Corte Madera Baylands

Conceptual Sea Level Rise Adaptation Strategy

Baylands that provide the first line of defense against coastal flooding along the San Francisco Bay shoreline are vulnerable to sea level rise, and measures will be needed to proactively manage them to improve their resilience.

Callaway (2012)

This project sheds new light on the flood risk reduction benefits baylands provide, and the specific measures that could be used to help maintain this and other key ecosystem services.

Intertidal mudflats and tidal marshes around San Francisco Bay (referred to as baylands) serve as a buffer between the Bay and shoreline development. As waves move across these relatively flat areas of shallow water, wave height and energy are reduced. This wave attenuation helps protect inland coastal communities from flooding that could result from overtopping or failure of shoreline structures such as levees, berms and revetments. The measurements and modeling conducted in this project inform the discussion of how preserving, enhancing, and restoring baylands can reduce future costs for repairing or raising structural shorelines in the face of sea level rise.

The resilience of baylands to sea level rise depends on their capacity to build upwards or move landward.

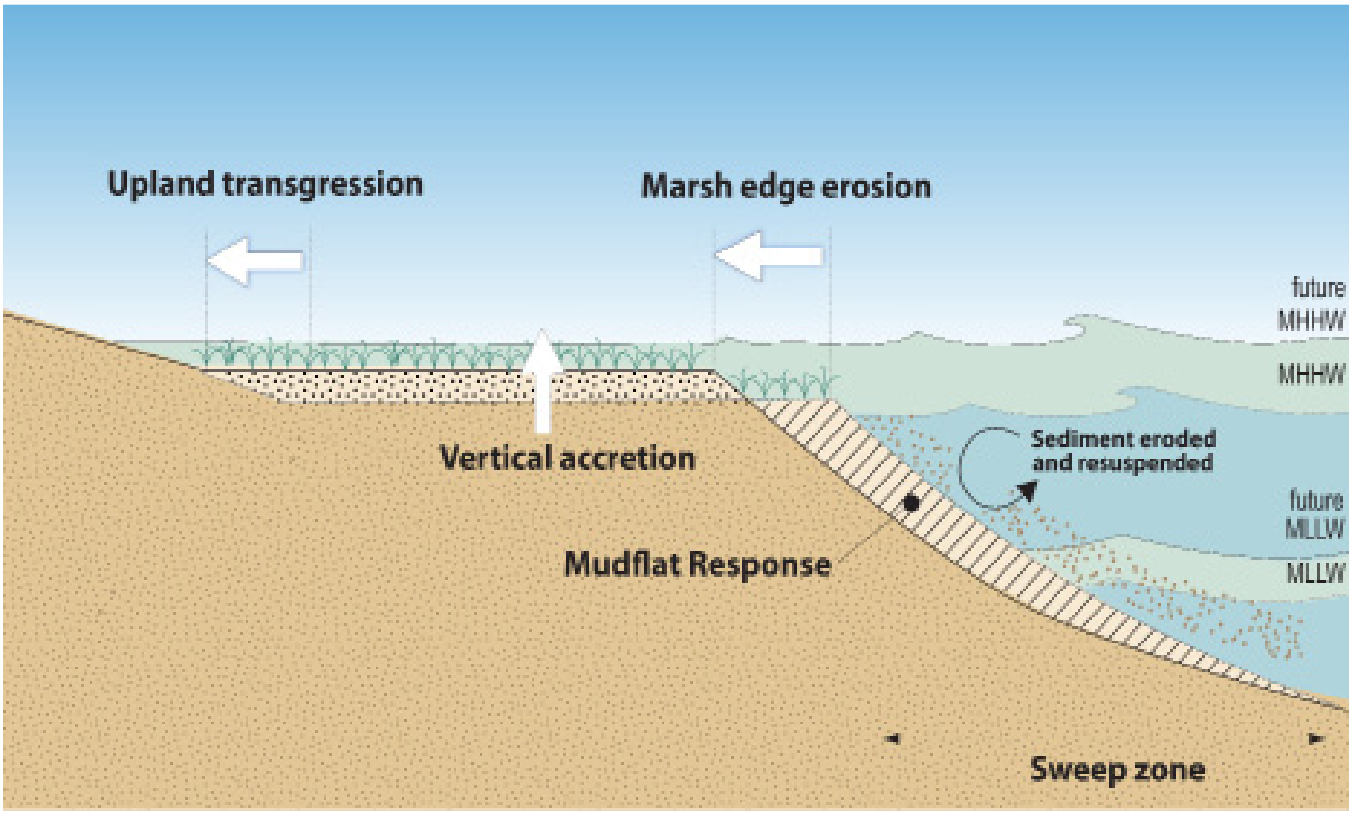
The resilience of baylands to sea level rise depends on their ability to build upward or move landward. If baylands do not keep up with accelerating sea level rise, they will drown and the flood risk reduction benefits they provide will be lost.

