GREATER FARALLONES ASSOCIATION

ADDENDUM to

BOLINAS LAGOON SOUTH END LIVING SHORELINES PROJECT PRE-FEASIBILITY STUDY

December 10, 2021

While this memo contains useful information, there have since been significant project updates in the scope and goals of the project to note. The project is now strictly focused on natural shoreline habitat development and nature-based sea level rise adaptation strategies. This memo includes several points of discussion focusing on roads, roadway design, and concept level design strategies that include traditional ‘gray’ infrastructure, hardscape, and hybrid components that are now obsolete. The project area is now conscribed to wetland-upland areas, involving enhancing shoreline habitat through natural solutions.

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Project name:
Bolinas Lagoon South End Living Shorelines Project

Project ref:
60585015

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Memorandum

Subject: Bolinas Lagoon South End Living Shorelines Project Pre-Feasibility Study

1 Introduction

1.1 Background

Bolinas Lagoon is a biologically rich 1,100 acre tidal estuary on the California coast in west Marin County. The lagoon is situated along the San Andreas Fault and enclosed by a curving sand spit along its southern shoreline. The lagoon is a designated Wetland of International Importance due to its location along the Pacific Flyway and its unique habitats. The lagoon is part of the Greater Farallones National Marine Sanctuary (GFNMS) and provides a diverse mix of channel, mudflat, marsh, and riparian habitat for many shorebirds, waterfowl, fish, marine mammals, invertebrates, and special status plants and animals.

The lagoon's long history of human impacts is described in the Bolinas Lagoon Ecosystem Restoration Project (BLERP) Recommendations for Restoration and Management report (GFNMS 2008). Historical logging, farming, grazing, land use changes, lagoon dredging and fill, channelization of creeks, road construction, and hardening of the lagoon edge have led to degradation of natural hydrologic and geomorphic processes. These changes also affected patterns of sedimentation in the lagoon and disconnected estuarine and marsh habitats with riverine corridors and adjacent upland areas. Hardening of the shoreline has impacted tidal-terrestrial transition zones which limits the ability of the lagoon and its tidal habitats to expand landward and migrate upslope in response to sea level rise.

One key area of impact is the lagoon's South End shoreline along the backside of the Seadrift spit (Figure 1). Historical impacts to the lagoon shoreline in this area have degraded wetland and marsh habitat resulting in an unnaturally steep eroding shoreline with poor alongshore connectivity.

Development along the upland edge of the shoreline will constrain the ability of lagoon habitats to respond to future sea level rise. In addition, low-lying areas of the shoreline along Calle Del Arroyo are prone to tidal and creek flooding from king tides, storm surge, and rainfall events in Bolinas Lagoon and Easkoot Creek. These flooding events will worsen in the future as a result of climate change. Calle Del Arroyo is the only access route into the Stinson Beach Calles, Patios, and Seadrift neighborhood, making it critical for access and emergency services.

Figure 1. South End Bolinas Lagoon Project Location

AECOM was contracted by the Greater Farallones Association (GFA) to conduct a pre-feasibility study to explore options to implement a living shoreline project along the South End shoreline to address these challenges. This memo identifies initial, concept level design strategies for shoreline enhancement, habitat connectivity, and sea level rise adaptation along Calle Del Arroyo and Dipsea Road. The findings of this assessment will be used by GFA to raise awareness of the project, garner Marin County Department of Public Works support for the project, facilitate identification of next steps, and solicit funding to support a more detailed feasibility study of a potential future project.

1.2 Purpose

1.2.1 Project Goals and Objectives

A number of prior studies and guiding documents provide support and motivation for a living shoreline project along the South End of Bolinas Lagoon. The Sanctuary's Climate Change Impacts Report (2010) identifies estuarine habitats abutting roads or steep slopes as particularly vulnerable to accelerated habitat loss as sea levels rise. The Sanctuary's 2016 Climate Adaptation Plan recommends living shoreline strategies and actions to respond to projected climate change impacts and vulnerabilities. The following actions identified in the Climate Adaptation Plan are particularly relevant to the South End shoreline:

- LS-1.1: "Identify locations within estuaries that are currently impacted by flooding and erosion, where nature-based shoreline protection projects could have co-benefits for natural systems and human communities";
- LS-2.2: "Replace armoring with nature-based solutions such as natural material to create sloped, transitional habitat"; and
- LS-3.5: "…in conjunction with raising/moving roads, look for opportunities to create functional habitat (e.g., replace hard/grey infrastructure… with living shorelines and migration space)."

The BLERP identified an overarching objective of restoring natural sediment transport and ecological functions of the lagoon and specifically calls out improving transitional habitat along Dipsea Road as a component of the Locally Preferred Plan. Similarly, Marin County's Sea Level Rise Adaptation Report (2017) recommends enhancing and restoring living shorelines within Bolinas Lagoon to provide habitat and flood protection benefits.

Objectives for the Bolinas Lagoon South End Living Shorelines Project include:

- Enhance existing habitat and provide sea level rise adaptation and transitional habitat for plants and wildlife along Calle Del Arroyo and Dipsea Road shorelines
- Preserve and enhance trail and public access along the Dipsea Road shoreline
- Reduce the frequency and severity of flooding along Calle Del Arroyo for existing conditions and future conditions with sea level rise using a living shoreline technique, thereby increasing the reliability of Calle Del Arroyo as the primary access route to the Seadrift neighborhood
- Reduce further erosion of the Dipsea Road shoreline
- Improve overall health and function of Bolinas Lagoon by improving and connecting existing shoreline habitats

Given the multiple objectives identified above, inter-agency collaboration and funding will be required to successfully implement this project. The Sanctuary, GFA, Marin County, Audubon Canyon Ranch, and Seadrift Association will likely be key partners to address the various components of the project. A hybrid project that incorporates living shoreline enhancements, drainage improvements, and traditional flood protection measures (such as a flood wall and/or limited road raising) would represent a win-win for the community and achieve project successes that a habitat enhancement or flood protection project would not be able to achieve alone. Ultimately, each project partner may be responsible for implementing various components of the project. This memo primarily focuses on the project components within the purview of the Sanctuary and GFA; however, it also recognizes the broader project objectives and identifies opportunities for collaboration with other project partners to maximize co-benefits of the project.

1.2.2 Purpose of memo

This memo is the first step in shaping potential project concept level strategies to address the project objectives identified above. These concept strategies can be used by GFA to support the development and scoping of a future feasibility study. Specifically, this memo will:

- Characterize existing site conditions along the South End shoreline of Bolinas Lagoon, define typical and storm water level conditions, and identify sea level rise projections for consideration in the feasibility study
- Describe concept level strategies along Dipsea Road to enhance the existing shoreline and provide transitional habitat to accommodate future sea level rise
- Describe concept level strategies along Calle Del Arroyo to provide transitional habitat and flood protection to accommodate future sea level rise
- Discuss advantages and disadvantages of each of the identified strategies
- Identify potential evaluation criteria and metrics for consideration in the feasibility study
- Discuss permitting considerations for the proposed shoreline enhancement activities
- Identify potential components of a follow-on feasibility study, approximate funding needs, and next steps

2 Site Conditions

2.1 Existing Conditions

Stinson Beach is a naturally occurring barrier feature at the mouth of Bolinas Lagoon. The east end of the spit is joined to the mainland at the intersection of Hwy 1 and Calle Del Arroyo, and extends west to form a peninsula with the Pacific Ocean on the south side and Bolinas Lagoon on the north side. In the 1950 to 1960s, the spit was developed and expanded into Bolinas Lagoon to create the Seadrift neighborhood. Fill was placed along the inner shoreline and bulkheads were constructed. The inner Seadrift Lagoon was also created at this time.

Starting at Hwy 1, Calle Del Arroyo runs along the north side of the spit for approximately 3,000 feet, terminating at the start of the Seadrift neighborhood, a private residential community that makes up the western portion of the spit (Figure 1). At the entrance to the Seadrift neighborhood, the road splits in two: Dipsea Road, which runs along the north side of the spit along Bolinas Lagoon, and Seadrift Road, which runs on the south side of the spit, along the Pacific Ocean. The Seadrift community is private land and road work and maintenance is the responsibility of the Seadrift neighborhood. However, the land in between Dipsea Road and Bolinas Lagoon (while owned by Seadrift Homeowners Association) is considered Marin County Open Space and is monitored each year by County staff, accompanied by annual status reports of the area. Calle Del Arroyo is owned and maintained by Marin County and is the main road along the western portion of Stinson Beach and the only access road that leads to the Seadrift neighborhood. A portion of the wetlands adjacent to Calle Del Arroyo is owned by Audubon Canyon Ranch. The Calles and Patios south of Calle Del Arroyo are private and not County-maintained. See Attachment A for parcels and ownership as it is understood at this point.

Calle Del Arroyo and Dipsea Road are located on the northern side of the spit and exposed to the waves and water level conditions in Bolinas Lagoon. Within Bolinas Lagoon, all areas below Mean High Water (MHW) are under the jurisdiction of the Sanctuary. Wetlands under the jurisdiction of state and federal agencies are also present along the edges of the lagoon.

The channelized and rerouted Easkoot Creek discharges into Bolinas Lagoon at the southeast corner of the lagoon after flowing through the town of Stinson Beach. Easkoot Creek drains an area of approximately 1.6 square miles of mostly undeveloped, steep, and heavily forested watershed on the western side of Mt. Tamalpais. Easkoot Creek has a long history of flooding in the town of Stinson Beach dating back to the 1950s (OEI 2014).

2.2 Water Levels in Bolinas Lagoon

Water levels in Bolinas Lagoon are primarily tidally driven, experiencing two highs tides and two low tides each day. A National Oceanic and Atmospheric Administration (NOAA) tide gauge is located on the north side of Seadrift, within Bolinas Lagoon (Figure 1). Tidal datums for the Bolinas Lagoon tide gauge are shown in Table 1. Also shown in this table are tidal datums from the Point Reyes gauge, which is located 18 miles north on the open coast. In comparing the two tide gauges, it can be seen that the lagoon experiences lower high tides and higher low tides than what is seen on the open coast, indicating that typical daily tides are muted in the lagoon.

Table 1. NOAA Tidal Datums at Bolinas Lagoon and Point Reyes

Tidal Datum	Bolinas Lagoon Station 9414958 (feet NAVD88)	Point Reyes Station 9415020 (feet NAVD88)
MHHW	5.39	5.74
MHW	4.78	5.08
MSL	3.35	3.08
MLW	1.86	1.16
MLLW	1.12	-0.02

Source: NOAA (obtained from Tides and Currents website, September 2018)
Notes: MHHW = mean higher high water, MHW = mean high water, MSL = mean sea level, MLW = mean low water, and MLLW = mean lower low water. NAVD88 = North American Vertical Datum of 1988.

The Federal Emergency Management Agency (FEMA) Flood Insurance Study for Marin County (BakerAECOM 2014) provides estimates of extreme tidal water elevations[1] in Bolinas Lagoon for specific return periods, as shown in Table 2. These values capture water levels due to coastal processes such as astronomical tides and storm surge; however, it is likely that riverine discharge into the lagoon may further increase water levels during storms – especially locally near the outlet of Easkoot Creek. There is also a pinch point at the location of the former causeway connecting Hwy 1 to Seadrift that may inhibit drainage of Easkoot Creek floodwaters to the main portion of Bolinas Lagoon and further elevate water levels along Calle Del Arroyo – an effect that could be verified through hydrodynamic modeling of combined riverine-coastal flood events in Bolinas Lagoon or through water level monitoring. This effect would not be captured in the FEMA analysis and therefore the FEMA estimates of extreme water levels may underestimate the true flood risk within Bolinas Lagoon.

[1] These estimates include the effects of astronomical tides and storm surge, but exclude the effects of wind setup within the lagoon and watershed precipitation and runoff.

Table 2. FEMA Extreme Water Level Estimates

Return Period	Bolinas Lagoon (ft NAVD88)*	Point Reyes (ft NAVD88)
2-year	6.6	7.6
5-year	6.9	7.9
10-year	7.1	8.2
25-year	7.3	8.5
50-year	7.5	8.8
100-year	7.6	9.1

Source: BakerAECOM 2014

Note: Return period refers to the average rate of occurrence of each water level over a long period of time. For example, a 10-year water level occurs on average once every 10 years (and has a 10% chance of occurring in any given year).

