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Draft Conceptual Design Report

Bolinas Lagoon North End Restoration Project

Marin County Parks and Open Space District

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Appendix A: Geotechnical Report (Draft)

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EXECUTIVE SUMMARY

The Bolinas Lagoon North End Restoration Project, also known as the North End Wetland Enhancement and Sea Level Rise Adaptation Project (project), presents an exciting opportunity to restore a unique and highly valued ecosystem using innovative design elements and restoration strategies that not only offer short term value ecosystem benefit but increased ecosystem resilience under anticipated future climate conditions.

The project area contains habitats unique in the Lagoon due primarily to the amount of freshwater inflow—both surface and subsurface—from Lewis Gulch Creek, Wilkins Gulch Creek, Salt Creek, and Wharf Creek that drain through the Wye and into the northern tip of the lagoon. The freshwater input, the interface among the varied habitats, and the connectivity between the lower marsh and high marsh and uplands provides ecosystem complexity and valuable habitat for fish and wildlife and several special status species. However, the lagoon, streams, and other portions of the study area have been significantly impacted by roadways, stream diversion, and culverts. The lagoon now has a hardened perimeter that constrains the ability of the lagoon to respond to sea level rise by moving higher up the valley and onto alluvial floodplains. The culverts disconnect the lagoon habitats from the alluvial plains and riparian and upland habitats. In the study area, the alluvial fan surfaces of Wilkins Gulch and Lewis Gulch Creeks have for the most part been abandoned, except at their toes. The fans are disconnected from flooding because single thread channels are incised, and the single channels are far more efficient at transporting sediment toward and into Bolinas Lagoon than if the flows were distributed on the fans' surfaces. Channels that are deeply incised into their valley flats or alluvial fans can significantly lower the water table and cause an increase in bank erosion through the loss of riparian vegetation that helps stabilize the stream bank.

As early as 1996, it was recognized that the Bolinas Lagoon Ecosystem was being degraded through a combination of historic land-use patterns and changing environmental conditions and would require an active restoration effort to restore desired functions and values. A diverse group of stakeholders, including public agencies, private partners, and local citizens have been engaged in finding a solution to the apparent loss of ecosystem function and public safety ever since. Marin County Parks and Open Space District (MCPOSD) has initiated a broad-based effort to develop feasible conceptual project design alternatives that meet stakeholder expectations and existing regulatory standards while accounting for future sea level rise under climate change scenarios. This report presents a milestone in MCPOSD's planning and design effort: the development of three feasible conceptual design alternatives that offer different design solutions to meet the stated project goals: habitat restoration and reconnection, road safety, and climate change / sea level rise adaptation.

During the project planning process, three conceptual alternatives were selected collaboratively with partner agency stakeholders, the Bolinas Lagoon Advisory Council (BLAC), and members of the Bolinas and Stinson Beach communities. The design of each alternative includes three construction phases, representing near-term, mid-term, and longer-term conceptual design improvements.

- **Alternative 1** – Alternative 1 includes raising California State Route (SR) 1 onto two causeways, restoring Lewis Gulch Creek, and restoring the downstream portion of the Wilkins Gulch Creek floodplain.
- **Alternative 2** – Alternative 2 is considered the hybrid approach and includes raising SR 1 onto two causeways, restoring Lewis Gulch Creek, and restoring the entire Wilkins Gulch Creek floodplain to the head of the alluvial fan (both downstream and upstream portions of the drainage).
- **Alternative 3** – Alternative 3 includes raising SR 1 onto a single causeway that intersects with a Bolinas-Fairfax Road causeway, restoring Lewis Gulch Creek, and fully restoring the Wilkins Gulch Creek floodplain to the head of the alluvial fan.

The alternatives include a number of other common design elements, including removal of the Crossover Road, raising the roadway elevation and widening along Olema Bolinas Road, and placement of shoreline fill. See Table ES-1.

Table ES.1. Summary of Project Alternatives

Alternative	Floodplain Connectivity		Roadway Raising			Reconfigure Wye	Vegetated Shoreline Resilience	Lewis Gulch Creek
	Wilkins Gulch Creek	Lewis Gulch Creek	SR 1 Causeway	Bolinas-Fairfax Road	Olema Bolinas Road			Culvert Upgrade
1	Partial	✓	Double	Fill	Fill/Bridge	✓	✓	✓
2	Full	✓	Double	Fill	Fill/Bridge	✓	✓	✓
3	Full	✓	Single Long-Span	Causeway	Fill/Bridge	✓	✓	✓

The opportunities and constraints analysis indicates that despite a number of short-term limitations on meeting project goals, the overall outcome of the project, under all alternatives, is an opportunity to provide the Bolinas Lagoon ecosystem with extensive habitat restoration, traffic safety and sea level rise adaptation benefits. Critical short-term constraints common to all alternatives include disruption of the community during construction; losses of wetland, creek, and sensitive species habitat during construction of roadways and restoration elements, and uncertainty related to the feasibility of Phase 2 and 3 design elements given unknown availability of funding and uncertainty in climate change projections. Important opportunities common to all alternatives include natural habitat expansion and increased resilience with removal of the crossover road and at-grade segments of SR 1; increased roadway safety with improved intersections, roadway elevation and widening (decreased flooding risk), and devoted bike-lanes; and development of gentle sloping topography along the lagoon edge to support species migration and reduce potential erosion and habitat loss due to rising sea levels.

When compared to one another, Alternative 3 is has the highest cost, however, it performs best across all other categories due to its overwhelming benefit to hydrologic connectivity, sensitive species habitat, and climate resiliency. Alternative 1 is the shortest and most cost effective project; however, lacks critical design elements offered under the other two alternatives and therefore is unable to maximize benefits associated with climate resilience and habitat restoration/reconnection. Alternative 2 was expected to be an ideal compromise solution between the short efficient approach under Alternative 1 and the more costly complex approach of Alternative 3; however, the identification of critical geotechnical conditions related to lagoon sediment stability and road-safety feasibility under the dual-causeway scenario in Alternatives 1 and 2 rendered Alternative 2 more costly and less effective at meeting project goals than initially anticipated.

Ultimately, regardless of which alternative is selected, the project will meet all of the project goals and will result in significant benefits to the North End. It is up to Marin County and partners to determine which alternative is the most suitable, based on the categories and scores provided in the alternatives analysis. It will improve traffic safety, reduce flooding and maintenance needs, restore and reconnect both the habitats along the lagoon's edge and the upland habitats, create connectivity between these ecologically valuable areas, and allow the lagoon to move inland in response to sea level rise.

PART I – PROJECT OVERVIEW

1. Introduction

This report presents three conceptual design alternatives and an opportunities and constraints analysis for the Bolinas Lagoon North End Restoration Project, also known as the North End Wetland Enhancement and Sea Level Rise Adaptation Project (project), prepared for Marin County Parks and Open Space District (MCOSD). The project includes two phases—Phase 1, a baseline site conditions assessment completed in 2016, and Phase 2, a conceptual alternatives development and opportunities and constraints analysis. Phase 1 of the project was completed in 2016, and Phase 2 is the subject of this report.

This report is divided into three sections:

- **Part I: Project Overview**: Describes the purpose and need, goals, and stakeholder involvement, and summarizes existing site conditions.
- **Part II: Alternatives Conceptual Design, Cost, and Timeline**: Describes the three conceptual design components by phase, presents high-level costs by alternative and phase, and provides a conceptual timeline for project design, environmental review, and build.
- **Part III: Opportunities and Constraints Analysis** presents the opportunities and constraints associated with the alternatives, and it discusses potential impacts, permitting, and mitigation.

Each conceptual design alternative evaluated in this report addresses traffic safety, ecological benefit, hydrologic reconnection, and sea level rise resilience, and each builds upon historic and current background studies presented in the project's *Site Conditions Report*[1]. The alternatives were selected collaboratively with partner agency stakeholders, the Bolinas Lagoon Advisory Council (BLAC), and members of the Bolinas and Stinson Beach communities.

[1]AECOM. 2016. *Bolinas Lagoon North End Restoration Project - Site Conditions Report*. June 2016.

1.1 Project Location

The project is located at the North End of Bolinas Lagoon (Figure 1). Bolinas Lagoon is located along the California coast, 15 miles northwest of San Francisco. The project study area is the extent of the area studied under Phase I and detailed in the *Site Conditions* Report (AECOM 2016). The project area was expanded in Phase II to include further stretches of California State Route (SR) 1 and Olema Bolinas Road. The project area includes the following roadways: Olema Bolinas Road, Bolinas-Fairfax Road, the connector road, and SR 1. The connector road, Olema Bolinas Road, and SR 1 form a triangle, referred to as the "Y." The northern end of the lagoon and its fringing marshes border these roadways. Lewis Gulch Creek, Wilkins Gulch Creek, Salt Creek, and an unnamed creek that is referred to as Wharf Creek flow through the project area and into the lagoon.

1.2 Purpose and Need

The project is part of a larger, long-term effort to restore Bolinas Lagoon, an area of environmental, social, geological, and historic importance. In 2008, The Greater Farallones National Marine Sanctuary (GFNMS), MCOSD, and USACE published the *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management Report*, which concluded that "*restoration and reconnection of habitat along the lagoon's edge and upland habitat will allow for connectivity between these ecologically valuable areas and allow the lagoon to move inland in response to sea level rise.*" This is the focus of this report.

The lagoon is a result of geotectonic activities associated with the San Andreas Fault Zone. Bolinas Lagoon is one of 37 internationally designated Ramsar[2] sites in the United States. The lagoon contains over 1,100 acres of marsh, subtidal, and intertidal lagoon habitat that supports a diverse array of wildlife, including a large harbor seal (*Phoca vitulina*) pupping site. Bolinas Lagoon is a critical Pacific Flyway stopover point for migratory shorebirds and waterfowl. The brackish marsh transition zone provides important for waterbirds as high-tide refugia. Black rail (*Laterallus jamaicensis;* California Threatened) occur in the high marsh areas. California red-legged frog (*Rana draytonii*; Federally Threatened) is present in Salt Creek. Critical habitat for steelhead trout (*Onchorhynchus mykiss irideus*) is present in Wilkins Gulch Creek, and salmonids are known to occur in Lewis Gulch Creek.

The project area has habitats that are unique in the Lagoon due primarily to the amount of freshwater inflow—both surface and subsurface—from Lewis Gulch Creek, Wilkins Gulch Creek, Salt Creek, and Wharf Creek that drain through the Wye and into the northern tip of the lagoon. The lower level mudflats transition into vegetated salt marshes and then to brackish marsh in upper tidal elevations as fresh water from groundwater and creek discharges mix in a "subterranean estuary" below the marsh. This is reflected in an abrupt discontinuity in vegetation between low salt marsh and tall, dense brackish alkali-bulrush marsh within a very gentle tidal elevation gradient. Above the brackish lagoon habitat, at supratidal elevations above the reach of all but the highest winter storm high tides, stands of alder and willow have developed. These forests continue above the crossover road into the Y, which is an isolated triangle of habitat that is physically separated from tidal influence. The upper watershed portions of the study area consist of mixed conifer forest along the Bolinas Ridge. Oak woodlands occupy the drainage along Wharf Creek and the west side of Lewis Gulch Creek, and with the addition of some grassland, also characterize the middle segments, along the alluvial fans. In some reaches, the streams have a corridor of riparian trees such as red alder, willows, maple, and buckeye before they reach brackish habitat. The freshwater input, the interface among the varied habitats, and the connectivity between the lower marsh and high marsh and uplands provides ecosystem complexity and valuable habitat for fish and wildlife and several special status species.

However, the lagoon, streams, and other portions of the study area have been significantly impacted by roadways, stream diversion, and culverts. The lagoon now has a hardened perimeter that constrains the ability of the lagoon to respond to sea level rise by moving higher up the valley and onto alluvial floodplains. The culverts disconnect the lagoon habitats from the alluvial plains and riparian and upland habitats. In the study area, the alluvial fan surfaces of Wilkins Gulch and Lewis Gulch Creeks have for the most part been abandoned, except at their toes. The fans are disconnected from flooding because single thread channels are incised, and the single channels are far more efficient at transporting sediment toward and into Bolinas Lagoon than if the flows were distributed on the fans' surfaces.

[2] A wetland site of international importance designated under the international Convention of Wetlands, "the Ramsar Convention"

Channels that are deeply incised into their valley flats or alluvial fans can significantly lower the water table and cause an increase in bank erosion through the loss of riparian vegetation that helps stabilize the stream bank. Overall, the salinity of the study area, and therefore the species that grow and thrive in the study area, is highly dependent upon the relationship between tidal flooding, freshwater discharges below-ground and above-ground, topography, and hydraulic conductivity of the wetland soils. Surface flows are seasonal and generally come in the winter rainy months. The groundwater discharge persists into the dry season when surface flows generally stop. The roadways and culverts also eliminate continuous transitional habitat between the lagoon and the higher marsh and uplands that are important for waterbirds (including black rail) as high tide refugia and may interrupt migration of special status amphibians and anadromous fish.

Since the early 19th century, land use changes have altered the historical shoreline and watershed of Bolinas Lagoon and increased sediment delivery to the lagoon, resulting in a loss of tidal prism and changes in habitat types.[3] Approximately 80% of the sediment entering Bolinas Lagoon is from the ocean; however, human land-use changes in the watershed have increased sediment accumulation in the North End at least two to three times more than late Holocene rates.[4] The rate of watershed sedimentation is expected to continue at the present level when averaged over several decades.[2] Anthropogenic land use changes and sedimentation have led to connectivity barriers as a result of logging, mining, agriculture, and infrastructure development over time. These activities have greatly altered the natural landscape of the North End and have led to a hydrologic and ecological disconnection of natural processes and a hardscape perimeter, which constrains the ability of the tidal brackish marsh and associated habitats to shift up slope as the sea level rises. Traffic safety is also a concern at the North End, as are intersection configurations and roadway flooding resulting from winter storm events and undersized culverts in the project area.

Since 1996, MCOSD has been developing and refining plans to restore Bolinas Lagoon. This project is the result of the 2008 *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management*[5], which found that "*restoration and reconnection of habitat along the lagoon's edge and upland habitat will allow for connectivity between these ecologically valuable areas and allow the lagoon to move inland in response to sea level rise.*" As a result of active community and partner agency collaboration, the project, which was originally identified as a traditional dredging-based approach for lagoon restoration, evolved into an opportunity for collaborative ecosystem restoration that extends beyond the shoreline of the lagoon onto the uplands and roadways. MCOSD has initiated a broad-based effort to develop feasible conceptual project design alternatives that meet stakeholder expectations and existing regulatory standards while accounting for future sea level rise under climate change scenarios. This effort includes development of clear project goals and expectations; investigation and reporting on the existing hydrological, ecological, and social conditions in the project area.

The purpose of Phase II of the project (this report) is to develop conceptual designs that restore the North End, address roadway safety, and increase resiliency to sea level rise through roadway reconfiguration and raising, reconnection of the watershed hydrology and floodplain restoration, and ecological reconnection and enhancement. The purpose of this report is to document the project planning process and outcome. Specifically, the report is intended to provide a record of the conceptual design development process, present the three chosen conceptual design alternatives with detailed descriptions of the design components, and analyze the opportunities and constraints associated with each conceptual alternative. The report evaluates each conceptual alternative for its constructability/complexity, environmental effects (impacts and benefits to sensitive environmental resources), social considerations (community, traffic, and recreation), and project benefits (climate resiliency, hydrologic connectivity, and road safety). Because restoration is at the core of the project purpose, habitat mitigation is built into the project. The practical intent of this reporting is to provide information and analysis that allows stakeholders to compare and contrast the conceptual alternatives and assess which project alternative best meets their goals.

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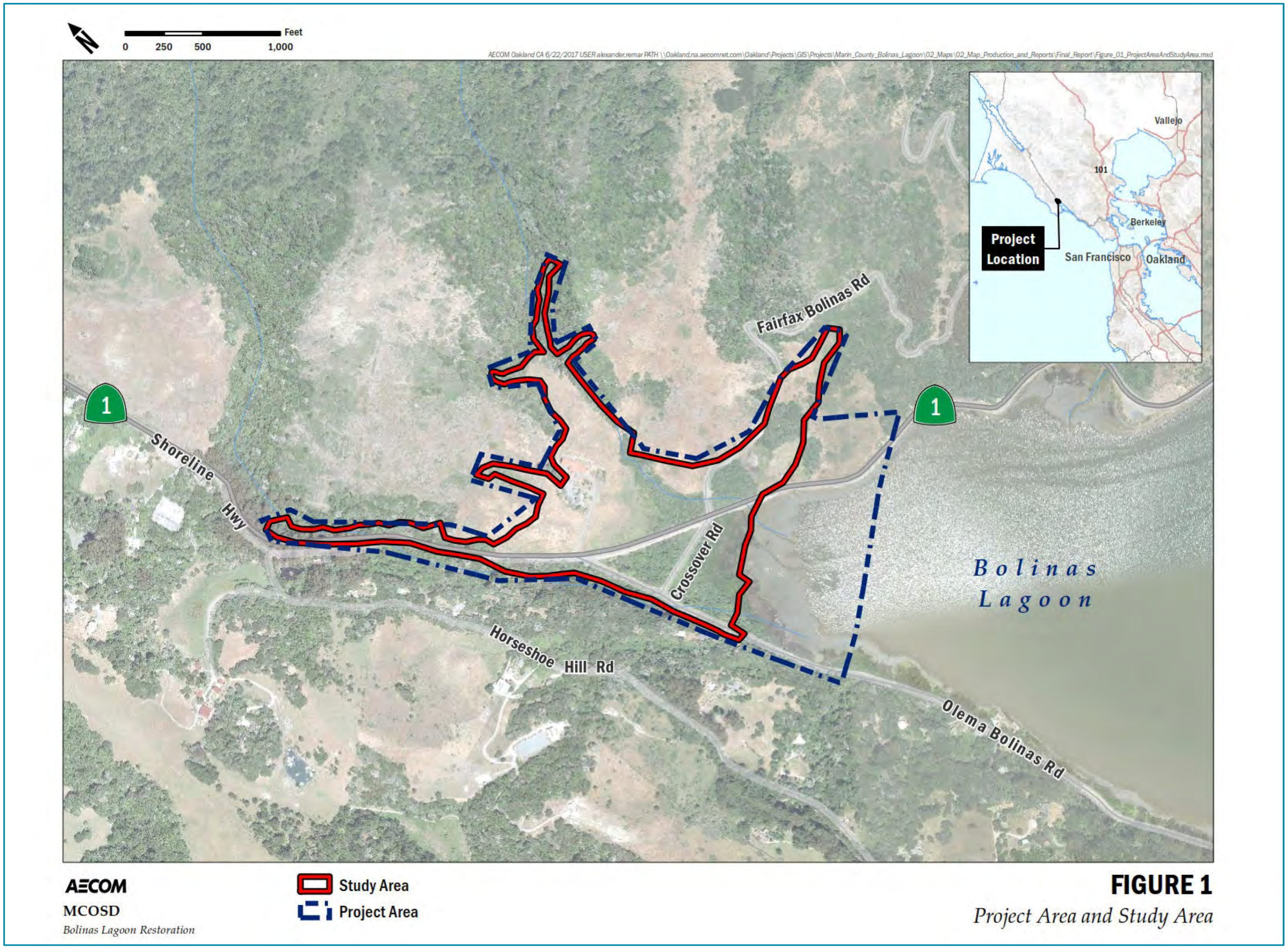
[3] MCOSD. 2006. Projecting the Future Evolution of Bolinas Lagoon. Prepared by: Philip Williams & Associates, Ltd. with WRA, Inc. July 2006.

[4] Byrne, R., L. Reidy, D. Sengupta, B. Watson, D. Schmidt, A. Arthur, M. Kirby, J. Krause, J. Sullivan, J. Borkowski, A. Yiu, and A. Menchaca. 2005. Recent (1850 - 2005) and Late Holocene (AD 400 - AD 1850) Sedimentation Rates at Bolinas Lagoon, Marin County, California. December 2005.

[5] Working Group of the Sanctuary Advisory Council, Greater Farallones National Marine Sanctuary with assistance from Marin County Open Space District, and the U.S. Army Corps of Engineers, San Francisco District. *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management*. August 2008. 101 pages. Available: https://nmsfarallones.blob.core.windows.net/farallones-prod/media/archive/eco/bolinas/pdf/finalplanoptnov.pdf

Figure 1: Project Area and Study Area



1.3 Project History

1996: Bolinas Lagoon Management Plan Update

In 1996, MCOSD updated the *1981 Bolinas Lagoon Resource Management Plan* and found that the foremost resource management issues for the lagoon were a loss of the tidal prism as a result of the continuing sediment accumulation and the loss of estuarine habitats, both consequences of human modifications to the landscape (e.g., stream diversion, logging, ranching, roadway creation, and mining). The plan concluded with two recommended management approaches: (1) watershed management and (2) additional study including the possibility of dredging to increase natural scouring and sediment removal by tidal forces. The plan recommended the development of a Sediment Management Plan to address continuing sediment accumulation.

1997: USACE Reconnaissance Study

In 1997, the U.S. Army Corps of Engineers (USACE) conducted a reconnaissance study and concluded that corrective action—dredging and/or other means of removing accumulated sediment or minimizing its entry into the lagoon—was a matter of national interest because of the lagoon's environmental significance.

1998: MCOSD-USACE-CCC Partnership Established and Feasibility Study Commenced

In 1998, MCOSD established a partnership with the USACE and the California Coastal Conservancy (CCC) to address the issues of sediment accumulation and loss of estuarine habitats. As a result of the partnership, a feasibility study of Bolinas Lagoon restoration was launched.

2002: USACE Draft Bolinas Lagoon Ecosystem Restoration Feasibility Study and Draft EIR/EIS

In 2002, the USACE and MCOSD released *The Bolinas Lagoon Ecosystem Restoration Feasibility Study and Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) done by TetraTech*, which identified a feasible project with a total estimated cost of $101.5 million (M) to restore nearly 600 acres of subtidal and intertidal habitat in Bolinas Lagoon by removing 1.4 million cubic yards of sediment.

2006: MCOSD Bolinas Lagoon Ecosystem Restoration Feasibility Project

In July 2006, responding to public concerns, MCOSD hired Phil Williams and Associates (PWA) to conduct a rigorous review of the feasibility study's conclusions, including a 50-year projection of the hydrological and ecological evolution of Bolinas Lagoon in a series of five reports. MCOSD assembled two panels of independent scientists to assist in identifying data gaps, to collect and analyze new data, and to provide peer review. Contrary to prior understanding, it was found that 80% of the sediment entering the lagoon is from the ocean. Yet anthropogenic sedimentation at the north and south ends due to land use and stream channelization have increased accumulation rates.

2008: GFNMS and MCOSD Bolinas Lagoon Ecosystem Restoration Project Recommendations Report

In 2008, The Greater Farallones National Marine Sanctuary (GFNMS), MCOSD, and USACE published the *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management Report*, which focused on addressing historic human impacts to Bolinas Lagoon by aiding ecological and hydrological processes. The report provided a suite of recommendations for long-term management actions and established an overall project goal, along with specific restoration objectives. A key element identified was floodplain restoration. The report concluded that "*restoration and reconnection of habitat along the lagoon's edge and upland habitat will allow for connectivity between these ecologically valuable areas and allow the lagoon to move inland in response to sea level rise.*"

2015: MCOSD Bolinas Lagoon North End Restoration Project Commencement

In 2015, the AECOM team was awarded a contract for the preparation of a Site Conditions Report and an Opportunities and Constraints Report with conceptual designs for the Bolinas Lagoon North End Restoration Project. The *Phase I – Site Conditions Assessment Report* was completed in 2016.

1.4 Report Components

This report includes the following:

- Development of three conceptual alternatives for re-routing and redesigning roads near the Wye that address resource enhancement and transportation, traffic safety, and sea level rise, including ; long-term phasing of alternatives into three phases and a conceptual traffic transition plan;
- Geotechnical borings and lab testing to determine the design feasibility of conceptual alternatives components from a geotechnical perspective;
- Estimation of the project costs and development of a project timeline;
- Development of an opportunities and constraints analysis of project features for meeting project goals; and
- Identification and assessment of potential project impacts and mitigation.

In the opportunities and constraints analysis, physical factors that may affect restoration and adaptation at the project site are described. The benefits and limitations of each alternative are presented clearly in the alternatives summary table (Section 11) so that the economic, social, physical, cultural, and biological costs can be weighed.

1.5 Stakeholder Input

Project input during Phases I and II was provided by several key stakeholders, including project partner agencies and adjacent landowners: Point Reyes National Seashore, Golden Gate National Recreation Area, and the GFNMS, the California Department of Transportation (Caltrans), Audubon Canyon Ranch, community members from Bolinas and Stinson Beach, and the Bolinas Lagoon Advisory Council (BLAC), formerly the Bolinas Lagoon Technical Advisory Council; conservation groups; and the Marin County Department of Public Works. Marin County established the BLAC to provide the community with an opportunity to participate in the management and restoration of Bolinas Lagoon. Parks and the partner agencies share responsibility for the landownership, management, and restoration of Bolinas Lagoon. Caltrans holds the rights-of-way over SR 1, which borders the northeastern side of the lagoon.

2. Goals and Objectives

The goals of the project are:

GOAL 1: Habitat Restoration and Reconnection: Improve the hydrologic function and stream flow conveyance of Lewis Gulch Creek and Wilkins Gulch Creek and enhance riparian and wetland habitats;

GOAL 2: Road Safety (including alignment and flooding): Alleviate chronic flooding of Marin County and State roadways and improve traffic safety;

GOAL 3: Climate Change and Sea Level Rise Adaptation: Allow for future expansion of Bolinas Lagoon and its tidal-freshwater transition zone as sea level rises.

All of the conceptual alternatives are designed to meet all of the project goals through implementation of three main objectives:

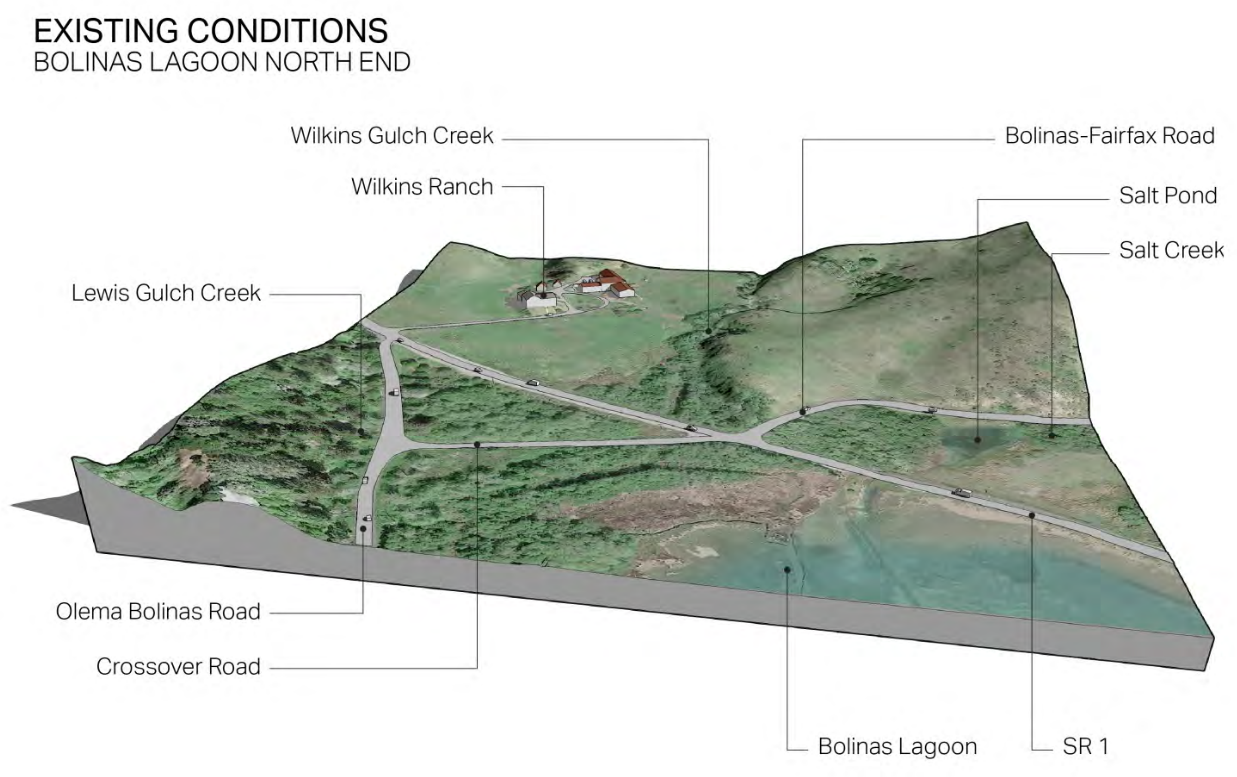
1) Restore hydrologic and ecological processes and reduce the need for human intervention and maintenance.
2) Realign roads to improve safety and reduce road flooding during winter storm and high tide events.
3) Raise the roadways and remove infrastructure to provide opportunity for upslope habitat migration and lagoon expansion, thus providing an unimpeded transition zone for areas subject to backwater flooding and delta development.

The goals of the project were developed over time as a result of stakeholder involvement and assessment. Goal 1: Habitat Restoration and Reconnection and Goal 3: Climate Change and Sea Level Rise Adaptation developed as a result of the 2008 *Bolinas Lagoon Ecosystem Restoration Project: Recommendations for Restoration and Management* report. The report stated that habitat restoration and reconnection will allow for ecological connectivity as the sea level rises. Goal 2: Road Safety is the outcome of stakeholder engagement, feedback from the BLAC and the community, and feedback from the Marin County Department of Public Works.

3. Existing Conditions

This section presents a summary of the physical environment of the project area. Detailed information is provided in the Site Conditions Report (MCOSD 2016). Bolinas Lagoon is a complex, dynamic ecosystem that is governed by interactions between climate, geologic processes, and land use.[6] Elevations within the project area range from mean sea level at the lagoon up to 321 feet along the Wharf Creek drainage on the west side of the project area and up to 1,653 feet at the headwaters of Wilkins Gulch Creek. A more in-depth discussion of the existing conditions in the project study area is provided in the Site Conditions Report. Figure 2 provides a three-dimensional topographic model of the existing conditions in the project area. Figure 3 shows a cartoon image of the project area with feature details.

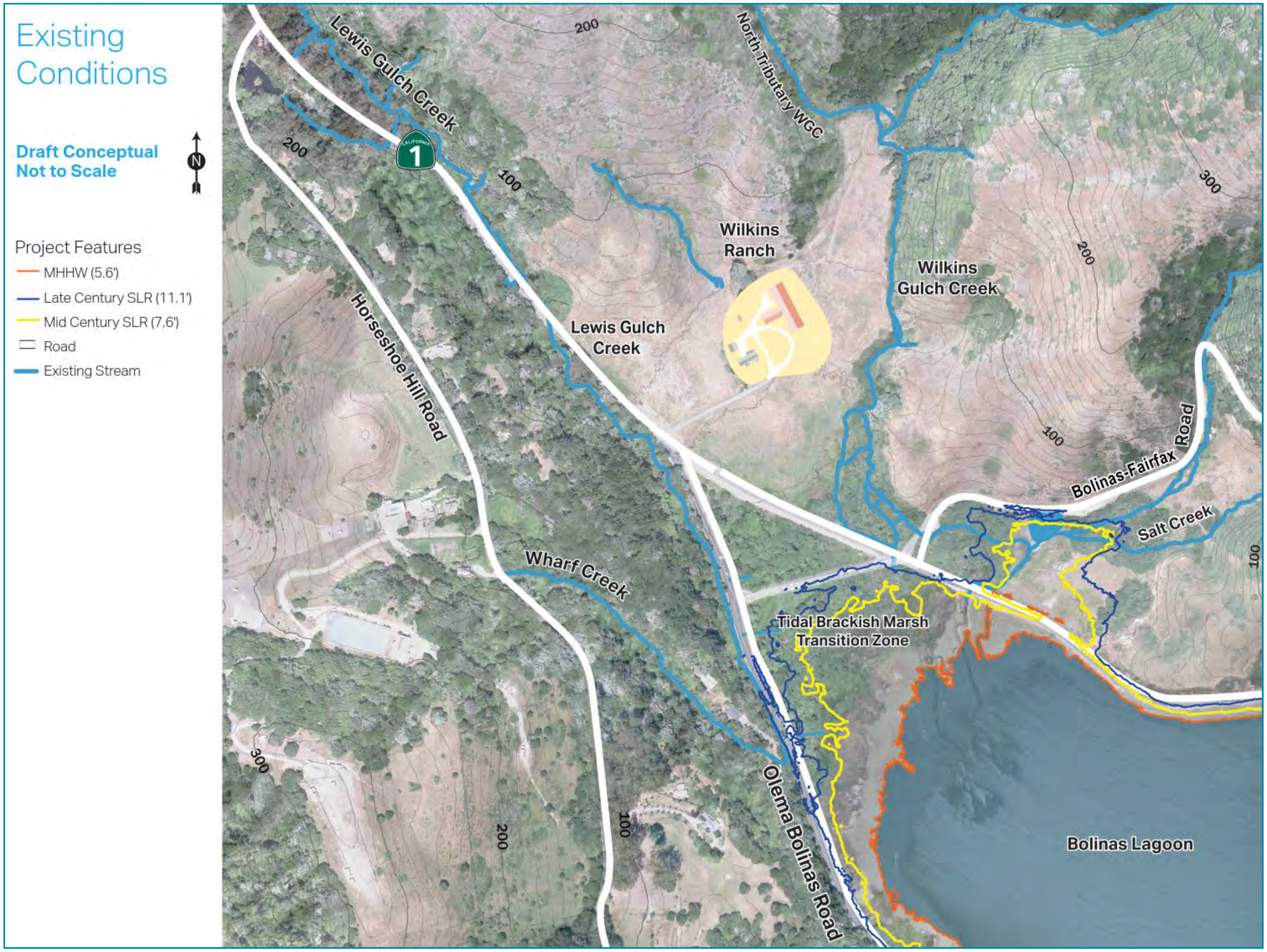
Figure 2: Existing Conditions – Bolinas Lagoon North End



Wilkins Gulch Creek (and its North Tributary) and Lewis Gulch Creek flow in ditched straightened channels in the Olema Valley before reaching the Bolinas Lagoon. These streams have largely lost their connection to their former floodplains. Wilkins Gulch and Lewis Gulch Creeks are intermittent streams in their middle reaches. Salt Creek may be considered ephemeral, with only seasonal flows. The northern portions of the lagoon within the project area are at sea level and contain unvegetated tidal mudflats dissected by defined channels formed by the creeks. Upslope, the mudflats transition into vegetated salt marshes. The lagoon becomes brackish, as freshwater from surface water and groundwater mix in a "subterranean estuary" below the marsh plain. An abrupt discontinuity in vegetation results, between low salt marsh and tall, dense, brackish alkali-bulrush marsh. Above the brackish lagoon habitat at supratidal elevations (highest winter storm high tides), stands of alder and willow occur. The alder/willow forest continues within the isolated triangle of habitat at the Y, which is not tidally influenced.

[6]MCOSD. 2006. Projecting the Future Evolution of Bolinas Lagoon. Prepared by: Philip Williams & Associates, Ltd. with WRA, Inc. July 2006.

Figure 3: Existing Conditions Alternative



3.1 Hydrology

3.1.1 Creeks and Freshwater

There are four creeks in the project area, as described below:

Wilkins Gulch Creek flows out of its canyon and joins with its North Tributary, before flowing into Olema Valley, east of Wilkins Ranch in an incised channel. Its downstream end is in a drainage ditch that carries water and sediment beneath a culvert beneath Bolinas-Fairfax Road into the Salt Creek drainage.

Lewis Gulch Creek flows along an inboard ditch in the 1906 San Andreas Fault line, between the steep hillslope to the west and bounded by roadways to the east (SR 1 in the north and Olema Bolinas Road in the south). Lewis Gulch Creek flows nearly to the confluence of Wharf Creek, well beyond its historical outfall at the lagoon apex.

Salt Creek flows in the next valley to the east and is a separate drainage. The freshwater Salt Pond exists near the previous head of lagoon arm. Subsurface groundwater flows are evident through the vast willow forest in the tidal brackish marsh transition zone.

Wharf Creek flows to the south of Lewis Gulch Creek. Wharf Creek outlet has been redirected to flow to the north, joining the inboard ditch and unnatural outlet of Lewis Gulch Creek.

Wilkins Gulch Creek, the North Tributary of Wilkins Gulch, Lewis Gulch Creek, and Salt Creek historically flowed on their relict alluvial fans through the project area. Lewis Gulch Creek flowed east of its current location. Wilkins Gulch Creek flowed on its alluvial fan east of Wilkins Ranch and down the Olema Valley, where present-day upland non-native grassland habitat occurs. The two creeks then converged towards the apex of the lagoon. Salt Creek flowed into an arm of the Bolinas Lagoon that later became backfilled behind an arm of what was once a natural spit, which became the present-day corridor for SR 1. Current subsurface groundwater flows are thought to have occurred as surface flows when the creeks flowed on their alluvial fans.

During the late nineteenth and early twentieth centuries, Wilkins Gulch Creek was ditched and confined against the east side of its alluvial fan to the north of SR 1, adjacent to the hillslope. This may have occurred to increase pasture for Wilkins Ranch. The lower stream reach was historically ditched to convey flow to the adjacent drainage of Salt Creek through culverts beneath Bolinas-Fairfax Road. Maintaining the creek in that location required periodic dredging or excavation of bedload accumulation. Excavated material was piled on a berm along the downstream right bank, which confined the channel to its new location against the hillslope. Wilkins Gulch and Lewis Gulch Creeks have incised, so flood flows no longer have access to the fan surface in their upper and middle reaches. Stream modifications of ditching and straightening the creeks have significantly altered the sediment regime. Whereas the majority of sediment was once deposited on the upper- to mid-fan surface, the majority is currently transported further downstream to the channel segments in the lower reaches of the channels and inner benches of the alluvial fans. Channelization, through entrenchment incision and loss of a functioning floodplain, has narrowed the riparian corridor and prevented redistribution of fine sediment across the floodplain. Currently, most of the sediment and bedload is transported to downstream reaches of the creeks. This has resulted in a reduction in the amount of base flow and groundwater available for dry season streamflow, which is important for sustaining freshwater and brackish water habitat.

Flooding is the natural process for building upland/tidal transition zones, but road berms, ditch diversions, de-silting activities, and culverts in the project area have altered the flood and sediment conveyance to the Bolinas Lagoon. The placement and design of all of the culverts and the orientation, shape, and size of channels leading to and from the roads contribute to road flooding issues. Much of the sediment load from the creeks is deposited in the roadside ditches on the upstream side of the road culverts and inside the culverts beneath the roads. During flood events, these culverts may become overwhelmed by the high sediment supply, causing a loss in capacity and resulting in roadway flooding. This is exacerbated during high tides, when channel velocities are reduced or halted at culvert outlets.

3.1.2 Tidal and Brackish Water

The lagoon is highly dynamic and cycles through periods of greater depth following periodic large scale earthquakes that drop the floor of the lagoon. This is followed by periods of high sediment deposition largely from littoral sands and finer sediment borough into the lagoon each tidal cycle. Coring studies show that 80% of the sediment in the lagoon is from littoral sources and 20% from the watershed. As sediment accumulation increases, the rate of net sediment deposition decreases and the lagoon can remain a shallow intertidal mudflat habitat for extended periods until another earthquake starts the cycle again.

Since the early 19th Century, land use changes have altered the historical shoreline and watershed of Bolinas Lagoon and increased sediment delivery to the lagoon, resulting in a loss of tidal prism and changes in habitat types (MCOSD 2006). In 1854, the lagoon was very shallow, with well-developed tidal channels in the north basin (MCOSD 2006). Land use changes that occurred in the watershed during the latter half of the 19th century at least doubled the amount of sediment entering the lagoon[7]. The 1906 earthquake deepened the lagoon and caused the Bolinas Bluffs to collapse, creating a substantial source of sediment that was carried throughout the lagoon and a period of rapid sediment accumulation followed[8].

In 2006 it was found that most of the sediment entering the lagoon is from the ocean rather than the lagoon's watershed, however, at the North End, sedimentation was exacerbated for a brief geological time to at least 2 to 3 times more than late Holocene rates as a result of anthropogenic causes and land use[8]. The watershed is now largely protected and in many ways has healed. Today, sediment delivery has slowed, however, it is still higher than pre-Europeans man.

In 2016, ESA conducted a study of Bolinas Lagoon bathymetry for MCOSD, using recent bathymetric data from 2012 and 2016 to re-assess the current bathymetry conditions at Bolinas Lagoon and to revise projections for the geomorphic evolution of the lagoon by 2050[8]. The study found that the tidal prism estimate has increased from 3.7 million cubic yards (MCY) in 1998 to 4.0 MCY in 2012/2016 and that localized areas of sedimentation and erosion are occurring. For an assumed sea-level rise (SLR) of 1.5 feet by 2050, the mudflats are likely to decrease in elevation relative to the tides and as a result, the projected 2050 tidal prism would become 4.4 MCY, an increase from present conditions[9]. The observed 2012/2016 tidal prism and projected 2050 tidal prism are both larger than the 1998 tidal prism, indicating that the lagoon's inlet will open, with decreasing risk of closure[9].

The salinity of the project area and therefore the species that grow and thrive in the project area are highly dependent upon the relationship between tidal flooding, freshwater discharges belowground and aboveground, topography, and the hydraulic conductivity of wetland soils. During periods of high freshwater discharge, salinity levels in the project area are lower, and vice-versa. Freshwater discharge is highest when there is a combination of surface and subsurface flows. Surface flows are seasonal and usually come during the rainy season (October to April). The groundwater discharge persists into the dry season, when surface flows generally stop. By increasing the amount of recharge of the groundwater table, summer flows can be increased and winter peak flows can be decreased.

3.2 Geology and Tectonic Activity

Bolinas Lagoon is a highly dynamic geologic area. It is part of the larger San Andreas Fault Zone that extends from the Gulf of California through much of northern California. The San Andreas Fault Zone is not a single fault; but a series of faults. Additional converging and diverging faults create complex local geology and seismic activity, resulting in a graben at the north end. The north end of the lagoon was formed by the down-dropping of this graben as a result of fault zone activity. Figure 4 shows the bedrock geology and the three great faults that form the San Andreas Fault Zone in the project area: the San Gregorio Fault, the San Andreas Fault (1906 rupture), and the Golden Gate Fault. Cretaceous sedimentary Franciscan rocks (Kjf) occur east of the Golden Gate Fault along Bolinas Ridge, and Miocene Monterey shale (Tm) occurs west of the San Gregorio Fault. Between the faults, there is a mixture of

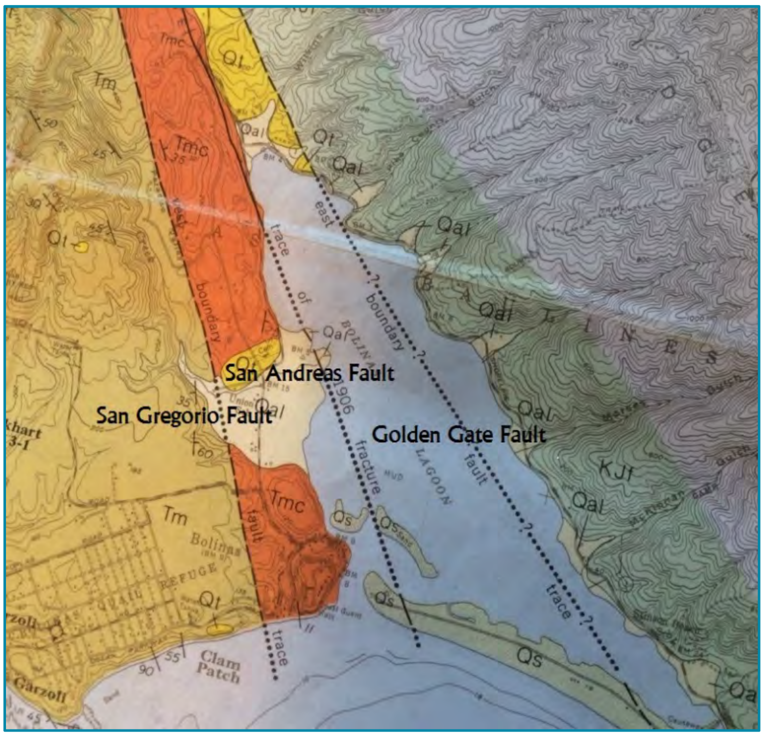
[7] Byrne, R., L. Reidy, D. Sengupta, B. Watson, D. Schmidt, A. Arthur, M. Kirby, J. Krause, J. Sullivan, J. Borkowski, A. Yiu, and A. Menchaca. 2005. Recent (1850 - 2005) and Late Holocene (AD 400 - AD 1850) Sedimentation Rates at Bolinas Lagoon, Marin County, California. December 2005.

[8] ESA. 2016. Draft Bolinas Lagoon Bathymetry Reassessment. Prepared for MCOSD. August 12, 2016.

Holocene-Pleistocene terrace (Qt) deposits, Plio-Pleistocene Merced siltstones (Tmc), and sandstones. A small amount of Holocene-age alluvium (Qal) is at the northern head of the lagoon near the present-day alluvial fans of the creeks flowing through the project study area.

The San Andreas Fault is a right lateral strike-slip fault where two or more tectonic plates slide past each other in bursts of movement that can be sudden and dramatic on the human time scale. The last active fault rupture along the San Andreas was a magnitude 7.8 event in 1906, which formed a rupture 296 miles long. This resulted in up to 12 feet of displacement near Bolinas and about 2 feet of down-dropping along the eastern side of the rupture in the Bolinas Lagoon[9]. The long-term average for right lateral movement on the San Andreas Fault ranges from about 12.7 millimeters per year (mm/yr) to 50 mm/yr.[10,11]

Figure 4: San Andreas Fault Zone Geology



Note: Adopted from Galloway, A.J. 1977. Map insert. In: Geology of the Point Reyes Peninsula, Marin County, California, Bulletin 202. Sacramento: California division of Mines and Geology.

3.2.1 Geotechnical Borings

Seven geotechnical borings, designated B-1 through B-7, were performed between March 27 through March 31, 2017, and on April 20 and April 21, 2017. A total of four groundwater wells were installed at the following boring locations: B-1, B-2, B-4, and B-6. The boring locations are shown on Figure 5. See Appendix A: Geotechnical Report for details. The borings ranged from 25.5 feet to 66.5 feet in depth. Groundwater wells comprised of 2-inch-diameter polyvinyl chloride (PVC) were installed in or adjacent to the borings per Marin County specifications, with a 5- to 10-

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9 Gilbert, G.K., R.L. Humphrey, J.S. Sewell, and F. Soulé. 1907. The San Francisco Earthquake and Fire of April 18, 1906 and Their Effects on Structures and Structural Materials. Washington, DC: Government Printing Office, 1907. Bulletin No. 324, Series R, Structural Materials, 1. http://pubs.usgs.gov/bul/0324/report.pdf

10 Niemi, T.M., and H.T. Hall. 1992. "Late Holocene Slip Rate and Recurrence of Great Earthquakes on the San Andreas Fault in Northern California." Geology, v. 20, no. 3, 195–198.

