and the project benefited from the advice and counsel of several Conservancy staff, including Sam Schuchat, Tom Gandesbery, Brenda Buxton, and Kelly Malinowski.

EXECUTIVE SUMMARY

The East Bay Dischargers Authority (EBDA)[1] currently discharges treated wastewater effluent into San Francisco Bay through a deep water combined outfall (CO); however, this infrastructure is aging and vulnerable to rising sea level. This project assessed the opportunities and constraints of decentralizing EBDA's discharge and re-introducing freshwater inputs to the San Leandro to Fremont shoreline. The project goals included: Increasing resilience to sea level rise for EBDA POTW (publically owned treatment works) wastewater distribution system; Reducing critical infrastructure in the hazard zone; Decreasing GHG emissions from EBDA POTW operations; Integrating wastewater discharges into natural habitats restoration; and Supporting multiple benefit ecosystem resilience and restoration goals.

EBDA's POTW system has three major regulatory and regional drivers in the future: 1) increasing its production and use of recycled water, 2) reducing its discharge of nutrients, and 3) responding to the challenges faced by sea level rise. EBDA's water quality issues in 40 years will be quite different than those EBDA faced 40 years ago when it was started. In the 1970s, the goal was to maximize dilution by building a long outfall to the deeper waters in the middle of the Bay. Collecting the flows from a number of East Bay communities was the most cost-effective way to accomplish this goal. The future issues will be reusing that wastewater flow as much as possible and minimizing the discharge of nutrients to the Bay (Chapter 2). Wetland and nearshore discharges, particularly during summer, may be one way to minimize those impacts.

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[1] The East Bay Dischargers Authority (EBDA) is a Joint Powers Agency consisting of five local agencies along Eastern San Francisco Bay from San Leandro to Hayward, formed in 1974 to collectively manage wastewater treat ment and disposal. EBDA serves a population of approximately 900,000 that includes its member agencies, and also provides for the discharge of wastewater originating from San Ramon, Pleasanton, Dublin, and Livermore.

In addition, EBDA's response to these issues fits within a larger regional context of integrating wastewater discharges with nature-based adaptations to climate change and natural infrastructure development, simultaneously deriving multiple and immediate benefits, including flood risk management, storm protection, resource protection, habitat and species restoration, public use and recreation, and wastewater and water management.

Historically, freshwater interfaced with the baylands through creek connections and more diffusely via groundwater and surface runoff (Chapter 3). These freshwater inputs were an important component of the baylands ecosystem, creating salinity gradients that added physical and ecological diversity to the baylands landscape as well as facilitating rapid vertical marsh growth. Today, the extent, magnitude, and seasonality of freshwater to the baylands has been greatly altered.

Several cross-jurisdictional, regional and sub-regional initiatives are also underway that will affect EBDA's menu of alternatives (Chapter 4). These include BCDC's Adapting to Rising Tides (ART), Baylands Ecosystem Habitat Goals Update (BEHGU), South Bay Salt Ponds Restoration Project (SBSP), Coastal Hazards Adaptation Resiliency Group (CHARG), San Francisco Bay Restoration Authority, and the Bay Fill Working Group. EBDA will continue to participate with others in regional and sub-regional initiatives to develop capacities to implement multi-benefit natural infrastructure projects and programs that can address climate change impacts and sea level rise adaptation.

In identifying possible EBDA alternatives, the team developed four technical memos (Appendix A) to brief approximately three dozen local stakeholders (Appendix B) on identifying different project alternatives. Workshop participants identified and focused attention on important opportunities to integrate wastewater discharge into the East and South San Francisco Bay shoreline to emulate the historic freshwater discharges. Concept alternatives (Chapter 5) for the present discharge included: 1) routing treated wastewater effluent to creek systems, 2) routing treated wastewater effluent through a seepage slope, as part of a horizontal levee, 3) contained wetland treatment systems, and 4) re-use of water. Conceptual models (Chapter 5) have also been developed to articulate how varies strategies could create a coherent landscape given physical and ecological considerations.

Several major barriers and constraints (Chapter 6) were identified involving crosscutting and landscape level issues, including: integrating multiple benefits in project design (and implementation); regulatory constraints and limitations; governance, funding and financing needs; potential land use, infrastructure, and/or environmental conflicts; aligning and integrating natural resources restoration and urban water, wastewater, and other public infrastructure improvements; and growing competing uses for treated wastewater. Participants emphasized the importance of understanding the different scales for program development, citing regional watershed- and landscape-level restoration needs and opportunities. Participants identified the need to better understand the linkages (and possible leverage) between and amongst different external and internal factors that will affect the timing and extent of any decentralized alternatives.

Specific implementation needs (Chapter 7) were identified that will have to be considered in future planning and feasibility analysis. If EBDA is to further consider decentralization of its CO system, important policy, regulatory, and statutory initiatives (e.g. BCDC Bay Fill Policy) will need to be fully implemented over the next 15 to 30 years. Any one of these individually, or more cumulatively, may well have significant effects on the development of, and need for, alternatives. A decentralized strategy for EBDA would require that all of the following conditions be met including: EBDA's project and program planning consider multiple drivers/goals; EBDA's Decentralization alternatives fit with other regional plans; Regulatory strategies incorporate a Regional multi-agency approach; and Governance, Funding, and Financing strategies incorporate a Regional Multi-agency approach. Additional initiatives should be implemented, including: an on-going South San Francisco Bay

Collaborative; an EPA-supported and funded SFB Regional Program; a continuing series of pilot and demonstration projects.

Several next steps (Chapter 8) were also identified, including: the generation and collection of research and performance data and information; undertaking additional pilot and demonstration projects; undertaking a range of feasibility analyses; and organizing expanded and enlarged collaborative initiatives.

While further research and planning is certainly needed to assess feasibility, this project was successful in informing EBDA of opportunities other than maintaining its existing outfall. Importantly it bought together diverse stakeholders to further the conversation on using treated wastewater as a resource for a resilient future East Bay shoreline.

CHAPTER 1: Introduction

The East Bay Discharges Authority, on behalf of its member sanitary agencies, investigated decentralized alternatives to an existing Combined Outfall transport and disposal system along the East Bay shoreline of San Francisco Bay (from Fremont to San Leandro) (Figure 1). The study goals included: Increasing resilience to sea level rise for EBDA CO wastewater distribution system; Reducing critical infrastructure in the hazard zone; Decreasing GHG emissions from EBDA CO operations; Integrating wastewater discharges into natural habitats restoration; and Supporting multiple benefit resilience and resources restoration goals.

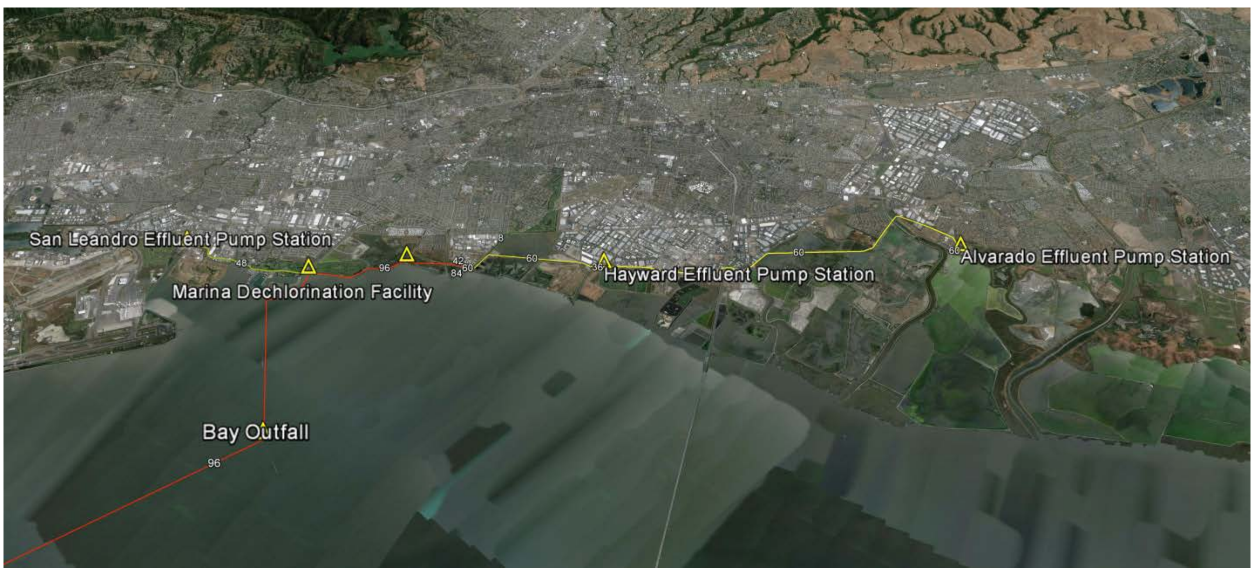


Figure 1. EBDA Combined Outfall System.

Through funding by the California State Coastal Conservancy's Climate Ready Grant program, EBDA was provided an opportunity to evaluate strategies (with input from multiple stakeholders) for modifying their infrastructure with benefits to bayland ecosystems and reduced infrastructure vulnerability. The process of informing decentralization opportunities and implementation had two main components: 1) technical memorandums, and 2) stakeholder workshops. The technical memorandums (Appendix A) prepared by EBDA staff and consultants in November 2014 covered several critical issues, including:

- *Wastewater Flows and Projections* - documented historical wastewater flows through the CO System and provided forecasts of future wastewater flows and infrastructure needs
- *Nutrient Loading* - summarized current understanding and data gaps regarding the range of amounts and effects of any potential increased nutrient loading to the Baylands System
- *Ecosystem and Habitat Effects* - focused on how targeted wastewater inputs can contribute to an overall complete and more resilient marsh ecosystem
- *Financial, Permitting, and Institutional Issues* - detailed financing options, and alternative possible permitting and approval systems, and governance and management needs

The technical studies helped inform opportunities for re-using treated wastewater for improved ecosystem functions and which opportunities would be most appropriate given historical and present landscape conditions. A brief description of each is provided below with full summaries provided in Appendix A of this report.

The next component of the project involved three agency and stakeholder workshops. In November 2014, workshop participants discussed technical studies and identified initial conceptual opportunities (and constraints) for developing multiple benefit natural infrastructure alternatives. During the second workshop, February 2015, participants revised alternative options and discussed opportunities for integrating opportunities into existing and proposed restoration and natural infrastructure programs. At the final workshop, June 2015, presenters, commenters, and participants discussed a range of implementation needs and strategies and mechanisms to support multi-benefit natural infrastructure projects, including several current initiatives aimed at regional policy changes, new organizational formations, and opportunities for expanded funding and financing.

CHAPTER 2: EBDA Flows and Water Quality Challenges

Since the late 1970's EBDA has operated the Combined Outfall (CO) for discharging wastewater to deep water in San Francisco Bay (Figures 2). Over the period 1999-2011, EBDA's treated effluent flow rates varied seasonally between 60-120 MGD, with highest and lowest flows in winter and summer, respectively, and the majority of estimates falling in the range of 60-80 MGD (Figure 3).

After nearly 50 years, EBDA must plan to replace the existing facilities with a new generation of facilities or consider alternative means of bay discharge, including decentralized discharges providing beneficial re-use. During this time improvements to the quality and constituents in the discharged wastewater provide the opportunity to reconsider location of outfalls and consider the needs for freshwater inputs to support habitat and species needs along San Francisco Bay.

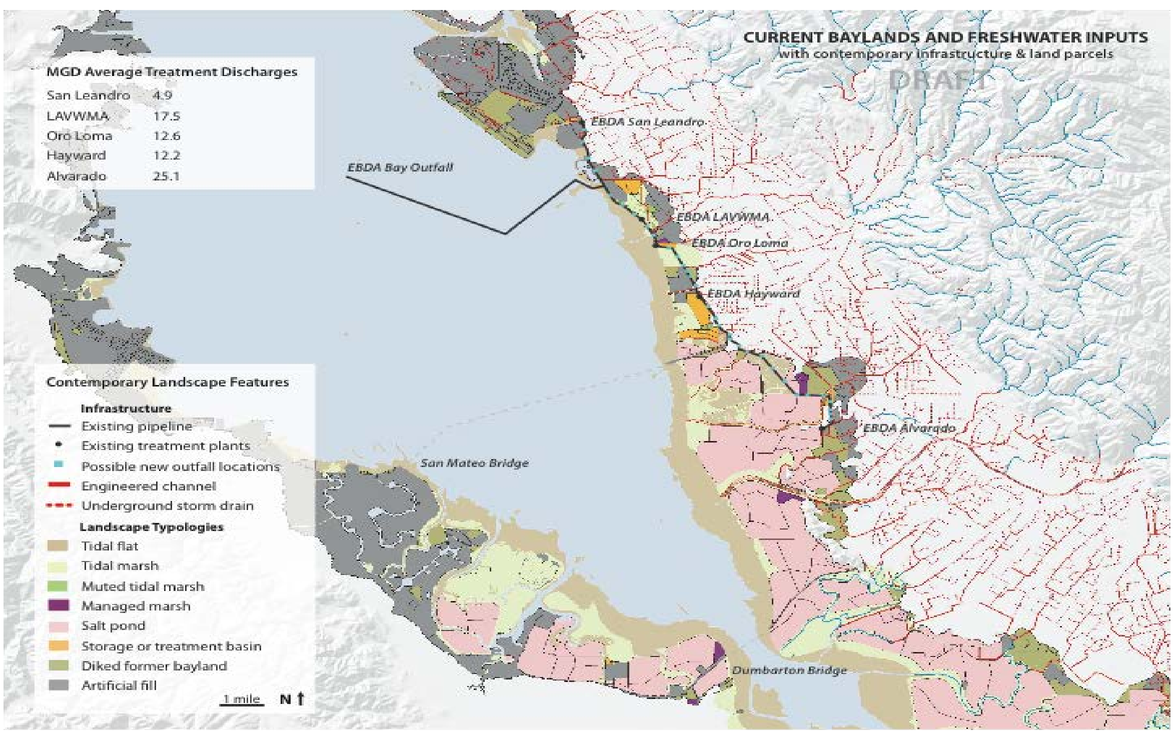


Figure 2. Current EBDA Combined Outfall Discharge System.

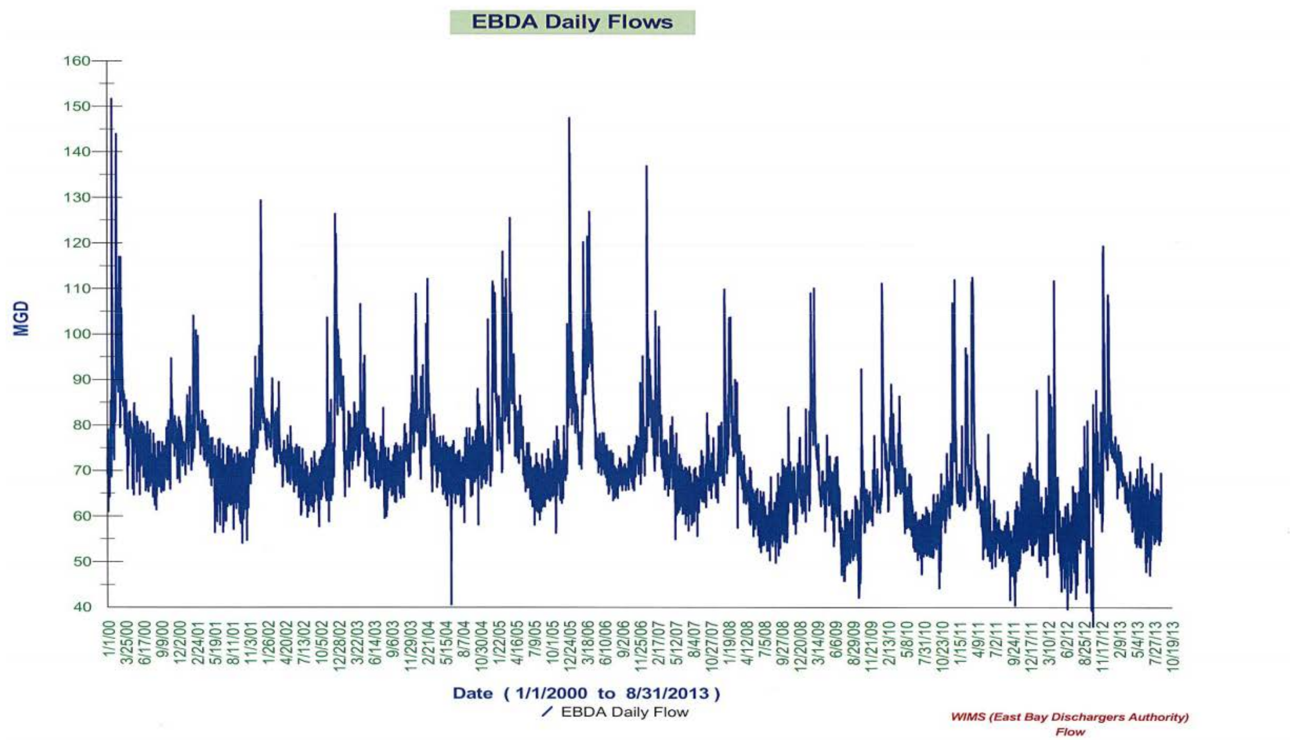


Figure 3. EBDA Historical Wastewater Discharges.

One of the main regulatory drivers for altering EBDA's outfall infrastructure is the potential water quality concerns of nutrient loading to San Francisco Bay (SFB). The SFB Area has 42 POTWs (Figure 4) that service the regions 7.2 million people and discharge either directly to the Bay or to receiving waters in adjacent watersheds that drain to the Bay. POTWs are the primary source of nutrients throughout most of San Francisco Bay. Several of the POTWs conduct nitrification or denitrification plus some forms of advanced treatment that remove a portion of nutrients prior to discharge. However most POTWs carry out only secondary treatment, which transforms nutrients from organic to inorganic forms, but generally does not remove much nitrogen (N) or phosphorus (P). N and P are essential nutrients for the primary production that supports food webs in SFB and other estuaries. When nutrient loads reach excessive levels they can adversely impact ecosystem health.

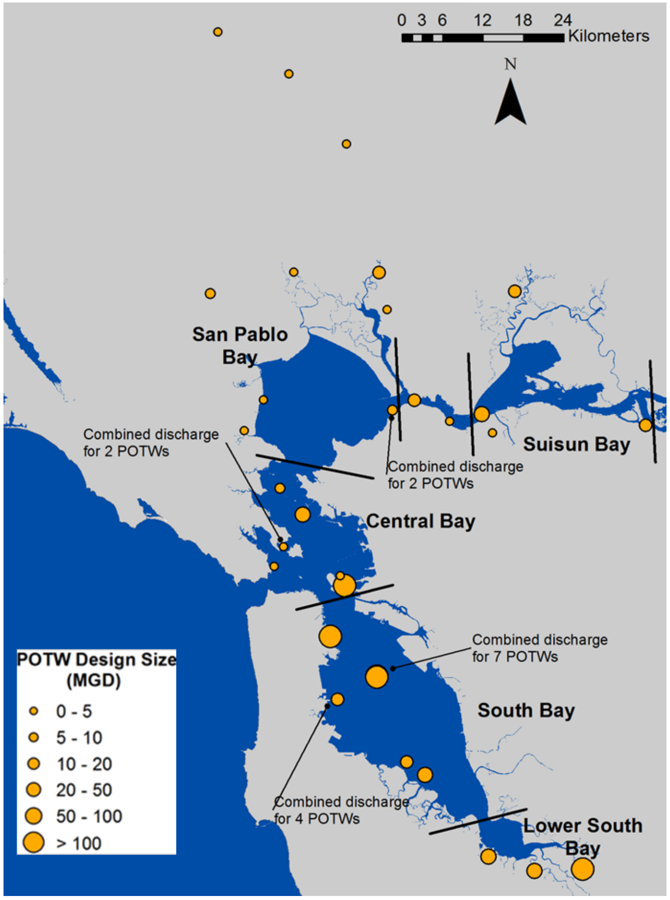


Figure 4. San Francisco Bay POTW's. Location and design size (in million gallons per day) for POTW's that discharge directly in San Francisco Bay or in watersheds directly adjacent to subembayments. Water Board subembayment boundaries are shown in black.

Over the past decade, NH4+ loads have generally been in the range of 6000-8000 kg d^{-1}, with occasional extreme maximum and minimum values approaching 10000 kg d^{-1} and 4000 kg d^{-1}, respectively (see Appendix A2 for monthly data related to EBDA's nutrient loads). Unlike estuaries in which nonpoint sources are major nutrient contributors, in some areas of San Francisco Bay it is reasonable to consider diversion of POTW discharges to bayland wetlands as a potential nutrient management option.

CHAPTER 3: Regional Baylands Past and Present

Baylands Habitats, Transition Zones, and Freshwater Inputs

The San Leandro to Fremont shoreline is a complex mosaic of dynamic intertidal bayland habitats - tidal marsh, tidal channels, salt pannes, beaches, alluvial fans, deltas. Historically, freshwater entered the baylands through creek connections and more diffusely via groundwater and surface runoff (Figure 5). Some of these inputs contributed freshwater to the baylands year-round (e.g. mouth of Alameda Creek or where willow groves or springs were found) while other freshwater inputs were highly seasonal at the mouths of intermittent creeks and areas adjacent to seasonal wetlands. These freshwater inputs were an important component of the baylands ecosystem, creating salinity gradients that added physical and ecological diversity to the baylands landscape as well as facilitating rapid vertical marsh growth. Sediment delivery to tidal marshes from fluvial sources was also a key component of tidal marsh formation and maintenance, particularly during high flows when streams transported sediment from watersheds to marshes, allowing for natural sediment accretion and marsh establishment.

Today, the extent, magnitude, and seasonality of freshwater to the baylands has been greatly altered (Figure 6). Current practices have created highly connected systems rather than diffuse inputs. Instead of streams discharging into the marsh or adjacent uplands, freshwater sources have now been paved over for development or re-routed to stormwater channel networks carrying freshwater discharges past the baylands to the Bay margin. Channel leveeing has also reduced freshwater connection to the baylands as stream flow now almost exclusively bypasses the baylands, further eliminating the historical extent of the fresh-brackish-saline mixing zone and sediment delivery to baylands. A more detailed description of habitats and freshwater dynamics along the East Bay shoreline can be found in Appendix A3. The consideration of the historical flow, the present plumbing, and the future needs of EBDA together suggest many opportunities for better management of the baylands (Table 1).

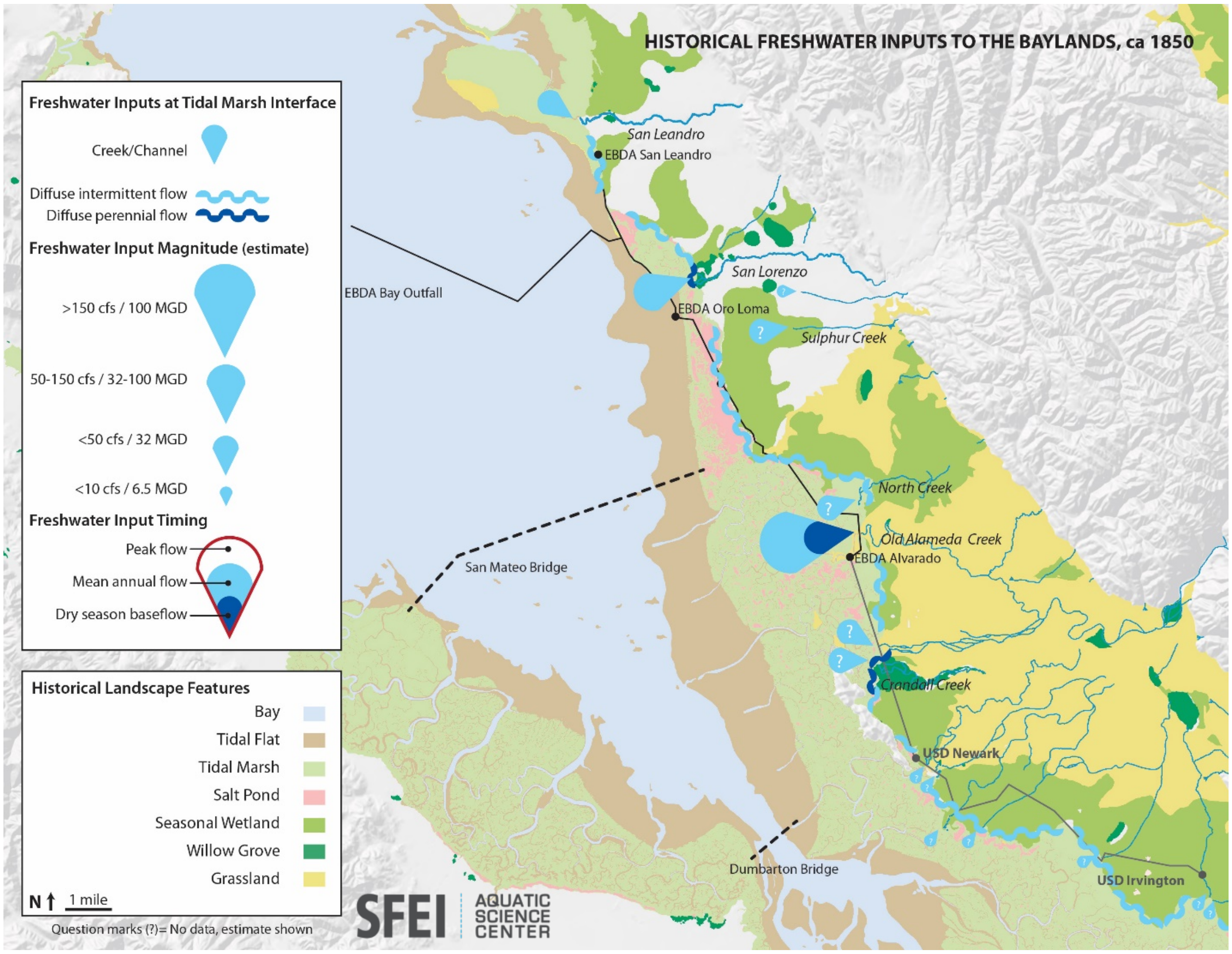


Figure 5. Historical Freshwater Inputs to the Baylands, ca 1850. Distribution and character of water delivered to the baylands from local watersheds under more natural conditions. Sources include: EcoAtlas (SFEI 1998) and Alameda Creek Watershed Historical Ecology Study (Stanford et al. 2013) which draw on numerous historical documents. The historical freshwater input flows were obtained from DWR (1923). Please note that historical stream flows are based on very limited data and streams without historical flow data are identified.

