The San Francisco Bay Living Shorelines: Nearshore Linkages Project

Coastal Conservancy

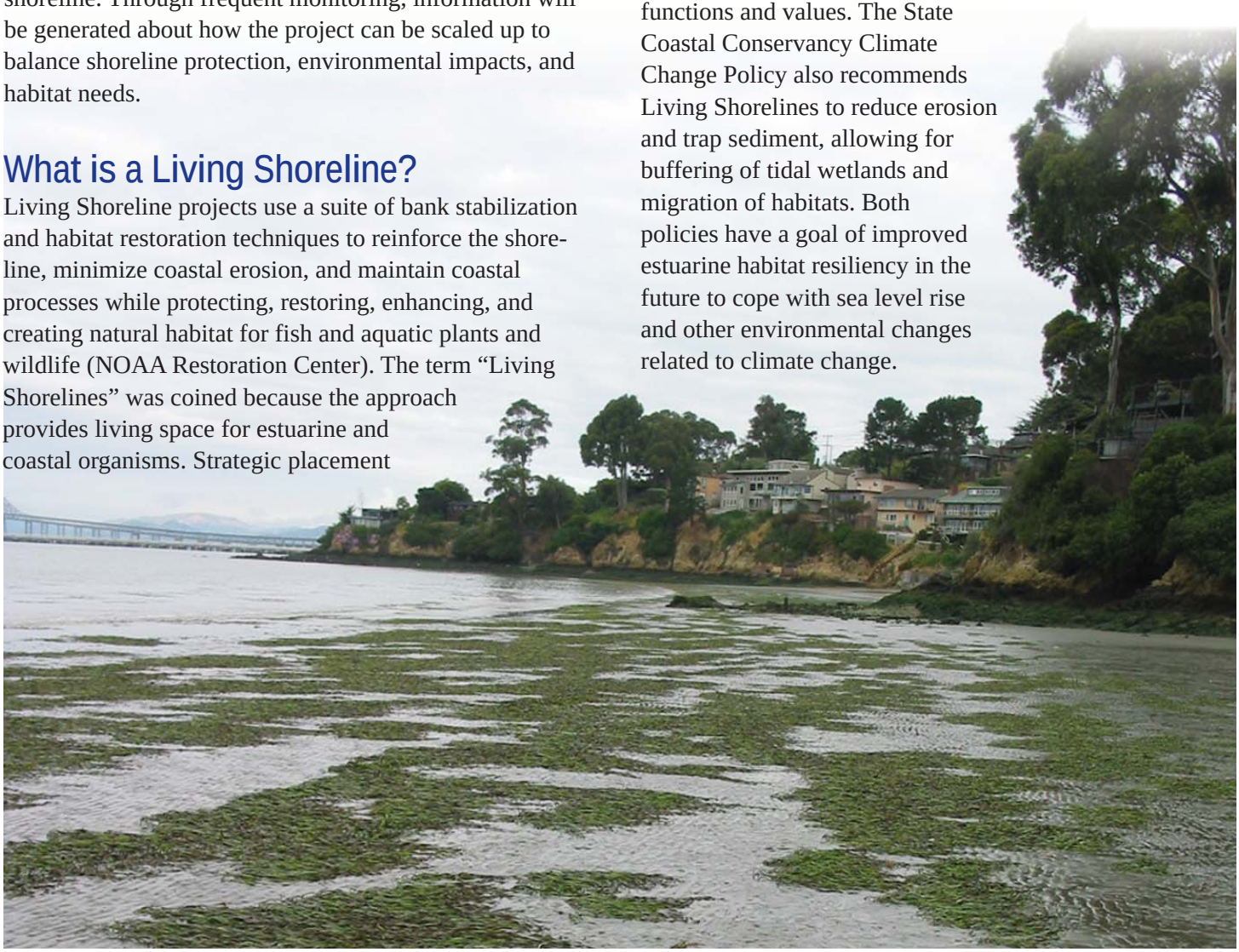
Restoration efforts in San Francisco Bay will advance in Summer 2012 as the San Francisco Bay Living Shorelines: Nearshore Linkages Project is implemented. The overarching project goal is to analyze subtidal restoration techniques and restore critical eelgrass and oyster habitat, while learning more about the potential physical benefits of biological reefs along the shoreline. An interdisciplinary team of scientists will test the effectiveness of restoration techniques on subtidal habitat values and begin to evaluate connectivity between submerged areas and adjacent tidal wetlands and creeks. This type of work is new to San Francisco Bay but will build on the lessons learned from other restoration efforts in the estuary and around the nation. The pilot project will be conducted in two locations: in San Rafael Bay and along the Hayward shoreline. Through frequent monitoring, information will be generated about how the project can be scaled up to balance shoreline protection, environmental impacts, and habitat needs.

What is a Living Shoreline?

Living Shoreline projects use a suite of bank stabilization and habitat restoration techniques to reinforce the shoreline, minimize coastal erosion, and maintain coastal processes while protecting, restoring, enhancing, and creating natural habitat for fish and aquatic plants and wildlife (NOAA Restoration Center). The term “Living Shorelines” was coined because the approach provides living space for estuarine and coastal organisms. Strategic placement of native vegetation, natural materials, and reinforcing rock or shell for native shellfish settlement enhance habitat values by creating new living space. The techniques also increase connectivity of wetlands and deeper intertidal and subtidal lands while providing a measure of shoreline protection. The approach has been implemented primarily on the East and Gulf Coasts, such as in the Chesapeake Bay and along the Alabama-Mississippi coastline.

