Coyote Creek to Bothin Marsh Dredge Sediment Beneficial Reuse Feasibility Study

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Coyote Creek to Bothin Marsh Dredge Sediment Feasibility Reuse Study

Introduction

This study performs a feasibility analysis of the potential impacts and costs for beneficial reuse of dredge sediments from the Coyote Creek flood control channel managed by Marin County Flood Control and Water Conservation District (the District) in the adjacent Bothin Marsh owned by Marin County Parks and Open Space Department (Parks) (Figure 1). The importance of re-engineering the sediment connection between tidal flood control channels and their adjacent tidal marshes has been widely recognized around the Bay as critical in recent years. Both to prepare for the impacts of sea level rise (SLR) as well as maintain tidal marsh habitat and ecological values. One adaptation approach evaluated in this study is to beneficial re-use natural sediments from the channel by selectively dredging and transporting the fine to coarse-grained dredge sediment fraction from the channel and 1) place the fine-grained fraction on the marshplain to create and/or maintain relatively high intertidal elevation gradients with special habitat features and 2) place the coarser-grained fraction along the marsh edge to buffer erosion. This type of beneficial reuse of dredged sediments can both maintain tidal marsh elevations and ecological values and functions as well as reduce shoreline erosion which is the leading cause of loss of tidal marsh habitat. This project is based on the realization by Marin County DPW and Marin County Open Space District for the need to jointly manage flood control and climate change impacts at Bothin Marsh to achieve the following long term goals:

(a) Maintain flood conveyance in the Coyote Creek channel within the tidally-influenced reaches;

(b) To offset the cumulative impacts of accelerated sea-level rise on sensitive tidal salt marsh habitats within Bothin Marsh that are now vulnerable to increasing submergence during maximum high tides; and,

(c) Identify a cost-effective SLR adaptation approach that utilizes the need for Flood Control to maintain channel capacity through dredging with the need for Marin Open Space to maintain marsh grades slowly over time and in a manner that protects and enhances habitat values

Bothin Marsh, adjacent to the Coyote Creek channel, is a tidal salt marsh and an ecological resource for two Threatened and Endangered (T&E) species as well as a heavily utilized public amenity due to the highly used public pathway that runs along the old railroad grade at the outer edge of the marsh. Bothin Marsh also fronts the urbanized area of Mill Valley to Tam Junction along Miller-Almonte Avenue. This area that regularly floods in the semi-annual King Tide events resulting in significant roadway closures and localized flooding. Flooding is predicted to significantly worsen under all future scenarios of sea level rise. It has developed important and valuable restored salt marsh habitat. Some of the existing salt marsh has formed on older (20^{th} century) artificial deposits of dredged sediment. However, like many tidal salt marshes in the Bay Area, its habitat quality is limited by scarce, poor quality upland transition zone habitat that is vulnerable to increasing impacts of sea level rise and marsh submergence. Bothin Marsh has recently exhibited signs of accelerated sea level rise and subsidence following the last El Niño events. The entire marsh is submerged during extreme high tides, leaving no cover for wildlife. Cordgrass vegetation is expanding in areas formerly dominated only by pickleweed indicating gradual submergence of the marsh. Likewise, adjacent Almonte and Miller Avenues undergo direct tidal flooding of the roadways during extreme high tides (typically between November through January) that render the roads unpassable. These problems are likely to intensify significantly, in the next two decades and beyond as sea levels rise. Bothin Marsh provides a number of ecosystem services. It provides a physical buffer between extreme high tides and the highly developed residential and commercial lands of Tam Junction and Mill Valley. Bothin Marsh provides not only marsh habitat, but as also wave attenuation (reduction of storm wave height and run-up during extreme tides) and flood protection benefits to the adjacent roadways.

The Coyote Creek flood control channel is periodically dredged to maintain a level of flood protection for the urbanized areas adjacent to the channel and the sediments taken out of the watershed to a landfill for use as cover (Figure 2). However, as southern Richardson Bay is one of the most vulnerable coastal lowlands in San Francisco Bay affected by sea level rise, there has been growing awareness of the need to prepare for sea level rise by reusing sediment from creeks in the local watershed to supplement insufficient sediment supply to tidal marshes and their upland buffer zones (Goals Project 2015).

Direct sediment addition to submerging and subsiding tidal marshes has been successfully performed in other regions of the United States, such as the Gulf of Mexico (Slocum et al. 2005, Schrift et al. 2008). In Gulf of Mexico tidal marshes, shallow deposits of sediment have been artificially applied over subsided marshes such that established marsh vegetation emerges directly through thin layers of applied sediment, and regenerates cover without reverting to bare mud and subsequent new establishment of vegetation. In the San Francisco Estuary, however, no direct placement of dredged sediments into tidal marsh habitat has been performed in an analogous method. This has been due primarily to a lack of proposals to test unprecedented marsh sediment nourishment projects in a region with rigorous regulatory permitting requirements for protection of listed wildlife species. San Francisco Estuary tidal marshes are complex ecosystems requiring careful design consideration for sediment placement.

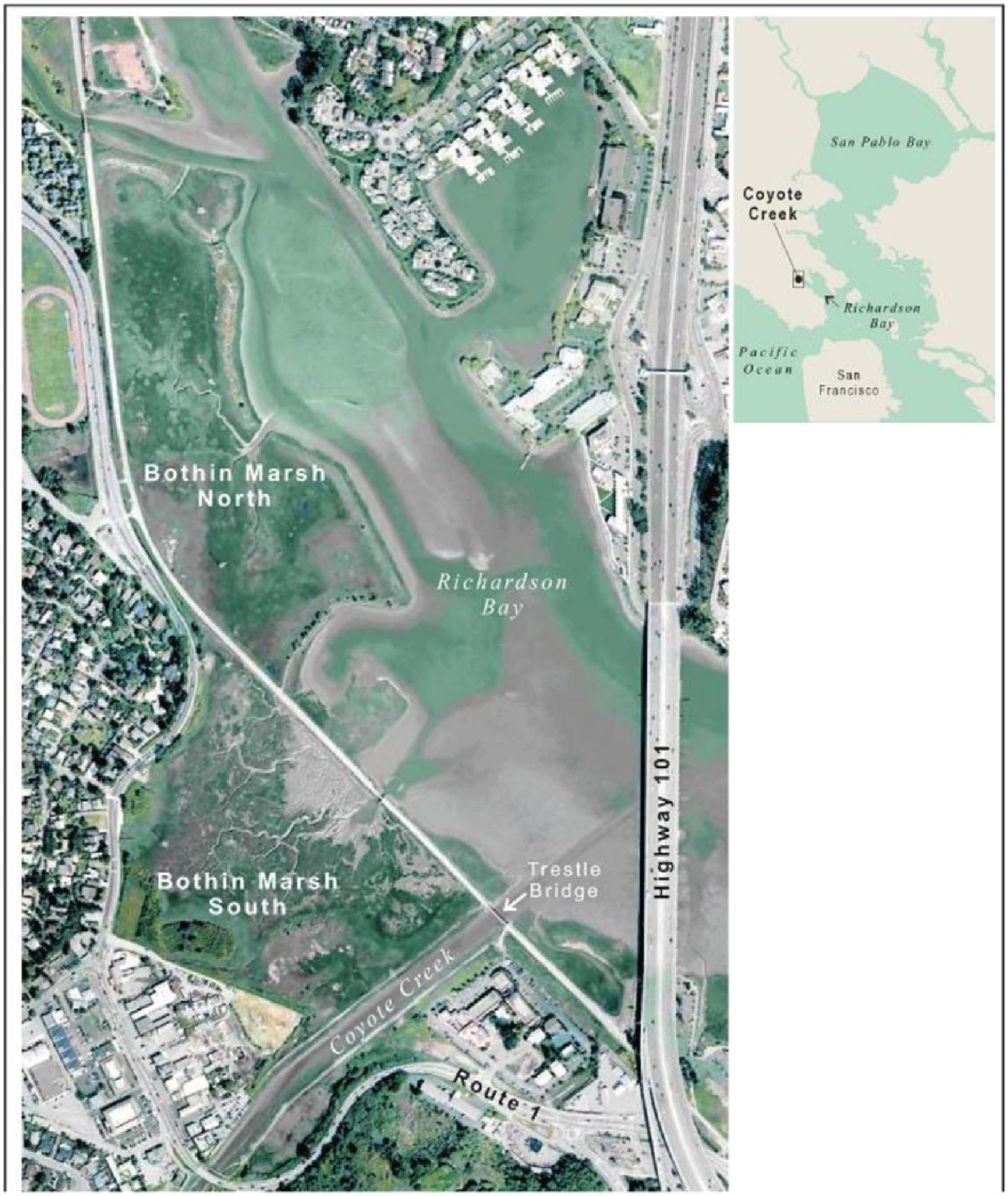

Figure 1: Map of Coyote Creek and Bothin Marsh (from PWA 2012)

Study Goals and Scope

The goals of this study are to evaluate the technical and permitting feasibility and associated costs for pilot projects demonstrating the reuse of dredged sediments from the Coyote Creek flood control channel to enhance the marsh ecologically in a manner that most replicates natural flow and sediment deposition conditions at the higher, landward edges of tidal salt marsh. The sediment deposition processes emulated in this project are those of terrestrial and fluvial (stream) flood deposits that occasionally build natural sediment fans and splays over edges of tidal marsh platforms. These storm-related terrestrial-origin sediment features (splays) are basically different from periodic, incremental small tidal deposits of bay mud on marsh platforms.

Thin-lift dredge sediment placement methods are analogs of natural sediment deposition with engineered equivalent of flood-deposit fan and splay features in landward edges of salt marsh (Photo 1 Note that all photos are contained in Appendix C). In this project, we evaluate applying the dredged creek sediments (mixed tidal and fluvial origin) using pipes that discharge slurry (sediment-water fluid mixtures) in thin-lifts (sediment layers less than 20 cm thick deposited in discrete pulses) that allow mimic natural deposition processes and patterns that beneficially maintain critical high salt marsh habitats. Photos 1 through 3 below show dredged sediment pipeline splays that mimic natural splay deposition and the type of hydraulic dredge splay proposed for the pilot projects in this study.

The proposed pilot projects would have usefulness well beyond this specific area. To-date, the most common dredge sediment beneficial reuse project types in the Bay Area have involved deep fill of dredged sediments (typically several feet) to restore diked and subsided baylands behind levees using sediment from marina, ferry and port dredging projects. These deep fill projects are less natural and do not mimic the natural sediment deposition from a thin-lift sediment placement project. Therefore, evaluation of constructability, costs and impacts for direct placement of both bay and terrestrial derived sediments to maintain adjacent tidal marsh grades and habitat and to inhibit shoreline erosion is critical to understand for flood agencies and land managers preparing for the impacts of climate change.

The ultimate goals of direct dredge sediment addition to tidal marshes at the project site will be to: (1) to maintain the ecological integrity of tidal wetlands that are vulnerable to gradual submergence by rising seas, by incrementally raising marsh substrate elevations; and to (2) to begin phased construction of future habitat-compatible levees that protect urban shorelines and adjacent lowlands from direct coastal flooding, while enhancing rather than adversely impacting tidal marshes.

This feasibility study is the first step towards the ultimate goals for the project. The specific tasks of this feasibility study are as follows:

- Perform a feasibility evaluation and conceptual design for the beneficial reuse of dredged sediments from Coyote Creek to enhance existing high marsh using fine-grained sediments to maintain marsh grades or using the coarse-grained sediment fraction along the marsh edge to inhibit marsh scarping or to construct high permeability zones in any future uplands-transition zone.

- The evaluation will look at methods of sediment placement to raise marsh elevations to increase the resilience of marsh-upland transition zone habitats threatened by long-term accelerated sea level rise, and to attenuate waves and provide increased levels of flood protection.
- This first phase of the evaluation will focus on the feasibility of artificially emulating natural terrestrial and stream flood deposition processes and landforms (shallow sediment fans and splays formed with a dredge pipe and sediment slurry) to provide this habitat and flood protection benefits. Future phases will include preliminary and final design and permitting followed by preparation of construction plans. The detailed cost estimate (Appendix A lists these future work phases).

- Prepare an opportunities and constraints summary for proposed pilot projects
- If the project identified as potentially feasible based on the analysis of opportunities/constraints and costs contained in this Study, we would develop an outline for the preliminary design of pilot scale projects that could be constructed as demonstration projects.
- Identify constructability and permitting issues for the pilot projects and recommend an approach that may be phased, as required, to address identified issues and meet project goals.
- Prepare first-cut cost estimates for subsequent design and construction phases of the project and to allow for securing of additional grant funding.

Background

This section provides a brief summary of the important information relevant to the study. This section is not meant to be fully comprehensive but rather a quick description of relevant information about the project area useful for understanding the proposed project.

Project Site and Physical Setting

Bothin Marsh, is located within Southern Richardson Bay is an approximately 100 acre tidal salt marsh complex formed within artificial dikes and berms bordering the mouth of Coyote Creek and southern Richardson Bay. Richardson Bay lies along the southeastern Marin shoreline as a sheltered shallow embayment adjacent to the deep waters of Raccoon Straights in San Francisco Bay. The bay has a broad, flat, gently sloping bottom extending from the head to the mouth between Sausalito Point and Belvedere Island to the northwest. The Bay formed from the submergence of river valleys within a faulted, subsided basin, filling with up to 150 feet of soft estuarine sediments during the post-glacial (Holocene) marine transgression. Estuarine sediments filled the earlier valleys cut by streams during Pleistocene glacial low stands of sea level (Atwater et al. 1979). Prior to human development, the tidal marshes of Richardson Bay occurred along its upland hillslope and valley borders, and were diked and filled in the 19th and early 20th century. Modern tidal salt marshes of Richardson Bay, including Bothin Marsh, occur within former mudflats or tidally breached dikes enclosing former mudflats.