11 Noller, J.S., Kelson, K.I., Lettis, W.R., Wickens, K.A., Simpson, G.D., Lightfoot, K., and Wake T., 1993, Paleoseismic and geoarchaeologic investigations of the northern San Andreas fault, Fort Ross State Historic Park, California: Final Technical Report, U.S.G.S. NHERP Grant # 14-08-0001-G2076, 17 pp.

foot 0.020 screen and a #3 sand filter pack installed to a bottom depth of about 25 feet below ground surface (bgs). The zone below the PVC well and filter pack was backfilled per Marin County permit specifications.

For each boring, the following laboratory test was conducted:

- Moisture content and density (ASTM D7236B),
- Grain size analysis (gradations) (ASTM D422 and ASTM D1140),
- Atterberg limits (ASTM D4318),
- Unconfined compressive strength (ASTM D2166), and
- Undrained-unconsolidated triaxial tests (TXUU) (ASTM D2850).

Figure 5: Geotechnical Borings Site Plan

FIGURE 10-1
Geotechnical Boring Locations

The groundwater levels as measured in the borings were approximately 1.5 feet to 10 bgs corresponding to an elevation range of 5 to 19 feet (NAVD 88). Initial readings were collected from wells B-1, B-2, B-4, and B-6; the water levels as measured are included in Table 1.

Table 1: Groundwater Elevations

Boring ID	Groundwater Elevation (feet)				
	March 29, 2017	March 30, 2017	March 31, 2017	April 20, 2017	April 21, 2017
B-1	2.9	2.7	2.7	2.75	2.8
B-2	--	0.3	0.3	0.3	0.3
B-4	--	--	--	2.7	2.7
B-6	--	--	--	--	1.17

The surface deposits at the project site are Holocene-age (11,700 years before present) artificial fill and alluvium, and Pleistocene-age (2.6 to 11,700 million years before present) older alluvium and terrace deposit soils overlying Pliocene-age (5.3 to 2.6 million years before present) Merced formation and Cretaceous (145 to 66 million years before present) to Jurassic (199.6 to 145 million years before present) Franciscan complex bedrock units. These deposits are described in further detail in Appendix A. Boring B-5 was the only boring location performed east of the Golden Gate Fault (see Figure 4 for fault locations in the project area). This boring encountered silty gravel with sand artificial fill to 4.5 feet bgs, overlying highly weathered siltstone and shale of the Cretaceous-age Franciscan Complex (Kfs). The initial 4 feet of siltstone encountered was weathered in-place residual soil.

3.3 Habitats and Wildlife

The project area consists primarily of mudflat, freshwater, brackish and salt marsh, riparian forest (alder and willow), and grassland habitats. Areas of scrub and eucalyptus forest are also present, but are smaller and scattered. Native plants grow intermixed with non-native plant species throughout most of the project area. Riparian and wetland vegetation, consisting of moisture-dependent trees, shrubs, and forbs, is found in portions of the intermittent and perennial creeks and drainages, and surrounds Salt Pond. Within the lagoon and adjacent to the project area are rookeries for egret and heron nesting and areas for harbor seal pupping. As described earlier, the project area provides habitat for special-status wildlife species, including black rail, California red-legged frog, and steelhead trout.

While Wilkins Gulch Creek is listed in the Federal Register as critical habitat for steelhead,[12] the stream dries out for a large portion of the year. The reach in the study area may not currently contain steelhead habitat. However, Lewis Gulch Creek has been known to support steelhead trout[13]. Further research is necessary to determine whether the project area supports steelhead and their habitat. Vegetation communities in the project area are heavily influenced by the groundwater flows and salinity.

Plant growth is minimal during periods of high surface flows. Groundwater flows dominate the area during periods of plant growth, when the plants are most sensitive to salt stress. Alders occupy areas that do not have a stagnant water table, but have seasonal fluctuations that provide times when the ground is not continually saturated. As sea level rises, the transition to salt-marsh-tolerant species is anticipated to move upland.

3.4 Cultural Resources

The Coast Miwok were hunter-gatherers who lived in large, permanent villages and occupied seasonal camps and task-specific sites, including the project area.[14] At the time of European settlement, historical topographic quadrangles (USGS 1897, 1941) reveal several late nineteenth- and early twentieth-century buildings and other possible historic features within or near the project area. Wilkins Ranch and the wharf represent an era when timber and sawmills operated at Dogtown, northwest of the lagoon.

The lighter wharf was located near the northern tip of the lagoon, between the historical outlets of Wilkins Gulch Creek and Wharf Creek. This wharf was used during the mid-1800s to ship lumber from the Dogtown area onto barges (called lighters), which floated out to deeper water where larger boats would bring the much-needed lumber to the rapidly growing San Francisco area.[15,16,17] It is estimated that 13 million feet of lumber were shipped to San Francisco before the supply was exhausted in the 1870s.[10] The Wilkins Ranch operated as a dairy.

12 Central California Coast Steelhead ESU as published in the Federal Register on Sept. 2, 2005 (70FR52488 - 52627).
13 Point Reyes National Seashore and North District of Golden Gate National Recreation Area (N.R.A.), Fire Management Plan: Environmental Impact Statement. July 2004.
14 Kelly, Isabel. 1978. Coast Miwok. In *Handbook of North American Indians*, Volume 8: California, edited by Robert F. Heizer, pp. 414-425. William C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.
15 Livingston, D.S. (Dewey). 1995. *A Good Life: Dairy Farming in the Olema Valley*. Historic Resource Study. Department of the Interior, National Park Services, San Francisco.
16 Kyle, Douglas E., Mildred Brooke Hoover, Hero Eugene Rensch, Ethel Grace, Rensch, and William N. Abeloe. 2002. *Historic Spots in California*. Fifth edition, revised by Douglas E. Kyle. Stanford University Press, Stanford, California.
17 Van Kirk, Susan. 2000. Historical perspective of Bolinas Bay (Lagoon). Historical Resources Consultant, Bayside, California.

3.5 Climate Change and Sea Level Rise

3.5.1 Projected Impacts

Over the past century, sea level in the San Francisco Bay Area has risen 8 inches and could rise up to 70 inches by the end of the century,[18][19] as described in Marin County's *Draft Climate Vulnerability Assessment*[20] (Assessment) an effort of the Sea-Level Rise Marin Adaptation Response Team (C-SMART) and the Marin County Community Development Agency (MCCDA). As described in the Assessment, low-lying roads in Marin's coastal communities are already susceptible to flooding at high tides, especially king tides and storms. At worst, some roadways will see relatively chronic flooding and could lose their functionality as the ocean rises. Postal service could be interrupted, schools closed down, and tourism capacity significantly reduced. Evacuation routes may be crowded or impassable, and emergency services may be unable to reach those in need. In the medium-term, 5.2 miles of roads may be exposed, including additional roadways in Bolinas. The Shoreline Highway and Olema Bolinas Road are two major roads of greatest concern and are exposed at several places along their route. This vulnerability is exacerbated by the low density of roads and lack of alternative routes[21].

The Bolinas Wye (Wye) and Olema Bolinas Road are two of the most vulnerable built assets in Bolinas, and are identified in Marin County's *Draft Climate Vulnerability Assessment*. As described in Marin County's *Draft Climate Vulnerability Assessment,* Olema Bolinas Road or its creek-spanning bridges become dysfunctional for extended period of time, Bolinas residents will be cut off from the rest of the coast, and from propane, food, and gasoline suppliers. Over $18 million worth of assessed property value is vulnerable, including several historic locations downtown. Increased tidal inundation of Bolinas Lagoon will affect plant and animal species, though could improve sediment concentrations. However, the lagoon is bordered by roads and development, leaving little room for migration inland. If water levels raise high enough, the lagoon with convert to mud flats and could overtop the surrounding roadways and properties[21].By late century, all roads in the project area are projected to be inundated as a result of sea level rise if nothing is done.

3.5.2 Sea Level Rise Data

Sea level rise estimates used in this report are based on Our Coast, Our Future (OCOF)[21] and Marin County's C-SMART approach, which draws on data from the OCOF tool and the range of sea level rise projections for California adopted by the National Research Council (NRC) in 2012. OCOF uses the USGS's Digital Elevation Model (DEM) constructed for the region with 2-meter horizontal grid resolution and USGS's numerical modeling system called Coastal Storm Modeling System (CoSMoS) to produce a combination of sea level rise and storms scenarios. Note these data account for ocean levels; impacts from creek flooding or changes in the coast line (geomorphology), which would increase these estimates, are not included. The OCOF model assesses the maximum depth of the flooding surface above the base elevation of Mean Higher High Water (MHHW).[22] The base elevation used to represent baseline conditions is Mean Sea Level (MSL) and was calculated from an averaging of data from Point Reyes and Fort Point tide stations.

The C-SMART approach uses five-scenarios to assess potential sea level rise impacts and to account for uncertainty in the magnitude and timing of future sea level rise. Scenarios 1 and 2 represent the near term sea level rise, and correspond to the 2030 NRC projected sea level range. Scenario 3 is considered medium-term and is within the 2050

[18] National Research Council NRC. 2012. *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future.*

[19] Science Daily Online News. 2014. University of Copenhagen. Oct. 14, 2014. http://www.sciencedaily.com/releases/2014/10/14101408590 2.htm. Original published in the journal *Environmental Research Letters*

[20] Sea-Level Rise Marin Adaptation Response Team and Marin County Community Development Agency. 2015. *Marin Ocean Coast Sea Level Rise Vulnerability Assessment.* September 2015. Marin County, CA. Available: marinslr.org.

21 Point Blue Conservation Science. 2017. Our Coast, Our Future. Contributors: NOAA Coastal Services Center, National Estuarine Research Reserve System, Bay Area Ecosystems Climate Change Consortium, National Park Service, National Marine Sanctuaries Gulf of the Farallones, and USGS. Available: http://data.pointblue.org/apps/ocof/cms/

[22] Mean Higher High Water is a tidal datum that is the average of the higher high water height of each day, observed over the National Tidal Datum Epoch, the official time period over which tide observations are taken (NOAA 2013).

NRC range. Scenarios 4 and 5 represent the long term sea level rise. Scenario 4 corresponds to the 2100 NRC range, and Scenario 5 represents levels based on additional research theorizing the worst case for sea level rise by 2100 is nearing 70 inches globally, 17 with the most reflective OCOF option of 77 inches, rounded to 80 inches in this document.

For this report, three sea level rise scenarios were assessed (current MHHW, mid-century, and late-century, which correspond with both the C-SMART and NRC projections), as shown in Table 2:

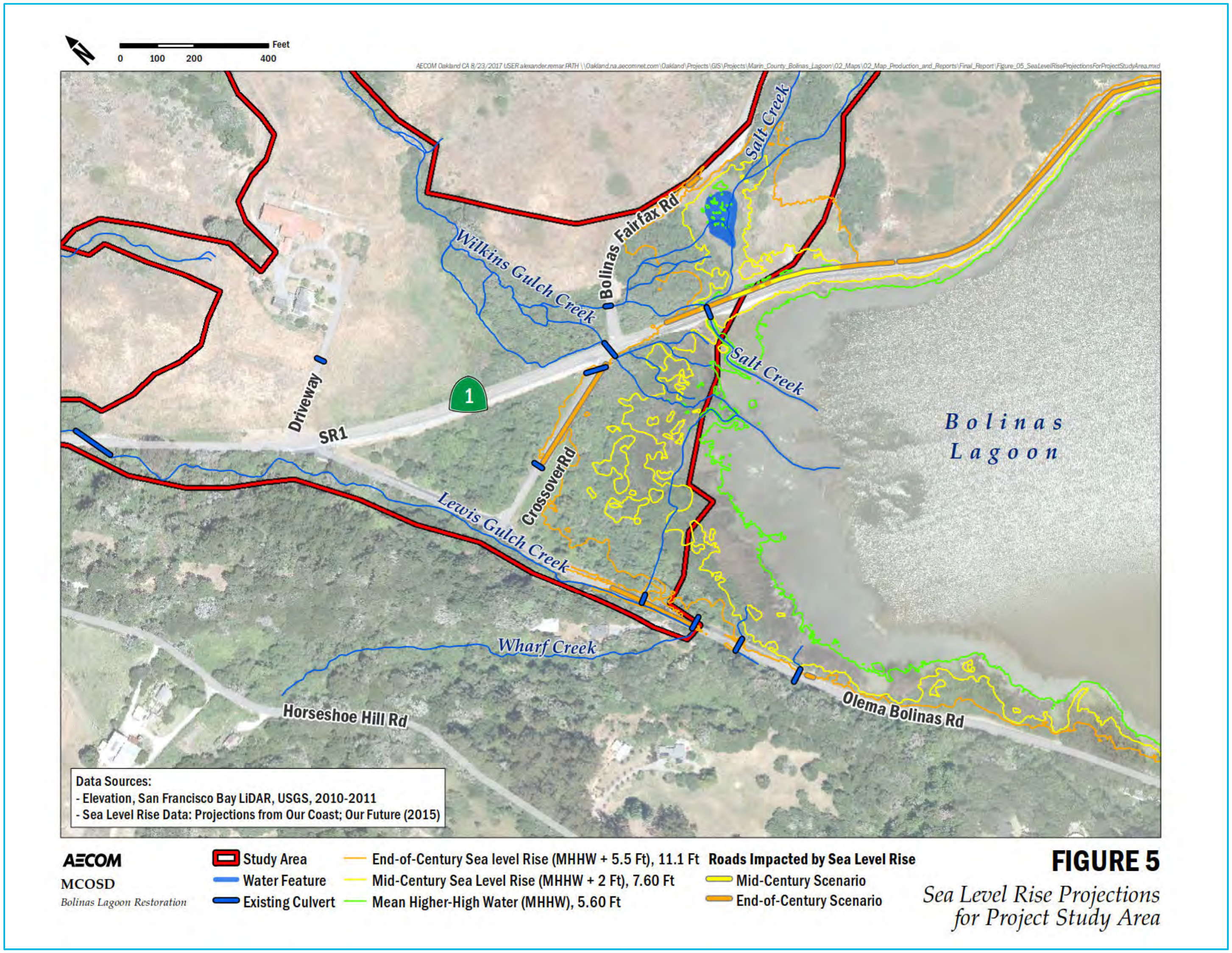
- **Current MHHW**: 5.6 feet NAVD88
- **Mid-Century Sea Level Rise**[23] (MHHW + 24 inches (2 feet)): 7.6 feet NAVD88 (consistent with C-SMART Scenario 3)
- **Late-Century Sea Level Rise** (MHHW + 66 inches (5.5 feet): 11.1 feet NAVD88 (consistent with C-SMART Scenario 4)

Table 2. Sea Level Rise Scenarios

Timeline	Sea Level Rise Projections		
	C-SMART	**NRC**	**MCOSD Project (NAVD88)**
Current MHHW	–	–	5.6 ft (67 in.)
Mid-Century	20 in. + 20-year storm event (Scenario 3)	4.7 – 24 in.	7.6 ft. (MHHW + 24 in.)
Late-Century	40 in. + 100-year storm event (Scenario 4)	16.6 – 65.8 in.	11.1 ft. (MHHW + 66 in.)

[23] Note that the Site Conditions Report shows MHHW + 3 feet, which is representative of a mid-century king tide scenario.

Figure 6. Sea Level Rise Projections for the Project Study Area



3.1 Additional Hydrology Study Considerations

In addition to installing the four groundwater monitoring wells in the spring of 2017, CLE Engineering Inc. and AECOM in the summer of 2017 collected representative cross sections and a longitudinal profile along Lewis Gulch Creek. Field topographic data will be integrated with existing USGS LiDAR data to produce a composite (DEM) surface that will be used in subsequent hydraulic analysis. Sea level rise projections for the project study area are shown on Figure 6. The hydraulic analysis consisting of a HEC-RAS model will evaluate the appropriate bridge, causeway, or culvert dimensions at two locations along Lewis Gulch Creek (at SR 1 and at Olema Bolinas Road). The cross-sectional and longitudinal profile data and the DEM surface will be useful in future design phases.

Additional hydrologic parameters that should be monitored to better inform future design of the project and the associated timeline may include:

- Additional groundwater well installation along the Wilkins Gulch Creek alluvial fan and water level monitoring in all monitoring wells. Monitoring would be valuable in better understanding existing water levels and seasonal changes, and how they might affect any restoration design. If subsurface groundwater is to be utilized in an experimental approach to stimulate the growth of tall brackish marsh vegetation as a method of shoreline protection, a monitoring well located near the groundwater extraction area would be useful to determine feasibility. *Timeline*: Near-term start to record sufficient high and low seasonal levels to inform design.
- Detailed cross-sectional and longitudinal profile topographical data along Wilkins Gulch Creek and Salt Creek to be combined with USGS LiDAR data to produce a more detailed DEM for use in design and hydraulic analysis. *Timeline*: Prior to 30% design.
- Hydrology and hydraulic analysis of Lewis Gulch and Salt Creek to inform design of appropriate channel, bridge, causeway, or culvert dimensions. *Timeline*: Prior to 30% design.
- Analysis of bankfull geometry along proposed segments of stream channel to be restored, along with a bankfull calibration study to verify dimensions for use in channel design. *Timeline*: Prior to 60% design.
- In-stream flow monitoring to help determine flow losses to the alluvial fan at various discharges and times of the year and to further determine any necessary design considerations for appropriate channel sizing along the length of the alluvial fan. *Timeline*: Prior to 60% design.
- References reach assessment for segments of channel requiring construction of a bankfull channel. This would involve identifying and surveying a stream reach (or reaches) outside of the project study area to be used as a reference reach for sizing aspects of a newly designed channel within the study area. *Timeline*: Prior to 60% design.

PART II – ALTERNATIVES CONCEPTUAL DESIGN

4. Conceptual Design Approach

4.1 Phasing

Each alternative is comprised of three phases representing the near-term, mid-term, and longer-term conceptual design improvements. While the phases are complementary, they were created to be designed and permitted as separate projects to enhance the overall feasibility and funding opportunities for the project as the climate changes.

4.2 Design Criteria and Assumptions

4.2.1 Roadway Design Standards

All conceptual roadway design elements for SR 1 and the intersections with the local roads will be designed to meet the standards described in the Caltrans Highway Design Manual (HDM). Nonstandard features, if any, will be approved by Caltrans. Conceptual roadway design elements were standardized to meet current traffic capacity and Caltrans design standards based on the *Final Marin State Route 1 Repair Guidelines*, which are intended to improve consistency in design and aesthetic considerations along SR 1 in Marin County. These repair guidelines were created based on the HDM, in collaboration with Caltrans' partners from the National Park Service (NPS), the California Department of Parks and Recreation (State Parks), Marin County, and the CCC. Per the guidelines,

> *"Projects should minimize change in order to protect the rural character of SR 1, stay within the existing right-of-way, be visually compatible with the surrounding environment, and maintain safety and functionality of all design elements"* [24].

[24] Caltrans. 2015. *Final Marin State Route 1 Repair Guidelines.* Caltrans District 4. July 2015.

The *Final Marin State Route 1 Repair Guidelines* recommends the following design guidelines:

Lane Width: *As a starting place in the design process, 12 feet is the preferred traveled-way width, with 11 feet (or less) acceptable in developed areas and under other circumstances.*

All roads in the project area for the conceptual design phase are designed to a 12-foot traveled-way width.

Shoulder Width: *A 4-foot-wide shoulder is the recommended shoulder width in rural areas. Note that HDM Table 307.2 calls for an 8-foot shoulder width for new two-lane, two-way roadways where the average daily traffic (ADT) is greater than 400. However, a 4-foot (or less) shoulder width can be used to promote the rural character of the roadway, provide space for multimodal users, and reduce visual impacts caused by the full geometric cross section and should be considered in sensitive areas. Considerations include avoiding negative project impacts that would be significant under applicable resource protection policies and accommodating cyclists according to project-specific topography and context.*

The road is considered "new" if a proposed project modifies it in some way, such as raising the profile, realigning it horizontally, or placing it on a causeway. Typically, transportation engineering designs prefer to keep the shoulder width uniform, if at all possible. Thus, if the causeway is designed with 8-foot shoulders, the approach would have an 8-foot shoulder, which would be reduced where the design confirms back to the existing road width. For the purposes of this report, 8-foot shoulders, which provide further room for disabled vehicles and bicyclists, are included as a conservative estimate.

To accommodate cyclists, the shoulders on SR 1 would be increased to 8 feet in each direction of travel for a Class II bikeway (Figure 7). To increase cyclist safety, a divider could be installed between the bikeway and the roadway in each direction. While the road would be widened in some areas to accommodate a wider shoulder, the overall design would result in a net increase of upslope lagoon habitat. See Section 3 for details.

Figure 7. Class II Bikeway with Striped Lane for One-Way Bike Travel[25]

Roadway Alignment: *Realignment of curves is not normally warranted and should be minimized. In general, realignment of curves should only be considered when there is a demonstrated crash history. When needed, they should be consistent with Marin County Local Coastal Plan policies, particularly C-TR-1 and C-TR-2 (see Section 3.2.4 of these guidelines), and the Coastal Act as well as NPS and State Parks management policies.*

[25] Caltrans 2016. "Class I, II, and III Bikeways Explained". Manila Non-Motorized Transportation Improvement Project.

Superelevation: *Use of the American Association of State Highway and Transportation Officials (AASHTO) standards as guidance is acceptable.*

Aesthetic features such as a see-through scenic bridge railing may be included, as per the *Caltrans Final Marin State Route 1 Repair Guidelines*: *"Bridge railings should be see-through type, to allow maximum views and consider all multimodal users. Designers should ensure that the railing height and rail opening widths meet current minimum design standards for both bicyclists and pedestrians where appropriate. Need to consider wider shoulders next to bridge rail and extended runs of guardrail."*

An example of a see-through bridge railing from Ten Mile River Bridge in Mendocino County, with a Class II bikeway, is shown on Figure 8.

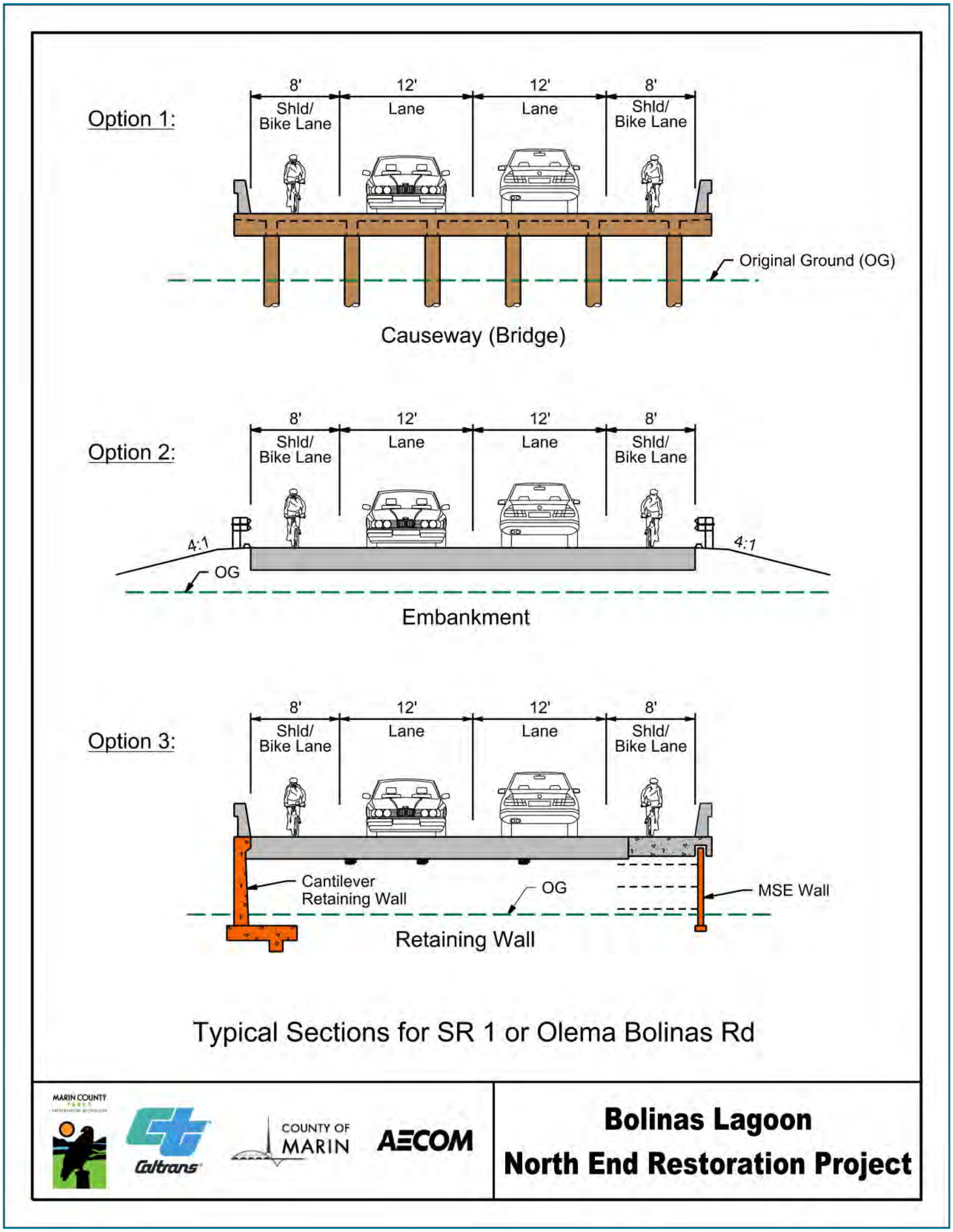
Figure 8. Scenic Bridge Railing on State Route 1

Typical sections of roadway improvements are shown on Figure 9. Types of project roadway modifications include:

- Bridges and causeways (viaduct-like structures);
- Raised roadways on fill/embankments with upgraded and added culverts;
- Retaining walls (mechanically stabilized earth (MSE) walls, which are soil constructed with artificial reinforcing); and
- Roadway relocation.

Based on a traffic study completed during Phase I (see the Site Conditions Report), it was determined that (a) design for increased capacity is not necessary at this point in time, and (b) removal of the crossover road will increase safety and will not increase traffic congestion.

Figure 9. Typical Sections of Roadway Improvements



Policies Relating to Roadway Designs

Policies relating to roadway designs in the project area are shown in Table 3, listed alphabetically by agency, in addition to Marin County's Local Coastal Program and Land Use Plan.

Table 3. Policies Relating to Roadway Designs in the Project Area

Agency	Policy
California Department of Transportation (Caltrans)	Highway Design Manual (HDM) Standard Design Guidelines
	Final Marin State Route 1 Repair Guidelines
California State Parks	Department Operations Manual (DOM), State Parks (0304:2.3)
	DOM, Scenic Values and Viewshed (0312.2)
California Coastal Commission	Coastal Zone Management Act
Marin County	Title 13 of the Marin County Code of Ordinances26
	Chapter 23.08.025: Marin County Grading Ordinance –minimum requirements for grading and filling within unincorporated County lands
National Park Service	National Park Service Director's Order 87D (2004, Section 3)
	National Park Service Management Policies 2006, Section 9.2 – Transportation Systems and Alternative Transportation
	National Park Service Organic Act of 1916

4.2.2 Climate Change and Sea Level Rise Adaptation

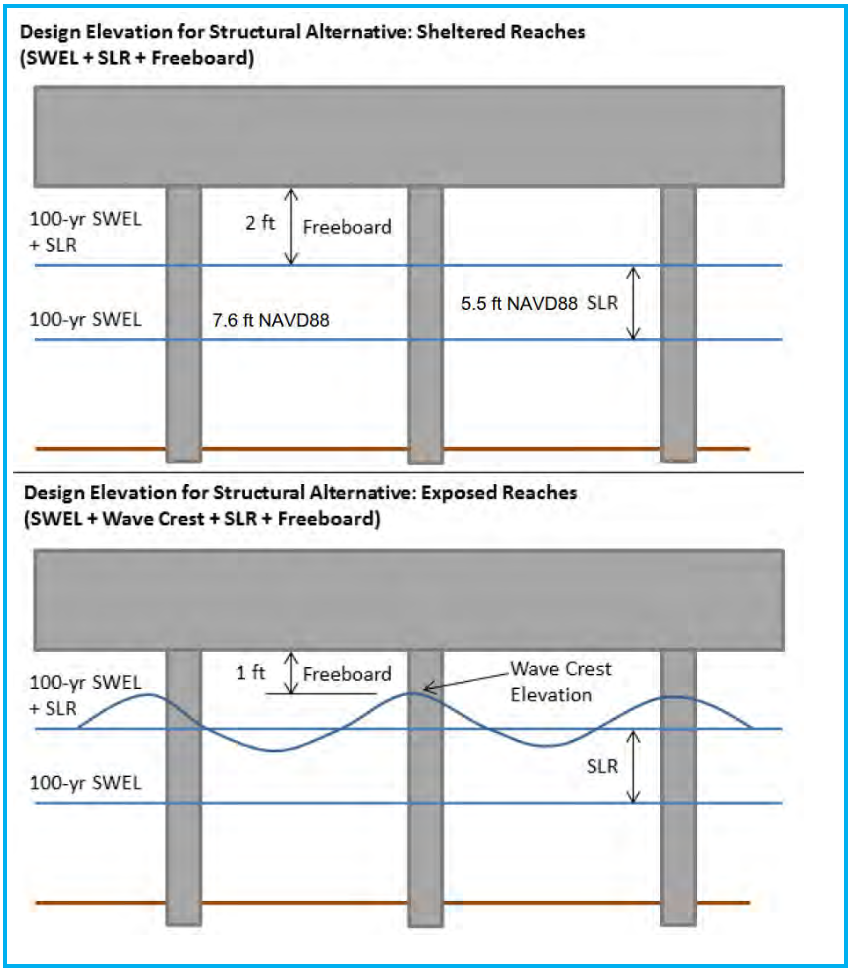
Sea level rise scenarios used for the basis of conceptual design are consistent with Marin County's C-SMART approach as described in Section 3.5. Minimum project design elevations are designed based on:

- The current 100-year tide level of the lagoon, an elevation of 7.6 NAVD88 (1% probability of SWEL [Stillwater Elevation: astronomical tide + storm surge + freshwater discharge]);
- End of century sea level rise (current MHHW [5.6 feet] + 5.5 feet = 11.1 feet)
- 2 feet of freeboard (to account for wave effects);
- 0.4 foot to account for the road's cross slope; and
- An additional 2 feet for the SR 1 causeway(s) to account for the structure depth (see Figure 10).

Current roadway designs are approximately between 10 and 27 feet in elevation. Minimum project designs included are 15.5 feet in elevation for raised roadways and 17.5 feet in elevation for the causeways. Roadways would be raised at varying amounts based on their existing elevations. In some areas no raising would be required, such as at the intersection of SR 1 and Olema Bolinas Road. In the areas with the highest raising, the roadway would be raised approximately 10 feet, such as on the causeway sections on SR 1 and in the low-lying section of Olema Bolinas Road. See figures 13 and 19 in Section 6 for details. Note that all estimates are based on preliminary data. Elevations would be further defined during project surveying, which would occur at a later project phase.

[26]Roadway modifications and bridges would be designed and built in compliance with the requirements outlined. Excavation, grading, and filling would be compliant with Chapter 23.08 and stormwater runoff pollution, described in Chapter 23.18.

Figure 10. Design Elevations Showing SWEL, Sea Level Rise (SLR), and Freeboard



4.3 Alternatives Considered but Eliminated from Further Consideration

A No-Action Alternative was considered during conceptual design but eliminated from consideration because it does not meet any of the project goals. It is therefore not considered further as a viable alternative in this Conceptual Design Report. In the event that the project requires analysis under NEPA, then the “no-action” or “no project” alternative would need to be compared and contrasted against the three project alternatives.

5. Overview of Alternatives

The three conceptual alternatives are similar in many aspects, and overlapping elements occur in each. The three conceptual design alternatives and their associated components are described in detail in this section. Table 4 below provides a summary of the alternatives. Table 5 provides a detailed summary of the alternatives' components, broken down by phase. Phase 1 represents near-term project components; Phase 2 represents mid-term project components; and Phase 3 represents long-term project components.

Table 4. Summary of Conceptual Design Alternatives

Alternative	Floodplain Connectivity		Roadway Raising			Reconfigure Wye	Vegetated Shoreline Resilience	Lewis Gulch Creek
	Wilkins Gulch Creek	Lewis Gulch Creek	SR 1 Causeway	Bolinas-Fairfax Road	Olema Bolinas Road			Culvert Upgrade
1	Partial	✓	Double	Fill	Fill/Bridge	✓	✓	✓
2	Full	✓	Double	Fill	Fill/Bridge	✓	✓	✓
3	Full	✓	Single Long-Span	Causeway	Fill/Bridge	✓	✓	✓

Phase 1 is the same in cost, scope, and timeline in all three alternatives. Phase 2 in Alternatives 1 and 2 is identical, and includes the raising of SR 1 onto two causeways. In Phase 2 for Alternative 3, SR 1 is raised onto a single long T-junction causeway. In Phase 3, Alternative 1 includes downstream floodplain restoration of Wilkins Gulch Creek, whereas Alternatives 2 and 3 include upstream restoration to the head of Wilkins Gulch Creek's relict alluvial fan in addition to downstream restoration

All three of the alternatives include:

- Reestablishing a Wilkins Gulch Creek floodplain in the project area by removing the creek from its ditched alignment;
- Restoring portions of Lewis Gulch Creek;
- Reducing roadway flooding by replacing culverts;
- Elevating roads on fill or piers;
- Installing a bridge over Lewis Gulch Creek on SR 1;
- Stabilizing the left bank of Lewis Gulch Creek at SR 1 and Olema Bolinas Road;
- Removing the crossover road and reconfiguring the Wye for safety; and
- Creating vegetated shoreline and soft erosion protection components wherever feasible to enhance sea level rise resiliency.

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Table 5. Details of Conceptual Design Alternatives by Phase

Alternative	*Phase (P) 1 = near-term 2 = mid-term 3 = long-term*	Floodplain Connectivity					Roadway Raising					Reconfigure Wye	Remove Crossover Road	Vegetated Shoreline Resilience	Creek Culvert Upgrades
		Lewis Gulch Creek			Wilkins Gulch Creek		SR 1 Causeway		Bolinas-Fairfax Road		Olema Bolinas Road (fill + bridge)				
		Stream Restoration	Olema Bolinas Road Bridge	SR 1 Bridge	Downstream Portion	Upstream Portion	Segmented	Continuous	Elevation Fill	Elevation on Causeway Piers					
1	P1	✓	✓	✓							✓	✓	✓		
	P2				✓		✓		✓						
	P3	✓							✓					✓	✓
2	P1	✓	✓	✓							✓	✓	✓		
	P2				✓		✓		✓						
	P3	✓				✓			✓					✓	✓
3	P1	✓	✓	✓							✓	✓	✓		
	P2				✓			✓	✓						
	P3	✓				✓				✓				✓	✓

Note:

Grey cells represent design consistency across all three alternatives.

Light-blue cells represent design consistency between Alternatives 1 and 2 for a particular component.

Orange cells represent design consistency between Alternatives 2 and 3 for a particular component.

Pink-shaded cells represent unique alternative components.

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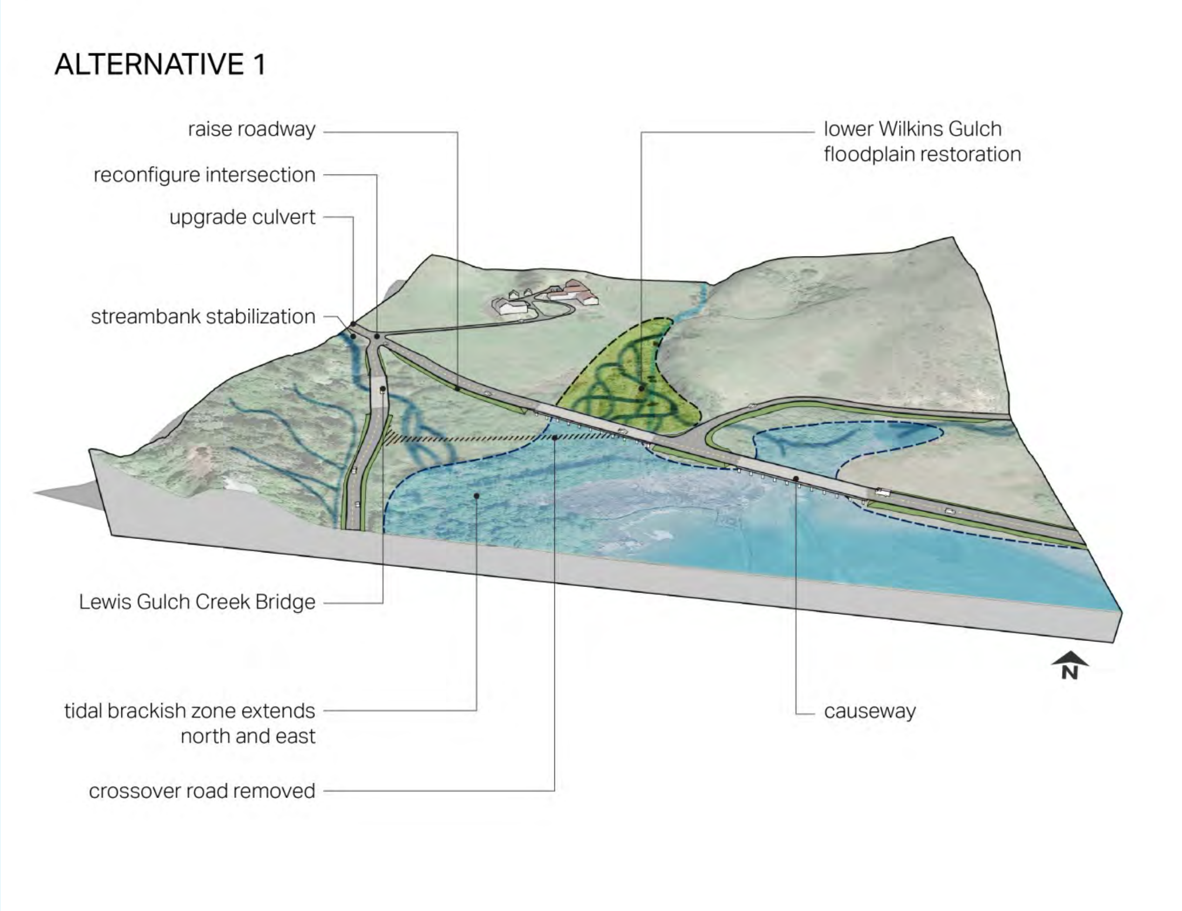
6. Alternative 1 Conceptual Design

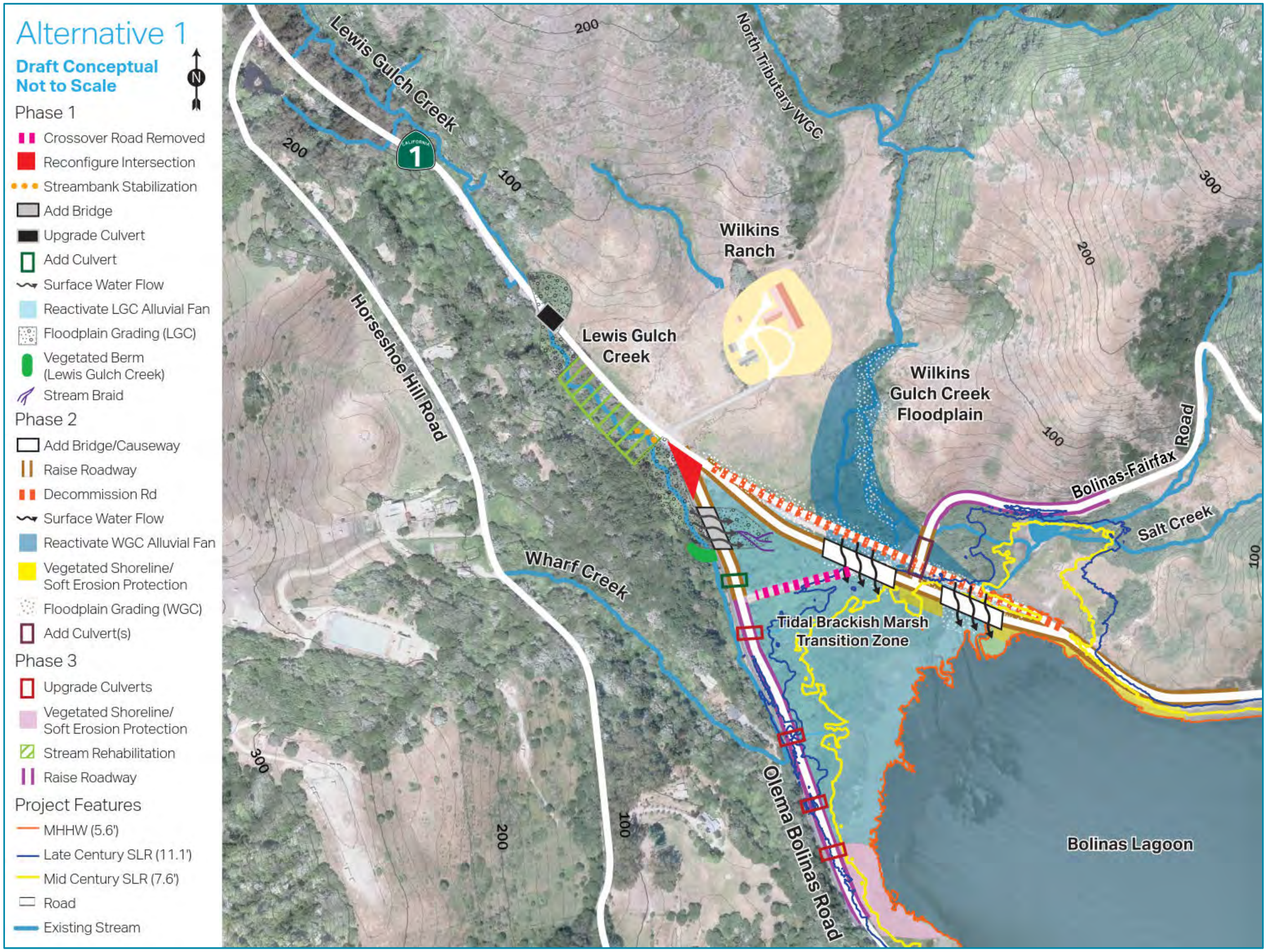
Alternative 1 includes raising SR 1 onto two causeways and restoring the downstream portion of the Wilkins Gulch Creek floodplain. Figure 11 below is an overview sketch of Alternative 1. Specific conceptual design components are shown on Figure 12.

Figure 11. Alternative 1 Conceptual Design



**Sea level elevation is an artist rendition of late-century sea level rise. Roadway raising, denoted by green shading beneath roadways, occurs on SR 1, Bolinas-Fairfax Road, and Olema Bolinas Road.*

Figure 12. Alternative 1 Conceptual Design Details



6.1 Phase 1

Phase 1 is identical in all three alternatives. It is the first phase of project activities that would occur under this conceptual design framework. Phase 1 will improve traffic safety on SR 1 at the intersection of Olema Bolinas Road, provide bank stability where Lewis Gulch Creek abuts SR 1 just north of the Wye, and upgrade the Lewis Gulch Creek crossings in the project area. The upgraded Lewis Gulch Creek crossings will better accommodate flows and improve the hydrologic connection to Bolinas Lagoon. The Olema Bolinas Road plan and profile is shown on Figure 13.

Phase 1 includes five main components, as shown on Figure 14. The sections that follow describe them in greater detail.

(1) Remove the crossover road, which connects Olema Bolinas Road with SR 1.
(2) Reconfigure the SR 1/Olema Bolinas Road intersection.
(3) Upgrade the existing Lewis Gulch Creek/SR 1 culvert to a larger culvert or small bridge, and raise the adjacent roadway to accommodate the new design grade (see Figure 13).
(4) Install a bridge crossing just south of the reconfigured intersection along Olema Bolinas Road, and redirect Lewis Gulch Creek onto the relict alluvial fan.
(5) Stabilize the Lewis Gulch Creek streambank adjacent to SR 1, north of the Olema Bolinas Road intersection.
(6) Install a new culvert near the intersection of the existing crossover road and Olema Bolinas Road.

Remove the Crossover Road

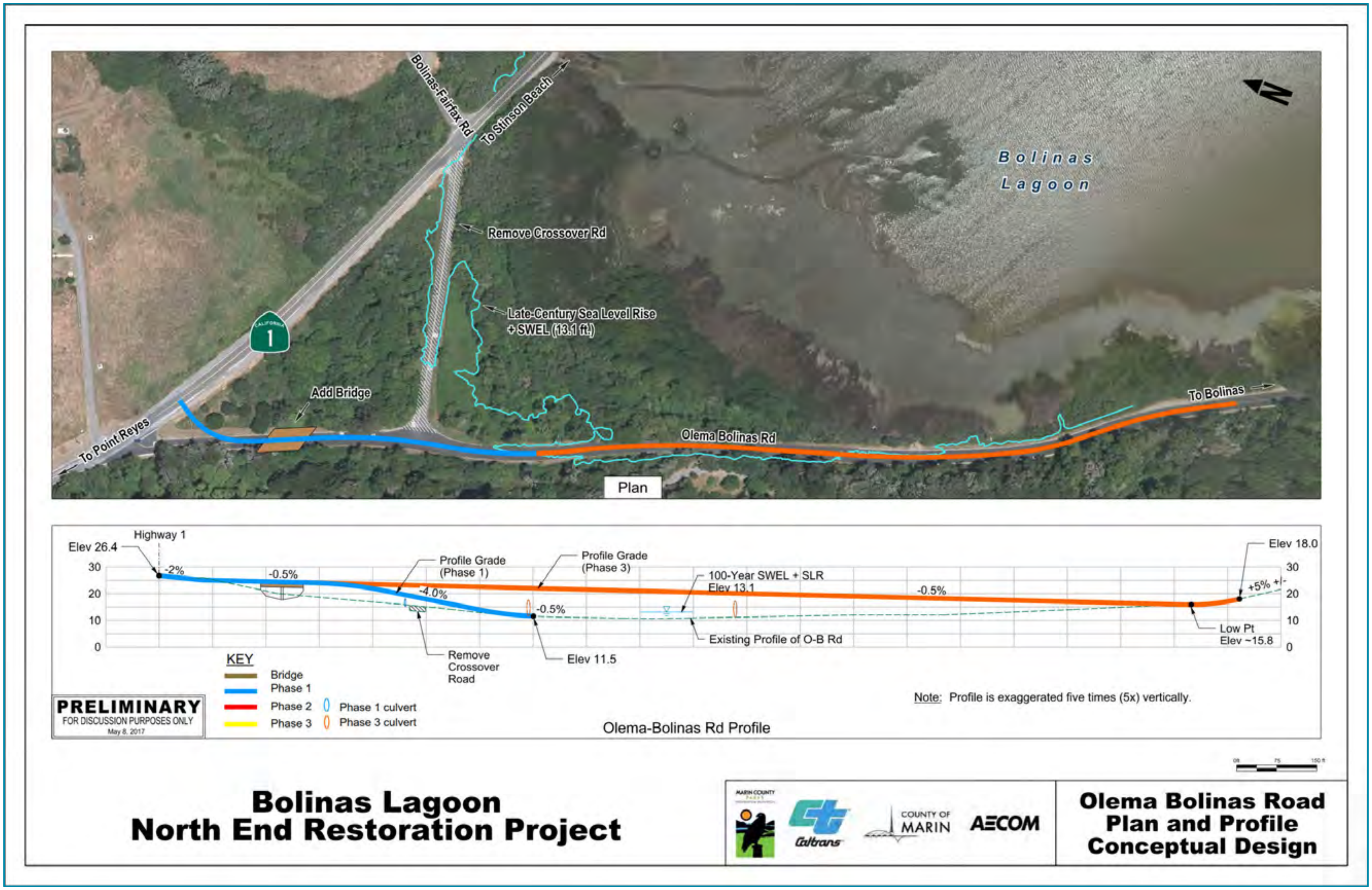
The crossover road bisects the relict alluvial fans of both Lewis Gulch Creek and Wilkins Gulch Creek. It bisects coastal bramble habitat dominated by California blackberry and red alder forest, and is currently upslope of the boundary of the tidal brackish marsh transition zone, which is expected to expand upslope under future climate change as a result of sea level rise. By late century, sea level rise is projected to be approximately 11.1 feet (see Figure 6). As a result, sections of the crossover road are anticipated to be inundated during daily high tides. Furthermore, the intersection of the crossover road and SR 1 has a nonstandard (50-degree) skew angle. Skew angles greater than 15 degrees are considered nonstandard by Caltrans. Removal of the crossover road would serve a threefold purpose:

(1) Improve traffic safety by removing the intersection of the crossover road with SR 1. This would allow the consolidation of the two highly skewed, nonstandard intersections on SR 1 into a single Caltrans-standard T-intersection, providing access to/from Bolinas via Olema Bolinas Road.
(2) Improve traffic safety by removing the traffic hazard on Olema Bolinas Road created by a high skew angle at the intersection of the crossover road.
(3) Allow for uninhibited flow of Lewis Gulch Creek to Bolinas Lagoon.[27]
(4) Allow for upstream migration of the tidal brackish marsh transition zone under future climate change projections.