*Based on preliminary review of observed water levels within Bolinas Lagoon (at the NOAA tide station), FEMA's estimates of extreme water levels within the lagoon may underestimate actual storm water levels due to coastal processes and riverine inflows.

The nearest active stream gauge[2] is located along Redwood Creek at Muir Beach. AECOM used this gauge to assess the coincidence of precipitation and coastal high water events near the project site. Within the last three years, the Bolinas Lagoon tide gauge shows several instances of water levels greater than the FEMA 25-year tide (7.3 ft NAVD88). During those events, the Redwood Creek gauge also showed coincident high discharge events – suggesting that rainfall was occurring in the area during these times. Therefore it is believed that riverine discharge into the lagoon increases water levels (at least locally) and should be considered in the selection of design water levels for any shoreline enhancements. As a result, the FEMA extreme water levels may underestimate actual water levels in Bolinas Lagoon during storm conditions.

Based on a preliminary review of the NOAA tide gauge water level record during typical winter months, a 1-year water level (or king tide event) is estimated to be approximately 7.5 ft NAVD88 in the lagoon for the purposes of this memo. In the last 5 years, there have been 29 events with water levels greater than 7 feet NAVD88, and 6 events greater than 7.5 feet NAVD88 (as measured at the Bolinas Lagoon tide station). This would also suggest that while typical daily tides in Bolinas Lagoon are muted relative to open coast tides (as measured at Point Reyes), higher astronomical tides (such as king tides) and storm surge events are closer in elevation. For example, the highest water level recorded at the Bolinas Lagoon tide station since 2009 was 8.02 ft NAVD88 and occurred on March 20, 2011. In comparison, the corresponding water level on this date at the Point Reyes tide station was 8.12 ft NAVD88 – a difference of only 0.1 ft. As a result, AECOM recommends using the Point Reyes extreme water level estimates for preliminary planning purposes until these values can be confirmed through further analyses. Recommended tidal datum and extreme tide level estimates for Bolinas Lagoon are shown in Table 3.

[2] The OEI (2014) report indicates that flow gauging of Easkoot Creek has been conducted by the National Park Service since 2000; however, these data were not readily available for preparation of this memo. These data and other streamflow data collected by the Stinson Beach County Water District could be obtained and analyzed further as part of the feasibility study.

Table 3. Recommended tidal datum and extreme tide level estimates in Bolinas Lagoon

Tidal Datum / Extreme Tide Level	Estimated Water Level (ft NAVD88)	Source
100-year	9.1	FEMA Point Reyes Tide Station
50-year	8.8	
25-year	8.5	
10-year	8.2	
5-year	7.9	
2-year	7.6	
King Tide	7.5	AECOM (this study)
MHHW	5.39	NOAA Bolinas Tide Station
MHW	4.78	
MSL	3.35	
MLW	1.86	
MLLW	1.12	

Sea level rise is expected to increase daily tide and extreme water levels along the California coast over the coming decades and beyond. Recent California state sea level rise guidance (OPC 2018) provides projections of potential sea level rise through the year 2150. There is considerable uncertainty in global and local projections due to uncertainty in global climate modeling, future greenhouse gas emission, and local factors such as vertical land motion. Sea level rise projections at the Point Reyes Tide Station are shown in Table 4.

Table 4. Sea Level Rise Projections at Point Reyes Tide Station

Year	Likely Range (inches)	High Range (inches)
2030	4 to 7	10
2040	6 to 10	16
2050	7 to 13	24

Source: OPC (2014). For each planning horizon, there is a 66% chance that sea level rise will fall within the likely range. There is a 0.5% chance that sea level rise will meet or exceed the high range value. Projections shown for RCP 8.5 emissions scenario.

2.3 Marsh and Transition Zone Elevations in Bolinas Lagoon

2.3.1 Marsh Elevations

The BLERP (2008) includes information on intertidal mudflat and vegetated marsh elevations within Bolinas Lagoon. The following habitat descriptions are relevant for the South End living shoreline project:

- Intertidal mudflats: occur between MLLW and approximately one foot above MSL

- Salt marsh: occurs at relatively high elevations within the tidal frame, usually higher than one foot above MSL up to five feet above MSL
  – Low salt marsh: typically occurs from 0.5 ft to 2.5 ft above MSL
  – Mid salt marsh: typically occurs from 2.5 ft to 3.5 ft above MSL
  – High salt marsh: typically occurs from 3.5 ft to 5 ft above MSL
- Upland: areas above 5 ft above MSL

Table 5 shows approximate marsh and transition zone elevation ranges based on the BLERP findings and water level analysis in Section 2.3. The limits of high marsh shown in Table 5 are generally consistent with the conclusions of the water level analysis presented in Section 2.3 which indicate annual king tide elevations of 7.5 ft – a proxy for the typical upper limit of the tides.

Table 5. Marsh and Transition Zone Elevation Ranges in Bolinas Lagoon

Habitat Type	Inundation Regime	Habitat Range	Approximate Elevation Range (ft NAVD88)	Approximate Elevation Range with 2 ft of SLR (ft NAVD88)
Subtidal	Always submerged	below MLLW	< 1 ft	<3 ft
Mudflat	Fully submerged daily	MLLW to 1 ft above MSL	1 to 4.5 ft	3 to 6.5 ft
Low Marsh	Fully submerged daily	0.5 to 2.5 ft above MSL	4 to 6 ft	6 to 8 ft
Mid Marsh	Inundated during spring tides	2.5 to 3.5 ft above MSL	6 to 7 ft	8 to 9 ft
High Marsh	Inundated during very high tides	3.5 to 5 ft above MSL	7 to 8.5 ft	9 to 10.5 ft
Transition Zone	Rarely inundated	Up to 1 m above MHW	Up to 8 ft	Up to 10 ft
Upland	Not inundated	above 5 ft above MSL	> 8.5 ft	> 10.5 ft

Note: Elevations are approximate and should be researched further or surveyed as part of the feasibility study. Habitat elevation ranges shown above have not been field verified as part of this pre-feasibility study.

2.3.2 Transition Zone Elevations

Recent studies have re-examined the importance of the tidal-terrestrial transition zone (or “ecotone”) in providing a number of ecological functions and services in wetland environments (SFEI 2013; SFEI and SPUR 2019). Ecotones harbor unique plant communities, provide critical wildlife support to adjacent ecosystems (such as high tide refugia and easing of predation pressures), and play an important role in linking marine and terrestrial systems. Historically, ecotone habitats have been disturbed or eliminated by development and are further threatened by inundation from sea level rise (Thompson 2013). Thompson’s (2013) literature review suggests an upper limit of the ecotone extending to one meter above MHW, which corresponds to an elevation of approximately 8 ft NAVD88 in Bolinas Lagoon. Additional research, literature review, and/or surveying could be conducted as part of the feasibility study to develop a more complete understanding of the relationship between Bolinas Lagoon water levels and typical vegetated marsh and ecotone elevation ranges.

2.4 Calle Del Arroyo

The elevation of Calle Del Arroyo is generally between 8 and 10 ft NAVD88; however, an approximately 500 foot section of road between Walla Vista and Rafael Patio dips below 8 feet, to as low as 7 feet NAVD88, as shown in Figure 2. This also aligns with a relatively low section of shoreline between Sonoma Patio and Sacramento Patio where a small berm is present at an elevation less than 7.5 ft NAVD88. Adjacent to this, there is a small vegetated embayment to the lagoon, with wetlands and marsh present along the shoreline[3]. Public parking is available along the shoulder to provide public access to Stinson Beach via Walla Vista.

Easkoot Creek runs parallel to Calle Del Arroyo and is topographically confined by development on the west side and Hwy 1 on the east side before entering the larger lagoon area. High discharge events from the creek can locally increase water levels along the shoreline resulting in higher frequencies of flooding than would be predicted by tides alone. Due to the low-lying shoreline, water levels as low as 7 feet NAVD88 can cause flooding of the shoulder and extend across the roadway. In the last 5 years, there have been 29 events with water levels greater than 7 feet NAVD88, and 6 events greater than 7.5 feet NAVD88 (as measured at the Bolinas Lagoon tide station). Based on FEMA's water level analysis, this means that a 10-year event is happening almost six times each year and a 50-year event is happening at least once per year in Bolinas Lagoon[4].

[3] This unfilled, vegetated marsh area adjacent to Calle Del Arroyo is owned by Audubon Canyon Ranch.
[4] This finding implies that the FEMA-estimated extreme water levels in Bolinas Lagoon may be too low and should be re-evaluated as part of the feasibility study.

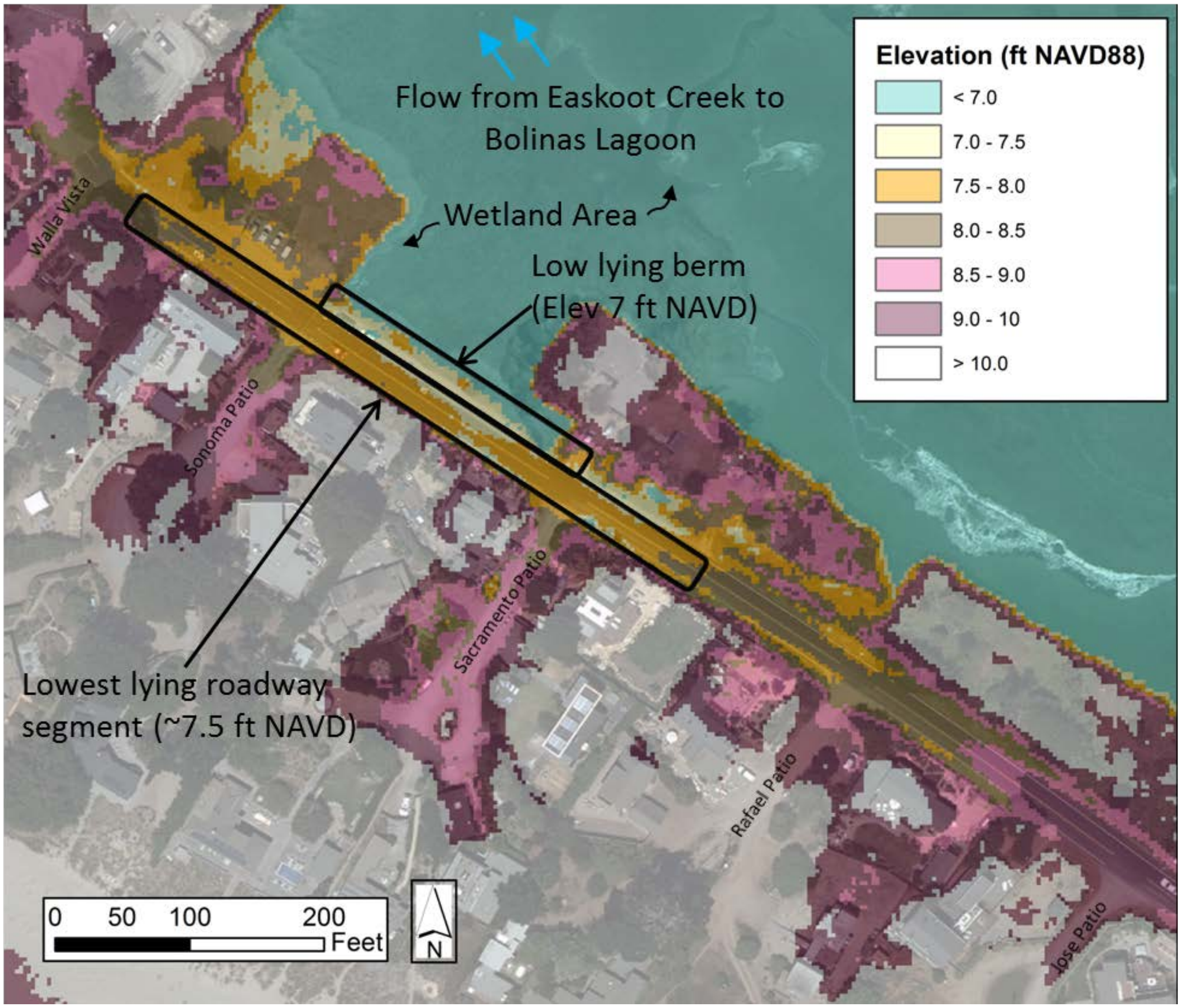

Figure 2. Existing elevation and features along Calle Del Arroyo

Figure 3 shows flooding of the roadway from a king tide and storm event on November 24, 2015. The recorded water level at the Bolinas Lagoon tide gauge at the peak of the storm was 7.1 ft NAVD88. This event corresponded with local precipitation in the Easkoot Creek watershed. The figure shows water overtopping the shoreline, flooding the shoulder, and extending across the road. Local residents indicate this area has been more severely flooded in the past, with water extending to cover a larger portion of road.