Southern Richardson Bay can be divided roughly into an inner and outer bay by the Highway 101 Bridge. The depths and shoreline of the inner and outer bay reflect a balance between sediment supply derived from a combination of local watershed and open San Francisco Bay sources, and the forces of waves and tides that move and redistribute these sediments. Shallow Bay muds (clay-silt) were deposited during historical times, when diking of tidal marshes reduced tidal prism and energy (the volume of tidal water) and induced sedimentation in reduced undiked tidal flat areas. (Gilbert 1917)

Sea level in San Francisco Bay has gone up and down during cycles of glaciation (low sea level) and deglaciation (interglacial periods; high sea level). At the glacial maximum of the end of the Pleistocene (ice age), sea level was about 400 ft lower than today, and San Francisco Bay was a river valley occupying a previous interglacial Bay. The San Francisco Bay basin was rapidly encroached by swiftly rising seas (up to 10 times faster than the early historical rate) and re-flooded from 10,000 to about 6,000 years ago. The modern bay and its oldest prehistoric tidal marshes formed during a period of very slow sea level rise during the last 4,000 years, mostly during the last 2000 years. The early historical maps of San Francisco Bay (U.S. Coast Survey T-sheets of 1850s) were a snapshot of a gradually rising shoreline over millennia. During past periods of sea level rise, habitats, plants, animals, and any people who were affected adapted to slow rising sea level by shifting gradually upslope. Today, the upslope, landward migration of tidal marshes is impeded by major infrastructure along the bay's edge.

Historical Conditions

Much of the southern Richardson Bay shoreline and developed flat lowlands are artificially filled, drained, and reclaimed tidal salt marshes converted to upland land uses. Over time, dewatering and consolidation of the underlying bay mud sediments has resulted in land subsidence and numerous issues associated with settlement, including cracking of buildings and roadways.

Existing tidal marshes from Mill Valley to Manzanita (North Sausalito) have developed on former tidal mudflats, eroded fills, or former diked baylands that have reverted to tidal hydrology (restored tidally by design or neglect). The area occupied by Bothin Marsh is former tidal mudflat enclosed by dikes; no prehistoric tidal marsh areas occur in Bothin Marsh. The original upland (terrestrial) borders and transition zones of the tidal marshes were severed from Bothin Marsh when the original tidal marshes were reclaimed and filled for development.

Tidal Marsh Habitats and Special-Status Wildlife and Plants of Bothin Marsh

This section presents an overview of the existing tidal marsh habitat and special status species at the marsh.

Bothin Marsh is a tidal salt marsh complex that formed in diked baylands that reverted to tidal hydrology in the late 20th century. Ecologically, Bothin Marsh is divided into two major units: South Bothin Marsh and North Bothin Marsh (Figure 5). North Bothin Marsh supports an extensive salt marsh plain with a broad gradient (ecotone) between higher pickleweed and saltgrass-dominated salt marsh, and lower cordgrass-pickleweed transition zones. North Bothin Marsh has unobstructed tidal channel connections to Richardson Bay through large breaches in the degraded outer levee. The outer North

Bothin levee has subsided and become submerged by high tides in recent years to undergo succession from terrestrial scrub and grassland (coyote-brush, fennel, and annual grasses) to high salt marsh (gumplant, pickleweed, saltgrass), with only skeletal remains of former scrub. (Photos 4-5)

South Bothin Marsh consists mostly of a low cordgrass-dominated salt marsh basin with internal flats and channels connected to the bay (Photo 6) through a rock-armored tidal inlet below a pedestrian bridge. The inlet chokes high tides and causes a lag between tidal water levels in the marsh and Richardson Bay; high tides are slow to drain from the marsh, prolonging submergence time relative to the open bay marshes. There is very limited high tide cover for endangered wildlife in South Bothin Marsh; almost none occurs along the pedestrian/bike path, and little occurs along the landward periphery, which have steep road embankments and steep artificial fill slopes with weedy vegetation. (Photos 7-9)

South Bothin Marsh has a wide high salt marsh terrace formed on old dredged sediment side-cast from Coyote Creek from previous decades of channel maintenance dredging. The Coyote Creek high salt marsh lacks well-developed tidal channels, and includes high marsh pans (barren sandy silt flats), poorly drained pools and depressional salt pans, and some artificial mosquito ditches. (Photo 10). California Ridgeway's rails (Photo 11) and black rails have been confirmed to inhabit the marsh here. Rails and small mammals, including the federally listed endangered salt marsh harvest mouse (*Reithrodontomys raviventris raviventris*), are vulnerable to predation during extreme high tides, when tall, high salt marsh vegetation cover is submerged and remote from their home ranges in the salt marsh. (Photos 11-12). Well-distributed high tide vegetation cover serving as tidal flood refuge habitat is an outstanding limiting ecological factor for these endangered salt marsh wildlife species.

Significant populations of northern salt marsh bird's-beak (Photo 13) occur in South Bothin Marsh, and both The locations of the salt marsh bird's-beak patches, and the movement of rails within the marsh, varies from year to year, but generally depends on the distribution of high salt marsh and terrestrial transition zones. In recent years, a population of rare salt marsh bird's-beak has also established in high salt marsh zones near the pedestrian bike path, particularly in the vicinity of old stabilized sediment fans with high shell content (Photo 4, left).

Between the low cordgrass tidal marsh, and the high Coyote Creek salt marsh terrace, a large, elongated wide pile of demolition rubble debris (mostly concrete) occupies the salt marsh, and is vegetated mostly by weedy non-native iceplant and fennel, providing poor habitat for marsh wildlife. (Photo 14). The rubble pile acts as a temporary island with poor cover for marsh wildlife during extreme high tide flood events that submerge the surrounding high marsh vegetation. (Photo 15). Invasive Mediterranean sea-lavender is rapidly colonizing the high salt marsh and pan edges of South Bothin Marsh near the rubble pile(Photo 16). This salt marsh weed threatends to displace habitat of salt marsh bird's-beak. The rubble pile grades steeply to the north towards the low cordgrass salt marsh of South Bothin Marsh (Photo 17).

Additional salt marsh areas occur on the bay side of the pedestrian/bike path berm. The old compacted railroad berm fill that supports the path is wave-scoured and bare where fringing salt marsh is narrow or eroded away. Heavy trampling and bike tracks along the banks, in addition to the highly-compacted fill itself, reduce the cover of the banks to patchy, prostrate high salt marsh vegetation. Fringing salt marsh edges at mudflats are also subjected to high impacts of erosional wind-waves, and are generally retreating as near-vertical scarps and slump blocks. Despite some recovery of slump-block marsh vegetation during calm intervals between erosion events, net erosion has been significant in recent years. Where high marsh has narrowed or eroded away, the path submerges almost completely during extreme high tides since 2010. Long-legged shorebirds, like the California Ridgway's rail (Photo 11), also use the limited high tide emergent habitat to roost or feed during extreme high tides, where they are subject to disturbance by pedestrians and pets using the path (Photo 18).

The endangered California Ridgway's rail (*Rallus obsoletus*) inhabit North and South Bothin Marsh. They move and feedparticularly along their tidal channels. The endangered salt marsh harvest mouse (*Reithrodontomys raviventris*) is presumed to occupy suitable high marsh habitat North Bothin Marsh. Both endangered species depend on scarce high tide cover in high salt marsh (levee remnants and landward edges) to survive marsh submergence events in winter extreme high tides.

Flooding and Sea Level Rise

Marin County Flood Control District (MCFCD) maintains the Coyote Creek channel through periodic dredging as part of flood operations to provide some level of flood protection to the residents of the lower Coyote Creek watershed. Coyote Creek drains a small steep watershed of approximately four square miles consisting of steep hillslopes draining to flatter areas of former marshlands. These flatter areas are highly urbanized and protected by non-FEMA certified levees that do not provide a hundred year level of flood protection. In particular, the levees are subject to overtopping from direct coastal flooding under current and all scenarios of future sea level rise. Figure2 below shows the three reaches of the Coyote Creek channel - the lower, middle and upper reaches.

Sediment

General

The Coyote Creek channel consists of a lower, middle and upper reaches (Figure 2). The lower and middle reaches are primarily fine-grained sediments (muds and clays) primarily derived from the bay as the sediment source. There may be patches of coarser grained watershed derived sediments in locations but the dominant sediment size would be fine-grained bay mud sediments. As one moves up the channel, the percentage of coarser-grained sediments such as sands and gravels increases significantly. Sediment samples were collected for grain size at three locations above Flamingo bridge where the dominant sediment size is coarser-grained. No samples were collected below the bridge since this work would have to be conducted from a boat.

Above the Flamingo Road Bridge, the sediments in the bed and bars of the channel of the channel are very coarse grained. From the confluence with Nyan Creek to Flamingo Bridge is the transition zone between the two sediment types. Although note that the channel contains areas of fine-grained sediment all the way to the concrete channel, however, they are primarily located in the overbank areas where the wetlands vegetation is primarily located.

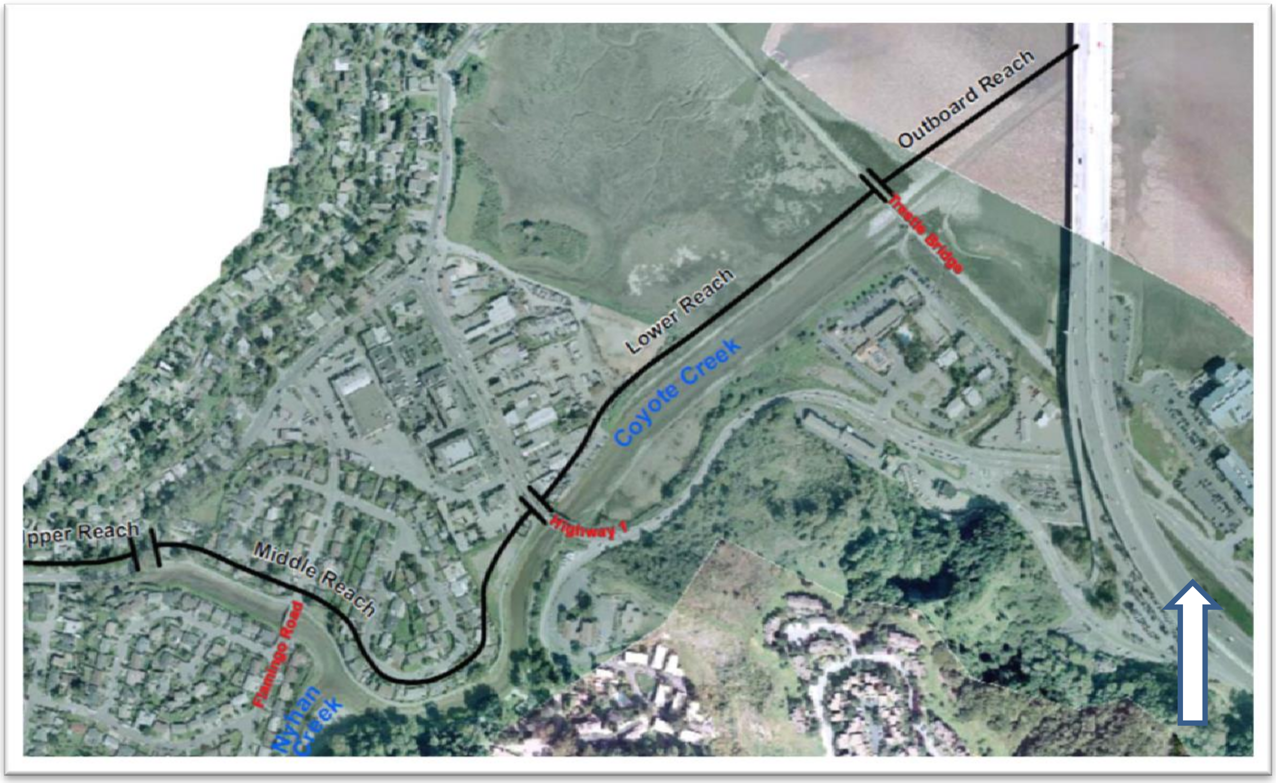

Figure 2: Location of Dredging Reaches Along Coyote Creek (from PWA 2012)

Grain Size Analysis

Three samples were collect from within the channel located upstream the Flamingo Road Bridge (Figure 3). These samples were collected from the coarser-grained reaches of the channel. No samples were collected from the downstream reaches because a boat would be required but will be needed for phase two of the feasibility analysis.

The results are summarized below and the results contained in Appendix B.

Table 1: Summary of Grain Size Results

Sample Number	*Classification*
Sample II	Well graded gravel with silt and gravel (SW-SM)
Sample III	Well graded sand with clay and gravel (SW)
Sample IV	Well graded gravel with sand (GW)

The results for this upper reach show a coarse grained material suitable for beaches or a permeable seepage zone for any future uplands transition zone construction.