Following decommissioning, the roadway would be graded to match the surrounding elevation. To enhance hydrologic connection into the lagoon, relict channels could be reconnected across the roadbed, and/or ponds could be created to provide additional wildlife habitat and a potential source of fill for project components, should soil quality be suitable. Further design development is necessary to determine these details.

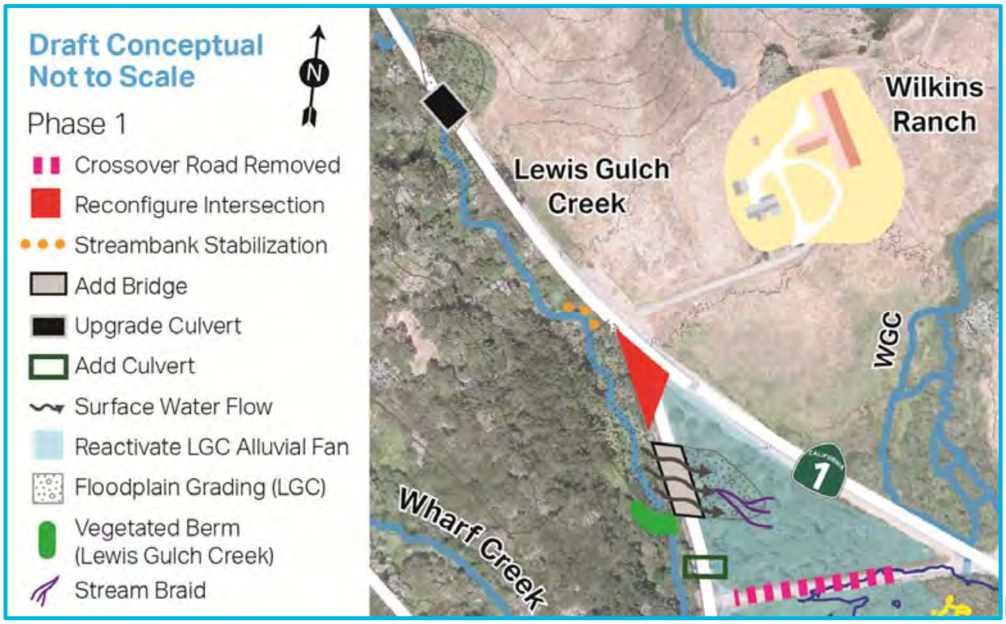
[27] The location of Lewis Gulch Creek in its existing location diverted above Olema Bolinas Road prevents the stream from flowing uninhibited where it must turn to pass beneath the bridge.

Figure 13. Olema Bolinas Road Plan and Profile



Note: The brown trapezoid represents the approximate location of the proposed Lewis Gulch Creek Bridge. Elevation 13.1 represents late-century sea level rise + 2 feet of SWEL.

Figure 14. Phase 1 Project Components



Reconfigure Olema Bolinas Road/SR 1 Intersection

The existing intersection at Olema Bolinas Road and SR 1 has a high (60-degree) skew angle, making left turns from northbound SR 1 and right turns from northbound Olema Bolinas Road challenging. In addition, the high skew angle allows southbound vehicles on SR 1 to make the right turn onto southbound Olema Bolinas Road at a relatively high rate of speed. For safety reasons, this is not desirable. With removal of the crossover road and its intersection with SR 1, all turning movements will have to be made at the intersection with Olema Bolinas Road. The intersection will be reconfigured into a Caltrans-standard T-intersection, providing standard sight distance and sufficient pavement for all turning movements by the 65-foot-long California Legal Design Vehicle (see Figure 15).

Figure 15. Potential Reconfigured Olema Bolinas Road at SR 1 Intersection

Upgrade Existing Lewis Gulch Creek/SR 1 Culvert to a Larger Culvert or Small Bridge

At the north end of the project area, Lewis Gulch Creek runs adjacent to the east side of SR 1 in the northwestern portion of the project area, before crossing beneath the highway in an undersized, 58-inch corrugated metal pipe and continuing downstream along the west side of the highway in an incised channel that is disconnected from its floodplain. The culvert is not far downstream of the head of the Holocene alluvial fan formed by Lewis Gulch Creek. It is possible that during the early 1800s, before logging and homesteading, the creek was able to spread into distributary channels and access its floodplain on the east side of SR-1 along the west side of Wilkins Ranch. At present, the creek only flows to the west side of SR 1 adjacent to the steep hillslope and entirely diverts into this culvert, which has a scour pool and drop height at its outlet. The current culvert may be a barrier to fish passage and upstream migration.

The culvert invert, shown on Figure 16, has been paved with concrete slurry to extend its service life. The existing culvert would be upgraded to a larger culvert or a small bridge, and this would allow Lewis Gulch Creek to flow in a less restricted alignment. In order to more gradually transition the channel slope and to improve fish passage during all life stages, channel restoration would be necessary upstream and downstream of the crossing. In Phase 3, to further support floodplain reconnection and habitat improvements, stream rehabilitation would occur downstream of the culvert crossing to Olema Bolinas Road, The cost estimate in this report assumes a small two-lane concreted bridge because it would provide the best possibility for floodplain reconnection and opportunity for improving fish passage. Upgrading to a box culvert is a lower-cost option.

Figure 16. View Looking Downstream at the Culvert Inlet and Headwall on Lewis Gulch Creek at SR 1

Install Olema Bolinas Road / Lewis Gulch Creek Bridge Crossing

Lewis Gulch Creek flows in a ditched channel approximately 750 feet along the west side of Olema Bolinas Road before turning 90 degrees and flowing eastward under the road in a 4-foot-high by 5-foot-wide concrete box culvert toward the Bolinas Lagoon. A new bridge crossing would be installed approximately 225 to 250 feet south of the SR 1 intersection, and would be sized to meet modern design standards for hydraulic flood capacity. The bridge deck would be approximately 4 feet higher than the existing road surface. To accommodate the new bridge structure, Olema Bolinas Road would be raised from the SR 1 intersection to the crossover road. The total length of the new Olema Bolinas Road profile in Phase1 would be approximately 700 feet. To accommodate the redirection of Lewis Gulch Creek, a segment of the existing channel upstream of the new crossing would be reshaped to transition flow from the more incised channel upstream onto a former floodplain. The new bridge would not be located closer to the intersection of Olema Bolinas Road and SR 1 because there is insufficient elevation difference from the existing Lewis Gulch Creek streambed to the Olema Bolinas Road surface (approximately 3 to 4 feet) to convey a 100-year flow under a bridge without raising the road surface elevation. To avoid raising SR 1 (and the associated cost) the bridge/stream crossing was located further downslope along Olema Bolinas Road to make up the necessary elevation needed to carry a flood with freeboard plus the thickness of the bridge/roadway infrastructure.

A channel block or compacted earthen berm will be required across the existing creek to prevent any flows from reconnecting its former inboard ditch. The ditch would continue downstream of the cutoff to capture road runoff and adjacent hillslope wash. The cost of a channel block or compacted earthen berm has been included in the cost estimate, and this potential requirement should be evaluated further in a subsequent design stage. Based on preliminary estimates, an 80-foot bridge was used for the cost estimate. Further studies and hydrologic modeling are necessary to determine the length and exact location of the bridge.

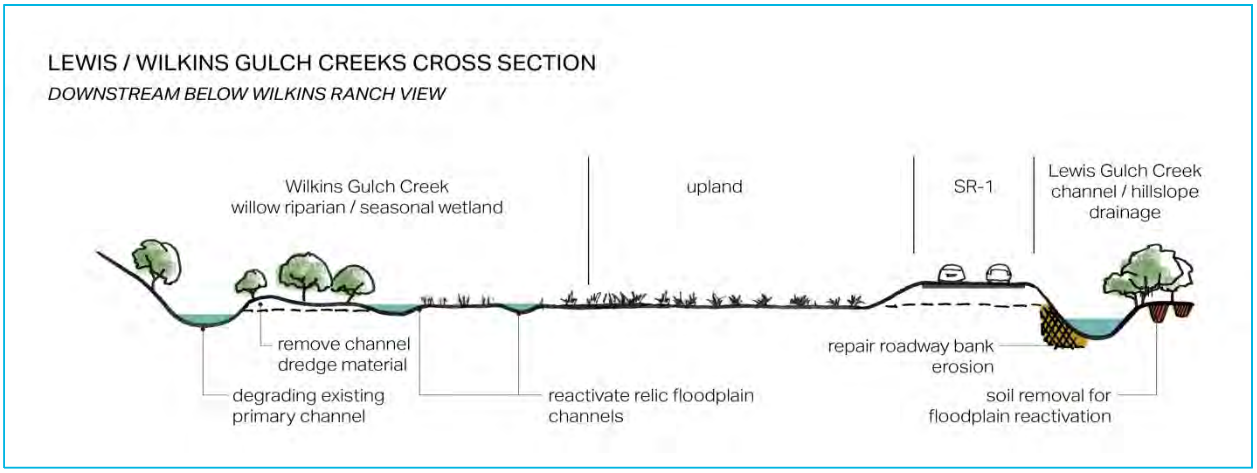
Flow redirection from Lewis Gulch Creek into the Wye

There were preliminary discussions of a primary and possibly secondary channel construction from the Wye to the lagoon to maintain fish passage, but the option was removed from further consideration due to cost, level of disturbance, and the lack of substantial evidence that Wilkins Gulch Creek historically maintained an active channel to the lagoon. There is no evidence of a primary channel in the Wye, but there are some intermittent swale areas south of the crossover road that maybe indications of former channel flow. Most of the area within the portion of the Wye surrounded by roadway was heavily disturbed by human land practices. The topographical surface derived from LiDAR data does not indicate any conclusive evidence of historical channel networks. A more detailed ground-based topographical survey may help define any swales or historic channels that may have existed that could then be field verified by excavating a soil pit and searching for evidence of recent alluvial deposits associated with a channel. There are various options of connecting the stream to the lagoon either in a more active approach (excavation) or more passive approach (vegetation clearing along a pathway to encourage channel formation). There are also various options to offset potential impacts of channel construction by creating additional habitat features (e.g. off channel pools, ponds, and wood debris installment to provide habitat complexity).

Stabilize Lewis Gulch Creek Streambank/SR 1 Roadway

Approximately 80 feet north of the junction of SR 1 and Olema Bolinas Road, Lewis Gulch Creek abuts the bank supporting the southbound lane of SR 1. The top of the 6-foot-high, vertically eroded streambank is within 5 feet of the edge of the pavement. Continued bank erosion may threaten the slope stability of SR 1. Under Phase 1, a bioengineered streambank revetment structure would be installed to stabilize the bank and roadway from continued lateral stream migration. Structural elements (e.g., large woody debris, rootwads, rock, and willow pole plantings [space permitting]) could offer riparian habitat benefits to supplement traditional engineered bank protection. The cost estimate for the streambank stabilization on Lewis Gulch Creek near the intersection of SR 1 and Olema Bolinas Road assumes the installation of approximately 86 linear feet of a rootwad/log cribwall. Rootwads would line the outside bend of the recontoured streambank approximately every 5 feet. Two footer logs would support the rootwads every 15 linear feet. It was assumed that up to five vertical lifts of roodwads and logs may be necessary to rebuild the bank. Between each lift, a durable coir erosion control fabric would encapsulate alluvium backfill, and willow cuttings would be placed horizontally out of the bank. Restoration components are shown on Figure 17.

Figure 17. Wilkins Gulch Creek Cross Section with Restoration Components - Downstream of Wilkins Ranch toward Bolinas Lagoon



The geometry of the meander bend and streambank may require minor grading of the creek bed to provide adequate space to rebuild the eroding bank (see Figure 18) and maintain channel capacity. The feasibility of a combined bioengineered and traditional engineered approach should be evaluated in more detail in a subsequent design stage.

Figure 18. Photo of Eroding Streambank along SR 1 North of the Wye, Facing North

New Culvert Installation near the Intersection of the Existing Crossover Road and Olema Bolinas Road

The approximate location of the culvert is shown on the proposed road profile along Olema Bolinas Road (Figure 13). Installation of the culvert in Phase 1 would eliminate the need to trench through the new road fill in Phase 3 when the remainder of Olema Bolinas Road is raised. The culvert would collect road and hillslope drainage from the west and redirect it on to the alluvial fan surface on the opposite side of the road. This culvert and additional culverts further along the road towards the existing box culvert on Olema Bolinas Road are intended to reduce concentrated flow accumulating and running along the toe of the road fill slope. The culverts would convey water to the fan at multiple locations rather than at one focus point to more closely mimic natural hillslope drainage processes towards the fan and lagoon.

6.2 Alternative 1 Phase 2 Components

Alternative 1 Phase 2 components are identical in scope, design, and cost to Alternative 2 Phase 2 components. At its current elevation (between 8 and 10 feet NAVD88[28]) along the Bolinas Lagoon shoreline between Stinson Beach and the north end of the lagoon, SR 1 is anticipated to be impacted by sea level rise and associated flooding by mid-century. Phase 2 will involve raising a segment of SR 1 parallel to its current alignment and the construction of two causeways—a northern causeway over Wilkins Gulch Creek and a southern causeway over Salt Creek. This will allow for hydrologic reconnection, avoid future flooding, and increase sea level rise adaptation.

The causeways will improve tidal exchange and will allow for upslope habitat migration as the sea level rises. The existing segment of SR 1 would be decommissioned following completion of the new raised route. Culverts would be added along Bolinas-Fairfax Road near the intersection of SR 1. A portion of Wilkins Gulch Creek downstream of Wilkins Ranch will be redirected to further reoccupy much of the surface of the relict alluvial fan by removing flow impediments. A vegetated shoreline and soft erosion protection will be implemented along the raised SR 1.

Phase 2 Alternatives 1 and 2 modifications include:

(1) Raising SR 1 on fill and constructing two causeways that will allow for hydrologic reconnection;
(2) Reconnecting Lewis Gulch Creek and Wilkins Gulch Creek to downstream floodplain benches and overbank flood flows to relict alluvial fan surfaces;
(3) Installing culverts along Bolinas-Fairfax Road near the intersection of SR 1;
(4) Decommissioning the existing SR 1 following raised causeway replacement; and
(5) Creating a vegetated shoreline with soft erosion protection along SR 1.

The sections that follow describe each of the five main Phase 2 components in more detail.

Raising SR 1 and Installing Two Causeways

A segment of SR 1 would be reconstructed at a higher elevation parallel to its current alignment, and two causeways would be constructed. The total length of the proposed SR 1 profile modification is approximately 1,700 feet, from 600 feet north of Bolinas-Fairfax Road (at approximately Elevation 21 feet) to 1,100 feet south of Bolinas-Fairfax Road (at approximately Elevation 9 feet); see Figure 19. The north causeway would extend approximately 320 feet over Wilkins Gulch Creek, and the south causeway would extend approximately 270 feet over Salt Creek; the total length would be approximately 600 feet. The causeways would allow flood flows from Lewis Gulch and Wilkins Gulch Creeks to reestablish the downstream floodplains.

The northern causeway length would maximize the width of the future floodplain between the presumed northern extent of the Wilkins alluvial fan and the intersection at Bolinas-Fairfax Road. The location and orientation of the abutments on either side of the causeway will be situated to provide a smooth flow transition in the down-valley direction. The 260-foot-long southern causeway's north abutment would be oriented in the direction of receiving flow from Wilkins Gulch Creek. The south abutment would be oriented in the direction of flow from Salt Creek drainage and incoming flow from the lagoon. While the length of the causeway could be increased by moving the north

[28] Elevations are based on the North American Vertical Datum of 1988 (NAVD88).

abutment toward the intersection of Bolinas-Fairfax Road, this would increase the project cost. The proposed span length and location are expected to provide adequate flood relief and tidal exchange while minimizing costs.

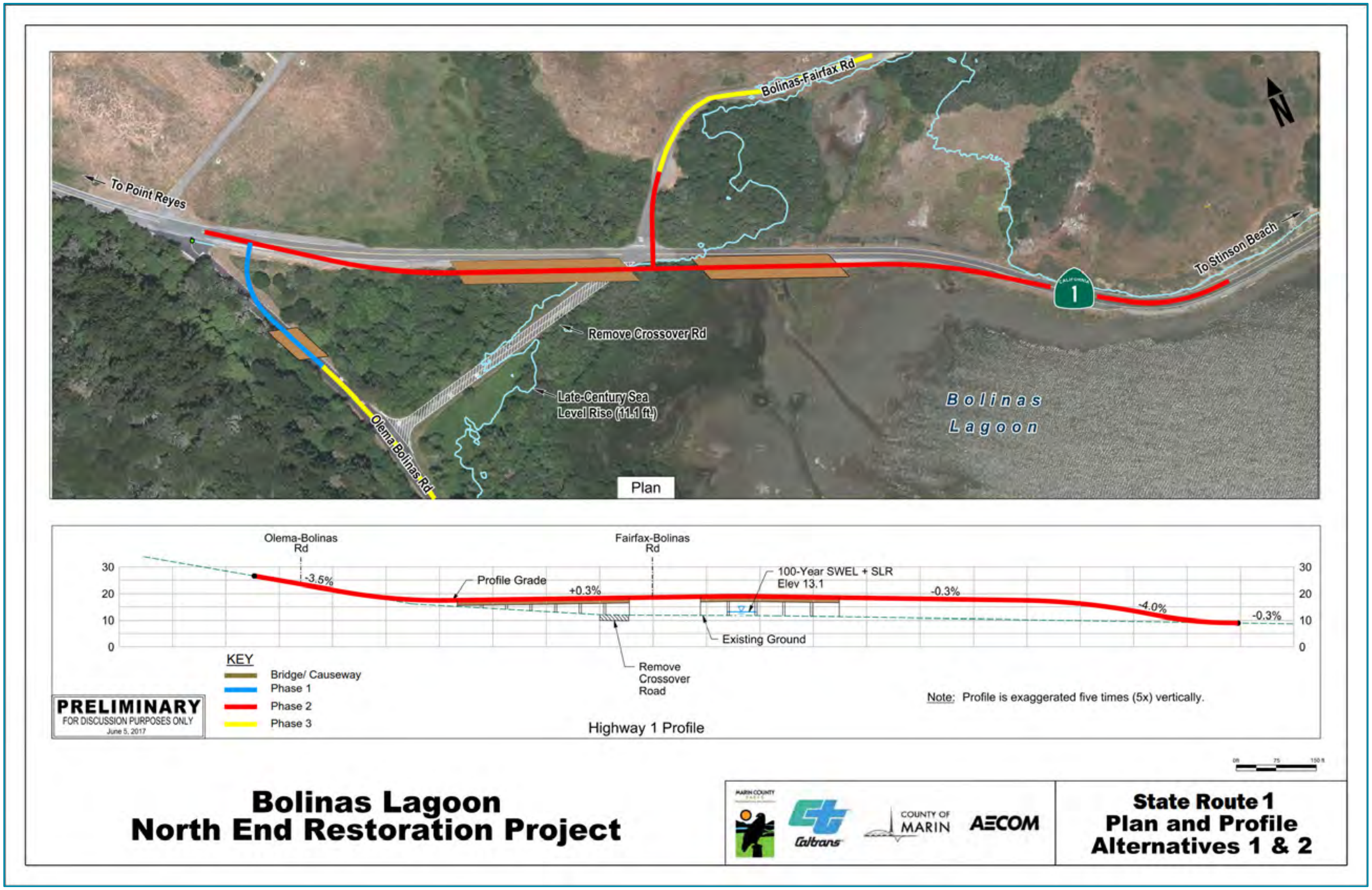
Wilkins Gulch Creek would largely remain in its current configuration downstream of the causeways, except that barriers to flow towards SR 1 will be removed along the lower end of the creek (approximately 600 feet upstream of Bolinas-Fairfax Road). Once more barriers to flow are removed along the right bank, additional redirected flow would eventually enlarge existing swales or create new channels flowing towards SR 1 and the lagoon, which may expand the existing wetland and riparian habitat present. Less flow would go under Bolinas-Fairfax Road towards Salt Creek. At some point it may be expected to cease, as that segment of channelized stream aggrades or as a new lower preferential flow path is created towards the south (to SR 1). If there is a desire to speed up the natural process, then minor hand or mechanical deepening of some of the breaches in the soil berm along the right banks of Wilkins Gulch Creek would immediately redirect most of the flow down existing swales towards SR 1 and out to the lagoon.

The redistribution of surface flow over a broader surface and the removal of surface and shallow subsurface flow barriers in Phase 1 (i.e., the removal of the crossover road) would deliver additional fresh water and fine sediment to existing wetlands currently not receiving streamflow. The elevated profile of SR 1 and the area under the causeways will allow largely unimpeded stream and tidal flows, will prevent future roadway flooding, and will likely support a more resilient and migrating tidal brackish marsh ecotone as sea levels rise.

Reactivating the Wilkins Gulch Creek Floodplain

To encourage the natural recruitment of Wilkins Gulch Creek to form stream channels and reconnect former flood-prone surfaces and to reactivate floodplains, the existing ditched Wilkins Gulch Creek channel would be graded. Excavation gaps or swales would be constructed at strategic locations along the spoil berm of the diversion ditch along the lower portion of Wilkins Gulch Creek (downstream of the Wilkins Ranch buildings). Based on preliminary topographic map interpretation and field reconnaissance, the spoil berm is approximately 500 feet long and is approximately 15 to 25 feet wide along the right bank of the creek upstream of Bolinas-Fairfax Road. Depths of excavation may average about 1 foot deep but could reach depths of 2 or 3 feet in some locations. To gain access to the soil berm, an old fence line that once separated the creek from the field would be removed. Soil excavation would occur in a manner that minimizes tree removal and trimming. Soil would be hauled to a staging/soil stockpile area or to other locations in the project area requiring fill material. Further investigation is necessary to determine the quality or characteristics of this excavated material as fill source for other project components.

Figure 19: Alternatives 1 and 2 – SR 1 Plan and Profile on Two Causeways



Note: Brown trapezoids represent the approximate locations of the proposed dual causeways. Elevation 13.1 represents late-century sea level rise + 2 feet of SWEL.

Raising Bolinas-Fairfax Road and Installing Culverts

In Phase 2, an approximately 150-foot-long segment of Bolinas-Fairfax Road will be raised onto an embankment to match the elevation of a raised SR 1. Currently the Bolinas-Fairfax Road embankment constrains as much as one-third the width of the former Wilkins Gulch Creek floodplain. To improve floodplain capacity and to restore or enhance connectivity to the former floodplain areas south of Bolinas-Fairfax Road, when raising the roadway a series of culverts would be installed beneath the raised roadway embankment under Bolinas-Fairfax Road, just east of the realigned and elevated SR 1 intersection. These newly installed culverts would allow the former Wilkins Gulch Creek floodplain to expand and would provide hydrologic reconnection between the Wilkins Gulch Creek floodplain and Salt Creek. Placement of culverts under the road embankment is a less costly option than placing the entire intersection on a causeway and would provide a similar function. These culverts would carry a significant portion of the Wilkins Gulch Creek streamflow and will allow channels to freely form over a wider area.

The number, type, size, and design of culverts could vary using concrete box or natural bottom arch culverts, depending on cost, desired features (e.g., artificial versus natural bottom), and hydraulic modeling results. Culverts with a natural bottom are preferred because they are adjustable, whereas hard bottoms from box culverts can create plunge pools that can ultimately undermine the structure. Furthermore, box culverts often require maintenance, as they can become clogged with woody debris and need to have sediment cleaned out. Metal pipe culverts create similar problems and often have a shorter life span due to the rust that can build up in saline environments. To accommodate fish passage, box culverts or other structures greater than 1.5 times the bankfull width are recommended. The culverts would be oriented in a down-valley flow direction and set with the invert of the pipe level with the upstream and downstream floodplain elevation. Minor grading may be necessary at the inlets and outlets of the pipes to remove any irregularity in the topography that could impede flow.

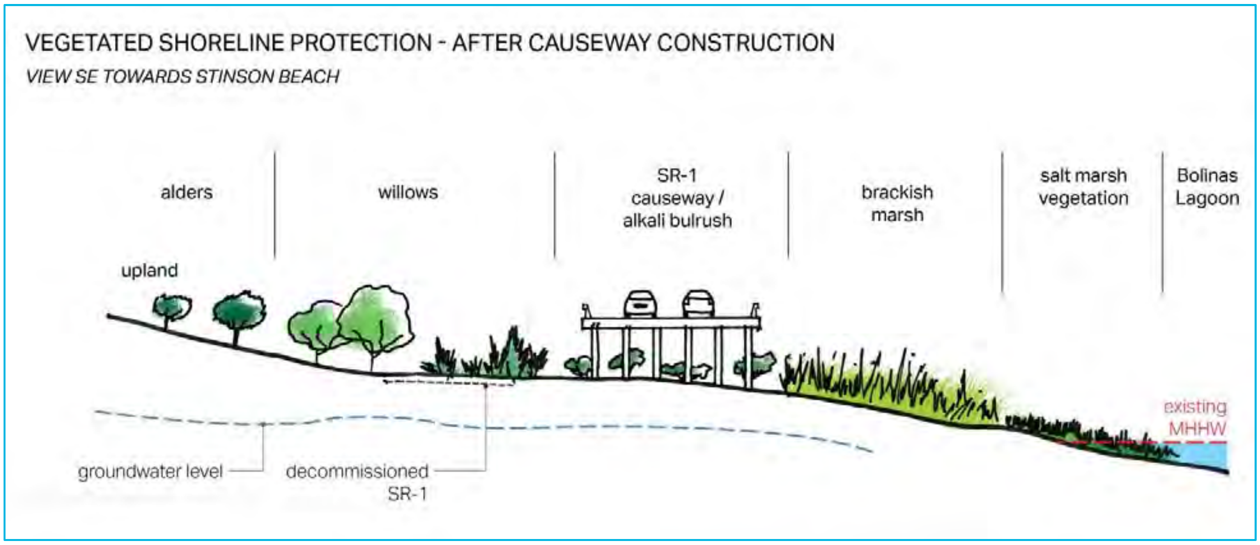
Decommissioning Existing SR 1 following Raised Causeway Replacement

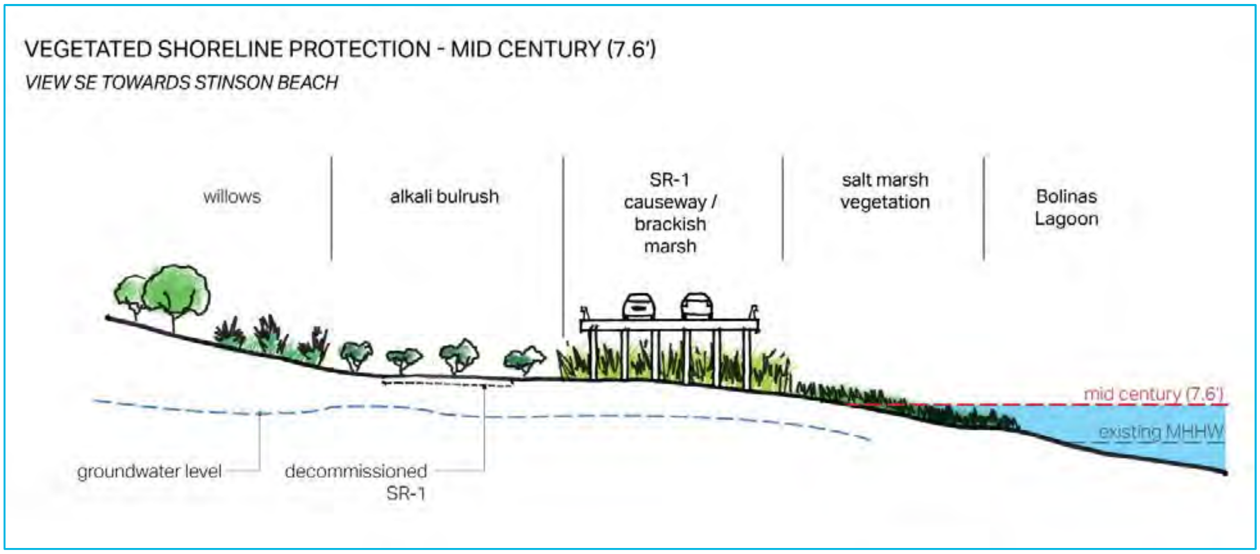
SR 1 will continue to carry traffic during construction of the causeway, which will be located adjacent to the existing highway. Following completion of the raised SR 1 segment, traffic will be diverted onto the new roadway and the existing roadway would be removed. Asphalt would be off-hauled and/or pulverized and recycled on-site, if feasible. Soil from the roadbed could be used to raise sections of Olema Bolinas Road under Phase 3, if the soil properties are determined acceptable as engineered fill. Areas of soil disturbance would be seeded and revegetated with appropriate vegetation, which could include willow thickets, alder forest, or seasonal wetland vegetation, depending on the area. Removing the fill for the old road and replacing it with a causeway will result in a huge net gain to wetland area. In the future, with sea level rise, some of this area will become tidal and provide direct connectivity with the lagoon.

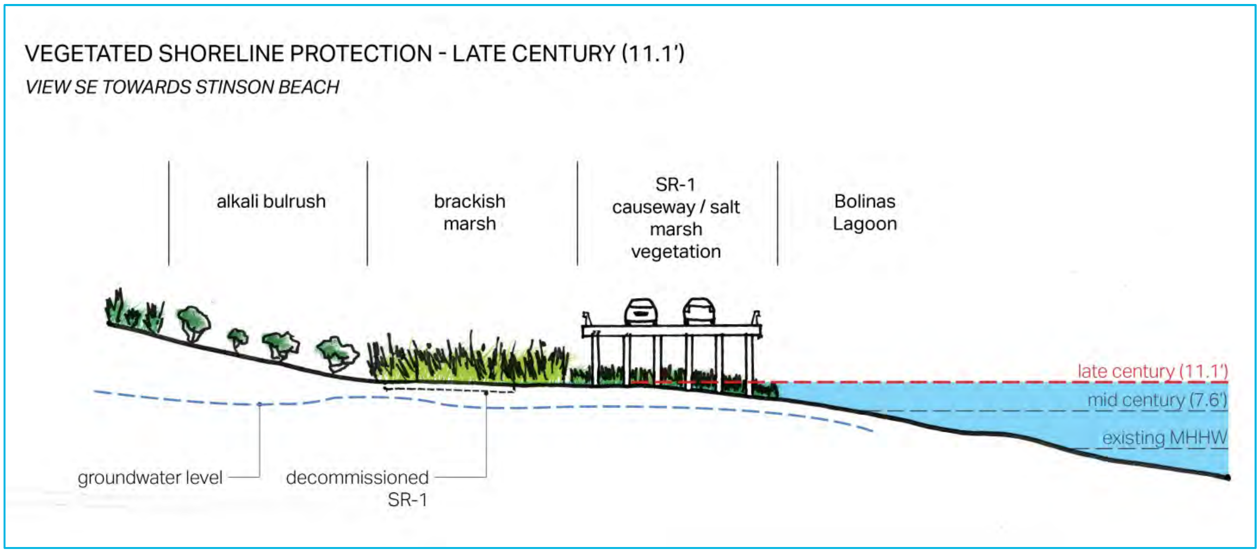
Creating a Vegetated Shoreline and Soft Erosion Protection

To reduce the potential impacts of erosion along SR 1, an alternative approach to having hard-engineered shoreline protective measures (e.g., riprap) along the shoreline is proposed in areas where a gradual slope of native vegetation can be established. A gradual slope transition of native vegetation would be created, where feasible, to provide protection from shoreline erosion adjacent to roadways and to allow for upward migration of intertidal and shallow-water vegetative communities. Suitable fill material would be placed from the fill slope of SR 1 to create a gradual 10:1 (horizontal: vertical) slope. In locations where the transitional slope is already adequate, fill would not be necessary. The mild slope will dissipate the incoming wave energy and eliminate the need for the hard armoring that would otherwise be necessary for steeper banks. Taller brackish water plant species, such as alkali bulrush (*Bolboschoenus maritimus*), hardstem bulrush (*Schoenoplectus acutus*), and cattail (*Typha* spp.), would be planted where feasible to buffer the shoreline from storm surges and wind waves. Figure 20 (not to scale) shows how removal of the roadway fill and installation of a causeway, when combined with a vegetated shoreline approach, removes the hardened perimeter barriers to upslope habitat migration as the sea level rises. MHW is already close to SR 1 and at some locations a slope of 10:1 is not feasible without having fill in the lagoon, which is a National Marine Sanctuary. See Section 12.2.1 and Figure 27 for discussion of constraints associated with where this approach is feasible.

Figure 20: Vegetated Shoreline Succession Associated with Raising SR 1 on a Causeway







As waves travel over this vegetated area, the wave energy would be reduced due to the increased bed roughness caused by the tall vegetation and reduced erosion along the shoreline. Furthermore, plant roots anchor into the soil, which helps to increase slope stability. The minimum slope required to provide soft erosion protection is dependent on many factors, including wave energy, storm surge, and soil type. Generally, as the slope increases, so does the need for harder shoreline protection features. At the location where the proposed causeway ties into SR 1, the slope of the vegetated shoreline would be increased to approximately 6:1 (instead of the milder-sloped 10:1 proposed in other soft shoreline protection areas) due to the narrow horizontal extent between the roadway and the mean higher water (MHW) line. This steeper slope would be required to avoid fill placement below the MHW line.

Some hardening elements (such as cobble, shells, or other bioengineered strategies) may need to be implemented along the slope if signs of erosion are observed. As the elevation of the causeway lowers and transitions into the existing highway south of the tie-in, the slope of the vegetated shoreline would flatten to 10:1, and a living shoreline approach to wave energy dissipation and shoreline protection can be adopted. Further research into attributes such as wind direction, current edge location of the lagoon, and wave distribution is necessary to determine specific locations where vegetated shoreline erosion creation would be beneficial in the project area.

Additional Design Option: Freshwater Filtration System

An experimental system of conveying and distributing fresh groundwater from upland sources from Salt Creek drainage could provide brackish water habitat for plant species that serve as shoreline buffers. The system could use perforated pipe placed in a gravel-lined trench, conveying water under SR 1 and distributing it through a branch network of perforated pipes along the shoreline. Groundwater studies would be necessary to determine if the phreatic water table surface is high enough in upland areas to supply adequate water to the shoreline areas. This optional experimental approach is not included in the cost estimate.

6.3 Alternative 1 Phase 3 Components

Phase 3 involves elevating the roads within Marin County's jurisdiction that are adjacent to the lagoon in order to make them more resilient to sea level rise. This includes Olema Bolinas Road and the northeastern extent of Bolinas-Fairfax Road. Existing culverts along Olema Bolinas Road will be upgraded to accommodate higher flows. A vegetated shoreline and soft erosion protection features will be installed to provide ecological resilience to wind waves and storm surge, and to allow for adaption of the intertidal and shallow water lagoon habitat to sea level rise along the lagoon interface. Rehabilitation of the Lewis Gulch Creek floodplain will occur along the stream between SR 1 and Olema Bolinas Road.

Phase 3 includes five main components:

(1) Raise Olema Bolinas Road approximately 5 feet in height and upgrade culverts for approximately 1,700 feet on engineered fill from the south abutment of the bridge over Lewis Gulch Creek constructed in Phase 1.
(2) Raise Bolinas-Fairfax Road on engineered fill approximately 5 feet in height for approximately 750 feet north from the end of the Phase 2 elevated roadway.
(3) Install vegetated shoreline and soft erosion protection features at the southern end of the project area along Olema Bolinas Road on newly raised roadway to further protect against sea level rise and to provide opportunity for upstream migration of intertidal and shallow water vegetation communities under sea level rise.
(4) Rehabilitate portions of Lewis Gulch Creek on the west side of SR 1.

The sections that follow describe each of the four main Phase 3 components in detail.

Raise Olema Bolinas and Bolinas-Fairfax Roads

Olema Bolinas Road will be raised from the south abutment constructed in Phase 1, just north of the current intersection with the crossover road, to the southern extent of the project area where the road is currently at an elevation of 18 feet. The roadway will be raised to accommodate sea level rise under the late-century climate change scenario, which is estimated at an elevation of 13.1 feet. The roadway will be raised on fill from its existing minimum elevation of 11 feet to a minimum elevation of 15.8 feet, which provides at least 2 feet of freeboard above the projected late-century sea level elevation, along with an additional 0.7 feet for the cross slope of the roadway to ensure that the edge of pavement/shoulder is above elevation 15.1 feet. Bolinas-Fairfax Road will be raised from the end of where it was elevated in Phase 2 (approximately 150 feet from the intersection with SR 1) approximately 750 feet to the northeast, to where the road is approximately at elevation 18 feet. The road will be raised in a similar fashion to Olema Bolinas Road to avoid flooding from late-century sea level rise.

Upgrade and Add Culverts along Olema Bolinas Road

To reduce the likelihood of flooding and the resulting maintenance costs, culverts along Olema Bolinas Road will be upgraded and at least one additional culvert will be installed. Conceptual design identified the need for a minimum of one additional culvert. Future project design phases will determine whether additional culverts will be necessary. Three existing culverts south of, and including, the Wharf Creek culvert are undersized and prone to plugging with debris. A new culvert will be installed between the Lewis Gulch Creek Bridge and the existing Lewis Gulch Creek box culvert. The existing box culvert under Olema Bolinas Road would remain in place and would continue to drain local runoff. The intent of multiple culverts is to more evenly distribute or convey surface runoff to the fan than would otherwise occur with all surface flow concentrated at one culvert with a direct channel to the lagoon. Multiple culverts would also reduce the likelihood of roadside flooding in extreme events. The path of water flow to the lagoon could occur through tie-ins to existing channels, creation of new channels, or reactivation of relict channels, which would be identified during the 30% design phase.

Install Vegetated Shoreline and Soft Erosion Protection along Olema Bolinas Road

To reduce the potential impacts of erosion along the fill slopes of Olema Bolinas Road, alternative approaches to hard-engineered shoreline protective measures are proposed (see also Section 7.2).

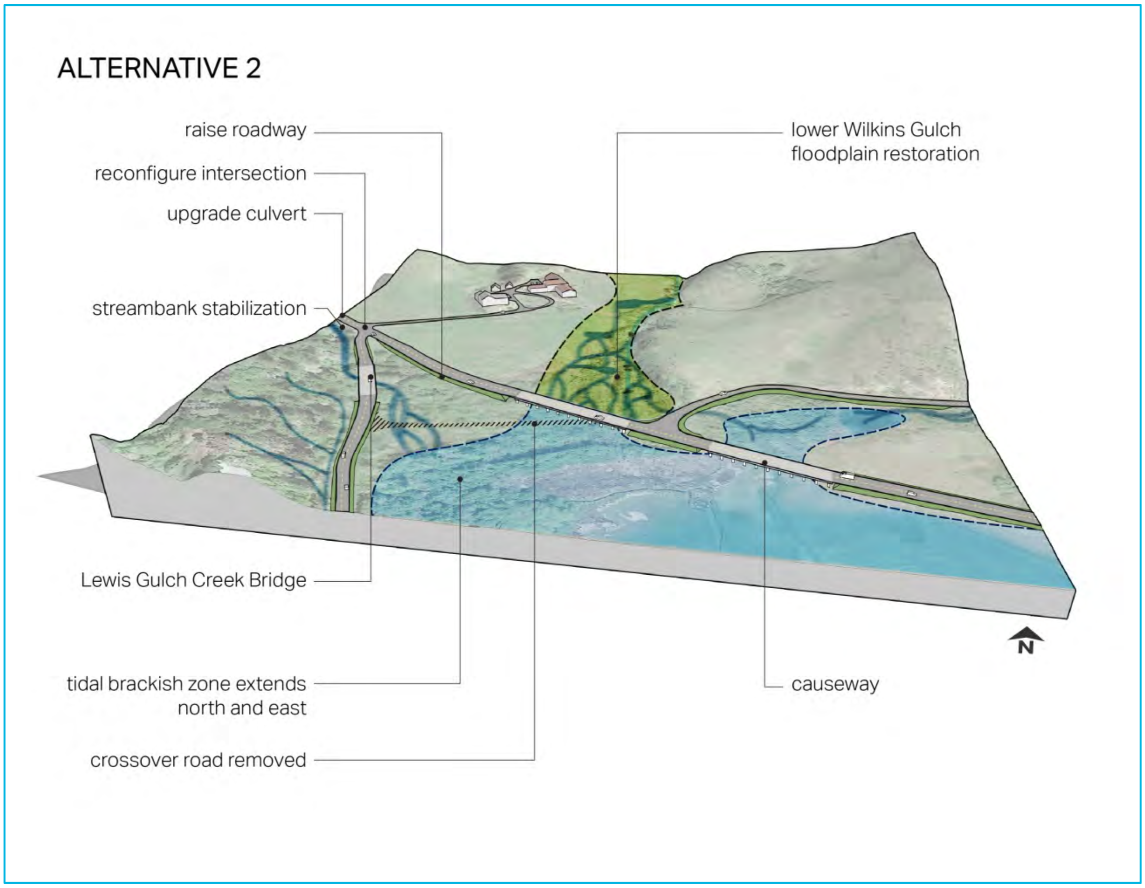
Rehabilitate the Stream along Lewis Gulch Creek

Rehabilitation of the Lewis Gulch Creek floodplain between SR 1 and Olema Bolinas Road would occur where stream restoration activities were completed in Phase 1. Currently, much of the stream channel is entrenched, with limited or no access to a flood relief area during a bankfull flow. As a result, higher-velocity flows transport much of the sediment through the reach, sediment that would otherwise deposit on the floodplain. Bank erosion is the most common source of sediment input due to channel confinement. Floodplain rehabilitation may involve either excavation of terrace deposits (former floodplain) to a new, lower elevation along either side of the channel and/or raising the streambed elevation so the stream can flood the existing terrace elevation at bankfull. Additional studies are necessary to select the most suitable design, one that limits environmental impacts and cost while improving long-term habitat conditions.

7. Alternative 2 Conceptual Design

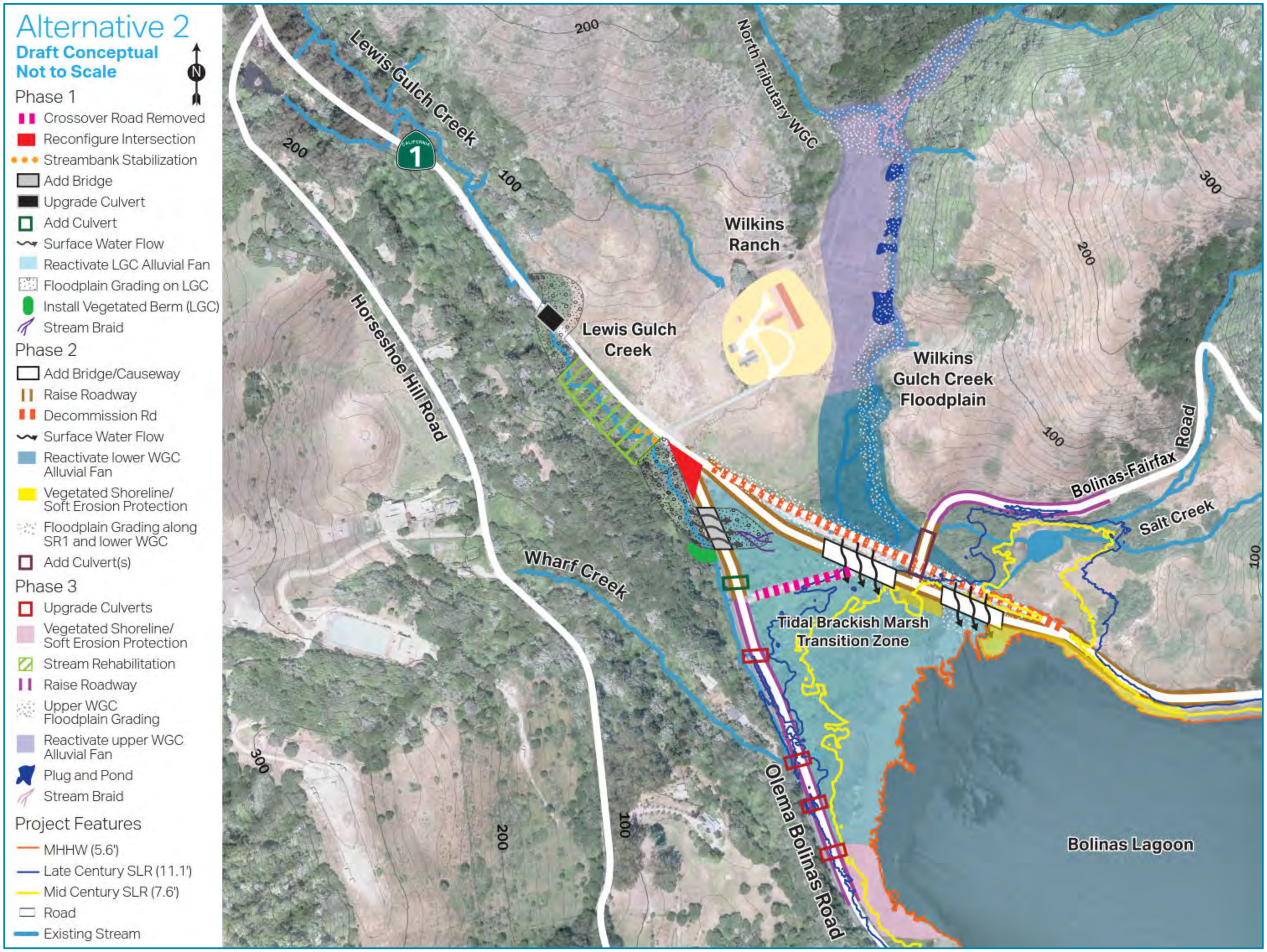
Alternative 2 includes raising SR 1 onto two causeways (same as in Alternative 1) and fully restoring Wilkins Gulch Creek floodplain to the head of the alluvial fan. In common with the other alternatives, it includes restoration of Lewis Gulch Creek. Figure 21 below is an overview sketch of Alternative 2. Specific project components are shown on Figure 22.