Figure 3. Flooding of Calle Del Arroyo during king tide combined with a storm during November 24, 2015 storm.

Note: Photo taken looking east along Calle Del Arroyo at Sonoma Patio. The low vegetated berm along the shoulder is visible (partially submerged) directly underneath the power lines.

Immediately west of the low-lying stretch of Calle Del Arroyo is a filled upland area at approximately 8 to 9 ft NAVD88 with a steep shoreline and rubble/riprap on the slope. Continuing westward towards Seadrift, the shoreline makes a right angle turn and parallels the route of the former causeway connecting Seadrift to Hwy 1. The shoreline is very steep and quickly transitions from tidal elevations to upland due to the historical filling and building out of the Seadrift spit for development.

The following constraints were identified for any proposed shoreline enhancement activities along Calle Del Arroyo:

- The site is located immediately adjacent to the Sanctuary. Placement or dredging of material below the MHW line will be subject to permitting review by the Sanctuary. These activities are generally not allowed within the Sanctuary except in situations where it can be demonstrated that there is a benefit to the Sanctuary. GFA and Sanctuary staff will continue to coordinate on this aspect of the project.
- The site is located immediately adjacent to sensitive wetland habitat[5]. The footprint of any fill placement adjacent to the shoreline may impact jurisdictional wetlands within Bolinas Lagoon and require mitigation. Wetland impacts along Calle Del Arroyo may be mitigated by wetland creation and/or enhancement in other areas.
- The vegetated marsh area adjacent to the low-lying stretch of Calle Del Arroyo is owned by Audubon Canyon Ranch. Other portions of shoreline in the project area are owned by Marin County Open Space and Seadrift Association. Coordination with these landowners will be

[5] A wetland delineation and habitat mapping were not developed as part of the pre-feasibility assessment; however, these tasks would likely be conducted as part of the feasibility study.

required for planning, design, and implementation of a living shoreline project along Calle Del Arroyo.

- Raising of the shoreline along Calle Del Arroyo may impede drainage of rainfall-runoff from the road. The selected shoreline enhancement strategy should manage storm water runoff to prevent ponding water on roadway. Coordination with Marin County Department of Public Works will be required for this aspect of the project.
- Sea level rise may reduce the level of flood protection provided by the shoreline enhancements over time. The selected shoreline enhancement strategy should be adaptable to sea level rise and compatible with potential neighborhood scale adaptation strategies that may be implemented in the future. Coordination with Marin County Planning Department, Department of Public Works, and homeowners will be required on this aspect of the project moving forward.

2.5 Dipsea Road Shoreline

Elevations along Dipsea Road range from approximately 10.5 to about 13 ft NAVD88 with most of the road between 11 and 13 ft NAVD88. The road is separated from the shoreline by a vegetated area varying in width from 45 to 125 feet. The shoreline along the eastern part of Dipsea Road is eroding and a steep scarp has formed in some locations, as shown in Figure 4. The shoreline is composed of loose sandy material dredged from the lagoon to construct the Seadrift Spit. As a result, the fill material is easily erodible. It is suspected that high velocities caused by the constriction of riverine and tidal flows through the eastern part of Bolinas Lagoon and the Easkoot Creek channel may be contributing to the shoreline erosion – particularly along the shoreline immediately west of the former causeway where flows are most constricted by fill. Hydrodynamic modeling of the lagoon would be required to confirm flow patterns and velocities along different portions of the shoreline and better understand the causes of erosion.

As Dipsea Road and the Seadrift spit angle south (near the mid-point of Seadrift lagoon), the tidal constriction relaxes and erosion west of that point is reduced, resulting in a less steep and more stable shoreline. In some locations along the shoreline, local topographic depressions are present immediately landward of the shoreline, creating isolated freshwater or brackish ponds (and associated wetland vegetation[6]) between the shoreline and Dipsea Road, as shown in Figure 5. An unmaintained recreational trail that runs for most of the length of Dipsea Road is located within the vegetated area along the shoreline. Erosion threatens the stability and accessibility of the trail in some locations.

The shoreline west of the bend is generally more stable and can be used a reference site for a natural, or equilibrium shoreline, for this area. Along this section the intertidal slope[7] ranges from 0.05 to 0.1 (or 20:1 to 10:1), and the upland transition slope[8] ranges from 0.1 to 0.2 (10:1 to 5:1).

The following constraints were identified for any shoreline enhancement activities along Dipsea Road:

- The site is located immediately adjacent to the Sanctuary. Placement or dredging of material below the MHW line will be subject to permitting review by the Sanctuary. These activities are generally not allowed with the Sanctuary except in situations where it can be demonstrated that there is a benefit to the Sanctuary. GFA and Sanctuary staff will continue to coordinate on this aspect of the project.

[6] The presence of jurisdictional wetlands within the topographic depressions could be determined by conducting a wetland delineation of the project area.
[7] Defined as the slope between the MSL and MHHW tidal datums
[8] Defined as the slope between the MHHW tidal datum and the crest (or high point) of the shoreline

- The site is located immediately adjacent to sensitive wetland habitat[9]. The footprint of any fill placement adjacent to the shoreline may impact jurisdictional wetlands within Bolinas Lagoon. Wetland impacts along Dipsea Road may be mitigated by wetland creation and/or enhancement in other areas.
- All of the Dipsea Road shoreline under evaluation for this study is owned by the Seadrift Association. Coordination with landowners will be required for planning, design, and implementation of a living shoreline project along Dipsea Road.
- The topographic depressions along the shoreline support existing freshwater and riparian habitat. Regrading of the shoreline as part of a living shoreline project could expose these freshwater habitats to more frequent inundation by marine waters. Further investigation of the existing habitat types and quality (including its historical occurrence) could be conducted during the feasibility study to better understand the importance of preserving this habitat.

Figure 4. Eroded section of shoreline and steep scarp along Dipsea Road.

[9] A wetland delineation and habitat mapping were not developed as part of the pre-feasibility assessment; however, these tasks would likely be conducted as part of the feasibility study.

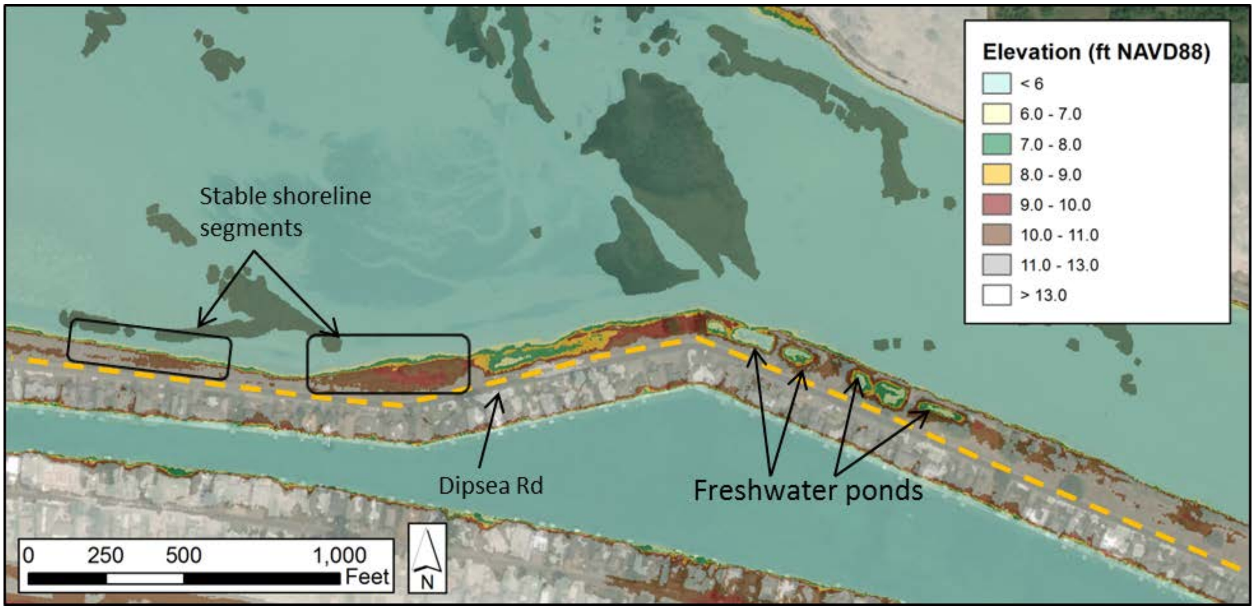

Figure 5. Overview of Dipsea Road and Seadrift Shoreline

3 Project Definition and Conceptual Strategies

3.1 Planning Level Design Criteria

AECOM developed planning level design criteria for the shoreline enhancements based on the existing topography, shoreline slopes, water levels, and marsh elevations within Bolinas Lagoon. These planning level design criteria apply to both the Calle Del Arroyo and Dipsea Road shorelines and are summarized below:

- **Planning horizon:** a planning horizon of 2050 was selected
- **Sea level rise:** a sea level rise projection of 2 feet (24 inches) was selected, corresponding to the upper range projection for 2050 based on current State of California sea level rise guidance
- **Ecotone elevation range:** Based on the findings of Section 2.3, an upper limit of the existing tidal-terrestrial transition zone of 8 ft NAVD88 was selected. With sea level rise over the selected planning horizon, this zone would extend up to an elevation of 10 ft NAVD88.
- **Ecotone slope:** based on observations of stable shoreline slopes at the reference site along the western portion of Dipsea Road, an ecotone slope range of 5:1 to 10:1 was selected
- **Water levels:** based on a review of recorded water levels at the Bolinas Lagoon tide station, an annual (king tide) water level of 7.5 ft NAVD88 was selected to inform the development of concept strategies. Recommendations for other water levels of interest are shown in Table 3.
- **Roadway design elevation:** A design elevation of 8 ft NAVD88 was selected for the low-lying segment of Calle Del Arroyo based on typical annual peak water levels and adjacent road elevations. It should be noted that this roadway elevation would address current annual king tide flooding of Calle Del Arroyo and flood events up to approximately a 5-year return period; however, the road would still be susceptible to flooding during more extreme events

or in the future with sea level rise if no additional shoreline or roadway modifications were implemented. A higher design elevation will not necessarily provide added protection or ensure access to the Calles or Seadrift neighborhood, as the other low-lying areas of shoreline would overtop and flood other portions of the road.

3.2 Conceptual Strategies

AECOM identified a number of potential nature-based and infrastructure strategies for shoreline enhancement, habitat connectivity, and sea level rise adaptation along Calle Del Arroyo and Dipsea Road, as described below.

3.2.1 Potential Nature-based Strategies

The sections below describe five nature-based strategies to enhance shoreline habitats along Calle Del Arroyo and Dipsea Road:

- Grade shoreline to create ecotone slope
- Place fill to create ecotone slope
- Grade shoreline to create intertidal wetland
- Sediment augmentation
- Vegetation management

Note that the strategies listed above and described in more detail below are not mutually exclusive and can be considered in different combinations along different reaches of the shoreline to achieve project objectives. Project alternatives that consider combinations of the strategies presented in this memo could be developed as part of the feasibility study.