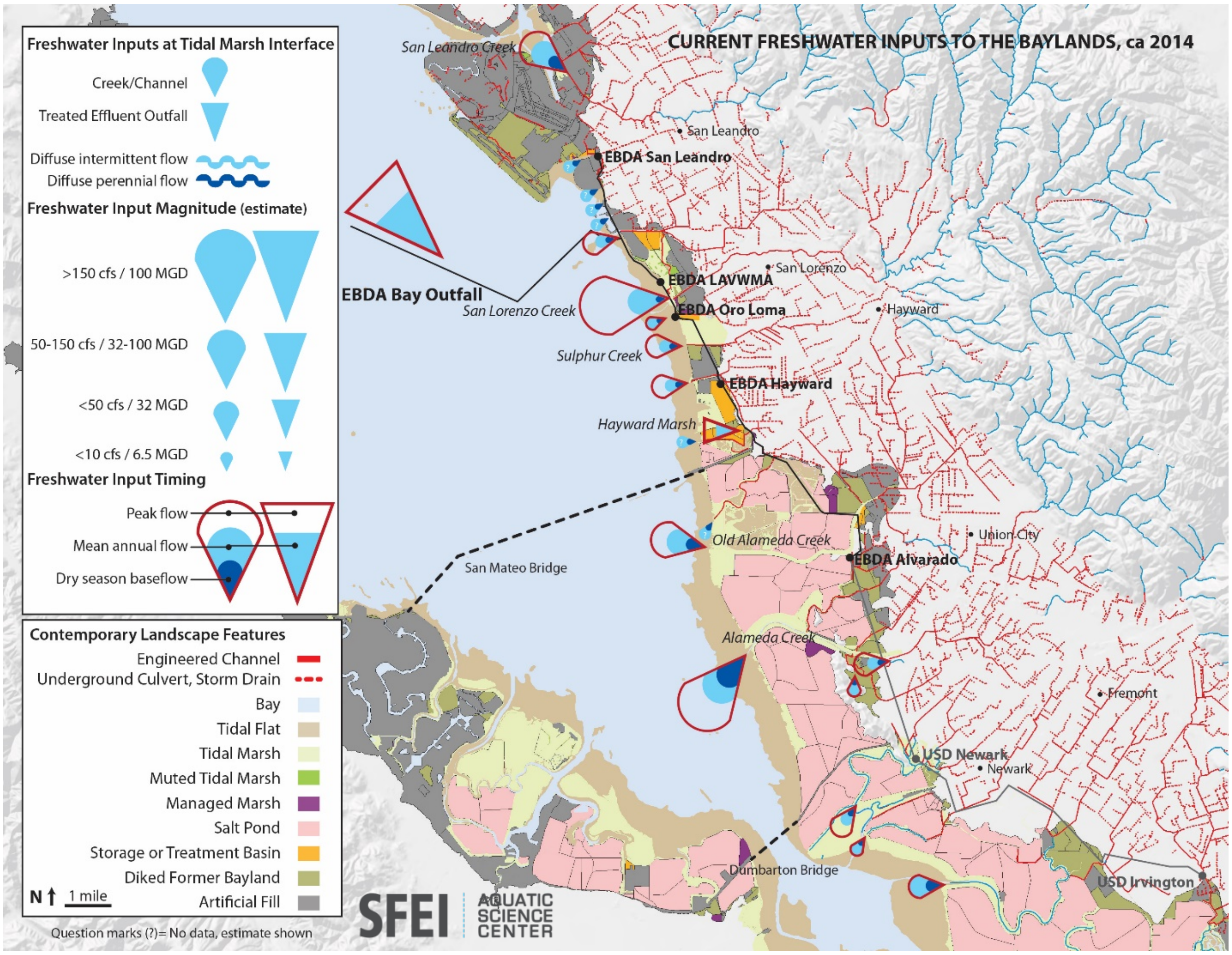


Figure 6. Current Freshwater Inputs to the Baylands, ca 2014. Alteration of freshwater inputs (both creeks and treated effluent) to the baylands. Sources include: Bay Area Aquatic Resources Inventory (BAARI; SFEI 2011) and EcoAtlas (SFEI 1998) for the contemporary baylands. For contemporary flow estimates, we used USGS gaged data for larger systems (e.g. Alameda Creek) and referenced Gilbreath et al. (2010) for estimates of smaller drainages. Channels and stormdrains were derived from Sowers (1996).

	HISTORICAL	CONTEMPORARY	Considerations for Future Resilience
Freshwater Influence	• Flows highly seasonal/ intermittent • A few large freshwater influence zones from large watersheds which disperse at the landward margin of the baylands • Smaller freshwater influence zones from small watersheds and groundwater discharge through springs or former alluvial fan channels • More diffuse inputs from overland flows	• Timing of flows more perennial • Highly connected systems which bring freshwater outputs directly to the Bay due to development/leveed channels • Less diffuse surface runoff as water is re-routed to storm drain networks • Peak flows have increased with urbanization	• Disperse freshwater flows at landward margin of baylands • Find opportunities to mimic diffuse flow at freshwater wetland-tidal marsh interface
Salinity Gradients	• Salinity gradients contributed to a complex interface between tidal and terrestrial habitat types creating physical heterogeneity and ecological diversity to the landscape	• Fresh-brackish marsh zone reduced or eliminated	• Strategically re-introduce freshwater to tidal baylands to create larger brackish zones
Sediment	• Sediment from local watersheds enabled natural sediment accretion and marsh establishment • Large tidal flats at mouths of large tributaries • Sections had natural sandy beach/berm wave buffers	• Sediment supply reduced from dams, development, and lack of floodplain connection	• Re-establish sediment supply • Direct/re-distribute selected freshwater inputs (with sediment) to target tidal marshland areas for faster vertical growth • Re-establish beaches where possible or analogous constructed features ("landmass")
Habitat Types	• Dominant large connected salt marsh • Intermixed pattern of brackish marsh zones and natural saltpond/salinas zones • Dry grassland and wet meadow transition zones associated with soil types	• Tidal marshland extent greatly reduced from conversion to other land uses • No natural salt ponds, now artificially managed	• Increased resilience with available natural areas and constructed horizontal levees • Widest natural marsh potential in South due to tectonics • Wider marsh potential between alluvial fans

Table 1. Baylands Landscape Changes.

Using Wetlands for Nutrient Removal of Waster water Effluent

Over the coming decades Bay Area environmental managers and regulators will be confronted with a number of important, infrastructure-intensive, and long-term management issues related to the health of San Francisco Bay. At a time of limited resources for infrastructure and many potentially costly issues on the horizon, there would be considerable advantage to identifying management actions that can achieve multiple benefits simultaneously. One possible action would be to route treated wastewater effluent into the baylands landscape to reduce concentrations of the nutrients nitrogen (N) and phosphorous (P) resulting in large part from the discharge of treated effluent.

Wetlands can be highly effective at removing nutrients from wastewater (e.g., Jasper et al. 2014). Well-designed treatment wetlands may also provide valuable habitat around the Bay's margins. In addition, if those wetlands are designed and operated in such a way that they gradually accumulate peat, restored wetlands could serve as a buffer against sea level raise. Additional information on the considerations for using wetlands as a potential approach for nitrogen removal and the possible impacts is found in Appendix A2.

CHAPTER 4: Complementary Shoreline Planning Efforts

Through the stakeholder workshops, many ideas were generated for opportunities to re-establish freshwater inputs along the shoreline. These opportunities need to be considered in the light of the significant habitat conservation, restoration, and infrastructure planning efforts already being undertaken along the East Bay shoreline.

These existing planning efforts include: BCDC's Adapting to Rising Tides (ART), Baylands Ecosystem Habitat Goals Update (BEHGU), San Francisco Bay Restoration Authority, South Bay Salt Ponds Restoration Project (SBSP). Both ART and BEHGU look ahead over the next century to provide a vision of both future ecological restoration and enhancement but also start to identify the vulnerabilities and adaptation strategies that could accommodate future projections of climate change and accelerated sea level rise. The SBSP project has completed long-term planning for this area as well as the first phase of restoration projects, resulting in over 3,700 acres of restored or enhanced habitats, and an overall new pond management regime designed to benefit wildlife. Phase 1 actions at the Eden Landing complex were focused on the northern half of Eden Landing (north of Old Alameda Creek).

Important policy initiatives such as ART, BEHGU, and related habitat conservation efforts, are significant and could become important elements in a program of integrated, multi-purpose natural infrastructure, and combined water and wastewater management. Figure 7 and 8 illustrate the sub-regional opportunities along the east bay shoreline of San Francisco Bay, highlighting publicly-owned resource, open space, and public access lands, and current and planned wetland and habitat restoration lands.

Natural resources restoration and adaptive management planning, and corresponding climate change and sea level rise adaptation planning are combining with other short-and long-term to demand integrated multiple benefit approaches to public infrastructure. Prop 1 from 2015 to 2020 will provide a major boost to Integrated Regional Water Management planning.

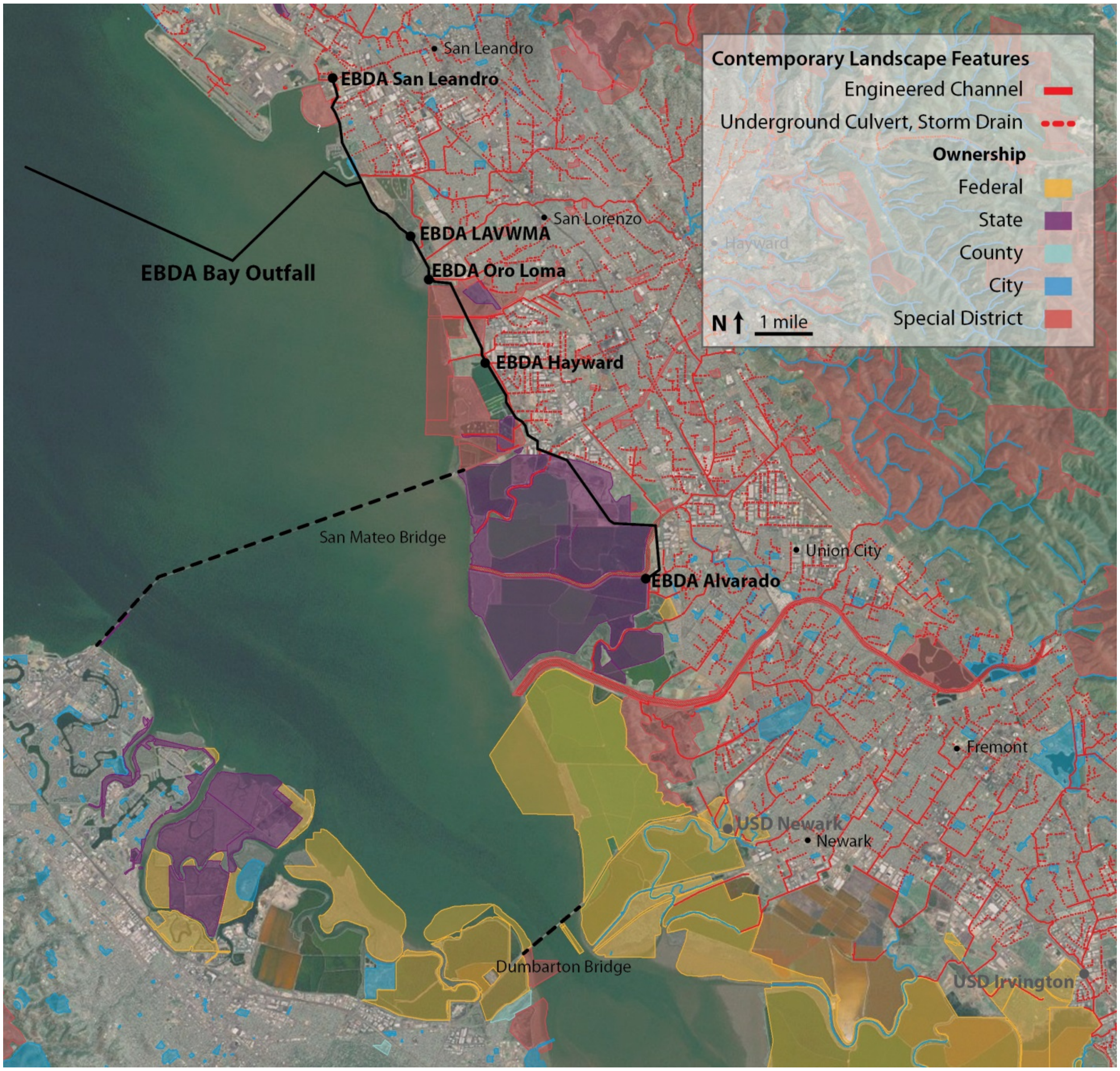


Figure 7. Ownership (2014) along the East Bay shoreline. (Source: California Protected Areas Data (CPAD) Portal, www.calands.org/data)

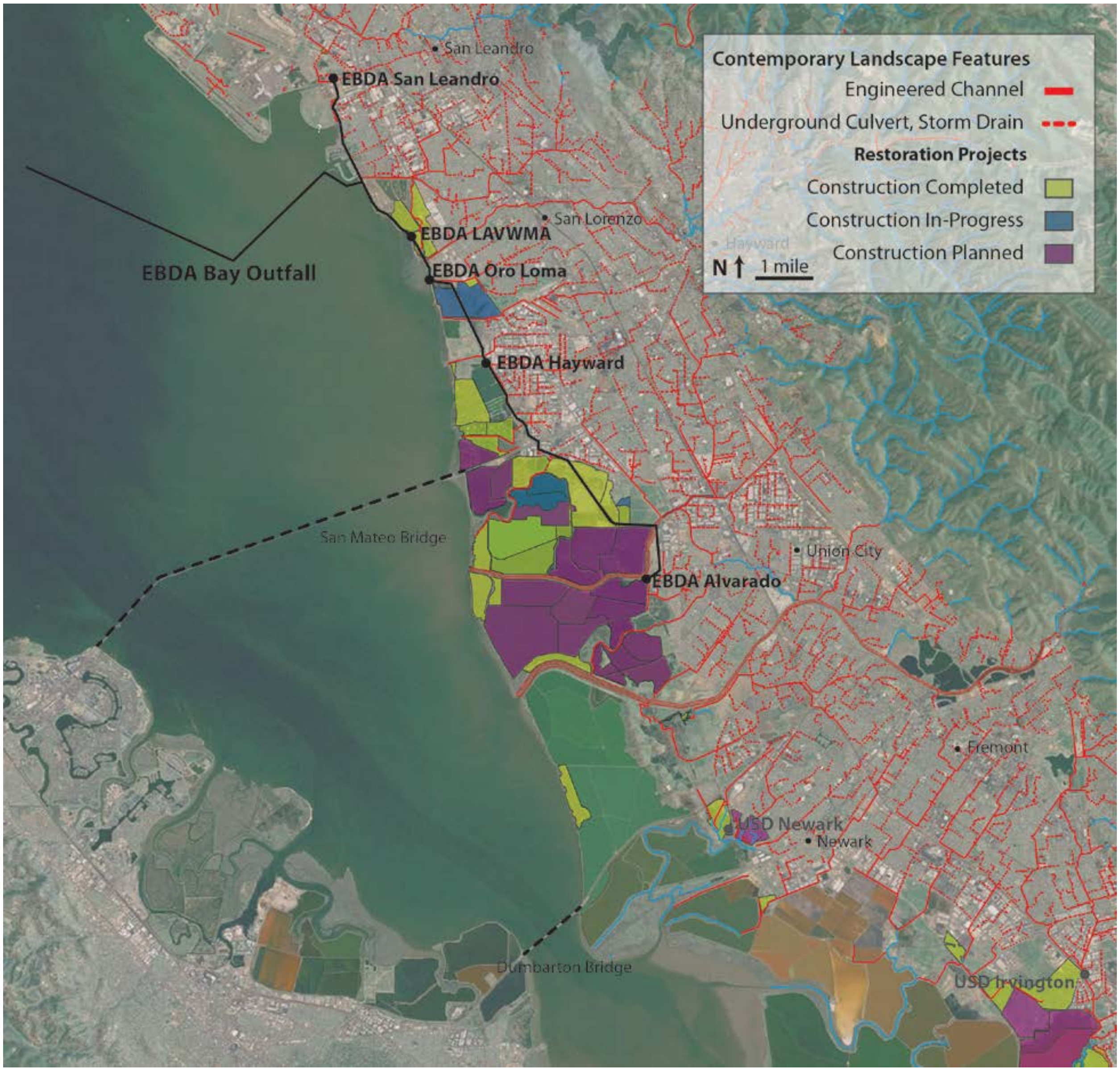


Figure 8. Status of restoration planning and completion (2014) along the East Bay shoreline. (Source: EcoAtlas, ecoatlas.org/regions/ecoregion/bay-delta)

CHAPTER 5: Concept Alternatives and Improved Resiliency

Workshop participants identified potential opportunities for integrating EBDA's wastewater discharge into the San Leandro to Fremont shoreline. The opportunities were grouped into four main concept alternatives: 1) routing treated wastewater effluent to creek systems, 2) routing treated wastewater effluent through a seepage slope as part of a horizontal levee, 3) contained wetland treatment systems, and 4) water re-use, water recycling, and groundwater recharge.

Several locations were suggested as appropriate and desirable for employing multiple options, either in tandem, or in a large array, to create strategies to maximize benefits, and increase resilience along the East Bay shoreline. For instance, the Hayward Shoreline has been suggested as a good location to combine seepage slopes and wetlands given the lack of space between the existing levee line and the outboard marshes and the proximity of the EBDA pipeline (see Appendix C for additional site specific opportunities).

Workshop participants also identified the need to better connect and employ the linkages (and possible leverage) between and amongst different external and internal factors that will affect the timing and extent of any decentralized alternatives. Over the next fifteen to twenty years, important policy and program, and regulatory and statutory, initiatives will be completed, and any one of these, and one or more cumulatively, may have significant effects on the development of, and need for, alternatives.

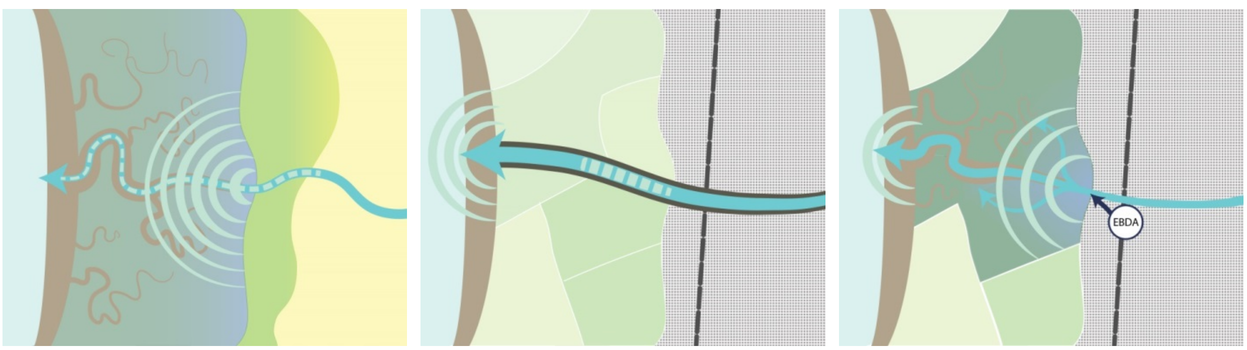
A number of factors would need to be considered to assess the feasibility of these concepts including local site conditions. This next section highlights key physical processes for the four main concept alternatives.

Concept Alternatives

Concept 1: Routing treated wastewater effluent to connected creek systems

Action

EBDA's wastewater discharge could be routed into creek systems (e.g., Old Alameda Creek), which could then be re-connected to marshes, reestablishing tidal floodplains and historic salinity gradients (Figure 9). Through levee lowering, removal or strategic breaching, water could be allowed to spread out over the adjacent marsh plain and re-establish pathways for freshwater and sediment delivery. The feasibility of re-connecting channels to the adjacent baylands will be determined by local channel conditions such as tidal extent, flow volumes, and sediment yields in addition to adjacent land availability.



Past **Present** **Future**

Figure 9. Re-establishing direct freshwater flows to the baylands. (Right) Historically freshwater flows from creeks were allowed to spread out over the baylands creating salinity gradients. (Center) Currently, many creeks are leveed which disconnect freshwater from the baylands. (Left) Creek levees could potentially be lowered with added EBDA's flow to re-establish salinity gradients.

Benefits

Hydrologic connection plays a large role in tidal marsh function as energy, material, and species are exchanged from the main channel to the marsh plain. Freshwater influence to the baylands is also beneficial in creating diverse habitat with varying salinity gradients. With accelerated sea level rise, watershed sediment inputs are also critical to increasing vertical accretion of the marshes.

<u>Processes</u>

Conditions at the fluvial-tidal interface of channels are complex with dynamic Bay and watershed processes and a merging of flow and sediment from both tidal and fluvial sources. Channels and associated floodplains at the fluvial-tidal zone also need storage capacity for both tidal water (daily tides, storm surge) and varying watershed flows (seasonality, magnitude). The analysis of altering channel conditions by increasing fluvial flows or removing channel levees will need to factor in these dynamic controls on water surface elevations. This will include backwater impacts on the creek water elevations in the fluvial section of the creek.

Channel leveeing causes a reduction in tidal prism and can lead to an increase in channel sediment accumulation. Sediment accumulation in the channel reduces channel flood capacity and is costly to dredge and maintain overtime. If the channel floodplain is expanded through creek re-connections to the marsh, tidal prism (the volume of water flowing in and out with the tides) could be increased as the tidal channel drains a larger area. A larger tidal prism would increase natural scouring of tidal channels and sediment transport resulting in a larger channel and increased channel flood conveyance.

If additional wastewater discharges were added to creek systems, water surface elevations in the channel could be raised and lead to flooding depending on the volume of water delivered to the creek and available channel capacity. Removal or breaching of levees could allow for an increase in flood storage capacity as water is allowed to spread out onto the marsh plain, resulting in a possible reduction of channel water surface elevations, although this would need to be modeled for specific site conditions.

Existing modeling conducted for Bay area channels highlights the complexities and potential improved flood capacity resulting from (re-connecting creeks or) increasing channel footprints within tidal reaches. For example, Stetson Engineers Inc. modeled tidal prism enlargement by connecting five additional floodplains along Corte Madera Creek, CA. The newly flooded area totaled 16 acres (surface area) and was found to enlarge the tidal prism by 21 acre-ft (upstream of Bon Air Bridge) (Stetson Engineers, 2011). Due to increased tidal prism and scouring of the tidal prism, modeled water surface elevations for a 100-year flood was found to be 0.4 ft. lower than existing conditions along a 2,000ft. bankfull reach and reduced peak 100-year flows by about 1,300cfs (Stetson Engineers, 2011).

Re-connection of creeks will be most viable if the land adjacent to the channel is undeveloped within the fluvial-tidal interface zone. However, many tributaries of the SF Bay are now constrained by development. The density and location of this development relative to a channels tidal extent will play a large role in the feasibility of routing wastewater into creek systems while still maintaining adequate flood protection.

Re-connecting creeks would allow the re-establishment of conditions most representative of historical conditions but additional site specific modeling would need to be completed to assess potential improvements or negative impacts (e.g., flooding of urban areas).

Concept 2: Routing freshwater through a seepage slope as part of a horizontal levee

<u>Action</u>

The seepage or ecotone slope concept (Figure 10) involves the construction of shallow upland / high marsh ecotone slopes bayward of existing flood risk management levees. The ecotone slope serves to provide protection from rising sea levels, further removal of nutrients from secondary effluent, and improved habitat.

The reuse of the wastewater will improve water quality by removing nutrients and there will be a net increase in area and diversity of wetlands providing increased habitat. In addition, building increased elevation wetlands around the Bay will reduce flooding under rising sea level. The feasibility of seepage slopes is being tested at the Oro Loma Demonstration Project.

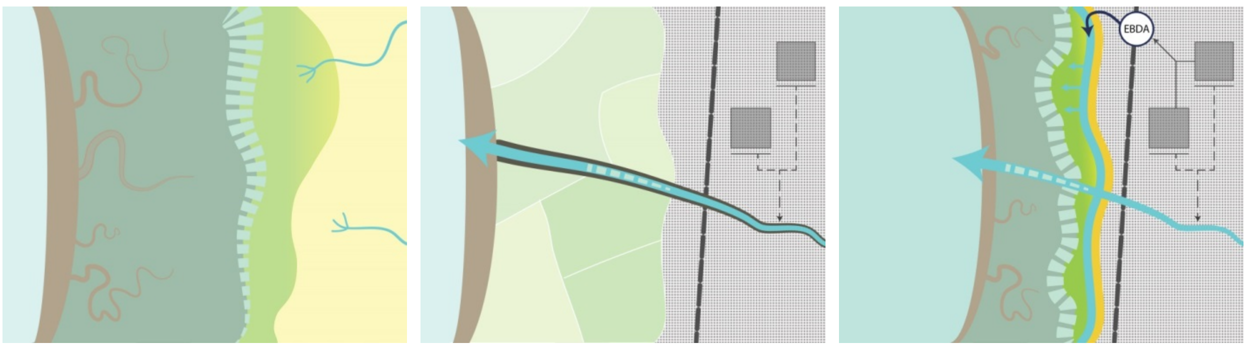


Figure 10. Re-establishing diffuse freshwater flows to the baylands. (Right) Historical diffuse flows near wet meadows. (Center) Elimination of diffuse flows with development and routing of water to stormdrains. (Left) Potential benefit of routing EBDA's treated wastewater effluent through a seepage slope to re-establish a salinity zone along the landward margin of the baylands.

Benefits

i. Water Quality

The seepage flow through an ecotone slope provides an effective, low cost, low energy, and environmentally sustainable method to nearly eliminate nutrient loadings and CEC's from the receiving waters. If proven successful, the project has the potential to radically improve water quality in the San Francisco Bay.

ii. Flood and Stormwater Management

The project has significant flood and stormwater management benefits. The proposed ecotone slope's primary function is to provide an environmentally friendly, adaptable, and robust defense against flooding associated with sea level rise.

During dry weather periods, urban stormwater can be routed through the ecotone slope to provide treatment of common fertilizer, hydrocarbon, and sediment based pollutants. The proposed pilot project on the Oro Loma site will incorporate this concept by routing stormwater from an industrialized area into the ecotone.

iii. Resource Stewardship (watershed management, habitat protection and restoration, recreation, open space, etc.)

The Oro Loma seepage ecotone slope will be the first Bay Area project to replicate an engineered equivalent of moist grassland / bayland ecotone of broad, flat alluvial fans that historically graded into the tidal marshes of most of South San Francisco Bay. Historically, moist grassland vegetation (lowland wet grassland and sedge-rush meadows) was prevalent along the Estuary and in the San Lorenzo Watershed. This now rare groundwater-seep-dependent ecotone will provide important seasonal terrestrial habitat for nesting mallards and the endangered salt marsh harvest mouse (spring foraging habitat and increasingly important terrestrial high tide refuge), particularly as sea level rises.