Figure 21: Alternative 2 Conceptual Design



Note: Sea level elevation is an artist rendition of late-century sea level rise. Roadway raising, denoted by green shading beneath roadways, occurs on SR 1, Bolinas-Fairfax Road, and Olema Bolinas Road.

Figure 22: Alternative 2 Conceptual Design Details



7.1 Alternative 2 Phase 1 Components

Phase 1 is identical for all three alternatives in scope, design, and cost. It is described in detail in Section 7.1.

7.2 Alternative 2 Phase 2 Components

Alternative 2 Phase 2 is identical to Alternative 1 Phase 2 in scope, design, and cost. It is described in detail in Section 7.2.

7.3 Alternative 2 Phase 3 Components

In addition to the universal Phase 3 components described in Section 7.3, under Alternatives 2 and 3, streamflow from the upper portion of Wilkins Gulch Creek would be restored to the head of the relict alluvial fan surface.

Phase 3 includes five main components:

(1) Raise Olema Bolinas Road on fill to accommodate sea level rise to the southern extent of the project area.
(2) Upgrade/add culverts along Olema Bolinas Road in newly raised areas
(3) Extend the raising of Bolinas-Fairfax Road from where it was completed in Phase 2 northward up Bolinas-Fairfax Road
(4) Install vegetated shoreline and soft erosion protection features at the southern end of the project area along Olema Bolinas Road on a newly raised roadway
(5) Restore a functioning floodplain to portions of Lewis Gulch Creek along the west side of SR 1.
(6) Restore streamflow from Wilkins Gulch Creek and the north tributary of Wilkins Gulch Creek to the surface of the relict alluvial fan. Fill and abandon the incised and channelized segment of the stream.

Components 1 through 5 are discussed in detail under Alternative 1 Phase 3 (Section 7.3); they are not described below.

Upper Wilkins Gulch Creek Floodplain Restoration

Wilkins Gulch Creek and its North Tributary would be reconnected to its floodplain near the head of the fan in a passive approach and allowed to establish a surface streamflow network toward the lagoon (see Figure 23). Field and topographic map investigations indicate a number of relict channels and swales remain along the length of the fan. By transitioning Wilkins Gulch Creek onto the relict alluvial fan surface, segments of the currently incised stream would be filled and stabilized, while other segments would be shaped as ponds, preventing recapture by the new channel. Streamflow would meander across the width of the fan, reoccupying relict channels, and floods would be reconnected to the relict fan surface. New channels might also develop. This would occur naturally over time. However, to increase the rate of this process, relict channels could be excavated out to initiate flow. See the *Design Approaches for Relict Alluvial Fan Reconnection* section below.

Following restoration, Wilkins Gulch Creek may establish a series of distributary channels that could gradually transition to a single-threaded stream that over time, may occupy alternate locations across the floodplain with no further human influence. In sections where the channel flow might become discontinuous (at present it is intermittent), flood events would provide opportunities for fish migration to the upper canyon where perennial reaches could exist.

If flows are returned to the surface of the fan, the infrastructure adjacent to the barn would be at nearly the same elevation as the floodplain, with the barn only a few feet higher in elevation. To protect against channel migration towards ranch buildings, a large, shallow swale along the western side of the fan would be filled to match corresponding elevations in the middle of the fan. Future modeling would evaluate whether a shallow, compacted, broad-sloped flood control levee berm along the western perimeter of the proposed floodplain would be required to further reduce the flood risk of historical outbuildings at Wilkins Ranch during large storm events (e.g., 100-year and 24-hour storm events). Depending on the desired level of flood protection, the berm may be 2 feet high and up to 600 feet long, particularly at the narrowest portion of the valley where the floodplain is approximately 185 feet wide. Once vegetated, the broad-sloped berm would blend into the visual landscape. Removal of the creek from the east side of its alluvial fan will eliminate the coarse and fine sediment supply from the numerous, existing active landslides. Compacted soil would help support the hillslope and reduce the frequency or degree of hillslope slumping or landslides.

Design Approaches for Relict Alluvial Fan Reconnection

Further studies (such as hydraulic modeling and groundwater monitoring) will determine a preferred design approach for relict alluvial fan reconnection. Conceptually, the transitioning of the creek out of its existing flow path and onto the relict alluvial fan would begin over a distance of approximately 600 linear feet from the head of the alluvial fan (where the stream begins to exit the confined and steep valley) down near the existing confluence of the North Tributary to Wilkins Gulch Creek. This would involve excavation of existing alluvial deposits on the terrace and fill within the existing channel, followed by reconstruction of the stream channel(s) atop the new floodplain. Reconstruction may involve construction of entirely new channel segment(s) atop fill material (at a higher elevation than the existing channel). This could be done along the 600 linear feet "transition area" where the existing channel bed is too low in elevation and the fan surface is too high. This is likely a preferred approach to a more extensive excavation of the fan sediments to create a new valley with the channel flowing at its current elevation near the outhouse (downstream of the picnic area/outdoor stage area) until it meets the fan surface closer to Wilkins Ranch. The upper portion of the transitioning stream could include a primary channel along with a secondary overflow channel or channels in the floodplain to provide alternate flow paths and habitat complexity. As the channel approaches the existing fan surface elevation, the primary channel could transition in shape and size, branching into smaller channels, thereby connecting existing relict channels on the fan surface.

Within the "transition area," the stream and its associated floodplain would be at an elevation between the channel and the floodplain. At the head of the fan, the floodplain is very minimal, as the channel is moderately incised. Moving downstream, the existing channel would be filled increasingly and the floodplain would be constructed until it joins the surface of the broader and wider alluvial fan near the North Tributary to Wilkins Gulch Creek. As the existing valley width opens up, so would the redefined floodplain area (currently confined to the channel) at a gradually increasing elevation relative to the existing channel bed elevation. Once the stream continues past the existing left bend (where it is channelized against the hillslope), the redefined floodplain (and associated fill or excavation) would fade into the broader alluvial fan surface until they are one and the same (fan surface becoming the "new" floodplain).

Plug and Pond Method to Generate Fill and Provide Habitat

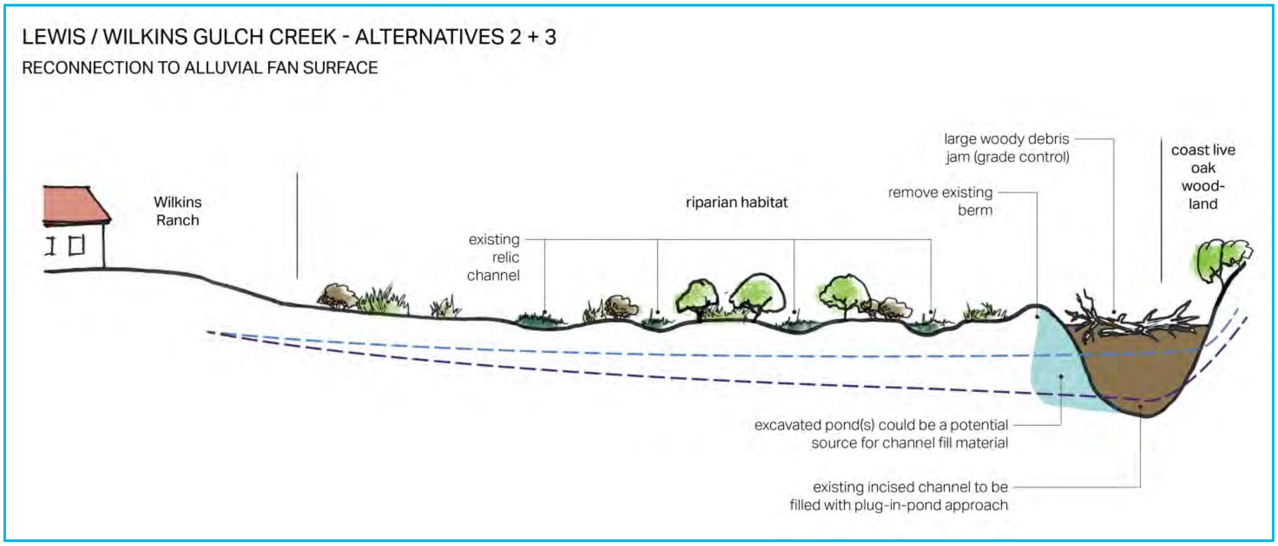
Segments of the existing abandoned channel would be backfilled with soil to the surface of the alluvial fan to prevent the stream from reoccupying the former channel. They would be separated by a chain of ponds. Grade control structures consisting of large woody debris and rock would be buried within the backfilled reaches and across the newly excavated floodplain in the valley transition to protect the soil from excessive scour erosion. In order to generate a sufficient volume of material to fill the existing channel and to keep construction costs reasonable, a number of ponds would be excavated along the approximate 1,000-linear-foot length of the abandoned channel segment. Ponds would be excavated deeper than the existing channel to generate fill material while occupying a portion of the channel, thereby reducing the channel area requiring fill (see Figure 23). To prevent head-cutting, the upstream and downstream edges of the ponds would be lined with the aforementioned large woody debris installments as grade control. Small drainage swales would drain surface flow from the ponds towards the main portion of the reestablished floodplain.

As shown on Figure 23, the reestablished floodplain is the surface of the existing alluvial fan. The elevation of the floodplain would be the same as the current fan surface elevation. A berm would not be necessary, since the fill in the existing channel would be flush with the surrounding fan surface (once the existing spoil berm is removed, where it exists). Ponds would likely be created in a manner such that, when full, the water surface on the downstream end of the pond would be near the fan surface elevation and thus any "overflow" would be drained out a shallow swale excavated in the fan surface and directed to meet an existing swale or to dissipate on the fan surface.

The ponds would predominately fill with water from surface and shallow subsurface flow, and would thus provide potential habitat for the California red-legged frog as well as other wildlife. The ponds will vary in size, shape and depth, providing more diversity of habitat and aquatic and riparian vegetation. The duration and depth of ponding would largely vary based on seasonal fluctuations in the shallow groundwater table. If a longer duration of ponding is desired, pond lining techniques could be employed (e.g., bentonite clay lining). An alternate design approach to generating sufficient material to fill the existing channel could include excavation of a new, lower floodplain along the length of the alluvial fan.

Figure 23: Wilkins Gulch Creek Stream Restoration

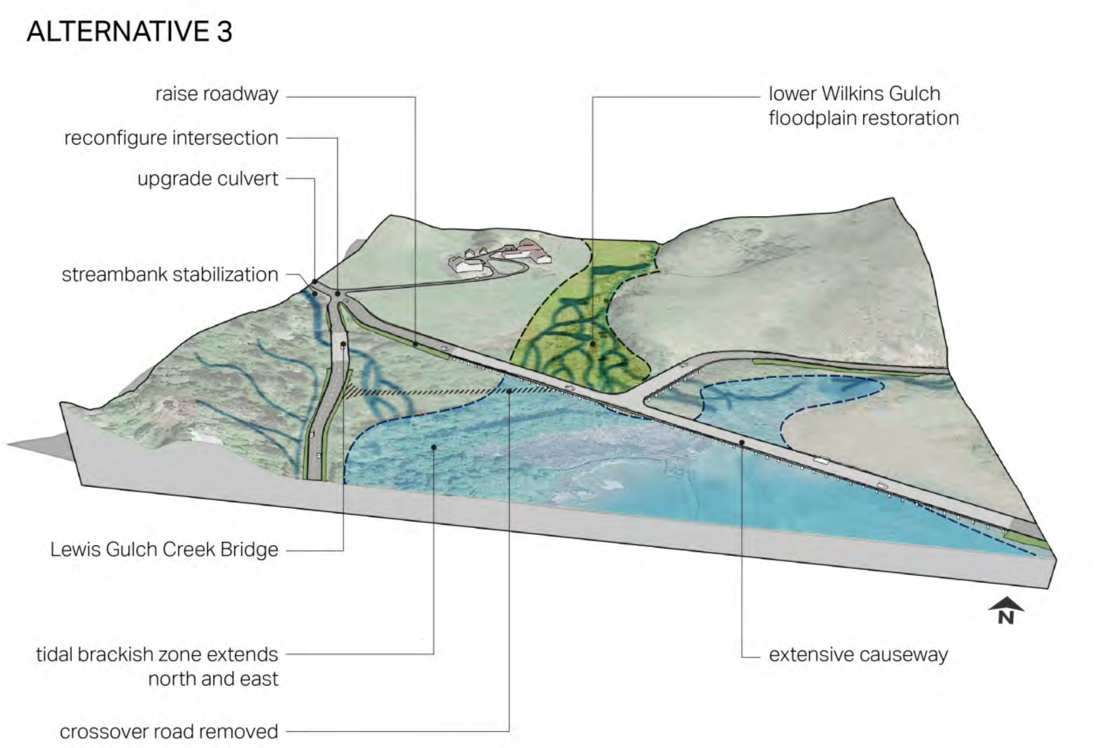
View downstream of Wilkins Ranch facing upstream, showing post-restoration conditions



8. Alternative 3 Conceptual Design

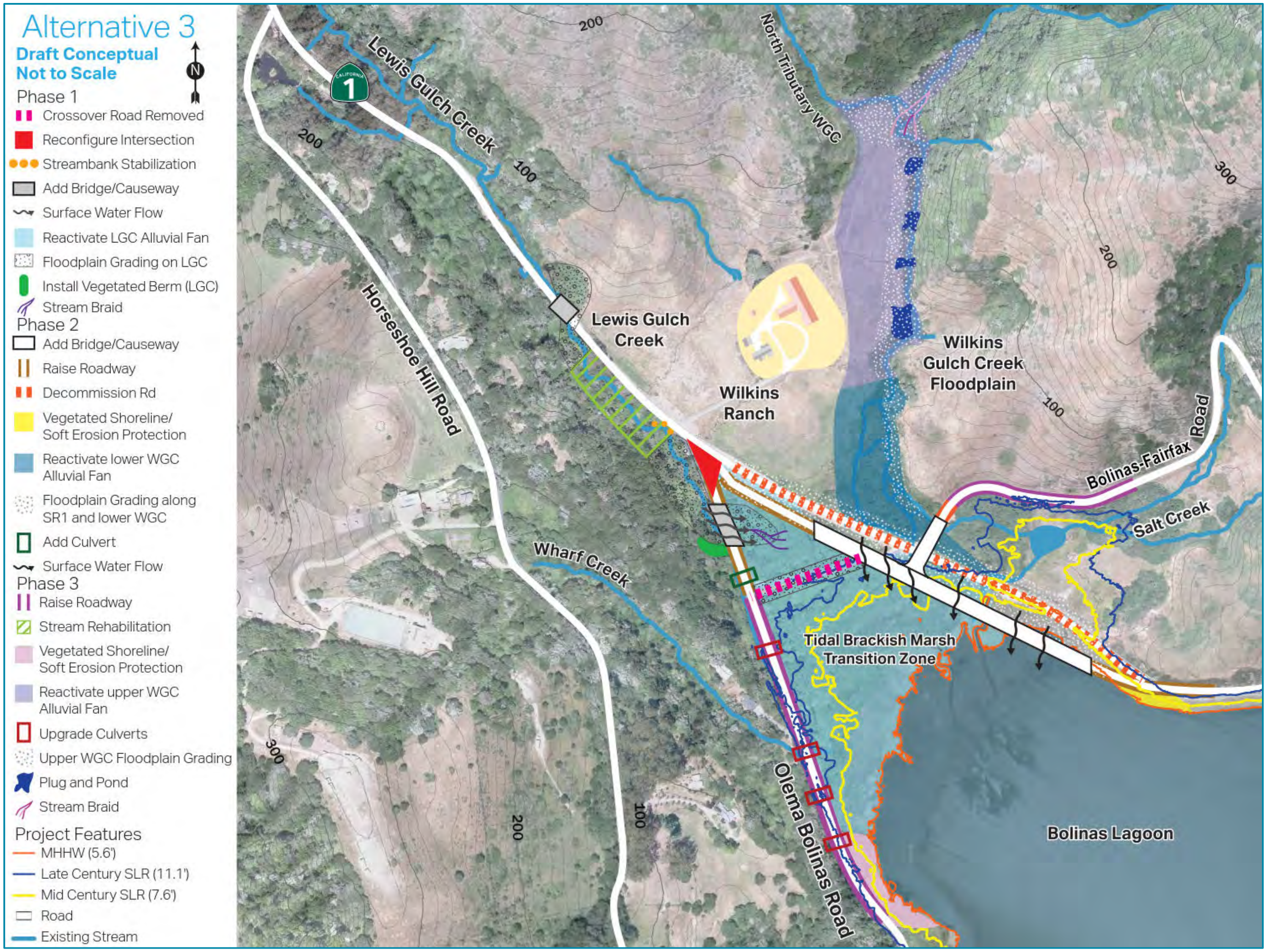
Alternative 3 includes fully restoring the Wilkins Gulch Creek floodplain to the head of the alluvial fan (same as Alternative 2). Unlike any of the other alternatives, it also includes raising SR 1 onto one causeway that intersects with a Bolinas-Fairfax Road causeway. Figure 24 below is an overview sketch of Alternative 3. Specific project components are shown on Figure 25.

Figure 24: Alternative 3 Conceptual Design



Note: Sea level elevation is an artist rendition of late-century sea level rise. Roadway raising, denoted by green shading beneath roadways, occurs on SR 1, Bolinas-Fairfax Road, and Olema Bolinas Road.

Figure 25: Alternative 3 Conceptual Design Details



8.1 Alternative 3 Phase 1 Components

Phase 1 is identical for all three alternatives in scope, design, and cost. It is described in detail in Section 3.1.

8.2 Alternative 3 Phase 2 Components

Alternative 3 Phase 2 will involve construction of a segment of SR 1 onto an elevated profile adjacent to the existing SR 1 roadway and rehabilitation of the Wilkins Gulch Creek floodplain downstream of Wilkins Ranch. A large portion of the elevated SR 1 would be placed on a causeway that would include the T-junction intersection with Bolinas-Fairfax Road, thereby providing additional floodplain for Wilkins Gulch Creek. The existing SR 1 would be decommissioned following completion of the newly elevated roadway alongside the existing route. A vegetated shoreline and soft erosion protection would be installed along the raised SR 1 adjacent to the lagoon for the length of the project area where roadway fill slopes occur.

Alternative 3 Phase 2 includes four main components:

(1) Raise the profile of SR 1 and install an 1,100-foot-long causeway that will maximize the width of the riparian corridor, allowing for nearly uninterrupted stream and tidal morphologic development over time;
(2) Decommission the existing SR 1 following completion of the causeway.
(3) Rehabilitate the Wilkins Gulch Creek floodplain, and reconnect it to the relict alluvial fan surface downstream of Wilkins Ranch.
(4) Install vegetated shoreline enhancement along SR 1.

Components 2 through 4 are as described in detail in Alternative 1 and therefore are not further discussed below. Component 1 is described in the next subsection.

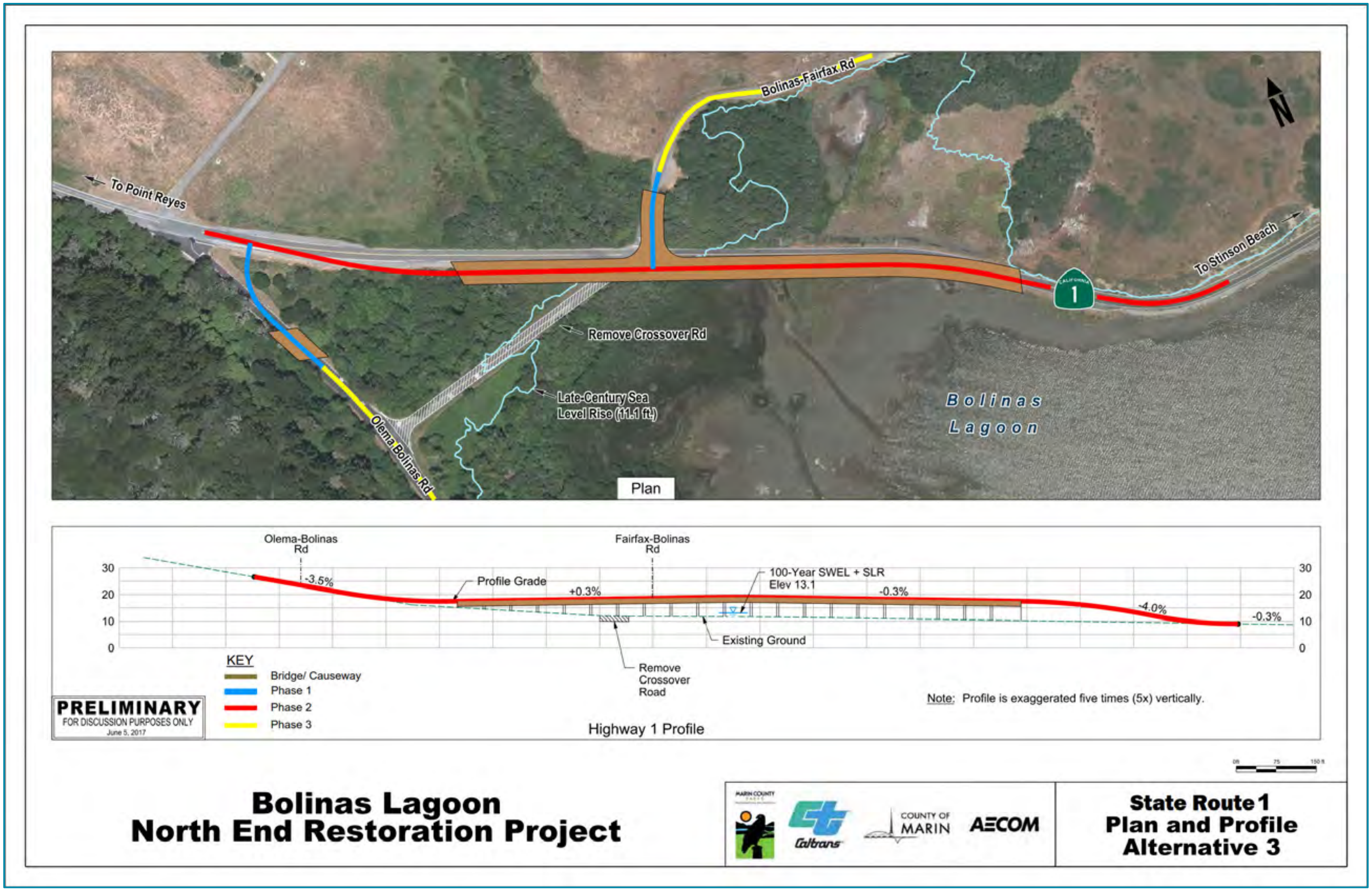
Raise SR 1 on Causeway and Decommission Existing SR 1

As described in Section 3.2.1, the current SR 1 elevation between 8 and 10 feet along the Bolinas Lagoon shoreline between Stinson Beach and the north end of the lagoon makes the highway susceptible to sea level rise and associated flooding impacts by mid-century (Figure 6). To increase the resiliency of SR 1 in the project area, SR 1 would be reconstructed to a higher elevation adjacent to its existing location, and the existing SR 1 would be decommissioned as described in Section 7.2. A single, T-shaped causeway would be constructed, totaling a length of approximately 1,050 feet along SR 1 (see Figure 26). The causeway would include a T-intersection with Bolinas-Fairfax Road and a 150-foot-long segment along Bolinas-Fairfax Road. SR 1 and Bolinas-Fairfax Road would be placed on engineered fill on the approach to the causeway. The total length of the proposed SR 1 profile modification is approximately 1,700 feet, from 600 feet north of Bolinas-Fairfax Road (at approximately Elevation 21) to 1,100 feet south of Bolinas-Fairfax Road (at approximately Elevation 9).

8.3 Alternative 3 Phase 3 Components

Phase 3 is identical to Alternative 2 Phase 3 in scope, design, and cost. It is described in detail in Section 8.1.

Figure 26. Alternative 3 – SR 1 Causeway Plan and Profile



Note: The long brown trapezoid on SR 1 represents the approximate location of the proposed T-junction causeway along SR 1 and Bolinas-Fairfax Road. Elevation 13.1 represents late-century sea level rise + 2 feet of SWEL.

8.4 Conceptual Traffic Transition Plan

Construction of all phases of the project can generally be completed while traffic is maintained on the existing roads. However, one-way traffic control and/or temporary closure of roads will be required, on occasion, to complete the work. For example, construction of a new bridge over Lewis Gulch Creek on SR 1 will likely require one or more temporary closures of the highway. In this situation, portable changeable message signs (PCMS) will be placed at least 1 week in advance to alert motorists to the upcoming closure. Roadside signs for detours will also be implemented to help direct traffic around the closure.

For the closure of SR 1 at Lewis Gulch Creek, north of Olema Bolinas Road, a detour via Olema Bolinas Road and Horseshoe Hill Road can be used to allow for the passage of traffic between Stinson Beach and Olema. For the closure of SR 1 between Olema Bolinas Road and Bolinas-Fairfax Road, the existing crossover road and Olema Bolinas Road can be used as a detour. Temporary closures of SR 1 south of Bolinas-Fairfax Road will require a more circuitous detour route. A PCMS will direct motorists to take Panoramic Highway and Sir Francis Drake Boulevard on a route around the east side of Mount Tamalpais to travel between Olema and Stinson Beach. Lastly, for temporary closures of Olema Bolinas Road, a detour via Horseshoe Hill Road can be used for traffic from/to Bolinas.

9. Cost

These construction cost estimates, prepared by AECOM, are based on a 10%-level conceptual design. Unit costs were developed based on bid results from similar projects, similar AECOM project experience, and professional engineering judgment. Earthwork quantities were estimated using the ArcMap GIS and CADD software and spreadsheet calculations using the average end-area method. A 40% contingency was added to the cost estimates to account for uncertainty in design assumptions and unit costs. Estimated costs do not include costs for engineering design, environmental documentation, permitting, or contract and construction administration.

The calculations include:

- Site Preparation: mobilization and demobilization, including wildlife exclusion fencing and monitoring;
- Clearing, Grubbing and Stripping;
- Demolition and Dewatering
- Roadway Earthwork, Pavement, Drainage, and Structures
- Dewatering
- Restoration Excavation and Fill, Erosion and Sediment Control, Structures, Planting, Irrigation, and 3 Years of Monitoring,

Assumptions made in the calculations include:

- This estimate does not include soft costs: engineering design; environmental documentation and permitting; and construction management.
- Most quantities are based on rough estimates of the area or linear distance of anticipated features. Areas and linear distances are calculated from conceptual CAD drawings separate of this estimate.
- Excavated material will be reused as fill material where possible.
- Topsoil excavation includes removal of the upper 6 inches of soil and grass, stockpiling the material on-site to be redistributed at completion of grading.
- Additional costs for material testing and sorting are included in the contingency.
- A 10% and 15% bulking factor is used for 80-85% and 95% compacted fill, respectively.

Dewatering costs assume that minor stream and or groundwater dewatering may be necessary to facilitate channel grading. Cost estimates for the conceptual design alternatives are shown in Table 6.

Table 6: Bolinas North End Project Conceptual Cost Estimates

Alternative	Construction Phase	Estimated Cost[1]				
		Riparian/Wetland Restoration	Roadway Construction	Restoration Maintenance, & Monitoring	50% Contingency	Total
1	Phase 1	$ 1,337,000	$ 7,366,000	$ 492,000	$ 4,598,000	**$ 13,793,000**
	Phase 2	$ 1,244,000	$ 18,431,000	$ 251,000	$ 9,963,000	**$ 29,889,000**
	Phase 3	$ 1,412,000	$ 12,978,000	$ 233,000	$ 7,312,000	**$ 21,935,000**
	Combined Phases	**$ 3,992,000**	**$ 38,774,000**	**$ 975,000**	**$ 21,871,000**	**$ 65,612,000**
2	Phase 1	$ 1,430,000	$ 7,366,000	$ 492,000	$ 4,644,000	**$ 13,932,000**
	Phase 2	$ 1,346,000	$ 18,431,000	$ 251,000	$ 10,014,000	**$ 30,042,000**
	Phase 3	$ 5,131,000	$ 12,978,000	$ 868,000	$ 9,489,000	**$ 28,466,000**
	Combined Phases	**$ 7,906,000**	**$ 38,774,000**	**$ 1,609,000**	**$ 24,145,000**	**$ 72,434,000**
3	Phase 1	$ 1,430,000	$ 7,366,000	$ 504,000	$ 4,650,000	**$ 13,950,000**
	Phase 2	$ 1,895,000	$ 24,450,000	$ 273,000	$ 13,309,000	**$ 39,927,000**
	Phase 3	$ 5,181,000	$ 12,856,000	$ 932,000	$ 9,485,000	**$ 28,454,000**
	Combined Phases	**$ 8,505,000**	**$ 44,671,000**	**$ 1,708,000**	**$ 27,442,000**	**$ 82,326,000**

10. Project Timeline and Phasing

The project is configured so that it can be divided into three discrete phases that can be designed and constructed separately, occurring in an overlapping timeline or sequentially. Initial studies and design for Phase 1 are anticipated to begin in early 2018. A high-level project timeline for Phase 1 is provided in Table 7. The timeline identifies the sequential tasks for design, environmental review and permitting, construction, and post-construction monitoring. The estimated duration given for each task is based on existing information and may be subject to change. If a Caltrans Project Initiation Document (PID) is required for Phase 1, the timeline would shift approximately 12 to 24 months to accommodate that preliminary step.

Table 7. Example Phase 1 Project Timeline

Task	Estimated Duration*	
	Begin	End
Environmental and Supporting Studies	January 2018	July 2019
Preliminary 30% Restoration and Roadway Design Plans	July 2018	December 2018
Environmental Review: CEQA / NEPA Documentation	January 2019	March 2020
Intermediate 65% Restoration & Roadway Design Plans, Specifications, Design Report	January 2020	June 2020
Environmental Permitting	April 2019	October 2020
Advanced 90% Restoration and Roadway Design Plans, Specifications, Design Report	October 2020	January 2021
Final 100% Design Plans and Specifications, Design Report	February 2021	May 2021
Bid Process Support	June 2021	July 2021
Contractor Selection	August 2021	September 2021
Contract Negotiations	October 2021	November 2021
Construction Work Plans / Constructability	January 2022	March 2022
Construction	May 2022	September 2023
Post Construction Monitoring	October 2023	October 2026

**If a PID document and a formal project study report are required by Caltrans, the timeline would shift 12-24 months unless it is possible to complete some environmental and supporting studies concurrently with the Caltrans documentation.*

The total estimated project timeline for Phase 1 is 5 to 7 years, depending on the possible addition of up to 24 months for a preliminary Caltrans PID and an associated formal project study report. Three additional years of monitoring have been assumed, for a total of 8 to 10 years from project inception to completion.

A timeline for Phases 2 and 3 is shown at a more general level so as to provide an overall estimate for the project timeline (Table 8). Specific dates are not provided, as Phases 2 and 3 would not begin for a minimum of 5 years. The timeline has been divided sequentially into the project tasks associated with design, environmental review and permitting, construction, and post-construction monitoring. A PID is anticipated for Phase 2 because of the significant amount of project activities that would occur on SR 1. The timeline estimates are based on existing information and may be subject to change.

Table 8. Project Timeline Estimate for Phases 2 and 3

Task	Estimated Timeline
Caltrans Project Initiation Document and Formal Project Study Report (Phase 2)	24-36 months
Environmental and Supporting Studies	12 - 18 months
Preliminary 30% Restoration and Roadway Design Plans	6 months
Environmental Review: CEQA / NEPA Documentation	15 - 18 months
Intermediate 65% Restoration and Roadway Design Plans, Specifications, Design Report	9 - 12 months
Environmental Permitting	18 months
90% Restoration and Roadway Design Plans, Specifications, Design Report	6 months
Final 100% Design Plans and Specifications, Design Report	6 months
Bid Process Support	4 months
Contractor Selection	2 months
Contract Negotiations	2 months
Construction Work Plans/ Constructability	4 months
Construction	2 - 3 years
Post Construction Monitoring	3 years

The total estimated project timeline for Phase 2 through construction completion is approximately 11 to 14 years. Three additional years of monitoring have been included, for a total of 14 to 17 years from project inception to completion. The total estimated project timeline for Phase 3 through construction completion is approximately 9 to 11 years. It is shorter because a Caltrans PID and formal project study report is not anticipated. Three additional years of monitoring have been included, for a total of 12 to 14 years from project inception to completion. These phases could be completed concurrently rather than sequentially, which would shorten the length of the overall project duration.

PART III – OPPORTUNITIES AND CONSTRAINTS

11. Alternatives Analysis

The Conceptual Design Report presents three detailed project alternatives for comparison, each composed of three construction phases. The phases of construction under each alternative include different construction elements that distinguish the overall alternatives from one another and have different implications for project cost and complexity as well as the environmental effects, social considerations, and anticipated project benefits. Each proposed conceptual alternative meets project goals; however, the degree to which each goal is achieved varies between alternatives. In order to compare the relative merits of the three proposed conceptual alternatives, a project-specific, qualitative comparison method was developed and applied to five project analysis categories: Project Cost/Timeline, Project Constructability/Complexity, Environmental Effects, Social Considerations, and Project Benefits – which is an assessment of how well the alternative meets the project goals, comparatively. These categories were further divided for qualitative analysis and comparison, as listed below:

Cost/Timeline (no subcategories)

Constructability/Complexity:

- Roadway / Built Environment
- Habitat Restoration

Environmental Effects:

- Wetlands, Creeks, and Lagoons
- Special-Status Species
- Sensitive Habitat
- Cultural Resources

Social Considerations:

- Surrounding Community
- Traffic
- Tourists/Recreation

Project Benefits:

- Climate Resilience
- Hydrologic Connectivity
- Sensitive Species Habitat
- Road Safety

Definitions of the functional categories and subcategories, including assumptions, are presented in Section 12 under each project analysis category heading. The opportunities and constraints discussions presented in Section 12 provide a narrative framework supporting the quantitative comparisons presented in this section. This section first describes the methodology used to develop the comparison of the alternatives, and then presents the results of the conceptual alternatives comparison followed by a brief discussion of the results.

11.1 Methods

In order to provide a useful comparison of project value between the phases of each conceptual design alternative, subcategory characteristics were compared by phase between the three alternatives. Subcategories received a rating of 1, 2, or 3 for each phase of each alternative, representing their comparative performance. The "1,2,3 scoring system" was developed to show the comparative rather than absolute value associated with the performance of any given subcategory of the project, and the values should be interpreted as follows:

Values of "1": The least preferable outcome related to performance of the project for a given subcategory, when compared against the other two conceptual alternatives.

Values of "2": An outcome that cannot be distinguished from that under another alternative and that performs equally well / unfavorably when compared to one or both of the other conceptual alternatives. In this case all similarly performing alternatives would also be rated as "2".

Values of "3": The most desirable outcome related to performance of the project for a given subcategory, when compared against the other two alternatives.

The benefit of using this rating system is that the relative (rather than absolute) scoring system allows a clear comparison of project performance across subcategories with very different metrics (e.g.,: acres of wetland impacts versus dollars of construction cost are not directly comparable but can be compared qualitatively using this system).

Color-coding is used to highlight category scores. The lowest score is shown in red, the median score is shown in yellow, and the highest score is shown in green.

This analysis assumes that all project analysis categories have equal weight and that the contribution of each analysis category to the project is equal to the average of their subcategory scores. In order to account for the fact that different phases of the project contributed more time, effort, and impact when compared against other phases, a weighting scheme was developed and applied to the subcategory average score. These "weighted averages," as shown in Table 9, reflect assumptions about relative contribution to the project of each phase, under each of the different alternatives:

Table 9. Relative Contribution of Each Phase to Conceptual Design Alternatives

	Alternative 1	Alternative 2	Alternative 3
Phase 1	30%	30%	30%
Phase 2	60%	50%	50%
Phase 3	10%	20%	20%

The results of the analysis are presented by phase within each alternative, and by alternative as a whole. The phase scores were derived by averaging the category scores within each phase. The alternative score was derived by averaging the weighted phase scores for each phase within an alternative. Given these assumptions and calculations, the relative value of the subcategories is explicitly established, and therefore the relative merits of the three conceptual alternatives may be compared to one another in greater or lesser detail using the scores presented in Table 10.

11.2 Results

Table 10 presents the results of the alternatives analysis for the three project conceptual design alternatives. Specifically, it numerically demonstrates the relative success of project alternatives in maximizing project benefits and minimizing project effects under specific analysis categories representing the project goals and priority resources, as expressed by Marin County and project stakeholders.

As the summary statistics in Table 10 show, all three alternatives total scores are close to one another. This is a result of the alternatives having many similar components. By color-shading the lower scores red, the middle scores yellow, and the higher scores green, the strengths and limitations of each alternative by category is revealed. While all three alternatives meet the project goals, Alternative 1 scores the lowest in Project Benefits and Alternative 3 scores the highest. Interestingly, Alternative 1 is the lowest in cost and Alternative 3 is the highest in cost, suggesting that a higher cost yields a greater overall benefit to the landscape. Alternative 2 scores average in every category.

Although Alternative 1 outperformed the other alternatives in terms of cost and timeline, it performed suboptimally in a number of categories due to the absence of project-benefitting design elements that could contribute to the restoration goals of the project. Alternative 1 lacks the project benefits associated with restoration of Upper Wilkins Gulch Creek, which as noted above, go beyond the Project Goals category and influence social considerations such as tourists and recreation. In most other subcategories Alternative 1 only performs as well as another of the alternatives, only exceeding their performance in the Environmental Effects category, where the limited scope of work during Phase 3 of Alternative 1 gives it overwhelming success in minimizing project effects to sensitive natural resources. Despite this success during Phase 3, differences in environmental effects between alternatives are negligible in Phase 1 and lowest (or best) for another alternative in Phase 2.

Alternative 3 receives the highest score, which can be interpreted to mean it offers the most project benefits and fewest project effects, when compared against the other two alternatives. Alternative 3 scores highest primarily due to its success in having a higher category score when compared to the other two alternatives. Design elements such as restoration of Upper Wilkins Gulch Creek and placement of a fully elevated causeway give Alternative 3 an advantage over the other two under multiple categories, including project benefits, social considerations (roadway safety and tourists/recreation), and constructability/complexity.

The challenges associated with reinforcing the elevated fill connector between the double causeways proposed under Alternatives 1 and 2 exceeded challenges associated with a longer-span bridge and gave Alternative 3 an unexpected advantage under the Roadway/Built Environment subcategory within Constructability and Complexity. In addition, Alternative 3 did not score “1” in any category. Even in cases where a particular design element performed suboptimally under a subcategory, this performance was not measurably worse than that of another alternative. However, Alternative 3 is the highest in cost and therefore scores the lowest in that category.

Table 10. Alternatives Analysis Table

Categories	Subcategories	Alternative 1 Phase 1	Alternative 1 Phase 2	Alternative 1 Phase 3	weighted avg. All	Alternative 2 Phase 1	Alternative 2 Phase 2	Alternative 2 Phase 3	weighted avg. All	Alternative 3 Phase 1	Alternative 3 Phase 2	Alternative 3 Phase 3	weighted avg. All
Cost and Timeline	(n/a)	2.0	2.0	3.0	2.1	2.0	2.0	2.0	2.0	2.0	1.0	2.0	1.5
Average		**2.0**	**2.0**	**3.0**		**2.0**	**2.0**	**2.0**		**2.0**	**1.0**	**2.0**	
Weighted Average		**0.6**	**1.2**	**0.3**		**0.6**	**1.0**	**0.4**		**0.6**	**0.5**	**0.4**	
Constructability/ Complexity	Roadways/Built Environment	2.0	2.0	2.0	2.1	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.3
	Habitat Restoration	2.0	2.0	3.0		2.0	2.0	2.0		2.0	2.0	2.0	
Average		**2.0**	**2.0**	**2.5**		**2.0**	**2.0**	**2.0**		**2.0**	**2.5**	**2.0**	
Weighted Average		**0.6**	**1.2**	**0.3**		**0.6**	**1.0**	**0.4**		**0.6**	**1.3**	**0.4**	
Environmental Effects	Wetlands, Creeks, & Lagoon (estuarine)	2.0	2.0	3.0	2.1	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.5
	Special Status Species	2.0	2.0	3.0		2.0	2.0	2.0		2.0	3.0	2.0	
	Sensitive Habitat	2.0	2.0	3.0		2.0	2.0	2.0		2.0	3.0	2.0	
	Cultural Resources	2.0	2.0	3.0		2.0	2.0	2.0		2.0	2.0	2.0	
Average		**2.0**	**2.0**	**3.0**		**2.0**	**2.0**	**2.0**		**2.0**	**3.0**	**2.0**	
Weighted Average		**0.6**	**1.2**	**0.3**		**0.6**	**1.0**	**0.4**		**0.6**	**1.5**	**0.4**	
Social Considerations	Surrounding Community	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.2
	Traffic	2.0	2.0	2.0		2.0	2.0	2.0		2.0	2.0	2.0	
	Tourists/Recreation	2.0	2.0	1.0		2.0	2.0	2.0		2.0	3.0	3.0	
Average		**2.0**	**2.0**	**2.0**		**2.0**	**2.0**	**2.0**		**2.0**	**2.3**	**2.3**	
Weighted Average		**0.6**	**1.2**	**0.2**		**0.6**	**1.0**	**0.4**		**0.6**	**1.2**	**0.5**	
Project Benefits	Climate Resilience	2.0	2.0	1.0	1.9	2.0	2.0	2.0	2.0	2.0	3.0	3.0	2.6
	Species Habitat	2.0	2.0	1.0		2.0	2.0	2.0		2.0	3.0	3.0	
	Hydrologic Connectivity	2.0	2.0	1.0		2.0	2.0	2.0		2.0	3.0	2.0	
	Road Safety	2.0	2.0	2.0		2.0	2.0	2.0		2.0	3.0	2.0	
Average		**2.0**	**2.0**	**1.3**		**2.0**	**2.0**	**2.0**		**2.0**	**3.0**	**2.5**	
Weighted Average		**0.6**	**1.2**	**0.1**		**0.6**	**1.0**	**0.4**		**0.6**	**1.5**	**0.5**	
Totals	phases (averaged by category)	2.0	2.0	2.4		2.0	2.0	2.0		2.0	2.4	2.1	
	phases (weighted average)	0.6	1.2	0.2		0.6	1.0	0.4		0.6	1.2	0.4	
	phases (weighted average)		2.0				2.0				2.2		

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11.3 Meeting Project Goals

All three conceptual alternatives are designed to meet the project goals and do so successfully, as described below. Although all project goals are met by the three conceptual alternatives, there are differences in the ways they are met and the degree to which different goals are met. The degree and success with which each goal is met by the different conceptual alternatives is presented in the opportunities and constraints discussion in Section 12.

GOAL 1. Habitat Restoration and Reconnection:

The reconnection of Wilkins Gulch and Lewis Gulch Creeks to their historical floodplains proposed under each of the three alternatives would expand the overall amount of floodplains within the project area at the North End. Creating openings in the hardened lagoon perimeter roadway, through adding additional culverts, upgrading existing culverts to bridges, and raising part of SR 1 onto an elevated bridge causeway structure, will reconnect the hydrology and the habitats in the North End. Floodplain reconnection creates opportunities for natural riverine processes to convey and distribute sediment and nutrients across the floodplain, reduce scour, and increase riparian habitat. This will also slow the rate of sedimentation to the lagoon. The removal of physical barriers to stream flow will increase fish passage for steelhead and other native fish, provide habitat connectivity, and increase wildlife movement throughout the project area. Overall, project components are designed to create a system that will meet the goal of restoring and reconnecting habitat through restoration of natural processes and facilities that would not be highly dependent on human intervention to maintain them.

GOAL 2. Road Safety (including alignment and flooding):

All project alternatives would “improve roadway safety through realignment and reducing road flooding during winter storm events,” as stated in Goal 2 by removing the crossover road and reconfiguring existing skew angle intersections into safer Caltrans standard intersections. Project components common to all three alternatives have been designed to increase road safety by reducing road flooding as a result of raising roadways and improving stream drainage with larger culverts. Wider shoulders and a class II bikeway have also been added, which improves cyclist safety in the project area.

GOAL 3. Climate Change and Sea Level Rise Adaptation:

All project alternatives would “… make the project area more resilient through raising the roadways and removing infrastructure to provide opportunity for upslope habitat migration and lagoon expansion as the sea level rises” and thus meet Goal 3 through the removal of the crossover road and SR 1, which would allow for upstream migration of the tidal brackish marsh transition zone and associated habitats under climate change and sea level rise. Additionally, raising roadways above future sea level rise projections would create resiliency to roadway flooding and improve roadway maintenance. Furthermore, increasing culvert size for stream drainage would reduce the flood potential that may occur due to extreme weather events resulting from climate change.

12. Opportunities and Constraints

Although all three project conceptual alternatives successfully meet the three project goals, they do so to varying degrees and with different levels of associated impacts and benefits. The purpose of the opportunities and constraints analysis is to develop a comparative analysis of the opportunities and constraints associated with the different project designs and their effect upon site conditions. The analysis applies an understanding of the project site from information gathered in the Site Conditions Report to the three proposed conceptual alternatives in order to determine project effects on various site conditions.

Opportunities include design choices that:

- Enhance natural features, processes, and habitat;
- Increase natural habitat and features;
- Improve roadway safety and infrastructure;
- Improve climate change and sea level rise resiliency; and
- Provide improved public access.

Constraints include design elements or physical site limitations that may be required/unavoidable but prevent or complicate the fulfillment of the identified project goals and/or render design components or phases too costly/time consuming/environmentally destructive to be feasible.

Opportunities and constraints presented in this chapter are organized into five broad categories for discussion and analysis: Cost and Timeline, Constructability/Complexity, Environmental Effects, Social Considerations, and Project Benefits. These broad categories are then separated into subcategories that correspond to particular elements of interest, as identified by project stakeholders. The categories and subcategories are first defined and then all opportunities and constraints associated with each are described. Opportunities and constraints common to all alternatives are presented first for a given category, followed by opportunities and constraints that are specific to one or more alternative(s).

12.1 Costs and Timeline

Costs are carefully defined in Section 9 and include only estimates for construction of the project. Estimated costs do not include effort associated with engineering design, environmental documentation, permitting, or contract and construction administration. As shown in Table 6, costs vary between the three alternatives: Alternative 1 has the lowest cost while Alternative 3 has the highest cost. The anticipated project timeline is presented in Section 10. It includes the anticipated duration of each phase of construction and permitting.

12.1.1 Specific to Alternatives 1

Opportunity (CT-OPP1): Alternative 1 has the Lowest Associated Construction Cost and Shortest Timeline. As shown in Table 6 and the construction timeline in Section 10, Alternative 1 meets all project goals while having the lowest construction costs and shortest anticipated construction timeline.

12.1.2 Specific to Alternatives 1 and 2

Constraint (CT-CON1): Increased Cost Associated with Stabilizing Fill Intersection between Dual Causeways. Alternative 1 was designed as the lowest-cost option; however, results of the geotechnical boring investigation increased the costs of Alternative 1 because new requirements to support and reinforce the elevated fill intersection between the two causeways on SR 1. Originally it was believed that fill could be added on top of the existing roadbed to elevate the intersection; however, the geotechnical boring investigation indicated that the ground is too soft and prone to settlement, thus unable to support the quantity of fill necessary to elevate the roadway and tie in to the two fixed causeway structures. The intersection area would require over-excavation and ground reinforcement, resulting in a greater cost to the project under Phase 2 of Alternatives 1 and 2.