Living Shorelines and Climate Change Adaptation

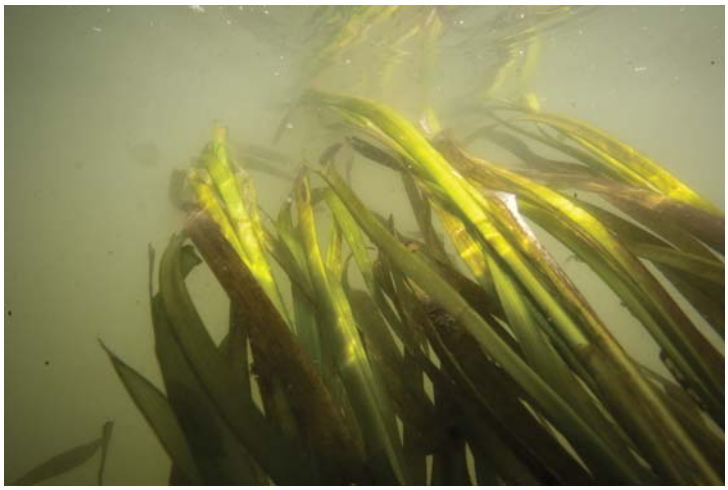
The California Climate Change Adaptation Strategy recommends the use of Living Shorelines as a potential adaptation method to reduce the need for engineered hard shoreline protection devices and to provide habitat functions and values. The State Coastal Conservancy Climate Change Policy also recommends Living Shorelines to reduce erosion and trap sediment, allowing for buffering of tidal wetlands and migration of habitats. Both policies have a goal of improved estuarine habitat resiliency in the future to cope with sea level rise and other environmental changes related to climate change.



Ecological Engineers: Eelgrass and Native Oysters

Eelgrass

Eelgrass is a foundation species that support diverse communities of invertebrates, fishes, and waterfowl and provides attachment locations for algae and encrusting invertebrates. Eelgrass is the most widely distributed seagrass in the Northern Hemisphere and occurs along the Pacific Coast of North America from the Bering Strait to lower Baja California. An estimated 3,400 km^2 of seagrass



have been lost globally between 1879 and 2006, largely due to human activities. The risk to vital habitat has generated much interest in slowing or reversing this trend. In the soft sediments of San Francisco Bay, eelgrass provides valuable ecological services, yet eelgrass beds cover less than 4,000 acres, or approximately 1% of submerged land in the bay [1,2]. Biophysical models estimate that nearly 30,000 acres of bottom area in San Francisco Bay may be suitable habitat[3].

Native Oysters

Native oysters, by attaching to hard substrates, form beds that increase living space for many other species, thus promoting increased diversity and providing food for fishes and other invertebrates. Historically, native Olympia oysters were an abundant and ecologically important part of the fauna and fishery in West Coast estuaries[4,5]. The popularity of the fishery that began in the 1850s and other habitat impacts resulted in the collapse of native oyster populations along the West Coast of the U.S. during the late 19th and early 20th centuries. The fishery was lost as were the key ecosystem services provided by native oysters.

Connecting the Pieces: San Francisco Bay Subtidal Habitat Goals

The 2010 San Francisco Bay Subtidal Habitat Goals Report (see www.sfbaysubtidal.org) recommends that the next generation of projects consider the possibility of integrating multiple habitat types to improve linkages among habitats and promote potential synergistic effects of different habitat features on each other as well as associated fauna. In addition, the South Bay Salt Pond Restoration Project includes multiple wetland restoration sites, and project leaders have expressed interest in the potential to integrate deeper habitats into the matrix of newly restored areas.

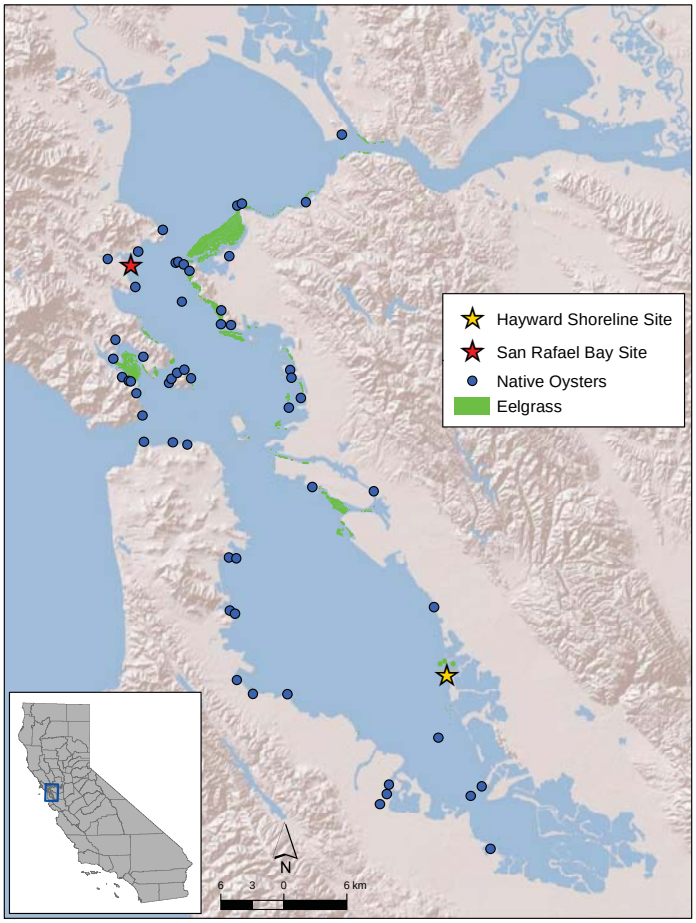
San Francisco Bay Subtidal Habitat Goals for Subtidal-Wetland Design Integration

Science Goals

1. Understand the ecosystem services supported by marsh subtidal integration and living shorelines, and in what quantities.
2. Develop best practices for integrating subtidal restoration with adjacent wetlands.
3. Develop best practices for pilot projects to create living shorelines.