3.2.1.1 Grade Shoreline to Create Ecotone Slope

Existing upland sections of shoreline along Calle Del Arroyo and Dipsea Road have transitional slopes of approximately 2:1. These steep slopes are relatively unstable, prone to erosion, and result in a very narrow width of low-quality transitional habitat. This strategy would cut into the existing fill material and lay back the slope to create a more stable shoreline. This will push the shoreline inland and help develop a more equilibrium shoreline slope that will be less prone to erosion, especially once vegetation establishes.

Figure 6 shows the potential shoreline grading to lay back the shoreline at a 5:1 or 10:1 slope. The excavation area for the 5:1 slope is shown in blue and the excavation area for the 10:1 slope is shown in red. These slope options represent a reasonable slope range for shoreline stability and match existing transitional slopes along the western shoreline of Dipsea Road (Figure 7). Sloping back the shoreline at a 10:1 slope would set back the shoreline by approximately 40 feet. At a 5:1 slope, the shoreline would be set back by approximately 10 feet. In general, there is more than enough room along the Dipsea Road shoreline to accommodate this setback. Slope could be varied along the shoreline to create more topographic diversity and a less uniform shoreline (to avoid creating a uniform linear feature). In addition, slope steepness could be varied depending on the available space for the shoreline setback, provided the slope stays within this range. In areas where there is insufficient space to lay back the shoreline, fill placement to create a transitional ecotone slope may be required (see Section 3.2.1.2).

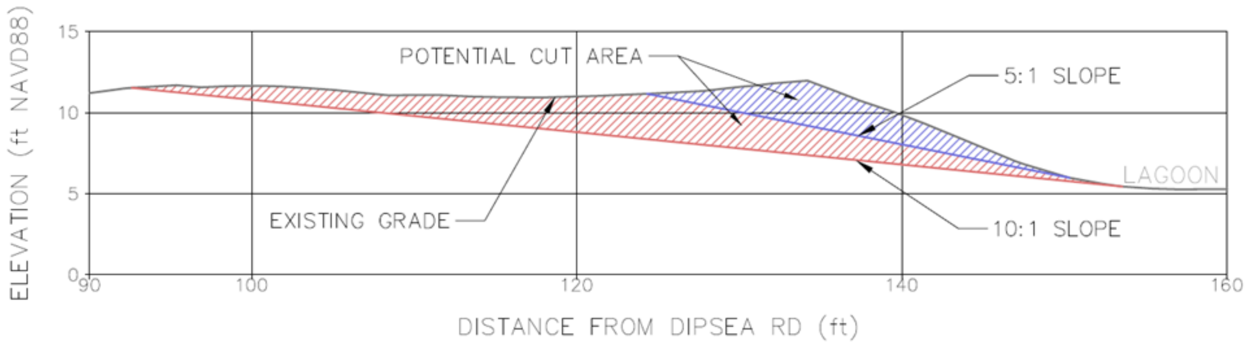

Figure 6. Typical cross-section of the setback shoreline for a 5:1 and 10:1 slope

Figure 7. Existing Transitional Habitat Along Western Dipsea Road Shoreline

Note: Existing shoreline slopes in this area are 5:1 to 10:1 and are similar to those proposed as part of the shoreline enhancement activities along Dipsea Road.

At locations along Dipsea Road where the topographic depressions occur, there is less space between the high ground and the existing eroded shoreline scarp. Laying back the shoreline in these areas will cut into the berm and lower the shoreline crest elevation, as shown in Figure 8.

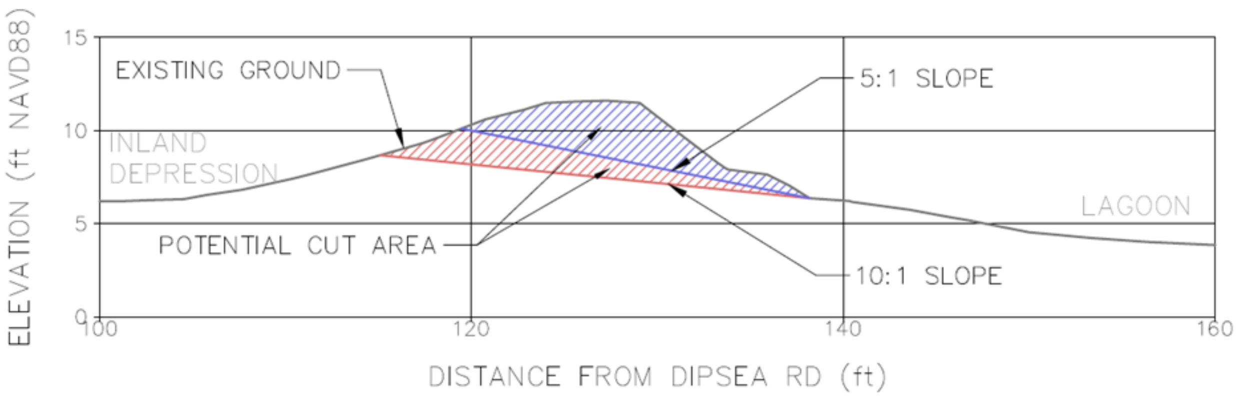

Figure 8. Typical cross-section of the setback shoreline adjacent to freshwater topographic depressions

With a lower crest elevation, lagoon floodwaters may overtop the berm more frequently during high water events and flow into and potentially impact the existing habitat[10]. This would be mostly of concern during elevated tide and storm surge events when lagoon water levels would primarily be marine water. During combined high tide and precipitation events, lagoon floodwaters may be more fresh or brackish and have less of an impact on the existing freshwater habitats. In front of the topographic depressions, with a 10:1 slope (red line in Figure 8), the shoreline crest lowers to approximately 8.5 feet NAVD88. With a 5:1 slope (blue line in figure), the shoreline crest lowers to approximately 10 feet NAVD88. In both alternatives, the crest remains above the 25-year water level, so overtopping would be infrequent under existing conditions (although would be more frequent in the future due to sea level rise). Cutting back the slope will not affect the flood risk of Dipsea Road because the road is at or above the 100-year flood elevation (the road is generally above 11 ft NAVD88, which means it would not be exposed to flooding by a 100-year event until approximately 24 inches of sea level rise). Additional research into lagoon salinity levels during typical high water events could be conducted during the feasibility study to better understand this dynamic.

Material excavated by laying back the shoreline could be used to either build a small flood berm inland for additional flood and sea level rise protection along low-lying shoreline segments (such as between Sonoma Patio and Walla Vista), as base material for a new setback access trail (which would need to be relocated behind the topographic depressions)[11], or to create a transitional ecotone slope elsewhere by placing fill material along the lagoon shoreline (Section 3.2.1.2).

3.2.1.2 Place Fill to Create Ecotone Slope

Using material excavated by shoreline grading (or from other sources), fill could be placed extending from the upland edge into the lagoon to create a transitional ecotone slope. The width of the fill placement would be approximately 50 feet. This strategy would likely be most appropriate in the vicinity of Calle Del Arroyo and the Seadrift Association office where there is limited space available to lay back the shoreline. The created transitional habitat could be contoured to tie in to the transitional habitat created by laying back the shoreline described in Section 3.2.1.1. The combination of laying back the shoreline where there is space and building out the shoreline in space-limited areas would provide a continuous, mildly sloped transitional edge habitat extending throughout the project area. A

[10] It is currently unknown if the topographic depressions contain fresh or brackish water. Additional investigation of existing conditions in these areas could be conducted during the feasibility study.
[11] Coordination with the Seadrift Association on potential impacts to and relocation of the trail is recommended.

schematic showing potential areas of excavation and fill to create a continuous transitional ecotone habitat is shown in Figure 9.

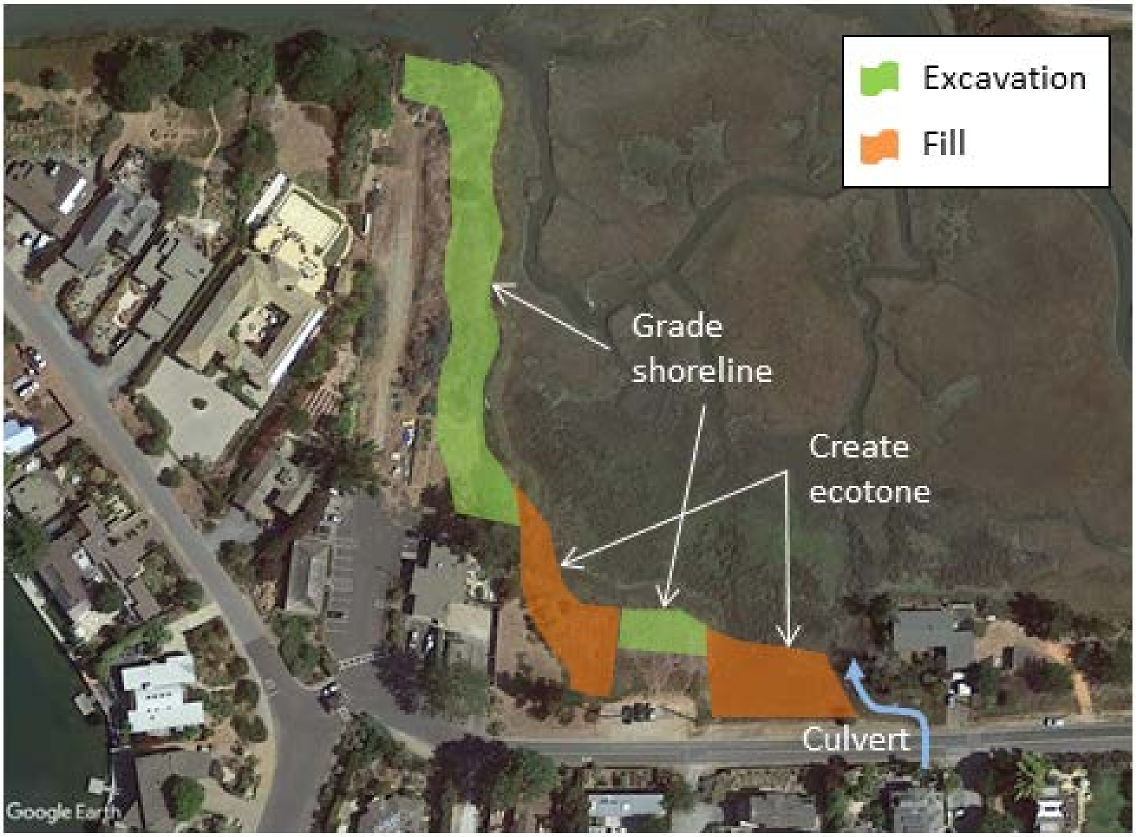

Figure 9. Approximate locations of excavation and fill placement to create transitional ecotone slope

In general, the ecotone slope would simply transition into the existing upland areas landward of the shoreline, which are relatively high in elevation (i.e., greater than 10 ft NAVD88 in elevation). The exception is the Marin County Open Space area between Sacramento Patio and Walla Vista, which is lower than 9 ft NAVD88. Along these stretches of shoreline, a small flood berm could be constructed at the top of the ecotone slope at an elevation of 10 ft NAVD88 to provide enhanced protection to inland areas.

3.2.1.3 Grade Shoreline to Create Wetland

In addition to grading the shoreline to create transitional habitat, upland areas could be lowered to elevations that would support intertidal wetland and marsh habitat to mitigate for impacts of the fill placement along Calle Del Arroyo. The transitional slopes could be connected to the new wetland areas to form a continuous topographic transition from mudflat to vegetated marsh to upland. The exact location and acreage of the wetland areas has not been determined at this point and would be refined in the feasibility study once actual mitigation needs are known. It is likely that the wetland creation areas would be located along Dipsea Road where there is more space available for shoreline setbacks. The mitigation needs may be relatively small due to the small footprint of fill placement required. The approximate acreage of the fill areas delineated in Figure 9 that may require mitigation is approximately 0.3 acres.

3.2.1.4 Sediment Augmentation

A number of recent pilot projects have investigated the feasibility of using thin-layer sediment augmentation to facilitate adaptation of mudflat and vegetated marsh habitats to sea level rise (also called mudflat and marsh recharge). One such example is the U.S. Fish and Wildlife Service project at Seal Beach National Wildlife Refuge[12]. The project applied a thin-layer of sediment to approximately 10 acres of low salt marsh habitat to raise the marsh plain elevation by approximately 8 to 10 inches in 2016. The site is being extensively monitored by researchers and the findings of the monitoring will provide valuable information and lessons learned for other potential applications.