12.1.3 Specific to Alternatives 3

Constraint (CT-CON2): One Long Causeway is More Expensive than Two Shorter Causeways. The cost of constructing the single causeway on SR 1 under Alternative 3 is more costly and time consuming than constructing the two, shorter causeways by virtue of increased materials requirements and the need for additional reinforcement associated with the longer elevated structure.

12.2 Constructability/Complexity

Constructability/Complexity is defined as the engineering and construction management effort associated with constructing the project. For instance, constructability/complexity takes into account the number of processes and independent components associated with the different design elements under each alternative as well as the degree of technical difficulty involved in engineering and building the different design components within each alternative. This category has two subcategories (roadways / built environment and habitat restoration) which have different metrics associated with them. Opportunities and constrains resulting from the three conceptual design alternatives and the associated constructability/complexity within design elements in each subcategory are described below.

12.2.1 Roadways / Built Environment

The roadways / built environment subcategory of analysis is assessed based upon the number of engineering elements and complexity of design within a given element (i.e. the complexity of road elevation or causeway design at a particular location).

Common to all alternatives

Constraint (CC-CON1): San Andreas Fault Zone Considerations, Subsurface Conditions, and Soft Soils. The presence of the San Andreas Fault Zone in the project area increases the structural design complexity of the causeways and bridge features. Foundations for structures would be required to be driven or drilled deeper. *S*ubsurface soils in the project area generally consist of soft clay, loose clayey sands, and gravel. A high amount of settlement is anticipated for raising roadways on fill sections as a result of the soft subsurface soil conditions which increases the complexity of reaching project goals.

Constraint (CC-CON2): Shoreline Fill Soil May Differ from Existing Sediment. It is likely that soil from on-site excavation areas will not be of the same soil texture and composition as existing sediment in the lagoon. Soil would be screened of rock but may not have the same fine silt and clay texture as the existing soil surrounding the lagoon. The coarse-textured soil may be less suitable and thus less successful at reestablishing marsh vegetation. Further analysis is necessary to determine the extent of this potential constraint.

Constraint (CC-CON3): Engineered Fill Required for Raising Roadways and Creating Vegetated Shorelines. The project requires a large amount of fill to raise the roadways and create vegetated shorelines at a slope of 10:1 and 6:1. On-site excavation of existing roadways and restoration work are not likely to generate sufficient material to balance the needed fill. As a result, suitable fill material would either need to be trucked in or borrowed from a location within or near the project site. Importing fill would add a significant cost to the project, particularly due to the remote location of the project area, and would result in added air resources impacts due to truck emissions. See the Section 9 for cost assumptions. In addition, a local borrow site may impact a stakeholder's land and require re-contouring and rehabilitation upon completion of the work. Abandoning the existing road embankment along SR 1 and the crossover road would provide needed fill material for other project components, such as the raising of other roadway sections. Table 11 below shows an order-of-magnitude estimate of the proposed amount of cut and fill proposed for the project based on the conceptual design.

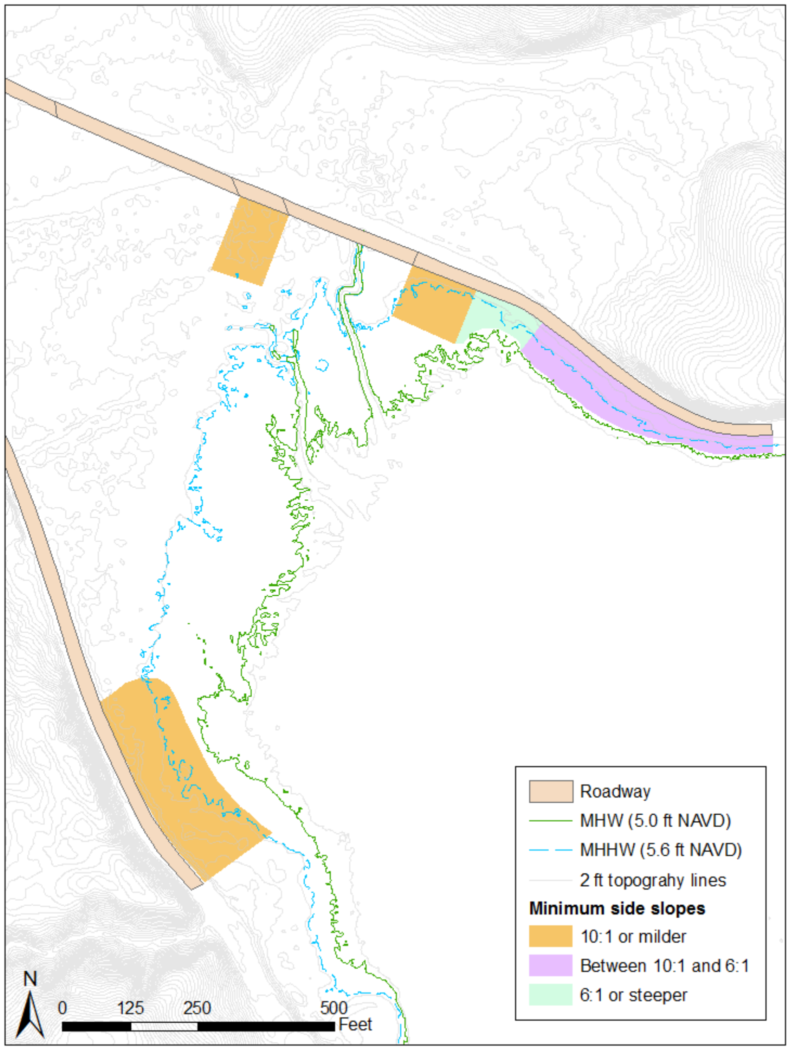
Table 11. Conceptual Design Order-of-Magnitude Excavation and Fill Quantities

Alternative	Construction Phase	Excavation Quantity (CY)	Fill Quantity (CY)	Soil Haul Quantity (CY)
1	Phase 1	7,000	4,000	4,000
	Phase 2	6,000	16,000	16,000
	Phase 3	6,000	21,000	26,000
	Combined Phases	**19,000**	**41,000**	**46,000**
2	Phase 1	7,000	4,000	4,000
	Phase 2	6,000	16,000	16,000
	Phase 3	11,000	30,000	28,000
	Combined Phases	**24,000**	**50,000**	**48,000**
3	Phase 1	7,000	4,000	4,000
	Phase 2	5,000	15,000	15,000
	Phase 3	14,000	29,000	27,000
	Combined Phases	**26,000**	**48,000**	**46,000**

Constraint (CC-CON4): Shading of Vegetation beneath Causeways. Vegetation that would migrate upslope as the sea level rises would pass beneath the causeways. The causeways would provide shading that may reduce the survivorship of plant species that require full sun.

Constraint (CC-CON5): Limited Space for Incorporation of Vegetated Shoreline and Soft Erosion Protection. The distance between the roadway and the MHHW line is narrow in some locations. Figure 27 shows where a vegetated shoreline could be installed. In certain locations a steeper slope of 6:1 and in some places, 4:1 would be necessary due to the distance between the shoreline and the roadway. Note that sea level rise is described by MHHW, which is the average of the higher daily high tide, whereas the boundary of the GFNMS is defined as MHW, the average of the two daily high tides, which is approximately 0.5 feet higher in elevation than MHHW. Additional fill within the lagoon below MHHW may require additional permitting and substantiation of net ecosystem benefits. At narrower locations, designs could include creating a terraced step near or within the MHHW line. Note that Figure 27 shows areas where these slopes would apply based on existing conditions. Depending on the timeline for these efforts, as the sea level rises, the available area will reduce over time.

Figure 27. Vegetated Shoreline Minimum Side Slopes in Project Area



Specific to Alternative 3

Opportunity (CC-OPP1): Construction of Single Span Causeway on SR 1. Under Alternative 3, a single-span causeway would be constructed beside the Bolinas Lagoon to replace an existing section of SR 1. The causeway would be supported on pilings drilled into the sediment using conventional methods. Under the other two alternatives, which each include two causeways connected by a raised berm, preliminary geotechnical analysis suggests that the underlying soil may not support the added weight of engineered fill placed atop the existing ground surface to construct roadways at a higher elevation. As a result, extensive excavation and reinforcement of the underlying ground would be required to construct Alternatives 1 and 2. Alternative 3 requires no such excavation or engineering reinforcement of existing ground to support the overhead causeway and therefore offers an opportunity to reduce construction complexity on the project.

Constraint (CC-CON6): Raising the Stream Channel May Increase Roadway Flooding and Channel Re-Incision Risk. Roadway flooding may occur as a shorter term problem if the Lewis Gulch Creek channel is raised to provide stream access to the existing terrace elevation. Raising the channel would require grade control structures to minimize the potential for channel re-incision through the fill, adding to design and construction costs. The resulting constraint is that the stream may not be able to be raised to its maximum extent in order to avoid roadway flooding. Longer term, the surface water level of the lagoon is elevating with sea level rise and therefore upland groundwater and surface flow elevations are predicted to adjust accordingly.

12.2.2 Habitat Restoration

The habitat restoration subcategory is defined as any design element that is explicitly included in project design to provide habitat restoration benefits to the area. The subcategory is analyzed by taking into account the number of acres of restoration work anticipated, the complexity of constructing and the proposed restoration work, any challenges associated with access to the area planned for restoration, and the distance of restoration work to existing roads and infrastructure. Examples of habitat restoration design elements include restoration of upper Wilkins Gulch Creek through grading and pond excavation and placement of shoreline fill along the edge of the Bolinas Lagoon.

Common to all alternatives

Constraint (CC-CON7): Private Property and Floodplain Restoration. Phase 1 and Phase 3 floodplain restoration work along Lewis Gulch Creek will involve channel and floodplain grading activities within two private properties (APNs 188-140-35 and 188-140-04) located west of SR 1 and Olema Bolinas Road. Proposed Phase 3 roadway activities along Olema Bolinas Road may require excavation or fill within five private properties (APNs 188-140-04, 188-140-60, 188-140-29, 188-140-19, and 188-140-32) located west of Olema Bolinas Road. Landowner interest in the project and amenability to work being performed on their property is unknown. Constructability of this restoration element could be constrained if landowners deny the county access to one or more of these properties and equipment has to leap-frog between stream segments. Project complexity would increase if landowners require extensive contracts and approvals for access to their property.

12.3 Environmental Effects

Environmental effects are defined as the anticipated gains and losses of specific environmental resources of interest in the project area. These resources constitute the subcategories of environmental effects and include: wetlands, creeks, and lagoon area; special-status species; sensitive habitat, and cultural resources. The existing condition of each of the resource subcategories in the project area was obtained from the Site Conditions Report[1]. By definition, the Project is designed to restore and enhance environmental resources in the project area; however, in order to achieve complex restoration goals, it is anticipated that there may be short-term, construction related impacts, including losses, of natural resources. By design, these losses are intended to be more than offset by the long-term gains associated with the restoration of these resources planned under each conceptual alternative.

The infrastructure and grading changes proposed, will have some shorter-term impacts to localized areas as discussed in Section 12.3. However, overall, the project will have net benefits for fish and wildlife, including special status species. In addition to the infrastructure modifications, the project has design components specifically to provide habitat benefits to special status species. For example, when Lewis Creek is rerouted, the existing reach that parallels Olema-Bolinas Road can be formed into small pool habitat that will be fed by fresh ground water from the adjacent hillside to provide breeding habitat for RLF. Similarly, the project proposes to create pool habitat for California red-legged frog in the Wilkens Creek incised channel after the Creek is rerouted to the head of its alluvial fan. Similar pools can be created in the area south of the Wye where the Crossover Road would be removed. Other design components, such as the vegetated soft shoreline protection along the improved and elevated roadways will provide additional high tide refugia for black rails and other waterbirds in the lagoon.

Short term impacts to special status species can be minimized or avoided by timing construction to periods outside of steelhead migration or California red-legged frog breeding periods. Some shift in plant communities are expected as the lagoon moves inland with sea level rise. However, the salt, brackish and freshwater areas will also move inland; it is important to realize that lagoon migration does not result in the loss of freshwater habitats or the “subterranean estuary” below the marsh. A significant benefit on the project is in fact providing the opportunity for the lagoon to naturally adjust with sea level rise and to maintain and improve both the mix and connectivity of wetland and upland habitats. Gains in any of the resource subcategories are related to restoration and rehabilitation of new and existing habitats and therefore considered long-term outcomes. Opportunities and constrains resulting from the three conceptual design alternatives and their associated short and long-term environmental effects are described below.

12.3.1 Wetlands, Creeks, and Lagoon

This resource subcategory includes all mapped wetlands and other waters under federal or state jurisdiction, including named creeks and the Bolinas Lagoon. Effects to wetlands, creeks, and lagoon are understood to be the short term losses and long-term gains to these habitats. Short term losses are from construction activities, and would occur through excavation and grading, placement of fill, and/or placement of permanent structures in these features. Long-term gains in wetlands, creeks and lagoon would occur by removing hardscape barriers in the project area that currently prohibit habitat connectivity and migration in response to changing sea level. Gains and losses under the various alternatives were compared by reviewing the acreage of all features removed during construction and created by removal of hardscape, without giving greater or lesser weight to any category or jurisdiction of feature. The analysis metric used to examine effects to wetlands and lagoon is acreage changes of wetland communities during project construction and long-term site re-establishment. Acreages in increments of 0.25 are provided to provide a high-level estimate of footprint during conceptual design. These are estimates that would be further developed during further project design. Differences in acreage of less than 0.25-acre were not considered significant due to the level of detail and accuracy associated with the underlying conceptual design drawings and mapped extent of vegetation communities.

Common to all alternatives

Near Term

Opportunity (EE-OPP1): Revegetation of Native Plants and Weed Removal. Native vegetation would be planted in areas of soil disturbance and may be considered in portions of the reestablished floodplain in order to assist the establishment of a riparian community. Weeds would be removed from the floodplains and project work areas. Riparian vegetation that will be disturbed during construction can be excavated and replanted where needed. The riparian community would vary along the length of Wilkins Gulch Creek. Seasonal wetland and arroyo willow (*Salix lasiolepis*) thicket communities would dominate the lower portion of the creek near SR 1 and the southern extent of the Wilkins Ranch buildings. Depending on the anticipated fluctuation in the water table, varying species of seasonal wetland and or willow vegetation may be planted surrounding any constructed ponds.

Constraint (EE-CON1): Constrained Lewis Gulch Creek Stream Alignment. Restoration of creek resources on the Lewis Gulch Creek stream alignment on the west side of SR 1 and Olema Bolinas Road is currently constrained between the adjacent hillslope and existing roadways. Because of the need to maintain Lewis Gulch Creek to the west of SR 1 due to property ownership, the extent to which the stream floodplain may be restored is limited. A constrained floodplain area impacts channel morphology and sediment dynamics by potentially increasing the flood elevations and stream energy (affecting channel and bank erosion). Depending on the floodplain design approach in Phases 1 and 3, effective floodplain area could vary. Maximizing the floodplain by relocating to the east side of SR 1 was removed from early conceptual design due to property ownership and differing stakeholder land management goals.

Long Term

Opportunity (EE-OPP2): Rehabilitating Natural Floodplain Processes Would Allow for a Broader, More Robust Riparian Wetland Community. Periodic disturbance from flooding would enhance the existing riparian habitat and would periodically scarify soil and distribute seed, fine sediment, and nutrients to establish more diverse and robust riparian vegetation on the Lewis Gulch Creek floodplain.

Opportunity (EE-OPP3): Removing Barriers and Reinforcing Shoreline with Fill to Stream and Tidal Flow and Wetland Connectivity. Removing barriers to habitat connectivity such as undersized culverts and roadway fill will provide room for riparian, freshwater wetland, brackish marsh wetland, and salt marsh wetland habitats to move landward along a gentle gradient in response to sea level rise. The placement of fill to reinforce shoreline at a 10:1 slope ratio will reduce steeper slopes that are prone to wave erosion, require revetment, and constrain habitat and species biodiversity. Barrier removal would provide an opportunity to enhance existing brackish tidal marsh habitat by allowing for more even redistribution of freshwater flows across a wider area. Additionally, removing barriers would provide an opportunity to increase fish passage for migrating anadromous fish.

Specific to Alternative 1

Constraint (EE-CON2): Limited Extent of Wilkins Gulch Creek Restoration May Lead to Bank Erosion and sediment conveyance. Phase 3 of Alternative 1 does not attempt to actively enhance or improve hydrologic function to the incised portion of upper Wilkins Gulch Creek. As a consequence, bank erosion would continue, and conveyance of coarse bedload and sand from upstream reaches and potential adjacent landslides of the eastern hillside would continue to be deposited more abruptly in the channel(s) and floodplain than under Alternatives 2 and 3. This sediment fan may result in more erratic and frequent shifts in channel position, continuing until the stream naturally widens and aggrades enough to establish a more stable channel and floodplain dimension. Existing bank erosion at the toe of the eastern hillslope may progress and create a large bank slump or continued sliding, which could exacerbate the process or result in gully erosion in a new location.

Opportunity (EE-OPP4): Restoration of Wilkins Creek Floodplain Restricted to Lower Reach. Phase 3 of Alternative 1 does not include restoration of upper Wilkins Gulch Creek, which would require large-scale grading, excavation, and disruption of the existing creek channel. The long-term goal is to restore the creek to its historical floodplain and increase creek, riparian and wetland habitat; however short term construction would still result in a large area disruption and temporary removal of creek and riparian habitat under Alternatives 2 and 3. The absence of this construction work is an opportunity for Alternative 1 to minimize losses of existing creek and riparian habitat. During Phase 3 of Alternative 1, short-term losses to wetlands and open waters are estimated to be approximately less than 0.25 acre, while short-term losses to wetlands and open waters under Alternatives 2 and 3 is expected to be approximately 1.5 acres. Impacts to wetlands and open waters in Phase 3 under Alternative 1 are avoided in Wilkins Gulch Creek as well as the following wetland communities: arroyo willow thickets, coastal brambles, and California annual grassland.

Specific to Alternative 3

Opportunity (EE-OPP5): Increase in New Wetland Habitat from Elevation of SR 1 onto Single Causeway. Under Alternative 3, the removal of a portion of SR 1 combined with the absence of a raised earthen berm would increase wetland habitat connectivity between the east and west sides of the existing SR 1 roadway at the Bolinas-Fairfax Road intersection. The section of SR 1 beside the new causeway would be removed and lowered to match wetland habitat elevations beside the old roadway, thus opening new areas for existing alder willow thicket and red alder forest wetland communities to expand and create larger contiguous wetland areas. The increase in wetland habitat could be as much as 0.5-acre under this alternative given rough estimates of newly available ground surface. The actual area of expansion is uncertain due to unknown rates of recolonization by these wetland communities and uncertain substrate conditions beneath the existing roadbed of SR 1.

12.3.2 Special Status Species

The project area supports habitat for numerous special-status wildlife and plant species. In order to provide an informative yet concise analysis three representative species, one with brackish water habitat needs, one with freshwater habitat needs and one requiring both fresh and salt water, were analyzed. These species include Black rail, California red-legged frog, and steelhead. Gains and losses of special-status species were assessed by considering the area of occupied or potentially suitable habitat for three key species (California red-legged frog, black rail, and salmonids) and how construction activities, duration, and elements might alter their suitable habitat and behavior. The metrics used to calculate impacts to these species included acres of black rail habitat, acres of upland habitat for California red-legged frog, linear feet of potential breeding aquatic habitat for California red-legged frog, and linear feet of steelhead habitat. Subcategories of near term and long term demonstrate that localized near term constraints would yield long term greater opportunities.

Common to all Alternatives

Near Term

Constraint (EE-CON3): Creek Channel Improvements and Surface Dewatering May Impact Aquatic Habitat. In order to modify the Lewis Gulch Creek stream channel, dewatering would be necessary, which could impact aquatic habitat and temporarily prevent aquatic species movement in the stream corridor. Surface dewatering of the channel may temporarily impact aquatic habitat until interstitial spaces in the unconsolidated fill are filled with stream sediments and/or are mobilized and replaced with a sufficient depth of stream deposits.

Constraint (EE-CON4): Potential Loss of Existing Salt Creek Pond Habitat for California Red-Legged Frog. Removing the fill slope separating Salt Creek Pond from the Bolinas Lagoon tidal brackish marsh transition zone, either by installing a single causeway or two bridges and an earthen berm, would increase the salinity of Salt Creek Pond under future sea level rise scenarios. Meeting Goal 1 and removing barriers to flow would produce a constraint to species occupying the freshwater pond and would result in an impact to freshwater aquatic species, including the California red-legged frog, and their habitat. This constraint could potentially be offset through the creation of freshwater pond habitat upslope along Wilkins Gulch Creek.

Constraint (EE-CON5): Potential Channel Habitat Loss on Lewis Gulch Creek. The diversion of Lewis Gulch Greek onto the relict alluvial fan could lead to a near-term and potentially permanent loss of in-channel habitat for anadromous fish, such as steelhead and other aquatic species. The immediate loss of in-channel habitat would inhibit upstream or downstream movement of most life stages of fish species except those that may move through the floodplain at flood stages.

Long Term

Opportunity (EE-OPP6): Rehabilitating Lewis Gulch Creek Floodplain Processes in Phase 3 would result in direct and indirect fish habitat improvements. Reconnected floodplain habitat would provide refugia for steelhead and other native fish during high-velocity discharges in the main channel, and installation of logs, rootwads, and willow vegetation would provide a more complex pool habitat structure as well as shade.

Opportunity (EE-OPP6): Incorporating Higher Micro-Topographical Variations along Lagoon Margins. The placement of shore line fill at a gentle grade along the margins of the lagoon will not only help protect roadway fill from erosion but may also develop into isolated “islands” of fill over time that offer raised substrate to support various brackish vegetation and other mid-stature vegetation. These areas may provide optimal habitat refuge niches for black rail and other shoreline bird species.

Opportunity (EE-OPP7): Reconnecting Streams Improves Species Habitat. Reconnecting the streams at the top of their historic alluvial fans will provide natural hydrologic functions, including allowing for increased freshwater intrusion and a prolonged freshwater ground flow through the area to the lagoon. This will provide improved habitat for California red-legged frog in the small brackish pond and in any small pools created in the Wye or along Wilkens Creek.

Opportunity (EE-OPP8): Replacing and Upgrading Culverts Improves Species Habitat Replacing and upgrading undersized culverts will allow the streams to naturally connect to the lagoon and provide much better fish passage for steelhead adults and smolts. Undersized culverts are notorious for interrupting fish migration, especially when compromised with sediment load as are the culverts on the project area.

Opportunity (EE-OPP9): Causeways Provide Transition Zone Habitat. Causeways (and to a lesser extend bridges and large box culverts) will allow future expansion of Bolinas Lagoon and provide a continuous low to high marsh to upland transition zone as sea level rises. This transition zone will also allow for the freshwater and brackish plant communities to move inland with lagoon expansion, providing high tide refugia for black rails and other water birds. It will also provide corridors for California red-legged frog to migrate upland to freshwater habitat as sea level rises.

Specific to Alternatives 1

Opportunity (EE-OPP10): Reduced Loss of Special-Status species Habitat during Phase 3 Construction. The absence of restoration construction activities in Upper Wilkins Gulch Creek during Phase 3 of Alternative 1 reduces the anticipated short-term losses of special-status species habitat. The area around the existing upper portion of the drainage is mapped as suitable dispersal and aestivation habitat for the species and would be disturbed and/or removed during Phase 3; however, ample dispersal habitat for the species is found immediately adjacent to the work area outside of the project construction footprint. This presence of suitable adjacent habitat lessens the value of preserving suitable California red-legged frog upland habitat offered by Alternative 1, as individual California red-legged frog are mobile and would likely disperse outside the project area.

The short-term loss of steelhead habitat, California red-legged frog non-breeding and California red-legged frog potential breeding habitat in creeks is also substantially lower under Alternative 1 due to the absence of work in Upper Wilkins Gulch Creek. During Phase 3 of Alternative 1 no steelhead habitat would be impacted while approximately 1,650 linear feet of steelhead habitat would be filled or excavated for flood plain re-routing and expansion during Phase 3 under Alternatives 2 and 3. Approximately 150 linear feet of California red-legged frog non-breeding habitat would be filled or excavated during Phase 3 of Alternative 1, while an approximately California red-legged frog linear feet would be filled or excavated under Phase 3 of Alternatives 2 and 3. Unlike adjacent dispersal habitat, there is no hydrologically connected adjacent habitat for California red-legged frog to use during construction or the recovery period immediately afterwards. It is anticipated that these habitat losses will be minimized by performing construction during the dry season, and that the impacted creek will be restored to functional flow by the start of the wet season. Additionally, restoration of the floodplain in Phase 3 under Alternatives 2 and 3 includes creating additional, highly desirable breeding and non-breeding habitat for California red-legged frog which is not included under Alternative 1 and would offset short-term losses of potential California red-legged frog breeding habitat.

Specific to Alternatives 2 and 3

Opportunity (EE-OPP11): Increase in Special-Status Species Habitat through Upper Wilkins Gulch Creek Restoration. Restoration of upper Wilkins Gulch Creek floodplain will greatly increase the amount of wetlands habitat in the project area, and will thereby increase the greater value of the entire creek landscape in the project area. Restoration of upper Wilkins Gulch Creek would increase habitat quality for California red-legged frog and steelhead, along with many other wildlife and plant species.

Specific to Alternatives 3

Opportunity (EE-OPP12): Removal of Hydrologic Barrier and Expansion of Brackish Aquatic Habitat at the Wilkins Gulch Creek Confluence with Bolinas Lagoon. Placement of SR 1 on a single causeway would provide increased access to Wilkins Gulch Creek for spawning salmonids, including steelhead. In addition, low-lying areas east of SR 1 at the foot of salt creek could function as protected estuarine nurseries for young salmonids. Black rail habitat would also be expanded with the removal of SR 1 as a hydrologic barrier and free-movement of lagoon tidal waters into the Salt Creek estuary.

Constraint (EE-CON6): Removal of Hydrologic Barrier and Expansion of Brackish Aquatic Habitat at the Wilkins Gulch Creek Confluence with Bolinas Lagoon. The removal of SR 1 as a hydrologic barrier between Salt Creek and the Bolinas Lagoon would increase tidal influence and the extent of brackish marsh at the foot of Salt Creek. This is important because freshwater and brackish water habitat will not disappear with sea level rise, but will migrate inland. The existing freshwater marsh, which includes a documented occurrence of California red-legged frog, is assumed to provide potential breeding habitat for the species, habitat which would be degraded by salt water intrusion and rendered unsuitable for the species which does not breed in saline environments.

Specific to Alternatives 2 and 3

Opportunity (EE-OPP13): Creating Pond Habitat that Supports the Federally Threatened California red-legged frog. New ponds will be created along Wilkins Gulch Creek in Phase 3 of Alternatives 2 and 3. These new ponds would serve as habitat refugia and potential breeding habitat higher up the floodplain for California red-legged frog and other species, and would be protected from sea level rise. Alternate locations for pond habitat creation could occur along the crossover road or other areas within the project footprint, depending on the alternative chosen.

12.3.3 Sensitive Habitat

Sensitive habitat is defined as all vegetation communities identified in the project area that are listed in the site conditions report as rare in California (rank S1, S2 or S3). These include alkali bulrush marshes, coastal brambles, pickleweed mats, and California bay forest. In addition, all riparian communities in the project area are considered sensitive habitat as their removal is regulated by the California Department of Fish and Wildlife under their lake and stream bed alteration program. The analysis metric used to examine effects to sensitive habitat is acreage of sensitive vegetation communities removed or disturbed during project construction. Differences in acreage of less than 0.25-acre were not considered significant due to the level of detail and accuracy associated with the underlying conceptual design drawings and mapped extent of vegetation communities.

Common to All Alternatives

Near Term

Constraint (EE-CON7): Riparian Tree Removal to Widen Lewis Gulch Creek Effective Floodplain. The current narrow stream channel width does not provide the flood width necessary for Lewis Gulch Creek in its existing alignment. Removal of oak riparian habitat, including a number of large riparian trees, is likely required in order to widen the stream channel of Lewis Gulch Creek and promote a more natural flow. Depending on the depth of excavation, existing tree densities, and tree locations, the effective flood area gained may not be as desired without the removal of trees or without potentially impacting tree health and limiting the size of this mature riparian corridor.

Constraint (EE-CON8): Loss of Alkali Bulrush Marsh and Pickleweed Mat Vegetation from Placement of Structures and Fill in Lagoon. Approximately one-acre of sensitive alkali bulrush marsh and 0.5-acre of sensitive pickleweed mat vegetation is anticipated to be removed during project construction due to the placement of fill and pilings in the project area for roadway elevation, shoreline fill placement, and road widening. Both sensitive vegetation communities are anticipated to re-establish after project completion, due to the abundance of adjacent acreage and local seed sources. As all vegetation communities move north and eastward into hydrologically connected and accessible habitat within the Bolinas Y and on newly placed shoreline fill, additional suitable acreage for colonization of these habitats are anticipated to be readily colonized.

***Constraint (EE-CON9): Loss of Alder Riparian Forest with Removal of Crossover Road*.** Despite plans for re-vegetation (re-planting and direct seeding) in all areas disturbed by project construction, the removal of the crossover road will allow saline lagoon flows to reach farther into the Bolinas Wye thus displacing less than 0.25-acre of alder riparian forest in the area.

Opportunity (EE-OPP14): Weed Removal and Restoration Replanting will Support Long-Term Health of Sensitive Habitat. Removing invasive species and revegetating all disturbed areas with native, locally adapted plant species, as proposed under all design alternatives, would support long-term site health by providing food sources and habitat for fish and wildlife species that live in and pass through the project site, therefore supporting sensitive habitat values. Supporting continued development of a diverse assemblage of native vegetation communities and plant species (rather than allowing the site to revegetate with aggressive weedy species) at the site would provide better long-term habitat resilience under changing climate scenarios as better suited native communities back-fill into areas left unoccupied by communities that are less resilient/unable to adjust to changing climate conditions.

Long Term

Opportunity (EE-OPP15): Reestablishment of Historical Riparian Wetland Habitat would occur over time through the process of ecological succession and the reestablishment of surface water flows. The middle portion of the alluvial valley, just above Wilkins Ranch, may evolve to include tree species, such as coast live oak (*Quercus agrifolia*) and California bay (*Umbellularia californica*) outside of a rich willow-riparian forest. The expansion of the creek out onto its historical floodplain will promote greater soil moisture across the alluvial fan and support riparian species that currently cannot persist in the middle portion of the valley. Upstream, where the valley and stream transitions to the surface of the fan, coast live oak, big-leafed maple (*Acer macrophyllum*) and California bay may establish. Historical maps indicate that oak savannah existed in the lower area of the alluvial fan.

Specific to Alternative 1

Opportunity (EE-OPP16): Preservation of Existing Arroyo Willow Thicket and Coastal Brambles. In the absence of restoration on Upper Wilkins Gulch Creek in Phase 3 of Alternative 1, losses to arroyo willow thickets and coastal brambles are minimized. The loss of sensitive habitat due to construction activities is reduced from 2 acres under Alternatives 2 and 3 to 1.5 acres under Alternative 1 due to the absence of restoration in Upper Wilkins Gulch Creek.

Specific to Alternative 2 & 3

Opportunity (EE-OPP17): Rehabilitating Wilkins Gulch Creek Floodplain and Excavating Ponds. The proposed method of filling the incised upper reach of Wilkins Gulch Creek with soil material excavated for ponds immediately downslope of the drainage would minimize the need to import fill from remote on-site or off-site locations. Using local fill material in the restoration design would benefit sensitive habitats by reducing the risk of importing weeds or other pathogens not currently found on-site.

12.3.4 Cultural Resources

Environmental effects regarding cultural resources were examined by assessing how many unique cultural resources areas within the project area would be impacted by project components and disturbance (placement of structures, excavation, grading, and /or fill) under each alternative. This analysis took into account not only known historic sites, but areas that were determined to have the potential to contain sensitive resources based upon our understanding of historic land-use and deposition patterns, such as the head of the Bolinas Lagoon. Unlike other environmental effects subcategories, there are no anticipated cultural resource gains associated with the project. Discovery and preservation of new cultural resources is not typically included as a project benefit and is not anticipated under any of the conceptual alternatives.

Common to All Alternatives

Constraint (EE-CON10): Disturbance of Known Cultural Resources in Lewis Gulch Creek. Three cultural resource sites are identified in Lewis Gulch Creek. Before ground disturbing work could be initiated in the Creek and within its floodplain the sites would need to be further evaluated to determine significance. Evaluation of the sites, including detailed investigation and documentation, may result in additional discoveries and would likely require consultation with the State Historic Preservation Officer (SHPO) to identify mitigation for effects to cultural resource sites, including unavoidable losses of sites in the path of road elevation or creek widening.

Constraint (EE-CON11): Potential for Buried Cultural Resources Associated with Alluvial Deposition at the Head of Bolinas Lagoon. The Bolinas lagoon has a rich history of diverse prehistoric and historic uses and is subject to active alluvial deposition. As a result, there is high potential for significant cultural resources to be buried in the project area, particularly at the head of the lagoon. Removal of the cross-over road and associated work in the area under all three alternatives has the potential to disturb buried cultural resources, and a geoarchaeological investigation would be required to evaluate the area and determine the presence of resources as well as need for mitigation for anticipated effects to buried resources.

Specific to Alternatives 2 and 3

Constraint (EE-CON12): Restoration of Upper Wilkins Gulch Creek May Increase Flood Risk to Wilkins Ranch. Returning streamflow to the surface of the Wilkins Gulch Creek alluvial fan under Alternatives 2 and 3 could increase the flood risk to historical buildings at Wilkins Ranch during large storms. Hydraulic modeling would be necessary to determine if and to what extent any flooding could occur that might or might not affect the ranch. In addition, due to the complexity of the site further documentation of historic buildings on the ranch may be required to characterize significance of the site.

Constraint (EE-CON13): Restoration of Upper Wilkins Gulch Creek May Disturb Cultural Resources. A preliminary cultural resources investigation identified four cultural resources in the Upper Reach of Wilkins Gulch Creek. Large-scale earth moving and creek work in the upper reach of Wilkins Gulch Creek proposed under Alternatives 2 and 3 would result in the removal of some oak riparian forest and ground disturbance that could disrupt these cultural resource sites. Detailed cultural resource investigations in the area would need to be undertaken and documented in before work is initiated in the upper reach of the creek.

12.4 Social Considerations

The Social Considerations category addresses subjective changes in the quality and value of the project area for people who rely upon it as residents, recreationists, or tourists. The subcategories examined in this analysis include surrounding community, traffic, and tourists / recreation. Opportunities and constrains resulting from the three conceptual design alternatives and their effect on each social consideration subcategory are described below

12.4.1 Surrounding Community

The surrounding community subcategory focuses primarily on residents of Bolinas, Stinson Beach and Olema and their experience living in and moving through the project area during project construction. In particular changes in the visual and auditory character of their familiar landscape are compared between alternatives. This subcategory also takes into consideration uncertainty or additional irritation associated with travel through the project area that may result from construction under the various alternatives.

Common to All Alternatives

Constraint (SC-CON1): Visual Impact of Causeways and Raised Roadway along Bolinas Lagoon. The development of one or more elevated causeways and raised roadways along Bolinas Lagoon will change the visual aesthetics of the Bolinas Lagoon North End, as the road surface would be raised approximately 7 to 8 feet above the existing roadway grade and be more visible from various vantage points. Causeway and roadway design should incorporate elements that reduce the aesthetic impact.

Constraint (SC-CON2): Visual Impact on Wilkins Ranch Cultural Landscape. The development of one or more elevated causeways and raised roadways along Bolinas Lagoon and associated project restoration in Wilkins Gulch Creek floodplain resulting in vegetation changes, as existing upland grasslands may be converted to wetland, willow, and riparian habitat overtime, will change the visual aesthetics of the Bolinas Lagoon North End, as the road surface would be raised approximately 7 to 8 feet above the existing roadway grade and be more visible from various vantage points. Furthermore, should future analysis determine that a flood protection levee berm is necessary at Wilkins Ranch, the aesthetic impact of such a levee berm could detract from the historical value of the ranch property. While the berm would be small, it would be different than exactly how the landscape looks at present. Alternatively a floodplain could be excavated down from the current fan surface generating fill for the incised channel, but this would result in a higher construction cost, would remove any relict channels that may be recaptured initially by the stream, and could impact other areas than might otherwise not need to be impacted.

Constraint (SC-CON3): Unfamiliar Driving Patterns with use of Horseshoe Hill Road and Removal of Crossover Road. Despite the long-term opportunity afforded the community by a more resilient Olema Bolinas roadway and safer intersection with SR 1, community members will likely require time to adjust to familiar routes being unavailable (the cross-over road) or slower (Horseshoe Hill Rd. traffic diversion). The absence of the Crossover Rd. may be perceived as a delay to local users, as it is considered a local “short-cut”, regardless of actual time savings. Horseshoe Hill Rd. is a notably slower route to SR 1 from Bolinas than the Olema Bolinas Road, and additional traffic on Horseshoe Rd. during construction may increase transit time to and from Bolinas as well as cause delays for the fifteen or so residences with driveways directly off of Horseshoe Hill Rd. Additionally, residents along Olema Bolinas Road. will have a longer commute to SR 1 than they are familiar with during Phases 1 and 3 while the roadway is closed and rebuilt.

Constraint (SC-CON4): Landowner Permission and Coordination. There are several landowners in the project area, both private and public entities, which may have different goals and perspectives on managing the landscape. Restoration and design changes must meet the goals and needs of the different stakeholders, landowners, and parties in order to be successfully accomplished. For instance, Lewis Gulch Creek crosses through four pieces of private property along Olema Bolinas Road and all four owners would need to give the project proponent their approval to complete proposed creek restoration work on the portions of the creek under their ownership. The project may be constrained by landowners if design components such as floodplain restoration on Lewis Gulch Creek and upper Wilkins Gulch Creek, and roadway modification at the intersection of Bolinas-Fairfax Road and SR 1 are deemed infeasible as a result of differing landowner goals.

Unique to Alternatives 2 and 3

Constraint (SC-CON5): Noise and Visual Disturbance from Restoration of Upper Wilkins Gulch Creek. Noise and visual construction disturbance, particularly related to large trucks transporting excavated material around the Upper Wilkins Gulch Creek channel during grading and re-shaping, is anticipated to disturb residents on the northeast end of Horseshoe Hill Road during the period of construction. Residents traveling along SR 1 beside the Ranch may also be impacted by the truck and construction noise and, to a lesser degree, the visual disturbance of unfamiliar construction equipment and trucks in the drainage, if they look to the east.

12.4.2 Traffic

The traffic subcategory includes changes in traffic patterns and the impact of those changes on traffic in the project area. This includes an examination of increases in vehicles on project-area roadways during construction, changes in time of use and road congestion, and availability of adequate detours. This subcategory also includes considerations of delays and re-routes that would affect transit time.

Common to All Alternatives

Constraint (SC-CON6): Limited Extent of Roadway Sea Level Rise Adaptation. The project only addresses sea level rise impacts to roadway flooding within the extent of the project area, which is a small portion of vulnerable roadway bordering the lagoon. Data suggest that under mid- and late-century sea level rise projections, flooding will occur along low-lying stretches of SR 1 outside of the project area for approximately 3.8 miles south to Stinson Beach. The cost of construction of a causeway from the project area to Stinson Beach is beyond the scope of this project and therefore traffic delays from flooding on the remaining portion of SR 1 would not be addressed by this project.

Constraint (SC-CON7): Increase in Truck and Equipment Traffic on Roads During Construction. The Project site is expected to experience an increase in vehicular traffic, particularly by trucks and equipment, on SR 1 and the Olema Bolinas Road during all periods of construction. In particular, raising the Olema Bolinas Road during Phases 1 and 3 will temporarily disrupt local traffic into and out of Bolinas, by re-routing local traffic onto Horseshoe Hill Road, a rural residential road that is not designed to for regular through traffic. During construction of the causeways on SR 1 and related activities, traffic will remain on the current alignment of SR 1 however may be slower as motorists adjust to construction equipment, views, and periodic truck congestion. Although traffic is anticipated to increase incrementally on Bolinas-Fairfax Road, the roadway is infrequently used and seasonally closed, limiting anticipated disruption to current traffic patterns.

12.4.3 Tourists / Recreation

The tourist/recreation subcategory is designed to capture the opportunities and constraints associated with non-resident users of the project area. Opportunities and constraints examined under this subcategory include a consideration of changes in access to recreational past-times such as hiking, biking, bird watching, fishing, and photography (scenic views) throughout the project area.

Common to All Alternatives

Opportunity (SC-OPP1): Increased Public Recreational Access in Project Area. The removal of the crossover road and surrounding restoration activities would offer public benefits by increasing public parking access to the project area. A small portion of the existing Connector Rd. at the intersection with Olema Bolinas Road could serve as a turnout or parking area for project interpretive signage, a raised boardwalk, and/or a trailhead to trails that wind through and along the streams and riparian corridor in the Bolinas Wye. Other unique features, such as an elevated viewing platform, could be incorporated for the public to view the project and lagoon from a treetop perspective.

Opportunity (SC-OPP2): Providing a Class II Bicycle Lane. Roadway design under all three alternatives includes a devoted bike lane and sufficient width to safely accommodate cyclists. The devoted lane would not only increase safety for cyclists who already use this scenic corridor for recreation but potentially encourage new user groups. The presence of a safe, devoted bike lane may encourage new groups such as families and foreign tourist parties, which tend to prioritize safety in their recreation planning, to explore the area more extensively.

Unique to Alternative 3

Opportunity (SC-OPP3): Expansion of Lagoon Habitat and Wildlife Viewing under the SR 1 Causeway. Under Alternative 3, the single SR 1 causeway would indirectly increase recreational opportunities for bird-watching by opening and expanding lagoon habitat, and occupancy by lagoon-dependent species, into the area east of SR 1 and south of Bolinas-Fairfax Road. Bird watching and photography of lagoon species is currently limited in the project area by narrow road-shoulders and narrow pullouts along SR 1. The expanded lagoon area at the foot of Salt Creek is accessible by foot from protected vehicle pullouts along Bolinas-Fairfax Road and safely removed from SR 1 traffic.

Opportunity (SC-OPP4): Complete Opening of Wilkens Gulch Creek Floodplain and Channel. The combination of a fully elevated causeway and extensive channel restoration, as proposed under Alternative 3, would dramatically enhance recreational opportunities in the project area by providing contiguous habitat for migrating salmonids up Wilkins Gulch Creek, offering the public ample viewing opportunities to observe and study salmonid migration. Although Alternative 2 also provides expanded floodplain habitat in upper Wilkins Gulch Creek, it does not provide the same downstream benefit of the open single causeway and therefore is not assumed to provide as much opportunity for habitat connectivity and resulting recreational enjoyment and viewing.

12.5 Project Goals

The project goals category addresses the opportunities and constraints associated with meeting the specific project goals. Subcategories examined under project benefits include increased climate resilience, hydrologic connectivity, and road safety. Project benefits associated with resources under the Environmental Effects category are addressed within section 12.3. Opportunities and constrains resulting from the three conceptual design alternatives and their effect on each Project Benefit subcategory are described below.

12.5.1 Climate Resilience

Climate resilience in the context of the proposed project is defined as the capacity of infrastructure and systems in the project area to experience changing climate conditions (particularly sea level rise) and retain the essential functions they are designed to provide (roadway safety, natural habitat for diverse species, and scenic character).

Common to All Alternatives

Opportunity (PB-OPP1): Providing Space for Upslope Migration of Species and Habitats under Rising Tides and Future Climate Change Scenarios. The project area supports a diverse assemblage of natural habitats and species, and their ability to adapt under future sea level rise scenarios is currently constrained by roads and other passage barriers (undersized culverts and channelized drainages) in the project area. Proposed restoration and infrastructure elements such as elevated causeways, roadway removal, and stream-channel widening, would improve sea level rise resiliency and provide the environment maximum capacity to develop appropriate self-sustaining habitats as climate changes.

Constraint (PB-CON1) Roadway Raising along SR 1 Confined to Project Area. While raising SR 1 in the project area will increase resiliency to sea level rise, the roadway elevation is at risk of sea level rise inundation extending beyond the project area south to Stinson Beach. Thus, the areas to the south along SR 1 would still be at risk to sea level rise.

Constraint (PB-CON3): Climate Science Uncertainty. Despite best available present day models and projections, climate resilience planning and prediction is an evolving science, and therefore the outcomes of Phases 2 and 3, which would occur at a later date, are less certain. These phases are higher in cost and rely on modeled scenarios that may change over time as climate science, modeling, and assumptions improve. For example, the amount and location of shoreline fill designed to achieve anticipated restoration and climate resilience benefits are based upon expectations that Phase 3 would occur in the near term (within 15-20 years). If Phase 3 is delayed until mid-century or later, the band of the shoreline fill slope will have diminished due to sea level rise. Beyond mid-century, the fill-slope approach may no longer be feasible. Additionally, future sea level rise rates may vary from projected rates, which would further affect the timeline of appropriateness for installing such features. Land use, habitat, hydrology, and landownership may also change over time and potentially result in a lower level of project confidence with the conceptual design alternatives presented in this report for Phases 2 and 3.

Specific to Alternative 3

Opportunity (PB-OPP2): Improving Stream Drainage and Hydraulic Conveyance on Wilkins Gulch Creek. Resiliency to sea level rise, particularly reductions in projected roadway flooding / roadway maintenance, is best accomplished under Alternative 3. The single elevated causeway and bridged portion of the Bolinas-Fairfax Road would provide the greatest resiliency to rising sea level and uncertain future climate scenarios by providing the fewest structural barriers to the Bolinas Lagoon expanding into a larger, more resilient estuary. The expanded flood plain of Wilkins Gulch Creek would complement the larger estuary area by reducing the flood potential from up-stream flows that may increase with extreme weather events predicted under climate change scenarios.

12.5.2 Hydrologic Connectivity

Benefits to hydrologic connectivity include all project elements that aim to reconnect hydrologic components in the project area and promote unimpeded flows through these components. Benefits to hydrologic connectivity include removal of hydrological barriers such as undersized culverts, increases in linear length of unobstructed flows, and increased connectivity between historically connected hydrologic features such as creeks, floodplains, wetlands, and the lagoon.

Common to All Alternatives

Opportunity (PB-OPP3): Reconnecting Wilkins Gulch and Lewis Gulch Creeks to their Relict Floodplains. This will restore more natural streamflow paths to the lagoon. Removal of road segments that currently act as barriers to the natural flow will allow stream channels to migrate more freely across the floodplain and adapt to changing climate and sea level conditions. Sediment loading to the lagoon should be reduced, and there is greater opportunity for deposition of woody debris on the floodplain rather than into the lagoon. Peak flows to the lagoon will become smaller and less flashy. Diversity of riparian habitats and associated species will increase. Erosive flows will be reduced within the existing channels during flood events allowing for more distributed conveyance and deposition of sediment and nutrients across the riparian corridor.

Opportunity (PB-OPP4): Removing the Flow Restrictions Caused by Existing Culverts and Roadways. This will allow for greater exchange of tidal and stream freshwater flows between the uplands and tidelands. This will promote natural scour of the channels and lessen sedimentation and flooding issues. It will also allow natural transitions for migrating species and plant succession.