Restoration Goals

1. Explore the integration of upland, intertidal, and subtidal habitats in San Francisco Bay.
2. Integrate habitat flexibility to increase resilience in the face of long-term change at habitat restoration sites around the bay.
3. Explore the use of living shoreline projects as a way to achieve multiple benefits in the future.



Living Shorelines in San Francisco Bay

While not a new concept, Living Shoreline projects are new to San Francisco Bay, where pilot restoration work on eelgrass and oyster reefs began in 2004. Several small-scale subtidal eelgrass restoration projects were established, coupled with extensive monitoring and genetics analysis from seven eelgrass beds in the bay. Native oyster monitoring and restoration efforts produced population data for more than 80 intertidal sites and data on substrate (surface) preferences. Successful restoration of tens of thousands of oyster recruits has occurred.

The San Francisco Bay Living Shorelines: Nearshore Linkages Project builds upon the successful methods and planning from earlier efforts to integrate oyster and eelgrass habitats. Resolutions to the constraints, timing, and design issues encountered in previous efforts have been merged with recommended regional initiatives to create uniquely designed San Francisco Bay Living Shorelines.

Overarching Project Goal

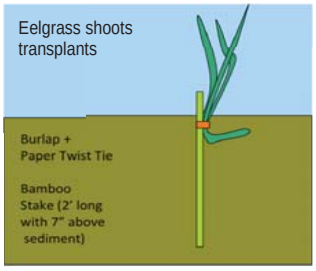
To create biologically rich and diverse subtidal and low intertidal habitats, including eelgrass and oyster reefs, as part of a self-sustaining estuary system that restores ecological function and is resilient to changing environmental conditions.

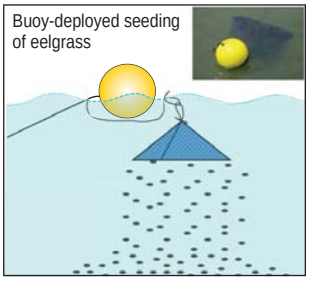
Objectives to Achieve Goal

1. Use a pilot-scale, experimental approach to establish native oysters and eelgrass at multiple locations in San Francisco Bay.
2. Compare the effectiveness of different restoration treatments in establishing these habitat-forming species.
3. Determine the extent to which restoration treatments enhance habitat for invertebrates, fish, and birds, relative to areas lacking structure and pre-treatment conditions.
4. Determine if the type of treatment (e.g., oyster reefs, eelgrass plantings, or combinations of oyster reefs and eelgrass) influences habitat for other species (e.g., fish) differently.
5. Begin to evaluate potential for subtidal restoration to enhance functioning of nearby intertidal mudflat, creek, and marsh habitats, e.g., by providing food resources to species that move among habitats.
6. Evaluate potential for living subtidal features to reduce water flow velocities, attenuate waves, and prevent erosion, and assess whether different restoration treatments influence physical processes differently.
7. Determine if position in the Bay, and the specific environmental context at that location, influences foundational species establishment, habitat provision, and physical processes conferred by restoration treatments.
8. Where possible, compare the ability to establish restoration treatments, habitat functions, and physical changes along mudflats/wetlands versus armored shores.

The Project Elements

Eelgrass Units





Eelgrass will be planted and seeded in 1.5 x 1.5 meter units. In each unit, 25 plants will be added as whole shoot transplants using a bamboo stake planting technique. Buoy-deployed seeding will supplement transplants and increase genetic diversity; flowering shoots of eelgrass will be placed into mesh bags attached to buoys, and ripe seeds will then drop onto the restoration site.

Oyster Substrate Units

Each oyster substrate unit will consist of four 1 x 1 meter elements, for an overall footprint of 4 m^2. Mounds of bagged oyster shell are the primary substrate to be used. In addition, several other substrates will be tested on a smaller scale.

Shell Bag Mounds

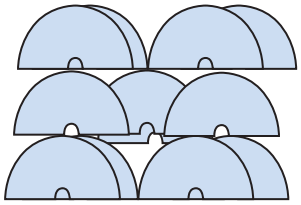
Bags of Pacific oyster shell have been successful in recruiting native oysters in several locations in San Francisco Bay. Shell bags at a restoration site in San Rafael Bay (Marin Rod and Gun Club) remain intact after 7 years and maintain a viable population of oysters, other invertebrates, and fish. The amount of surface area for juvenile oyster settlement and interstitial space in a bag of shells is larger than any other type of oyster substrate known to the oyster culture industry. The mesh covering affords some protection from predators while the oysters are small. The shell bag mounds will be set on top of coconut fiber coir fabric. We expect some settlement to occur, which will require additional shell bags to be added over time.

The next four methods involve constructing artificial reef elements from a mixture of roughly 80% native bay sediments (sand, clay, fossilized native oyster shell) and 20% cement. These oyster substrates will also be placed onto coir fabric. This design should reduce settlement into the sediment and scour around the treatments experienced in previous projects.

Dome Style Reef Balls

Reef Balls are in use in San Francisco Bay at two restoration sites: the Marin Rod and Gun Club (San Rafael) and Berkeley Marina (north of Cesar Chavez Park). Reef Balls are hollow with an open top that can be capped. They are relatively easy to install and remove and have been demonstrated to be successful in recruiting oysters.

Reef Ball Stacks



Reef Ball Stacks, which combine smaller, basketball-sized Reef Balls in a stacked configuration, create different sizes of interstitial spaces where oysters can grow. The domes are anchored to one another for stability and have the advantages of the single dome-style Reef Ball, but are easier to deploy and monitor. The project will test this type of structure for the first time in San Francisco Bay.

Layer Cakes

The Layer Cake design includes cross-sectional layers from a reef ball mold, and mimics naturally occurring rock structure. The amount of interstitial space is relatively large, particularly underneath the layer levels. These structures are easy to deploy and monitor. The project will test this type of structure for the first time in San Francisco Bay.