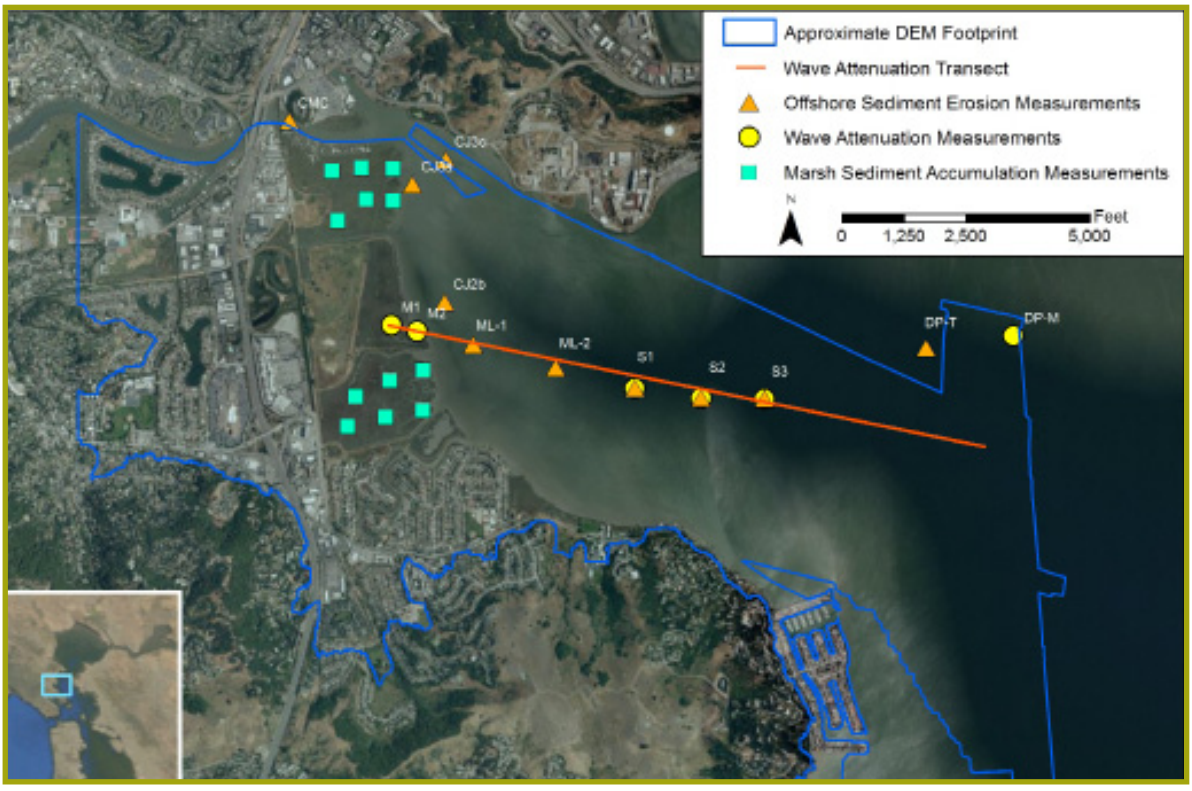
The elevation of the marsh plain is maintained by vertical accretion, that is, the accumulation of sediment and the input of organic matter from local plant production. Current science indicates that suspended-sediment concentrations in the Bay appear to be decreasing, so future supply may be limited. Furthermore, as marshes are outpaced by sea level rise, vegetation will be stressed, reducing sediment-trapping potential and inputs of organic matter. This leads to less accretion and, relative to rising water levels, loss of marsh elevation which will further stress vegetation. If suspended-sediment concentrations do not increase, the trend will be for tidal marshes to "downshift" from high to mid marsh, from mid to low marsh, and eventually to mudflat.