Groundwater, soil, and vegetation interactions of wet meadows will support important carbon and biogeochemical nutrient transformation and sequestration processes that are currently excluded from diked baylands and tidal marshes disconnected from groundwater discharges.

<u>Processes</u>

The seepage slope functions as a" gently sloping" platform for sea level rise that functions hydrologically as a seepage terrace slope, and supports a vegetation type best understood as "wet meadow" (basically a freshwater slope marsh) dominated by grass-like plants and riparian scrub. The really distinct zone is at the toe, where the wet meadow and riparian scrub grades down to the elevation range of the highest tides, and forms the actual terrestrial-tidal marsh ecotone, which contains brackish tidal marsh at the lower end. The toe of the slope is also where the “filtered” groundwater from the seepage terrace seeps out of the ground and where it contacts tide (akin to shallow ponds at the back of the tidal marsh). Not all the water reaches the marsh - evapotranspiration is a major pathway for dissipating wastewater in spring-summer-fall. The brackish marsh (transition) zone is the gradient between the toe of the seepage terrace where it intersects with highest tides, plus the adjacent full tidal marsh “diluted” with some freshwater seepage.

Behind the seepage slope is an engineered levee meeting all strict flood control definitions and structural criteria and is a ‘backstop’ for the sloping terrace. The terrace and its vegetation reduce wave run-up (by wave energy dissipation; friction), so the size of the true levee should be smaller than without the terrace. Most existing levees aren’t FEMA standards, but are inherited old salt pond levees that weren’t engineered but improvised structures for industrial use at former lower sea levels.

Marsh ponds (brackish pans) were a widespread historical feature of many tidal marshes that bordered riparian zones with surface and groundwater discharges, and they still form in some parts of the Bay’s modern tidal marshes. But modern levees separate terrestrial groundwater and surface water from most tidal marshes. A seepage slope should re-unite them, and the backmarsh ponds are an expected feature to spontaneously self-regenerate, especially as marshes gradually drown with sea level rise.

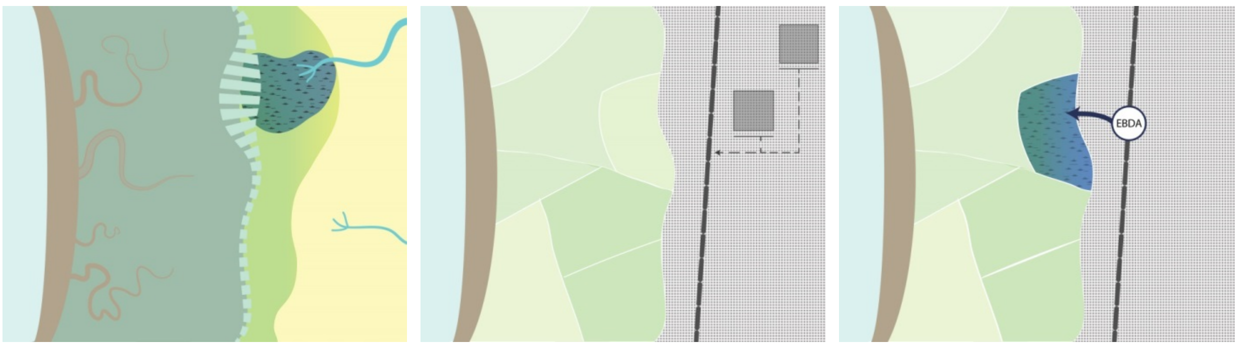
Concept 3: Wetland Treatment Systems

Action and Goals

The goal of discharge to wetlands would be to provide freshwater wetland habitat using treated wastewater. There are different potential habitats that could be supported in association with treated wastewater discharges, including emergent wetland, riparian, and upland habitat. Research has documented the effectiveness of wetlands to reduce concentrations of BOD, total suspended solids (TSS), nutrients, metals, pathogens, and trace organic compounds.

Benefits

Other multiple benefits could include recreation, education, water storage, flood control, and additional water treatment, or groundwater recharge. Created treatment wetlands could provide additional reclaimed water storage capacity by including permanently or seasonally flooded areas. Wetlands could also provide some functions as seasonal wetlands did historically (Figure 11).



Past **Present** **Future**

Figure 11. Introducing freshwater flows to treatment wetlands. (Right) Historically creeks supplied freshwater to seasonal wetlands. (Center) Many creeks (e.g. disconnected from baylands) have now become stormdrains or developed over. (Left) Potential benefit of routing EBDA's treated wastewater effluent to a contained wetland for nutrient removal benefits.

A limited number of treatment wetland projects have been permitted in SF Bay and along the California Coast, summarized in Table 2 below, involving the creation or restoration of freshwater, brackish, and salt marsh.

Wetland Location	Wetland	Part of Treatment	Wetland Type: Freshwater	Wetland Type: Brackish	Wetland Type: Salt Marsh
Calera Creek-Pacifica	Restored Wetland	No	X	X	X
Hayward Marsh	Improved Wetland	Yes	X	X	
Arcata Marsh	Constructed Wetland	Yes	X		
Mt. View SD-Martinez	Constructed Marsh	Yes	X	X	
Ellis Ck-Petaluma	Constructed Wetland	Yes	X		
Palo Alto	Constructed Pond	No	X		
American Canyon	Constructed Marsh	No	X	X-North Slough	

Table 2. Treatment Wetland Types Utilizing Wastewater in SF Bay and Coastal Northern California.

Treated wastewater discharged to surface waters must comply with strict effluent quality requirements of the SF Bay Regional Water Quality Control Board. Current Regional Board policy regarding wastewater discharges to wetlands is contained in Policy 94-086 (Policy on the Use of wastewater to Create, Restore, and/or Enhance Wetlands).

Current policy language restricts the use of existing wetlands to receive wastewater, stating

> Generally, this policy will not permit the enhancement or restoration of existing wetlands with wastewater. In exceptional cases, enhancement or restoration of exiting wetlands may be considered. However, the discharger will be required to demonstrate that the existing wetlands are unlikely to be

restored by other means, and that the resulting discharge to the wetland will both maintain existing beneficial uses and create new beneficial uses. *In no cases will the Regional Board consider the use of existing wetlands as treatment systems.*

Policy Provision 3[2]

The SF Regional Water Quality Control Board has proposed to study the six POTW with wetland discharges currently operating under Regional Board permits in San Francisco Bay in order to develop updated policies governing the discharges of treated wastewater into bay wetlands.

Concept 4: Water Re-use, Water Recycling, and Groundwater Recharge

Current state requirements mandate 20% water recycling by 2020. As a result of this requirement, and increasingly as a result of continuing drought conditions in California, water recycling is increasing. Demands for water re-use and recycling, including groundwater recharge, could increase substantially in the future.

Wastewater re-use and recycling is accomplished in several different ways, including public institutional, commercial and industrial re-use. EBDA member agencies provide wastewater to local publicly owned golf courses along the East Bay shoreline. In addition, EBDA member agencies provide wastewater to large-scale commercial and industrial users. Additional water re-use, recycling, and groundwater recharge is currently being analyzed by member agencies.

Increased water recycling will result in decreased discharges to SF Bay, and reduced freshwater available for discharge to transition habitat areas and bay wetlands. Increased groundwater recycle would similarly result in decreased discharges to SF

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2 SFRWQCB 1994 Policy Wastewater: 94-086.

Bay, and reduced freshwater available for discharge to transition habitat areas and bay wetlands.

Table 3 shows current water re-use totals for EBDA Member agencies as of 2014. Currently approximately 10,000 acre-feet of water is being re-used/recycled. EBDA member agencies currently meet the 20% requirement during a portion of the year. These agencies are considering additional water re-use, recycling, and groundwater recharge projects.

Agency	Annual (acre feet)	Max (MGD)	Ave Waste Water Flow (MGD)
USD	3,300	20	25
Hayward	2,500-3,000	3-4	11
OLSD/CVSD	200-250	1	11
San Leandro	600	1.2	5
DSRSD	3,200	7	8
Livermore	~1,000	3.6	5
Total	~10,000	~20	65

Table 3. EBDA Member Agency Wastewater Re-Use.

Future Vision: Improving Resiliency

It is also important to consider which processes support the baylands landscape and how individual alternatives would need to be best placed and coordinated along the shoreline.

The San Leandro to Fremont shoreline is a complex mosaic of dynamic intertidal bayland habitats - tidal marsh, tidal channels, salt pannes, beaches, alluvial fans, deltas. Watershed and Bay processes, such as fine and coarse sediment transport, floodplain inundation and transitional habitats are essential to the continual evolution of these habitats. While many of these important processes have been altered or eliminated over the decades, facilitating their re-establishment to the fullest extent possible will enhance the existing habitats and provide a more resilient landscape for the future.

For example, many marshes and floodplains have been disconnected from their watersheds by the leveeing of stormwater channels. Reconnecting creeks to tidal marshes brings freshwater and sediment to reestablish salinity gradients that support a diverse native ecosystem and to allow marshes to accrete and keep pace with sea level rise.

Just as the distribution of habitats has been altered by leveeing and draining, so too the distribution of freshwater spatially and temporally has been changed by wastewater treatment and flood risk management infrastructure. To emulate the historical distribution of salinity gradients on the marshes and floodplains, in the future some areas of the shoreline should have large freshwater inputs related to creeks while other areas would have more limited and diffuse freshwater influences such as wet meadows and could be dominated by more saline habitats (e.g., salt pannes). The delivery of sediment from the watersheds and accretion in the baylands would also vary spatially. Alluvial fans would form where creeks entered the marshes and deltas where they entered the Bay. This could again lead to topographical variability and sorting of sediment textures.

The reconnection of creeks to marshes is part of a large physical system that sustains tidal wetlands. Wind waves and tidal currents drive sediment transport in the Bay and shape the marsh edge. The presence and lateral extent of marshes, mudflats and beaches is driven by sediment supply, nearshore sediment transport dynamics, and wave energy. Wider mudflats are characteristic of shorelines with high suspended sediment; their shape and width reflecting the distribution of wave energy along the shore. Beaches occur along shorelines with conditions of higher wave energy and the availability of coarser sediment. Figure 11 (Future Landscape Sustaining Processes) illustrates the range of drivers which sustain these diverse intertidal habitats.

In addition to improving the physical functioning of the shoreline by reestablishing geomorphic and hydrologic processes, shoreline planning and restoration should integrate ecological resiliency principles of landscape connectivity, diversity and complexity, redundancy, and scale (Beller et al. 2015). Functional connectivity should be created or maintained by creating corridors along riparian creeks corridors and through intertidal habitats. Such corridors allow wildlife movement on different time scales, gene flow, and the ability for habitat to migrate with sea level rise.

Gradients within the landscape create habitat complexity and diverse hydrologic conditions. Reconnecting creeks to tidal marshes also creates variable salinity gradients and provides habitat conditions favorable for estuarine plants, fish and wildlife (e.g., tidewater goby, black rails). Wildlife can also benefit from topographic highs (e.g., natural levees, marsh mounds) and estuarine-terrestrial transitional zones, which provide high water refuge for rare and endemic species (e.g., Ridgway's Rail, salt marsh harvest mice) and marsh migration space (or room for marsh to migrate inland). Redundancy of habitats also contributes to ecological resiliency by reducing the risk of local extinction or functional loss in any particular habitat.

Habitat patch sizes should also be large enough to allow for self-sustaining populations, minimal edge-effects, and establishment of complex tidal channel structure. With accelerating sea level, some habitats which cannot easily migrate, such as salt pannes, may be better suited along the upland edge of the baylands, away from the Bay, if it has a sufficient buffer zone or even landward of the flood risk management levee. As salt panne inhabitants are primarily avian species (e.g., plovers) and invertebrates, the food webs in these habitats might still function even if located behind levees.

Restoration actions (e.g., horizontal levee, creek connection to baylands) should be organized and structured in a way that supports ecological functions and biodiversity, referred to as landscape coherence (Beller et al. 2015). For example, a treatment wetland could disrupt a continuous baylands corridor for species movement or reduce a habitat patch size needed to support varies species life history functions. Understanding how concepts and opportunities interact with each other and “fit into” the landscape will help optimize landscape planning to ensure greater ecological resiliency. While land-use constraints may be limiting, a coherent landscape should be the goal (Figure 12- Landscape Coherence/Ecological Resiliency).

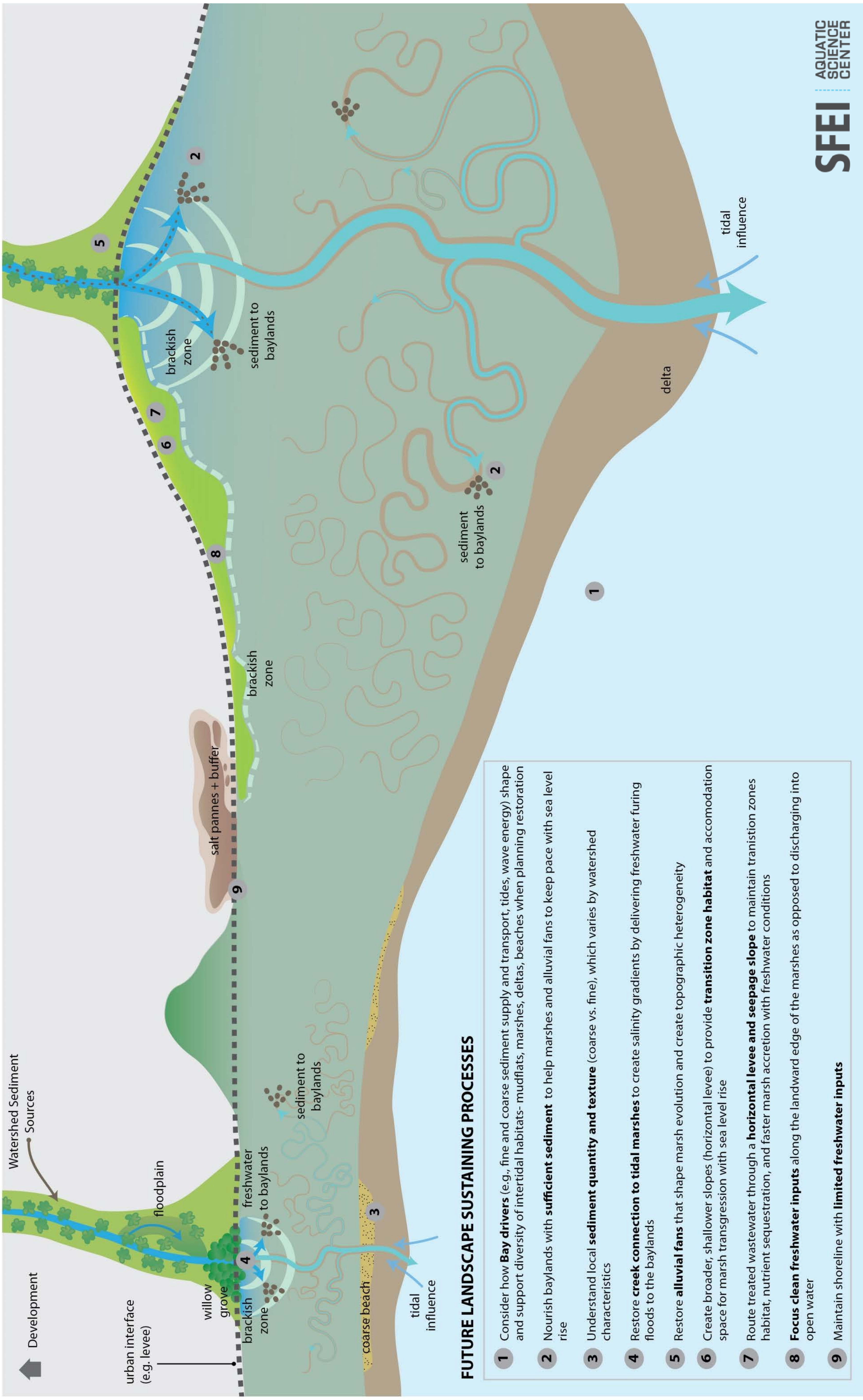

Figure 11. Future Landscape Sustaining Processes

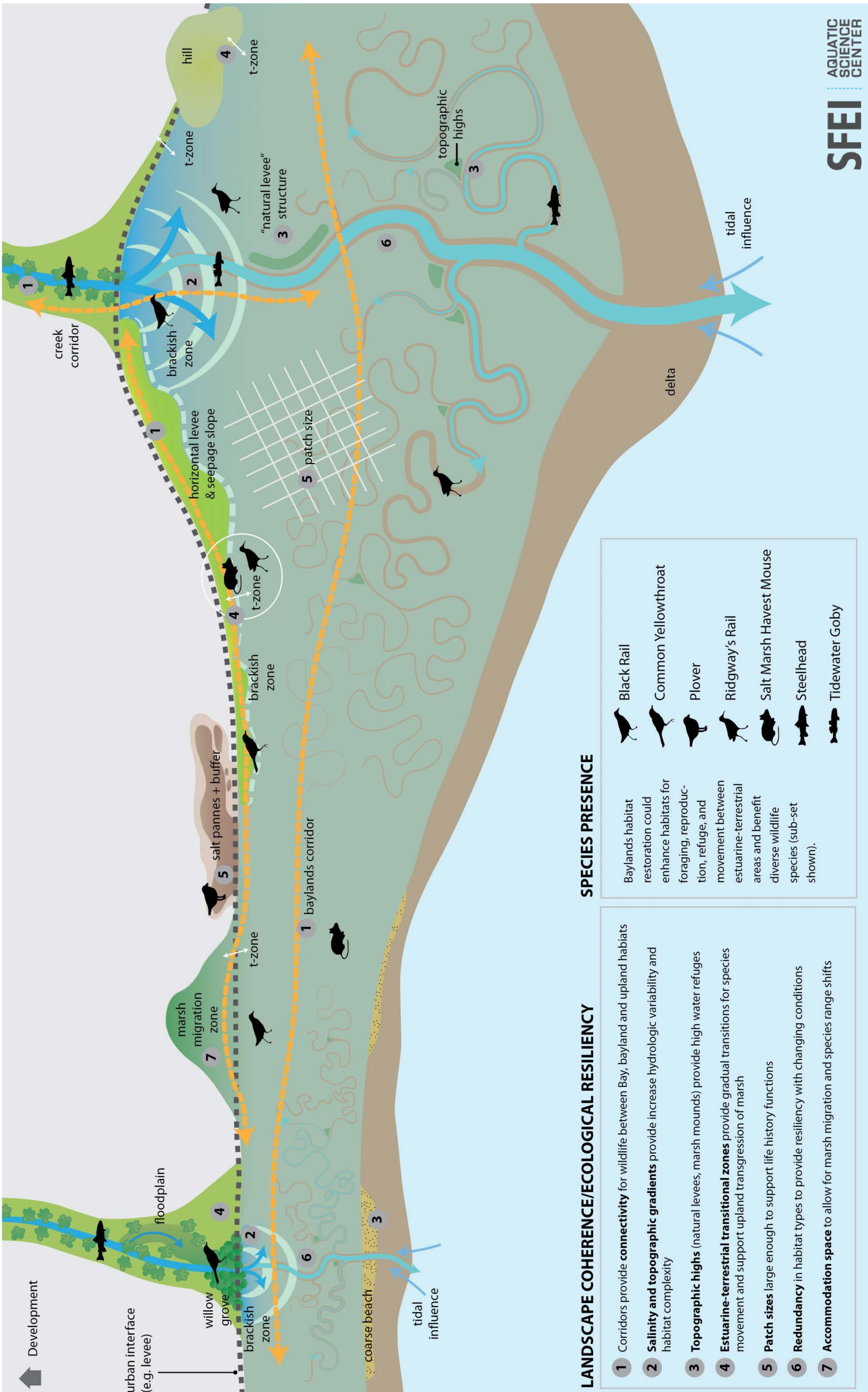

Figure 12. Landscape Coherency/Ecological Resiliency

CHAPTER 6: Barriers and Constraints

During the workshops, several major barriers and constraints were identified involving important and complex crosscutting and landscape level issues. These included: integrating multiple benefits in project design and Implementation; regulatory constraints and limitations; governance, funding and financing; potential land use, infrastructure, and/or environmental conflicts; aligning natural resources and infrastructure; and competing uses for treated wastewater.

Integrating Multiple Benefits and Values into Project Goals and Design: Participants have reported that there are inadequate mechanisms and or partnerships in place to implement multiple-purpose restoration/natural infrastructure projects, incorporating sea level rise adaptation, wastewater discharge, flood risk management, habitat restoration, and public access. 'Bridging' organizations and agencies, and 'bridging' policies and actions, are needed. More organizations that are formal, legal, restoration 'project management' agencies, who are interdisciplinary, bridging scientific, policy, and active restoration ownership and management are needed, such as various JPAs currently in place in SFB or California.

Regulatory constraints and limitations: Participants cited a need to address current regulatory constraints, and potentially develop new approaches/rules for multiple benefit habitat restoration and green infrastructure. Current constraining policies and regulations span a range of multi-disciplinary issues and topics, including placing sediment for augmenting wetland restoration projects in SF Bay, protecting and conserving endangered species, and attaining water quality standards and regulations.

Governance: Crosscutting project management and program governance mechanisms were identified as an essential need, but participants thought current efforts inadequate. Participants did identify some current examples of 'limited' regional coordination, including the 'fledgling' effort at increased regional coordination in south San Francisco Bay, and two other current regional coordination initiatives, specifically, Integrated Regional Water Management Planning (IRWMP), and the recently formed San Francisco Bay Coastal Hazards Adaptation Resiliency Group (CHARG). Other examples of multi-party and multi-agency coordination identified include the Bay Area Ecosystem Climate Change Consortium (BAECCC).

Funding and Financing: Existing project and grant funding is based nearly entirely on State General Obligation (GO) Bonds, including the recently enacted in November 2014, the Proposition 1 "Water Bond." In the past twenty years in California, the other major water-related funding source in California has been the State Revolving Fund (SRF), which provides loan financing for water and wastewater infrastructure projects.

Existing State financing is not programmed nor sized for large-scale multiple benefit projects, and is often restricted to capital components. In California, including in the San Francisco Bay region, there are not reliable funding sources for important components of project development and implementation, including importantly many planning and feasibility tasks, as well as many monitoring and adaptive management tasks. Significant regional funding has not to date been successfully implemented.

Linking Science and Policy: Participants identified demonstration and pilot projects as an essential next step. Starting with Oro Loma Demonstration Project, participants suggested that pilot projects be supported to provide critical information on performance, constructability, and operational feasibility. Additional pilot projects are needed to validate design of horizontal levees, including needed data on performance of differing widths/gradients of seepage slopes, types and combinations of different plant species, and other alternative design needs. Pilot projects can also help develop the metrics needed to evaluate success for levee, wetland, beach, and other multiple benefit natural infrastructure solutions.

Infrastructure, Land Use, and Environmental Conflicts: Many existing utility corridors, landfills, recreational shoreline improvements, or habitat management and restoration projects may present potential conflicts to developing multi-benefit projects. Several historic landfills are located along the East Bay shoreline from Oyster Point to the Hayward shoreline, potentially impeding shoreline re-configuration options and alternatives. In addition, several different utility corridors span the length of the East Bay through which EBDA's CO traverses, potentially impeding shoreline re-configuration options and alternatives.

Ecological/ Habitat Planning: Important multi-decade landscape-level habitat planning is underway in several places within San Francisco Bay, including East and South Bay, and regionally across San Francisco Bay. Current habitat planning for the East Bay shoreline area call for more freshwater shoreline inputs and increased brackish wetland habitat. The policy and program suggestions need to be informed by best available science and additional research is needed, for example, informing the question "What are the long-term freshwater needs of bay shoreline habitats, including tidal wetlands, and related transition and upland habitat types, proposed for conservation and restoration in the next thirty to fifty years?"

While there are important conservation and restoration successes in SFB, simultaneously there are many stressors to these systems. Several areas of East Bay shoreline are already subject to bay erosion, e.g., Cogswell Marsh at the Hayward shoreline, and "Long Beach" at Robert's Landing. At the same time, there are sedimentation issues in adjacent shoreline marshes, including the Hayward Marsh.

Competing Uses for Treated Wastewater: Current water recycling regulations require 20% water recycling be achieved by 2020, but there is potential for significant increase in water recycling and in groundwater recharge and management, in both the short- and long-term. Among other trade-off issues, there may be long-term water competition between marsh and bay discharge vs. groundwater recharge and water recycling.

CHAPTER 7: Implementation of a Decentralized Strategy

EBDA must address several important factors if it is to further consider decentralization of its CO system over the next 15 to 30 years.

1. Policy, Program, and Regulatory and statutory Requirements.

Important policy, program, and regulatory and statutory, requirements will have to be met, and each of these will have a significant effect on the development of, and need for, alternatives. For wastewater agencies, the Water Board and the Air Board have been emphasizing a number of regulatory initiatives:

- Sufficient treatment provided for 20% of flows by 2020 to meet recycled water uses;
- Stricter nutrient discharge limits to address bay eutrophication concerns;
- First flush" seasonal stormwater flows routed to wastewater treatment plants for secondary treatment;
- Long-term schedules for sewer lateral repair to reduce sanitary sewer overflows; and
- Stricter limits on methane and nitrous oxide emissions as part of its greenhouse gas reduction goals.

Besides these distinct regulatory drivers, wastewater agencies must also plan for ongoing regional drivers such as ensuring their systems can withstand disruptions from earthquakes or increased flooding risk associated with climate change and sea level rise. Planning strategies that can accomplish multiple goals–e.g., sea level rise, wetlands habitat restoration, nutrient removal, and greenhouse gas emissions–are more attractive for outside grants.

And funding is a key concern for wastewater agency customers. Infrastructure repair and maintenance is generally low on the public's priority list. However, as the recent drought responses have shown, public funding can be mobilized to respond to societal crises.

There are timeframes and deadlines associated with the different regulatory, economic, social, and political drivers. For EBDA, the most important drivers involve water quality regulations, including nutrient limits, stormwater regulations, and water recycling requirements. Existing California legislation requires each water agency to recycle 20% by 2020. In addition, there are other planning and regulatory drivers associated with habitat and wetland restoration. For example, BEHGU (2105) recommends completing wetland restoration projects by 2030 to allow marshes to establish before accelerating sea levels. Currently BCDC Sea Level Rise (SLR) guidance projects a 12" increase by 2050 and a 36" by 2100.

2. Focus on Planning Needs and Opportunities.

Cross-jurisdictional, regional and sub-regional initiatives are an essential missing ingredient to ensure the successful implementation of multiple benefit projects. EBDA should support the development of regional and sub-regional initiatives to increase capacities to implement multi-benefit natural infrastructure projects and programs, including importantly, South San Francisco Bay (Figure 13 - Oro Loma Demonstration Project).