Figure 3: Location of Sediment Samples for Grain Size Analysis

Sediment Chemistry Analysis

Tidal sediment chemistry can have important impacts on plant regrowth. In particular, high levels of sulfides in dredged sediment (iron sulfide, and volatile hydrogen sulfide) can inhibit plant growth and injure plant tissues in upper marsh soil horizons, and can cause temporary water quality impairment during discharge that may impact aquatic invertebrates and fish. Tidal salt marsh soils are naturally anoxic and develop elevated sulfides below the uppermost soil horizons, particularly in poorly-drained marsh plains between tidal channels. The impacts of sulfidic sediments occur when they are displaced from subsurface to near-surface or above-surface locations, or in the water column. Following prolonged exposure to air (soil drainage), sulfidic sediments can also oxidize to persistent acid sulfates that inhibit plant growth, or even cause barren patches to form. During discharge of sulfidic, anoxic sediments, aquatic organisms (invertebrates, fish) can suffer acute mortality from oxygen depletion and direct toxicity of volatile sulfides and associated high ammonia levels in anoxic sediment.

The tidal sediment environmental conditions in tidal reaches of flood control channels that promote formation and accumulation of high sulfides include: warm temperatures, high organic matter (carbon source for metabolism of sulfur-reducing bacteria), and anoxic conditions (favored by fine sediment and low hydraulic conductivity). These conditions may occur in creeks during low flow conditions. Storms (high creek discharge events) flush out fine or organic sediments, and deposit relatively mostly coarse sediment bars (sand, gravel) and relatively low amounts of buried organic debris. Therefore, the channel is unlikely to contain large deposits of sulfide-rich sediment. The relative amount of high-sulfide sediment in channels subject to dredging may vary significantly among years. To assess sediment chemistry, samples were collected from the upstream locations of channel above the confluence where there is the transition from fine-grained sediments to the coarser grained sediment from the watershed (Figure 4).

The results are shown below and the lab sheets are contained in Appendix B. Note that prior to placement on the marsh, the full analysis to demonstrate compliance with RWQCB sediment cover criteria will be required for permit approval (RWQCB 2000).

Table 2: Summary of Sediment Chemistry Results for Ammonia and Sulfide

Sample number	*Ammonia as NH3 (mg/kg) [RL=2]*	*Sulfide mg/kg [RL=25]*
SA-1	ND	640
SA-2	ND	33
SA-3	4.6	810
SA-4	2.4	540
SA-5	ND	460
SA-6	ND	290

RL= reporting limit, ND= non-detectible at reporting limits

The results indicate that some organic-rich fine sediments had significantly elevated sulfides in 2015. This shows that depositional tidal environments in Coyote Creek may generate high sulfide anoxic sediments in some years. High streamflow events may erode and re-deposit coarse and fine sediments in the channel before dredging takes place. Channel bed and bar sediments in dredging locations will need to be re-sampled to determine sulfide and ammonia levels in the year of dredging before applying to the treatment areas.

High sulfide sediments would be most suitable for burial below marsh grade (backfill of borrow pits in areas of excavation where demolition debris is removed in South Bothin Marsh), but not for direct at the placement at biologically active marsh surface or unconfined discharge into tidal waters. High sulfide sediments would be relatively unsuitable for placement in sediment fans above Mean Higher High Water, where they would drain and form acid sulfate soils. Acid sulfate soils can be amended by applications of lime, or ameliorated over time by rainfall and leaching, but optimum mitigation is avoidance of acid sulfate soils by placing high sulfide sediments in subsurface layers near permanent saturation zones where they will not oxidize. The proportion of flood channel sediment with significantly elevated levels of sulfide is expected to be a small percentage of the total sediment load (organic-enriched local deposits).

Coarse sediment with some moderately elevated sulfide may be suitable for unconfined discharge at the upper intertidal zone at low tides, where slurry would not directly flow into tidal waters before dispersing, volatilizing or oxygenating sulfides. Most coarse sediment deposits in tidal reaches of stream channels have relatively high porewater flux that reduces the likelihood of anoxic conditions producing high sulfides. But high organic debris levels mixed with coarse sediment may create strongly reducing conditions favoring elevated sulfide levels. In January 2017, large storm events with high stream discharge eroded and redeposited stream and tidal sediment in Richardson Bay watersheds, resulting in the high potential for the deposition of substantial coarse sediment loads. Therefore, sediment testing from 2015 is not likely to represent 2017 sediment chemistry conditions, and will need to be re-tested.

Figure 4: Sampling Locations for Sediment Chemistry Analysis

Public Access and Trails

One of the most heavily used and beloved pathways in Marin County is the Mill Valley-Sausalito bike and pedestrian pathway that runs from Mill Valley down to Sausalito (shown but not labeled in Figure 1). This pathway, which runs along the old railroad grade, is very highly used by the public. However, this pathway is currently overtopped on a regular basis during the semi-annual King Tide flooding events. This pathway flooding is expected to significantly worsen under all scenarios of sea level rise flooding.

Infrastructure

Other infrastructure in the marsh includes PG&E utility towers and associated wooden catwalks Adjacent to the marsh, there are significant infrastructure resources including the Mill Valley sanitary treatment plan (SASM), Miller-Almonte Roadway, ATT lines, the Highway 1 shoreline highway as well as utility, sanitary and stormwater pipeline collection and distribution systems. Note that CalTrans owns a parcel in the area proposed for the pilot projects (mainly the area where their reported rubble piles are located). Therefore, an agreement with Caltrans would be required for final implementation of the proposed pilot projects.

Opportunities and Constraints

This section presents and opportunities and constraints analysis for the project.

Opportunities

The site has numerous opportunities that make it an excellent location to demonstrate the effectiveness of beneficial reuse of dredged sediments.

- The site is adjacent to a dredged flood control channel that contains both fine-grained and coarse grained sediments.

- The site is an active marsh (both an opportunity and a constraint) that would allow for real-time monitoring of vegetation regroup in the marsh following beneficial reuse placement.

- There are areas of the marsh that are barren and that would be amenable to thin-lift placement without major disruption of habitat. These are areas of barren or low and stunted vegetation growth.

- There is an actively eroding marsh edge that would be amenable to placement of a coarse-grained sediment placement as a pilot project (Figure 5).

- At least a portion of the dredging costs would be paid for by the local flood zone and therefore would not require special grant funding for the entire project. This connection with flood control also works to solve ongoing issues with flood control agencies across the Bay to beneficially reuse dredged sediment locally with the minimal environmental impacts and maximize habitat benefit and longer term preparation for the impacts from sea level rise.

- There is broad support at the County for this type of innovative sea level rise demonstration project to move forward if proven feasible. Support from within DWP and County Open Space as well as the upper levels of County government will be critical to moving this project forward. There is also technical expertise in both DPW and Parks that will be useful to moving the project forward.

Constraints

There are also significant constraints to the project site for evaluation of beneficial reuse of dredged sediments.

Specials-status wildlife and plant species. There are at least four special-statusspecies in the marsh that would require mitigation (take avoidance of fully protected species; take minimization of federally listed wildlife species; CEQA impact avoidance, minimization, or compensation) :

a. California Ridgway's rail (*Rallus obsoletus*) – Federal, State listed – endangered

b. California black rail (*Laterallus jamaicensis coturniculus*) – State-listed threatened and Fully Protected (CA)

c. Salt marsh harvest mouse (*Reithrodontomys raviventris raviventris*) -Federal & State listed – endangered; Fully Protected (CA)

d. Northern salt marsh bird's-beak (Point Reyes Bird's-beak; *Chloropyron maritimus* subsp. *palustre*) – California Native Plant Society list 1B.2 (rare, threatened or endangered in CA); State Rank S2 (Imperiled); CEQA

Regulatory complexity. Obtaining permits for this placement operations would be complex because sediment nourishment of tidal marsh, even for restoration and enhancement with net long-term beneficial impacts, requires rigorous review and is subject to the same general policies as fill discharges in tidal wetlands with adverse impacts. CDFW regulations do not allow for incidental take of fully protected species like the salt marsh harvest mouse. Permits would be required by the RWQCB, USACE, BCDC and CDFW.

Tight spaces for unconfined sediment slurry discharges in sensitive wetland habitats. The sediment placement area is very constrained because of closely adjacent tidal marsh habitats with sensitive species. Constructability for thin-lift placement would be constrained by requirements to control sediment discharges enough so marsh habitats are enhanced, but not degraded or converted to non-wetlands. This is a necessary and unavoidable consequence of sediment nourishment in tidal marshes that must adapt to accelerated sea level rise with minimal impacts to existing mosquito ditches.

Avoidance of new or exacerbated mosquito breeding habitat. Sediment discharges cannot impair tidal circulation of existing drainage ditches in Coyote Creek high marsh, or increase mosquito production to a significant extent.

Public nuisance during construction. The site is a high profile location because the pedestrian/bike path is heavily used all week, even though public access and entry to marsh areas is minimal. Aesthetic visual and noise impacts during construction would likely cause temporary but substantial disruption of scenic and recreational uses of the shoreline.

The final volumes required for the dredge to achieve flood control goals is also currently unknown until channel surveys that are likely to be conducted in Spring/Summer 2017 or 2018. The pilot projects can place approximately 2,000 to 3,000 cy of fine-grained sediments in the marsh and perhaps up to 1,000 to 2,000 cy of coarser grained sediment along the shoreline edge. If additional dredging is required for flood protection goals, then these cost would be accounted for in a separate cost estimate and likely be paid for by the Flood Zone.

Proposed Pilot Study Description

This section describes the potential pilot projects along with the results of the study evaluations.

General Overview

The project tests two methods of direct sediment nourishment in different compartments (geographic units) of Bothin salt marshes:

Potential Pilot Project #1 – Thin-Lift Hydraulic Dredge Placement of Fine-Grained Sediments in Bothin Marsh to Restore High Marsh Habitat. This project will direct point-discharge of flood control channel sediments as a pipeline slurry that spreads into wide, shallow sediment fans at the upper edges of high salt marsh, thinning to fine sheets as it spreads diffusely to middle or low marsh zones. Deposited sediment fans will form gently sloping gradients between high salt marsh and terrestrial (lowland) habitats. These habitats will include expanded areas for rare plant habitat and high tide cover (flood refuge) habitat for rare wildlife species to colonize. Slurry pipeline would follow Coyote Creek and booster pumps (if needed) and would extend discharge points to marsh locations. The conceptual design of this potential pilot project is illustrated in Figures 6-8. The total area anticipated to be impacted is 2 to 3 acres.

Potential Pilot Project #2 – Coarse-Grained Sediment Dredge Placement Along Erosional Banks of Salt Marsh and Bike/Pedestrian Pathway Trail and/or Marsh Scarp. Direct point-discharge or mechanical placement of coarse-grained flood control channel sediment (high % sand, gravel > 70%) below steep, eroded wave-cut marsh banks. Coarse sediment deposited as unstable, transient "sacrificial" bars will be eroded and redistributed by storm-driven wind-waves, forming high salt marsh berms and ramp-like beachfaces that buffer erosion. Finer sediments in the mix would wash out and resuspend in the system where they would likely deposit on the marsh during subsequent tidal cycles. The conceptual design of this potential pilot project is illustrated in cross-section in Figures 9.

The two methods of dredged sediment placement would be applied to different wetland environments within Bothin Marsh. Figure 5 shows the approximate distribution of contrasting salt marsh eco-geomorphic units within Bothin Marsh, composed of distinct marsh and vegetation types in North and South Bothin Marsh. These distinct units provide the framework for project design and location. The principal eco-geomorphic units simplified and preliminary for this report for purposes of project feasibility planning are South Bothin Marsh, North Bothin Marsh, and Bayside Marsh and Flats. Additional units may be delineated in subsequent design phases or other studies proposed for Bothin Marsh by the Marin Open Space District.

South Bothin Marsh Simplified Preliminary Eco-Geomorphic Units

Coyote Creek High Salt Marsh – North bank of Coyote Creek pickleweed-dominated salt marsh with large playa-like high marsh pans (barren fine sandy flats), marsh pools, and no distinct tidal channels other than artificial mosquito ditches. This unit extends to the cordgrass-dominated salt marsh of the South Basin, and the pedestrian/bike path berm. Small high salt marsh mounds also occur at the north end of this unit.

South Basin – Low to mid-intertidal salt marsh with tidal channels, and high mudflats (most covered with cyanobacterial and algal mats) west of the pedestrian/bike path berm, connected to Richardson Bay by a constricted rock-armored tidal inlet below a pedestrian/bike bridge.

Rubble pile – An elongated pile of concrete slab demolition debris and weedy upland fill between Coyote Creek High Salt Marsh and South Basin cordgrass marsh. See Photos 14-15.

North Bothin Marsh Simplified Preliminary Eco-Geomorphic Units

Salt marsh plain complex - The extensive salt marsh plain between the derelict outer levee and the pedestrian/bike path, including pickleweed and cordgrass-dominated marsh with tidal channels, back-marsh pools (depressional salt marsh pans), and old stabilized dredge sediment fans (forming high salt marsh) along the pedestrian/bike path.

Outer levee - The perimeter levee supports high salt marsh vegetation with a canopy that remains emergent even during extreme high tides when the levee crest itself is submerged. The levee crest supportsscattered skeletal remains of former upland scrub (killed by extreme high tides and soil salts). Some live, dying, and dead coast live oaks and toyon (native shrubs and trees) persist locally at the south-facing segment of the levee. Photo 20.