The vegetated marsh area immediately adjacent to the low-lying stretch of Calle Del Arroyo initially appears to be a potential candidate for sediment augmentation because it is a quiescent, sheltered area where mobilization of sediment by currents and increased turbidity could be minimized (Figure 10). In addition, the marsh plain appears to support lower elevation marsh vegetation in this area such as cordgrass, which may be more susceptible to drowning by sea level rise in the future due to its lower starting elevation.

Potential considerations for application of thin-layer sediment augmentation to Bolinas Lagoon include the following:

- Sediment sampling would be required to understand the existing sediment composition (i.e., sand vs. mud) to find a suitable source material (e.g., dredging, culvert clean-out, etc.)
- A method to disperse the sediment across the mudflat/marsh would need to be evaluated (e.g., import, slurry, and spray; dredge, slurry, and spray or discharge, etc.)
- A vegetation buffer, sediment fencing, or hale bales could be used to help contain placed sediment and prevent losses from the placement area and lessen turbidity
- Additional analyses would be required to estimate the long-term elevation gains from placement of sediment, accounting for losses, settlement, and compaction/consolidation of underlying sediment
- Additional research and lessons learned from other pilot projects could be investigated to understand the timeframe for revegetation of the impacted areas
- Monitoring of post-project performance and evolution would be critical to demonstrate the effectiveness of thin-layer sediment augmentation in Bolinas Lagoon, including documentation of factors that contribute to project success or shortcomings

[12] https://www.fws.gov/refuge/seal_beach/what_we_do/resource_management/Sediment_Pilot_Project.html

Figure 10. Potential thin-layer sediment augmentation site adjacent to Calle Del Arroyo

Note: This marsh area is owned by Audubon Canyon Ranch (see Attachment A).

3.2.1.5 Vegetation Management

Vegetation management, such as removing non-native and invasive plant species (such as ice plant) and planting native, climate appropriate vegetation could be a part of all of the nature-based strategies identified above. Vegetation would also help stabilize the transitional slopes and reduce future erosion, while providing additional habitat benefits.

Other emerging vegetation management techniques may also provide additional benefits to the South End living shorelines project. Ongoing research by San Francisco State University scientists into a vegetation management technique called "arboring" shows initial promise in promoting the vertical growth of marsh plants such as pickleweed and California seablite[13]. Arboring is a technique where vertical lattices are constructed in the marsh using natural materials such as branches to facilitate the vertical growth of marsh vegetation. As plants grow, additional height can be added to the lattices to further promote growth above the marsh plain, which can provide high tide refugia for marsh species, predation relief, and sea level rise adaptation benefits. Pilot studies are currently being conducted in San Francisco Bay to evaluate the effectiveness of the technique and test different treatments such as height and spacing of the lattices. Additional benefits may include wave and current attenuation on marshes, which could lead to enhanced sediment accumulation and reduction in shoreline erosion. Further evaluation and coordination with researchers is recommended to assess the suitability of techniques such as arboring as part of the South End Living Shorelines Project in Bolinas Lagoon.

[13] https://farallones.org/wp-content/uploads/2019/04/1A_Santos.pdf

3.2.2 Potential Grey and Hybrid Strategies

The sections below describe three traditional flood protection and hybrid strategies that could be combined with the shoreline enhancements described above to provide additional co-benefits, sources of funding, and involvement of additional project partners such as Marin County Department of Public Works, Flood Control District 5, and local homeowners:

- Raise Calle Del Arroyo and shoulder
- Place fill to create a flood berm
- Hybrid green and grey strategy

These aspects of the project are critical to meeting the flood protection objectives of the project and would likely be implemented by other project partners besides the Sanctuary or GFA; however, it is useful to consider them in tandem with the shoreline enhancement aspects as they are closely related and complementary. The infrastructure strategies are not intended to be implemented by themselves, but rather as part of a larger project along with the shoreline enhancement strategies.

Additional consideration could be given in the feasibility study to the potential phasing of such hybrid strategies. For example, the living shoreline aspects of the project could proceed on a different timeline than the road raising or flood berm construction – or vice versa. Regardless of timing, care should be taken to design the various components of the project in such a way that they can be phased and proceed on different design, funding, and construction timelines if necessary. Given the potential multiple project partners that may ultimately be involved in the project, this may provide more flexibility to move forward with some aspects of the project while other components are still under development.

3.2.2.1 Raise Calle Del Arroyo and Shoulder

This strategy would raise the low-lying portion of the Calle Del Arroyo roadway (approximately 500 feet in length), and the adjacent shoulder (200 feet in length) to 8 feet NAVD88. Existing elevations along this section of road are between 7 and 8 feet NAVD88, so this alternative would result in at most one foot of raising. The road and shoulder would be graded with a mild slope so that water will drain off the road. The adjacent berm, which is 200 ft long, would be raised, where necessary, to the same elevation. Some portions of the existing berm are already at 8 feet NAVD88 or higher, so this strategy would fill in the low spots along the berm to create a level feature. At the end of the raised roadway section, and at the intersecting side streets (Sonoma Patio and Sacramento Patio) and driveways, the road would tie into the existing elevation between 8 and 8.5 feet NAVD88. The layout of this strategy is shown in Figure 11 and a typical section is shown in Figure 12.

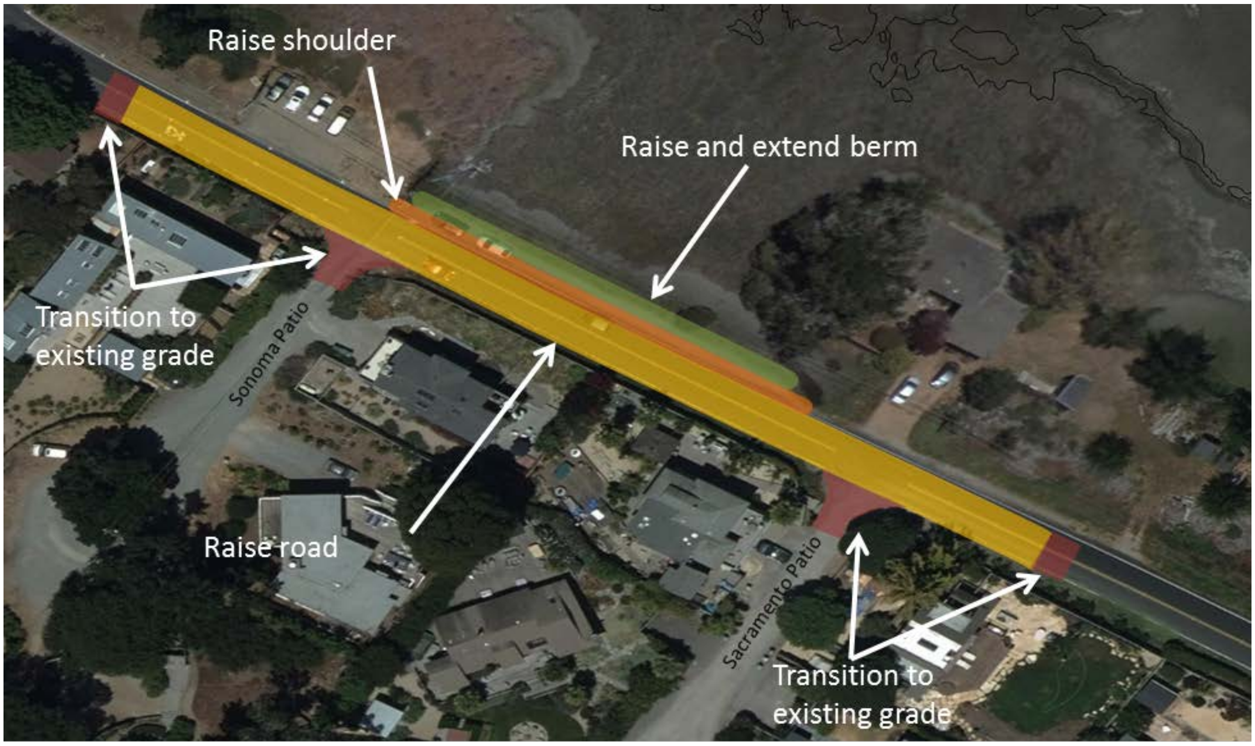

Figure 11. Raise Calle Del Arroyo, shoulder, and shoreline berm

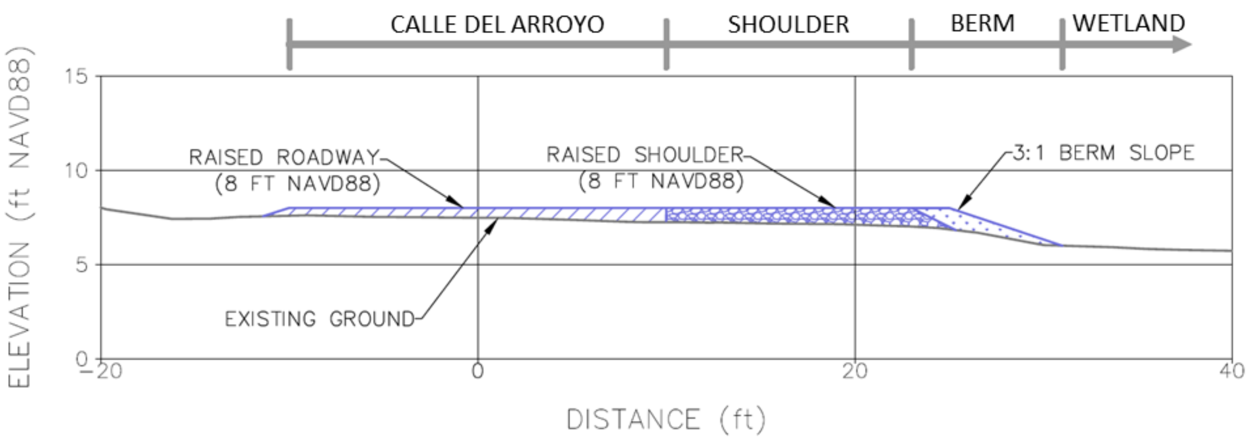

Figure 12. Typical cross section to raise Calle Del Arroyo, shoulder, and shoreline berm

This strategy could be combined with the shoreline enhancements (such as transitional ecotone creation or thin-layer sediment augmentation) to provide ecological, sea level rise adaptation, and flood protection benefits. It should be noted that raising the road to an elevation of 8 ft NAVD88 is only a near-term flood protection strategy for Calle Del Arroyo. Discussion of additional flood pathways for Calle Del Arroyo and future adaptation planning needs is provided in Section 7.

3.2.2.2 Place Fill to Create Flood Berm – Calle Del Arroyo

This strategy would raise the existing shoreline berm along the low-lying segment of Calle Del Arroyo to an elevation of 10 ft NAVD88 and extend the slope toward the lagoon at a 3:1 slope (Figure 13).

This strategy would have the benefit of minimizing impacts to adjacent wetlands while providing near-term flood protection for the road; however, the 3:1 slope is relatively steep and would provide a relatively narrow transitional slope for sea level rise adaptation of the adjacent marsh. This strategy could also raise Calle Del Arroyo up to an elevation of 8 ft NAVD88 and would likely include drainage improvements (for example, catch basins, stormwater conveyance system, and outfall with tide flap gate or valve) to manage stormwater and prevent ponding of runoff on the roadway and shoulder.