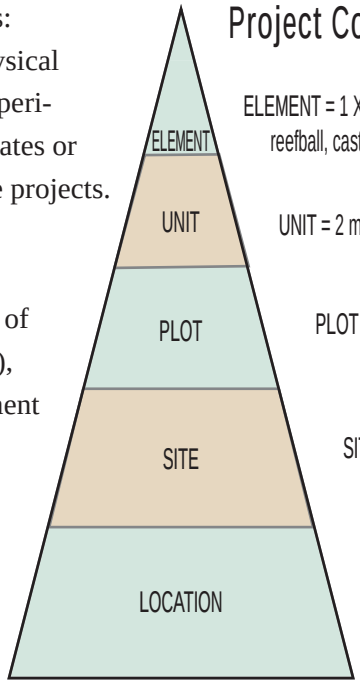
Reef Castles

Reef castles are structures built to any dimension as an assortment of vertical and horizontal surfaces. They are relatively inexpensive and easy to assemble. Reef castles have less three-dimensional surface area than shell bags but are more complex than other reef designs, which may enhance oyster recruitment by providing more interstitial space. The project will test this type of structure for the first time in San Francisco Bay.

Experiment Descriptions

The project is composed of two types of experiments: "Larger scale" experiments to test biological and physical effects of treatment plots, and smaller "substrate" experiments to test the biological effects of different substrates or surfaces that could be used on a larger scale in future projects.

Project Components



ELEMENT = 1 X 1 m square of eelgrass, shellbag mound with reefball, castle, or layercake

UNIT = 2 m x 2 m of 4 elements

PLOT = 32 m x 10 m arrangements of units and space between units

SITE = arrangement of four plots parallel to shore; may contain both large scale and substrate element experiments

LOCATION = place where experiment is conducted, either San Rafael Bay or Hayward Shoreline

Larger Scale Experiment

The larger scale experiment will compare the effects of one type of native oyster substrate (oyster shell bags), eelgrass, and a combination of the two. This experiment will be large enough to examine effects on physical processes such as wave attenuation and sediment accretion as well as effects on biological activities (e.g., bird and fish utilization, water quality, interactions of oysters and eelgrass).

Four large treatment plots (32 meter x 10 meter each) will be situated along a line parallel to and approximately 250 meters from the shore. The four plots will each have their own treatment: an oyster shell bag treatment, an eelgrass treatment, a treatment with both oyster shell bags and eelgrass, and a control plot with no treatment. Oyster units will be separated by 2 meters to minimize scour potential. In the combined eelgrass-oyster treatments, eelgrass will be added to the oyster arrangement, creating a denser treatment plot.

Substrate Experiment

The substrate experiment will compare native oyster recruitment and growth for different oyster substrates to inform future restoration projects. Single oyster substrate elements (1 meter x 1 meter each) of different types will be lined up parallel to the shoreline with 4 or 5 meter spacing, depending on the project site. The emphasis is on the biological response in this smaller-scale experiment.

Site Selection Criteria

Highest priority	*Very important*	*To achieve if possible*
Appropriate region and depth for eelgrass and oysters	Large enough shoreline, oriented so that treatment array can be placed parallel to the shore and perpendicular to the direction of waves	Multiple locations to provide replication and allow comparison of treatment effects in different regions
Appropriate sediment for oyster reefs and eelgrass	Distance to shore amenable to shore access for ease of monitoring	Same experimental design and depth if multiple locations
Willing landowners with expected reasonable time frame for permits/ approvals		Soft shoreline with paired comparison to hard shoreline nearby, if possible

Location #1: San Rafael Bay

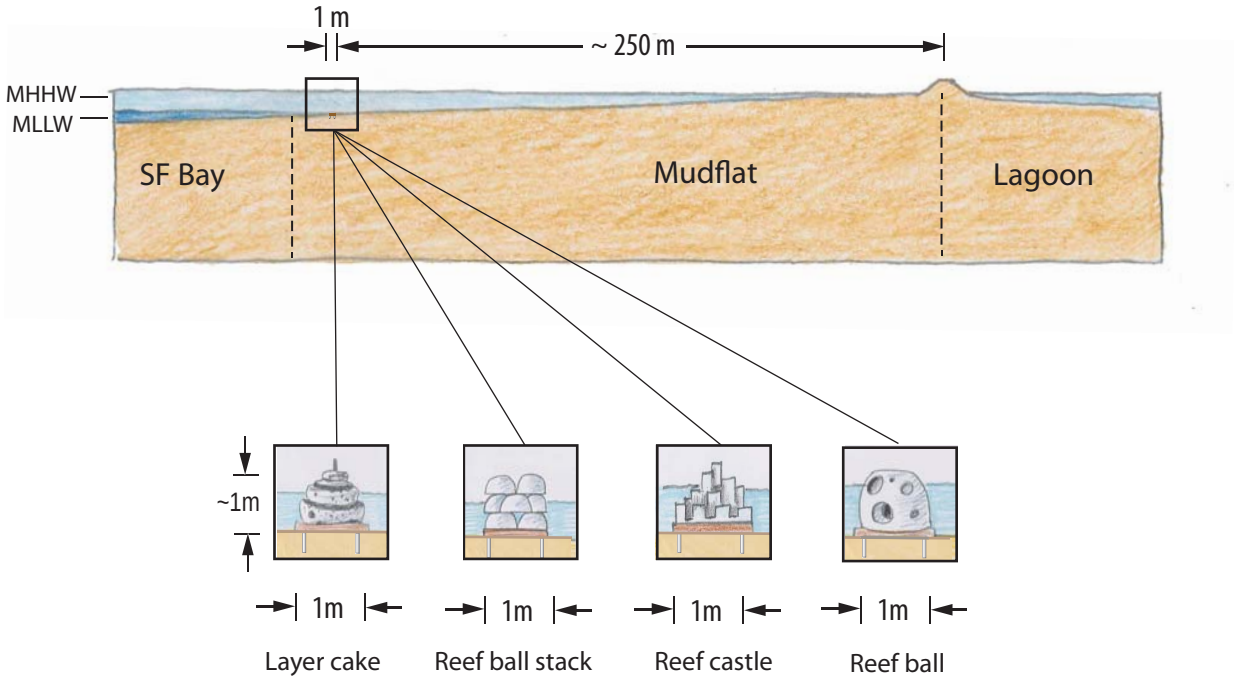
San Rafael Bay lies between Point San Quentin to the south and Point San Pedro to the north, and is a wide, shallow mudflat. This mud, which was deposited in the 1800s during the hydraulic mining period, is slowly degrading and appears to be approaching conditions prior to mining.