Fringing salt marsh and scarp – Seaward of the outer levee at southeastern North Bothin Marsh, a narrow, erosional salt marsh fringes the levee. The fringing marsh and levee have a vertical wave-cut scarp. The east-facing fringing marsh exhibits cycles of erosion and recovery, but the south-facing fringing marsh (exposed to higher wave impacts) exhibits significant net erosion.

Bayside Salt Marsh and Flats - Seaward of the pedestrian/bike path south of North Bothin Marsh's outer levee consists of mudflats and transitional cordgrass-pickleweed marsh that is completely submerged during extreme high tides.

Erosional Fringing Salt Marsh – Wave-cut high marsh and mudflats on old fill along the bay side of the pedestrian/bike path, south of North Bothin Marsh

Figure 5: Conceptual Layout of Bothin Marsh Preliminary Eco-geomorphic Units and Major Project Components

Red outline: rubble pile. Dashed white line: sediment slurry deposition zone. Green dots: high salt marsh mound pairs at heads of tidal channels (mitigation) Yellow lines: coarse sediment placement zones. Tan lines: old perimeter levees (breached, subsided). Green dotted line: Coyote Creek high marsh plain. Orange line: likely pathway for ground-based equipment over upland fill, with wood mat crossings over ditches. Base image: Google Earth August 14, 2016. No scale.

Pilot Project #1 Construction Activities

South Bothin Marsh would be the location of Pilot Project 1. This pilot project would be implemented in the following sequence of activities:

<u>Rubble Pile Removal</u>. There are several ruble and construction debris piles located primarily in the Caltrans owned parcel in the marsh (Figure 6). Although removal of these rubble piles is not integral to the proposed pilot projects, we have included costs for pile and debris removal and use of this degraed area as the location off the proposed pilot studies. The rubble piles would be removed by ground-based equipment working on mats to minimize compaction of salt marsh soils. Equipment routes would likely extend from an upland fill peninsula at the west end of South Bothin Marsh (acacia and French broom

weed vegetation) in fall (outside the breeding season of California Ridgeway's rail and California black rail). Rubble would be over-excavated to remove compacted fill and demolition debris below grade.

Back-fill of Rubble Pile. Sediment with significantly elevated sulfides levels following resampling and/or coarse sediment slurry may be placed as "foundation" backfill in the pit left by fill removal in the footprint of the rubble pile. The upper limit of coarse sediment backfill would be at marsh grade. This would depend on the relative volume of coarse and fine sediment dredged and the depth of the hole to be backfilled. "Foundation" fill below grade of adjacent marsh, after capping with fine sediment (see next action), would have minimal influence on final vegetation and habitat structure. It is currently unknown the exact depth of the rubble extends but visual observation and the assumption that the rubble was dumped at the site and not buried would indicate that the depth of the rubble is only one to two feet. This would be confirmed by future site investigation.

Channel Dredging and Thin Lift Sediment Placement to Mimic Natural Sediment Fan Deposition. A small 8- to 12-inch hydraulic dredge would dredge the creek and sediment would be placed along the alignment of the existing rubble pile that would be removed under this pilot project. The sediment would be spread through a diffuser hose set-up and adjusted to avoid excessive velocities that transport sediments beyond the work area. Figure 6 shows the anticipated extents of the sediment placement area.

Fine sediment slurry would be deposited at multiple points along the center line of the backfilled at-grade rubble fill footprint. Sediment slurry would be discharged in pulses ("lifts"), allowing control over the spread (horizontal extent) and thickness of splays (delta-like flows) composing growing sediment fans (Figure 8). The point of slurry discharge would be moved adaptively at intervals to distribute sediment fans in increments, and allow partial settling and consolidation between pulses. Silt fences (stakes with geotextile fabric fastened at the marsh surface) would be set in place to guide the flow of sediment slurry around locations of annual rare plant colonies (which would be seed sources for subsequent dispersal and colonization of new habitat) at the periphery of new active sediment fans. Sediment fans would spread as low mounds over the footprint of the former rubble mound, thinning to "feather-edge" sediment sheets (approximately 1-5 cm thick) over adjacent pickleweed and cordgrass vegetation. Existing marsh vegetation would regenerate intact through thin (1-5 cm) sediment fan edges. Portions of sediment fans exceeding 15-20 cm in thickness in the footprint of rubble pile removal would be expected to recolonize primarily by seedlings or transplants from the surface, rather than vegetative regeneration from buried plants below; taller pickleweed, however, may partially regenerate from over 15 cm depth of sediment burial. Maximum fan elevations prior to consolidation and settling would not exceed elevations of highest spring tides (approximately 8 ft NAVD88).

Post-consolidation Saline Sediment Fan Revegetation. When sediment fans have dewatered and consolidated after deposition, with substrate firm enough to plant, the highly saline sediment would be sprigged with native perennial saltgrass rhizome plugs or sod fragments in fall, to establish initial pioneer vegetation and to provide erosion resistance by the second winter after deposition. Additional first-year transplants below the high tide line elevation would include gumplant and pickleweed.

Post-Desalinization Revegetation of Sediment Fans. One year after sediment deposition, after sediments have been exposed to one rainfall season to leach salts enough to allow planting of terrestrial transition zone plants, additional perennial pioneer species will be transplanted as dormant sod fragments or dormant bare-root transplants. Local Bothin and Richardson Bay populations of native creeping wildrye, Baltic rush, western ragweed, poverty-weed, alkali-heath shall be transplanted in late fall/early winter at a density of $1/m^2$, and yellow hayfield tarweed shall be sown over areas above high tide line prior to soil-saturating fall rains at an average rate of at least 15 seed/m^2. Seed and vegetative stock for planting shall be propagated in open outdoor beds one year in advance of planting.

Construction of Mitigation Marsh Mounds. To mitigate for temporary disturbance of construction, a series of high salt marsh mounds would be manually constructed within South Bothin cordgrass marsh during the non-breeding season of California Ridgway's rails and black rails (Figure 9). These high intertidal marsh mounds would provide vegetation structure with high tide flood refuge functions for wildlife, which are lacking within South Bothin Marsh cordgrass marsh. Mounds would be constructed from locally excavated mud, and capped with bare-root transplants of pickleweed and gumplant in late fall. A total of 10 mounds would be distributed near tidal channel heads. The project will learn from the mound building work of the invasive spartina project who has constructed a number of these types of mounds.

Figure 6: APN Map for Bothin Marsh

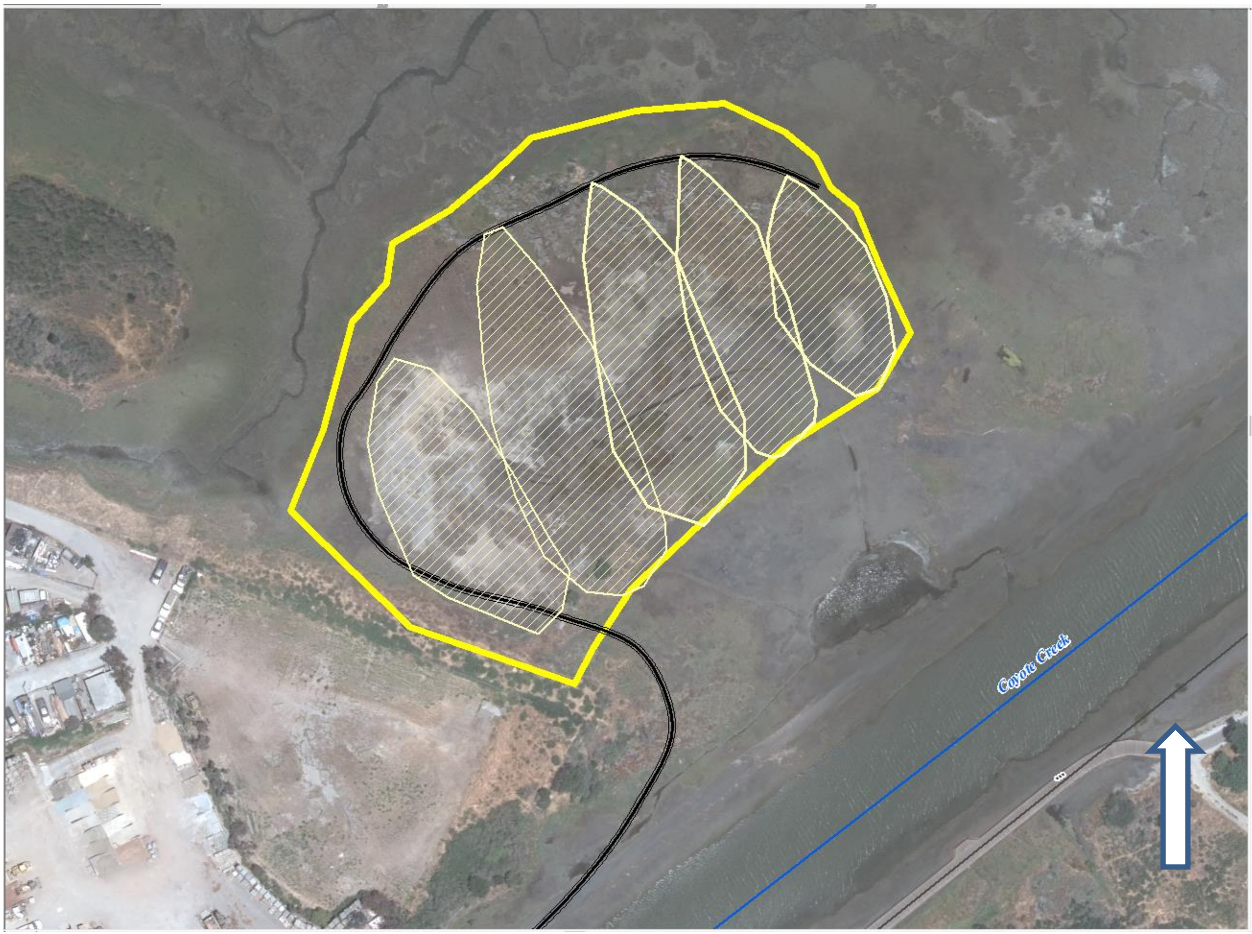

Figure 7: Schematic Location of Sediment Pipeline and Thin-Lift Sediment Placement Extents

First year vegetation management. During the first growing season (spring-summer) after deposition, sediment fans would be surveyed for early detection of high-risk/high impact invasive plants, especially Algerian sea-lavender. High-risk invasive plant pioneer colonies would be manually removed before they flower and produce seed.

Second year revegetation. In the late fall of the year after fan deposition, additional native high salt marsh-terrestrial grassland transition zone (ecotone) plants would be planted along gradients of the sediment fans to provide long-term habitat diversity and erosion control.

Pilot Project 2 Construction Activities

The Bayside Marsh and Flats would be the location of pilot project #2, which would deliver coarse sediment (gravel and sand) to wave-impacted, eroded marsh bank edges and erosional bayside banks of the pedestrian/bike trail berm (Figure 10). This project would include the following actions:

- Placement of embedded large woody debris or boulders serving as micro-groins. Coarse sediment would drift alongshore where wave approach from the south (Golden Gate) is oblique to the shoreline. Decay-resistant seasoned eucalyptus logs, root wads, and limbs (esthetically indistinguishable from large driftwood) would be embedded deeply in bay mud at intervals along the marsh shoreline to trap sand and gravel, and impede its transport alongshore. Boulders, like the existing greenstone boulders along the banks of the berm, may be used instead of eucalyptus logs.

- Placement of coarse sediment parallel to shore. As noted above, hydraulic dredging of the upper reach is likely not feasible due to shallow water depths, a preliminary finding that will be further investigated under the next phase of design work. If hydraulic dredging and transport of the coarse grained sediments is not possible (or cost prohibitive) these areas may be mechanically dredged and the coarse grained sediments separated and transported by small trucks to the proposed pilot site along the trail and marsh edge and placed with excavators and a backhoe (which would require access down the pathway). If direct hydraulic dredge and pumping to the area is feasible, then the coarse sediment would be deposited as a slurry along the shoreline, in the mid-intertidal zone within 30 feet from the shoreline. Coarse sediment would mound near discharge points. Discharge points would be moved frequently to generate a temporary gravel-sand bar.

Natural wave-reworking of coarse sediment and deposition of swash bars. The coarse gravel-sand bar sediment then would be reworked over time by subsequent episodes of high waves, and would be transported onshore (Figure 10 shows a possible sequence). High to moderate wind-waves would form small swash bars (bay beaches) that would gradually stabilize with vegetation, and become marsh berms with sand/gravel beachfaces that buffer storm erosion of the shoreline. Berm crests would be gravel. Sand would occur lower and mix with mud. The eroded compacted fill at the path banks would become covered with high salt marsh berms and storm gravel bars.

Constructability

This section describes preliminary level constructability aspects of the proposed projects. This analysis will be further defined during later phases of project design and is intended to only present a broad overview of the major constructability issues associated with the project implementation. Note that stringent permitting agency requirements can significantly alter constructability and costs.