Several current initiatives should be supported that form the basis for contributing to long-term resilience goals. These include the San Francisco Bay Restoration Authority, the South Bay Saltponds Restoration Project, the Bay Ecological Habitat Goals Update (BEHGU), Bay Area Ecosystems Climate Change Consortium (BAECCC), the Coastal Hazards Adaptation Resiliency Group (CHARG), and Adapting to Rising Tides (ART).

Figure 13. Oro Loma Demonstration Project. EBDA G.M. Mike Connor talks with Bruce Wolfe Executive Director of the San Francisco Regional Board and California State Senator Wieckowski about opportunities for, and barriers to, implementing horizontal levee-type projects.

EBDA should pay attention to BCDC's policies for a Rising Bay and RWQCB's reevaluation of The Basin Plan to help include enabling conditions for these types of projects.

Additional initiatives should be considered, including:

- South San Francisco Bay Working Group or Collaborative
- EPA-supported and funded San Francisco Bay Restoration Program
- Additional pilot and demonstration projects

3. Financial, Permitting and Governance.

Multiple benefit projects that integrate wastewater discharge and natural resources restoration into a complex network of nature-based infrastructure will require new funding sources, new organizational initiatives, and may require new authorities for existing agencies.

There are many traditionally used funding sources that can provide a portion of the needed funding, but only a portion of that which will be required to plan for and implement multiple benefit natural infrastructure. In addition to existing funding sources, these projects may well require using new kinds and types of financing. New collaborations and partnerships will be required integrating coordinated efforts of multiple jurisdictions.

Previous studies have recommended consideration of a Shore Realignment Master Plan process for a sub-region of the east bay shoreline focused on Hayward (HASPA 2010). A sub-regional South San Francisco collaborative process is needed to support multiple benefit, integrated wastewater, infrastructure, and natural resources restoration.

A sub-regional integrated ecological restoration and sea-level rise program/project could offer several important incentives, including financial and institutional support, and could be a source of support and funding for habitat restoration elements supporting an integrated wastewater discharge program.

CHAPTER 8: Recommendations

The group came up with several recommendations for regional wastewater agencies, other regional utilities, and the regulatory agencies.

1. Identify and support specific implementation needs that should to be considered in future planning and feasibility analyses.
2. Identify and foster a range of "enabling conditions" needed to ensure the successful implementation of innovative multiple benefit projects. Two particularly relevant regional policies are the BCDC Policy for a Rising Bay and the San Francisco Water Board's Basin Plan.
3. Collect additional physical and natural science data to better understand habitat and species freshwater base-flow needs, nutrient loading performance data, and engineering and design performance data.
4. Develop additional economic and organizational feasibility information regarding operational and technical feasibility, governance, and funding an financing.
5. Undertake essential communications and partnership engagement efforts focused on 'Communicating Results,' using multiple venues and platforms, such as State of the Estuary (2015), South Bay Saltponds Restoration Science Conference (2015), and proposed South San Francisco Bay Symposium (2016).
6. Support pilot projects to test and evaluate the introduction of treated wastewater effluent on the shoreline.
7. Develop more detailed local visions and strategies along individual creeks and waste ater treatment facilities.
8. Expand efforts to build local and regional capabilities to plan and implement multiple benefit natural infrastructure projects. Existing partnerships, including ART, IRWMP, CHARG, HASPA, SBSP, and BEGHU have been quite effective.
9. Identify and map current initiatives that could aid in developing and implementing decentralization projects and options. Such a 'gap' analysis would identify any needed expanded or new authorities.

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PART TWO: Appendices

APPENDIX A. Technical Memorandums, November 2014

Appendix A1. EBDA Wastewater Flows and Projections

1.1 Introduction

EBDA is a Joint Powers Agency consisting of five local agencies, City of Hayward, City of San Leandro, Oro Loma Sanitary District, Union Sanitary District, and Castro Valley Sanitary District, formed in 1974 to collectively manage wastewater treatment and disposal, serving a population of approximately 900,000. In addition to its member agencies, EBDA also provides for the discharge of wastewater originating from San Ramon, Pleasanton, Dublin, and Livermore. In response to climate change, EBDA is investigating whether decentralized alternatives to existing treatment and disposal practices and facilities at locations along the East Bay. What strategies for changes to regional wastewater discharge would protect facilities from sea level rise, and potentially use treated wastewater to enhance wetland habitats (Coastal Conservancy, 2014)?

The study is examining concept alternatives for decentralizing discharge facilities, many of which are currently vulnerable to sea level rise. The study will look at the possible use of treated but nutrient-rich wastewater in wetlands to build shoreline buffers and capture and sequester carbon from the atmosphere. A select number of concept alternatives are being formulated and supported by information contained in a series of technical memorandums, including this memo covering historical flows and future wastewater projections.

1.2 Summary History: Combined Outfall Infrastructure 1986-2014

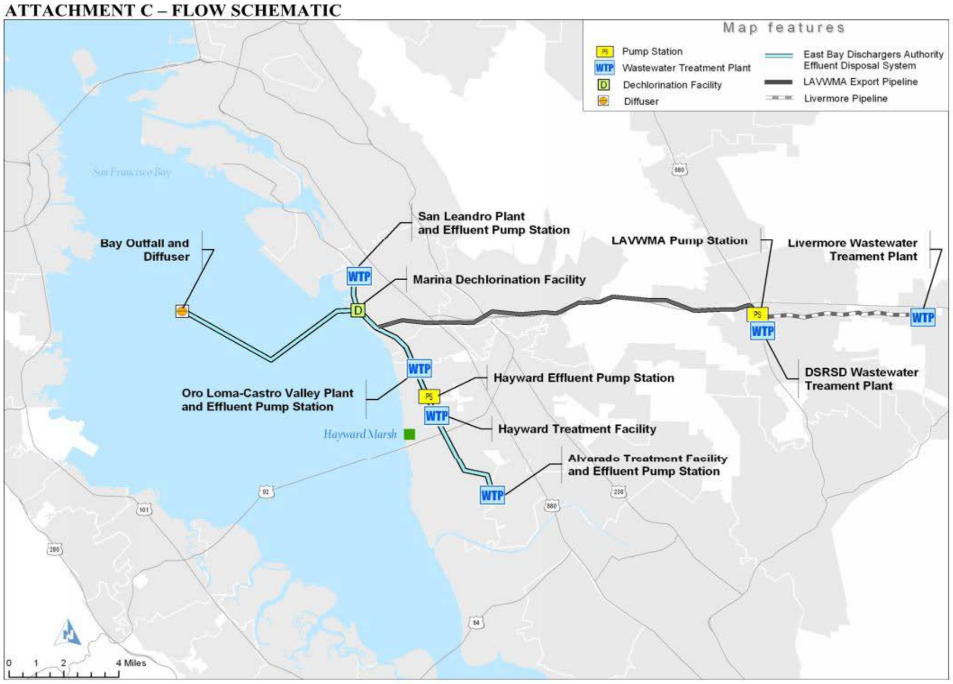
Since 1978, EBDA has been operating a joint wastewater discharge system with a combined transport, outfall pipe, and pumping system, discharging dechlorinated treated wastewater effluent to SF Bay. These are shown below on a map of SF Bay in Figure 1.1. These facilities are listed below in Table 1.1-EBDA Facilities. The Combined Transport System currently operates under a renewable 5-year permit from the San Francisco Water Board.

The treated wastewater from the EBDA facilities is combined and then dechlorinated by sodium bisulfite at the Marina Dechlorination Facility prior to discharge via EBDA's deep-water outfall to San Francisco Bay. The Combined Outfall and Transport System has performed very well through the intervening time period. Over this period, the treated wastewater transported through the outfall system has improved considerably in meeting federal and state water quality standards and EBDA has not had a permit exceedance since 2006.

Figure 1.1. Map of all EBDA Facilities

East Bay Dischargers Authority
ORDER NO. R2-2006-0053
NPDES NO. CA0037869

ATTACHMENT C – FLOW SCHEMATIC



Attachment C – Flow Schematic C-1

As part of its NPDES permit, each member facility is permitted an average flow based on the design of their treatment plant. Table 2.1.1 below shows the numeric flow limits for each agency utilizing the EBDA Combined Transport System.

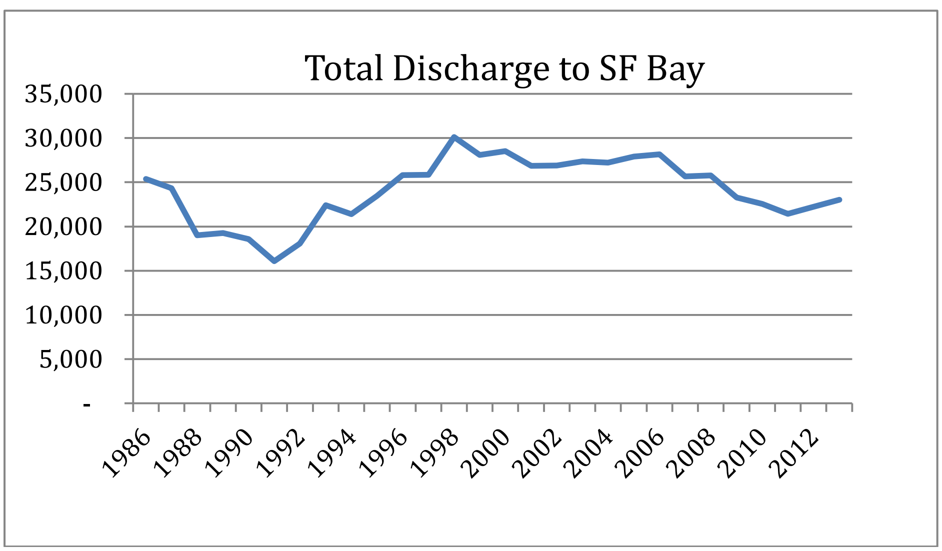
Table 1.1. EBDA Member Facility Permitted Average Dry Weather Flow (ADWF) (2010)

	Agency Flow	ADWF Capacity	Existing Capacity	ADWF Peak
San Leandro	4.9	7.6	7.6	22.3
OLSD/CVSD	12.6	20.0	20.0	69.2
Hayward	12.2	18.5	18.5	35.0
Union SD	25.1	33.0	38.0	42.9
Subtotal	54.8	79.1	84.1	169.4
LAVWMA	17.5	28.7	35.0	41.2
Facility Design Total	71.3	107.8	119.1	189.1

1.3 Wastewater volumes historical totals- 1986-2013

The historical discharges and flows are shown in Figure 1.2 below. Total annual flows have fluctuated during the period from a low of 16,000 Million Gallon (MG) in 1991 to a high of 30,000 MG in 1998, averaging under 25,000 MG/annually over the period.

Figure 1.2. EBDA Total Discharge to SF Bay, by Year, 1986-2013 (Million Gallons)

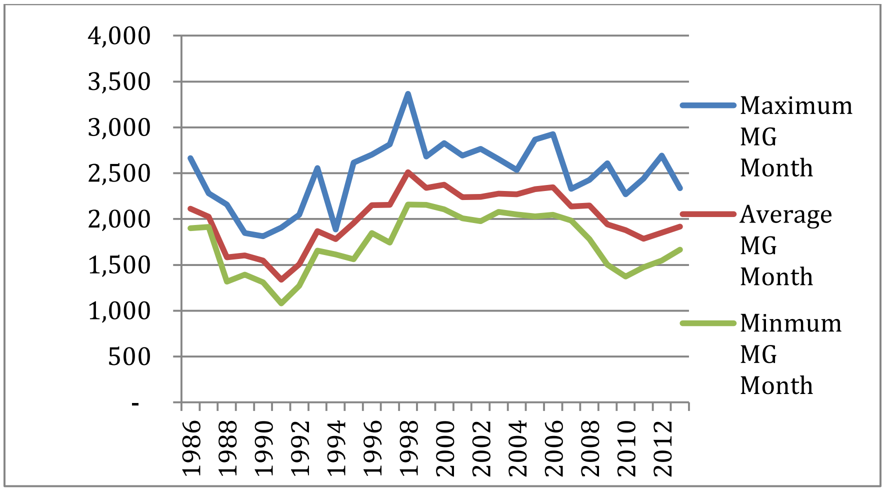


Source: Combined Flows, 1986-2013, EBDA, 2014.

Total flow volumes mirror wet and dry winter weather patterns observed and measured. Over the period from 1986 to 2013, the largest discharges have been associated with wet weather conditions. During the dry periods winter peak flows are minimized. Current yearly total flows are below historic average yearly flows.

Figure 1.3 below shows monthly discharges, recording maximum, minimum, and average discharges for 1986-2013, annually. The monthly totals show the difference between wet and dry seasons and show how important both time of year and reported calendar year are to understanding total system discharges.

Figure 1.3. EBDA Combined System Discharges to SF Bay (MG/ month)



1.4 Wastewater Projections: Wastewater flow future trends 2014-2040

The combined service areas of the EBDA agencies' jurisdiction are very mature urban areas, all of which have been transformed in types and kinds of land use and intensities over the past fifty years. Going forward these service areas have limited growth forecast for increasing service needs, even with strong land use and business growth. Slower mature residential growth, with reduced per capita use rates and greater efficiencies across a range of urban economic and land uses will combine to reduce growth in service demand needs. Additionally, several conditions point to reductions in total discharges and flows to SF Bay, particularly current water re-use requirements, mandating 20% re-use by 2020.

1.5 Water Re-Use

Water re-use projects for the EBDA agencies have received increased attention with the ongoing drought. As demonstrated in Table 1.2, water re-use meets the 20% goal on some days, but each agency is pursuing other possible projects.

Table 1.2. Wastewater re-use by EBDA and LAVWMA agencies

Agency	Annual (acre ft)	Max (MGD)	Avg WW Flow
USD	3300	20	25
Hayward	2500-3000	3-4	11
OLSD/CVSD	200-250	1	11
San Leandro	600	1.2	5
DSRSD	3200	7	8
Livermore	~1000	3.6	5
Total	~10,000	~20	65

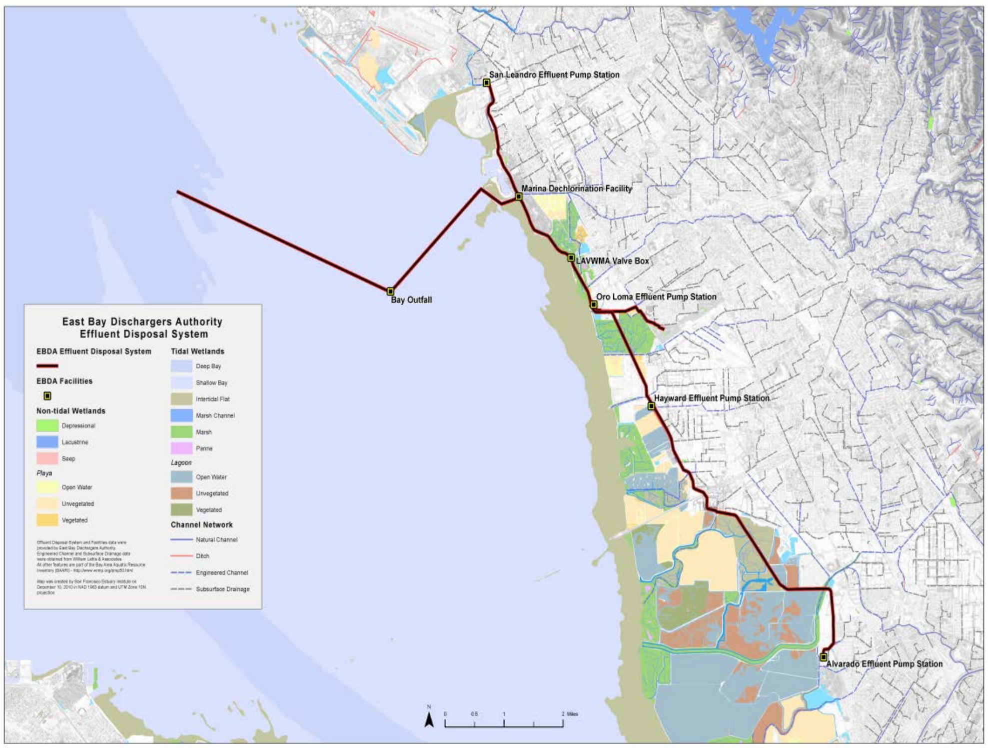
1.6 Wastewater Projections: Infiltration/Inflow volume future trends, 2014-2040

There are now active programs addressing infiltration/inflow that are intended to reduce current peaking factors over the next 15-20 years. EBDA's estimate of future flows reflects this assumption as part of its long-term forecast. While these projected reductions represent a small percentage of total flow, as the peak of infiltration/inflow occurs during wet weather conditions, any reduction in Infiltration/inflow will have an important effect of directly reducing a portion of the peak system conditions.

1.7 Draft Alternative Decentralized Wastewater Disposal Scenarios

EBDA has identified a number of decentralized wastewater disposal scenarios for the period 2015 to 2040, focused on integrating wastewater discharges with natural resource habitat restoration to create multi-beneficial habitat restoration and "green" infrastructure improvements. Figure 1.3 shows the location of EBDA's system along the eastern edge of San Francisco Bay.

Figure 1.3. Bay and Shoreline Natural Habitats and EBDA Facilities



Staff and consultants have identified a range of draft alternative options, including an option to continue and replace the combined outfall system and armor the system components against sea level rise and threats of flooding.

These preliminary draft options are:

1. Combined Outfall Option– Replace and modernize the Combined Outfall with slight improvements in secondary treatment and with minimal side-stream nutrient removal, increased water recycling, lower flows, and co-digestion of food wastes. (All options recommend planning armoring component system facilities against sea level rise and climate threats of flooding and inundation, as required);

2. Seepage Slope Option- Use multiple points along the current system to develop discharge releases through constructed 'seepage slopes';

3. Wetland Option-Wetland discharge for all EBDA flows all year. (Extensive side-stream nutrient recovery for N and P. 6000 kg/d N and 100 kg/d P);

4. Creeks Option-Creeks discharge for all EBDA flows. 8000 kg/d N and 500 kg/d P discharged at southern sites, principally within the Hayward Marsh and South Bay Salt Ponds (directed pumping strategy: wetland match) and

5. Water Recycling Option-Reduce wastewater discharge totals through increased water recycling initiatives.

Table 1.3 below summarizes the range of options for alternative wastewater discharge identifying bay habitat and water quality conditions and intended outcomes.

Table 1.3. EBDA Wastewater Alternatives Scenarios for 2015-2040

Option	Project/Program Description	Bay Outfall Flows	Bay Habitat and WQ	Wetland Habitat and WQ	Specs	Major Elements
Option 1 Combined Outfall	Replace Combined Outfall in like	70-190 mgd			-10% reduction in fresh water and in nutrient discharges	Replace existing Bay Outfall in kind
Option 2 Seepage Slopes	Seepage Slopes discharge for all EBDA flows all year with extensive side-stream nutrient recovery for N and P.	0	Eliminates Dry and Wet Discharges	? Kg/d N ? Kg/d P	Discharges at local sites along EBDA Combined Outfall	Plan, Construct, and Operate a modified system of near shore bay and tidelands discharge
Option 3 Wetlands Option	Wetland discharge for all EBDA flows all year with directed flow management from all five local sites to marsh and wetland location	0	Eliminates Dry + Wet Weather Discharges in bay with wetland + saltponds nourishment and restoration option	? Kg/d N	Discharges at wetland location within Hayward Shoreline or south bay salt ponds at Eden Landing-?	Plan, Construct, and Operate a modified system of near shore bay and tidelands discharge
Option 4 Creeks Option	Creeks discharge for all EBDA flows all year with directed flow management from all five local sites to Creek locations	0	Eliminates Dry + Wet Weather Discharges in bay with creek discharges			
Option 5 Water Recycling		0				

Appendix A1 References

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Appendix A2. Nutrient Loading

Overview of Nutrient Related issues in SFB

Nutrient loads, cycling, and ambient concentrations in SFB: The San Francisco Bay (SFB) Area has 42 POTWs (Figure 1) that service the regions 7.2 million people and discharge either directly to the Bay or to receiving waters in adjacent watersheds that drain to the Bay (note: these numbers do not include discharges east of Suisun Bay that enter through the Delta). While several of these POTWs conduct nitrification or denitrification plus some forms of advanced treatment that remove a portion of nutrients prior to discharge, most POTWs discharging to SFB carry out only secondary treatment, which transforms nutrients from organic to inorganic forms, but generally does not remove much N or P. Table 6.1 summarizes typical N and P concentrations and forms in effluent subjected to varying degrees of nutrient removal.

Figure 2 presents an overview of DIN and DIP loads to SFB, divided among its five main sub-embayments (see SFEI 2014#704 for more details). Groundwater and direct atmospheric deposition to the Bay's surface loads are expected to be relatively small and are not discussed here. Discharge of treated wastewater effluent by publicly owned treatment works (POTWs) to SFB's subembayments is a major source of N and P. Bay-wide, POTWs discharged (annual average) 34000 kg d-1 NH4+, 12000 kg d-1 NO3-, and 4000 kg d-1 total P. Results from detailed effluent monitoring that began in July 2012 suggests ~90% of total N discharged was in the form of DIN and ~80% of total P discharged was in the form of o-PO4 (SFEI, 2014b). Refineries also contribute N and P loads to Suisun Bay and San Pablo Bay, but their contributions appear to be relatively minor. The dominant sources of N and P loads, and the form of N, vary substantially among subembayments (Figure 2). In Lower South Bay (LSB), South Bay, and Central Bay, POTWs are the dominant source of N and P. In LSB, NO3- is the dominant N form discharged because LSB POTWs carry out nitrification. In South Bay and Central Bay, NH4+ is the dominant N form released by POTWs. In San Pablo Bay, direct POTW loads are relatively minor and primary release NH4+. In Suisun Bay, NH4+ is the primary form of N discharged, and the importance of those direct loads relative to other inputs varies seasonally. Stormwater flows deliver seasonally-varying N and P loads to SFB. Only rough estimates of those loads have been made thus far due, and these estimates suggest that stormwater DIN and o-PO4 loads are substantially less than POTW loads (Figure 2). In general, SFB is a net source of nutrients to the coastal ocean throughout most of the year, although periodic net transport of NO3- and o-PO4 into SFB may occur during coastal upwelling events (Largier and Stacey 2014). Hydrodynamic exchange between subembayments may comprise a large proportion of loads to some subembayments, and are also not included in the load estimates (except for San Pablo Bay), although nutrient concentrations in the southern reaches of South Bay in particular are expected to be substantially-influenced by loads entering from LSB.

Long-term monthly monitoring data from stations throughout SFB (Figure 3) show that nutrient forms and concentrations vary considerably as a function of space and season (Figure 4-5). These variations are caused by spatial and temporal variability in nutrient loads and physical factors (volume of subembayment, mixing, tides, freshwater inputs) and biogeochemical factors (e.g., nitrification, denitrification, uptake and assimilation, re-mineralization of organic matter) that influence pseudo-steady state concentrations. LSB and southern South Bay have the highest and second-highest DIN and DIP concentrations Bay-wide (Figure 4-5), due to high loads to this area, relatively low water volume (shallow), and the San Bruno Shoal that causes muted exchange of the water volume south of s27 with the rest of the Bay. The highest observed DIN concentrations have been measured at 300-400 µM in Coyote Creek, which carries treated effluent from San Jose to LSB.

Nitrification and denitrification likely play quantitatively important roles in determining the observed N forms and concentrations in SFB subembayments. For example, although the vast majority of N loaded to Central Bay and South Bay occurred in the form of NH4+ (Figure 2), ambient N was present primarily as NO3- (SFEI 2014 #731), evidence of in situ nitrification's importance. Spring and summer DIN concentrations in LSB and southern South Bay were 30-40% lower than winter concentrations (Figure 4), with the lower concentrations likely due to a combination of denitrification at the sediment: water interface when water temperatures warm and higher uptake rates by phytoplankton during this time of year.

Concentrations of organic N and organic P in SFB are uncertain, since they have not been consistently measured (except in Suisun Bay). However, because of the large anthropogenic DIN and DIP loads SFB receives, it reasonable to hypothesize that DIN and DIP often dominate total N (TN) and total P (TP).

Potential nutrient impacts in SFB

N and P are essential nutrients for the primary production that supports food webs in SFB and other estuaries. However, when nutrient loads reach excessive levels they can adversely impact ecosystem health. Individual estuaries vary in their response or sensitivity to nutrient loads, with physical and biological characteristics modulating estuarine response (e.g., Cloern 2001). As a result, some estuaries experience limited or no adverse impacts at loads that have been shown to have substantial impacts elsewhere. Excessive nutrient loads can have adverse impacts in SFB along several potential pathways (Figure 6). Each pathway is comprised of multiple linked physical, chemical, and biological processes, some of which are reasonably well understood while others are poorly understood or data are scarce (see SFEI 2014b for more information).

Over the past 15 years, statistically significant increases in phytoplankton biomass have been observed throughout SFB. Most notably summer/fall phytoplankton biomass tripled between the mid-1990s and the mid-2000s (Figure 7; Cloern et al., 2007) in South Bay and LSB, representing a shift in trophic status from oligo-mesotrophic (low to moderate productivity system) to meso-eutrophic (moderate to high productivity system) (Cloern and Jassby, 2012). More recent data from South Bay suggests that, at least presently, biomass concentrations have plateaued at a new level instead of continuing to rise (SFEI 2014 #732). Since the late 1990s, fall blooms have begun occurring regularly in South Bay and LSB, areas where they seldom occurred previously (Figure 8, and Cloern and Jassby 2012).

Harmful phytoplankton species also represent a growing concern. The harmful algae, Microcystis spp., and the toxin they produce, microcystin, have been detected with increasing frequency in the Delta and Suisun Bay since ~2000 (Lehman et al., 2008). In addition, the HAB toxins microcystin and domoic acid have been detected Bay-wide (SFEI 2014 #731). The ecological significance of observed toxin levels in the Bay are not yet known. A number of phytoplankton species that have formed harmful algal blooms (HABs) in other systems have been detected throughout SFB (SFEI 2014 #731). Although the abundances of HAB-forming organisms in SFB have not reached levels that would constitute a major bloom, they do periodically exceed thresholds established for other systems (Kudela et al., in prep), and major Microcystis spp blooms and elevated microcystin levels have been observed with some regularity in the Delta (Lehman et al., 2008). Moreover, since HAB-forming species are present in SFB and nutrients are abundant, HABs could readily develop should appropriate physical conditions create opportunities that HABs can exploit (e.g, the unprecedented large red tide bloom in Fall 2004 that followed a rare series of clear calm days, and chl-a levels reached nearly 100 times their typical values; Cloern et al. 2005). In addition, harmful-bloom forming species have been detected at elevated abundances in salt ponds in LSB undergoing restoration (Thebault et al., 2008), raising concerns that salt ponds could serve as incubators for harmful species that could then proliferate when introduced into the open bay.