The San Rafael Bay project location is in a coastal area owned by The Nature Conservancy, and is subject to the mixed semi-diurnal tides typical to San Francisco Bay. The east-southeast orientation of San Rafael Bay provides protection from the easterly summer sea breezes, and exposure to the southeasterly winter storms. The Marin Islands National Wildlife Refuge protects the site from direct wave action from the east, out of the more exposed portions of San Pablo Bay. The shoreline near the project site is also affected by ship, boat, and seaplane landing wakes.

The project location allows the experiments to be conducted near an armored shoreline. Native oysters are abundant on the lower rip-rap along the shoreline, and eelgrass test plots have been successful on this property over the last 4 years. Both eelgrass and native oysters have been successfully restored nearby at the Marin Rod and Gun Club. Herring often spawn along this shoreline and should benefit from restored subtidal habitat.

Substrate Elements at San Rafael Bay

Cross Section

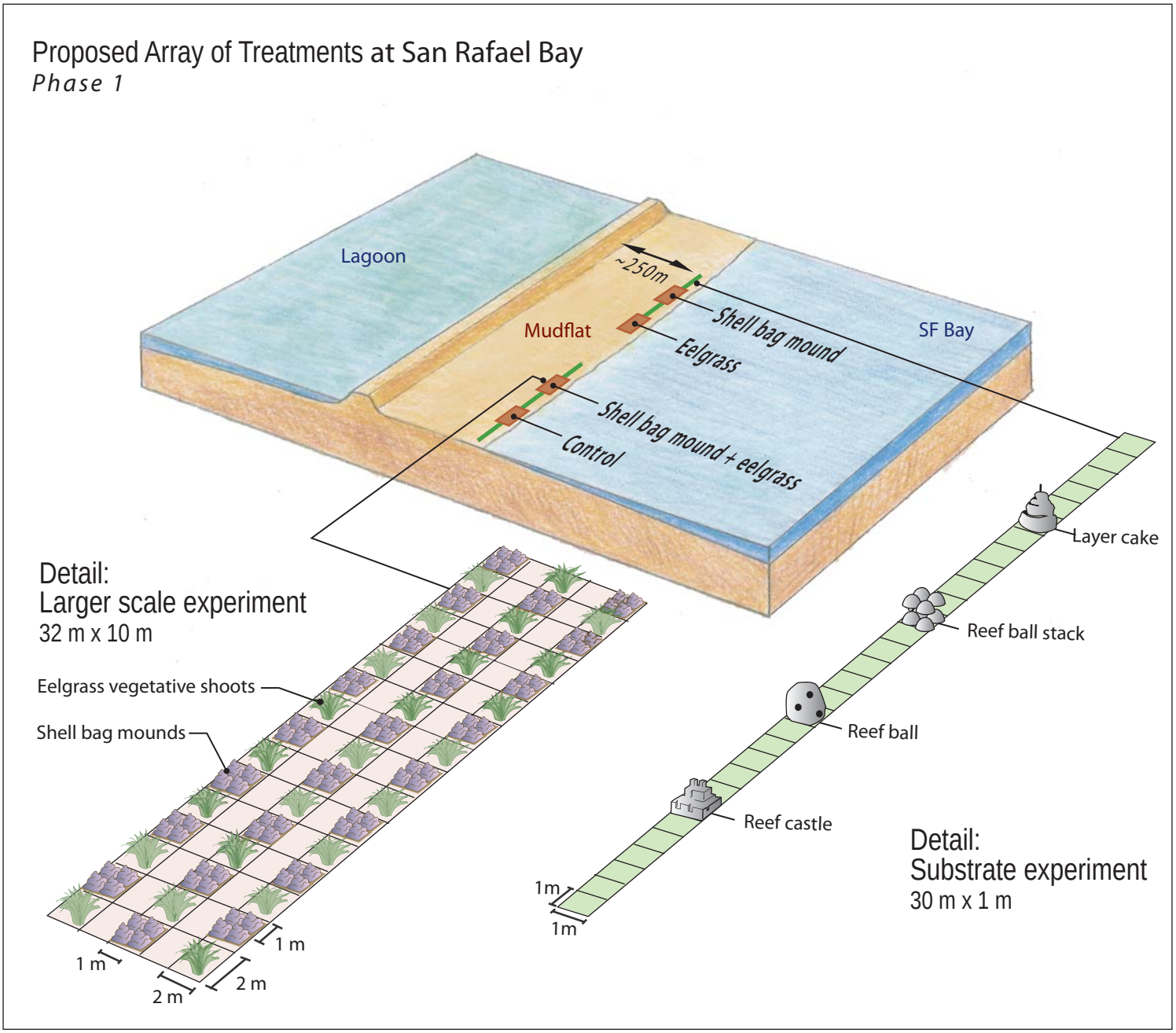


Note:

Schematic representation, not to exact scale

San Rafael Bay Location Experiment Details

At this location, both the larger scale and substrate experiments will be conducted. The substrate experiments will be set up in the 30-m spaces between and on either side of the line of the larger scale plots. The four oyster substrate types not tested in the larger scale experiment (reef balls, reef castles, mini-reef balls, layer cakes) will be replicated 5 times, for a total of 20 elements. These elements will be placed in blocks of four, with each of the four substrate types represented once in each block.