Opportunity (PB-OPP5): Increasing the Frequency of Overbank Flows and Raising the Water Table Elevation. These two opportunities would result from two proposed approaches to Lewis Gulch Creek floodplain rehabilitation under all three project alternatives. One approach is to excavate and lower the existing floodplain which would increase the frequency of flood flows onto a new floodplain and have the added benefit of generating fill material that could be used for other project components, but it would lower the water table. An alternative approach includes raising the streambed which would have the added benefit of raising the water table elevation and may benefit existing vegetative communities by not disturbing existing vegetation on the reoccupied floodplain.

Constraint (PB-CON5): Lewis Gulch Creek Bridge Location Elevation. The design of a bridge over Lewis Gulch Creek on Olema Bolinas Road is constrained by the low relative elevational difference between the bed of the stream and the roadway overcrossings of Olema Bolinas Road and SR 1. As a result, there is minimal space for woody debris to pass under the bridge without becoming obstructed. This poses a constraint to meeting Goal 2 and reducing roadway flooding, because the stream may not have enough capacity to flow beneath a bridge in this location during large storm events. Hydraulic modeling is necessary. Furthermore, the Bridge is also confined in location, preliminary calculations show the bridge could occur 200 to 250 feet south of the SR 1 and Olema Bolinas Road intersection, due to topographic variation. On the approach, the stream channel will be required to make a fairly sharp left turn to pass under the road bridge. It may be more hydraulically beneficial to have the stream maintain its southeastward flow as it heads into the newly opened Y area. This would require reconfiguring the road junction and/or elevating SR 1.

Constraint (PB-CON6): Private Property within Lewis Gulch Creek Restoration Area. Phase 1 and Phase 3 floodplain restoration work along Lewis Gulch Creek will involve channel and floodplain grading activities within two private properties (APNs 188-140-35 and 188-140-04) located west of SR 1 and Olema Bolinas Road. Proposed Phase 3 roadway activities along Olema Bolinas Road may require excavation or fill within five private properties (APNs 188-140-04, 188-140-60, 188-140-29, 188-140-19, and 188-140-32) located west of Olema Bolinas Road. The ability of the restoration effort on Lewis Gulch Creek to provide hydrology benefits to the project is based on the assumption that the entire reach be restored. Hydrologic connectivity could be hindered if landowners deny access to segments of the creek located on one or more of these private properties.

Specific to Alternatives 2 and 3

Opportunity (PB-OPP6): Restoring Upper Wilkins Gulch Creek with its Relict Floodplain. Under Alternatives 2 and 3 the incised channel of upper Wilkins Gulch Creek would be filled in order to redirect flow to the head of the alluvial fan. This restoration action would provide an opportunity to expand the existing floodplain and reconnect to the full extent of the relict floodplain, raise the seasonal water table, and distribute sediment and nutrients along the length of the fan as opposed to confining the distribution of sediment and organic materials in the lower reaches of the creek. Redirecting the flow would allow for changes in the surface and ground water flows that could result in recruitment of riparian species through the distribution of seed and nutrients.

Specific to Alternative 3

Opportunity (PB-OPP7): Further Reducing Flow Restrictions and Restoring more Contiguous Floodplain Processes. Reducing flow restrictions and restoring more contiguous floodplain processes in proposed Alternative 3 causeways at Wilkins Gulch Creek, Salt Creek, and Bolinas-Fairfax Road *would* enhance the ecological value of the Wilkins Gulch Creek corridor and provide additional space for landward migration of habitats and species in response to sea level rise. Removing existing road embankments would provide further connection. This would increase the ecological and hydrologic resiliency of the North End in the face of climate change.

Opportunity (PB-OPP8): Removing the “Diverted” Channel from the Base of the Eastern Hillslopes. This will increase hillslope stability by reducing potential for stream incision. It will also reduce the landslide-related delivery of coarse and fine sediments from all the landslides on the eastern hillslope, adjacent to the alluvial fan.

12.5.3 Infrastructure/Road Safety

The road safety subcategory applies to elements that make roadways safer for people both in cars and on bicycles or other forms of transportation. Considerations include visibility, road width and striping, accessibility for various forms of transportation (i.e. cars, bicycles, busses, and pedestrians), time spent by construction crews working in proximity to vehicular traffic, and other safety concerns associated with multiple user groups attempting to access the same roadways.

Common to All Alternatives

Opportunity (PB-OPP9): Reducing Road Maintenance for the Marin County Public Works Department. Reducing road maintenance frequency and effort is a potential project opportunity, as the project would reduce sedimentation and flooding issues that require maintenance at Wilkins Gulch Creek, Salt Creek, and Lewis Gulch Creek. Decreased road maintenance would benefit road safety as well as reduce county costs. Road maintenance needs would be reduced by replacing or removing undersized culverts with larger culverts or bridge crossings, thus altering the approach angle of channels upstream of culverts, and installing headwalls.

Opportunity (PB-OPP10): Increasing Traffic Safety. The high skew angle at the intersection of the crossover road to SR 1 is a safety hazard as visibility for cross-traffic is limited. Furthermore, the crossover road has safety issues associated, including blind corners at each end intersection, is a narrow road, motorists routinely travelling at excessive speeds, among others. By removing the crossover road, reconfiguring existing intersections in the project area, and adding devoted bike lanes, traffic and public safety is improved under all alternatives.

Opportunity (PB-OPP11): Reduce Short- and Long-term Roadway Flooding. Raising roadways and improving stream drainage and hydraulic conveyance through (currently) undersized culverts by enlarging existing culverts or replacing them with a causeway in Wilkins Gulch and Lewis Gulch Creeks would provide an opportunity to increase roadway safety by reducing localized flooding.

Specific to Alternative 3

Opportunity (PB-OPP12): Reducing Quantity of imported Fill Required to Raise the Roadway. At a qualitative level, raising SR 1 on a single long causeway instead of a causeway plus fill approach would inherently reduce the amount of fill required on the project.

12.6 Environmental Review and Potential Impacts

12.6.1 CEQA

The California Environmental Quality Act (CEQA) applies to projects requiring a discretionary action to be taken by the State or a local public agency (Public Resources Code [PRC] §21080). The proposed project would require the County of Marin to approve a land use permit to authorize the project and therefore must comply with CEQA. The County of Marin is not only the project proponent but is anticipated to take the role of CEQA lead agency for the project. In order to comply with CEQA, the County would need to prepare environmental documentation describing the anticipated impacts of the project on various environmental factors. Impacts, as defined under CEQA, are likely to occur during project activities throughout the project area, particularly at the north end of the Bolinas Lagoon and along Lewis and Wilkins Gulch Creeks where sensitive environmental resources and receptors are concentrated. Potential impacts to the following environmental factors may occur as a result of the proposed project:

Air Quality. Truck and equipment emissions and associated dust during project construction may impact air quality in the vicinity of the project area. However, emissions from construction equipment is not anticipated to result in a cumulatively considerable net increase in criteria pollutants nor expose sensitive receptors to substantial pollutant concentrations.

Biological Resources. Impacts to special-status species, sensitive habitats, and jurisdictional wetlands and other waters may occur as a result of placement of fill material and structures in natural habitat within the project area. The following sensitive resources are present and could potentially be affected by the projects: federally- and state-listed wildlife species, potentially jurisdictional wetlands and open waters, a sensitive estuarine habitat, the Bolinas Lagoon, and riparian vegetation along Wilkins and Lewis Gulch Creeks.

Cultural Resources. Cultural resources such as Wilkins Ranch, could be impacted by project activities if modifications to the floodplain of Wilkins Gulch Creek change drainage patterns at the ranch site. In addition, the expansion of the Wilkins Gulch Creek floodplain to the margin of the Bolinas Lagoon could directly or indirectly modify unique buried geoarchaeological or paleontological resources. Further detailed studies would be required to determine the extent of these potential impacts and possible mitigation.

Hydrology/Water Quality. Water diversions and alteration to the existing drainage pattern of the project site could lead to temporary decreases in water quality and temporary disruptions of hydrologic processes in the project area; however, the project is anticipated to provide an overall benefit to localized hydrology and water quality by restoring natural floodplain connectivity and capacity, and increasing the resiliency of the site to flooding and sea-level rise.

Transportation/Traffic. Removal of the crossover road could impact transportation and traffic patterns by causing a temporary increase in traffic as local residents acclimate to new patterns and to higher concentrations of construction vehicles. Traffic may also increase along SR 1, as project construction may require lane closure and lead to a reduced level-of-service during the construction period of each project phase.

Beneficial Impacts. The project will allow the public year-round access to the town of Bolinas from the Olema Bolinas Road where it connects to SR 1. It will provide improved safety for drivers near the junction and additional safe turn-outs along SR 1.

Overall the project is a restoration and resiliency project that will improve terrestrial and aquatic habitat connectivity, reconnect anadromous fish habitat between the lagoon and upstream freshwater spawning sites, and enhance environmental processes that add a net benefit to the landscape. The majority of project impacts would be temporary when compared to the longer-term benefits and would occur during the construction phase of the project. Best management practices along with avoidance, mitigation, and minimization measures would reduce project impacts.

The proposed project is divided into three independent phases, which exhibit independent utility and therefore may address compliance under CEQA independently. A programmatic CEQA document is not recommended for the overall project, as it would delay the start of Phase 1, which is anticipated to be the Phase with the fewest environmental impacts. As such, it is anticipated that Phase 1 could be addressed with an initial study and mitigated negative declaration (IS/MND) while environmental impacts associated with Phase 2 and 3, which are more complex and anticipated to take much longer, may each require full documentation in Environmental Impact Reports (EIR). An EIR may be avoidable under Phase 3 of Alternative 1; however is likely to be required under Phase 3 of Alternatives 2 and 3 due to potentially unavoidable cultural resource and biological resource impacts associated with major construction work in Upper Wilkins Gulch Creek.

12.6.2 NEPA

For all project phases that obtain federal funding and/or occur on federal lands, the National Environmental Policy Act (NEPA) compliance would be required. Given the extent of National Park Service (NPS) lands within the project area, it is anticipated that the NPS would act as NEPA lead agency. Ideally, the NEPA process would be completed in joint CEQA/NEPA document where NEPA analyses are provided under each environmental resource factor. Joint IS/MND-Environmental Assessments (EAs) would be anticipated for Phase 1 while a joint EIR/Environmental Impact Statement (EIS) would be anticipated for Phases II and potentially Phase 3 under some of the alternatives.

12.7 Natural Resource Regulatory Permitting

Regardless of the chosen alternative, construction of the project will require the County to obtain a range of regulatory approvals and permits for planned construction. Under all three alternatives, project construction, particularly placement of permanent structures, is anticipated to occur within sensitive natural habitats that support special-status species and other jurisdictional resources. Due to the complex mixture of land ownership rights and the relatively narrow corridors for transportation and utilities, avoiding all impacts to sensitive natural resources through project design is unlikely and could compromise project goals. The regulatory agencies involved in permitting the project would include federal, state, regional, and local entities. The following discussion presents the regulatory statutes and agencies with potential jurisdiction over natural resources in the project area:

12.7.1 Federal

Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act

Under Section 404 of the Federal Clean Water Act, the U.S. Army Corps of Engineers (Corps) takes regulatory jurisdiction over the placement of dredge or fill material in Waters of the U.S. (i.e. wetlands and other non-vegetated waters that meet Corps jurisdictional criteria, including a significant nexus to a traditional navigable water). Under Section 10 of the Rivers and harbors Act, the Corps takes jurisdiction over structures placed in currently and historically navigable waters. All project alternatives would result in the placement of dredge and/or fill material in jurisdictional waters of the U.S. that fall under both definitions. As a result, all project alternatives would require authorization from the USACE under Section 404 and Section 10 in advance of project construction. Due to the nature of the activities proposed under Phases I and III of the project, restoration of Lewis Gulch Creek and Wilkins Gulch Creek, respectively, it is anticipated that these two phases could be permitted separately under the Corps Nationwide Permit (NWP) program, specifically under NWP 27: *Aquatic Habitat Restoration, Enhancement, and Establishment Activities.* NWP 27 would require submittal of a preconstruction notification (PCN) to the district engineer of the San Francisco District Office of the Corps. Phase 2 of the project (under all alternatives) would likely require an Individual Permit from the USACE under Sections 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act due to the large quantity of fill proposed to be placed in jurisdictional waters and extensive infrastructure improvements planned within the Bolinas Lagoon and estuary.

Section 7 of the Endangered Species Act

Under Section 7 of the Federal Endangered Species Act (ESA), the United States Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NOAA Fisheries) regulate potential effects to federally-listed wildlife and plant species and their habitats. The USFWS takes jurisdiction over federally-listed terrestrial and freshwater species while NOAA Fisheries takes jurisdiction over federally-listed anadromous fish and other marine species. Because project alternatives could potentially adversely affect federally-listed species (California red-legged frog and steelhead), consultation with both agencies under Section 7 and receipt of Biological Opinions from the wildlife agencies would be required. Typically the wildlife agencies are amendable to joint documents, wherein species under both USFWS and NOAA jurisdiction are addressed in a single decision document. For large, complex projects that contain multiple species under each agency's jurisdiction, this is often the recommended approach for compliance as the permit document is valid for the duration of the project[29]. Development of a programmatic, joint Biological Opinion (BOs) for the entire project would allow the County to engage USFWS and NOAA early in the project and provide a full accounting of all restoration actions (project benefits) in the assessment of project effects. It is anticipated that this approach would result in lowering the proposed compensatory mitigation ratio to offset adverse effects to federally-listed species.

In addition to the ESA, NOAA fisheries regulates essential fish habitat (EFH) under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Because designated EFH is present in Bolinas Lagoon, the proposed action (project) may have adverse effects to EFH and consultation with the NMFS under the MSFCMA would be required under all phases of the project.

Marine Mammal Protection Act, (MMPA)

The MMPA prohibits the "take" of marine mammals. "Take" is defined as "the act of hunting, killing, capture, and/or harassment of any marine mammal; or, the attempt at such." The MMPA defines harassment as "any act of pursuit, torment or annoyance which has the potential to either: a. injure a marine mammal in the wild, or b. disturb a marine mammal by causing disruption of behavioral patterns, which includes, but is not limited to, migration, breathing, nursing, breeding, feeding, or sheltering." The potential to harass marine mammals exists on this project, particularly during the Phase 2 causeway construction. For this phase, it is recommended that causeway construction activities be restricted to one year and that the project applicant apply for an Incidental Harassment Authorization (IHA) with NOAA, which would allow harassment for up to one year. Should project activities occur for longer than one year, then an Letter of Authorization (LOA) would be necessary; however, note that for an LOA, NOAA NMFS must issue regulations associated.

National Historic Preservation Act, Section 106

Under Section 106 of the National Historic Preservation Act, the State Historic Preservation Office regulates impacts to cultural resources. The project may affect various cultural resources, including documented above ground sites, historic properties that are listed or eligible for listing on the National Register of Historic Places (NRHP), and/or buried geoarchaeological or paleontological resources. In order to comply with Section 106, a cultural resources investigation would need to be performed within the anticipated ground disturbance footprint and findings reported to the SHPO for consultation. It is recommended that each phase perform independent consultation with the SHPO as project design changes are anticipated to be ongoing up until the start of each phase, and design changes may dramatically change the ground disturbance footprint of a given alternative and thus the level of effort associated with performing Section 106 compliant study and documentation for the project.

National Marine Sanctuaries Act.

The National Marine Sanctuaries Act (NMSA) directs Greater Farallones National Marine Sanctuary to take an ecosystem-based approach to management with the primary mandate of resource protection in the sanctuaries under

[29] Of note, the BO is valid for the life of the project only so long as the conditions in the BO do not change. Therefore if the amount of take allowed in the BO is exceed, a new species is listed by the USFWS, new critical habitat is designated, or species may be affected in a way that was not covered by the BO, ESA consultation with the USFWS or NOAA Fisheries, as appropriate, would need to be re-initiated. Often reinitiating consultation is a limited effort as it does not require a brand new, full project analysis. It only requires an analysis of changed conditions.

its jurisdiction. Bolinas Lagoon is a designated National Marine Sanctuary and therefore activities in the lagoon, defined as the open-water area below the high water line, fall under their jurisdiction. All project alternatives propose construction of a causeway adjacent to the Bolinas Lagoon, between the existing SR 1 roadway and the lagoon edge, and would require drilling permanent fill (piers) below the high water line. Typically placement of fill is prohibited in a National Marine Sanctuary; however, because the project is designed to result in a net benefit to the lagoon, a manager's permit may be issued to allow the project actions to occur at the discretion of the GFNMS. Parks and GFNMS will need to work closely together to plan and permit fill that will be placed into the lagoon.

Federal Clean Air Act (CAA)

National ambient air quality standards are set under the Clean Air Act (CAA) and compliance with these standards is managed locally by the Bay Area Air Quality Management District (BAAQMD). For the project BAAQMD has the authority to issue permits and ensure compliance with air quality regulations.

12.7.2 State

Clean Water Act Section 401 and Porter Cologne Water Quality Act

Water quality in the state of California is mandated under Section 401 of the federal CWA as expanded under the Porter Cologne Water Quality Act. Compliance with Section 401 of the Clean Water Act is the responsibility of the State Water Resources Control Board (SWRCB) which sets basin standards for clean water and beneficial uses of surface waters in the state. The state board delegates regulatory enforcement of water quality standards to local regional water quality control boards. All project alternatives include construction activities that could degrade water quality associated with waters of the State, including wetlands. As a result, the County would need to obtain water quality certification from the San Francisco Bay Regional Water Quality Control Board (SFRWQCB) for impacts to waters of the state under each project phase.

Clean Water Act Section 402

Project alternatives could result in discharges of pollutants into waters of the State, which include "any surface water or groundwater, including saline waters, within the boundaries of the State." A National Pollutant Discharge Elimination System (NPDES) permit would be required for construction-related discharges to surface waters as the project are will be over on-acre in size.

California Coastal Act of 1976

The California Coastal Act passed by California legislature in 1976 created a mandate for coastal counties to manage the conservation and development of coastal resources through a comprehensive planning and regulatory program called the Local Coastal Program (LCP). Marin County manages its own LCP, and as the proposed action would take place within the coastal zone (an area that generally extends inland 1,000 yards from the mean high tide of the line of the sea), construction of permanent structures and removal of vegetation associated with all three alternatives would require a coastal permit from the Marin County Community Development Agency. It is recommended, for efficiency and to capture all project benefits, that the County requests a single coastal permit covering all three project phases rather than apply for three separate permits.

Section 1600 of the California Fish and Game Code

The California Fish and Game Code includes the CDFW's lake and streambed alteration program under Section 1600 et seq. Under this program CDFW regulates construction activities that could substantially divert or obstruct the flow or substantially change the bed, channel, or bank of a river, stream, or lake, actions typically restricted to freshwater systems. Changes to bed, channel, and/or the bank of freshwater creeks in the project area are proposed under all Phases of the three project alternatives, and therefore the County would need to submit notification of Streambed Alteration to CDFW for each phase. Phase 1 of all three conceptual alternatives may qualify as a small-scale, voluntary habitat restoration project under the Habitat Restoration and Enhancement Act of 2014, and as a result avoid the need for a Lake or Streambed Alteration Agreement and instead submit a Request to Approve Habitat Restoration or Enhancement to the CDFW. This request also eliminates the need for an ITP under California Endangered Species Act (CESA) for Phase 1.

Section 2081 (b) of the California Fish and Game Code

Section 2081 subdivision (b) of the California Fish and Game Code allows CDFW to authorize take of species listed under the California Endangered Species Act (CESA) as endangered, threatened, candidate species if that take is incidental to otherwise lawful activities and if certain conditions are met. Take authorizations are commonly referred to as incidental take permits (ITPs). Because project alternatives could potentially cause “take” of state-listed species (ex: California red-legged frog, Coho salmon, and California freshwater shrimp), consultation with the CDFW and issuance of an incidental take permit (ITP) would be required. Due to the high likelihood for presence of many state fully protected species (California black rail, white-tailed kite, golden eagle, bald eagle, and California least tern) it is not recommended that the project request a consistency determination, using the USFWS/NOAA Biological Assessment as a joint document for species listed under ESA as well as CESA. A consistency determination is not recommended, as the CDFW will not be able to agree to take conditions that have been approved by the USFWS for Fully Protected species. Instead preparation and consultation for state-listed species under separate ITPs for Phase 2 and Phase 3 is recommended. As described in greater detail above, Phase 1 may qualify as a small voluntary habitat restoration project under the Habitat Restoration and Enhancement Act of 2014 and not require an ITP under CESA.

12.7.3 Local

Chapter 22.27 Marin County Code of Ordinances: Native Tree Protection and Preservation

The Marin County Native Tree Protection and Preservation Ordinance establishes the value placed on native and heritage trees by the County of Marin and establishes the conditions under which a protected tree (defined under Chapter 22.130.030 - Definitions of Specialized Terms and Phrases) may be removed or altered. The ordinance states that protected Trees shall not be removed except in compliance with Section 22.62.040 (Exemptions), and as provided for Marin County Code of Ordinances, Chapter 22.62 (Tree Removal Permits).

13. Conclusion

The project is designed to be self-mitigating, because of the quality and extent of the habitat improvements. As this is a restoration project, the overall project provides enhanced habitat quality, creates wetlands, improves habitat connectivity, and restores environmental processes through the enhancement of on-site habitat, increased fish passage, stream rehabilitation, vegetated shorelines, and improved hydrological connections. Temporary project impacts would be reduced or eliminated with the implementation of avoidance, mitigation, and minimization measures and standard best management practices. Table 12 provides a summary of the project impacts and benefits, using high-level conceptual design acreages to demonstrate differences in size between the three alternatives. The category "All Phases" accounts for areas outside of the project impact footprint that are designed to be restored either through direct planting and/or weeding or that would benefit from adjacent restoration actions and naturally revert to wetlands/riparian habitat/etc. For example, creek restoration will require targeted areas of work that will benefit in significantly improved habitat and expansion of wetland and riparian areas.

Table 12. Summary of Project Impacts and Benefits to Wetlands and Waters, Vegetation Communities, and Special-Status Species

Alternative	Construction Phase	Impact: Habitat Area Lost (acres)	Benefit: Habitat Area Created/Restored (acres)	Restoration Outcome: Habitat Created (acres)
1	Phase 1	1	1	0
	Phase 2	3	3	0
	Phase 3	2	2	0
	All Phases	0	19	19
	Total Alternative 1	**6**	**25**	**19**
2	Phase 1	1	1	0
	Phase 2	3	3	0
	Phase 3	6	6	0
	All Phases	0	22	22
	Total Alternative 2	**9**	**32**	**23**
3	Phase 1	1	1	0
	Phase 2	2	3	1
	Phase 3	6	6	0
	All Phases	0	22	22
	Total Alternative 3	**9**	**32**	**23**

Table 12 demonstrates that irrespective of alternative selected, the benefitted areas will greatly outnumber the impacted areas. Furthermore, overall, regardless of ultimately which alternative is selected, the project will meet all of the project goals and will result in significant benefits to the North End. Alternative 1 is the lowest in cost, however, it scores the lowest in meeting the project goals in the alternatives analysis. Alternative 3 is the highest in cost, and it scores the highest in meeting the project goals. It is up to Marin County and partners to determine which alternative is the most suitable, based on the categories and scores provided in the alternatives analysis. It will improve traffic safety, reduce flooding and maintenance needs, restore and reconnect both the habitats along the lagoon's edge and the upland habitats, create connectivity between these ecologically valuable areas, and allow the lagoon to move inland in response to sea level rise.

Appendix A. Geotechnical Report (Draft)

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Bolinas Lagoon North End Restoration Project
Geotechnical Evaluation Report (Draft)
Marin County Parks and Open Space District

Dear Ms. Tremain:

AECOM's Geo-Engineering team is pleased to present the results of our geotechnical exploration to evaluate the subsurface site conditions and provide geotechnical recommendations for the planned Bolinas Lagoon North End Restoration Project.

1.0 Introduction

Marin County Parks and Open Space District has requested that AECOM conduct a geotechnical investigation, as part of the Bolinas Lagoon North End Restoration Project. The following provides a summary of our exploratory borings, geotechnical engineering analyses, and preliminary recommendations addressing the geotechnical aspects of the project.

The project involves the conceptual development of alternatives that address raising roadway grades along portions of Highway 1 and Olema-Bolinas Road near the north end of the Bolinas Lagoon. The primary project purposes include flood control, hydrological connectivity, habitat enhancement, safety, and sea level rise adaptation.

The conceptual alternatives address potential roadway profile modifications along an approximately 2,000-foot stretch of Highway 1 and another 2,000-foot stretch along Olema-Bolinas Road. The current conceptual design alternatives consider an elevated causeway along a portion of Highway 1 supported on columns and/or raised grades including retaining walls or other retaining systems.

The geotechnical engineering design aspects of the improvements can be distinguished between the proposed Olema-Bolinas Road raised grade utilizing engineered fill and the raised grade along Highway 1 that includes structurally supported causeway alternatives.

Olema-Bolinas Roadway

The design concept along the Olema-Bolinas Roadway involves raising the roadway grade as an earthen engineered fill embankment beginning near the intersection of Highway 1 and extending south approximately 2,000 feet. The grade is planned to be raised approximately 8 feet near the middle of the section and thin-out in profile meeting the existing grades at the north and south ends.

Highway 1

The Highway 1 design alternatives consider a combination of a structural causeway sections supported by columns and engineered fill to raise the roadway. Alternates 1 and 2 consider an earthen fill embankment at the intersection of Fairfax-Bolinas Road and Highway 1, meeting structural causeways sections on the east and west sides. The Alternate 3 concept considers a longer continuous column supported causeway.

2.0 Purpose and Scope

The purpose of the geotechnical investigation was to provide further information to evaluate the feasibility of the proposed conceptual roadway modifications. The outcome of this investigation provides information for opportunities and constraints analysis and cost estimates. The boring data obtained from this geotechnical investigation can be used as information for the preliminary design process. Caltrans may require additional information to meet final design criteria.

3.0 Site Conditions

The site is located approximately 2 miles north of the City of Bolinas, at the north end of the Bolinas Lagoon confluence of Highway 1 and Olema Bolinas Rd, as shown on Site and Geotechnical Boring Location Plan (Figure 1). The site is gently sloping from approximate Elevation 29 feet to approximate Elevation 8 feet (NAVD 88). Both Highway 1 and Olema-Bolinas Rd currently have one lane in each direction of traffic. Highway 1 has pull-out lanes every 500 to 1000 feet, in both directions of traffic.

4.0 Geotechnical Explorations Borings

Seven (7) Geotechnical borings designated B-1 through B-7 were performed between the dates of March 27 through 31, 2017 and April 20 through 21, 2017, as shown in Figure 1. The borings ranged from 25.5 feet to 66.5 feet in depth, and were performed under the supervision of our site geologist Sheri Janowski, CEG. The borings were performed using two drill rigs owned and operated by Pitcher Drilling Company of East Palo Alto, California: a CME 55 truck-mounted rig for the Highway 1 borings, and a CME 850 track-mounted rig for the Olema-Bolinas Road borings. Boring B-1 was advanced using hollow-stem auger (HSA) methods to full depth, and the other six borings were advanced using rotary wash (RW) drilling methods. The geotechnical borings and logging procedures were performed in general conformance with the requirements of ASTM D1586, D1587, D2113, D2488, D4220, and D6066 test methods. The boring logs are included in Appendix A.

All borings and wells were completed to Marin County Environmental Health Services specifications. The RW borings were backfilled with neat cement grout to the ground surface. Shallow 2-inch diameter PVC wells were installed in HSA boreholes (B-1, B-2, B-4, and B-6). Wells B-2, B-4, and B-6 were installed in HSA boreholes drilled adjacent to the full-depth RW holes, with the screen section spanning approximately 10 feet to 15 feet below ground surface (bgs). Well B-1 was installed in the full-depth geotechnical investigation borehole with the screen section spanning 20 feet to 25 feet; the zone below the filter pack was backfilled with neat cement grout and allowed to set before the well installation. The as-built wells installations are presented on the boring logs.

5.0 Laboratory Test Results

Tests relevant to the recommendations presented in this report include moisture content and unit weight, unconfined compressive strength, unconsolidated undrained compression tests, sieve analysis, and Atterberg limits. Specifically: 1) Twenty Moisture Content test were performed in accordance with ASTM D2216 test procedures, 2) Ten Minus #200 Wash tests (ASTM D1140), 3) Three Liquid and Plastic Limits tests (Atterberg Limits Tests - ASTM D4318), 4) Eleven Sieve Analyses tests (ASTM D422), 5) Three Unconfined Compressive Strength tests (ASTM D2166), 5) 10 (ASTM D2850) Unconsolidated Undrained Compression test , 6) 14 ASTM D7263b Moisture and Density tests, and 7) one (ASTM D2435) Consolidation test were performed on select laboratory samples. Laboratory Sieve Analyses tests, Consolidation test, and Liquid and Plastic Limits tests are presented in Appendix B. All of test results are presented on the boring logs.

6.0 Subsurface Conditions

The surface deposits at the project site are Holocene-age artificial fill and alluvium, and Pleistocene-age older alluvium and terrace deposit soils overlying Pliocene-age Merced formation and Cretaceous to Jurassic Franciscan complex bedrock units. These deposits are described below using the interpretation collected from the borings performed for this investigation, B-1 through B-7.

The north end of the Bolinas Lagoon is part of the larger San Andreas Fault Zone, as described in Section 8 below. The soil and bedrock encountered in the boreholes varied depending on location in relation to fault lines. Therefore, the subsurface conditions are described below in three distinct sections, determined based on the geologic interpretation of recovered samples in each boring. The sections are titled: east of Golden Gate Fault, east of San Andreas 1906 rupture, and east of San Gregorio Fault.

Figures 2-1 and 2-2 present the idealized geologic profiles (A and B) along Olema-Bolinas Road and Highway 1, respectively, and are based on the subsurface data obtained from the borings performed for this investigation.

East of Golden Gate Fault

Boring B-5 was the only boring location performed east of the Golden Gate Fault. This boring encountered silty gravel with sand artificial fill to 4.5 feet bgs, overlying highly weathered siltstone and shale of the Cretaceous-age Franciscan Complex (Kfs). The initial 4 feet of siltstone encountered was weathered in-place residual soil.

East of San Andreas 1906 Rupture

Borings B-2, B-3, B-4, and B-6 were performed east of the San Andreas 1906 rupture. Boring B-4 encountered 4.5 feet of silty to clayey gravel with sand artificial fill beneath the roadway aggregate. Artificial fill was not encountered in the other borings. Beneath the surface pavement, topsoil, or fill, these borings generally encountered between 11 feet and 20.5 feet of recent alluvium or lagoon deposits which ranged from soft to stiff clay and elastic silt, and very loose silty sand and clayey sand, with gravel layers and varying amounts of organic material. These recent alluvial deposits overlaid Quaternary-age terrace deposits (Qt) which consists of medium dense to very dense sandy silt, silty sand, clayey sand, and silty to clayey gravel, with minor stiff to hard lean to fat clay interbeds with varying sand and gravel content.

Boring B-6 encountered pervasively sheared shale at 59 feet bgs which is likely part of the Tertiary-age Merced formation (Tmc). This would indicate a fault contact between the depths of 51 feet and 59 feet bgs at this location.

East of San Gregorio Fault

Borings B-1 and B-7 were performed east of the San Gregorio Fault. Neither boring encountered artificial fill beneath the topsoil. Stiff sandy lean clay recent alluvium was encountered in the upper 8 feet of Boring B-7 to 15 feet in Boring B-1. Boring B-1 encountered medium dense to dense clayey sand with gravel older alluvium to 28 feet bgs. The alluvial soils in both borings overlie Tertiary-age Merced formation, which consists of highly to completely weathered sandy claystone to sandy siltstone, weathering decreasing with depth.

7.0 Groundwater Conditions

The groundwater levels as measured in the borings were approximately 1.5 feet to 10 feet bgs, corresponding to Elevation range of 5 feet to 19 feet (NAVD 88). Initial readings were collected from the wells B-1, B-2, B-4, and B-6; the water levels as measured are included in Table 1 below.

Table 1

Depths to Groundwater from Existing Ground Surface (Feet)

Boring Number	29-Mar-17	30-Mar-17	31-Mar-17	20-Apr-17	21-Apr-17
B-1	2.9	2.7	2.7	2.75	2.8
B-2	--	0.3	0.3	0.3	0.3
B-4	--	--	--	2.7	2.7
B-6	--	--	--	--	1.17

8.0 Geology Seismicity and Faults

The Bolinas Lagoon is part of the larger San Andreas Fault Zone. The San Andreas Fault is a major right-lateral strike-slip fault extending from the Gulf of California through much of northern California. It is not a single fault, and in many places, such as the region surrounding the study area, there are other converging or diverging faults that create complex local geology and seismic activity. Figure 3A shows an oblique view of the Bolinas Lagoon and the juxtaposition of three faults and Figure 3B shows a geologic map of the Point Reyes Peninsula along the western side of the San Andreas Fault zone and the Tomales Bay (USGS, 2005). The major geologic units are detailed in the map legend.

Figure 4, shows the bedrock unit geology and faulting of the Bolinas Lagoon area in a larger-scale map, produced by Galloway (1977). In it, the three faults are shown, though with different names than on the U.S. Geological Survey (USGS) map.

Cretaceous sedimentary Franciscan rocks (KJf) occur east of the East Boundary Fault along Bolinas Ridge. At the head of the Bolinas Lagoon, Holocene-Pleistocene terrace deposits (Qt) define much of the west side of the East Boundary Fault between the 1906 earthquake fracture of the San Andreas Fault. The Plio-Pleistocene Merced siltstones (Tmc) and sandstones occur between the East and West Boundary Faults where the 1906 fracture of the San Andreas Fault bisects the two boundary faults. Miocene Monterey shale (Tm) occurs west of the West Boundary Fault (west of the study area).

The Working Group on California Earthquake Probabilities (1999) reported a 12% probability for a magnitude 6.7 quake in the next 30 years along the North Coast South segment of the San Andreas Fault (the segment that crosses Bolinas Lagoon). Byrne and Reidy (2005) determined from their subsurface study of long cores taken in the upper Bolinas Lagoon that five major earthquakes have influenced the lagoon depth in the last 1,600 years. The prior ones occurred in about 450 AD, 1080 AD, 1220 AD, and 1520 AD. The mean recurrence interval of major quakes is reported to be about 300 years, although the time between the second and third quakes was only 130 years. Byrne et al. also suggested that sand lenses found at depth in the cores could have been deposited from a large tsunami, or they were rapidly deposited from frequent winter storms during the Little Ice Age (ca. AD 1400–AD 1800). An alternative hypothesis presented here to Byrne's suggestions about causes of sand lenses found in sediment cores sampled in the Bolinas Lagoon is that the sand is associated with down-dropping of a Holocene graben that caused the Stinson Beach sand spit to be overwashed by tides until it was rapidly rebuilt. A graben is a down-dropped section of land between parallel faults.

9.0 Geotechnical Engineering Design Considerations and Impacts

The geotechnical engineering design aspects of the improvements can be separated between the proposed Olema-Bolinas Road raised grade utilizing engineered fill and the raised grade along Highway 1 that includes structurally supported causeway alternatives.

Olema-Bolinas Roadway

The design concept along the Olema-Bolinas Roadway involves raising the roadway grade as an earthen engineered fill beginning near the intersection of Highway 1 and extending south approximately 2,000 feet. The grade is planned to be raised approximately 8 feet near the middle of the section and thin-out in profile meeting the existing grades at the north and south ends.

The primary geotechnical engineering design consideration for the raised grade along the Olema-Bolinas Roadway is the potential for long term consolidation settlement resulting from the applied load of the engineered fill over the existing native subgrade soils. The results from our exploratory borings and laboratory tests indicate the near surface soils consist of soft compressible clay that is prone to long term consolidation settlement. The maximum settlement is estimated to be on the order of 7 inches near the middle of the roadway section where the embankment fill will be thickest. The settlement analysis results are discussed in further detail in Section 10.

The settlement will diminish gradually toward the southern and northern extents of the new roadway section. The differential settlement along entire length of the roadway is therefore anticipated to be relative minor and with a properly prepared subgrade and compacted fill the impact to the new roadway surface is expected to be negligible.

The raised grade will also include culverts installed to allow surface water flow through stream channels, and a bridge or box culvert near the north end near Highway 1. Retaining walls or reinforced slopes may be required on the outboard edge of the roadway to stabilize the raised sections adjacent to the lagoon. Geotechnical parameters for retaining structures are presented in Section 18.

Highway 1

The Highway 1 design alternatives consider a combination of a structural causeway sections supported by columns and engineered fill to raise the roadway. Alternates 1 and 2 consider an earthen fill embankment at the intersection on Fairfax- Bolinas Road and Highway 1 meeting structural causeways sections on the east and west sides. The Alternate 3 concept considers a longer continuous column supported causeway.

The borings from our geotechnical exploration indicate the subsurface soils along the Highway 1 section generally consist of soft clay and with some interbeds of loose clayey sands and gravels to depths of 35 to 40 feet below grade. Below these depths the materials become considerably more dense and granular or consist of fractured and weathered bedrock. The bedrock becomes shallower at the east end of the section.

Based on these findings, the columns of the causeway structures will need to be supported on deep foundations such as driven piles or drilled reinforced concrete piers extending into the more competent bearing material below 35 to 40 feet. Driven piles are likely the preferred alternative to drilled piers considering the complications of drilling open pier holes below the shallow groundwater. The driven piles would develop axial capacity primarily as skin friction between the piles and more competent soil and rock below 35 to 40 feet. The causeway columns would connect to pile caps near the existing grade. Drilled piers and driven pile analysis are discussed further in Sections 13.

The Alternatives 1 and 2 concepts that consider an earthen fill section at the intersection of Fairfax-Bolinas and Highway 1 present a geotechnical engineering challenge because the engineered fill section will be prone to significant consolidation settlement of the existing near surface soft clay soils. The estimated settlement analysis due to the applied loads of an engineered fill embankment are approximately 6 inches as presented in Section 10.

The pile supported causeways section on either sides of the fill section will experience little or negligible settlement that would result in unacceptable differential settlement between the engineered fill embankment and structurally supported sections.

Several geotechnical engineering alternatives such as the use of lightweight fill materials and ground improvement methods may be considered to mitigate differential settlements for the Alternatives 1 and 2 and are presented in Section 14.

10.0 Estimated Elastic and Consolidation Settlement of Embankment Fills

Embankment Fill at Highway 1 - Alternatives 1 and 2

The maximum estimated settlement was calculated for the middle section of Highway 1 at the intersection of Fairfax-Bolinas Road and Highway 1. The settlement estimates address the applied loads due to a conventional aggregate fill embankment as considered in the Alternates 1 and 2 road sections.

Immediate and consolidation settlements associated with the engineered fill was calculated based on the assumption that a total of approximately 1,100 psf of load will be applied on top of the existing ground surface due to the placement of the embankment fill. The calculated immediate settlement is on the order of 1 inch, which will mostly occur during construction, and the anticipated long term consolidation settlement is on the order of 6 inches assuming an Over Consolidation Ratio (OCR) of 2 for the subsurface clayey soils. We estimate that 90 percent of the consolidation settlement will occur over a period of 10 to 15 years.

Embankment Fill Settlement at Olema-Bolinas

Immediate and consolidation settlements associated with the engineered fill were calculated based on the assumption that a total of approximately 1,100 psf of load will be applied on top of the existing ground surface due to the placement of the fill. The calculated immediate settlement was on the order of 1 inch, and the anticipated consolidation settlement was on the order of 7 inches assuming an Over Consolidation Ratio (OCR) of 2- to 3 for the subsurface clayey soils. We estimate that 90 percent of the consolidation settlement will occur over a period of 10 to 15 years.

11.0 Seismic Design Parameters

The following seismic design parameters were developed from the ASCE 7-10 Design Maps:

S_S	2.61 g	**S_1**	1.25 g
F_a	1.0	**F_v**	1.5
$S_{MS} = F_aS_S$	2.61 g	**$S_{M1} = F_vS_1$**	1.88g
$S_{DS} = (2/3)S_{MS}$	1.74 g	**$S_{D1} = (2/3)S_{M1}$**	1.25g
PGA		1.00 g	
F_{pga}		1.00 g	
Site Classification		D	

12.0 Liquefaction Induced Settlement and lateral Spreading

Liquefaction is a phenomenon whereby soil deposits temporarily lose shear strength and collapse. This condition is caused by cyclic loading during earthquake shaking that generates excess pore water pressures within the soil deposits. The soil type most susceptible to liquefaction is loose, cohesionless, granular soil below the water table and within about 50 feet of the ground surface. Liquefaction can result in a loss of foundation support and settlement of overlying structures, ground subsidence and translation due to lateral spreading, ground cracking, and differential settlement of affected deposits.

Based on the site-specific information from the current field investigation, the subsurface conditions below the water table consist of interbeds of sandy and clayey soil layers. In general, these layers appear to vary in thickness at the site and are relatively continuous throughout the site. The soils within the sandy soil layers include clayey sand, silty sand, sand and no-to-low plasticity silt, which are susceptible to liquefaction. The preliminary liquefaction triggering analysis was performed by following the procedure described in Boulanger and Idriss (2014) using the blowcount data collected from borings B-1 through B-7. An earthquake magnitude of 7.7 and peak ground acceleration of 1.0g, as provided in Section 11, were used for the analysis. Based on the results of our analysis, there is considered to be a potential for liquefaction to occur within the sandy soil layers during a seismic event. The total thickness of the potential liquefiable materials along the Highway 1 project alignment vary from 2 to 13 feet as identified in Borings 1 through 4 with the maximum thicknesses at Borings 2 and 3. The thickness of liquefiable soil along the Olema Bolinas Road alignment varies from zero to 10 feet as identified in Boring 6. We estimate that the liquefaction induced ground settlement during a seismic event is anticipated to be up to 4 inches along the middle-to-western extent of the Highway 1 project alignment, and up to 2 inches along the middle section of Olema-Bolinas Road project alignment.

Lateral spreading is the lateral deformation of soil as a result of liquefaction. Normally a slope and/or a free face such as a shoreline are necessary to initiate the event. The potential for lateral spreading at the project is considered to be very high because of the seismic setting and the site's proximity to the Bolinas Lagoon shoreline. Further analysis would be required to evaluate the anticipated amount of lateral spreading, however, we estimate that lateral spreading of the near surface could be as high as one to several feet in the liquefiable zones.

13.0 Deep Foundation Alternatives for Highway 1 Causeway Sections

Deep foundation alternatives, such as drilled piers and driven piles, can be considered to support the structural loads. The foundation type and size can be chosen based on structure loading, allowable settlement and economics.

Cast-in-drilled-hole (CIDH) piers have the advantages of easy penetration into dense/hard soil zones, the availability of larger diameters for increased lateral capacity, and adaptability of length to variable subsurface conditions. However, the presence of shallow groundwater or caving soils can complicate the use of CIDH piers. CIDH would need to be drilled through temporary casing advanced with the auger drill to keep the pier hole open during drilling.

On the other hand, the driven piles offer the advantage of the ability to be installed with relative ease in shallow groundwater and caving soil conditions and perhaps most importantly do not produce drill spoils. They can also be installed at a battered angle that lends itself to a higher lateral pile capacity. However, installing driven piles through very dense sand or gravel layers would generally be difficult and would likely require pilot hole drilling to some depth before driving the pile. Based on the results of the subsurface investigation and subsurface conditions, driven piles are the preferred deep foundation alternative.

As part of this preliminary evaluation, AECOM evaluated the frictional capacities of 14-inch and 18-inch diameter reinforced concrete driven piles using methods recommended by FHWA NHI-05-043. Ultimate axial capacities were calculated for both the 14-inch and 18-inch diameter reinforced concrete piles. We estimate that the required pile lengths to achieve an ultimate axial capacity of 100 kips are 50 feet for 14-inch diameter pile, and 45 feet for 18-inch diameter pile.

Factors of safety of 2 and 3 should be applied for compressive and tensile loading conditions, respectively. It is noted that these calculated pile capacities need to be reduced for pile group effects if the piles are spaced closer than three pile diameters. It is our opinion that no reduction in axial capacity due to group interaction is required for pile spacing of at least three pile diameters.

The pile group would be interconnected at the top of the piles with a structural concrete pile cap to support the column.

The lateral load capacities due to earthquake would also need to be considered in the pile capacity design. The piles could also be designed to resist lateral loading due to liquefaction induced lateral spreading. We estimate that a group of at least four piles would be needed at each pile cap and column location along the structurally support causeway sections.

14.0 Ground Improvement Methods for Highway 1 - Alternates 1 and 2

Project Concept Alternatives 1 and 2 include a raised roadway embankment at the intersection of Highway 1 and Fairfax-Bolinas Road. The embankment is approximately 7 feet high and extends approximately 130 feet between the abutments of the proposed pile supported causeways on Highway 1, and is approximately 200 feet long approaching Highway 1 on the Fairfax-Bolinas Road. The embankment is 46 feet wide on Highway 1, and 40 feet wide on Fairfax-Bolinas Road, with 4:1 (horizontal: vertical) side slopes.

Our geotechnical investigation included one soil boring designated B-3 drilled at the proposed embankment location. The boring encountered 4 feet of fill overlying a 14 foot thick layer of soft to medium stiff lean clay, overlying interbedded layers of stiff to very stiff clay and medium dense sand Terrace Deposits. Groundwater was encountered between 1 and 2 feet below existing grade. We estimate that the earthen embankment would induce long term consolidation settlements of the soft to medium stiff lean clay on the order of 6 inches, with 90 percent settlement to occur over the first 10 to 15 years as discussed in Section 10. The adjacent pile supported causeways will be designed to have negligible long-term settlements, so the roadway performance issue is the potential 6 inches of differential settlements at the transitions from the pile supported causeways to the roadway embankment sections.

We present below several alternatives to mitigate the predicted differential settlements – these include options to reduce the imposed embankment surcharge load, and options to reduce or bypass the compressibility of the soft clay layer. For all the alternatives, the areal extent of improvement should extend to the toe of the embankment side slope, to the extent practical. The alternative to replace the embankment fill section with a pile supported causeway is described as Project Concept Alternatives 3.

14.1 Lightweight Aggregate Fill

Lightweight fill is a natural aggregate mined and produced from geologic deposits that have high porosity and low density, such as a volcanic pumice deposit. Lightweight fill is used to replace normal weight aggregate bases and soils where a reduction in ground loading and dead weight is desired. Lightweight fill is durable, inert, and is compacted in lifts much like a conventional fill. Gradations meeting Caltrans Structure Backfill or Aggregate Base are available. The unit weight of lightweight fill ranges from about 45 to 55 pounds per cubic foot (pcf), while conventional fills may be in the 110 to 125 pcf range. We assume that the top 3 feet of the road embankment would be a conventional structural section; to compensate for the embankment surcharge loading, approximately 10 feet of native soil would need to be excavated and replaced with lightweight aggregate fill. The shallow groundwater table will likely require an excavation shoring system, and the associated cost and environmental impacts of this alternative make it less practical.

14.2 Lightweight Cellular Concrete

Lightweight Cellular Concrete (LCC) is an engineered and low density material that primarily consists of preformed foam, Portland cement, fly ash, and water. The density of the LCC can range from about 20 to 120 pounds per cubic foot (pcf), depending on the mix design. LCC can be batched in both nonpermeable and permeable formulations, the latter being suitable for use below the groundwater table to prevent uplift, and consequently is more expensive. Lightweight cellular concrete would require a similar excavation depth as the lightweight aggregate fill, and is an expensive option, so is not recommended for further consideration.