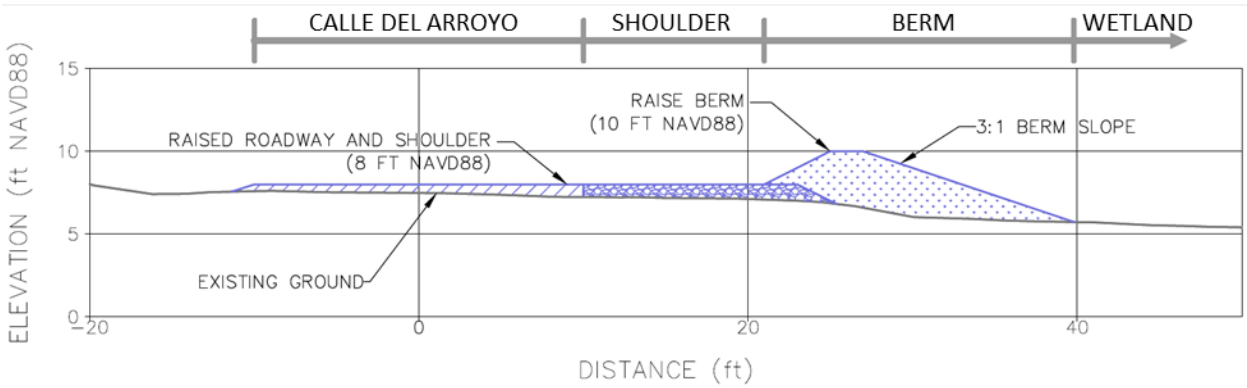

Figure 13. Flood berm strategy to address flooding along Calle Del Arroyo

Note: Stormwater/drainage improvements not shown.

This strategy could be combined with the shoreline enhancements (such as transitional ecotone creation or thin-layer sediment augmentation) to provide ecological, sea level rise adaptation, and flood protection benefits. It should be noted that raising the road to an elevation of 8 ft NAVD88 is only a near-term flood protection strategy for Calle Del Arroyo. Building the berm up to an elevation of 10 ft NAVD88 would allow for, and be compatible with, a future more significant raising of Calle Del Arroyo along its entire length. Such a strategy will likely be part of a long-term sea level rise adaptation strategy for the surrounding neighborhood.

3.2.2.3 Hybrid Strategy – Calle Del Arroyo

As discussed in the two strategies presented above, opportunities exist to create hybrid grey-green strategies to achieve multiple co-benefits as part of this project. Figure 14 shows a hybrid strategy that includes raising the road to 8 ft NAVD88 while also placing fill to create a transitional ecotone slope along the shoreline. The limits of fill placement assuming a 10:1 transitional slope and a design elevation of either 9 or 10 ft NAVD88 are shown. The width of fill placement would be approximately 50 feet for a 10 ft design elevation. The figure shows a small retaining wall along the shoulder to retain the fill placement; however, the exact method to transition from the top of the ecotone slope to the shoulder could be developed further in the feasibility study (e.g., retaining wall, earthen embankment, etc.).

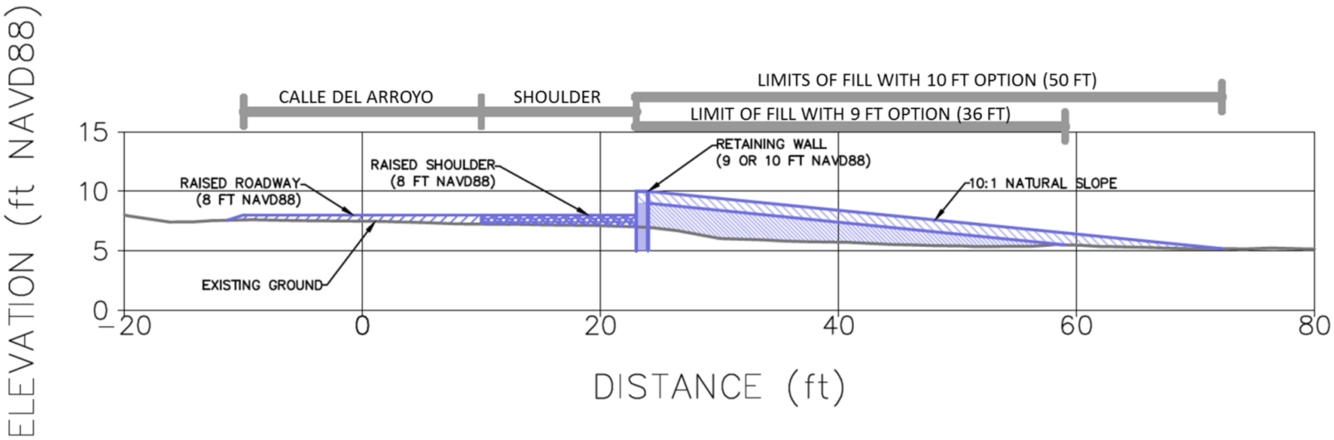

Figure 14. Hybrid Strategy to Address Flooding and Create Transitional Habitat Along Calle Del Arroyo

It should be noted that raising the road to an elevation of 8 ft NAVD88 is only a near-term flood protection strategy for Calle Del Arroyo. Building the ecotone slope up to an elevation of 10 ft NAVD88 would allow for, and be compatible with, a future more significant raising of Calle Del Arroyo along its entire length. Such a strategy will likely be part of a long-term sea level rise adaptation strategy for the surrounding neighborhood.

4 Discussion of Strategies

A high-level assessment of the identified potential shoreline strategies is presented in Table 6. All strategies appear feasible from a constructability perspective. In addition, substantial improvements to shoreline habitat could likely be realized with a relatively small impact (in terms of acreage) to adjacent wetland areas. Opportunities exist to combine nature-based shoreline enhancement strategies with traditional flood protection strategies to achieve multiple project objectives and create a hybrid project that could bring in additional project partners and sources of funding.

Table 6. Advantages and disadvantages of potential shoreline strategies

Strategy	Advantages	Disadvantages
Nature-based Strategies		
Grade shoreline to create ecotone slope	• Creates transitional habitat and provides for future marsh migration up to 2 ft of SLR • Minimal impacts to existing intertidal wetlands • Relatively straightforward permitting and construction	• Need to identify a beneficial reuse of excavated material or truck offsite to disposal area • May allow marine waters to enter existing freshwater/ brackish habitats along Dipsea Road

Strategy	Advantages	Disadvantages
		• Adequate space to setback shoreline does not exist everywhere
Place fill to create ecotone slope	• Creates transitional habitat and provides for future marsh migration up to 2 ft of SLR • May provide secondary flood protection benefits to Calle Del Arroyo if small flood berm is constructed at top of ecotone slope	• Substantial impacts to existing wetlands within footprint of fill placement • Need to identify a source of fill material and method to deliver material to site • Complex permitting issues due to placement of fill in lagoon • More difficult construction due to placement of fill on weak soils in lagoon
Grade shoreline to create wetland	• Creates additional intertidal habitat (or enhances existing habitat) along Dipsea Road where existing intertidal habitat is limited and narrow • Relatively straightforward permitting and construction • Construction can incorporate transitional slopes for future marsh migration • May mitigate potential wetland impacts elsewhere in project area	• May impact existing shoreline trail along Dipsea Road (trail would need to be relocated behind new wetland areas
Sediment augmentation	• Helps existing marshes keep pace with sea level rise • Potential for incremental applications in response to future sea level rise	• Unproven technique that may require future research, pilot studies, and monitoring to confirm effectiveness • Need to identify source of sediment (may require dredging in lagoon or import from elsewhere) • May impact existing mudflat and marsh habitat
Vegetation management	• Relatively low cost (can leverage existing GFA volunteer groups) • Adaptable to future SLR	• May require monitoring and adaptive management, maintenance, etc.
Grey and hybrid strategies		
Raise Calle Del Arroyo and shoulder	• Lessens frequency and severity of flooding of Calle	• Does not address long-term flooding issues along Calle Del Arroyo

Strategy	Advantages	Disadvantages
	Del Arroyo from high tides and runoff events • Compatible with proposed shoreline enhancement strategies • Adaptable to higher levels of future SLR	• Likely requires drainage improvements (storm drains, culverts, etc.) to drain runoff from Calle Del Arroyo
Place fill to create flood berm	• Lessens frequency and severity of flooding of Calle Del Arroyo from high tides and runoff events • Relatively low cost flooding strategy • Compatible with potential long-term adaptation of Calle Del Arroyo	• Does not address long-term flooding issues along Calle Del Arroyo • Likely requires drainage improvements (storm drains, culverts, etc.) to drain runoff of Calle Del Arroyo • Provides less ecological benefits than proposed shoreline enhancement strategies (due to steeper slope)
Hybrid green and grey strategy	• Addresses habitat and flooding goals of project • Project can be phased depending on project timeline and funding available to implement • Compatible with multiple future adaptation strategies along Calle Del Arroyo	• Does not address long-term flooding issues along Calle Del Arroyo • Likely requires drainage improvements (storm drains, culverts, etc.) to drain runoff of Calle Del Arroyo

5 Project Evaluation Criteria and Metrics

Development of appropriate project evaluation metrics will be an important component of the alternatives evaluation in the feasibility study. An initial list of potential evaluation criteria and metrics is identified below. This list will be refined further as part of the feasibility study. An example qualitative alternatives matrix and evaluation framework is included in Attachment B.

- **Engineering feasibility and cost:** Is the alternative feasible from an engineering perspective? How much does it cost?
  - Potential metrics: shoreline design elevation, length of shoreline enhancements, quantity of excavation and fill, ability to balance cut/fill, length of road raising, construction cost and duration, impacts to existing utilities
- **Effectiveness and lifespan:** What is the lifespan of the shoreline enhancements?
  - Potential metrics: project lifespan (with respect to sea level rise), reduction in depth and extent of flooding

- **Adaptability to sea level rise:** Is the alternative adaptable to future sea level rise? How compatible is the alternative with potential future measures that may be required to adapt to higher sea levels?
  – Potential metrics: Adaptability (yes or no)
- **Habitat benefits:** Does the alternative provide habitat benefits for flora and fauna? Do the habitat benefits persist or change in the future as a result of sea level rise?
  – Potential metrics: length of shoreline enhancement, size (acres) of additional wetland habitat, width of transitional habitat
- **Public access:** Does the alternative maintain or improve public access?
  – Potential metrics: None (yes or no)
- **Environmental impacts:** Does the alternative impact existing habitats or wetlands?
  – Potential metrics: size and type (i.e. permanent, temporary) of habitat impacts including impacts that would trigger permitting requirements
- **Permitting feasibility:** What permits will be required? What is the permitting cost and timeline?
  – Potential metrics: Number and types of permits required, permitting timeline
- **Governance and administrative:** What level of coordination with other agencies is required to implement the project?

6 Permitting Considerations

The project will need to be evaluated for compliance with the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA). The compliance determination, along with consultation under the federal Endangered Species Act (ESA), will be made by the lead state and federal agencies. The feasibility study would further consider what actions may be required for compliance with CEQA/NEPA.

The project would need to be analyzed for consistency with the federal Coastal Zone Management Act of 1972 and the California Coastal Act of 1976. Authorization may need to be sought from the California Coastal Commission (CCC), and/or a Local Coastal Program enacted and administered by local government (e.g., Marin County). A Coastal Development Permit may be required for the project and may require several technical studies to support the permit application (e.g., comprehensive resource constraint mapping [for environmentally sensitive habitats], water quality study, public and recreation studies, hazard assessment, wetland delineation, visual impact assessment, and cultural resource assessment). The CCC would likely require public access as part of the project. The local CCC office can be contacted to determine whether or not a Coastal Development Permit is required.

It is anticipated that the shoreline enhancement activities along Calle Del Arroyo and/or Dipsea Road may impact adjacent jurisdictional wetlands. The exact acreage of wetland impacts is not known at this point without a wetland delineation and more detailed design and evaluation of the shoreline enhancement strategies.

Potential impacts to wetlands could trigger the need to obtain environmental regulatory permits from the US Army Corps of Engineers (USACE) and the San Francisco Bay Regional Water Quality Board (RWQCB), who regulate discharges to wetlands under the Federal Clean Water Act Sections 404 and

401, respectively. It is anticipated that the project could be covered under the USACE's Nationwide Permit Program (potentially NWP 27 for Aquatic Habitat Restoration, Enhancement and Establishment Activities; NWP 14 for Linear Transportation Projects; or NWP 13 for Bank Stabilization). Wetlands are considered special aquatic sites, and if impacted by the project, would trigger the submittal of a Pre-Construction Notification to USACE describing steps taken to avoid and minimize potential impacts to wetlands. Cumulative impacts to wetlands less than 0.10 acre would be assessed by the USACE District Engineer on case-by-case basis and if considered *de minimus*, may not be required to include compensatory mitigation. Impacts to wetlands greater than 0.10 acres would need to be self-mitigating or would likely require compensatory mitigation at a minimum one-for-one ratio approved by USACE. The need for wetland mitigation would be assessed independently by the RWQCB, and they could agree to the mitigation requirements of USACE, or they could impose alternative or additional wetland mitigation requirements.