DO concentrations in deep subtidal habitats throughout the Bay typically remain at levels above 5 mg L-1 (SFEI 2014 #731), the San Francisco Bay Basin Plan standard. However, in LSB, ship-based sampling has most frequently occurred at slack high tide. Recent continuous measurements at the Dumbarton Bridge indicate that DO levels at low tide are commonly 1-2 mg/L lower than at high tide during summer months (e.g., Figure 9; SFEI, 2014 #732), and can occasionally dip below, 5 mg L-1. In addition, low DO commonly occurs in some shallow margin habitats that ring Lower South Bay and South Bay (Figure 10). For example, studies of salt ponds undergoing restoration in LSB found that they experience large diurnal DO fluctuations (Topping et al., 2009) and occasionally experience sustained periods of anoxia (Thebault et al., 2008). In some slough habitats of LSB, DO regularly dips below 5 mg L-1, frequently approaches 2 mg L-1 (Shellenberger et al., 2008), and at a site in Alviso Slough, DO remained near or below 2 mg L-1 for sustained lengths of time (up to consecutive hours 10-12 hours in a row) over periods of days to weeks during Summer 2012 and Summer 2014 (SFEI,2014 #732). Under natural conditions, shallow subtidal and tidal wetland habitats commonly experience low DO, and plants and animals native to these habitats are often well-adapted to these DO swings. However, there is a paucity of DO data in margin habitats, and the severity of low DO (frequency, duration, spatial extent, concentration), whether it is impacting biota, and the extent to which excess nutrients cause or contribute to the low DO conditions are all poorly known.

In addition to characterizing and addressing any current nutrient-related problems in SFB, there is a need to anticipate potential future adverse impacts. The highly elevated DIN and DIP concentrations Bay-wide provide the potential for future impairment to develop. Any major reductions in loads to SFB will take years-to-decades to implement. Thus, if future problems are to be averted, potential impairment scenarios need to be anticipated, evaluated, and, if deemed necessary, managed in advance of their onset. A proactive approach to characterizing and managing potential problems – while they are on the somewhat-distant horizon, as opposed to imminent – will allow greater flexibility in the management options that can be pursued.

EBDA Nutrient Loads

Over the period 1999-2011, EBDA's treated effluent flow rates varied seasonally between 60-120 MGD, with highest and lowest flows in winter and summer, respectively, and the majority of estimates falling in the range of 60-80 MGD (Figure 11; SFEI 2014 #704). Effluent $NH4+$ concentration data were available for the past 10+ years, but fewer data were available for other N species ($NO3-$) and P species. Nonetheless, since the vast majority of DIN in EBDA's combined effluent is expected to occur primarily as $NH4+$, $NH4+$ concentrations and loads serve as a reasonable surrogate for DIN. $NH4+$ concentrations appear to have increased over the past several years from concentrations ≤ 25 mg L-1 to values closer to 30 mg L-1. This increase co-occurred with a decrease in average flows, suggesting that the concentration increase has been due in part to water conservation efforts. Over the past decade, $NH4+$ loads have generally been in the range of 6000-8000 kg d-1, with occasional extreme maximum and minimum values approaching 10000 kg d-1 and 4000 kg d-1, respectively. Detailed monthly monitoring for all nutrient forms at EBDA and other Bay Area POTWs began in July 2012. N measurements showed, as expected, that ~90% of DIN in EBDA's effluent was present as $NH4+$ (~29 mg L-1) and ~10% was present as $NO3-$ (~2.5 mg L-1). The annual average DIN load for the period of July 2012- June 2013 was 7900 kg d-1 (based on 1-2 measurements per month, including peak conditions). Total P concentrations were in the range of 1.5-2 mg L-1, of which >80% was in the dissolved phase, and ~70% was dissolved reactive phosphorous. Between July 2012–June 2013, EBDA total P loads varied between 400 and 800 kg d-1 with a median of ~500 kg d-1.

Considerations related to wetlands as a potential multi-benefit approach for N removal: EBDA focus

As described above, POTWs are the primary source of nutrients throughout most of San Francisco Bay. Therefore, unlike estuaries in which nonpoint sources are major nutrient contributors, in some areas of San Francisco Bay it is reasonable to consider diversion of POTW point-sources to wetlands as a potential nutrient management option. Although the discussion below focuses primarily on N, P removal will also eventually need to be considered.

As part of assessing the potential effectiveness and feasibility of this approach, a number of factors need to be evaluated, including:

1) The desired load reduction. Achieving the desired load reduction depends on a number of factors that will in turn have major influences on design considerations, in particular the required wetland area to ensure sufficient residence time and sufficient N removal, and include:
    a) Whether the same load reduction is required year round or can vary seasonally.
    b) Seasonal variability in flow and load. Currently, EBDA's flows and loads vary by as much as a factor of 2. Treating high flows would require at least twice as much wetland area as dry flows.
    c) The form of N (as NH_4^+ or NO_3^-), and its influent concentration. If N arrives primarily in the form of NH_4^+, in general nitrification of NH_4^+ to NO_3^- must occur first, followed by denitrification (unless N loss goes forward by anamox)
    d) Seasonal variability in removal efficiency due to the effect of temperature. For a given area and flow or loading rate, removal efficiency can vary by more than a factor of 5.
2) Designing wetlands such that they achieve the combined effect of increased wetland habitat, nutrient removal, and wetland accretion to stave off sea level rise, which may require some compromises on all three fronts to achieve an overall optimum design.

Requirements for N removal

Below are a few simplistic approaches intended to provide order of magnitude estimates of required wetland size and/or residence time to reduce the N load from EBDA's effluent.

A basic rule of thumb for N removal from treatment wetlands assumes is 500 mg N m-2 d-1 removal in summer, and an order of magnitude lower removal in winter (Horne 1995;). Based on EBDA's current flows and loads, a high degree of removal (i.e., approaching 100%) under summertime conditions could be achieved with a treatment area of 2.7 x 106 m2 (670acres; assumes 500 mg/m2/d removal, depth = 0.5m, hydraulic residence time ~6 days). An inherent assumption/simplification is that N loss proceeds as a zero-order reaction (i.e., independent of concentration), which is not accurate.

Results from a recent study in a pilot open-water treatment wetland (0.007-0.02 MGD) in Discovery Bay, CA provide a more mechanistically-precise means of estimating the design requirements for NO3- removal (Jasper et al., 2014). During summer months (similar T as might be expected in wetlands adjacent to South Bay), the Discovery Bay treatment wetland achieved nearly 2/3 removal of NO3- on an annual basis and nearly 95% removal during summer months. Jasper et al. (2014) also found that removal rates were greater in their open-water treatment pond (no emergent vegetation) than has been observed previously in vegetated wetlands (Figure 13). Figure 14 illustrates removal efficiencies as a function of area and T, based on the removal rates in Jasper et al (2014) and scaled to EBDA's flowrate. For example, a treatment area of ~600 acres would be needed to achieve 90% removal during summer months (T = 25 C), and could achieve 40% removal in winter (T = 15 C). If 90% was also the winter removal target, a much larger area would be needed (~2500 acres, T = 15 C). If lower removal efficiencies are needed, treatment area would decrease.

While Discovery Bay provides an estimate of N removal in a well-controlled pilot wetland setting, the oxidation ponds at the Sunnyvale POTW provide a full-system scale estimate (~20-25% of EBDA's influent N loads). Sunnyvale has a system of oxidation ponds and channels (~400 acres) primarily for BOD removal and nitrification. However, despite not being intended or optimized for denitrification, during summer months, these ponds also allow for 75% reduction in N loads, presumably via denitrification, before discharge to the Bay (Figure 15).

A possible design for EBDA effluent treatment could also be similar to the approach being pursued for the Oro Loma pilot study, i.e., a horizontal levee with at least partial removal of N as it seeps through surface soils. A recent study by Garcia-Garcia (2013) describes N removal in a riparian wetland with predominant subsurface perennial flows and a Mediterranean climate. That study observed high N retention efficiency, in a similar range as riparian wetlands with surface flows, and no symptoms of N saturation despite agricultural N loading. The dominant vegetation was a mix of reeds (*Phragmites australis*) and halophytes in same genera present in SF Bay tidal marsh/terrestrial ecotones. However, under conditions of high N loads from wastewater effluent, it is conceivable that organic carbon could become limiting and slow denitrification rates.

Impacts of treated wastewater effluent in marshes

Morris et al (2013) in a study for the Mississippi River Delta reviewed current research on the impacts of diverting freshwater, nutrients and sediment into wetlands. They found input of sediment, nutrients, and fresh water are likely to:

- change the community composition of some wetlands and their biogeochemical processes;
- most of the nitrogen input should be assimilated or denitrified;
- labile organic matter is likely to degrade more quickly, but labile organic matter does not add 'new' soil volume and its speed of decay is of little consequence;
- it is likely that refractory organic matter should increase and contribute positively to sediment accretion.

Community. Plant production in coastal wetlands is limited primarily by nitrogen availability as well as by stresses from flooding, salinity, and sulfides (Mendelssohn and Morris 2000). Nutrient enrichment increases flood tolerance in some wetland species like baldcypress (*Taxodium distichum*) (Effler and Goyer 2006) and bulrush (*Schoenoplectus americanus*) (Langley et al. 2013), and increases salt tolerance in others like *Spartina alterniflora* (Cavalieri and Huang 1979). *Spartina* patens salt tolerance does not increase with increasing nutrient availability, but it does benefit from reduced salinity (Merino et al. 2010, Fig. 15). Figure 16 shows growth response to nutrients when the salinity exceeded 35 ppt but nutrients increased growth 3-fold when salinity was less than 5 ppt.

The input of mineral sediment, fresh water, and nutrients will likely change plant community composition in fresh or brackish, peat-dominated wetlands, resulting in a complex cascade of events. An increased rate of mineral input may result in a marsh community that can vertically accrete faster and is more resilient to disturbance, provided that the soil organic matter is preserved. However, the creation of freshwater wetlands by diversions can result in weaker soils because low salinity marsh soils are generally weaker than higher salinity marsh soils (Howes et al. 2010; Morton and Barras 2011).

Plant species do not benefit equally from nutrient enrichment, and it can be anticipated that freshwater diversions will modify plant community composition; this will be most pronounced at the freshwater end of the system. Nitrophilous species such as *Phragmites* and *Typha* could in many cases replace established species (Rickey and Anderson 2004). Moreover, freshwater diversions will reduce salinity, and this too will shift species composition in places away from species typical of salt or brackish water habitats (e.g., *Spartina* spp.) to less salt-tolerant species. Diversions can increase flooding, which may stress existing vegetation and select for more flood-tolerant species, confounding nutrient effects.

<u>Aboveground Biomass</u>. The growth of vegetation in response to nitrogen fertilization of salt marshes decreases as the in situ control biomass increases (Figure 16). When the control biomass is very high, very little can be gained in the way of added production from fertilization, but at a low control biomass there is a large potential for increasing productivity, provided that salinity and flooding stresses are relatively

low (Morris et al 2012). Other factors also serve to limit aboveground biomass, including osmotic stress, hypoxia, herbivory, disease, soil chemistry (toxicity and/or micronutrient deficiencies), and perhaps others. The relative importance of these will depend on the salinity, climate, weather, and elevation relative to the tidal frame.

Belowground Biomass. Plant developmental processes and growth are greatly affected by nutrient availability. With few exceptions, the absolute production of roots and shoots increases with nutrient loading. The nutrient effect on roots, however, is not universally the same. For instance Langley et al. (2013) found that the response of *Spartina* patens belowground biomass was dependent upon relative elevation: at elevations 5-15 cm below mean sea level, biomass was about 100 % greater in fertilized treatments, but the response declined with increasing relative elevation. Priest (2011) found that nutrient additions increased belowground biomass of *S. alterniflora* in a North Carolina study at all elevations, but the response was greatest (+115 %) at the lowest elevation

Plant root:shoot ratios decline as nutrient loading increases (Morris 1982). If added nutrients decrease belowground production, as some studies show, then soil strength will decrease with the loss of root structure, and the additive effect of roots on soil volume would be diminished (Darby and Turner 2008a; Turner 2010).

There are significant concerns of increasing nutrient loadings to highly organic marshes, particularly dissolved nitrogen, as this may increase the rate of belowground decomposition to a reduction in belowground biomass and increased soil organic matter mineralization (Swarzenski et al. 2008). As biomass decreases so the capacity of wetlands to keep pace with sea-level rise will be reduced. A number of studies show this inverse relationship, for example:

- Darby and Turner (2008a) reported that additions of inorganic nutrients reduced belowground biomass in *Spartina alterniflora* marshes in the Mississippi Delta and along the East coast.

- Morris and Bradley (1999) reported that fertilization of a marsh in North Inlet, SC led to an increase in soil respiration rates and a decline in soil organic matter content in the top 5 cm of sediment.

Composition and decomposition of vegetation will differ significantly according to the salinity of the marsh. *Spartina alterniflora*, for example, decays more slowly and produces a higher fraction of refractory organic matter than a typical freshwater plant (Morris et al 2012).

Table 1. Typical concentrations and forms of N and P in treated wastewater effluent at different treatment levels

Treatment type	NH4 (mg N L^{-1})	NO3 (mg N L^{-1})	TN (mg N L^{-1})	TP (mg P L^{-1})
Level 1: Secondary treatment	20-30	<1	25-35	4-6
Nitrification	<1	20-25	20-30	4-6
Level 2: Nitrification + biological nutrient removal	<1	8-12	10-15	0.5-1
Level 3: Nitrification + Advanced TN/TP removal	<1	3-6	4-8	0.1-0.3
Level 4: "Limit of Technology" not including Reverse Osmosis	<1	<1	<3	<0.1
Reverse Osmosis	<1	<1	<2	<0.02

[1] Based on Falk, M.W., Neethling, J.B., Reardon, D.J. (2011). Striking the Balance Between Nutrient Removal in Wastewater Treatment and Sustainability, WERF research project NUTR1R06n and BACWA 2011 report

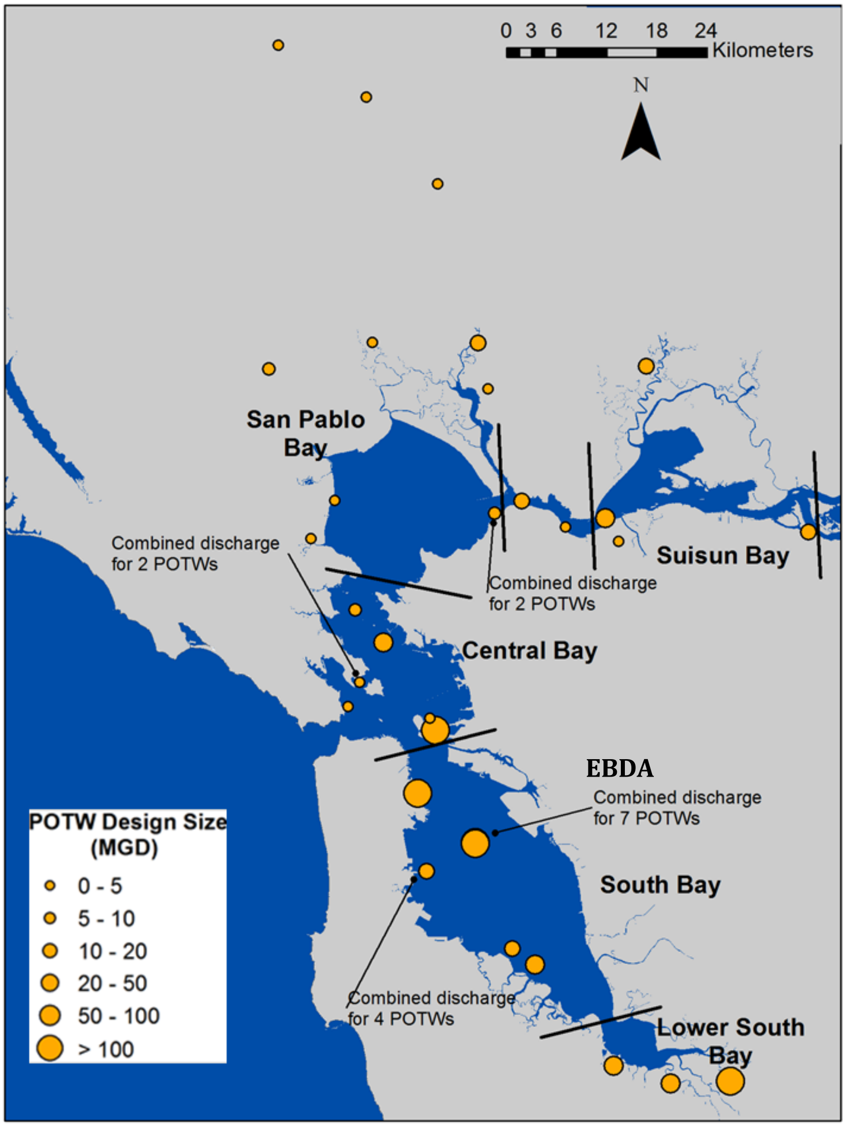


Figure 1. Location and design size (in million gallons per day) for POTWs that discharge directly in SFB or in watersheds directly adjacent to subembayments. Water Board subembayment boundaries are shown in black.

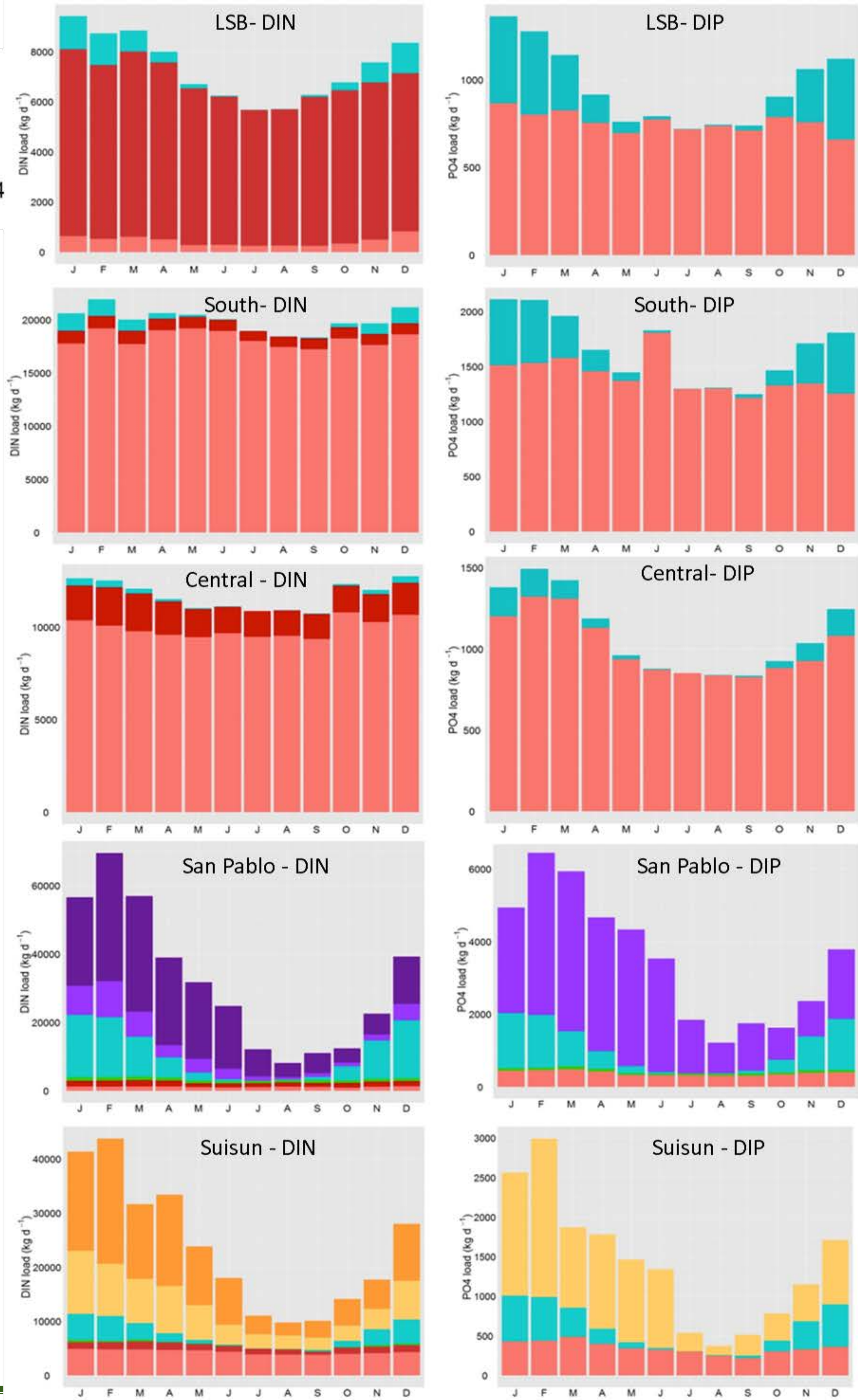


Figure 2. N and P loads to SFB subembayments. In the cases of LSB, South Bay, and Central Bay, only direct loads to the subembayments were considered and not exchange between subembayments. Loads to San Pablo Bay include estimates of up-estuary loads from Suisun Bay. See SFEI 2014b for more details.

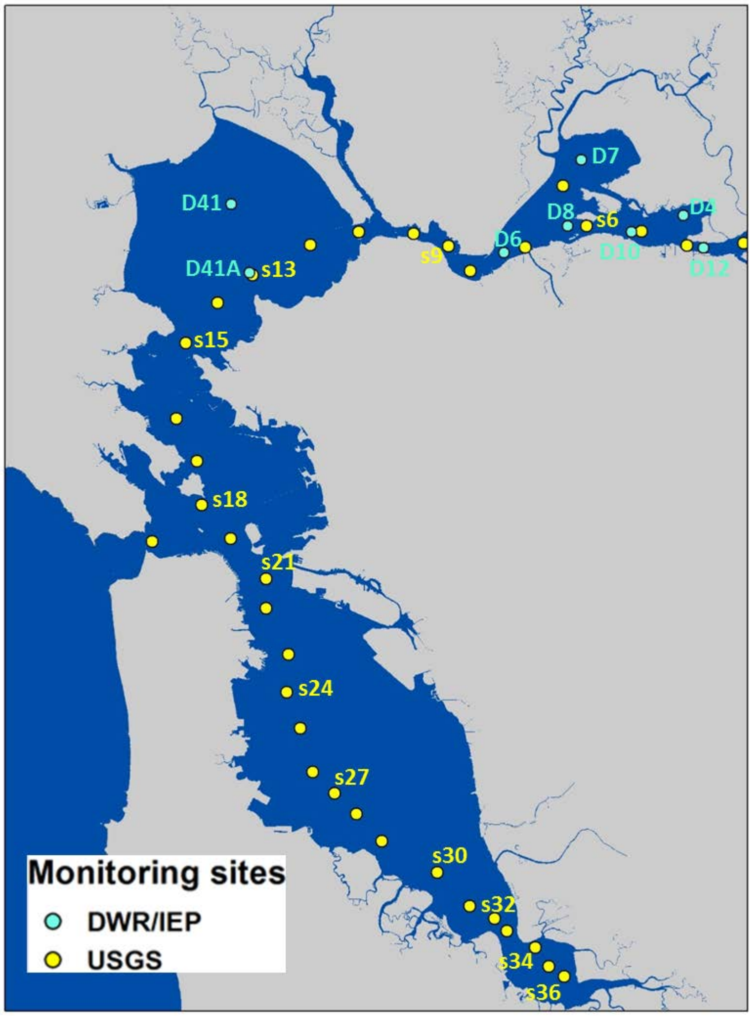


Figure 3. Location of DWR/IEP and USGS monthly sampling stations. Data from labeled USGS Stations are used in Figures 4, 5, and 6.