Construction Access

Land Based Access for Rubble Removal and Pipeline Placement

Construction access for the pipeline will likely be through the back side of the marsh off of Allmonte Avenue. There are several existing small tidal channels that will have to be crossed with equipment to remove the concrete rubble and set the dredge pipeline. These channels would be bridged with geotextile mats suitable for low pressure ground equipment to work without compacting marsh soils. Based on the construction experience at Sonoma Creek (M. Cederborg, Hanford Arc, personal communication) which is a much softer soil site, we anticipate that low ground pressure equipment will be used with mats where needed and to cross tidal channels. Based on site inspections, the rubble piles do not appear to extend much below ground level and therefore we anticipate that removal can be accomplished with an excavator loading small trucks and moving the rubble off-site along the approved roadway alignment. Rubble would be over-excavated to remove compacted fill and demolition debris below grade and the area restored with slurried sediment from the pipeline.

Hydraulic and Mechanical Dredging and Pipeline Access

We anticipate that the dredge will be a small 8- to 10-inch suction hydraulic dredge brought to the site by truck and placed into the creek above the Highway 1 Bridge. Work in the lower and middle reaches could be conducted at most higher tide levels (hydraulic dredge requires at least 2 to 3 feet of depth to operate), however, in the upper reaches hydraulic dredging may be significantly limited by the tides. Therefore, at the very upper reaches of the dredge (likely at or above the Flamingo Road bridge), hydraulic dredging may not be possible and the dredge method would change to mechanical dredging following installation of a cofferdam. Dredge methods will be further developed during subsequent phases of the project design. For areas dredged by mechanical methods (i.e. with an excavator), a cofferdam across the creek will have to be constructed to allow for dewatering and removal of sediment without significant impacts to downstream water quality. For our concept level cost-estimate, we have assumed that the upstream reach will have to be dredged using mechanical equipment from the adjacent levees with a cofferedam and dewatering system.

For this study, we have assumed that the pipeline will run along the creek channel until the edge of Bothin Marsh where it will come into the marsh and follow along the location of the rubble piles (which by then will be removed) where the thin-lift slurry will be placed. The pipeline will consist of a 8 or 10 inch HDPE pipe that will be fused welded at the joints to prevent leakage. Note that this will be confirmed during subsequent design phases of the project. If it is found to be feasible to hydraulically dredge the upper reach of the project and transport the coarser grained gravel fraction to the shoreline edge, then a revised pipeline route will be developed during subsequent design phases to allow for placement of this coarse grained fraction directly onto the shoreline edge under pilot project #2. Otherwise, this upper reach dredge will be accomplished using mechanical excavation and the coarse grained sediments transported by trucks down the Sausalito-Mill Valley pathway to the shoreline edge placement site. Figure 7 shows the anticipated routing of the dredge pipeline from the location furthest upstream (just below the Flamingo Road) bridge for the hydraulic dredging.

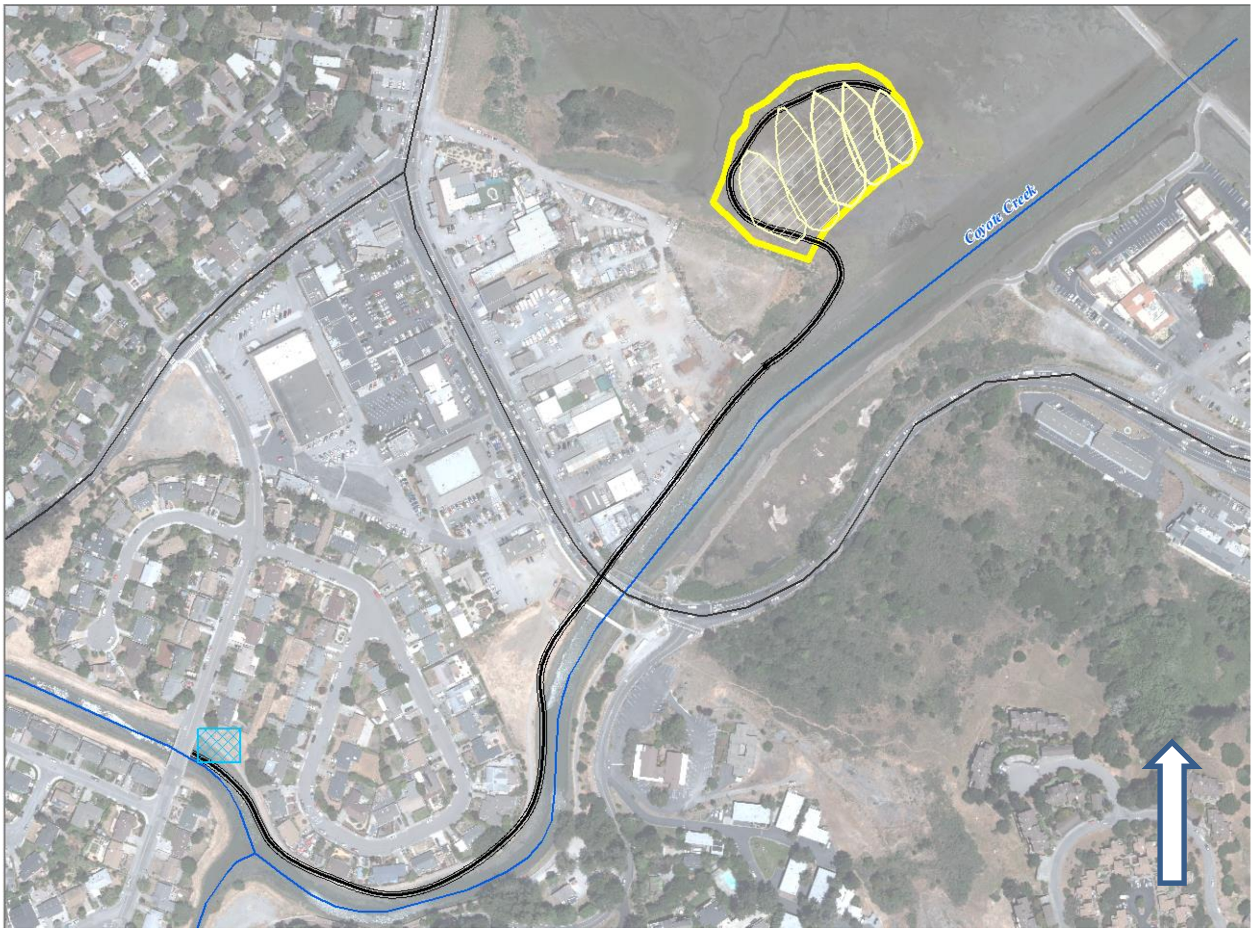

Figure 8: Schematic Location of Hydraulic Dredge Pipeline(blue hatched rectangle at upstream is the likely furthest location up the channel of the hydraulic dredging operation). The reach from Flamingo Road Bridge upstream to the concrete channel is assumed to be dredged mechanically using an excavator on the adjacent levee.

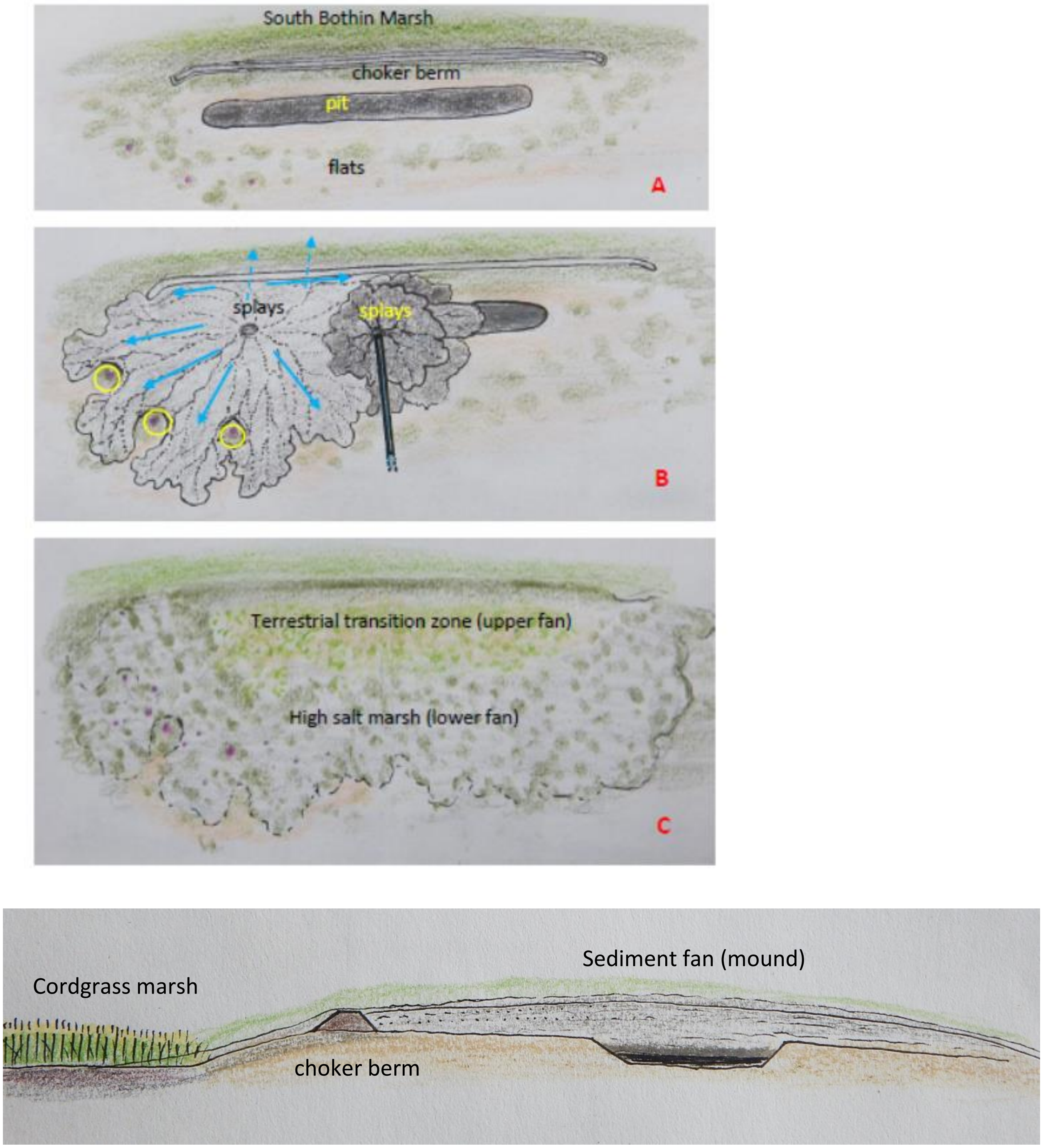

Figure 9: Plan and Profile View of choker berm between South Bothin Marsh cordgrass habitat, and sediment fans form proposed thin-lift dredge placement. The low berm restricts the flow of sediment slurry until the upper lifts are deposited, and spill over the berm. Cordgrass and pickleweed are expected to regenerate and the subject of post-placement monitoring

A: Shallow pit excavated below demolition rubble removal area. A low (approximately 1 ft) choker berm borders the high salt marsh zone of South Bothin Marsh to direct most flow of sediment slurry

southward into high marsh flats, allowing limited overspill into low cordgrass marsh. Bottom sediment layers contain black mud with highest iron sulfide content. B: Hydraulic sediment slurry backfills the shallow pit and flows over the high flats. Sediment fans are discharged in pulses, with partial consolidation of each lift between pulses as the dredge pipe discharge point is moved along the pit. Cone-shaped fan drainage flow patterns radiate from the point of (pipe) discharge. Patches of rare plants (yellow circles) are sheltered by half-circle geotextile fabric silt fences that deflect low-velocity sheetflow of slurry around them. C: Sediment fans coalesce, consolidate, and revegetate over several growing seasons. Pickleweed and saltgrass directly regenerate through shallow (0-20+ cm) sediment layers of the outer fan. Annual northern salt marsh bird's-beak (purple dots) is expected to form daughter colonies in the new vegetation, seeded from remains of persistent parent plants. The upper (above-tide) sediment mound establishes native saltgrass, gumplant, pickleweed, and creeping wildrye from plantings.