Additionally, the Project will need to assess potential impacts to plants and wildlife species listed under the Federal and California Endangered Species Acts administered by the United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and the California Department of Fish and Wildlife (CDFW). Potentially occurring species may include, but are not limited to, California red-legged frog (*Rana draytonii*), California black rail (*Laterallus jamaicensis*), western snowy plover (*Charadrius nivosus nivosus*), and central California coast steelhead (*Oncorhynchus mykiss irideus*). The feasibility study would further assess what species and habitats could be impacted and what permits would be required. If it is determined that the project could result in take (as defined by USFWS) of a federally-listed species, a Biological Assessment would need to be conducted to evaluate potential for occurrence, habitat, potential project effects, and avoidance and minimization measures. Upon consultation with USFWS (and NMFS for effects to anadromous fish or marine mammals), the USFWS/NMFS may issue the project a Biological Opinion or concurrence letter. An assessment of impacts to Essential Fish Habitat (EFH) may be required as an additional consultation with NMFS, if it is determined that EFH could be impacted. If it is determined that the project could result in take (as defined by CDFW) of a state-listed species, an Incidental Take Permit would be required by CDFW.

A permit from the Greater Farallones National Marine Sanctuary will also be required. The Sanctuary regulates activities such as discharging or depositing material within or beyond the boundary of the Sanctuary (if it subsequently enters the Sanctuary); dredging or otherwise altering the submerged lands of the Sanctuary; or constructing any structure on or in the submerged lands of the Sanctuary. Because the proposed shoreline enhancement activities may require placing fill within the Sanctuary or immediately adjacent to the Sanctuary, continued Sanctuary involvement in the project will be critical to ensure its success.

7 Additional Flooding Pathways

The 500-foot section of Calle Del Arroyo between Walla Vista and Rafael Patio is the lowest segment of the road and therefore has the most frequent flooding under existing conditions. However, as seen in Figure 15, there are other low-lying segments along Calle Del Arroyo that are between 8 and 9 feet NAVD88 that may be exposed to flooding from Bolinas Lagoon and Easkoot Creek under existing and future conditions. The following additional low-lying road segments along Calle Del Arroyo were identified:

- A 100-foot segment at the intersection of Joaquin Patio between 8.5 and 9 feet NAVD88

- A 230-foot segment at the intersection of Alameda Patio between 8 and 9 feet NAVD88
- A 500-foot segment between Calle Del Embarcadero and Shoreline Highway between 8 and 9 feet NAVD88

These areas may be flooded during more extreme events (such as a 50-year extreme tide) or with future sea level rise and highlight the need for a comprehensive long-term flood protection strategy for the Stinson Beach/Seadrift neighborhood. This pre-feasibility assessment focused on shoreline strategies along the most vulnerable section of roadway only; however, the topographic maps show that other segments are also at risk and additional work needs to be done at a neighborhood scale to reduce the flood risk to the road and surrounding homes as part of future planning efforts.

In their sea level rise adaptation report, Marin County identified Calle Del Arroyo as being a concern for flood risk and suggests raising the entire roadway as a flood protection strategy for the Stinson Beach/Seadrift neighborhood (Marin County 2018). This strategy was also identified in the Stinson Beach Watershed Program Flood Study and Alternatives Assessment (2014) by O'Connor Environmental (OEI). The road raising strategy identified in this pre-feasibility study would raise only a short portion of the road. Even with the proposed road raising / shoreline enhancements along Calle Del Arroyo, the road and surrounding homes could experience future flooding with low to moderate sea level rise.

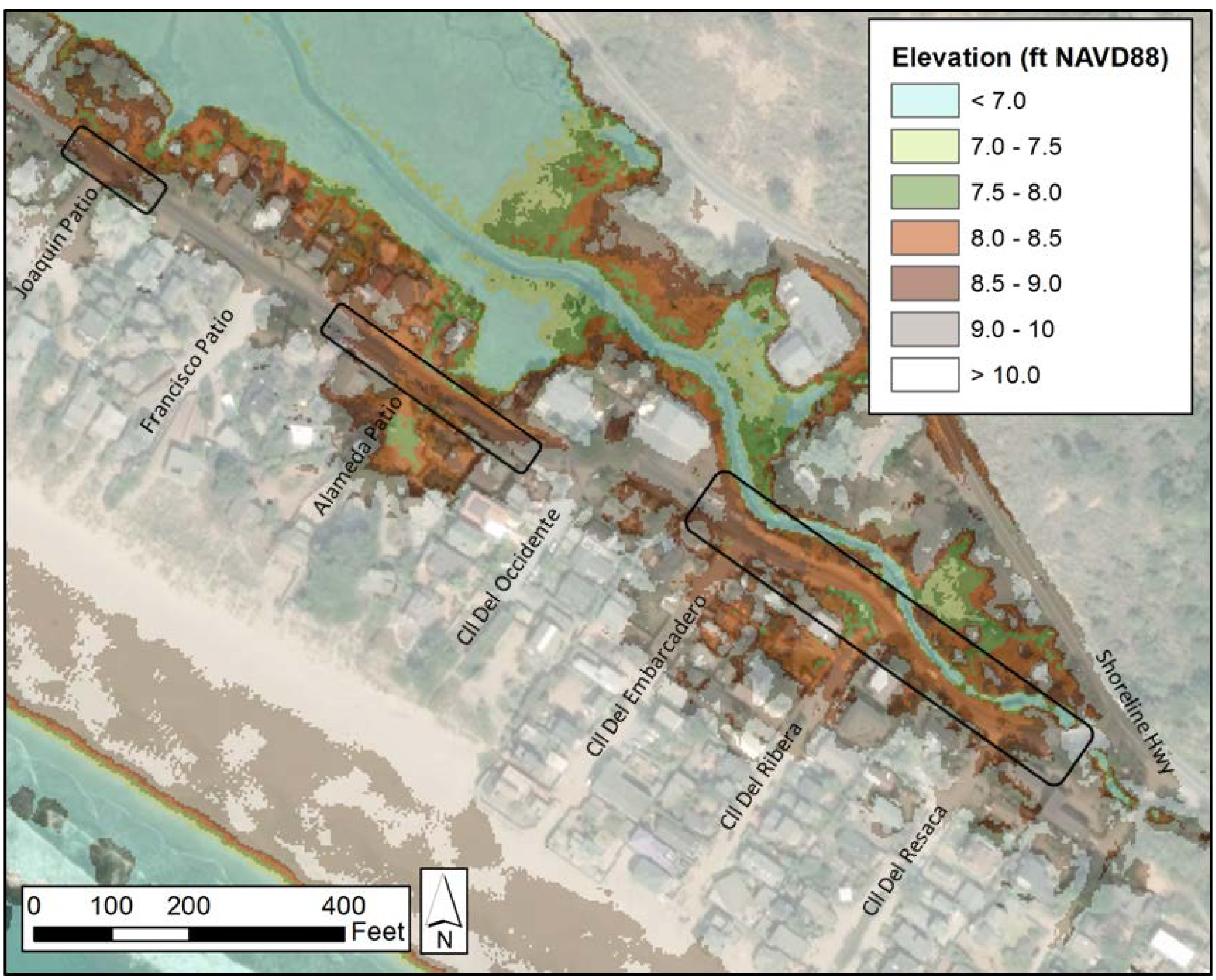

Figure 15. Low-lying segments of Calle Del Arroyo.

Table 7 shows the potential exposure at different water levels and what actions may be required to prevent or lessen these risks. The extreme water levels have been estimated based on AECOM's preliminary analysis of the recorded water level at Bolinas Lagoon tide gauge and were guided by the FEMA published extreme water levels at Point Reyes (see Table 3). This table shows that other low-lying portions of the road may become flooded during a 25-year return period event in Bolinas Lagoon.

As sea level rise occurs, the extreme water elevations identified in Table 7 will occur more frequently. For example, with 12 inches of sea level rise, the large-scale flood impacts identified for the present day 25-year event would occur on an annual basis. With 19 inches of sea level rise, the flood impacts identified for the present day 100-year event would occur on an annual basis.

Table 7. Estimated extreme water levels and potential flood exposure along Calle Del Arroyo

<table>
<tr><th>Tide / Storm Event</th><th>Estimated Water Level (ft NAVD88)</th><th>Impacted Areas of Calle Del Arroyo</th></tr>
<tr><td>MHHW</td><td>5.4</td><td>No impacted areas</td></tr>
<tr><td>King tide (1-year)</td><td>7.5</td><td>200-foot section between Sonoma Patio and Sacramento Patio</td></tr>
<tr><td>5-year storm</td><td>7.9</td><td>500-foot section between Walla Vista and Rafael Patio</td></tr>
<tr><td>25-year storm (or king tide + 12” SLR)</td><td>8.5</td><td rowspan="2">850-foot section between Seadrift Rd and Rafael Patio

230-foot section at intersection of Alameda Patio and adjacent homes

500-foot segment between Calle Del Embarcadero and Shoreline Hwy and adjacent homes</td></tr>
<tr><td>50-year storm (or king tide + 16” SLR)</td><td>8.8</td></tr>
<tr><td>100-yr storm (or king tide + 19” SLR)</td><td>9.1</td><td>150-foot segment at the intersection of Joaquin Patio</td></tr>
</table>

Note: Estimated water levels correspond to the recommended planning values presented in Table 3.

8 Feasibility Study Outline and Budget

AECOM understands that a follow-on feasibility study may be conducted to further evaluation of existing site conditions, opportunities and constraints, and design alternatives and costs. The outline below provides and overview of potential feasibility study components. The estimated costs to complete the tasks as outlined below is approximately $225,000 to $295,000 (see Attachment C for additional details). The costs are approximate and could vary depending on a variety of factors. GFA will have to work with the project team to develop appropriate scope and budget for the tasks identified below. In addition, GFA staff have indicated that they may perform some of these tasks in-house, which could lessen the costs needed for consultant support. A next step would be to refine the outline and work responsibilities to identify lead and support roles for GFA and consultant support.

Feasibility Scope Outline

1. Project Goals and Objectives
2. Existing Conditions and Site Assessment
    - 2.1. Topographic and Marsh Vegetation Survey
    - 2.2. Refined Water Level Analysis
    - 2.3. Habitat Assessment and Wetland Delineation
    - 2.4. Groundwater and Lagoon Salinity Monitoring
    - 2.5. Geotechnical and/or Soil Investigations
    - 2.6. Hydrodynamic Modeling and Erosion Study
3. Opportunities and Constraints Analysis
4. Preliminary Design Strategies
    - 4.1. Design Criteria
    - 4.2. Conceptual Design and Costs
    - 4.3. Adaptation Strategy
5. Alternatives Evaluation
    - 5.1. Evaluation and Performance Metrics
    - 5.2. Alternatives Evaluation
    - 5.3. Geomorphic Assessment
    - 5.4. Preferred Alternative
6. Permitting and Mitigation Strategy
    - 6.1. Identify Potential Permits
    - 6.2. Agency Coordination
    - 6.3. Permitting Strategy
    - 6.4. Identify Impacts and Mitigation Needs
7. Engagement and Outreach

7.1. Strategy Development

7.2. Stakeholder Engagement

7.3. Public Outreach

8. Funding and Financing Options

9. Next Steps

10. Feasibility Study Report

11. Project Management

9 Statement of Limitations

The findings and recommendations presented in this memo were based on a very limited review of existing data and observations during a site visit, review of readily available data, conversations with local residents and GFA staff, and the authors' professional experience on similar projects. The schematics and concepts presented in this memo have not been evaluated to a sufficient level of detail for permitting or construction and should not be used as such. Further evaluation of the feasibility of the identified strategies is warranted and the concepts presented will continue to be refined with further analysis and study. The information presented is intended for the sole use of GFA and should be considered "for discussion purposes" only and not relied upon for identification of existing or future flood risks; nor does it make specific recommendations for design elevations of flood protection measures. In addition, AECOM offers no guarantees that the strategies presented in this memo will eliminate existing or future flood hazards if implemented as presently described.