14.3 Geofoam

Geofoam is an expanded polystyrene product that is formed in blocks that have predictable stiffness, are very lightweight, and are used regularly in lightweight roads, retaining walls, bridge abutments and other related applications. Geofoam meets the specifications of the ASTM D6817 Standard Specification for Rigid Cellular Polystyrene Geofoam. Geofoam is exceptionally light, weighing only a few pounds per cubic foot, and therefore a much shallower excavation is required relative to lightweight fill to compensate for the embankment fill. We assume that the top 3 feet of the road embankment would be a conventional structural section; to compensate for the embankment surcharge loading, approximately 4 feet of native soil would need to be excavated and replaced with Geofoam. Geofoam should be specially treated to resist insects, and it should be protected by a geomembrane or concrete slab to resist degradation by petroleum products. In addition, Geofoam is buoyant, and can only be used beneath the groundwater table if fill above the geofoam or an anchoring system provides sufficient resistance to uplift loads. Geofoam is considered a feasible alternative.

The following ground improvement alternatives have the added benefit of mitigating the potential for liquefaction induced settlement and lateral spreading as well as consolidation settlement:

14.4 Jet Grouting

Jet grouting is an in-situ ground improvement technique that injects a mixture of grout, air, and drilling fluid into the soil at high pressure through a rotating drill string, and creates a column in place. Jet grout columns are unreinforced, but develop sufficient compressive strengths to support lightly to moderately loaded structures such as the proposed embankment. Jet grout columns could be installed in these soils to approximate diameters of 3-5 feet in an overlapping pattern, to an approximate depth of 25 feet. The resulting jet grout block would eliminate the compressibility of the soft to medium stiff lean clay layer. Jet grouting is an expensive ground improvement alternative.

14.5 CDSM Columns

Cement Deep Soil Mixing (CDSM) is a ground improvement method that blends cement grout with the in situ native soils to create columns that can transfer loads to deeper more competent strata. The CDSM drill rig advances a hollow shaft with mixing paddles into the soil, and the cement grout is pumped through the hollow stem of the revolving shaft and discharged at 300 to 500 psi laterally along the lower mixing paddle where it is mixed with the native soil. When the design depth is reached, the tool is withdrawn while maintaining, or often increasing, the rotational speed of the mixing tool, which results in a well-blended column of native soil and cement grout, which will cure over time to the required design strength. An area replacement ratio of 30-40% is typical for this application, and could be achieved with 72 inch diameter columns (installed in an equilateral triangular spacing 10 feet on center), to 60-inch diameter columns (installed 7 feet on center). Preliminary CDSM column lengths of 50 to 60 feet are estimated, and are a function of column diameter and spacing. A load transfer pad would need to be constructed at the base of the embankment, and would consist of geogrid and aggregate, cement treated aggregate or a reinforced concrete mat.

14.6 Drill Displacement Columns

Farrell Design-Build is a specialty foundation contract that installs a variety of proprietary ground improvement and foundation systems. They are most known for GeoPier densified gravel columns, but that application is not suitable for this site. Their Drill Displacement Columns (DDC) system is a deep, full displacement pressure grout column, ground improvement method that is suitable for the soft soils at this site. DDC columns are installed in 14 to 24 inch diameters in an equilateral triangular spacing 7 to 10 feet on center. Preliminary DDC column lengths of 50 to 70 feet are estimated, and are a function of column diameter and spacing. A load transfer pad would need to be constructed at the base of the embankment, and would consist of geogrid and aggregate, cement treated aggregate or a reinforced concrete mat.

15.0 Subgrade Preparation for Embankment Fill and Road Sections on Grade

The construction new embankment fills and roadway sections on grade will involve: 1) removal and off-haul of the existing asphalt concrete; 2) removing soft soils, scarifying, and compacting the existing subgrade; 3) placing and compacting a granular engineered fill material such as Caltrans Class 2 Aggregate Base rock; and 4) repaving with flexible asphalt concrete. Roadway subgrade preparation and construction should be performed in accordance with Caltrans Design Manual Guidelines.

In general, the existing surface and subgrade along the planned new Olema-Bolinas roadway embankment fill section and sections of Highway 1 supported on engineered fill meeting existing grade should be prepared as follows:

The new roadway sections should be cleared of asphalt-concrete pavement and all obstructions including abandon buried utilities and be cleared of surface vegetation and organic laden soils. Abandon utility lines that are within 3 feet of the pavement subgrade should be completely removed.

We estimate that an additional 12 inches of organic laden or soft soil, possibly occurring within old stream channels or other naturally occurring depressions, will be required to be removed locally at several sections of the roadway. The subgrade should be scarified to a minimum depth of 12 inches and moisture conditioned and compacted to a minimum 95 percent relative compaction as described in the Section 16.0 below. Where softer moist soils are encountered, over-excavating may be required or the subgrade strengthened with geogrid reinforcement materials before backfilling.

Retaining walls or reinforced steepened slopes may be required on sections of the engineered fill embankment such as raised sections adjacent to the lagoon. There are several alternate approaches to construct steepened reinforced slopes that support natural vegetation and provide erosion control coverage. Geotechnical parameters for retaining structures are presented in Section 18.

16.0 Backfilling and Compacting

The engineered fill material for the embankment fill shall be Caltrans Class 2 aggregate base (AB). Fill and backfill materials shall be placed in loose lifts not exceeding 8-inches. Each loose lift shall be compacted with the appropriate equipment to the specified degree of compaction, minimum relative compaction of 95 percent. The moisture content shall be controlled within 2 percent of the optimum water content. All compaction criteria refer to the maximum dry density and optimum moisture content determined in accordance with ASTM D1557 test method. In addition to being compacted to the required density, the engineered fill should also be stable, i.e., not exhibit "pumping" behavior.

The Caltrans Class 2 aggregate base AB material for the structural pavement section shall be compacted to at least 95 percent relative compaction (ASTM D1557) and be compacted near the optimum moisture content.

Utility trench backfill that will be under roadway should be compacted to a minimum 95 relative compaction (ASTMD1557) in the upper 3 feet below the structural pavement section. Utility trench backfill not in roadways shall be compacted to 90 percent relative compaction (ASTMD1557).

All paved areas should be scarified to a minimum depth of 12-inches moisture conditions and compacted to the minimum 95 percent relative compaction (ASTM D1557).

17.0 The Asphalt Pavement Design

The asphalt pavement design should be based on R-value tests from existing near surface samples and traffic index (TI), in accordance with Caltrans Highway Design Manual calculation methodology. We estimate an R-value on the order of 7 to 10 for the existing near surface soils based on soil classification. However, most of the new roadway sections will be supported on relatively thick sections of compacted Caltrans Class 2 aggregate embankment fill which has a relatively high R-value. For cost estimate purposes, we estimate that the roadways sections would consist of a minimum 4 inches of asphalt concrete over a minimum 18 inches of Caltrans Class 2 aggregate base rock.

18.0 Shallow Foundations and Retaining Structures

18.1 Shallow Spread Foundation

The following information is provided for retaining structures designed with conventional shallow spread footings to support structural retaining walls near the shoreline or culverts. The retaining structure foundations should bear on a minimum 12-inches of Class 2 engineered fill materials prepared according to guidelines provided in Section 16.

New footings should be founded at least 24-inches below the adjacent finished grades. Shallow spread footings should have a minimum width of 24-inches. All new footing excavations should be finished in a neat condition. Any softened or disturbed soil should be removed from the footing excavation prior to placing reinforcing steel bars. It is recommended that the time during which the prepared foundation bearing surface is exposed be kept to a minimum to reduce the potential for disturbance. A protective layer of concrete (referred to as a mud slab or rat slab) can be placed on top of the foundation bearing surface to protect it before the footing is poured. It is also recommended that the footing excavations be observed by AECOM prior to placing steel and concrete, in order to verify that the recommendations of this letter have been followed, and that an appropriate bearing stratum is encountered.

To evaluate new shallow footings, the following allowable bearing pressures are recommended for foundations bearing on the engineered fill embankment constructed in conformance with the recommendations provided above:

- Dead Loads 2,500 psf
- Dead and Live Loads 3,000 psf
- All Loads, including Wind and Seismic 4,000 psf

18.2 Lateral Force Resistance

The following parameters apply to retaining structure supporting and foundations against compacted Class 2 engineered embankment fill materials prepared in accordance with the guidelines presented Section 16.0. In order to resist lateral loads, a friction factor of 0.35 can be used. The lateral force resistance can be determined by multiplying this factor by the dead load of the structure. We recommend that active lateral earth pressures for long term static conditions be computed using an equivalent fluid weight of 40 pcf. Resistance to seismically- or wind-induced transient lateral loads can be developed by passive earth pressure acting against the sides of the footings. To estimate resistance to lateral loads, an ultimate equivalent fluid unit weight of 400 pcf can be used to calculate the ultimate passive pressure; however, the passive pressure should be limited to a maximum value of 3,000 psf. The passive pressure can be computed from the top of the footing as long as the top of the footing is a minimum of 24-inches below the ground surface. A minimum factor of safety of 1.5 should be applied for static loads.

19.0 Additional Construction Considerations

If earthwork construction is performed during the rainy season, the site subgrade soils may have considerably higher moisture content which would make scarification and compaction efforts more difficult. Under such conditions, it may be necessary to over-excavate soft materials and/or perform mitigating measure such as soil treatment or provide geogrid stabilization materials on the subgrade before backfilling.

Excavations may be required to remove old utilities and install new utilities. Excavations deeper than five feet that will be entered by workers should be shored or sloped in accordance with Occupational Safety and Health Administration (OSHA) standards. Excavations below five feet relative to the existing grade will likely encounter groundwater which will require dewatering before backfilling installation of new utilities.

20.0 Limitations and Closure

These recommendations have been provided in accordance with the standard of care commonly used as state-of-the-practice in the profession. No other warranties are either expressed or implied. The recommendations presented in this report are based on the assumption that the soil conditions do not vary significantly from those encountered in our subsurface explorations near the site. Should differing conditions be discovered during construction, we should be advised and will revise these recommendations accordingly.

We appreciate the opportunity to work with you on this project. If you have any questions regarding these recommendations, please contact the undersigned at (510) 893-3600.

Sincerely,
AECOM

John Tabor, P.E.
Project Engineer

Figures:	1	Project Site and Geotechnical Boring Location Plan
	2-1	Alignment Profile A: Olema Bolinas Road
	2-2	Alignment Profile B: Highway 1
	3A/3B	Geologic Map of Point Reyes National Seashore
	4	Bolinas Lagoon Bedrock Geology and Faults
Attachment:	A	Boring Logs
Attachment:	B	Laboratory Test Results

References

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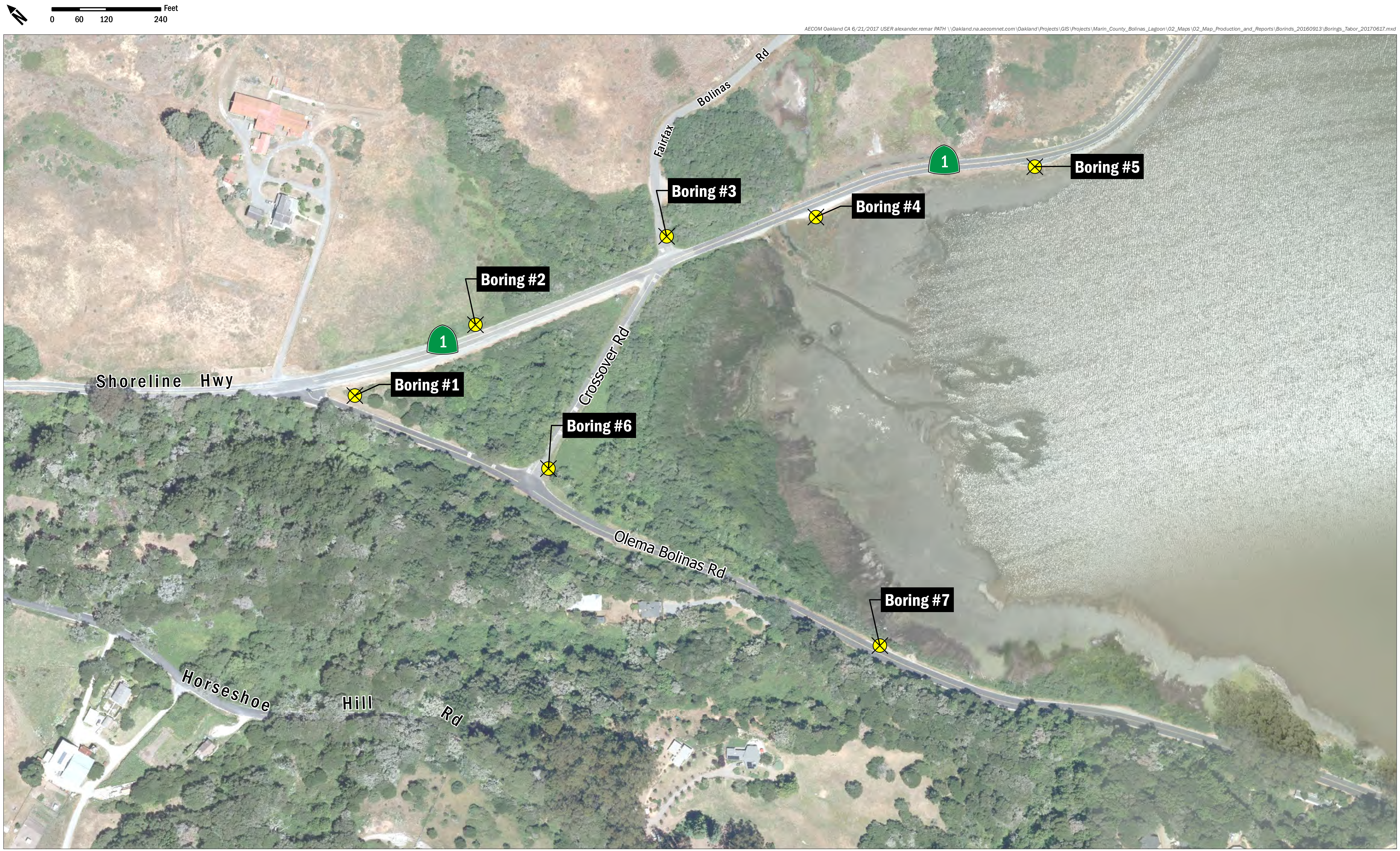


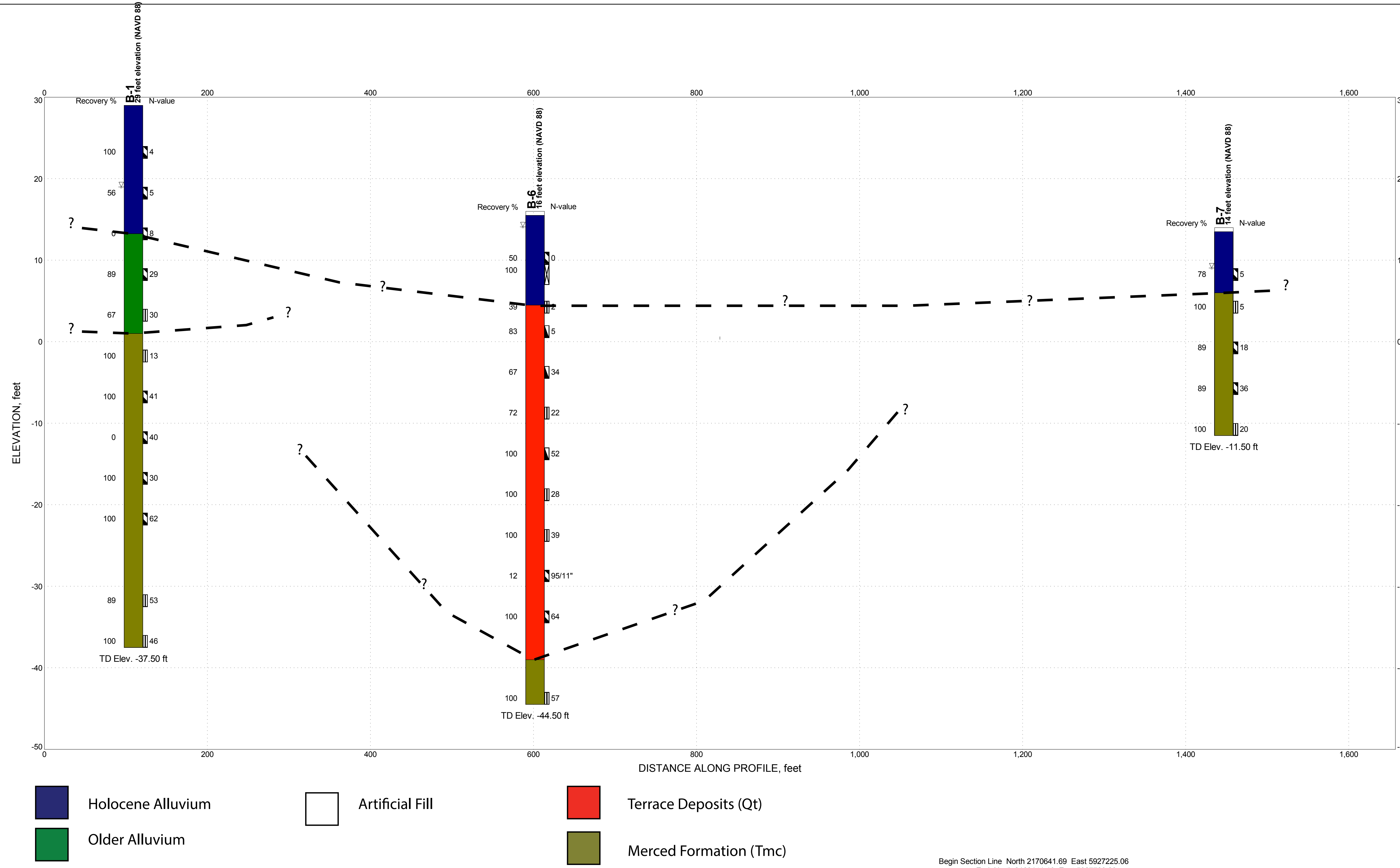
AECOM
Marin County
Bolinas Lagoon Restoration

EXPLANATION

Geotechnical Boring (AECOM, March - April 2017)

FIGURE 1

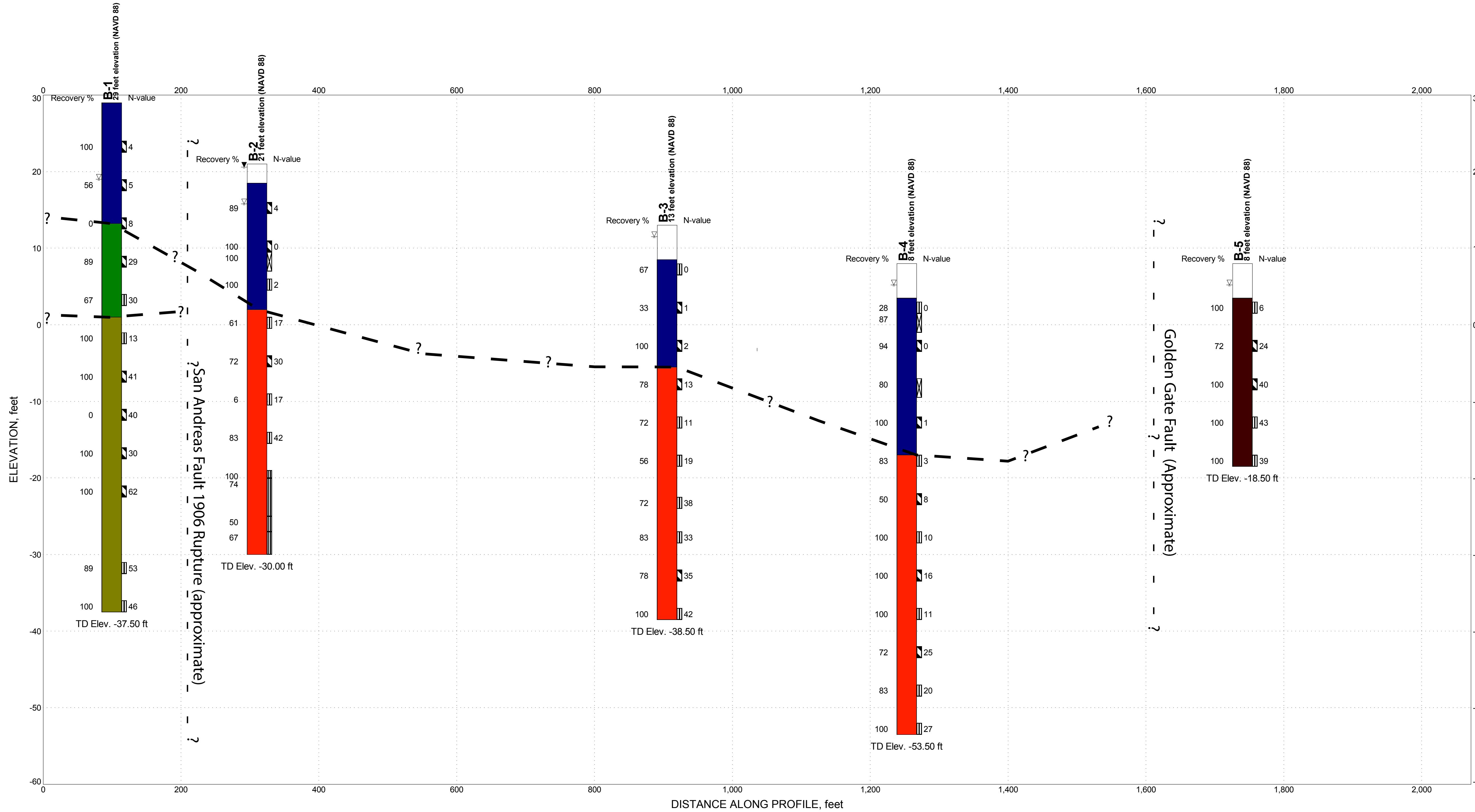
Project Site and Geotechnical Boring Location Plan, June 2017



4/25/17 SOIL WITH WEATHERING_N_R% BOLINAS AECOM ROCK CORE.GPJ SECTION
Bolinas Lagoon North End Restoration Marin County, CA

Begin Section Line North 2170641.69 East 5927225.06
End North 2169141.10 East 5927780.23
Begin Distance 0.00 ft
End Distance 1600.00 ft

AECOM	60393194 Bolinas Lagoon North End Restoration	Alignment Profile A: Olema Bolinas Road	Figure 2-1



Holocene Alluvium

Older Alluvium

Artificial Fill

Terrace Deposits (Qt)

Merced Formation (Tmc)

Franciscan Complex (Kfs)

4/25/17 SOIL WITH WEATHERING_N_R% BOLINAS AECOM ROCK CORE.GPJ SECTION
Bolinas Lagoon North End Restoration Marin County, CA

Begin Section Line North 2170588.02 East 5927189.30
End North 2169682.60 East 5928972.62
Begin Distance 0.00 ft
End Distance 2000.00 ft

AECOM	60393194 Bolinas Lagoon North End Restoration	Alignment Profile B: Highway 1	Figure 2-2

View in image above is looking toward Stinson Beach (SB) and Bolinas Bay from an overlook area on Bolinas Ridge. The town of Bolinas (B) is on the West side of the mouth of Bolinas Lagoon. Duxbury Reef (DR) is at the south end on the Point Reyes Peninsula. Lines show the approximate location of the three great faults that merge to form the San Andreas Fault Zone in Olema Valley - the San Gregario, San Andreas (1906 rupture), and the Golden Gate faults.

Source: Bolinas Lagoon North End Restoration Project Technical Memorandum, Current and Historicl Geomorphology and Hydrology, AECOM, 2016

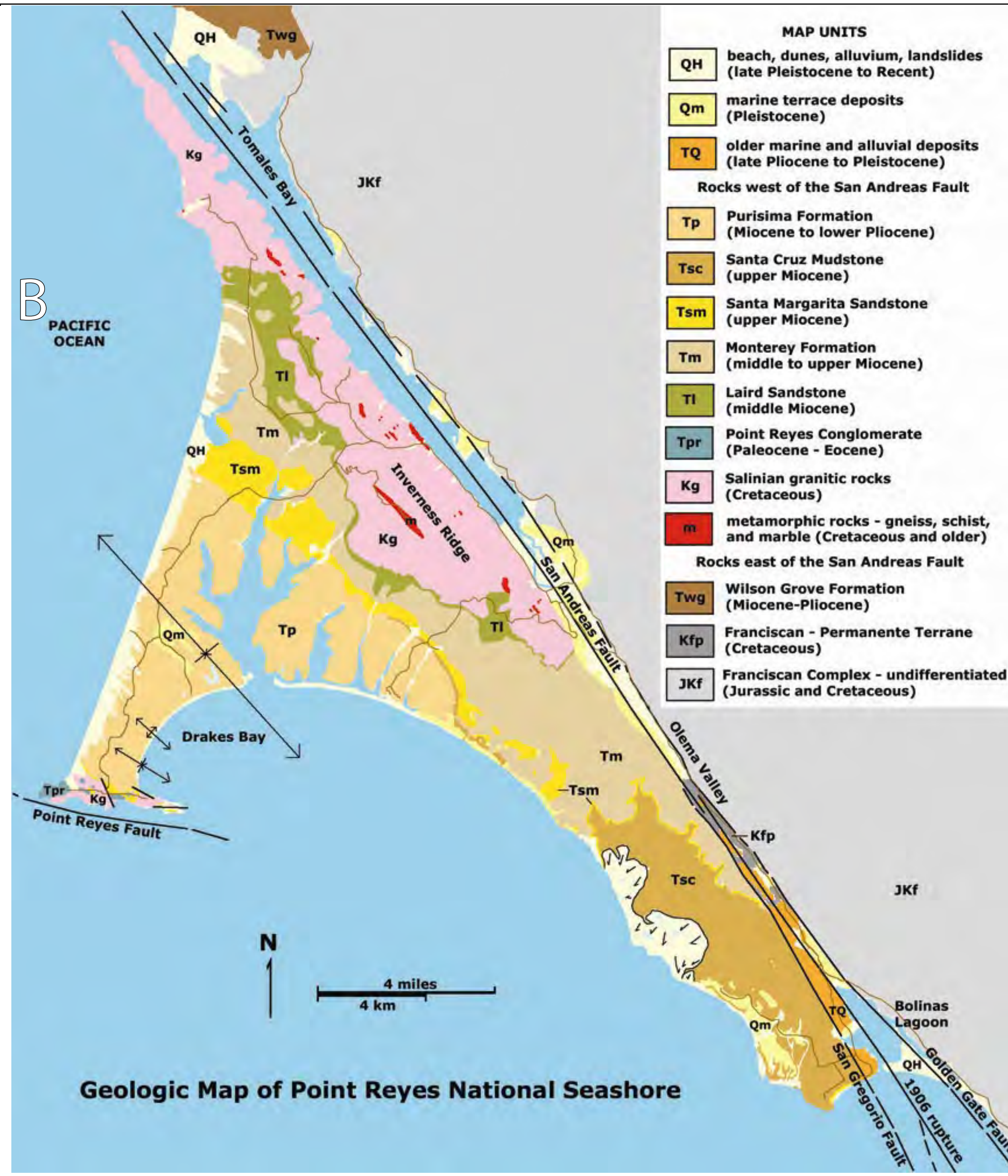
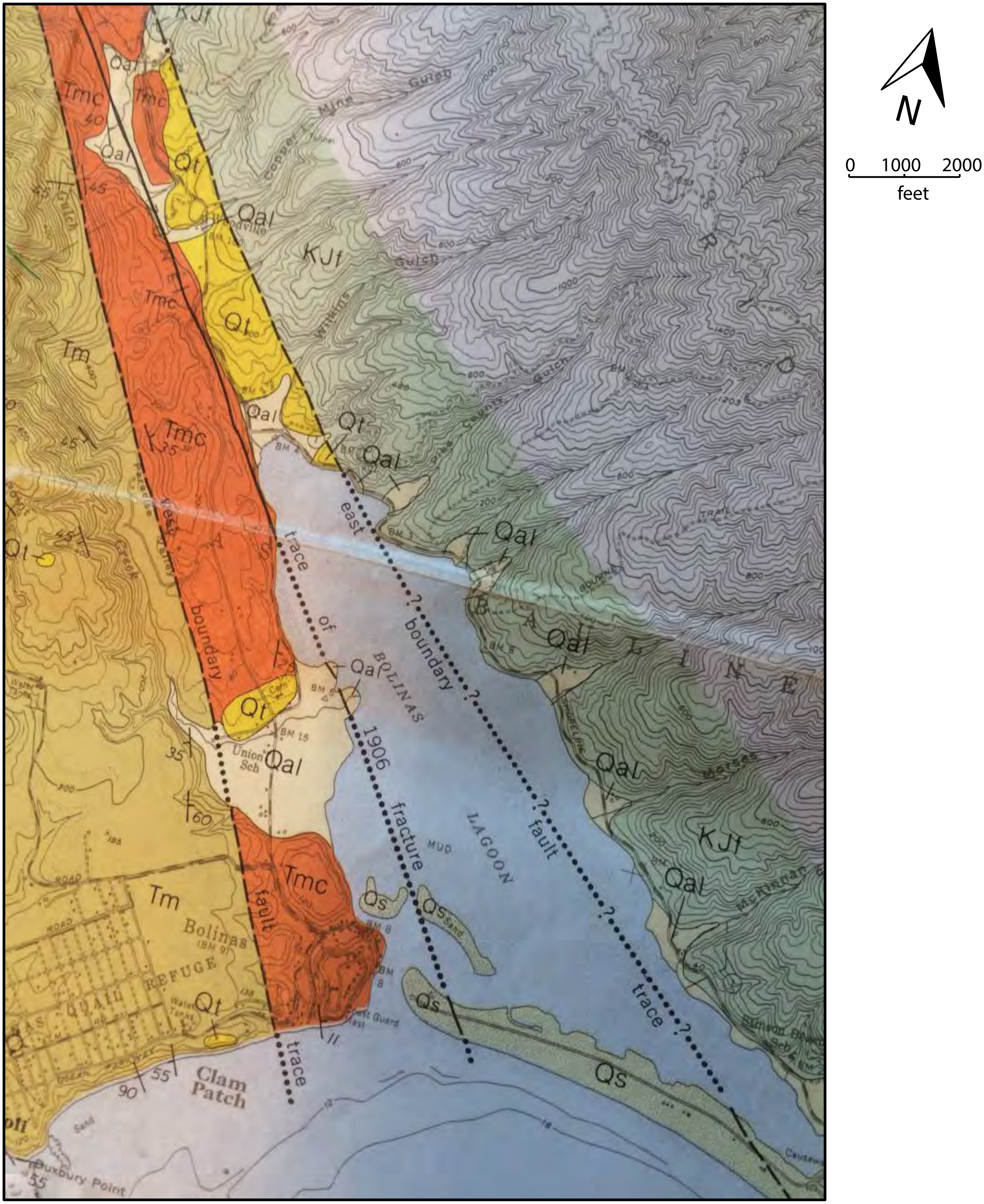


Figure 9-2. Generalized geologic map of Point Reyes National Seashore after Clark and Brabb (1997), Blake and others 2000), and Bruns and others (2002).

AECOM	60393194 Bolinas Lagoon North End Restoration	Geologic Map of Point Reyes National Seashore	Figures 3A & 3B



Source Map: Galloway, A.J., 1977, Geology of the Point Reyes Peninsula, Marin County, California, California Division of Mines and Geology, Bulletin 202, scale 1:48,000

AECOM	60393194 Bolinas Lagoon North End Restoration	Bolinas Lagoon Bedrock Geology and Faults	Figure 4

Attachment A

Geotechnical Boring Logs

Project: Bolinas Lagoon North End Restoration
Project Location: Marin County, CA
Project Number: 60393194

Key to Log of Soil Boring

Elevation feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance blows/foot	SAMPLES: Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight (pcf)	Fines Content (% <200 Sieve)	REMARKS AND OTHER TESTS
1	2	3	4	5	6	7	8	9	10	11	12

COLUMN DESCRIPTIONS

1 **Elevation:** Elevation in feet referenced to specified datum.

2 **Depth:** Depth in feet below the ground surface.

3 **Sample Type:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

4 **Sample Number:** Sample identification number.

5 **Sampling Resistance:** Number of blows required to advance driven sampler 12 inches beyond first 6-inch interval, or distance noted, using a 140-lb hammer with a 30-inch drop; or down-pressure for pushed sampler.

6 **Recovery:** Percentage of driven or pushed sample length recovered; "NA" indicates data not recorded.

7 **Graphic Log:** Graphic depiction of subsurface material encountered; typical symbols are explained below.

8 **Material Description:** Description of material encountered; may include density/consistency, moisture, color, and grain size.

9 **Water Content:** Water content of soil sample measured in laboratory, expressed as percentage of dry weight of specimen.

10 **Dry Unit Weight:** Density of soil as measured in the laboratory, in pounds per cubic foot

11 **Fines Content** Percentage passing the #200 sieve as measured in the laboratory

12 **Remarks and Other Tests:** Comments and observations regarding drilling or sampling made by driller or field personnel.

pp= Pocket Penetrometer [tsf]
T= Torvane Penetrometer [kg/sq. cm]
LL= Liquid Limit from Atterberg limit test [%] ASTM D4318
PL= Plastic Limit from Atterberg limit test [%] ASTM D4318
UC: Unconfined Compressive Strength test [psf] ASTM D2166
TX-UU: Unconsolidated, Undrained Triaxial test [psf] ASTM D2850
Consol Consolidation Test performed ASTM D2435

TYPICAL MATERIAL GRAPHIC SYMBOLS

- TOPSOIL/ASPHALT as indicated
- POORLY GRADED GRAVEL (GP)
- CLAYEY GRAVEL (GC)
- SILTY GRAVEL with SAND (GM)
- CLAYEY GRAVEL with SAND (GC)
- SILTY SAND (SM)
- SILTY SAND with GRAVEL (SM)
- CLAYEY SAND (SC)
- CLAYEY SAND with GRAVEL (SC)
- SANDY SILT (ML)
- ELASTIC SILT with SAND (MH)
- SANDY ELASTIC SILT (MH)
- ORGANIC ELASTIC SILT (OH)

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Standard Penetration Test (SPT)
- 2.0-in ID California Sampler
- 2.5-in ID California Sampler
- Shelby Tube Thin-Walled Sampler
- HQ Rock Core

OTHER GRAPHIC SYMBOLS

- ∇ First water encountered at time of drilling
- ▼ Static water as measured
- Change in material properties within a stratum
- — — — Inferred or transitional contact

GENERAL NOTES

1. Soil and rock descriptions and contact lines are interpretive. Field descriptions may have been modified to reflect results of lab tests.
2. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced.

AECOM

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance	SAMPLES: Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Well Diagram	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
1	2	3	4	5	6	7	8	9	10	11	12

COLUMN DESCRIPTIONS

1 **Elevation:** Elevation in feet referenced to mean sea level (MSL) or other specified datum.

2 **Depth:** Depth in feet below the ground surface.

3 **Sample Type:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

4 **Sample Number:** Sample identification number.

5 **Sampling Resistance:** Number of blows required to advance driven sampler 12 inches beyond first 6-inch interval, or distance noted, using a 140-lb hammer with a 30-inch drop.

6 **Recovery:** Percentage of driven or pushed sample recovered relative to sampled interval; "NA" indicates data not recorded.

7 **Graphic Log:** Graphic depiction of subsurface material encountered; typical symbols are explained below.

8 **Material Description:** Description of material encountered; in addition to classification and USCS, may include relative density or consistency, color, moisture, and grain size.

9 **Well Diagram:** Graphic depiction of well or piezometer installation; materials are listed in header block; graphic symbols are explained below.

10 **Water Content:** Water content of soil sample measured in laboratory, expressed as percentage of dry weight of specimen.

11 **Fines Content, %** Percent finer than #200 sieve, as measured in the laboratory

12 **Remarks and Other Tests:** Observations regarding drilling or sampling made by driller or field personnel. Other field and laboratory test results, using the following abbreviations:

TYPICAL MATERIAL GRAPHIC SYMBOLS

LEAN CLAY (CL)

LEAN CLAY with SAND (CL)

SANDY LEAN CLAY (CL)

SANDY LEAN CLAY with GRAVEL (CL)

SILTY CLAY (CL-ML)

LEAN to FAT CLAY (CL-CH)

LEAN to FAT CLAY with GRAVEL (CL-CH)

FAT CLAY (CH)

FAT SILTY CLAY (CH-MH)

FAT SILTY CLAY with GRAVEL (CH-MH)

SANDSTONE

SANDY SILTSTONE

SILTSTONE

CLAYSTONE

SHALE

MELANGE SHALE

TYPICAL WELL GRAPHIC SYMBOLS

2" PVC Solid Casing in Neat Cement Grout

2" PVC Solid Casing in Bentonite Pellets

2" PVC Solid Casing in #3 Sand

2" PVC 0.020-in Slotted Casing in #3 Sand

#3 Sand in hole

Project: Bolinas Lagoon North End Restoration
Project Location: Marin County, CA
Project Number: 60393194

Log of Soil Boring B-1

Date(s) Drilled	**3/27/2017-3/28/2017**	Logged By	**S. Janowski**	Checked By	**J. Tabor**
Drilling Method	**Hand auger to 5'; 8-in hollow stem auger (HSA) thereafter**	Drill Bit Size/Type	**4" hand auger; 8" OD HSA**	Total Depth of Borehole	**66.5 feet**
Drill Rig Type	**CME 55 Truck-mounted rig (TMR)**	Drilling Contractor	**Pitcher Drilling Company**	NAVD 88 Ground Surface Elevation	**Approximate 28-ft**
Groundwater Level(s)	**10' while drilling**	Sampling Method(s)	**SPT, 2" Modified California**	Hammer Data	**Automatic hammer; 140 lbs, 30-inch drop**
Borehole Completion	**2" PVC piezometer installed**			Coordinate Location	**N 2170545 E 5927279**

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance	SAMPLES: Recovery, %	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	0					6-inch thick TOPSOIL SANDY LEAN CLAY (CL); moist; dark brown (10YR3/3); 5% GRAVEL to 3/4"; 43% fine-grained SAND; 52% low plasticity FINES; rootlets --ALLUVIUM--			**WELL: 12" steel Christy box installed at surface** **WELL: 2" PVC solid casing and neat cement grout to surface**
25									
	5		1-2 1-3	1 2 2	100	Becomes very soft	22.3	52	pp=1.0 tsf; TX-UU: Max. deviator stress=988 psf;confining pressure=450 psf
20									
	10		2	1 2 3	56	Becomes wet; mottled dark brown (10YR3/3) and dark gray (4/N); with 15% fine GRAVEL; 56% FINES	22.3	56	pp=1.25 tsf; Sample #2 bagged
15									
	15		3	1 3 5	0	SANDY LEAN CLAY (CL); medium to very stiff; wet; dark grayish brown (2.5Y4/2); 7% subangular GRAVEL to 3/4"; 41% fine- to coarse-grained SAND; 52% low plasticity FINES --OLDER ALLUVIUM--			No recovery: sampler replaced in hole and recovered; Sample #3 disturbed and bagged **WELL: 2' Bentonite Pellet seal** Water level measured at 16.1' after Sample #3
10									
	20		4-2 4-3	3 13 16	89		23.2	52	**WELL: #3 sand filter pack 18'-25.5'** **WELL: 2" PVC 0.020 slotted screen**
5									
	25		5	14 16 14	67	Becomes dense; dark greenish gray (5G4/1)			**WELL: Neat cement grout 25.5' to 66.5'**
0						CLAYEY SAND (SC); medium dense; moist; black (7.5YR2.5/1); 60% fine-grained SAND; 40% low plasticity FINES --MERCED FM Tmc--			
	30								

AECOM

Elevation feet	Depth, feet	Samples: Type	Samples: Number	Samples: Sampling Resistance	Samples: Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Well Diagram	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	30		6	5 6 7	100		CLAYEY SAND (SC); medium dense; moist; black (7.5YR2.5/1); 60% fine-grained SAND; 40% low plasticity FINES. Becomes dark greenish gray (10GY4/1) at 31' --MERCED FM Tmc-- *(continued)*				No rock fabric observed in sample
-5							SILTY SAND (SM); dense to medium stiff; moist; greenish gray (10GY5/1); 60% fine-grained SAND; 40% no plasticity FINES				
	35		7-2 7-3	8 16 25	100				19.9		TX-UU: Max. deviator stress=2581 psf;confining pressure=3200 psf
-10											
	40		8	16 18 22	0		Becomes light gray and brownish yellow (10YR7/2+6/6); 10% subrounded GRAVEL to 3/4"				No recovery: sample recovered from slough collector on sampler and bagged
-15											
	45		9-2 9-3	12 14 16	100		SANDY CLAYSTONE; very stiff; moist; dark greenish gray (10BG4/1); 20% fine-grained SAND; 80% medium to high plasticity FINES; completely altered; very to extremely weak				pp=3.25 tsf Hard drilling
-20											
	50		10-2 10-3	12 22 40	100		Becomes hard; dark greenish gray (10Y4/1); 60% FINES		19.3	60	Hard drilling
-25											
	55										
-30											
	60		11	17 24 29	89						pp=>4.5 tsf
-35											
	65										

Project: Bolinas Lagoon North End Restoration	Log of Soil Boring B-1
Project Location: Marin County, CA	
Project Number: 60393194	Sheet 3 of 3

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Well Diagram	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	65		12	17 19 27	100		SANDY CLAYSTONE; hard; moist; dark greenish gray (10Y4/1); 20% fine-grained SAND; 80% medium to high plasticity FINES; completely altered; very to extremely weak --MERCED FM Tmc-- *(continued)*				pp=>4.5 tsf
							TOTAL DEPTH = 66.5 FEET **Grout bottom of hole 3/27/2017, Well install 3/28/2017**				
-40											
	70										
-45											
	75										
-50											
	80										
-55											
	85										
-60											
	90										
-65											
	95										
-70											
	100										

Report: GEO_12W_OAK; File: BOLINAS AECOM ROCK CORE.GPJ; 6/15/2017 B-1

AECOM

Log of Soil and Core Boring B-2

Project: Bolinas Lagoon North End Restoration
Project Location: Marin County, CA
Project Number: 60393194

Date(s) Drilled	**3/28/2017-3/29/2017**	Logged By	**S. Janowski**	Checked By	**J. Tabor**
Drilling Method	**Hand auger to 5'; rotary wash thereafter**	Drill Bit Size/Type	**4" hand auger; 5" & 4" drag and tricone bits**	Total Depth of Borehole	**51.0 feet**
Drill Rig Type	**CME 55 Truck-mounted rig (TMR)**	Drilling Contractor	**Pitcher Drilling Company**	NAVD 88 Ground Surface Elevation	**Approximate 21-ft**
Groundwater Level(s)	**5.2' while drilling**	Sampling Method(s)	**SPT, 2" Modified California, Shelby tube**	Hammer Data	**Automatic hammer; 140 lbs, 30-inch drop**
Borehole Completion	**2" PVC piezometer installed in an adjacent HSA hole**			Coordinate Location	**N 2170483 E 5927484**

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Sampling Resistance	Samples: Recovery, %	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
20	0					12-inch thick ASPHALT; 3 layers			**WELL: 12" steel Christy box installed at surface**
						SILTY GRAVEL with SAND (GM); dry; tan-brown --BASECOURSE--			**WELL: 2" PVC solid casing 0'-10' and neat cement grout to surface**
						SANDY LEAN CLAY with organics (CL); soft to very stiff; moist; black (5Y2.5/1); 20% fine-grained SAND; 69% low plasticity FINES; roots --ALLUVIUM-- Becomes wet Becomes stiff; mottled dark yellowish brown (10YR3/4)			pp=2.5 tsf
15	5		1-2 1-3	1 2 2	89		28.2	69	pp=1.0 - 1.5 tsf; TX-UU: Max. deviator stress=1078 psf;confining pressure=450 psf **WELL: 3' Bentonite Pellet seal 5'-8'** Switch to rotary wash; advance 6" casing to 3.5'
						SANDY SILT (MH); soft; wet; very dark greenish gray (10Y3/1); 33% fine-grained SAND; 67% elastic FINES; some organic detritus			**WELL: #3 sand filter pack 8'-16'**
10	10		2-2 2-3	0 0 0	100		28.1	67	pp=0.5 tsf T=1.75 kg/sq.cm; UC: 964 psf **WELL: 2" PVC 0.020 slotted screen 10'-15'**
			3	50 psi	100				pp=<0.25 tsf
						CLAYEY GRAVEL with SAND (GC); wet; very dark greenish gray (10Y3/1); subrounded GRAVEL to 1/4" at bottom of sample tube			
						CLAYEY SAND (SC); stiff to very loose; wet; very dark greenish gray (10Y3/1); 10% subrounded GRAVEL to 1/4"; 45% fine-grained SAND; 45% medium plasticity FINES; vertical roots			
5	15		4	0 0 2	100				pp=1.0 tsf
						GRAVEL of mixed lithologies seen in cuttings and in Sample #5 slough			Gravel in cuttings
						SANDSTONE boulder; moderate yellowish brown (10YR5/4) and greenish gray (5G6/1); highly weathered; very weak; fining with depth --Terrace Deposits (Qt)--			Obvious rock fabric
0	20		5	9 11 6	61	SANDY SILT (ML); medium dense; moist; moderate yellowish brown (10YR5/4) and greenish gray (5G6/1); 15% GRAVEL to 1"; 35% fine- to coarse-grained SAND; 50% low plasticity FINES			
									Rig chatter
									Smooth drilling
-5	25		6-1 6-2	22 17 13	72		18.6	50	pp=2.5 tsf; Advance 5" casing to 25'; remove 6" casing; End of day 3/28/2017 Begin day 3/29/2017 AM water level=1.0' bgs Switch to 4" tricone bit
						LEAN to FAT CLAY (CL-CH); hard; moist; light brown (5YR5/6) and moderate yellowish brown (10YR5/4); trace fine-grained SAND; medium to high plasticity FINES; thin laminations			
	30								

Project: Bolinas Lagoon North End Restoration
Project Location: Marin County, CA
Project Number: 60393194

Log of Soil and Core Boring B-2

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Well Diagram	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
-10	30		7	5 7 10	6		LEAN to FAT CLAY (CL-CH); hard; moist; light brown (5YR5/6) and moderate yellowish brown (10YR5/4); trace fine-grained SAND; medium to high plasticity FINES; thin laminations --Terrace Deposits (Qt)-- *(continued)*				Only gravel and clay slough recovered
							SILTY SAND (SM); dense; moist; grayish blue green (5BG5/2); lightly consolidated; disturbed from sampling				
-15	35		8	9 20 22	83						
							CLAYEY GRAVEL with SAND (GC); moist; dusky blue green (5BG3/2) and dark greenish gray (5G4/1); 40% subrounded GRAVEL to 2"; 30% fine- to coarse-grained SAND; 30% medium plasticity FINES				Hard drilling; rig chatter
-20	40		1		100						Switch to HQ advancement; #8 diamond bit; RQD=0% RQD=0%
							CLAYEY SAND; hard; wet; grayish black (N2); 60% fine- to medium-grained SAND; 40% low plasticity FINES				
			2		74						pp=>4.5 tsf
-25	45										
			3		50		CLAYEY GRAVEL with SAND (GC); moist; greenish black (5G2/1); 40% subrounded graywacke sandstone GRAVEL to 2"; 30% fine- to coarse-grained SAND; 30% low plasticity FINES; sheared and disturbed				RQD=0%
			4		67						Bit blocked off; RQD=0%
-30	50										
							TOTAL DEPTH = 51.0 FEET **Grout to surface and drill an adjacent HSA hole to 16' for installation on 3/29/2017**				
-35	55										
-40	60										
	65										