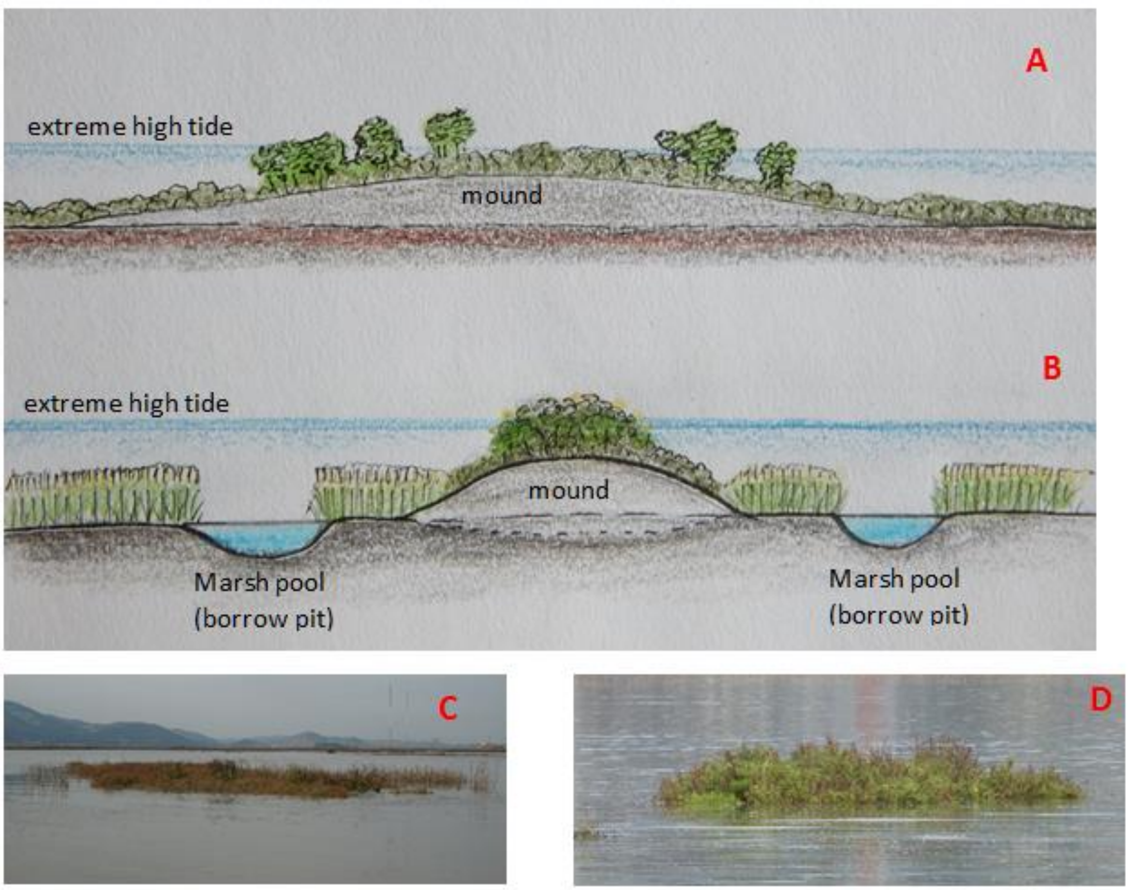

Figure 10: Mitigation measure: high salt marsh refuge habitat mounds constructed in North Bothin Marsh pickleweed marsh (A) and South Bothin Marsh cordgrass marsh (B).

The mounts provide emergent vegetation canopy cover for wildlife above the water surface during extreme high tides that submerge the marsh topography. Larger, flatter, wider mounds are deposited

by sediment slurry in North Bothin Marsh. Smaller, narrower, steeper mounds are constructed from mud manually excavated from small borrow pits in cordgrass marsh. Mounds provide critical limiting habitat for endangered wildlife during extreme high tides that otherwise submerge nearly all cover in the salt marsh. (C-D) Actual high salt marsh mounds constructed at the Bahia, Novato tidal marsh restoration project, shown at 4 years old in 2012 during an extreme high tide; (D) high marsh mound constructed at Muzzi Marsh in 2015, shown at 2 years old in 2017 during extreme high tide of January 2017.

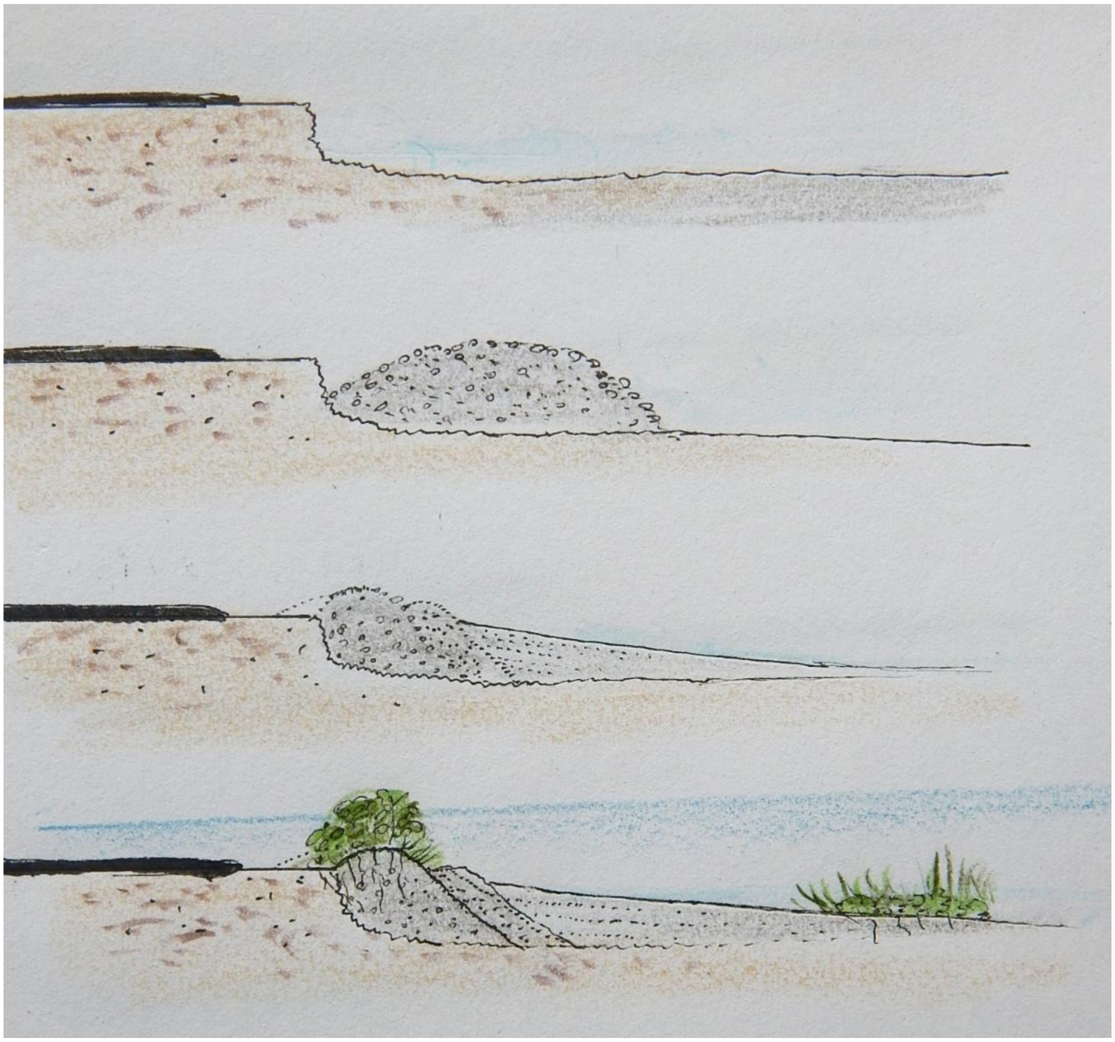

Figure 11: Cross-section diagram of coarse sediment placement on eroded bay side bank of pedestrian/bike path.

A – Existing eroded, trampled bay side bank

B - Coarse gravel and sand excavated from flood control channel bars is deposited along the high tide line, exposed to subsequent wave action during high tides and high winds.

C – Winter storm high tides and waves sort and rework gravel and sand into gravel berms and sand beachface.

D – Patchy high salt marsh vegetation establishes on gravel berm crests and muddy sand.

Protection of Existing Resources

We anticipate that construction silt fences will be placed to protect sensitive areas from direct disturbance from sediment placement. Prior to construction, individual locations of listed plant species within the work area will be identified and marked and surrounded by exclusion fencing where required by the project biologist.

Staging Areas

Construction staging will likely be at the entrance to the Bothin marsh site off of Almonte. Ruble removed from the project area will be stored here until off-haul to a landfill can be arranged. Mechanically excavated coarse-grained sediments slated for use along the marsh edge will be stockpiled here also prior to placement.

Possible Mitigation Measures

This section describes potential mitigation measures that may be required by the permitting agencies based on our experience working in bay tidal marshes. The actual mitigation measures will be determined during the next phase of the project design and may differ significantly from those described below. This list is not intended to be complete but only to provide a list of likely or possible mitigation measures as part of our feasibility level analysis and cost estimates for the project. Temporary construction impacts to scenic and recreational uses (esthetic, noise, access impacts), salt marsh (wetland vegetation), special-status wildlife, invasive species spread, and special-status plants are foreseeable, but they can be mitigated to less-than-significant levels by the following mitigation measures.

MM-1. California Ridgway's rail and black rail mitigation measures. Black rails and Ridgway's rails both occur in South Bothin marsh. Construction activities would be scheduled to occur during the non-breeding season in late summer and fall, in compliance with what are expected to be in the terms of a U.S. Fish and Wildlife biological opinion issued as part of formal consultation for a U.S. Army Corps of Engineers permit. Pre-construction surveys would be conducted by a qualified expert to determine likely locations of rails that may be present at the time of project construction. No construction would occur during spring October high tides when rails may be forced to seek high tide cover in areas affected by construction disturbances. To compensate for potential temporary impacts to rails, we would likely propose that five pairs of high marsh mounds (consistent with general designs used at Muzzi Marsh by the Invasive Spartina Project, California Coastal Conservancy) would be manually constructed near the heads of tidal creeks in South Bothin Marsh, with post-settlement crest elevations approximately matching higher spring high tide elevations. High marsh mounds would be planted with pickleweed and gumplant, and sprigged with embedded decay-resistant woody debris no higher than two feet above the mound surface. A qualified biologist would supervise construction activities and make observations (visual or auditory) of rail behavior during construction. Construction activities would be modified to minimize or avoid rail disturbance, in response to biological supervisor guidance.

MM-2. Northern salt marsh bird's-beak mitigation measures. The locations of all bird's-beak colonies of the contemporary year would be flagged and symbolically delineated in the field during June-July prior to construction. All bird's-beak colonies within 200 feet of dredge sediment discharge points would be encircled with geotextile fabric silt fences fastened to the ground surface with wood stakes, to prevent biologically significant burial of dispersed seeds of the current year. Prior to construction, approximately 10% of seed capsules bearing seed in September would be harvested from plants, temporarily stored dry. Seed would be re-dispersed at interfaces between new sediment fans and established or regenerated pickleweed or saltgrass near original bird's-beak colony positions in November following construction. The number, size, and reproductive output of bird's-beak colonies would be monitored in the year prior to construction, and two consecutive years following construction in South Bothin salt marsh, Coyote Creek salt marsh, and Bayside salt marshes.

MM-3. Salt marsh harvest mouse mitigation. To prevent abrupt sediment deposition impacts of turbulent, high-viscosity hydraulic slurry on salt marsh harvest mice, sediment fan areas containing pickleweed habitat suitable for the salt marsh harvest mouse will be flooded with repeated preparatory brief pulses of bay water pumped from Coyote Creek prior to sediment placement. Pulses of marsh surface flooding would elicit dispersal of small mammals within home ranges, away from pathways of turbulent flows.

MM-4. Recreational and scenic mitigation. There will need to be mitigation measures developed to address a variety of impacts in this category. Additional work will be done on this during future design phases during the permitting process. We anticipate that some kind of public outreach and education about the pilot project, with emphasis on its environmental need and objectives, will be accomplished through public meetings, docent-led tours in cooperation with Marin Parks, and interpretive signs (with photograph and design graphic displays) along the pedestrian/bike path near the project site may be implemented but this will be developed during future design phases.

MM-5. Invasive plant species spread. To prevent new disturbed sediment from becoming a major new habitat for colonization and population increase of Algerian sea-lavender (*Limonium ramosissimum;* and *L. duriusculum*) that is present on site, all non-native sea-lavender shall be manually removed before flowering and seed set in summer prior to construction. Sediment fans shall bury residual Algerian sea-lavender that excapes removal. In the spring following sediment deposition, the project area shall be re-surveyed for new exotic sea-lavender seedlings or plants regenerating from burial by sediment. All exotic sea-lavender shall be removed from the project area prior to flowering and seed set for two years following project completion. In terrestrial transition zones of sediment fans (rubble pile footprint), other local non-native terrestrial invasive plants that have high potential to persist despite competition with dominant native species planted, such as iceplant, French broom, acacia, fennel, and poison-hemlock, shall be manually removed before flowering and seed production for three years after sediment placement.

Proposed Monitoring Program

This section presents a concept monitoring program for the proposed project. Actual project monitoring requirements with a revised budget will be further developed during subsequent project phases and following discussions with the permitting agencies. The goal is a robust monitoring program that allow for development of a “lessons learned” summary of the project success and failures and dissemination of this information.

Monitoring program objectives would be aimed at the following:

(1) Measuring recovery and colonization of salt marsh vegetation and terrestrial transition zone vegetation developing on sediment fans for five years after physical placement of sediment;

(2) Measuring population change and distribution patterns of northern salt marsh bird’s-beak colonies for two years after project completion;

(3) Verifying development of suitable high tide cover for rails on constructed high salt marsh mitigation mounds for three growing seasons (likely five years);

(4) Assessment of geomorphic and vegetation development of coarse sediment swash bars and marsh berms along the bay shoreline.

The project site may be photographically monitored at annually with high-resolution digital aerial photography using commercial UAV overflights. Digital aerial photographs will be ground-truthed with well-distributed plots (releves) to record plant species composition and cover-classes of vegetation, and fixed-perspective permanent ground photo stations. Shoreline geomorphic changes shall be monitored by GIS analysis of aerial photographs in years 1, 3, and 5 after sediment placement.

Pilot Project Construction Cost Estimate

A feasibility level cost estimate has been prepared to develop a possible range of costs. At this feasibility stage of project development, the costs are approximate and subject to significant revision upon future analysis during future design phases.