Location #2: Hayward Shoreline

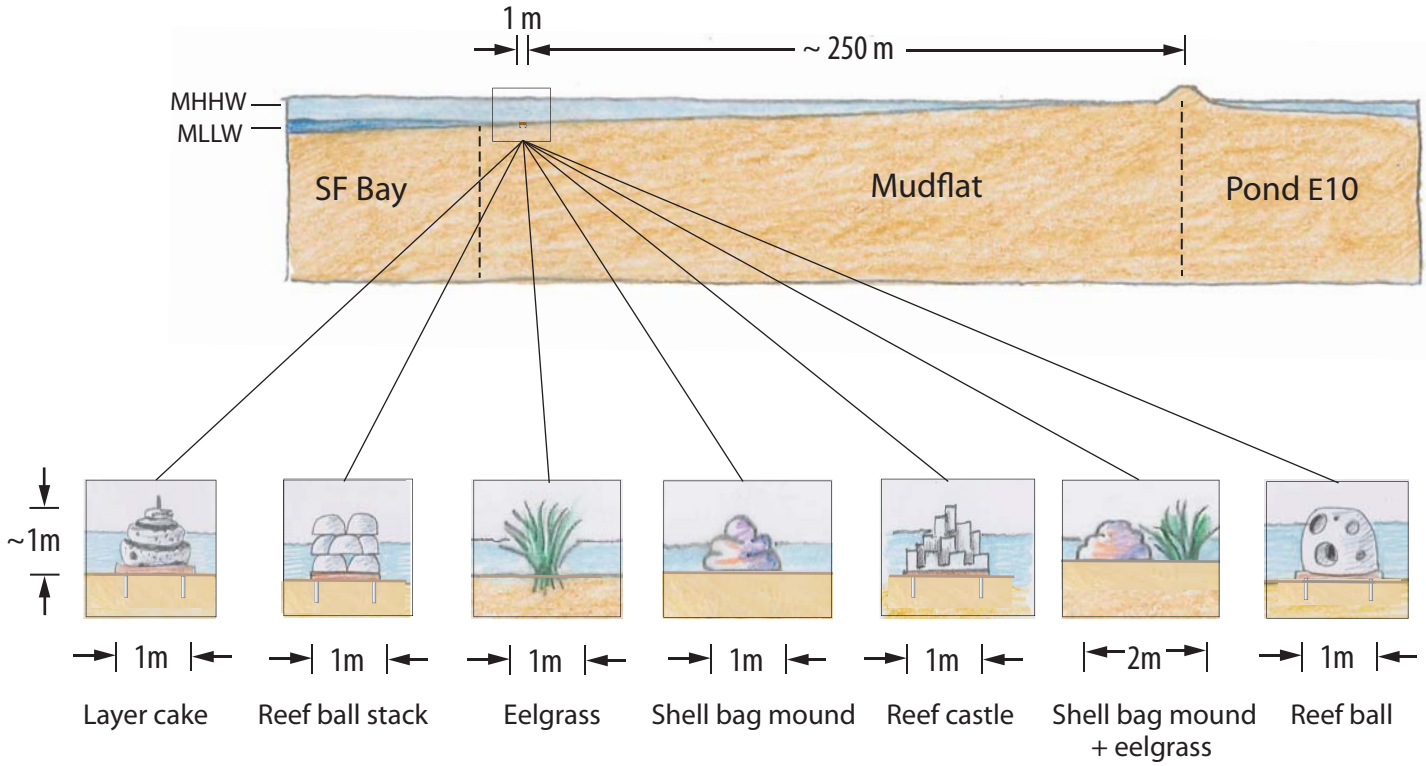
The South Bay is a large shallow basin, with an inundated, deep, relict river channel surrounded by broad shallow mudflats, small areas of fringing tidal marsh and expansive shoreline armoring. The areas between mean high and low tide contain a network of small branching channels that effectively drain the South Bay at low water, leaving an expanse of exposed mudflats. Over the past 150 years, the subtidal and intertidal flats along the east shore of the South Bay have eroded, feeding depositional areas elsewhere across the estuary.

The Hayward Shoreline project location is near the eastern shore of South San Francisco Bay near the San Mateo Bridge where it is subject to mixed semi-diurnal tides and open to prevailing winds and waves. The intertidal flats are considered "sovereign land" held in public trust by the California Wildlife Conservation Board. The project location is adjacent to the Eden Landing Ecological Reserve (ELER), a 6,000 acre pond complex that includes Old Alameda Creek, Mt. Eden Creek, North Creek, and the Alameda Creek Flood Control Channel.

North of Mount Eden Creek, the shoreline is riprapped, while to the south, Whale's Tail Marsh provides a softer adjacent marsh edge. Native oysters have been found on limited hard substrate in the area, and eelgrass grows nearby. This location is a shallow mudflat that extends bayward for more than a mile, and the depth from shore is a bit shallower than might be ideal for native oysters and eelgrass. Thus, a phased approach is planned that will permit understanding more about this site's potential before deploying the larger scale treatment plots in a future phase.