If sea level rise outpaces vertical accretion, marshes will need space to migrate, or transgress, upland. There is limited room to move landward as many baylands are bordered by levees or surrounded by development.

Evolution of baylands

Baylands respond to sea level rise by building upward and migrating landward through four evolution processes: mudflat response, marsh edge erosion, vertical accretion, and upland transgression. Accelerating rates of sea level rise coupled with declining sediment supply will make these processes of evolution more difficult, leading to baylands habitat downshifting and loss. (MHHW refers to mean higher high water. MLLW refers to mean lower low water. For more information about tides, refer to: tidesandcurrents.noaa.gov.)



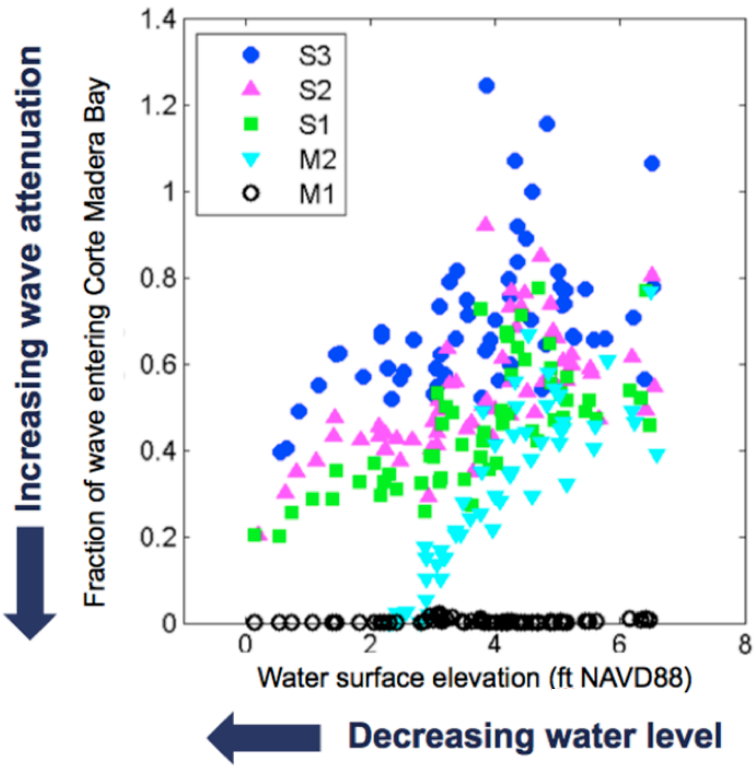


Project location

To investigate wave attenuation and its sensitivity to sea level rise, a Digital Elevation Model (DEM), field measurements and 1-D and 2-D modeling were completed for the Corte Madera Baylands in Marin County just north of the Tiburon Peninsula in central San Francisco Bay.

Wave attenuation and its sensitivity to sea level rise was investigated at the Corte Madera Baylands to inform how flood risk reduction benefits will change. Currently, as waves enter Corte Madera Bay they are reduced by as much as 80% before they reach the marsh. Waves that move across the marsh at high water levels, such as during storms that occur at high tide, are further reduced. Water depths decrease dramatically from the mudflat to the marsh. Wave attenuation is largely determined by water depth, therefore wave height and energy are significantly reduced at the marsh edge. Vegetation on the marsh plain provides additional wave attenuation, regardless of species (i.e., cordgrass or pickleweed). Marsh downshifting due to sea level rise will increase water depths and decrease wave attenuation, and a wider marsh will be needed to maintain flood risk reduction benefits.