Note on feasibility study scope and estimated budget: Estimate was prepared for Greater Farallones Association for the purposes of raising funding and budgeting of future work. Estimate is based on typical costs to perform the tasks described based on similar projects and should be re-evaluated and refined along with a corresponding detailed scope of work. Estimate is not a fee proposal by AECOM nor a commitment by AECOM to perform the work described for the estimated fee.

10 Attachments

Attachment A. Parcels and land ownership within the project area

Attachment B. Example alternatives matrix and evaluation framework

Attachment C. Feasibility Study outline and approximate task budgets

11 References

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Attachment A. Parcels and land ownership within the project area

Attachment B. Bolinas Lagoon South End Living Shoreline Project: Example Alternatives Matrix and Evaluation Framework

	Project Description	Engineering Feasibility and Cost				Effectiveness and Lifespan				SLR Adaptability		Habitat Benefits			Public Access	Environmental Impacts		Permitting Feasibility		Governance
	• Project description • Length of shoreline enhancement • Length of road raising • Volumes of excavation, fill, and net • Design elevations	Site access	Construction cost and duration	Construction impacts (permanent and temporary)	Net volume of imported fill and/or exported material	Meets project objectives?	Project lifespan	Provides flood protection co-benefits?	Level of flooding and sea level rise to which alternative meets project objectives	Adaptable to SLR?	Compatible with future neighborhood adaptation actions?	Length of shoreline enhancement	Acres of additional wetland habitat created	Width of transitional habitat	Maintains or improves public access?	Size and type of temporary habitat impacts	Size and type of permanent habitat impacts	Number and types of permits	Permitting cost and timeline	Number of agencies to coordinate with
Alternative 1	*[Description]*																			
Alternative 2	*[Description]*																			
Alternative 3	*[Description]*																			

Bolinas Lagoon South End Living Shorelines Project
Initial Ideas on Shoreline Enhancement Alternatives Evaluation Framework

Shoreline Enhancement Alternatives Evaluation Framework

Once a preliminary set of alternatives is developed, it is important to have a framework in place to evaluate the performance of each alternative with respect to the goals and objectives of the project. This exercise can help determine which alternatives best reflect the agreed upon project goals, objectives, and community values.

Methodology for Developing Alternatives Evaluation Framework

The alternatives evaluation framework and criteria could be informed by the following elements:

- The vision, goals, and objectives of the project
- Consistency with the visions, goals, and objectives of other plans governing the project area and neighboring areas
- The input of key stakeholders and community members

Alternatives Evaluation Framework

Building upon the initial list of evaluation criteria identified in the pre-feasibility memo, GFA could consider the following categories of evaluation criteria and considerations:

- Engineering feasibility and cost
- Effectiveness and lifespan
- Adaptability to sea level rise
- Habitat benefits
- Public access
- Environmental impacts
- Permitting feasibility
- Governance and administrative

A qualitative or quantitative ranking system could be used for most of the criteria to score the overall performance of each proposed strategy. Each criteria category could also be weighted in proportion to the agreed-upon priorities of GFA in terms of its contribution to the overall scoring. The goal should not necessarily be to select the highest scoring strategy, but to evaluate the trade-offs between the different criteria categories, and select strategies that that are the most balanced across the categories. Table 1 shows a sample range of ordinal ranks that could be considered for the evaluation exercise. This ranking system would allow for a qualitative comparison of the strategies without the need for a total quantitative score. It should be noted that the criteria and ordinal rankings shown below are merely illustrative. Ranking rationales and scoring metrics would be developed for each criterion at a later stage of the project, once specific criteria are developed.

Table 1: Example Ordinal Ranking System for Evaluation Criteria

ORDINAL RANKS	RANK NOTATION
Significantly Positive	++
Positive	+
Neutral	0
Negative	-
Significantly Negative	--
Not Applicable	NA
To Be Determined	TBD

Table 2 shows examples of potential criteria within each category and illustrative ranking. If a quantitative ranking method is preferred, the rank notations shown in Table 1 could be converted to numerical values to develop quantitative scoring.

Table 2: Examples of Alternatives Evaluation Criteria and Ordinal Ranking Rationale

CRITERIA ID	ILLUSTATIVE CRITERIA	ILLUSTRATIVE RANKING LOGIC	
	Illustrative Technical (T) Effectiveness Criteria	**Illustrative Ordinal Ranking Rationale**	
T1	Ability to access site and construction areas	**Accessibility**	**Rank**
		Project can be constructed from land	+
		Project requires waterside access	-
T2	Construction costs	**Capital Cost**	**Rank**
		<$100K	++
		$100K - $500K	+
		$500K - $1M	0
		$1M - $5M	-
		>$5M	--
T3	Construction duration	**Duration**	**Rank**
		<6 months	++
		6-12 months	+
		12-18 months	0
		12-24 months	-
		>24 months	--
	Illustrative Effectiveness and Lifespan (L) Criteria	**Illustrative Ordinal Ranking Rationale**	
L1	Meets project objectives	**Effectiveness**	**Rank**
		Meets 5 of 5 objectives	++
		Meets 4 of 5 objectives	+
		Meets 3 of 5 objectives	0

CRITERIA ID	ILLUSTATIVE CRITERIA	ILLUSTRATIVE RANKING LOGIC	
		Meets 2 of 5 objectives	-
		Meets <2 of 5 objectives	--
L2	Number of years alternative will meet project objectives	**Lifespan**	**Rank**
		>30 years	++
		20-30 years	+
		10-20 years	0
		5-10 years	-
		<5 years	--
L3	Level of flood protection provided	**Level of protection**	**Rank**
		100-year including SLR	++
		50 to 100-year	+
		10 to 50-year	0
		5 to 10-year	-
		< 5-year	--
	Illustrative Sea Level Rise Adaptability (A) Criteria	**Illustrative Ordinal Ranking Rationale**	
A1	Adaptable to future SLR	**Adaptable**	**Rank**
		Yes	+
		No	-
A2	Compatible with future neighborhood adaptation actions	**Compatible**	**Rank**
		Yes	+
		No	-
	Illustrative Habitat (H) Benefits Criteria	**Illustrative Ordinal Ranking Rationale**	
H1	Length of shoreline enhancement	**Shoreline Length**	**Rank**
		>3000 ft	++
		1000 to 3000 ft	+
		<1000 ft	0
H2	Acres of additional wetland habitat created	**Wetland Acreage**	**Rank**
		>2 acres	++
		1-2 acres	+
		< 1 acre	0
H3	Width of transitional habitat	**Width**	**Rank**
		>40 ft	++
		20 to 40 ft	+
		<10 ft	0
	Illustrative Public Access (PA) Criteria	**Illustrative Ordinal Ranking Rationale**	
PA1	Maintains or improves public access	**Access**	**Rank**
		Improves public access	++
		Maintains public access	0
		Reduces public access	--
	Illustrative Environmental (E) Criteria	**Illustrative Ordinal Ranking Rationale**	
E1	Size and type of temporary	**Temporary impacts**	**Rank**

CRITERIA ID	ILLUSTATIVE CRITERIA	ILLUSTRATIVE RANKING LOGIC	
	habitat impacts	Minimal impacts that can be fully restored	0
		Substantial impacts that can be fully restored	-
E2	Size and type of permanent habitat impacts	**Permanent impacts**	**Rank**
		Minimal impacts that cannot be restored	-
		Substantial impacts that cannot be restored	--
	Illustrative Permitting (P) Feasibility Criteria	**Illustrative Ordinal Ranking Rationale**	
P1	Number and types of permits	**Permits required**	**Rank**
		Minimal permits that can easily be obtained (or permits from a small number of agencies required)	+
		Numerous permits that can easily be obtained	0
		A few permits that will be difficult to obtain	-
		Numerous permits that will be difficult to obtain (and from multiple agencies)	--
P2	Permitting timeline	Permits can be obtained in <6 months	+
		Permits can be obtained in 6-12 months	0
		Permits can be obtained in >12 months	-
	Illustrative Governance (G) Criteria	**Illustrative Ordinal Ranking Rationale**	
G1	Number of agencies, departments, and organizations to coordinate with	**Coordination**	**Rank**
		Project can be implemented by GFA alone	+
		Coordination with one other agency required	0
		Coordination with multiple agencies required	-

Bolinas Lagoon South End Living Shoreline Project
Attachment C. Estimated Budget for Feasibility Study
Date **May 20, 2019**
By: **J.Vandever (AECOM)**

Task	Description	Approx. Cost Range Low		Approx. Cost Range High		Notes
1	**Project Goals and Objectives**	**$**	**4,000**	**$**	**6,000**	Reconfirm project goals and objectives
2	**Existing Conditions and Site Assessment**	**$**	**75,000**	**$**	**100,000**	
2.1	Topographic and Marsh Vegetation Survey	$	10,000	$	15,000	Survey project area including elevations of marsh vegetation and transition zones
2.2	Refined Water Level Analysis	$	10,000	$	15,000	Re-evaluate water level analysis in Bolinas Lagoon to confirm extreme water level estimates
2.3	Habitat Assessment and Wetland Delineation	$	15,000	$	20,000	Delineate existing wetland areas and describe existing shoreline habitats and vegetation species, etc.
2.4	Groundwater and Lagoon Salinity Monitoring	$	20,000	$	20,000	Monitor salinity in inland topographic depressions; monitor salinity in lagoon during winter storm events
2.5	Geotechnical and/or Soil Investigations	$	-	$	-	TBD; not estimated; may not be required for feasibility study
2.6	Hydrodynamic Modeling and Erosion Study	$	20,000	$	30,000	Confirm estimates of extreme water levels, especially combined coastal-riverine flood events
3	**Opportunities and Constraints Analysis**	**$**	**5,000**	**$**	**8,000**	Reconfirm shoreline enhancement opportunities and site constraints
4	**Preliminary Design Strategies**	**$**	**50,000**	**$**	**60,000**	Reconfirm design criteria and develop preliminary design and costs (30% preliminary design level), potential phasing,
	Design Criteria					including adaptability of strategies.
	Concept Design and Costs					
	Adaptation Strategy					
5	**Alternatives Evaluation**	**$**	**15,000**	**$**	**20,000**	Develop alternatives from conceptual strategies and evaluate with respect to evaluation criteria and metrics; identify preferred alternative
	Evaluation and Performance Metrics					
	Alternatives Evaluation					
	Geomorphic Assessment					This task may be performed by GFA staff with support by others and is not included in the cost estimate.
	Preferred Alternative					
6	**Permitting and Mitigation Strategy**	**$**	**10,000**	**$**	**15,000**	Identify mitigation needs, potential permits, initial coordination with agencies, and develop permitting strategy
	Identify Potential Permits					
	Agency Coordination					
	Permitting Strategy					
	Identify Impacts and Mitigation Needs					
7	**Engagement and Outreach**	**$**	**6,000**	**$**	**10,000**	Assume GFA led with consultant support to participate in meetings, etc.
	Strategy Development					
	Stakeholder Engagement					
	Public Outreach					
8	**Funding and Financing Options**	**$**	**5,000**	**$**	**8,000**	Identify potential funding sources for various elements of project
9	**Next Steps**	**$**	**5,000**	**$**	**5,000**	
10	**Feasibility Study Report**	**$**	**30,000**	**$**	**35,000**	Identify next steps and/or data gaps based on findings of feasibility study
	Subtotal	**$**	**205,000**	**$**	**267,000**	
11	**Project Management**	**$**	**20,500**	**$**	**26,700**	Assumed to be 10% of subtotal of other tasks
	Total	**$**	**225,500**	**$**	**293,700**	

Note Estimate was prepared for Greater Farallones Association for the purposes of raising funding and budgeting of future work. Estimate is based on typical costs to perform the tasks described based on similar projects and should be re-evaluated and refined along with a corresponding detailed scope of work. Estimate is not a fee proposal by AECOM nor a commitment by AECOM to perform the work described for the estimated fee.