Costs have been divided into the following categories:

- *Construction and Site Operations* – including site preparation, pipeline layout and implementation of site environmental protection measures. These costs also include the removal of up to 3000 cubic yards (4,500 tons) of construction debris and rubble assumed suitable for Class III disposal at a landfill. Silt fencing will be installed around identified special status plants and to inhibit inflow of sediments into mosquito ditches.
    - Hydraulic dredge and thin lift sediment placement of approximately 2,000 to 3,000 cy of fine-grained sediment from the creek channel within the pilot area has been included along with the mechanical dredge and placement of up to 1,000 cy of coarser grained

sediments along the shoreline edge. At this time, it is unclear how much additional dredging may be required to restore the channel flood conveyance capacity (past dredge cycles did not document how much sediment was removed from the middle and lower channel reaches). A survey is planned for 2017 or 2018 to help define these volumes. If additional dredging is required for flood control needs then these costs would be paid for form zone funds.

- *Engineering Design and Permitting* Costs - This section includes cost for the next stages of design and permitting assuming a mitigated negative declaration for the proposed dredge and pilot studies. These assumptions will be checked during subsequent design phases.

- *Monitoring and Reporting* – A first cut estimate for costs associated with monitoring and reporting for five years following project construction have been developed and contained in the cost table.

The results of the cost estimate are summarized below. Note that we have provided three results; the estimate total cost (design, permitting, construction and monitoring) with the 50% contingency, the total costs without the contingency and the costs for just the proposed pilot studies without the cleanup costs associated with concrete rubble piles, which although included as part of the overall project, are not integral to the pilot study evaluations but rather are part of the larger marsh restoration. Appendix A contains a detailed summary backup for these costs. Note that these costs will be further refined in future phases of the project.

Table 3: Summary of Feasibility Level Cost Estimates

Cost Item	Costs with 50% Contingency ($)	Costs with no Contingency ($)	Costs for Pilot Project Only w/o contingency ($)
Construction costs	$ 1,727,625	$ 1,151,750	$ 746,600
Engineering design and permitting	$ 489,000	$ 326,000	$ 326,000
5 year monitoring and reporting	$ 142,500	$ 95,000	$ 95,000
TOTALS:	$ 2,359,125	$ 1,572,750	$ 1,167,600

Next Steps

This study presents a feasibility level analysis of the potential of reusing dredged sediments from Coyote Creek within the adjacent Bothin Marsh. The results of this analysis show that the project is feasible with some additional work required to confirm cost and sample and evaluate the entire channel of sulfides and ammonia and reassess approaches if the sampling results showing high sulfides levels within some of the sediments. If sulfides are shown to be an issue following resampling, then the design can be modified to include burial of high sulfide sediments in the location of the former rubble mounds. The design and layout of two potential pilot projects in Bothin Marsh have been developed and laid out with costs.

Next steps include the following:

1. Phase II Preliminary Design – Development of detailed project description for permit agency consultations
2. Complete channel surveys and sediment chemistry samples
3. Prepare and submit permit applications
4. Development of Final Design and Preparation of Plans and Specifications for Construction
5. Public outreach and preliminary flora and fauna surveys
6. Work to secure funding
7. Bid and Construct
8. Monitor and Report

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Appendix A

Cost Estimates

Project Name:	Coyote to Bothin Marsh Feasibility Level Cost Estimate - Dredge Sediment Beneficial Reuse Study				
Preparer:	RDL				
Date Last Revised	1/28/2017				
Level of Estimate:	Feasibility level (+-50%)				
item	*quantity*	*units*	*unit cost ($)*	*total cost ($)*	*comments*
CONSTRUCTION and OPERATIONS					
Site Preparation - Temp Haul Road and Rubble Removal					
Mobilization	1	ls	$ 27,000.00	$ 27,000.00	H-A draft estimate 1/11/17
Stormwater Plan and Reporting	1	ls	$ 20,500.00	$ 20,500.00	H-A draft estimate 1/11/17
Install construction entrance	1	ea	$ 10,500.00	$ 10,500.00	H-A draft estimate 1/11/17
Temo BMPs and Dust Control	3000	lf	$ 17.00	$ 51,000.00	H-A draft estimate 1/11/17
Temorary Haul Road Construction	800	lf	$ 200.00	$ 160,000.00	assumes 3 small tidal channel crossings with mats; assumes soils are not very soft so extensive mats are not needed
Remove and Stockpile Concrete Rubble	1700	cy	$ 30.00	$ 51,000.00	H-A draft estimate 1/11/17
Processing of Concrete Rubble	2550	tons	$ 14.00	$ 35,700.00	H-A draft estimate 1/11/17
Haul and Dispose of Concrete Rubble	3825	tons	$ 37.00	$ 141,525.00	H-A draft estimate 1/11/17
Dispose of Misc Debris	25	tons	$ 257.00	$ 6,425.00	H-A draft estimate 1/11/17
			SUBTOTAL Site Prep:	$ 503,650.00	
Hydraulic Dredge of Portions of Lower and Middle Reaches					
Survey and sampling	1	ls	$ 15,000.00	$ 15,000.00	Flood Zone 3 expense
8 inch dredge mob and demob	1	ls	$ 150,000.00	$ 150,000.00	Dixon- Marine draft updated estimate 1/19/17
pipeline placement	2800	lf	$ 25.00	$ 70,000.00	Dixon- Marine draft updated estimate 1/19/17
thin-lift sediment placement (per day)	15	days	$ 12,000.00	$ 180,000.00	Assume low productivity since have to dredge with tides; only for pilot study dredge (approx 3,000 cy). Additional dredging costs for flood control is not incluced DM estimate 1/19/17
change diffuser types	3	each	$ 5,000.00	$ 15,000.00	
			SUBTOTAL Hydraulic Dredge:	$ 430,000.00	

Mechanical Dredge of Upper Reach and Transport of Gravels to Shoreline Edge					
cofferdam construction below Flamingo bridge	1	ls	$ 20,000.00	$ 20,000.00	H-A draft estimate 1/11/17
mob long reach excavator	1	ls	$ 5,000.00	$ 5,000.00	H-A draft estimate 1/11/17
Dig with excavator the upper creek and concrete portion of channel with the coarser grained sediments	1000	cy	$ 30.00	$ 30,000.00	H-A draft estimate 1/11/17
Screen for coarse grained gravels from fine grained muds	5	days	$ 2,000.00	$ 10,000.00	H-A draft estimate 1/11/17
off-haul fine grained muds to landfill	1000	cy	$ 40.00	$ 40,000.00	H-A draft estimate 1/11/17
demob cofferedam	1	ls	$ 5,000.00	$ 5,000.00	H-A draft estimate 1/11/17
placement of coarse-grained gravels along trail edge	700	cy	$ 12.00	$ 8,400.00	H-A draft estimate 1/11/17
placement of coarse-grained gravels along marsh edge	300	cy	$ 15.00	$ 4,500.00	H-A draft estimate 1/11/17
construction of small micro-groins and shore normal wood	6	ea	$ 3,000.00	$ 18,000.00	H-A draft estimate 1/11/17
General Construction Conditions	1	ls	$ 20,000.00	$ 20,000.00	H-A draft estimate 1/11/17
			SUBTOTAL Mechanical Dredge:	$ 160,900.00	
Mitigaiton Measures					
construciton of marsh mounds	10	ea	$ 2,300.00	$ 23,000.00	H-A draft estimate 1/11/17
			SUBTOTAL Mitigation Measures	$ 23,000.00	
Site Placement Staff Operations					
DPW Senior Engineer	100	hours	$ 150.00	$ 15,000.00	RL
Consulting Ecologist	100	hours	$ 120.00	$ 12,000.00	PB
Consulting Biologist	60	hours	$ 120.00	$ 7,200.00	KB
			SUBTOTAL Staff Operations:	$ 34,200.00	
	Sub-Total Construction and Operations:			$ 1,151,750.00	
			contingency (50%)	$ 575,875.00	
			TOTAL CONSTRUCTION	$ 1,727,625.00	

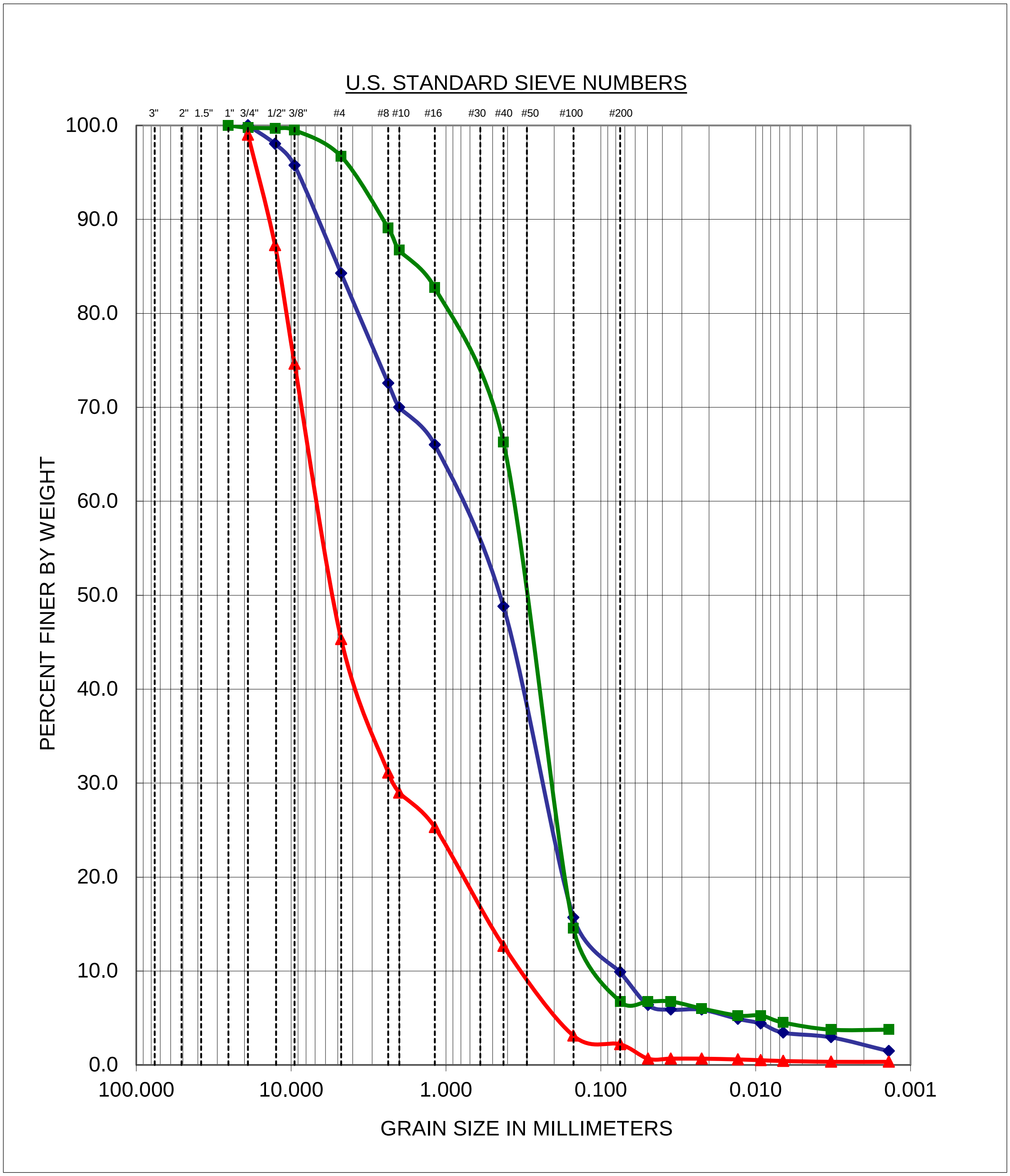
DESIGN AND PERMITTING					
Preliminary design	1	ls	$ 60,000.00	$ 60,000.00	
Final design	1	ls	$ 80,000.00	$ 80,000.00	
Permitting (asume mitigatd neg dec)	1	ls	$ 150,000.00	$ 150,000.00	
Special Status Species Protection Plan	1	ls	$ 8,000.00	$ 8,000.00	
Monitoring and reporting Plan	1	ls	$ 10,000.00	$ 10,000.00	
Agency Consultations	60	hrs	$ 150.00	$ 9,000.00	
Public Outreach (coordination with Parks and OneTam)	60	hrs	$ 150.00	$ 9,000.00	
			SUBTOTAL Design and Permitting:	$ 326,000.00	
			contingency (50%)	$ 163,000.00	
	TOTAL DESIGN AND PERMITTING			$ 489,000.00	
MONITORING and REPORTING					
Post construction veg surveys (5 years)	5	years	$ 3,000.00	$ 15,000.00	
Monitor change and distribution of northern salt marsh bird's-beak colonies	5	years	$ 2,000.00	$ 10,000.00	
verify development of high tide cover for rails	5	years	$ 2,000.00	$ 10,000.00	
assessment of geomorphic and vegetation development of croase grained berms	5	years	$ 2,500.00	$ 12,500.00	
Annual reporting (assume 10 years) - consultant	5	years	$ 6,500.00	$ 32,500.00	
Annual reporting DPW staff	5	years	$ 3,000.00	$ 15,000.00	assume 20 hours per year
			SUBTOTAL Montioring and Reporting:	$ 95,000.00	
			contingency (50%)	$ 47,500.00	
	TOTAL MONITORING AND REPORTING (5 yrs)			$ 142,500.00	
		TOTAL WITH 50% CONTINGENCY		$ 2,359,125.00	
		TOTAL W/O CONTINGENCY		$ 1,572,750.00	
		TOTAL RELATED TO PILOT PROJECTS		$ 1,167,600.00	Costs directly related to pilot projects. Removes costs associated with concrete rubble removal and cleanup within Bothin Marsh which are not directly due to pilot projects. No contingency included

Appendix B

Grain Size and Sediment Chemistry Results

Miller Pacific
ENGINEERING GROUP

PARTICLE SIZE ANALYSIS CHART



SYMBOL	SAMPLE SOURCE	CLASSIFICATION
(blue line, diamond)	Sample II	Well Graded SAND with Silt and Gravel (SW-SM)
(green line, square)	Sample III	Well Graded SAND with Clay and Gravel (SW)
(red line, triangle)	Sample IV	Well Graded GRAVEL with Sand (GW)

Test: ASTM D-422

Appendix C

Project Photos

Report Date: November 24, 2015

Laboratory Report

Roger Leventhal
Marin County DPW
P.O. Box 4186
San Rafael, CA 94913

Project Name: **Misc Testing**

Lab Project Number: **5111302**

This 7 page report of analytical data has been reviewed and approved for release.

