Science Foundation Chapter 6
Appendix 6.1: Evaluation of Carbon Dynamics in the Baylands

In order to evaluate carbon dynamics within historic wetlands within the San Francisco Baylands, it is necessary to evaluate pool and fluxes across the range of different wetland habitats. The historic landscape of the San Francisco Baylands include a rich mosaic of habitat types, with carbon stored primarily in wetland soils that are rich in organic matter. The overall pool of soil carbon within these systems (and current tidal wetlands) is a function of 1) the extent of area covered by tidal wetland habitats, 2) the mass of carbon per unit volume in wetland soils (known as carbon density and determined by soil carbon content and soil density), and 3) the depth of accumulated wetland organic soils. Plant tissues, especially recalcitrant components of belowground biomass, are the dominant carbon source to soil C pools (e.g., $\delta^{13}C$) (Malamud-Roam and Ingram 2001). Prior to soil incorporation, above and belowground components of vegetation represent significant albeit short-term standing stocks of carbon.

In estimating pools of soil carbon, we have data on:

- Historic wetland distributions (FROM SFEI/ previous Habitat Goals Project)
- Current soil carbon content and soil bulk density (from soil surveys and recent soil cores); we assume that values from relatively undisturbed sites reflect historic carbon density

However, we do not have any comprehensive and reliable data on the historic depths of wetland soils (or even much data on current depths of wetland soils). Without data on soil depth, it is not possible to estimate the magnitude of carbon pools vulnerable to future emissions; however, historic emissions resulting from changes in pools can be estimated as outlined below.

In estimating emissions of CO_2 emissions from former tidal wetlands, we have data for:

- Acreage of converted wetlands (including current land use as defined by EcoAtlas)
- Loss in elevation of soil of converted wetlands (assuming that historic marsh plain elevations were close to MHHW and using current elevations of converted wetland elevations from recent LiDAR surveys)
- Current wetland soil characteristics, which can be used as a proxy for historic soil characteristics

To calculate the mass of CO_2 released with soil drainage, the simplifying assumption is made that the amount of carbon emitted from impacted wetlands soils (kg) is equal to amount of historic carbon throughout that section of the surface soil profile that has been lost = loss in elevation (m)*area affected by the loss (m^2)*carbon content (as %)*soil density (kg/m^3). This first order approximation could underestimate carbon loss by not accounting for additional loss from below the surface of remaining drainedsoils, and could overestimate if organic carbon is eroded away with soil and remains deposited in other locations. In estimating historic carbon density and other characteristics of wetland soils, we relied on information from the USDA National Resources Conservation Service SSURGO data (Soil Survey Staff 2013), as well as field data from existing wetland soils. There are seven common soil series found adjacent to the San Francisco Estuary: Joice, Novato, Omni, Reyes, Suisun, Tamba, and Valdez, as well as modified "urban" soils (Figure 1); these eight series cover over 90% of the study area adjacent to the Estuary. We focused our analysis on loss of carbon from wetland soils that have been altered in the past 150+ years by drainage for agricultural activities including row crops, orchards, and grazing, as well as other human impacts, including diking, creation of salt ponds, duck ponds, and urbanization.

Spatially-explicit soil data were downloaded by county and merged for the entire San Francisco Bay area using ArcMap 10.1 (ESRI 2013). The total area of each the eight soil series above was calculated within nine landcover types for each study area segment (Table 1; Figure 2). This area was combined with the change in land surface elevation to calculate the volume of soil lost over the last 150 years in areas that were formerly tidal wetlands but are now diked, muted, or drained. To estimate the loss in land surface elevation, we subtracted current elevations from historic wetland elevations. We assumed that historic wetlands were found at MHHW, and current elevations came from the digital elevation model created by Stralberg et al. (2011). We did not adjust for potential increases in marsh elevations due to increasing sea level over the last 100 years (approximately 20-30 cm), and as a result we may overestimate carbon loss by 10 – 25%. We then calculated the potential loss of carbon through wetland conversion by multiplying the average elevation of each converted wetland by its surface area. Carbon density was estimated from 50-cm sediment cores collected from natural wetlands in North Bay (China Camp, Petaluma River, and Coon Island) and Suisun Bay (Rush Ranch and Browns Island) as part of recent carbon sequestration project (Callaway et al. 2012). Carbon density was calculated based on sediment bulk density (g/cm^3) and organic carbon content (% carbon). Bulk density was measured directly for 2-cm sections of cores (25 sections/core and approximately 1,000 samples total). Organic carbon content was estimated based on the measured organic matter content (measured by burning subsamples in a muffle furnace [loss-on-ignition method] for the same 1,000 samples) and a correlation between organic matter content and carbon content from a subset of these samples (see Callaway et al. 2012 for details). Carbon density averaged 23.3 mg/cm^3 for salt marsh cores and was very consistent across sites. Average carbon density for the brackish sites was 33.4 mg/cm^3, again with little variation between the two sites. An earlier study of Louisiana tidal wetlands found a value of 26 mg/cm^3 across a wide range of salt, brackish, and freshwater sites. We used average carbon density values for salt marshes and brackish wetlands, 23.3 and 33.4 g/cm^3 to estimate carbon loss from historic tidal wetland soils.

To determine the potential carbon storage that could occur with current and planned restoration projects, we utilized a wetland restoration site GIS database compiled by SFEI. We restricted the analysis to restoration sites that are for tidal wetlands only and for those that are in progress or planned. For each restoration site, the volume of soil lost was calculated using the average elevation within the polygon and the surface area of the site. This volume was multiplied by the same carbon densities listed above to calculate the potential carbon storage obtained through restoration.