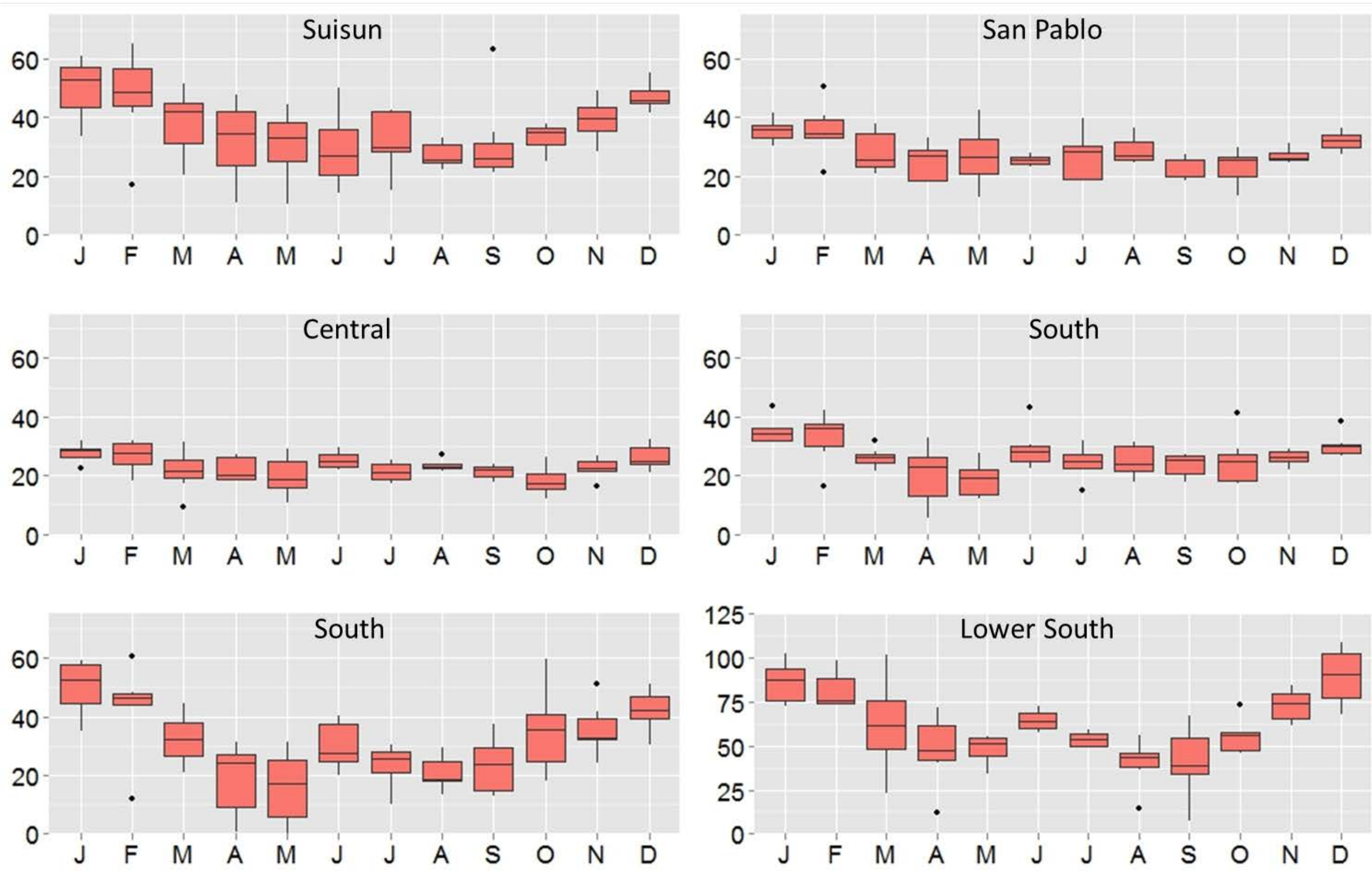


Figure 4. Monthly variations in DIN (µM): 2006-2011. Data from USGS stations s6 (Suisun), s15 (San Pablo), s18 (Central), s21 (northern South Bay), s27 (southern South Bay) and s36 (Lower South) were used. Note the vertical different scales. SFEI 2014b. Data source: http://sfbay.wr.usgs.gov/access/wqdata/

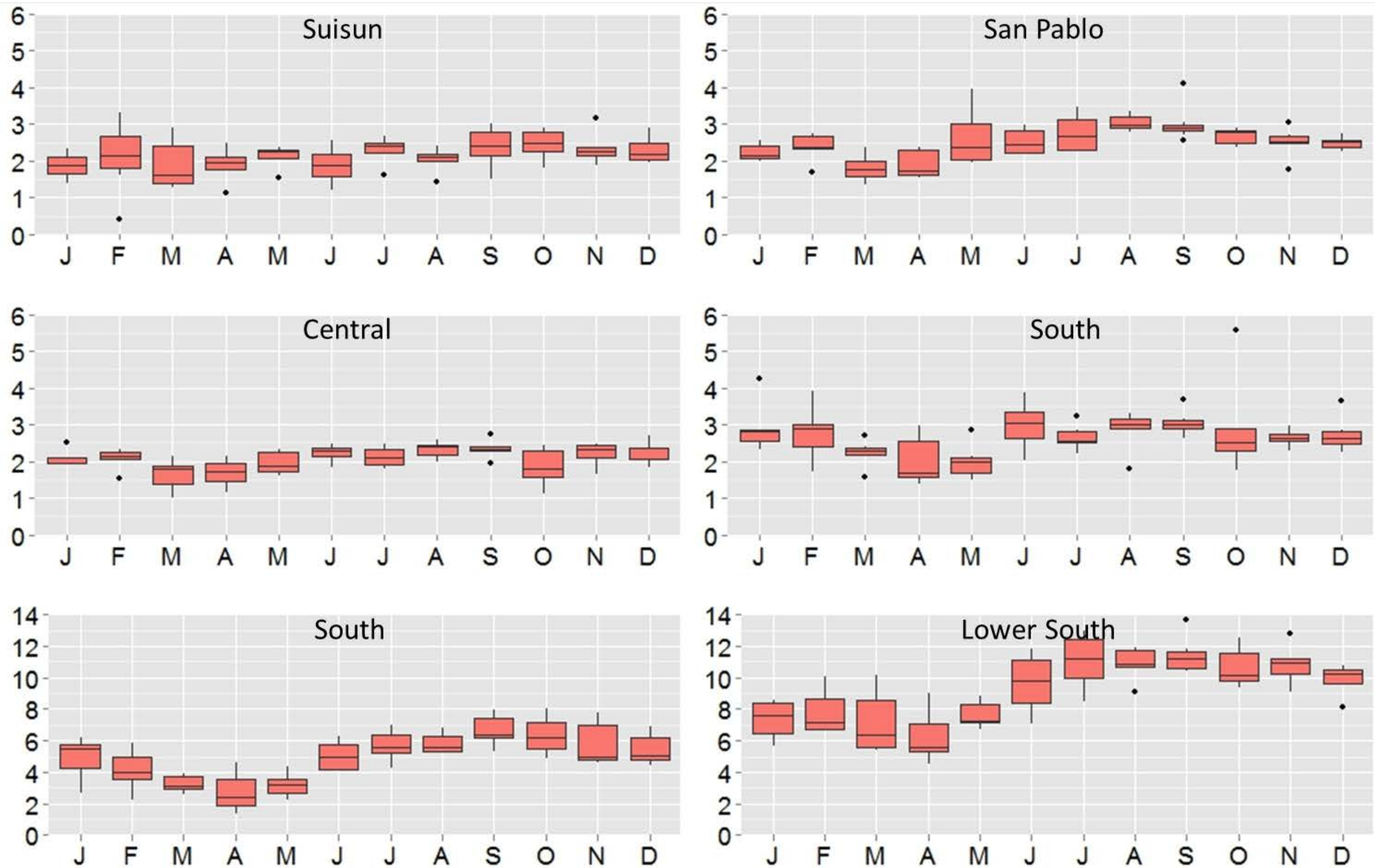


Figure 5. Monthly variations in o-PO_4 (µM): 2006-2011. Data from USGS stations s6 (Suisun), s15 (San Pablo), s18 (Central), s21 (northern South Bay), s27 (southern South Bay) and s36 (Lower South) were used. Note the different vertical scales. SFEI 2014b. Data source: http://sfbay.wr.usgs.gov/access/wqdata/

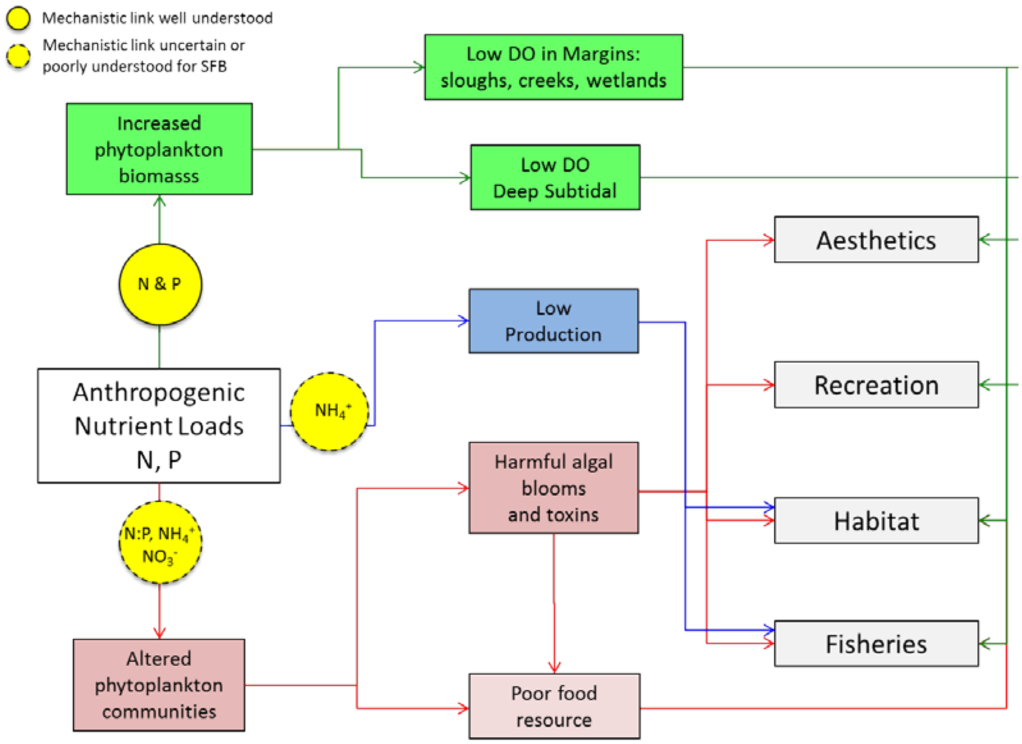


Figure 6. Potential adverse impact pathways: linkages between anthropogenic nutrient loads and adverse impacts on uses or attributes of SFB. The shaded rectangles represent indicators that could actual be measured along each pathway to assess condition. Grey rectangles to the right represent uses or attributes of SFB for which water quality is commonly managed. Yellow circles indicate the forms of nutrients that are relevant for each pathway.

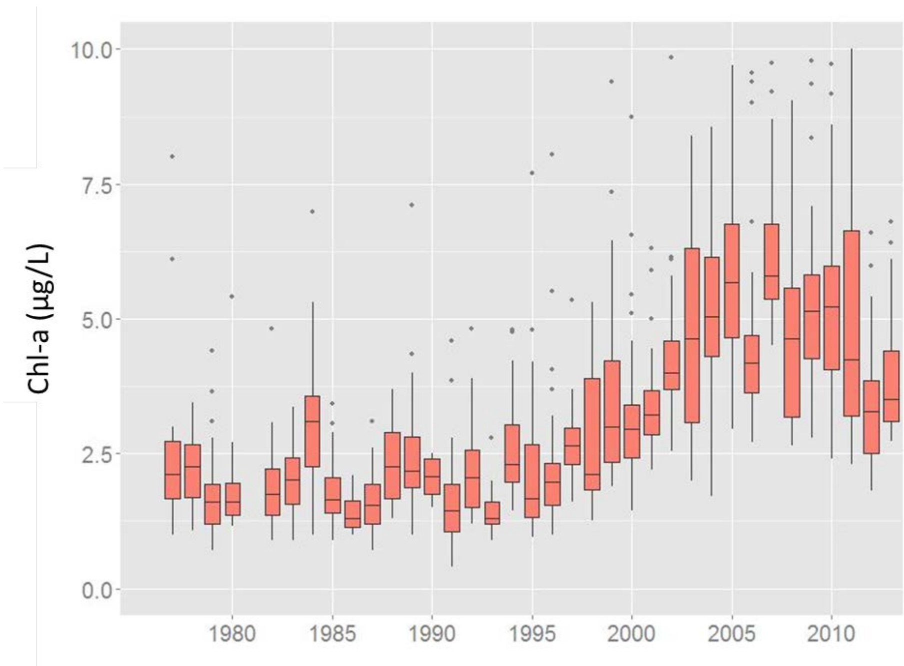


Figure 7. Same stations as and data as presented Figure 3.5, with data extended through 2013 (Interquartile range of Aug-Dec chl-a concentrations averaged across all USGS stations between Dumbarton Bridge and Bay Bridge, 1977-2013). Source: SFEI 2014c

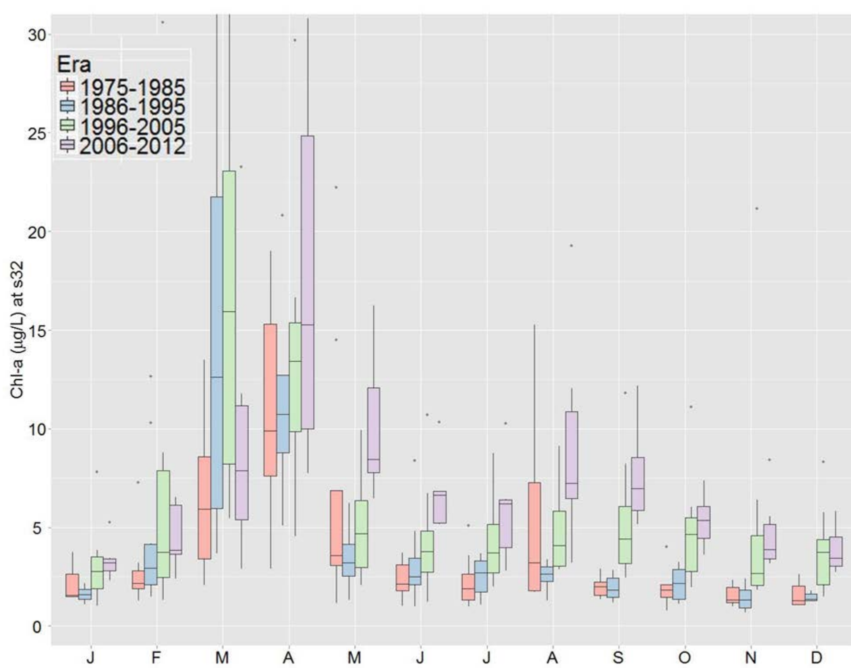


Figure 8. Seasonal box plot of chlorophyll-a concentrations near the Dumbarton Bridge (USGS s32), divided into ~10 year eras. Increases in summer baseline chl-a concentrations have been evident since 1996-2005. Fall blooms have also become a regular occurrence. The increases are statistically significant during all months except March and April.

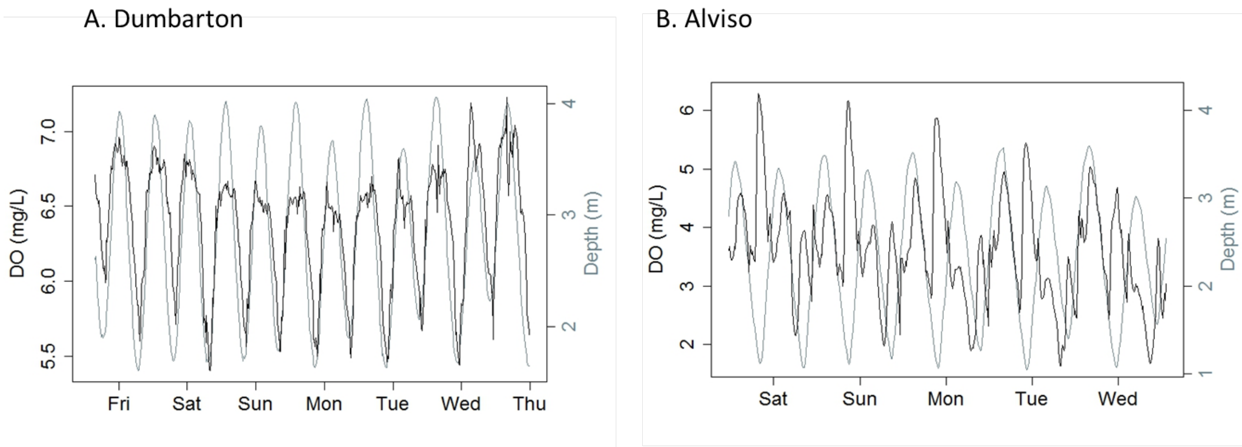


Figure 9. Time series of DO (mg/L) and depth at **A.** Dumbarton Bridge and **B.** Alviso Slough, Sep 5-12 2013.

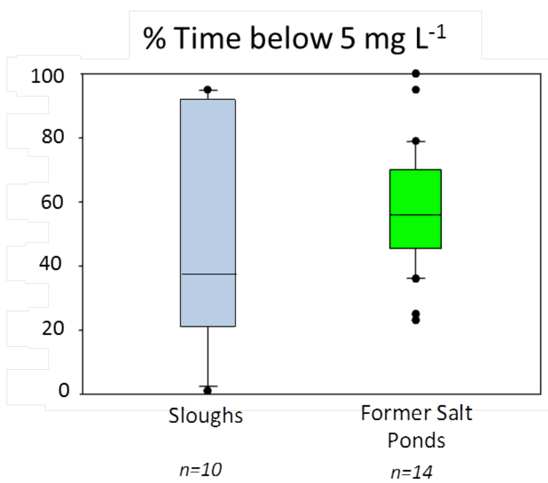


Figure 10. Percentage of time DO less than 5 mg/L in sloughs and salt ponds rimming Lower South Bay, based on a review of all available multi-program continuous sensor measurements. Source: SFEI 2014c

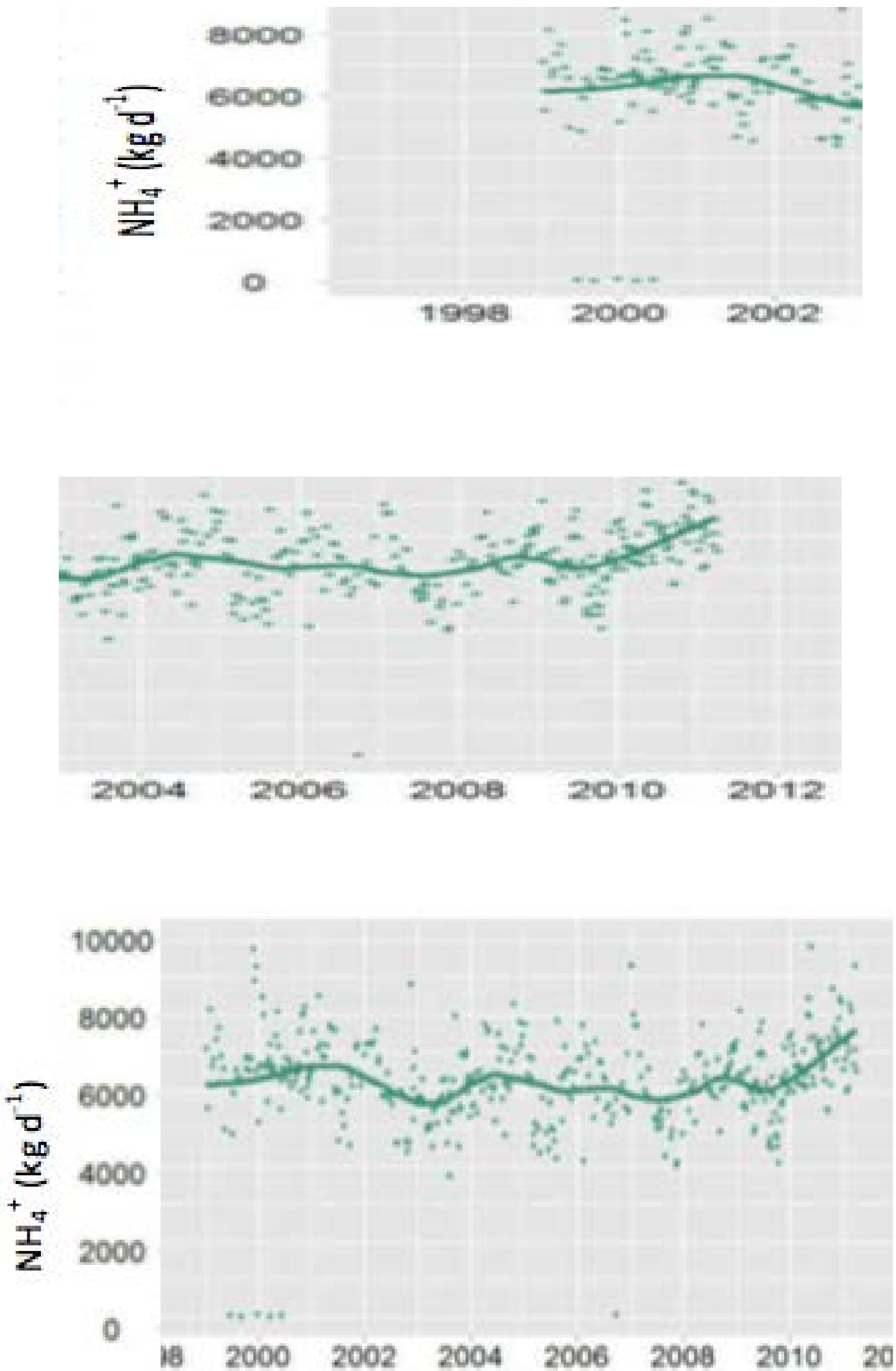


Figure 11. EBDA flow and NH4 loads 1999-2011

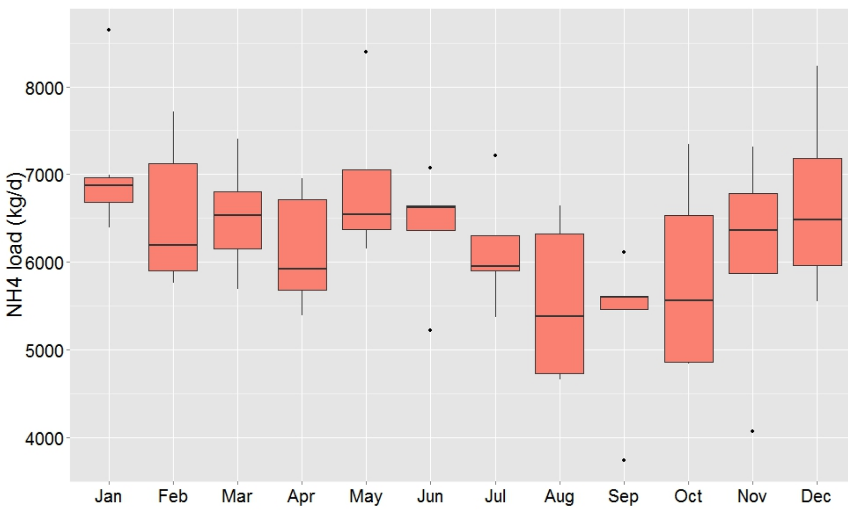


Figure 12. Seasonal variations of EBDA's NH_4^+ loads to San Francisco Bay

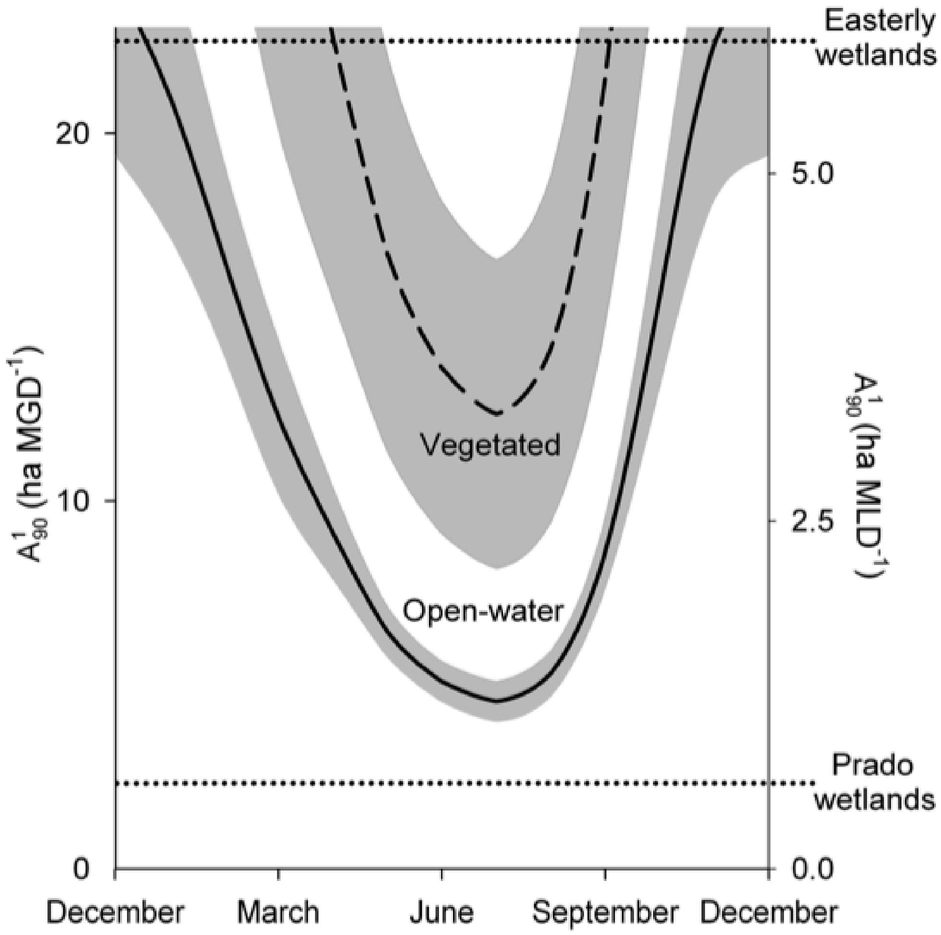


Figure 6. Mean area predicted to provide 90% removal of NO_3^- from 1 MGD or 1 MLD of wastewater effluent in open-water (solid line) and vegetated (dashed line)[20] treatment wetlands throughout the year (A^1_{90}). Nitrate removal rates were calculated using eq 2 using average water temperatures in Discovery Bay, CA (i.e., from 10 °C in the winter to 23 °C in the summer; SI Table SI 1). Gray area indicates ± standard error of the mean. Dashed lines show the area per MGD of the existing full-scale Prado and Easterly treatment wetlands.[65,66]

Figure 13. From Jasper et al. 2014

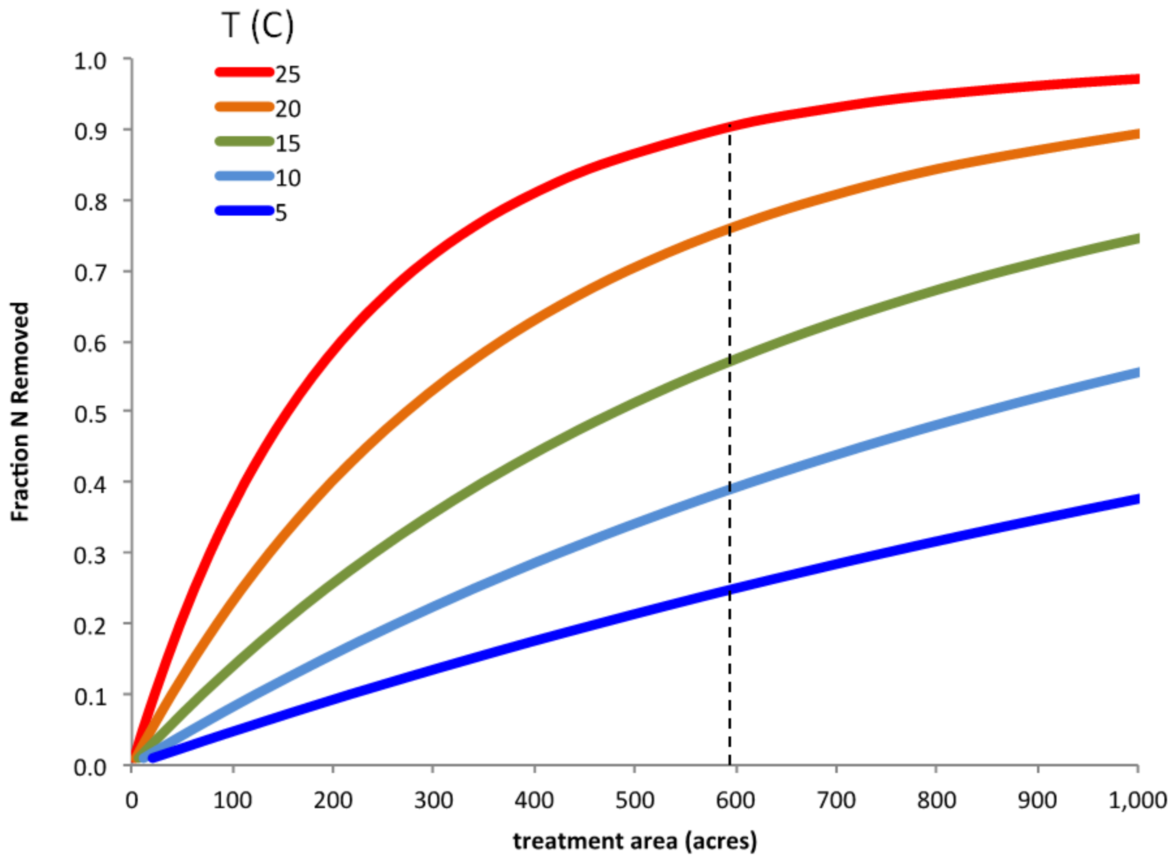
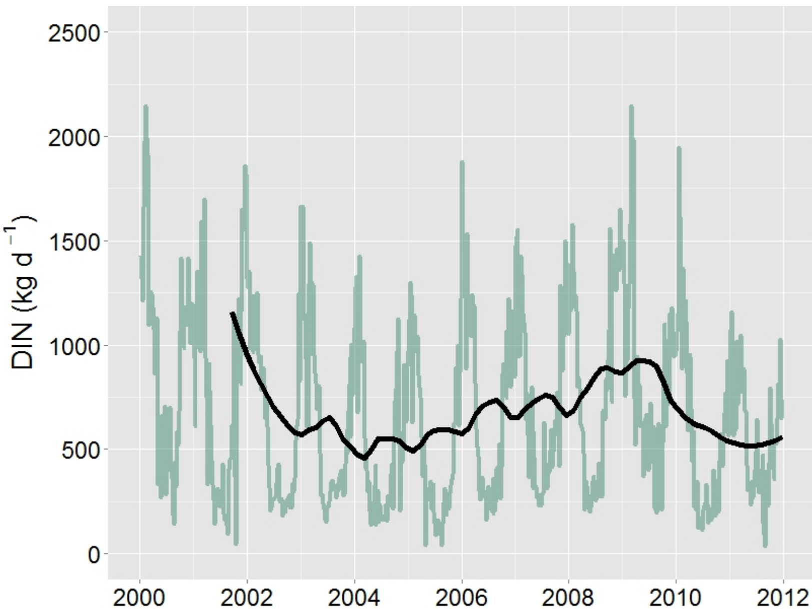


Figure 14. Potential fraction of N removed from EBDA's discharge as a function of treatment area and temperature. Based on rates in Jasper et al. 2014 for an vegetated pond. Vertical dashed line illustrates removal efficiency for an example 600 acre pond: 90% removal could be achieved in summer (T = 25 C), down to 40% removal in winter (T = 10 C).