Mark A. Valentini, Ph.D.

Laboratory Director

Ammonia

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-01	**SA-1**	Ammonia as NH3	ND	2.0

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015220
Date Received:	11/13/15	Method:	SM 4500-NH3 D-2011		

Ammonia

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-02	**SA-2**	Ammonia as NH3	ND	2.0

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015220
Date Received:	11/13/15	Method:	SM 4500-NH3 D-2011		

Ammonia

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-03	**SA-3**	Ammonia as NH3	4.6	2.0

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015220
Date Received:	11/13/15	Method:	SM 4500-NH3 D-2011		

Ammonia

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-04	**SA-4**	Ammonia as NH3	2.4	2.0

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015220
Date Received:	11/13/15	Method:	SM 4500-NH3 D-2011		

Ammonia

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-05	**SA-5**	Ammonia as NH3	ND	2.0

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015220
Date Received:	11/13/15	Method:	SM 4500-NH3 D-2011		

Ammonia

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-06	**SA-6**	Ammonia as NH3	ND	2.0

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015220
Date Received:	11/13/15	Method:	SM 4500-NH3 D-2011		

Sulfide

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-01	**SA-1**	Sulfide	640	25

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015218
Date Received:	11/13/15	Method:	SM 4500-S^2 F-2011		

Sulfide

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-02	**SA-2**	Sulfide	33	25

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch:	B015218
Date Received:	11/13/15	Method:	SM 4500-S^2 F-2011		

Sulfide

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-03	**SA-3**	Sulfide	810	25

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch: B015218
Date Received:	11/13/15	Method:	SM 4500-S^{2} F-2011	

Sulfide

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-04	**SA-4**	Sulfide	540	25

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch: B015218
Date Received:	11/13/15	Method:	SM 4500-S^{2} F-2011	

Sulfide

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-05	**SA-5**	Sulfide	460	25

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch: B015218
Date Received:	11/13/15	Method:	SM 4500-S^{2} F-2011	

Sulfide

Lab#	Sample ID	Compound Name	Result (mg/kg)	RDL (mg/kg)
5111302-06	**SA-6**	Sulfide	290	25

Date Sampled:	11/12/15	Date Analyzed:	11/18/15	QC Batch: B015218
Date Received:	11/13/15	Method:	SM 4500-S^{2} F-2011	

Quality Assurance Report

Ammonia

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B015220 - NO PREP										
Blank (B015220-BLK1)				Prepared: 11/17/15 Analyzed: 11/18/15						
Ammonia as NH3	ND	1.0	mg/kg							
Matrix Spike (B015220-MS1)		**Source: 5111302-06**		Prepared: 11/17/15 Analyzed: 11/18/15						
Ammonia as NH3	5.16	1.0	mg/kg	5.26	ND	98	70-130			
Matrix Spike Dup (B015220-MSD1)		**Source: 5111302-06**		Prepared: 11/17/15 Analyzed: 11/18/15						
Ammonia as NH3	5.14	1.0	mg/kg	4.84	ND	106	70-130	8	20	

Sulfide

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B015218 - NO PREP										
Blank (B015218-BLK1)				Prepared & Analyzed: 11/18/15						
Sulfide	ND	25	mg/kg							
LCS (B015218-BS1)				Prepared & Analyzed: 11/18/15						
Sulfide	1850	25	mg/kg	2000		92	70-130			
Duplicate (B015218-DUP1)		**Source: 5111302-06**		Prepared & Analyzed: 11/18/15						
Sulfide	272	25	mg/kg		290			6	20	

Notes and Definitions

RDL	Reporting Detection Limit
ND	Analyte NOT DETECTED at or above the reporting detection limit (RDL)
RPD	Relative Percent Difference
NR	Not Reported

Analytical Sciences
P.O. Box 750336, Petaluma, CA 94975-0336
110 Liberty Street, Petaluma, CA 94952
(707) 769-3128
Fax (707) 769-8093

CHAIN OF CUSTODY

Lab Project Number: 511302
Client's Project Name:
Client's Project Number:

CLIENT INFORMATION

Company Name: MARIN COUNTY DPW FLOOD CONTROL
Address: 3501 CIVIC CENTER DR, #304
SAN RAFAEL 94903
Contact: ROGER LEVENTHAL
Phone #: 415-473-3249
Fax #:
E-mail: RLEVENTHAL@MARINCOUNTY.ORG

TURNAROUND TIME (check one)

Same Day			
48 Hours		24 Hours	
5 Days		Normal	X

Page 1 of 1

ANALYSIS

Item	Client Sample ID	Date Sampled	Time	Matrix	# Cont.	Presv. Y/N	SULFIDE	AMMONIA												Comments	Lab Sample #
1	SA-1	11/12/15	4:30	SOIL	4															UPSTREAM	511302-01
2	SA-2		4:40																		-02
3	SA-3		451																		-03
4	SA-4		458																	JUST AT THE BRIDGE	-04
5	SA-5		500																		-05
6	SA-6		5:01																	DOWNSTREAM	-06
7																					
8																					
9																					
10																					

SIGNATURES

Relinquished By: [signature]
Signature
Sampled By:
Date 11/13/15 Time 8:10
Received By: [signature]
Signature
Date 11/13/15 Time 810

PHOTO PHOTOS


Photo 1. Natural alluvial fan sedimentation over mature salt marsh, China Camp State Park, San Rafael, Marin County, 2006-2012. Storm runoff from adjacent hillslopes partially buries pickleweed salt marsh in 2006; by 2012, the marsh has regenerated as dense, tall gumplant and pickleweed with higher cover.


Photo 2. Artificial dredge sediment fan at Sonoma Baylands, San Pablo Bay, Sonoma County, deposited in 1996 (left) matured into dense, tall pickleweed and gumplant high salt marsh before 2006 (right).

Photo 3. Artificial dredge sediment fan at Montezuma Wetlands, Suisun Marsh, Solano County, developing salt marsh vegetation in diked, non-tidal basin.


Photo 4. North Bothin Marsh salt marsh vegetation canopy is almost completely submerged (continuous open water surface) during extreme high tide of Jan 12, 2017, with the exception of local high marsh mounds. Mounds are gently sloping artificial topographic high areas, shallowly submerged ground surface, but supporting emergent vegetation canopy. They formed on former dredge spoil deposits located along the pedestrian/bike path (left) and at the SE corner of N Bothin Marsh west of the old subsided perimeter levee (right). These high marsh mounds provide high tide refuge cover for shorebirds (willets, yellowlegs, and other species) as well as potential high tide refuge cover for the endangered Ridgeway's rail and salt marsh harvest mouse.


Photo 5. Field evidence of long-term subsidence and recent sea level rise at North Bothin Marsh. The conversion to high salt marsh is due to Dead shrubs, originally established and growing on fill and levees above tide during the 1970s, persist in high salt marsh along the unmaintained levees of North Bothin Marsh. September 14, 2016.

Photo 6. Emergence of upper mudflats and abundant cordgrass marsh cover at South Bothin Marsh during ebbing tide, June 20, 2016. The marsh vegetation canopy is completely submerged during extreme high tides (Compare Photo 7).

Photo 7. Left: South Bothin Marsh salt marsh interior vegetation is completely submerged before extreme high tide on Jan 12, 2017. Few patches of taller gumplant canopy remain emergent along the bike path edge where pedestrian/bike path use may conflict with wildlife use, but the interior marsh lacks cover. Right: A smaller fall high tide on October 12 2016, in contrast, leaves high salt marsh and cordgrass tops emergent and available for wildlife cover.

Photo 8. October 1, 2017, pedestrian and bike bath banks along South Bothin Marsh (left) and Richardson Bay (right), during ebbing tide

Photo 9. Shoulder of pedestrian/bike path berm along Richardson Bay, before complete submergence of paved path surface, one hour before extreme high tide of Jan 12, 2017.

Photo 10. Coyote Creek (north bank)-South Bothin Marsh, high salt marsh turf and sandy flats (pans formed on stabilized former dredge spoils from Coyote Creek), with sparse, low cover and scattered populations of the rare northern salt marsh bird's beak. Location is adjacent and south of rubble piles. September 14, 2016 (left) and July 9, 2016 (right).

Photo 11. An adult California Ridgeway's rail (*Rallus obsoletus*; federally listed as endangered) flooded out of South Bothin Marsh during an extreme high tide on November 13, 2009, forced onto boulders along the pedestrian/bike path shoulder (circled) because there was no available high tide cover.

Photo 12. High tide refuge habitat during extreme high tides at Bothin Marsh. Small mammals are flooded out of high salt marsh and terrestrial transition zones during the extreme high tide of Jan 12, 2017, and are forced to swim for cover if they are close enough to reach any before avian predators (hawks, egrets, herons) prey on them while they are exposed. A mole (above; weak swimmer) and vole (below; strong swimmer) were exposed during the Jan 12, 2017 extreme high tide, when cover was extremely scarce except at the perimeter levee. The endangered salt marsh harvest mouse (not shown) similarly requires high tide cover within its home range to avoid excessive predation pressure or drowning during extreme high tides.

Photo 13. The special-status salt marsh plant, northern salt marsh bird's-beak, *Chloropyron maritimum* subsp. *palustre* in flower (left), and in typical association with California sea-lavender, saltgrass, gumplant, seaside plantain, alkali-heath, and Jaumea in high salt marsh vegetation at South Bothin Marsh, July 9, 2015.

Photo 14. Demolition rubble piles between Coyote Creek north bank high salt marsh and pans, and South Bothin Marsh. July 9, 2015.

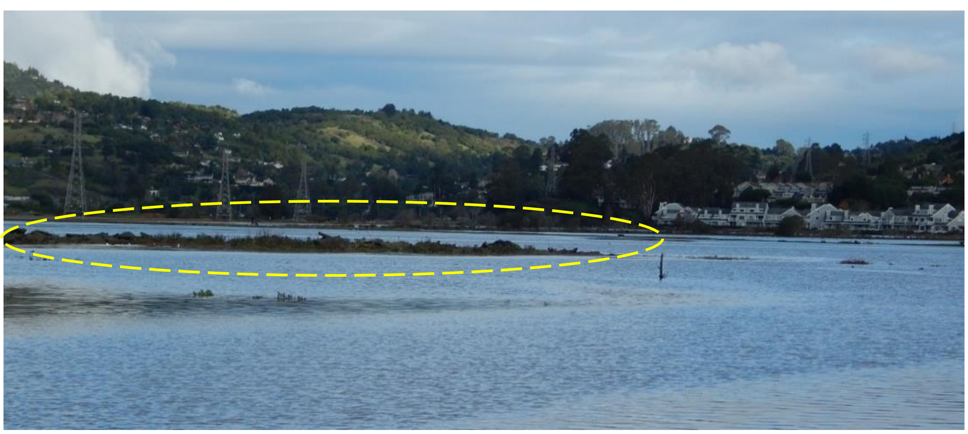


Photo 15. Island-like rubble debris pile above water level, South Bothin Marsh, 1 hour before extreme high tide January 12, 2017; high salt marsh and vegetation canopy is submerged.

Photo 16. Algerian sea-lavender, *Limonium ramosissimum*, an invasive non-native species rapidly spreading in high salt marsh vegetation of South Bothin Marsh. June 20, 2016.

Photo 17. South Bothin Marsh bordering the rubble pile. Left: high marsh transition zone sloping towards low cordgrass marsh adjacent to the rubble pile September 14, 2016. Right: low cordgrass marsh and marsh pans, July 9 2015.

Photo 18. The pedestrian/bike path along South Bothin Marsh was completely submerged (0.5 to over 1 ft deep along median line) except at one bridge crossing during peak high tide, Jan 12, 2017.

Photo 19. Shorebirds (willets) occupy partially emergent vegetation cover on sparse topographic high areas along the bay shore of the pedestrian/bike path before high tide Jan 12, 2017. The close adjacency between pedestrian/bike traffic and primary high tide refuge cover for wildlife is problematic for wildlife conservation.

Photo 20. The outer levee of North Bothin Marsh supports high salt marsh that provides most of the high tide vegetation cover during extreme high tides. Skeletal trees and shrubs, remaining from former supratidal levee crests that have subsided and become submerged by rising sea levels, persist on the levee. January 12 2017.