Substrate Elements at Hayward Shoreline North

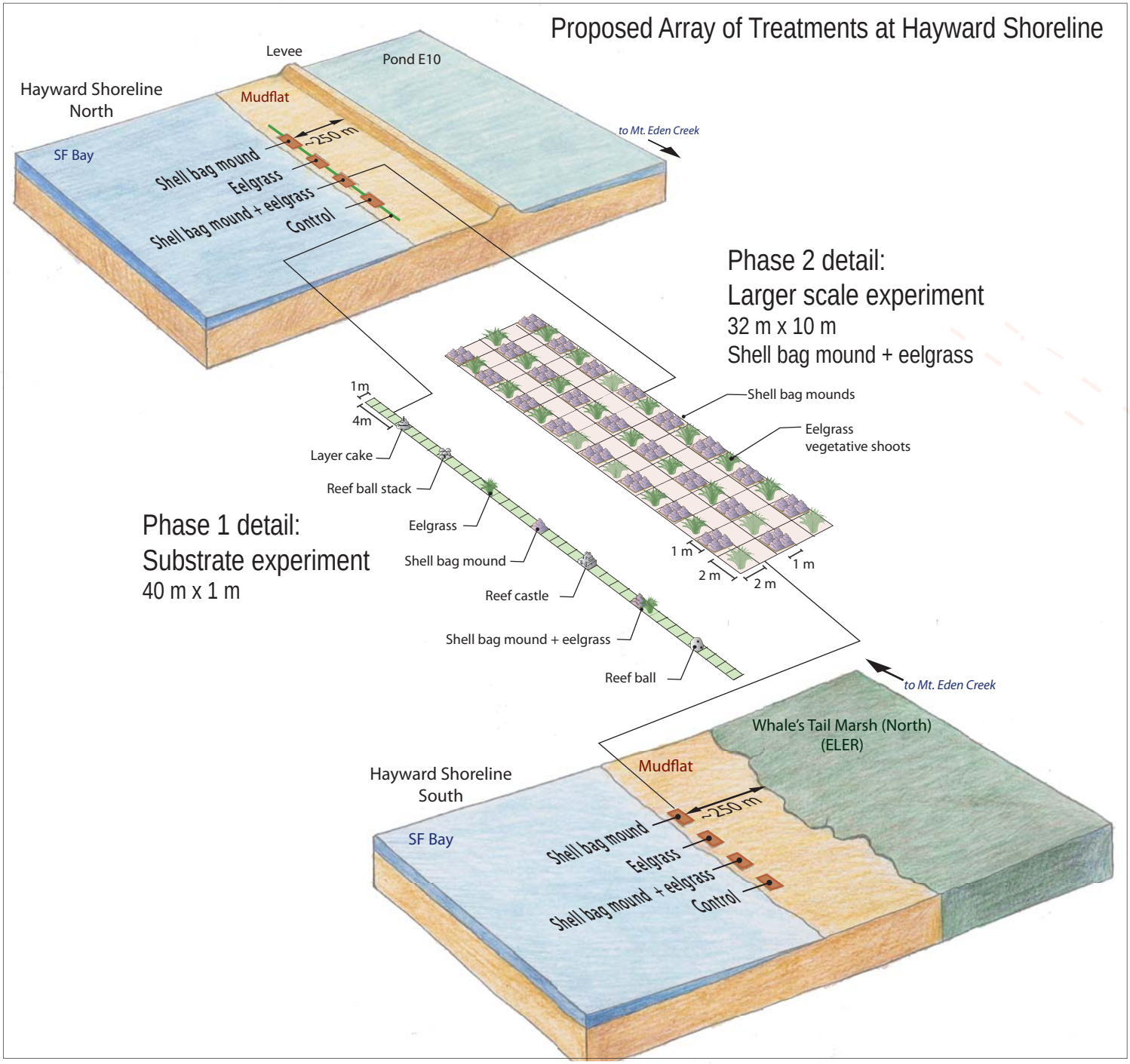
Cross Section



Hayward Shoreline Location Experiment Details

The project will occur in two phases at the Hayward site. Phase 1 will consist of the substrate experiment only, to evaluate recruitment of native oysters, eelgrass, and their associated communities, and assess the stability of the heavier oyster elements. All five oyster substrate types will be tested as well as an eelgrass-only treatment and an eelgrass-shell bag mound combination, all replicated five times. This phase will be north of the Mt. Eden Creek mouth along the hard shoreline.

Pending the successful outcome of Phase 1 (planned for summer 2012), and adapting the experiment design as necessary, the larger scale experiment would be installed in Phase 2 (planned for summer 2013). Phase 2 would be placed north and south of Mt. Eden Creek along both the hard and soft shorelines.



Potential Impacts

The small amount of disturbed habitat and the habitat-promoting nature of the project make it unlikely to adversely affect endangered and threatened species. Since the project is located offshore, no adverse impacts are expected for non-aquatic species. Also, by design, recreational use of the bay near the project locations is not anticipated to be affected.

San Francisco Bay and its freshwater tributaries are home to a number of endangered and threatened fish, including species of steelheads, smelts, and salmon. Construction activities are not expected to adversely affect these species at either project location. Waterbirds and shorebirds will be able to avoid construction crew and boats. Marine mammals may forage in the project location, but there are no haul-out sites nearby. During construction, the seabed will be temporarily disturbed, which may impact benthic habitats. However, once installed, the oyster elements and eelgrass plantings will allow for a more diverse habitat and support the colonization of native oysters, eelgrass, and myriad other organisms.

Any impacts from monitoring will be small and temporary. Nearby mudflat habitat is abundant, so shorebirds will not have to move far to forage while the team members are monitoring. Fish traps, which have been used for similar research in San Francisco Bay, are not expected to trap endangered species. Monitoring physical processes will have little if any impact on the biota.