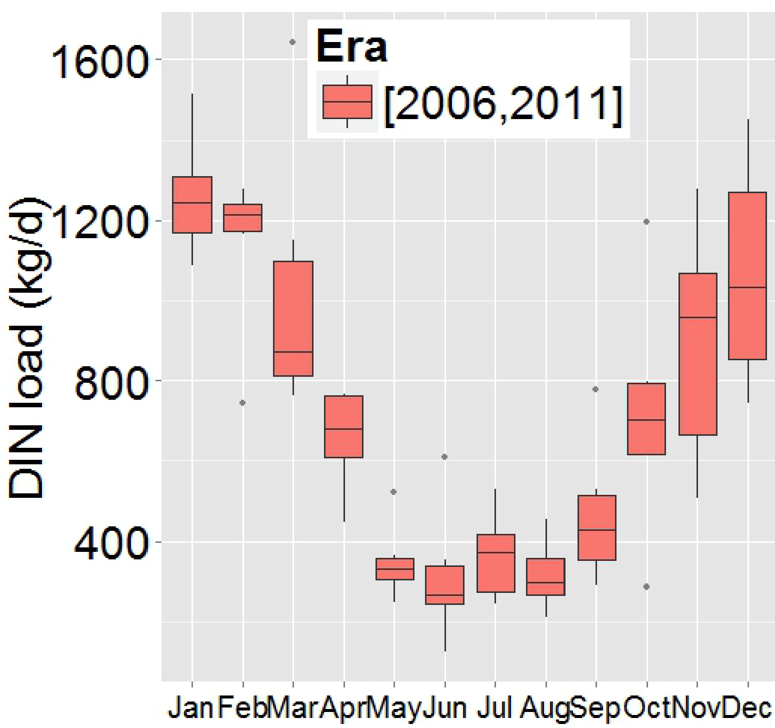


Figure 15. DIN loads exiting ponds in Sunnyvale at remove a large portion of DIN through denitrification or uptake by algae during summer months, when DIN loads leaving the treatment plant are 4-5-fold lower than winter months.

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Appendix A3. Landscape Changes: Habitat Types, Freshwater Inputs

Historical Baylands Landscape

The shoreline of the southeast Bay was historically dominated by broad tidal baylands. Tidal marsh was nearly continuous from San Leandro through Fremont (Figure 1). The underlying geology played a role in the location and extent of historical tidal marsh. The width of tidal marshes varied greatly, from 1,500ft. to more than 4 miles, depending largely on the pattern of alluvial deposits associated with major creeks: San Leandro, San Lorenzo, and Alameda with the widest extent between alluvial fans. Bayward of the tidal marsh plain, intertidal flats from 0.3 to 1.9 miles wide separated the tidal marsh from the open water of the Bay (Goals Project 1999, Collins and Grossinger 2004).

Several types of tidal marshland can be identified, associated with different physical settings and providing differing habitat types. To the north (San Leandro Creek to San Mateo Bridge), higher wave energy and steeper topography helped to create narrower marshes dominated by natural salt ponds, including Crystal Springs, and few tidal channels, formed behind barrier beaches (Atwater et al. 1979). South of San Mateo Bridge, the marshes were wider and had extensive tidal channel networks and marsh pannes. South of Dumbarton Bridge also had extensive tidal channel networks, with drainage divide pannes, and a band of natural salt ponds ("salinas") along much of the tidal-terrestrial transition zone (Beller et al. 2013).

Immediately inland of the baylands, terrestrial habitats supported on alluvial fans of adjacent creeks created a complex interface between tidal and terrestrial habitat types. Most of the tidal-terrestrial transition zone ("T-zone") was characterized by transitions between tidal marsh, seasonally flooded wet meadows, alkali meadows, and vernal pool complexes. Willow groves were also present at sites of perennially high groundwater (most notably near the mouths of San Lorenzo and Crandall creeks). In addition, a number of channels of varying sizes also intersected the tidal-terrestrial interface, from large creeks (e.g., Old Alameda Creek) to small sloughs or overflow channels.

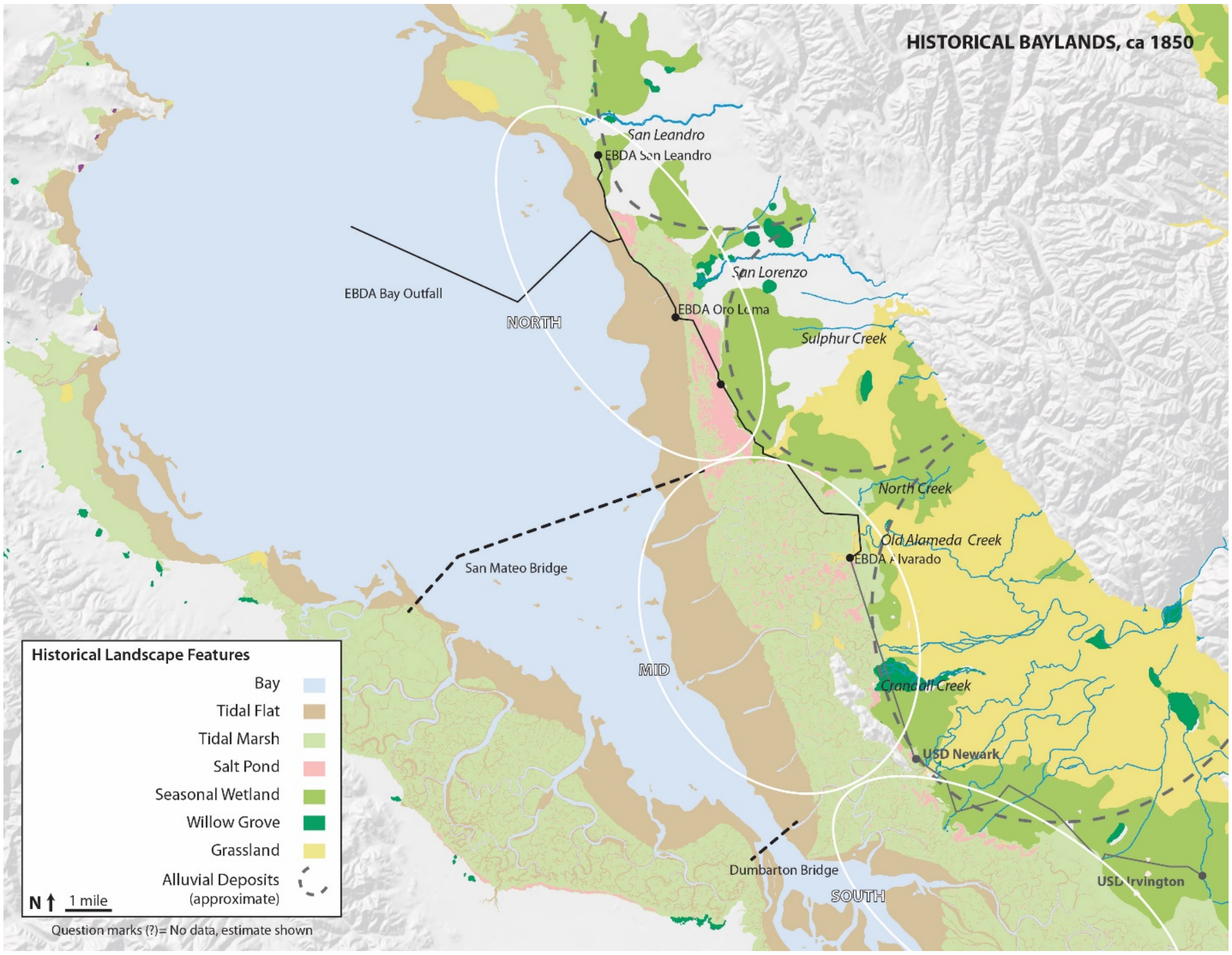

Figure 1. Historical Baylands, ca 1850. Distribution of habitat types within three natural landscape units (shown in white circles). Sources include: EcoAtlas (SFEI 1998) and Alameda Creek Watershed Historical Ecology Study (Standford et al. 2013) which draw on numerous historical documents.

Freshwater inputs to the baylands derived from a variety of sources, each characterized by a distinct flow volume, seasonality, and sediment load (Figure 2). Streams draining to the Bay ranged from major streams with large watersheds that intercepted groundwater in their lowest reaches (i.e., Alameda Creek) to moderately sized systems (e.g., San Lorenzo and San Leandro creeks), to small distributary channels or sloughs draining localized areas. Some of the smaller streams did not connect directly to the tidal marsh complex, and instead dissipated into alluvial fans and seasonal wetlands (e.g., Sulphur Creek). In addition to fluvial discharge, freshwater entered the baylands more diffusely across the landscape through groundwater (e.g., springs and seeps) and surface runoff (e.g., sheet flow). Some of these inputs contributed freshwater to the baylands year-round (for example, at the perennial mouth of Alameda Creek or where willow groves or springs were found). Freshwater inputs to the baylands were highly seasonal at mouths of intermittent creeks and areas adjacent to seasonal wetlands, with wetter conditions during winter months and dry conditions most of the year.

The quantity of sediment supplied to the baylands through each source also varied, with larger sediment inputs coming from streams with upland watersheds; surface runoff and groundwater sources contributed little or no sediment. Winter floods delivered large sediment loads and a freshwater pulse from the watershed to the tidal marshes.

These freshwater inputs were an important component of the bayland ecosystem, creating salinity gradients that added physical heterogeneity and ecological diversity to the bayland landscape. Though we have no strong characterization of the precise spatial extent and effects of freshwater flows on bayland ecology, it is clear that in many places lower salinities within the salt marsh produced freshwater/brackish plant communities that contributed significantly to the plant species diversity of the Estuary (Vasey et al. 2012, Collins and Grossinger 2004). A suite of fish species associated with fresh-brackish marshes was also likely found in these zones. (For example, Snyder (1905) found Splittail, Hitch, Thicktail Chub, Tule Perch in Coyote Creek, likely in an estuarine transition area (see Leidy 2007).)

The freshwater effect would have likely been greatest near the mouths of large creeks, which presumably had relatively broad gradients of freshwater influence compared to other tidal-terrestrial interfaces with more limited freshwater inputs. Even in locations with more diffuse or seasonal flow, however, a range of freshwater-brackish-saltwater conditions was likely historically present along the landward margin of the baylands – for example, seasonal ponding of fresh or brackish water in natural salinas. These areas would have provided a suite of wildlife functions including habitat, refuge, and migration corridors distinct from those provided in more saline parts of the baylands. Sediment delivery to tidal marshes from fluvial sources was also a key component of tidal marsh formation and maintenance, particularly during high flows when streams transported sediment from watersheds to marshes, allowing for natural sediment accretion and marsh establishment. Variations in sediment texture and volume across different input types also contributed to the physical complexity of the marsh plain.

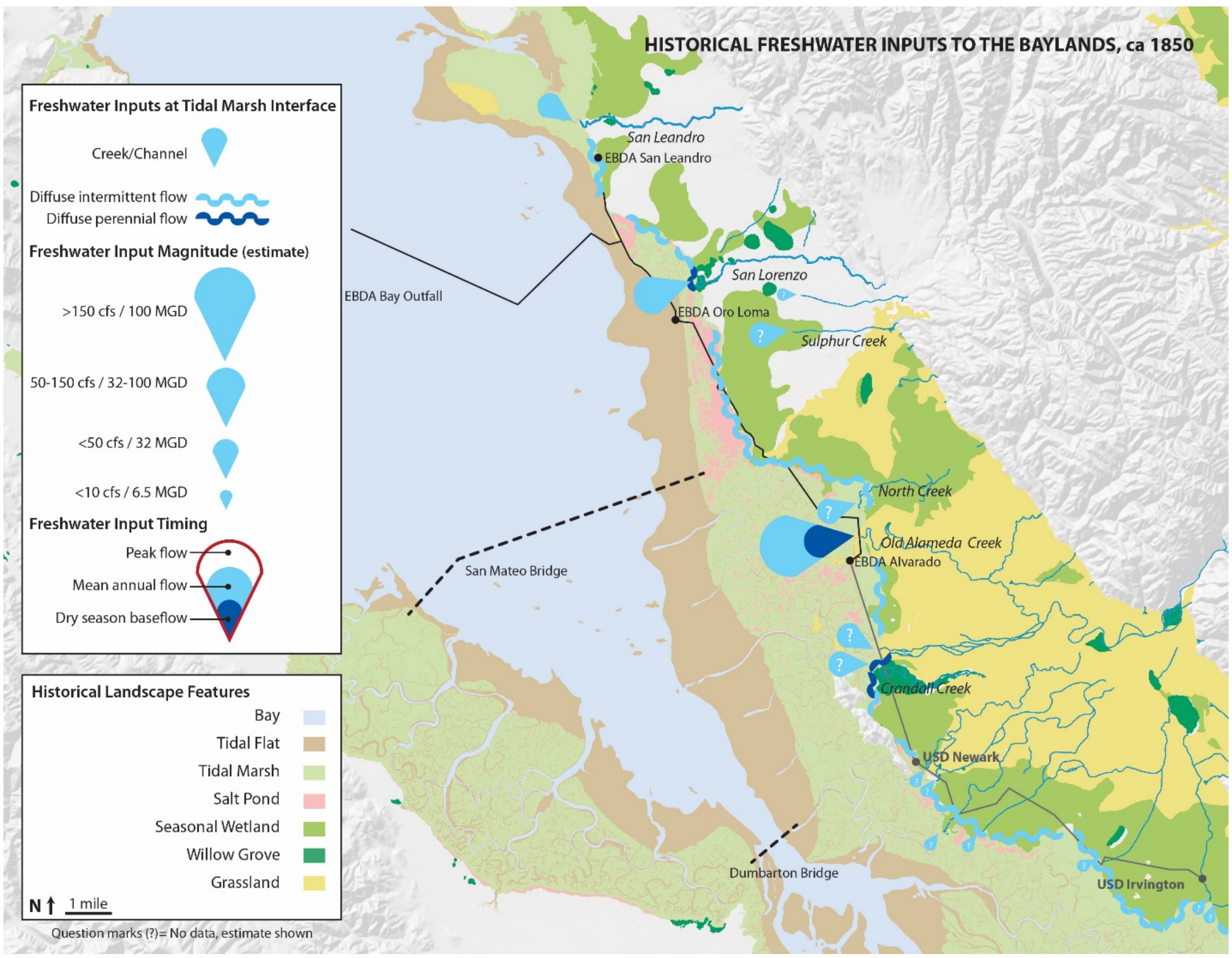

Figure 2. Historical Freshwater Inputs to the Baylands, ca 1850. Distribution and character of water delivered to the baylands from local watersheds under more natural conditions. Sources include: EcoAtlas (SFEI 1998) and Alameda Creek Watershed Historical Ecology Study (Standford et al. 2013) which draw on numerous historical documents. The historical freshwater input flows were obtained

from DWR (1923). Please note that historical stream flows are based on very limited data and streams without historical flow data are identified.

Contemporary Baylands Landscape

Relative to historical conditions, the extent and character of contemporary bayland habitats has been significantly altered (Figure 3). Much of the historical southeast Bay bayland habitat area has been converted to other land uses, including residential and commercial development, salt ponds, sewage treatment, and landfills. Transition zone habitats adjacent to the baylands have experienced similarly severe modifications due to the expanse of the urban landscape. Additionally, stream systems have been channelized, leveed, and dammed.

Due to land-use changes, freshwater sources, connection to the baylands, seasonality, and relative sediment loads have changed from mid-nineteenth century conditions. Current conditions now favor highly connected systems rather than diffuse inputs. Smaller distributary streams, which historically dissipated on alluvial fans or through freshwater wetlands, no longer exist. The historical locations of freshwater discharges have also been eliminated or shifted. Instead of streams discharging into the marsh or upland bayland interface, freshwater sources have now been paved over for development or re-routed to stormdrain networks carrying freshwater discharges past the baylands to the Bay margin. Channel leveeing has reduced freshwater connection to the baylands as stream flow now almost exclusively bypasses the baylands, further eliminating the historical extent of the fresh-brackish-saline mixing zone.

Modifications to the hydrologic regime have also altered the seasonality and magnitude of flows. Seasonality of freshwater flows has shifted from streams with summer-dry or low baseflow conditions historically to discharges now dominated by more consistent year-round flow. Dry season baseflows have generally increased due to additional water contributions from urban water uses. Peak flows have also increased due to urban development of the landscape. Upstream water storage has likely altered seasonal timing and reduced peak flows. Additionally, sediment loads have been altered from historical conditions by a variety of factors, including urban development, channel incision and aggradation, and upstream water storage.

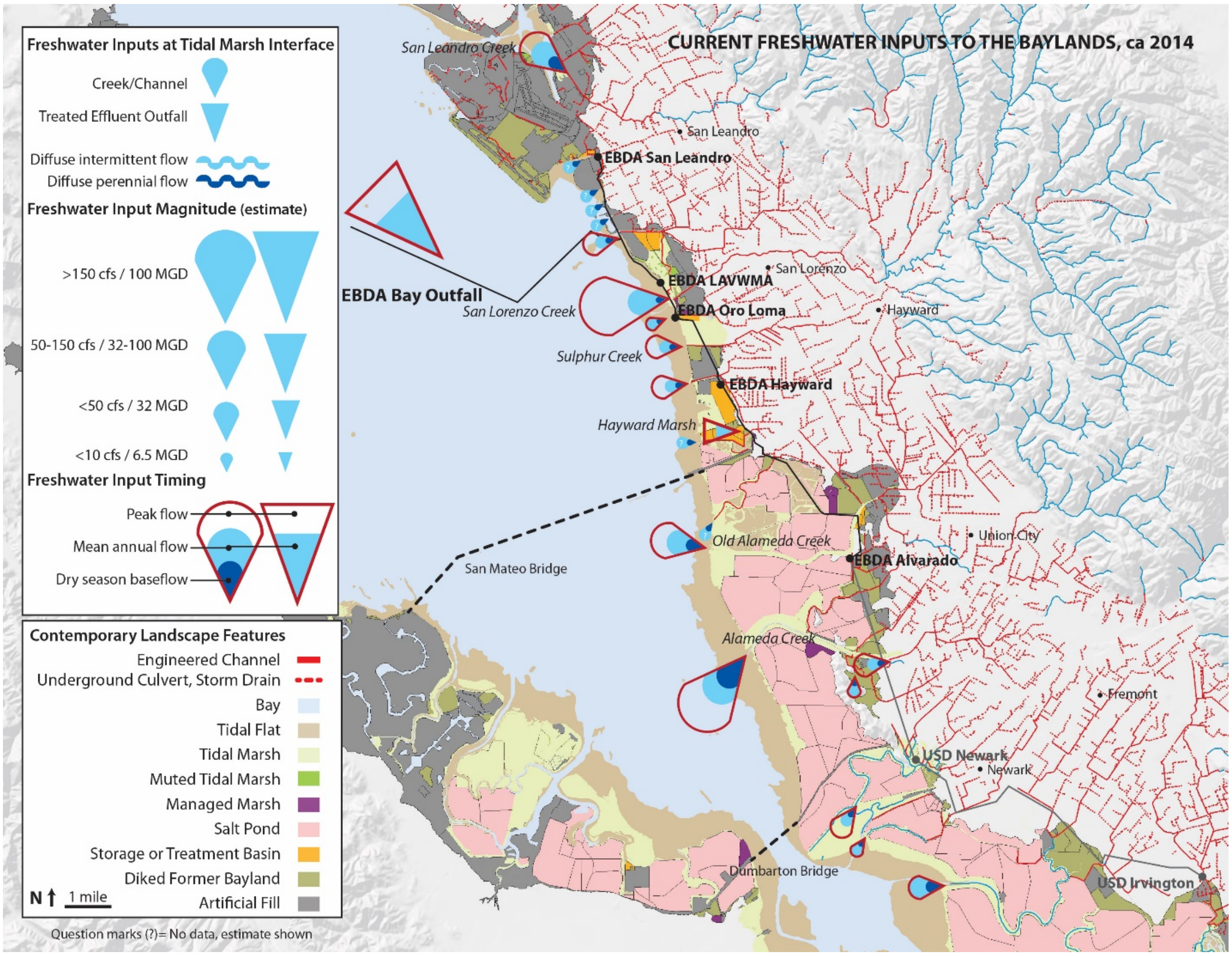

Figure 3. Current Freshwater Inputs to the Baylands, ca 2014. Alteration of freshwater inputs (both creeks and treated effluent) to the baylands. Sources include: Bay Area Aquatic Resources Inventory (BAARI; SFEI 2011) and EcoAtlas (SFEI 1998) for the contemporary baylands. For contemporary flow estimates, we used USGS gaged data for larger systems (e.g. Alameda Creek) and referenced Gilbreath et al. (2010) for estimates of smaller drainages. Channels and stormdrains were derived from Sowers (1996).

Table 1. Baylands Landscape Changes

	HISTORICAL	CONTEMPORARY	Considerations for Future Resilience
Freshwater Influence	• Flows highly seasonal/intermittent • A few large freshwater influence zones from large watersheds which disperse at the landward margin of the baylands • Smaller freshwater influence zones from small watersheds and groundwater discharge through springs or former alluvial fan channels • More diffuse inputs from overland flows	• Timing of flows more perennial • Highly connected systems which bring freshwater outputs directly to the Bay due to development/leveed channels • Less diffuse surface runoff as water is re-routed to stormdrain networks • Peak flows have increased with urbanization	• Disperse freshwater flows at landward margin of baylands • Find opportunities to mimic diffuse flow at freshwater wetland-tidal marsh interface
Salinity Gradients	• Salinity gradients contributed to a complex interface between tidal and terrestrial habitat types creating physical heterogeneity and ecological diversity to the landscape	• Fresh-brackish marsh zone reduced or eliminated	• Strategically re-introduce freshwater to tidal baylands to create larger brackish zones
Sediment	• Sediment from local watersheds enabled natural sediment accretion and marsh establishment • Large tidal flats at mouths of large tributaries • Sections had natural sandy beach/berm wave buffers	• Sediment supply reduced from dams, development, and lack of floodplain connection	• Re-establish sediment supply • Direct/re-distribute selected freshwater inputs (with sediment) to target tidal marshland areas for faster vertical growth • Re-establish beaches where possible or analogous constructed features (“landmass”)
Habitat Types	• Dominant large connected salt marsh • Intermixed pattern of brackish marsh zones and natural saltpond/salinas zones • Dry grassland and wet meadow transition zones associated with soil types	• Tidal marshland extent greatly reduced from conversion to other land uses • No natural salt ponds, now artificially managed	• Increased resilience with available natural areas and constructed horizontal levees • Widest natural marsh potential in South due to tectonics • Wider marsh potential between alluvial fans

Appendix A3 References

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Appendix A4. Regional Planning on the East Bay Shoreline

There are significant planning efforts being undertaken along the EBDA shoreline today through the South Bay Salt Pond (SBSP), BCDC's Adapting to Rising Tides (ART) project and the Baylands Ecosystem Habitat Goals Science Update (BEHGU). The SBSP project has made major progress toward Baylands restoration in the South Bay. It has completed long-term planning for this area as well as the first phase of restoration projects, resulting in over 3,700 acres of restored or enhanced habitats, and an overall new pond management regime designed to benefit wildlife. Phase 1 actions at the Eden Landing complex were focused on the northern half of Eden Landing (north of Old Alameda Creek). They included adding managed pond improvements to Ponds E12, E13, and E14; restoring Ponds E8A, E8X, and E9 to tidal marsh; adding a kayak launch into Mt. Eden Creek; and adding and improving several trails and interpretive features. Both ART and BEHGU look ahead over the next century to provide a vision of both future ecological restoration and enhancement but also start to identify the vulnerabilities and adaptation strategies that could accommodate future projections of climate change and accelerated sea level rise.