Field measurements suggest that the Corte Madera Baylands are currently keeping pace with sea level rise; however, there are several lines of geomorphic evidence that suggest these baylands are sediment-limited. Regional marsh sustainability modeling predicts that the Corte Madera tidal marshes will drown and convert to mudflat towards the end of the century. Proactive management of these baylands will therefore be needed to improve their resilience and preserve the ecosystem benefits they provide.



Wave attenuation

Measurements show that wave attenuation increases in shallower water. Waves entering Corte Madera Bay are only a fraction of their original height when they reach the mudflats and shallows (S1, S2 and S3) and the marsh edge (M2). This reduction, or attenuation, was greater at lower water levels. No significant wave activity was measured over the marsh (M1) during the study period.

To demonstrate the information and process that can be used to develop and select management measures, a conceptual sea level rise adaptation strategy was crafted for tidal marshes in the Corte Madera Baylands. The objective of the strategy was to preserve ecosystem services, primarily flood risk reduction benefits, by maintaining high, wide marshes over time.

Seven management measures were considered. Using a geomorphic conceptual model as a decision-support tool, four were selected for the Corte Madera Baylands. Three of the measures enhance existing features to maximize resilience through mid-century: stabilizing with a coarse beach reduces erosion of the marsh edge caused by wave energy; recharging the mudflat and marsh increases local sediment availability; and, improving sediment pathways promotes vertical accretion through natural processes. The fourth measure, increasing the transition zone, prepares adjacent uplands so that marshes can migrate inland when they can no longer keep pace with sea level rise.

Lessons learned in developing this conceptual adaptation strategy and studying wave attenuation at the Corte Madera Baylands can be applied throughout the region as the challenges of accelerating sea level rise rates and declining sediment supply are generally similar across the Bay. To develop a site-specific sea level rise adaptation strategy, it is important to identify the ecosystem services to be protected, and have a good understanding of the local geomorphic context, sediment availability and status of shoreline change. Additionally, depending on the project scope, field observations and wave attenuation modeling may be necessary or desirable.

Lastly, experience with these management measures in the Bay varies. Some have been used successfully in Bay restorations, while others are untested and need further refinement and appraisal.

Baylands can play a significant role in reducing coastal flooding and future capital investments in structural shoreline protection. To achieve this potential, additional regional research is necessary. Critical needs include: a better understanding of estuarine sediment transport processes, particularly in mudflats and marshes; more field studies to calibrate and validate marsh wave attenuation models; and, the integration of baylands management into coastal hazard mitigation in support of climate change adaptation planning.

Management Measures

Seven management measures to improve baylands resilience are grouped below by the key process of baylands evolution they affect. Four measures (marked with an asterisk) were selected for the Corte Madera Baylands.

Mudflat response & marsh edge erosion measures slow the loss of marsh along the bayfront edge due to erosion

- Reduce nearshore wave energy with coarse gravel or oyster shell low-crested berms constructed at or near low water
- Stabilize with coarse beach* material to dissipate wave energy at the marsh edge

Vertical accretion measures to build marsh elevation by promoting sediment and organic matter accumulation

- Recharge mudflat and marsh* by introducing fine sediment directly into the water column or by placing sediment on the mudflat
- Improve sediment pathways* by increasing the channel network so that turbid water is distributed onto the marsh at high water
- Enhance sediment trapping by slowing the flow of incoming tidal water through increased vegetation density or sediment fences

Upland transgression measures create space for baylands to migrate inland to avoid "coastal squeeze"

- Increase the transition zone* by creating gently sloping uplands akin to a lowland floodplain that support landward marsh migration
- Realigning levees by moving them to a new location further inland to allow for marsh migration

The project was supported with funding from the U.S. Environmental Protection Agency through the San Francisco Estuary Partnership with a Resilient Watersheds for a Changing Climate grant of the San Francisco Bay Water Quality Improvement Fund and by the generous contributions of research partners including the U.S. Geological Survey, UNESCO-IHE, and Marin County. This project is the culmination of numerous scientific studies conducted by the research team. The full report is available at: www.bcdc.ca.gov/planning/climate_change/WetlandAdapt.shtml