Monitoring

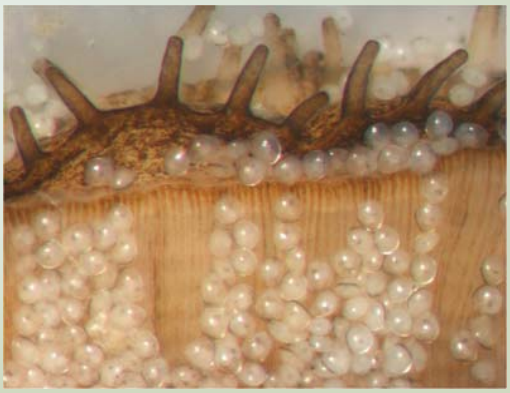
Before the project begins, bathymetric surveys are planned to establish baseline conditions. Other pre-project monitoring will include collecting sediment cores to assess benthic invertebrate species richness and density and observing bird, fish, and epibenthic invertebrate use of the site before construction activities occur.

After the experiments have started, biological monitoring of eelgrass and oysters will track growth rates, densities, and recruitment in the different treatments. Traps, suction sampling, and coring will be used to assess fish and invertebrate responses while waterbird and shorebird densities and behaviors will be tracked. The physical processes monitoring will focus on changes to waves, currents, and sedimentation/erosion rates at the larger scale experiment treatments only. Water properties will also be measured, including temperature, salinity, pH, dissolved oxygen, and turbidity.

Success Criteria

The larger scale project and substrate experiment projects are expected to provide lasting habitat for numerous organisms in the high subtidal to low intertidal zone. Natural interannual cycles will cause variation in densities of desired organisms but the project will be deemed successful if one or more of the following criteria are met within the 5-year period following construction:

- Native oysters will recruit, with densities of >10,000 oysters per acre of substrate.
- Invertebrate species richness will increase by 15% relative to control plots with no physical structure and initial cores collected prior to construction.
- The number of visits by fish species to the larger scale project will increase by 50%, relative to pre-construction visits and the large control area with no physical structure.
- Eelgrass will establish and spread to at least twice initial planting densities.



Permitting

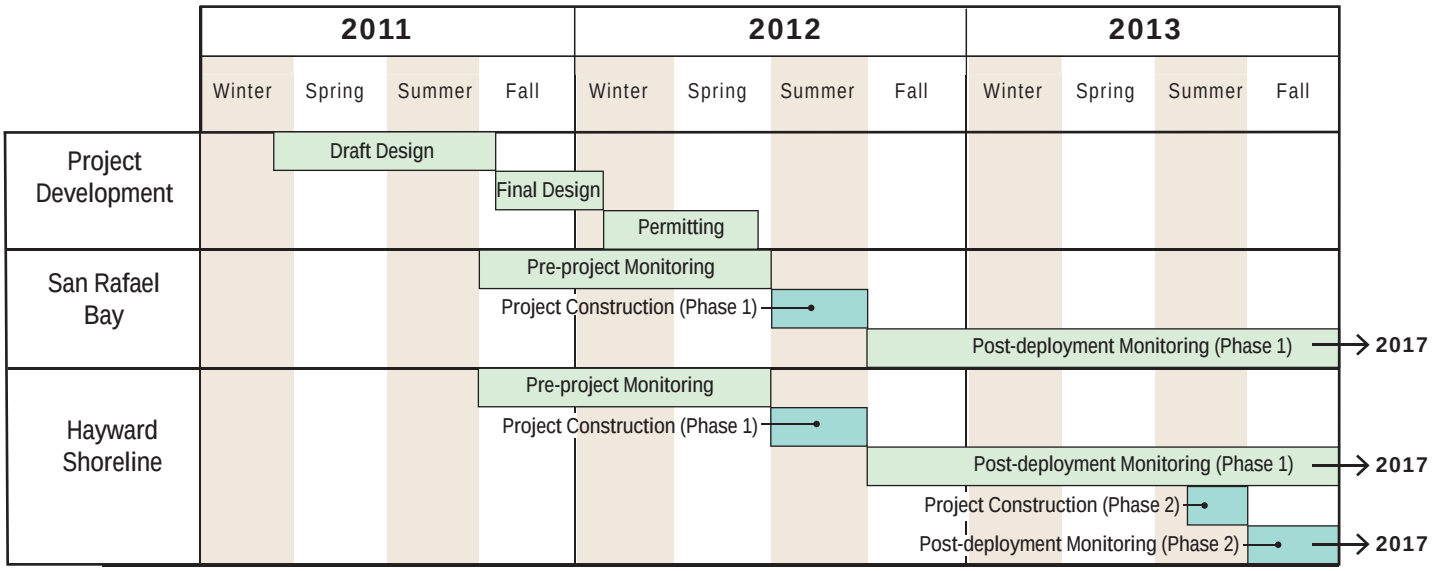
The State Coastal Conservancy looked to other restoration efforts for guidance about regulatory overview to bring Living Shorelines to San Francisco Bay. Project managers used a Joint Aquatic Resource Permit Application (JARPA) to engage several federal and state agencies simultaneously. Questions regarding bay fill, impacts to existing wetlands, interference with navigation, and public access and notices were addressed during the consultation process.

Regulatory agencies for this project include the San Francisco Bay Regional Water Quality Control Board (RWQCB), US Army Corps of Engineers (Corps), CA Dept of Fish and Game (DFG), National Marine Fisheries Service (NMFS), San Francisco Bay Conservation and Development Commission (BCDC), and State Lands Commission (SLC).

Partners

The project is being managed by the State Coastal Conservancy, in collaboration with funding partners including the Environmental Protection Agency, San Francisco Estuary Partnership, Wildlife Conservation Board, and NOAA Fisheries. Consultants leading the project include San Francisco State University, UC Davis, USGS Western Ecological Research Center, ESA PWA, ENVIRON, and Isla Arena Consulting.

Timeline



Volunteer Opportunities

We welcome community volunteers to participate in monitoring activities with the project. Please contact Project Manager Marilyn Latta if you are interested.

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Photo credits

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- San Francisco State University, Romberg-Tiburon Center for Environmental Studies (Wim Kimmerer, Katharyn Boyer's lab)
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