Based on how the systems function both past and present there are actions that are or should be incorporated into the future Baylands ecosystem to maximize resiliency:

- Pattern of freshwater influence zones and areas with freshwater influence with regard to native species
- Local and potential for natural or semi-natural salt ponds/Salinas and beach/berm systems
- Delivery of freshwater and sediment to maximize vertical accretion in response to accelerated sea level rise
- Import of sandy beach-natural salt pond systems to increase biodiversity
- Presence of a few large freshwater influence zones from large watersheds

- Additional smaller freshwater influence zones from small watersheds and groundwater discharge through Springs or former channels
- Extensive areas with no fluvial input creating Salinas zones
- Dry grassland and wet meadow transition zones associated with soil types

However significant constraints to the natural Baylands still exist. Invasive Spartina remains a challenge for the South Bay, especially as newly restored tidal areas are breached. There will be increasing development pressures and scarcer shoreline migration space. Regulatory and logistical hurdles complicate achieving regional sediment management, beneficial reuse of sediment in the Baylands, and the creation of broad transition zones.

BEHGU Landscape Vision

The Baylands Ecosystem Habitat Goals Science Update (BEHGU) identifies the need restore large tidal marshes as soon as possible and increase the resilience of existing marshes in the face of accelerating sea level rise. Given the large areas available for restoration and generally high sedimentation rates in the South Bay, the objectives are to prioritize tidal marsh restoration (including the creation of transition zones) and supplement local sediment availability to increase long-term shoreline resilience (including investigation of novel approaches to beneficial reuse). This would also include the connection of local tributaries more directly to and through the tidal Baylands and protect and restore riparian corridors and willow groves wherever possible.

BEHGU ("Goals Project Update"; report in preparation) identifies a number of future management actions:

- Connect all types of tidal marshes with wide corridors.
- Restore natural transitions from mudflat through tidal marsh to upland.
- Restore naturalistic, unmanaged saline ponds.
- Protect and enhance adjacent moist grasslands.

- Create broad transition zones adjacent to flood-risk management levees.
- Intersperse pond complexes, managed to optimize water bird support, throughout the subregion.
- Create eelgrass beds and oyster reefs where appropriate.
- Create coarse beaches where appropriate.

BEHGU identifies several opportunities on the EBDA shoreline to restore and enhance tidal habitats, and strengthen the habitat linkages between subtidal, baylands, creeks, and upland habitats. There also are opportunities to protect and restore other habitats such as moist grassland/seasonal wetlands adjacent to the Roberts Landing area, and several roosting sites. This segment is highly urbanized and constrained by development directly adjacent to the baylands. The Update discusses recommendations in terms of near-term (first half of the century, low rate of sea level rise) and long-term (latter half of the century, high rate of sea level rise).

- In the near term, when sea level rise rates will still be relatively low, actions that enhance the existing baylands and provide immediate ecological benefits maximize its resilience. There are some opportunities for landward migration of marshland, but in many locations it is likely that the fringing tidal marshes will drown as sea levels rise. However, opportunities exist to partner with the industrial and residential communities along the shoreline to develop green infrastructure which would create habitat bayward of their flood-protection levees ("horizontal levee", "living shorelines", "green infrastructure" concepts). There are opportunities for preservation, enhancement, and creation of diverse pocket habitats that could be linked together to create a sub-regional habitat corridor.

- In the long term, sea level rise rates will likely outpace vertical accretion rates and marshes in this segment generally do not have enough space to transgress upland to survive. Prior to that point, a plan for relocating the

> functions within the existing tidal marshes out of the hazard zone should be implemented. Creation of wetlands bayward of the flood protection levees, possibly using wastewater to enhance habitat on the slope, could provide space for upland transgression. Simply restoring tidal action to the managed ponds late in the century may result in the creation of deep tidal ponds close inshore; to alleviate this a process of 'warping up' of the

BEHGU discuss the possible use of treated wastewater to create freshwater and brackish marsh terrestrial t-zone habitat at the existing marsh complex at Oro Loma/Hayward Shoreline and in the Eden Landing Complex to provide dense, tall and extensive high tide cover for rail species, and attenuate tidal flooding and wave runup.

South Bay Salt Ponds (SBSP) Landscape Vision

There are significant opportunities to restore tidal marsh in former salt ponds in the Eden Landing area that are no longer used for production that will help create a continuous corridor of tidal marsh along the bayshore between Old Alameda Creek (OAC) and Alameda Flood Control Channel (ACFCC), as well as inland to the urban edge. The SBSP planning process has identified all ponds between OAC and ACFCC and a portion of the diked wetlands that are used by ACFCD as ponding areas and detention ponds before the stormwater is pumped into OAC as suitable for restoration.

Tidal restoration actions would include the reconnection of complex channel networks, incorporate topographic variation by placing material to mimic features such as natural levees and high ground transition zones and could incorporate shallow pans. Preliminary planning for flood risk management involves building up the existing berm at the edge of the Bay and using restored marshes to damp the incoming tides. To accelerate the accretion of the marsh surface in the moderately subsided ponds, dredge sediment could either be placed directly or placed on adjacent mudflats to be redistributed by wave and tidal action into the ponds.

Slopes to create elevation gradients and transitional zone between tidal marsh and adjacent upland areas could be created within existing ponds (prior to restoration) or adjacent to existing high ground and levees to provide buffer and high tide refugia as well as habitat in its own right. In addition, salinity gradients could be recreated by seeping treated wastewater effluent from the Union Sanitary District site through created transitional zones, to incorporate brackish tidal marsh. Old Alameda Creek and the Alameda Creek Flood Control Channel could be connected to the adjacent marshes by levee breaches or water control structures which accommodate fish passage, creating fish nursery grounds and allowing water, plant propagules and sediment to enter the marshes from the creek.

The Eden Landing Preliminary Alternatives Analysis Report (SBSP 2014) identifies a number of alternative concepts for the restoration between OAC and ACFCC. They include both Flood Risk Management components, such as levees, and Restoration components. A new approach under development by Alameda County provides coastal flood risk protection by means of

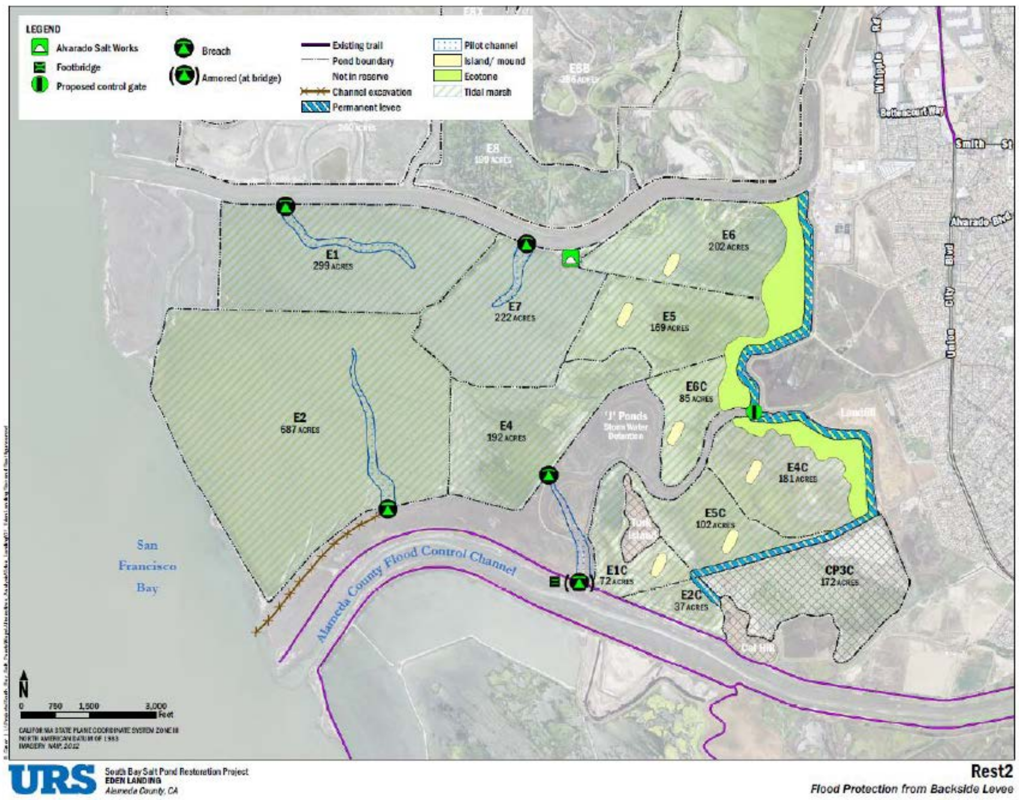
> a "land mass"—a wide and high earthen feature—that would be constructed along the existing outboard levees of Ponds E1 and E2. The land mass feature would be designed to preclude catastrophic failures that sometimes occur on traditional levee features and may also include a broad slope that provides habitat elements such as an upland transition zone (UTZ). The land mass would function like a barrier island.

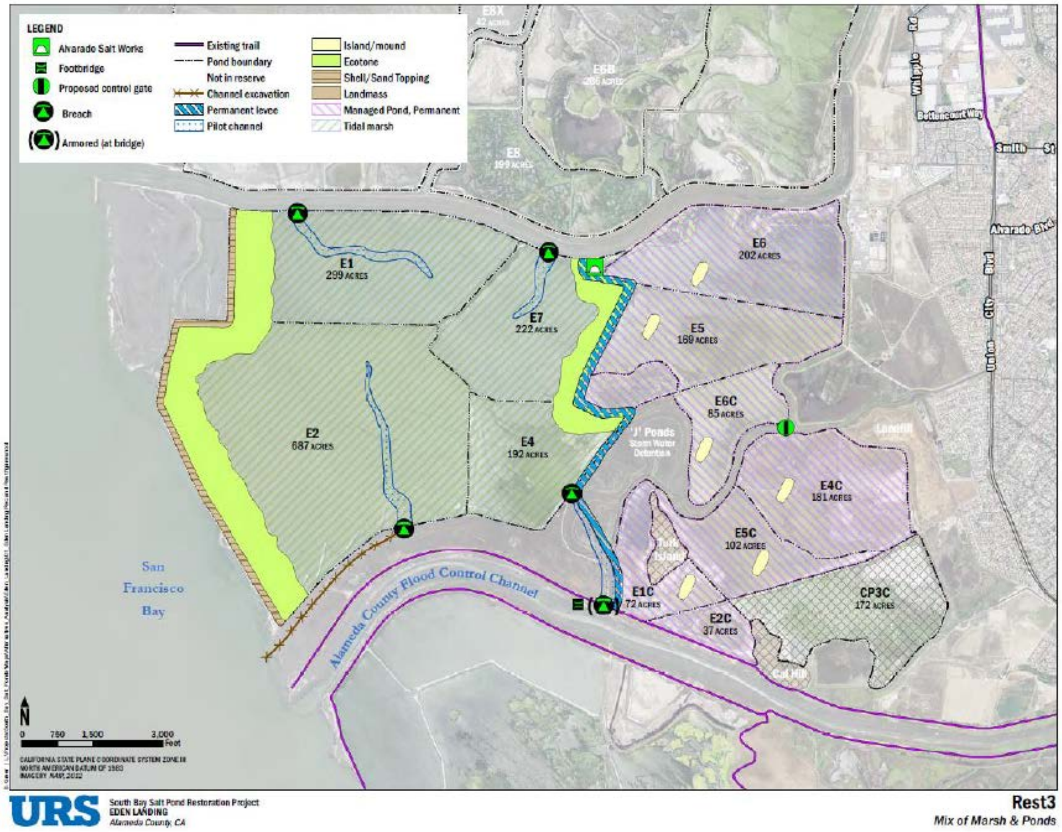
A significant restoration component that is discussed is the upland transition zone (UTZ):

> Another enhancement is constructing UTZs to increase flood protection, buffer against sea-level rise, and increase habitat diversity. There are options for UTZs in the Inland Ponds or the Southern Ponds if these become tidal marsh. However, if those pond groups are retained as enhanced managed ponds, then the UTZs would be built against the permanent version of the mid-complex levee within the Bay Ponds.

… water from the Union Sanitary District (USD) would be used to facilitate establishment of brackish marsh within portions of the ponds and/or native vegetation on the UTZs. (SBSP 2014, p 7)

Four proposed alternatives are shown in Figures 1 below.





Figures 1 a,b. Restoration and Flood Risk Management Alternatives.

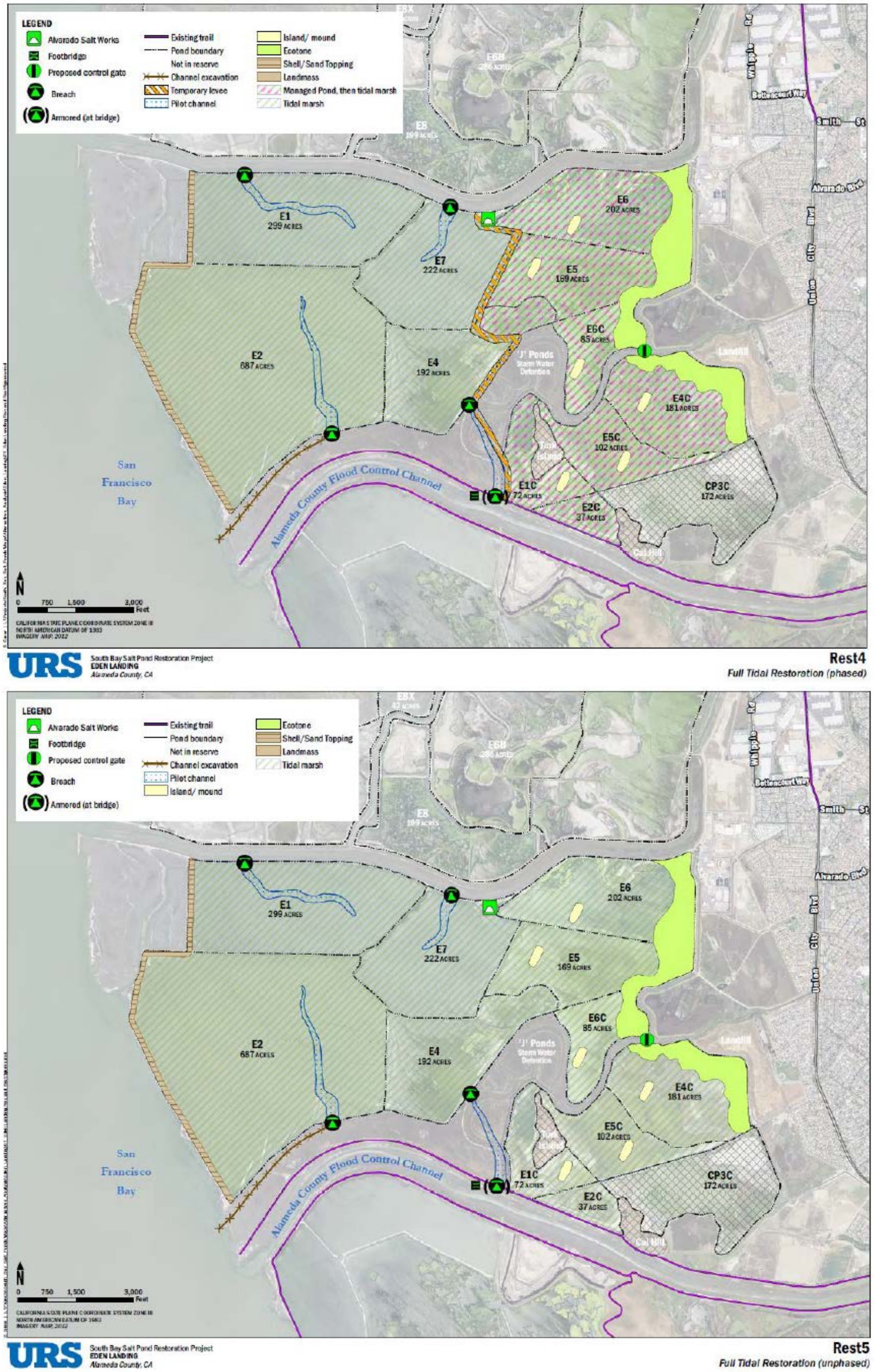


Figure 1 c, d. Restoration and Flood Risk Management Alternatives

ART Project Landscape Vision

The BCDC ART project discusses the vulnerability of both built and natural elements of the Hayward Shoreline. They make a series of recommendations for adaption which include for the EBDA system:

- *Complete a system-wide assessment on infrastructure condition.*
- *Complete study on decentralized alternatives to existing wastewater treatment and discharge practices incorporating stakeholder and expert input and technical review.*
- *Based on study results, conduct further feasibility analysis on select concepts and strategies.*
- *Based on feasibility analysis, plan for the future EBDA system as centralized or decentralized wastewater treatment and discharge and partner with EBRPD, HARD, ACFCWCD and the City of Hayward to investigate opportunities for long-term, coordinated, multi-benefit shoreline protection approaches. (ART 2014)*

For the natural system, such as Cogswell marsh, they predict to downshift from high marsh to mid marsh by mid-century and then to low marsh and mudflat by the end of the century. Backed by the Hayward Water Pollution Control Facility oxidation ponds, the marsh has no room to migrate landward to avoid being squeezed against steep levees by a rising Bay. Cogswell Marsh provides wildlife habitat and flood protection benefits that will not be sustained if the marsh downshifts to low marsh or mudflat. ART recommend:

- *Partner with HARD to engage resource managers and agencies, particularly the South Bay Salt Pond Restoration Project and California Department of Fish and Wildlife, to articulate shared goals, decision-making, and funding responsibilities for addressing sea level rise and storm event impacts on tidal marshes and managed ponds in the Hayward Regional Shoreline.*
- *Develop a marsh sea level rise adaptation strategy, form partnerships to monitor and identify when the marsh is approaching thresholds for possible*

interventions, and conduct hydrologic, geomorphic, and ecological analyses to determine the feasibility of possible interventions.

- *Partner with City of Hayward, EBRPD, HARD, and EBDA to investigate opportunities for long-term, coordinated, multi-benefit shoreline protection approaches that would maintain or create marsh habitat, improve flood control capacity in Zone 4, protect inland commercial and industrial areas from flooding, and reuse treated wastewater. ART (2014)*

In developing adaptation strategies for the Hayward shoreline, ART has created a number of conceptual alternatives to stimulate stakeholder discussion (Figure 2 and 3).

Figure 2. Traditional levee approach

Figure 3. Horizontal levee approach

Appendix A4 References

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

BCDC. 2014. San Francisco Bay Conservation and Development Commission: Adapting to Rising Tides.

SBSP. 2014. South Bay Salt Pond Restoration Project: Eden Landing Preliminary Alternative Analysis Report.

Appendix B. EBDA Workshop Participants

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Appendix C. Summary of Opportunities & Constraints DRAFT March 2015

Detailed below are the shoreline area opportunities & constraints focused on the main inflow locations to the EBDA CO transport system.

San Leandro (Oyster Bay) Shoreline

From San Leandro Pump Station and Oyster Bay shoreline in the north to the San Leandro Marina in the south. EBDA System: 4.9 mgd for re-distribution at San Leandro pump-station. Opportunity to focus San Leandro treated wastewater in the vicinity of Oakland Airport and Oyster Bay shoreline (and potentially disconnect EBDA line south of San Leandro Marina?).

Freshwater Opportunities

1. Water recycling: Irrigation of public open space and Metropolitan Golf Course; Potential to increase recycling to golf course(s) with water re-use/infiltration and potential to examine further stormwater/flood control system discharge

   BENEFITS- could contribute to state and regional water recycling requirements; EBRPD Oyster Point Turf irrigation; Potential Industrial water recycle users

2. Freshwater/Brackish marsh: Create freshwater/brackish marsh west of Metropolitan golf course

   BENEFITS- ~10+ acres of additional shorebird and waterfowl habitat; Transitional habitat from Bay to uplands

Other Ecological Opportunities

3. A. Restored Oyster Bay regional shoreline

   Opportunity to increase resilience to sea level rise from shoreline natural resource restoration, i.e., oyster beds, eelgrass beds, shoreline dunes and coarse beach

   B. Restored Watershed Connections

   Opportunity presented by tidal channel through bay fill at Estudillo FCC?

   C. San Leandro Marina to end dredging in 5 years- Opportunity for shoreline re-configuration?

Barriers/Constraints

1. Conflict between birds and adjacent airport operations
2. Historic Oyster Point landfill
3. Airport Marsh-patch size too small?
4. Limit/amount of marsh discharge of treated wastewater
5. Private landowners

San Leandro (Robert's Landing) Shoreline

From south of the San Leandro Marina to Robert's Landing at San Lorenzo Creek. EBDA System: 17.5 MGD for re-distribution from LAVWMA line. Opportunities to contribute to multiple benefit marsh, creek, flood control and shoreline restorations focused on Heron Bay, San Lorenzo Creek and Robert's Landing.

Freshwater Opportunities

1. Horizontal seepage levee: Construction of ~1.5 miles of nutrient processing (e.g., Pro tects vital infrastructure from tidal influence

   i. ~1.5 miles of nutrient processing (e.g. de-nitrification, nutrient sequestration)

   ii. Upland refugia during rising tides (e.g. salt marsh harvest mice)

   iii. Transitional zone to connect species between marsh and upland environments

   iv. Allows for tidal marsh migration inland in response to accelerated sea level rise

2. In-Stream flow: Lewelling Creek-permitted for peak wet weather flow to San Lorenzo Creek

   BENEFIT- Opportunity presented by existing tidal channel at San Lorenzo Creek through Bay fill supporting restoration of bay and upland connectivity

3. Wetland Discharge

   Potential Opportunity for expanded transition wetland habitats

Other Ecological Opportunities

4. Creation of coarse beaches

   BENEFIT-Contribute to shoreline protection

Barriers/Constraints

1. Species Regulation/Refuge
2. Multiple Existing utility corridor(s)
3. Shoreline erosion

Oro Loma Shoreline

From San Lorenzo Creek south to the southern edge of Oro Loma Marsh. EBDA System: 12.6 MGD available for re-distribution from Oro Loma pump -station. Opportunity to focus wastewater discharge on Oro Loma Marsh and support multi-benefit shoreline protection, flood control, and habitat and species restoration.

Freshwater Opportunities

1. Water recycling: Irrigation of Skywest Golf course; Stormwater and treated wastewater retrofit for increased storage and infiltration

   BENEFIT- could contribute to state and regional water recycling requirements

2. Horizontal seepage levee: Opportunity for horizontal levee discharge with upland habitats; Construction of 2.3 miles (from Bockman Canal south to Hayward Flood Control Canal; landward of Oro Loma East Marsh)

   BENEFITS-

   i. Protects vital infrastructure from tidal influence

   ii. ~2.3 miles of nutrient processing (e.g. de-nitrification, nutrient sequestration)

   iii. Upland refugia during rising tides (e.g. salt marsh harvest mice)

   iv. Transitional zone to connect species between marsh and upland environments

   v. Allows for tidal marsh migration inland in response to accelerated sea level rise

3) Marsh Discharge: Opportunity for marsh discharge

   BENEFIT-Contribute to managed freshwater discharges

   Potential Opportunity for expanded transition wetland habitats (Approximately 100 acres)

Other Ecological Opportunities

4. Restoring shoreline to take high stormwater flows?

   BENEFIT- would support flood risk management and storm protection

Barriers/Constraints

1. Utility Corridors
2. Historic Landfill (Sulfur Creek)
3. Amount of discharge at Oro Loma is too much for just horizontal levee release, will require releases to marsh/creek/flood control channel
4. Presence of saltmarsh harvest mouse in diked marshes
5. Alameda County FCWCD disposal site

Hayward Shoreline

From south of Oro Loma Marsh to Highway 92. EBDA System: 12.2 MGD available for re-distribution from Hayward pump station. Opportunity to focus wastewater discharge on Hayward shoreline marshes and managed ponds (and contribute to long-term water management)

Freshwater Opportunities

1. Water recycling:
   Possibly to increase water recycling to urban areas?
   BENEFIT-Could contribute to state and regional water recycling requirements
2. Brackish marsh:
   BENEFIT-Enhance flows at existing Hayward Marsh providing for managed freshwater discharges
3. Horizontal seepage levee: Construction of ~1.7 miles (from Hayward Flood Control Channel south to San Mateo Bridge; landward of existing oxidation ponds and Hayward Marsh)
   BENEFITS-
   i. Protects vital infrastructure from tidal influence
   ii. ~1.7 miles of nutrient processing (e.g. de-nitrification, nutrient sequestration)
   iii. Upland refugia during rising tides (e.g. salt marsh harvest mice)
   iv. Transitional zone to connect species between marsh and upland environments
   v. Allows for tidal marsh migration inland in response to accelerated sea level rise

Other Ecological Opportunities

4. Opportunity to increase habitat connectivity?

Barriers/Constraints

1. Historic landfill
2. Status of Marsh Ecological Health-Hayward Marsh has serious existing ecological problems, including sedimentation and presence of avian diseases (EBRPD and USD considering eliminating freshwater marsh?)
3. Preservation of bayfront public access must be integrated into plans
4. Plans for increased water recycling (City of Hayward and Industrial Users)

Eden Landing Shoreline

From Highway 92 south to the Alameda County Flood Control Channel. EBDA System: 25.1 MGD available for re-distribution at Alvarado pump station. Opportunity to focus Alvarado PS effluent on Eden Landing Ecological Reserve (and opportunity to disconnect EBDA line south of Hwy 92?)

Freshwater Opportunities

1. Brackish marsh: Re-route flows to Eden Landing Pond E6, possible connection to Old Alameda Creek

   BENEFIT-Increase marsh habitat patch size for clapper rails and salt marsh harvest mice

2. Horizontal seepage levee: Construction of ~4.6 miles (from San Mateo bridge south to Old Alameda Creek; landward of Eden Landing & from E6 to E3C)

   BENEFITS-

   i. Mimics historical diffuse freshwater flow at freshwater wetland-tidal marsh inter ace

   ii. Increase Fresh Water to back Marsh/Creek Complex

   iii. Provide connections between tidal marsh complexes…

   iv. Introduce uplands transition zone and habitats to EL complex

3. In-stream flow: Route additional flow to Old Alameda Creek channel

   BENEFIT-

   Benefits to estuarine fish?, additional seasonal habitat?

Other Ecological Opportunities

4. A. Creek connection to Baylands: Allow Old Alameda Creek to flow into adjacent bay lands

   BENEFITS-

   i. Re-establish sediment supply to Eden Landing to help marsh keep pace with sea level rise…Increase Freshwater and Brackish Water Marsh components

   ii. Mimic historical (1850's) freshwater flows at landward margin of baylands (rather than directly to the Bay)

   iii. increase habitat and species biodiversity through a larger brackish zone, Increase habitat diversity and habitat connectivity

   B. Bay to Upland and Watershed Connections: Support Creek and Watershed Restoration

Opportunities presented by tidal channels (3) through diked baylands at Old Alameda Ck and at the Alameda Flood Control Channel.

C. Potential to combine storm-water and wastewater detention and storage with hori zontal levee

Barriers/Constraints

1. Existing stormwater storage ponds
2. Preserve flood control and management capacities
3. Endangered Species-Snowy Plover and Salt Marsh Harvest Mouse (SMHM)
4. Utility and Flood Control Channel structures