Project: Bolinas Lagoon North End Restoration Project Location: Marin County, CA Project Number: 60393194	**Log of Soil Boring B-3** Sheet 1 of 2

Date(s) Drilled	**3/30/2017**	Logged By	**S. Janowski**	Checked By	**J. Tabor**
Drilling Method	**Hand auger to 5'; rotary wash thereafter**	Drill Bit Size/Type	**4" hand auger; 4" drag and tricone bits**	Total Depth of Borehole	**51.5 feet**
Drill Rig Type	**CME 55 Truck-mounted rig (TMR)**	Drilling Contractor	**Pitcher Drilling Company**	NAVD 88 Ground Surface Elevation	**Approximate 13-ft**
Groundwater Level(s)	**1.5' while drilling**	Sampling Method(s)	**SPT, 2" Modified California**	Hammer Data	**Automatic hammer; 140 lbs, 30-inch drop**
Borehole Backfill	**Neat cement grout to surface**	Borehole Location	**On east edge of Fairfax Bolinas Road, 40' north of Hwy 1**	Coordinate Location	**N 2170268 E 5928042**

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	0						1-inch thick ASPHALT				
							SILTY GRAVEL with SAND (GM); moist; dark brown (10YR3/3); occasional COBBLES; angular GRAVEL to 3"; fine- to coarse-grained SAND; no plasticity FINES. Becomes wet at 1.5' ▽ --FILL?--				
10											Caving gravels
	5		1	0 0 0	67		LEAN CLAY with organics (CL); very soft to soft; moist; black (10YR2/1); 5% fine-grained SAND; 90% medium plasticity FINES; with organics --ALLUVIUM--				pp=0.25 tsf; T=2.4 kg/sq.cm
											Switch to rotary wash; advance 5" casing to 3.5'
5											
	10		2-1	1 0 1	33			48.0	69		TX-UU: Max. deviator stress=494 psf;confining pressure=900 psf; LL=41 PL=24
0											
	15		3-2 3-3	0 0 2	100		Becomes medium stiff; less organic and increased plasticity with depth	58.3		90	pp=0.75 tsf; T=2.5 kg/sq.cm
-5											
							CLAYEY GRAVEL with SAND (GC); moist; dark greenish gray (5G4/1); 40% subrounded GRAVEL to 1"; 30% fine- to coarse-grained SAND; 30% low plasticity FINES --Terrace Deposits (Qt)--				
	20		4-1 4-2	10 8 5	78						4-1 contains slough
							SANDY LEAN CLAY (CL); stiff; moist; very dark greenish gray (10BG3/1); 30% fine-grained SAND; 70% low plasticity FINES				p=1.25 tsf
-10											
											Rig chatter
	25		5	2 6 5	72		SILTY SAND with GRAVEL (SM); medium dense, moist; very dark greenish gray (5BG3/1); 15% subrounded GRAVEL to 1/4"; 63% fine- to coarse-grained SAND; 22% no plasticity FINES	20.7		22	No rock fabric observed in sample
-15							CLAYEY SAND with GRAVEL (SC); stiff to very stiff; moist; very dark gray (2.5Y3/1); 32% subangular to subrounded GRAVEL to 1"; 45% fine- to coarse-grained SAND; 23% medium plasticity FINES				
	30										

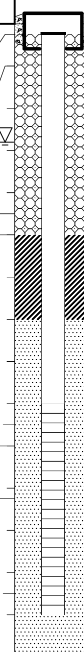
AECOM

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	30		6	9 9 10	56		CLAYEY SAND with GRAVEL (SC); very stiff; moist; very dark gray (2.5Y3/1); 32% subangular to subrounded GRAVEL to 1"; 45% fine- to coarse-grained SAND; 23% medium plasticity FINES --Terrace Deposits (Qt)-- *(continued)*				No rock fabric observed in sample pp=3.25 tsf
-20											
	35		7	9 17 21	72			7.7		23	30% Water circulation return (WCR); rig chatter Attempt sample at 35'; 4' cave measured Advance 4" casing to 35'
-25											
	40		8	9 15 18	83						pp=>4.5 tsf No rock fabric observed in sample
-30							SANDY LEAN CLAY (CL); hard; moist; very dark gray (2.5Y3/1); 7% subangular to subrounded GRAVEL to 3/4"; 40% fine- to coarse-grained SAND; 53% medium plasticity FINES				
	45		9-1 9-2	10 15 20	78			15.0	121	53	pp=4.0 tsf; TX-UU: Max. deviator stress=4000 psf;confining pressure=4986 psf 30% WCR; thicken mud
-35											
	50		10	10 17 25	100		Washed zone, not retained Very stiff; lesser GRAVEL content				pp=3.75 tsf
							TOTAL DEPTH = 51.5 FEET **Neat cement grout tremmied to surface on 3/30/2017. Well aborted due to high water table and fine-grained alluvium in proposed filter pack zone.**				
-40											
	55										
-45											
	60										
-50											
	65										

Project: Bolinas Lagoon North End Restoration
Project Location: Marin County, CA
Project Number: 60393194

Log of Soil Boring B-4

Date(s) Drilled	**3/31/2017**	Logged By	**S. Janowski**	Checked By	**J. Tabor**
Drilling Method	**Hand auger to 5'; rotary wash thereafter**	Drill Bit Size/Type	**4" hand auger; 4" drag and tricone bits**	Total Depth of Borehole	**61.5 feet**
Drill Rig Type	**CME 55 Truck-mounted rig (TMR)**	Drilling Contractor	**Pitcher Drilling Company**	NAVD 88 Ground Surface Elevation	**Approximate 8-ft**
Groundwater Level(s)	**2.8' while drilling**	Sampling Method(s)	**SPT, 2" Modified California, Shelby tube**	Hammer Data	**Automatic hammer; 140 lbs, 30-inch drop**
Borehole Completion	**2" PVC piezometer installed in an adjacent HSA hole**			Coordinate Location	**N 2170073 E 5928333**



Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, %	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	0					3-inch thick road shoulder GRAVEL			
						GRAVELLY LEAN CLAY with SAND (CL); very stiff; moist; brown --FILL--			**WELL: 12" steel Christy box installed at surface** pp=3.75 tsf **WELL: 2" PVC solid casing 0'-9' and neat cement grout to surface**
5						SILTY GRAVEL with SAND (GM); dry; brown; occasional subangular COBBLES; 50% subangular GRAVEL to 3"; 35% fine- to coarse-grained SAND; 15% no plasticity FINES. Becomes wet at 2.8' --FILL--			
	5		1	0 0 0	28	ELASTIC SILT with SAND and organics (MH); soft; wet; black (N2.5/1); 20% fine-grained SAND; 50% elastic FINES; 30% organic detritus --LAGOON DEPOSIT--			Switch to rotary wash; advance 5" casing to 3.5' pp=0.25 tsf; T=1.4 kg/sq.cm **WELL: 3' Bentonite Pellet seal 5'-7'**
0			2	50 psi	87	← SANDier at base of tube			Gravel slough at top of tube **WELL: #3 sand filter pack 7'-15'**
	10		3-2 3-3	0 0 0	94	ORGANIC ELASTIC SILT (OH); very soft; wet; black (N2.5/1); 84% FINES; strong organic odor	109.7	84	pp=0.5 tsf Advance 5" casing to 8.5' TX-UU: Max. deviator stress=981 psf;confining pressure=900 psf
-5						LEAN CLAY (CL); moist; very dark brown (10YR2/2); 10% fine-grained SAND; medium plasticity FINES			**WELL: 2" PVC 0.020 slotted screen 9'-14'**
						ELASTIC SILT with SAND and organics (MH); soft; wet; black (N2.5/1); 20% fine-grained SAND; 50% elastic FINES; 30% organic detritus			
	15		4	50 psi	80	← Shells and strong organic odor at base of tube			
-10						SILTY CLAY with organics (CH-MH); soft to medium stiff; moist; dark olive gray (5Y3/2); 2% fine- to medium-grained SAND; 98% high plasticity FINES; organic detritus and organic odor			
	20		5-2 5-3	1 0 1	100		80.8	98	pp=0.5 tsf; T=1.7 kg/sq.cm; TX-UU: Max. deviator stress=1242 psf;confining pressure=1800 psf
-15									
	25		6A 6B	3 2 1	83	CLAYEY GRAVEL with SAND (GC); moist; dark greenish gray (5G4/1); 40% subrounded GRAVEL to 1"; 30% fine- to coarse-grained SAND; 30% low plasticity FINES --Terrace Deposits (Qt)--			Rig chatter; pp=1.0 tsf
-20						SANDY LEAN CLAY (CL); stiff; moist; brownish black (5YR2/1); 30% fine-grained SAND; 70% medium plasticity FINES			
						CLAYEY GRAVEL with SAND (GC)			
	30								

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Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Well Diagram	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	30		7-2	1 4 4	50		CLAYEY GRAVEL with SAND (GC); moist; dark greenish gray (5G4/1); 40% subrounded GRAVEL to 1"; 30% fine- to coarse-grained SAND; 30% low plasticity FINES --Terrace Deposits (Qt)-- *(continued)*				Strong evidence is decomposed rock Bottom 6" slid out of sampler
-25							SANDY LEAN CLAY (CL); stiff; moist; brownish black (5YR2/1); 30% fine-grained SAND; 70% medium plasticity FINES; some wood fibers				
	35		8	0 4 6	100						pp=1.25 tsf
							CLAYEY GRAVEL with SAND (GC); moist; dark greenish gray (5G4/1); 40% subrounded, mixed lithology GRAVEL to 1"; 30% fine- to coarse-grained SAND; 30% low plasticity FINES				
-30							SANDY LEAN CLAY (CL); stiff; moist; brownish black (5YR2/1); 30% fine-grained SAND; 70% medium plasticity FINES; lightly cemented				
	40		9-2 9-3	2 6 10	100						Light rock fabric; pp=1.0 tsf
-35							GRAVELLY CLAY (CL-CH); stiff; moist; dark greenish gray (5G4/1); 50% completely decomposed, friable grayish blue green (5BG5/2) SANDSTONE clasts to 3/4"; 50% medium to high plasticity FINES				
	45		10	0 4 7	100						No rock fabric observed in sample pp=1.25 tsf
-40							CLAYEY GRAVEL (GC); medium dense to very stiff; moist; brownish black (5YR2/1); 60% GRAVEL of mixed lithologies; some clasts decomposed; 10% fine- to coarse-grained SAND; 30% medium plasticity FINES				
	50		11-1 11-2	10 11 14	72						
-45											
	55		12	7 8 12	83						pp=3.25 tsf
-50											
	60		13	6 11 16	100		Becomes hard				pp=4.0 tsf
-55							**TOTAL DEPTH = 61.5 FEET** **Grout to surface and drill an adjacent HSA hole to 16' for installation on 3/31/2017**				
	65										

Project: Bolinas Lagoon North End Restoration
Project Location: Marin County, CA
Project Number: 60393194

Log of Soil Boring B-5

Date(s) Drilled	3/30/2017	Logged By	S. Janowski	Checked By	J. Tabor
Drilling Method	Hand auger to 5'; 8-in hollow stem auger (HSA) thereafter	Drill Bit Size/Type	4" hand auger; 8" OD HSA	Total Depth of Borehole	26.5 feet
Drill Rig Type	CME 55 Truck-mounted rig (TMR)	Drilling Contractor	Pitcher Drilling Company	NAVD 88 Ground Surface Elevation	Approximate 8-ft
Groundwater Level(s)	2.8' while drilling	Sampling Method(s)	SPT, 2" Modified California	Hammer Data	Automatic hammer; 140 lbs, 30-inch drop
Borehole Backfill	Neat cement grout to surface	Borehole Location	60' west of east edge of northbound Hwy 1 turnout before switchback	Coordinate Location	N 2169797 E 5928739

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	0						6-inch thick TOPSOIL				
							SILTY GRAVEL with SAND (GM); moist; brown (10YR4/3); occasional COBBLES; 50% subangular to subrounded GRAVEL to 3/4"; 35% medium- to coarse-grained SAND; 15% no plasticity FINES. Wet at 2.75' --FILL-- ▽				
5											
	5		1	1 2 4	100		FAT CLAY (CH); very stiff; moist; yellowish brown (10YR5/8) and greenish gray (10BG5/1); 2% fine- to medium-grained SAND; 98% high plasticity FINES; rootlets --Kfs Residual Soil--	24.6		98	pp=3.0 tsf
0											
							SILTSTONE; dark yellowish brown (10YR4/2); highly weathered; very weak; occasional charcoal specks; iron oxide staining on parting surfaces; very stiff --Kfs--				
	10		2-1 2-2	5 7 17	72			19.5	114	83	pp=>4.5 tsf; obvious rock texture; UC: 4523 psf
-5											
	15		3-2 3-3	8 13 27	100		MELANGE SHALE; dark gray (N3); highly weathered; very weak; medium plasticity; minor iron oxide staining on parting surfaces; slightly moist				pp=>4.5 tsf
-10											
	20		4	8 14 29	100		Becomes MELANGE SHALE and SERPENTINITE; dark greenish gray (5G4/1); very dry				
-15											
	25		5	11 18 21	100						
							TOTAL DEPTH = 26.5 FEET **Neat cement grout tremmied to surface on 3/30/2017**				
-20											
	30										

AECOM

Log of Soil Boring B-6

Project: Bolinas Lagoon North End Restoration
Project Location: Marin County, CA
Project Number: 60393194

Date(s) Drilled	**4/20/2017**	Logged By	**S. Janowski**	Checked By	**J. Tabor**
Drilling Method	**Hand auger to 5'; rotary wash thereafter**	Drill Bit Size/Type	**4" hand auger; 4" drag and tricone bits**	Total Depth of Borehole	**60.5 feet**
Drill Rig Type	**CME 850 Track-mounted rig**	Drilling Contractor	**Pitcher Drilling Company**	NAVD 88 Ground Surface Elevation	**Approximate 13-ft**
Groundwater Level(s)	**1.9' while drilling**	Sampling Method(s)	**SPT, 2" & 2.5" Modified California, Shelby tube**	Hammer Data	**Automatic hammer; 140 lbs, 30-inch drop**
Borehole Completion	**2" PVC piezometer installed in an adjacent HSA hole**			Coordinate Location	**N 2170099 E 5927493**

Elevation, feet	Depth, feet	Sample Number	Sampling Resistance	Recovery, %	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	0				6-inch thick TOPSOIL with vegetation			
10					SILTY CLAY (CL-ML); very soft; wet; black (10YR2/1); 12% fine-grained SAND; 88% medium plasticity FINES --LAGOON DEPOSIT--			
	5	1-2	0 0 0	50		38.9	88	pp=0.25 tsf; T=2.5 kg/sq.cm pp=0.5 tsf; T=2.7 kg/sq.cm Switch to rotary wash; advance 5" casing to 4'; TX-UU: Max. deviator stress=699 psf;confining pressure=450 psf; LL=47 PL=22 Consol
5		2	25 psi	100		35.6		
					CLAYEY GRAVEL (GC); wet; dark gray			
	10	3	1 1 1	39	FAT SILTY CLAY with SAND and GRAVEL (CH-MH); soft; wet; greenish black (10Y2.5/1); 20% decomposed blue green sandstone GRAVEL to 3/4"; 30% fine-grained SAND; 50% high plasticity FINES --Terrace Deposits (Qt)--			pp=0.25 tsf; T=1.5 kg/sq.cm
0	15	4-2 4-3	0 2 3	83	No decomposed GRAVEL in visible portion of sample	23.5	50	pp=0.75 tsf; T=1.0 kg/sq.cm; TX-UU: Max. deviator stress=1732 psf;confining pressure=1350 psf
-5	20	5-2	11 18 16	67	SILTY GRAVEL with SAND (GM); medium dense; moist; olive gray (5Y4/2); 40% subangular to subrounded GRAVEL to 3/4"; 35% fine- to medium-grained SAND; 25% no to low plasticity FINES			Lithology change in Sample 5-2; photo
-10	25	6	8 10 12	72	CLAYEY SAND with GRAVEL (SC); very stiff to hard; moist; dark yellowish brown (10YR5/6); 26% partially decomposed GRAVEL to 1/2"; 30% fine-grained SAND; 44% low plasticity FINES	17.0	44	pp=3.0 - >4.5 tsf
-15	30	7-2	10 24	100	Becomes hard; 25% subangular GRAVEL to 3/4"; 20% fine- to medium-grained SAND; 55% low plasticity FINES			pp=4.25 tsf

Report: GEO_12W_OAK; File: BOLINAS AECOM ROCK CORE.GPJ; 6/15/2017 B-6

Elevation feet	Depth, feet	Type	Number	Sampling Resistance	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Well Diagram	Water Content, %	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	30		7-3	27			CLAYEY SAND with GRAVEL (SC); hard; moist; dark yellowish brown (10YR5/6); 30% subangular GRAVEL to 3/4"; 24% fine- to medium-grained SAND; 46% low plasticity FINES --Terrace Deposits (Qt)-- *(continued)*				
-20							Becomes greenish black (10BG2.5/1)				
	35		8	7 13 15	100				16.9	46	pp=4.0 tsf
											Rig chatter
-25											
	40		9	16 19 20	100		Becomes subrounded to rounded GRAVEL to 1"				
-30											
	45		10	40 45 50/5"	12		2" GRAVEL clast blocked shoe of sampler				Sample bagged
-35							LEAN CLAY with SAND (CL); hard; moist; black (2.5/1); 5% subrounded GRAVEL to 1/4"; 20% fine- to medium-grained SAND; low plasticity FINES				
	50		11-1 11-2 11-3	17 27 37	100		Charcoal-rich zone, bagged				pp=4.5 tsf; Sample 11-1 bagged
-40											
	55						SHALE; dark greenish gray (5G4/1); highly weathered; very weak; friable; pervasively sheared --MERCED FM Tmc?--				Possible fault contact; no change in drilling performance between samples 11 and 12 to indicate contact
-45											
	60		12	20 27 30	100						
							TOTAL DEPTH = 60.5 FEET **Grout to surface and drill an adjacent HSA hole to 13' for installation on 4/20/2017**				
-50											
	65										

Project: Bolinas Lagoon North End Restoration Project Location: Marin County, CA Project Number: 60393194	**Log of Soil Boring B-7** Sheet 1 of 1

Date(s) Drilled	**4/21/2017**	Logged By	**S. Janowski**	Checked By	**J. Tabor**
Drilling Method	**Hand auger to 5'; rotary wash thereafter**	Drill Bit Size/Type	**4" hand auger; 4" drag and tricone bits**	Total Depth of Borehole	**25.5 feet**
Drill Rig Type	**CME 850 Track-mounted rig**	Drilling Contractor	**Pitcher Drilling Company**	NAVD 88 Ground Surface Elevation	**Approximate 12-ft**
Groundwater Level(s)	**4.95' while drilling**	Sampling Method(s)	**SPT, 2" Modified California**	Hammer Data	**Automatic hammer; 140 lbs, 30-inch drop**
Borehole Backfill	**Neat cement grout to surface**	Borehole Location	**220' SE of 1125 Olema Bolinas Rd driveway, 5' north of pavement**	Coordinate Location	**N 2169284 E 5927725**

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Fines Content (%<#200 Sieve)	REMARKS AND OTHER TESTS
	0						6-inch thick TOPSOIL with vegetation				
10							LEAN CLAY with SAND (CL); soft to stiff; moist; dark yellowish brown (10YR5/6); 3% subrounded GRAVEL to 3/8"; 18% fine-grained SAND; 79% medium plasticity FINES; some organic material --ALLUVIUM--				pp=1.25 tsf
	5		1-1 1-2	4 3 2	78		With abundant wood fragments ▽	36.6	81	79	pp=1.0 tsf; TX-UU: Max. deviator stress=1057 psf;confining pressure=450 psf
5											Switch to rotary wash; advance 5" casing to 4'
							FAT SILTY CLAY (CH-MH); stiff; moist; greenish gray (5GY5/1); trace fine-grained SAND; medium to high plasticity FINES; completely weathered CLAYSTONE; lightly consolidated --MERCED FM Tmc--				
	10		2	2 2 3	100						pp=1.0 tsf
0							Becomes very stiff; yellowish brown (10YR5/6); light rock fabric observed; iron oxide staining on parting surfaces; 85% FINES				Color change observed in cuttings
	15		3-2 3-3	6 8 10	89			29.9	93	85	pp=3.25 tsf; UC: 2361 psf
-5											
	20		4-2 4-3	7 12 24	89		SANDY SILTSTONE; hard; dry to moist; very dark greenish gray (10Y3/1); 30% fine-grained SAND; 70% no to low plasticity FINES; highly weathered; very weak; friable; little to no cementation				Lithology change observed in cuttings pp=>4.5 tsf
-10											
	25		5	7 8 12	100						pp=>4.5 tsf
							TOTAL DEPTH = 25.5 FEET **Neat cement grout tremmied to surface on 4/21/2017**				Mud pump broke into 2 parts; not repair-able in field. B-7 aborted at 25.5'
-15											
	30										

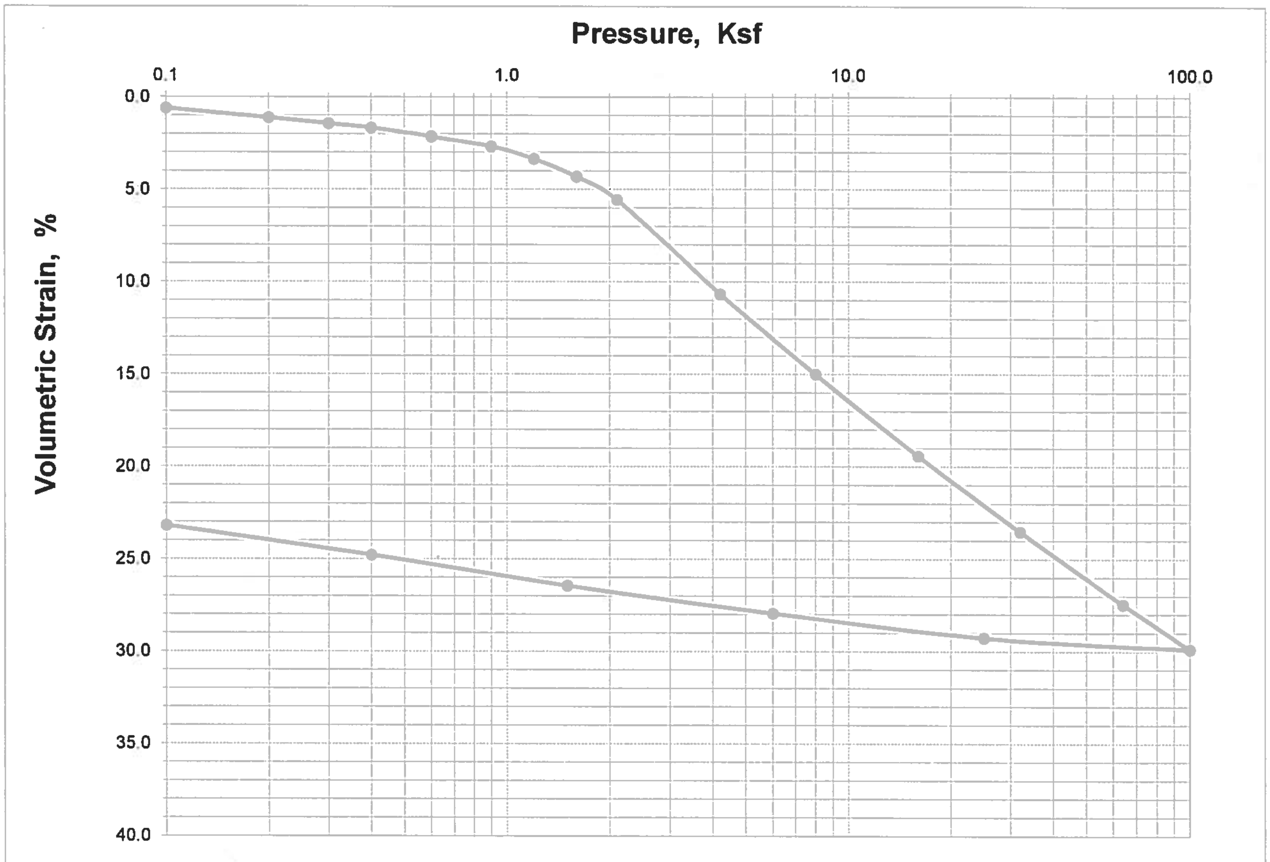
AECOM

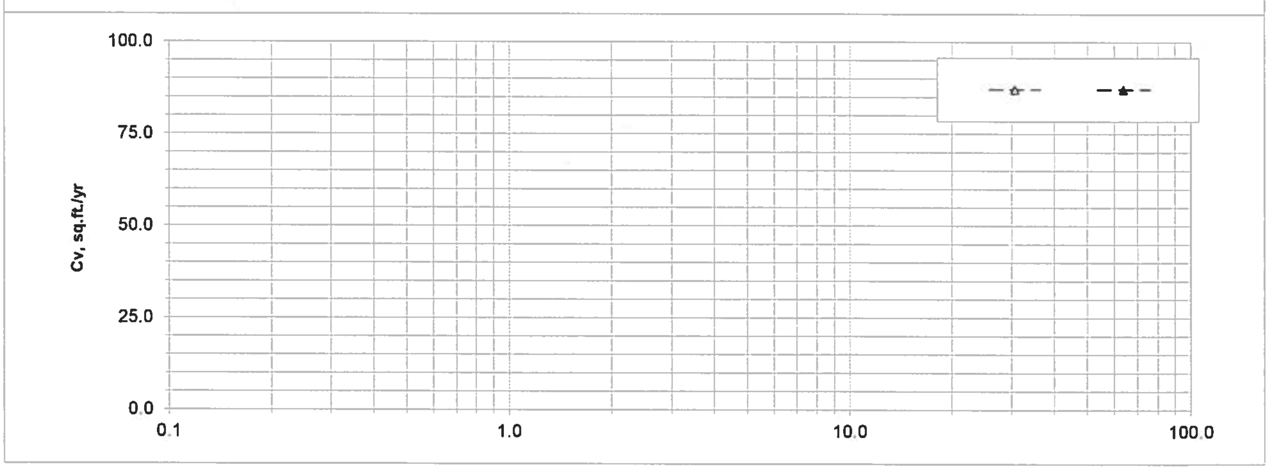
Attachment B

Laboratory Test Results

CONSOLIDATION TEST ASTM D - 2435

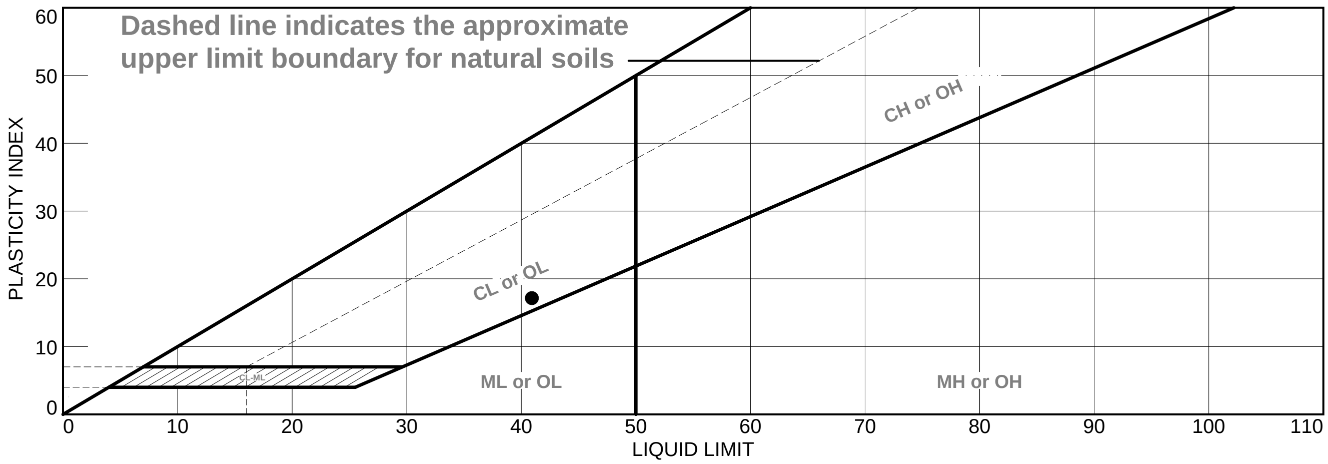
Boring Number	B-6	Sample Number	2	Depth (ft)	6.5-9			
Soil Description	Black clay (soft)							
	Water Content, %	Total Wet Unit Weight, pcf	Void Ratio	Saturation %	Height in	Diameter in	Specific Gravity	Liquid Limit, %	Plasticity Index, %
Initial	35.6	109.7	1.084	88.6	1.00		(assumed)		
Final	22.3	128.8	0.601	100.3	0.768	2.420	2.70		





60393194 **INSPECTION SERVICES, INC.** 5/31/2017

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Very soft gray clay	41	24	17			

Project No. **Client:** AECOM

Project: Bolinas Lagoon

60393194

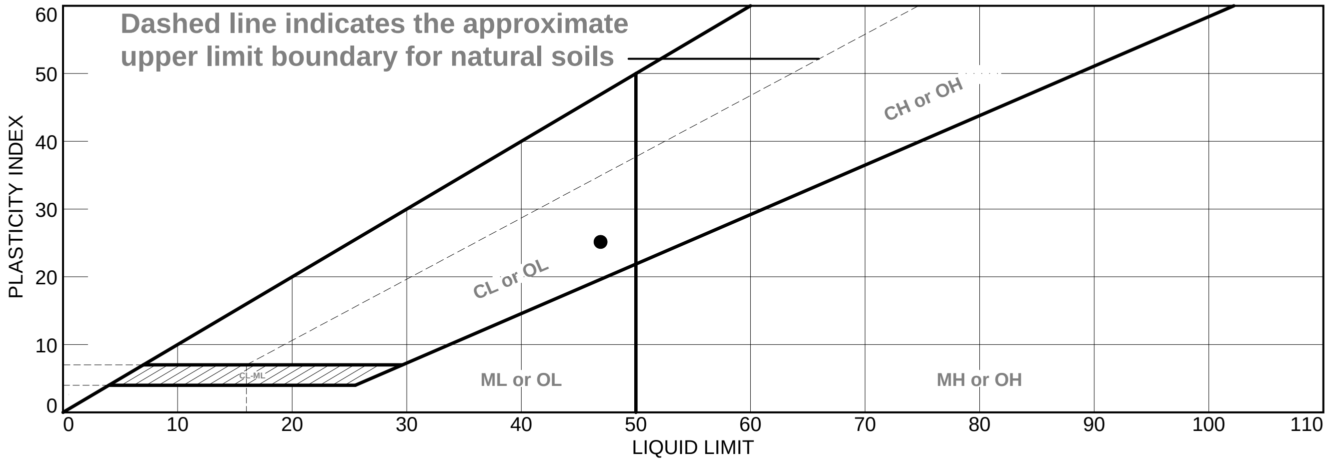
● **Source of Sample:** B-3 **Depth:** 10-11.5 **Sample Number:** 2-1

Remarks:

Figure

Tested By: JH **Checked By:** JH

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Very soft dark gray clay	47	22	25			

Project No. **Client:** AECOM

Project: Bolinas Lagoon

60393194

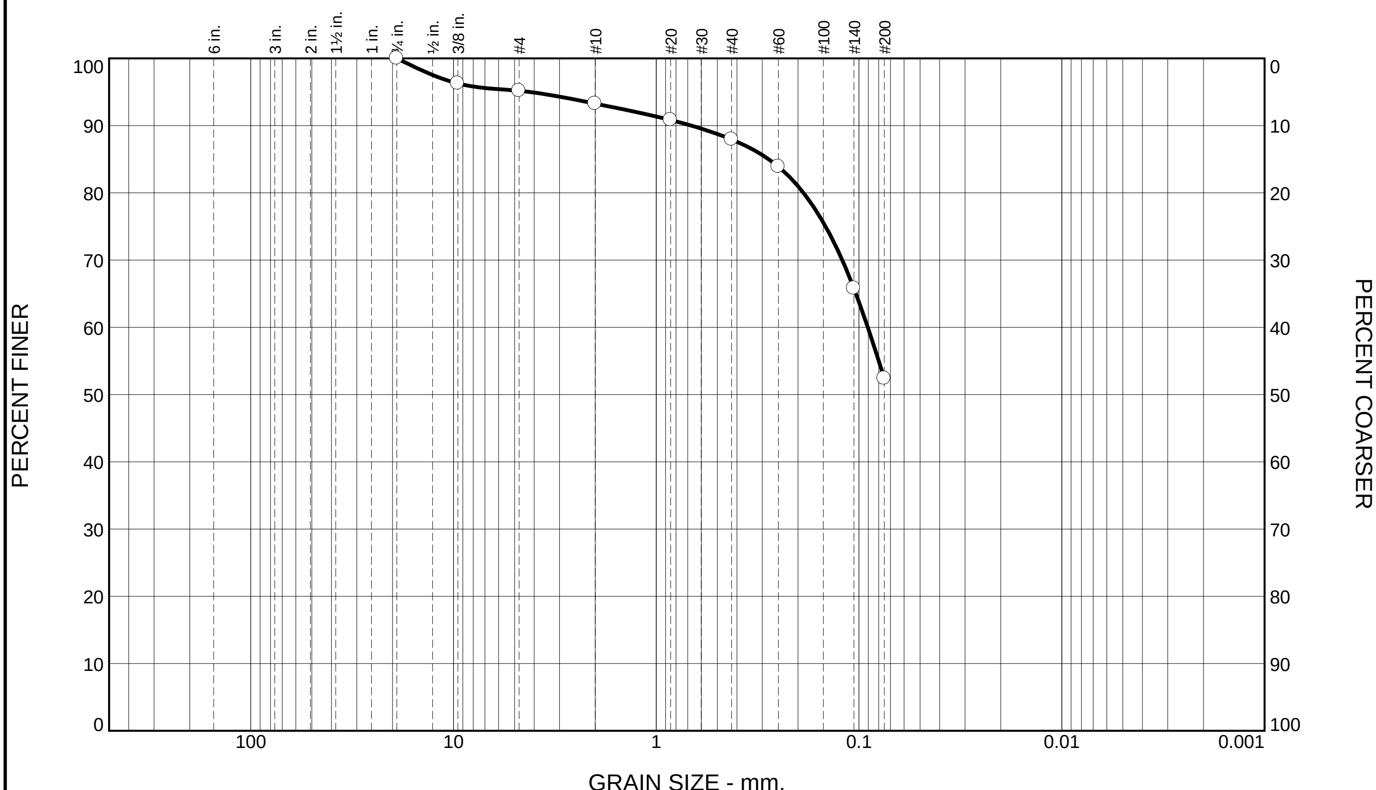
● **Source of Sample:** B-6 **Depth:** 5.5-6 **Sample Number:** 1-2

Remarks:

Figure

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	5	2	5	36	52	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4	100		
3/8	96		
#4	95		
#10	93		
#20	91		
#40	88		
#60	84		
#140	66		
#200	52		

* (no specification provided)

Material Description

Dark brown sandy clay

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.6734 D_{85}= 0.2792 D_{60}= 0.0906
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

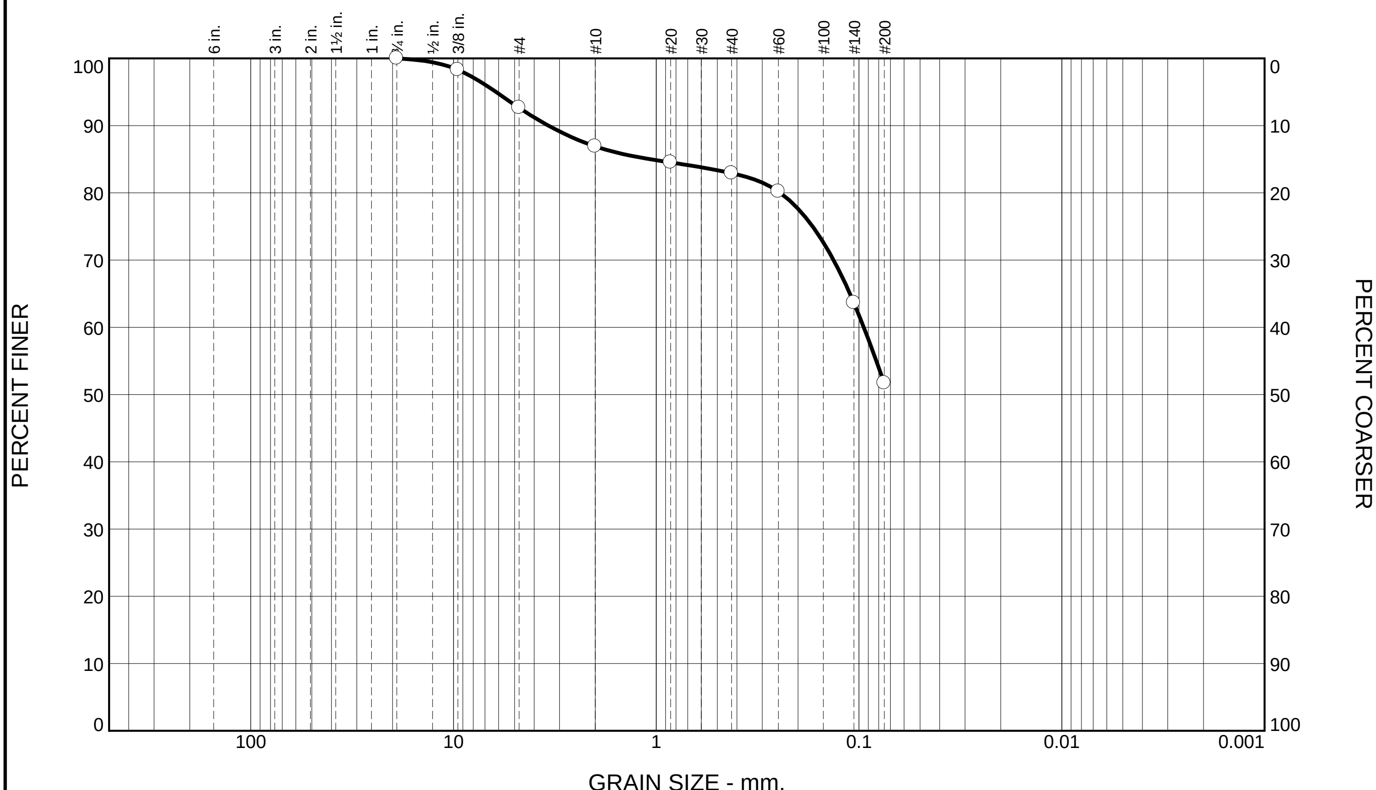
Source of Sample: B-1 **Depth:** 5.5-6
Sample Number: 1-2 **Date:** 6-14-17

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	7	6	4	31	52	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4	100		
3/8	98		
#4	93		
#10	87		
#20	85		
#40	83		
#60	80		
#140	64		
#200	52		

* (no specification provided)

Soil Description

Gray sandy clay

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 3.4061 D_{85}= 1.0737 D_{60}= 0.0948
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: B-1 **Depth:** 20-21.5
Sample Number: 4-2

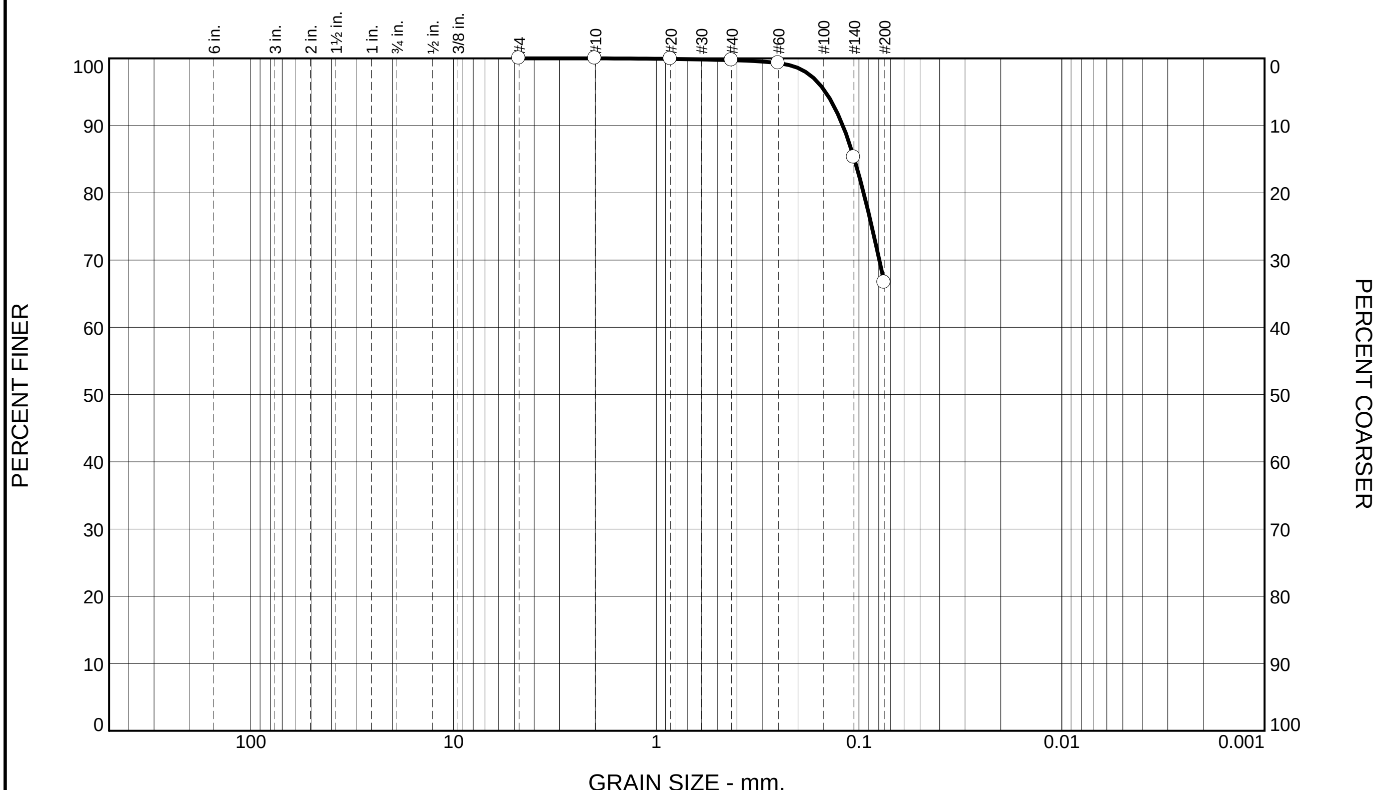
Date: 6-6-17

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	0	0	33	67	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100		
#10	100		
#20	100		
#40	100		
#60	99		
#140	85		
#200	67		

* (no specification provided)

Soil Description

Dark gray sandy silt with clay

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.1202 D_{85}= 0.1054 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Soft and Saturated sample

Source of Sample: B-2 **Depth:** 10.5-11
Sample Number: 2-2

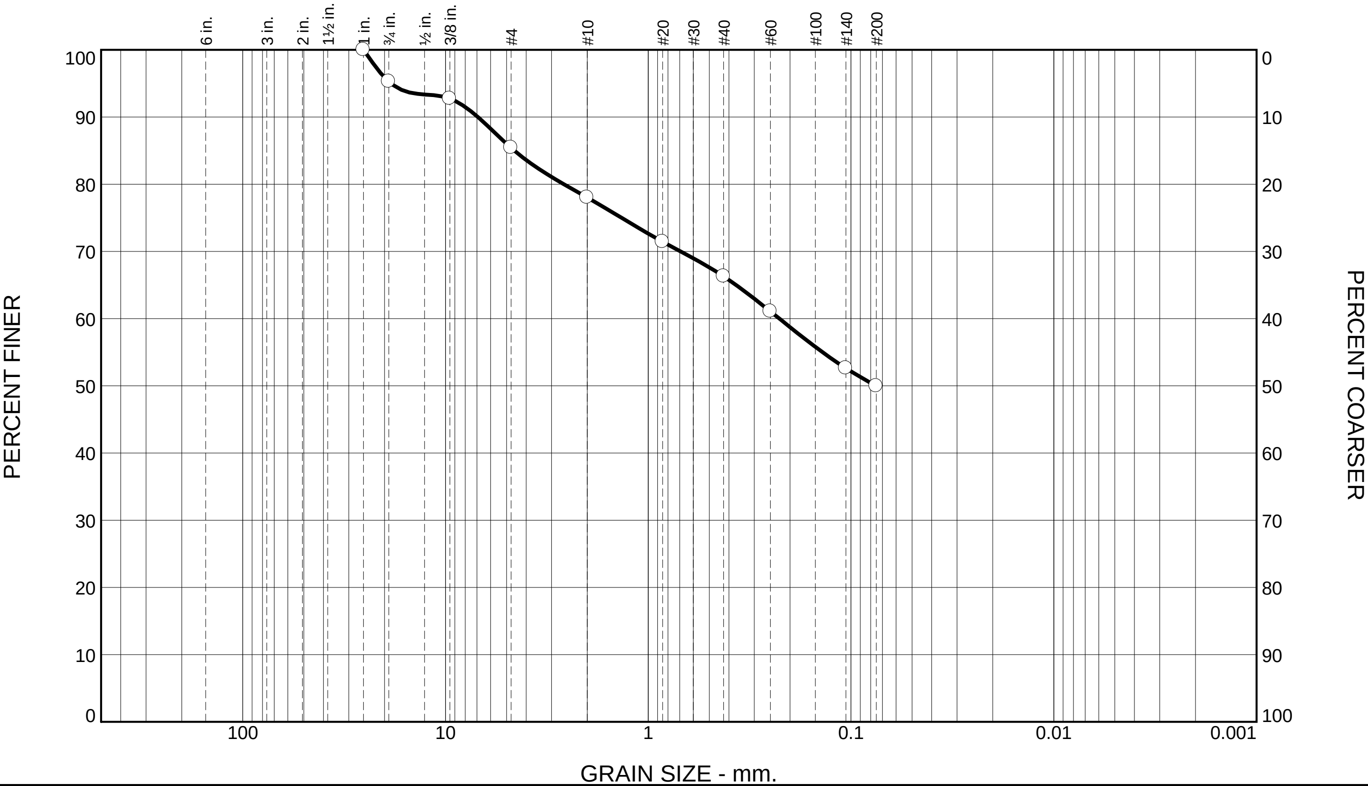
Date: 6-8-17

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	5	10	7	12	16	50	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100		
3/4	95		
3/8	93		
#4	85		
#10	78		
#20	71		
#40	66		
#60	61		
#140	53		
#200	50		

* (no specification provided)

Soil Description

Grayish brown sandy clay with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 6.9314 D_{85}= 4.5784 D_{60}= 0.2258
D_{50}= 0.0755 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: B-2 **Depth:** 25.5-26
Sample Number: 6-2

Date: 6-6-17

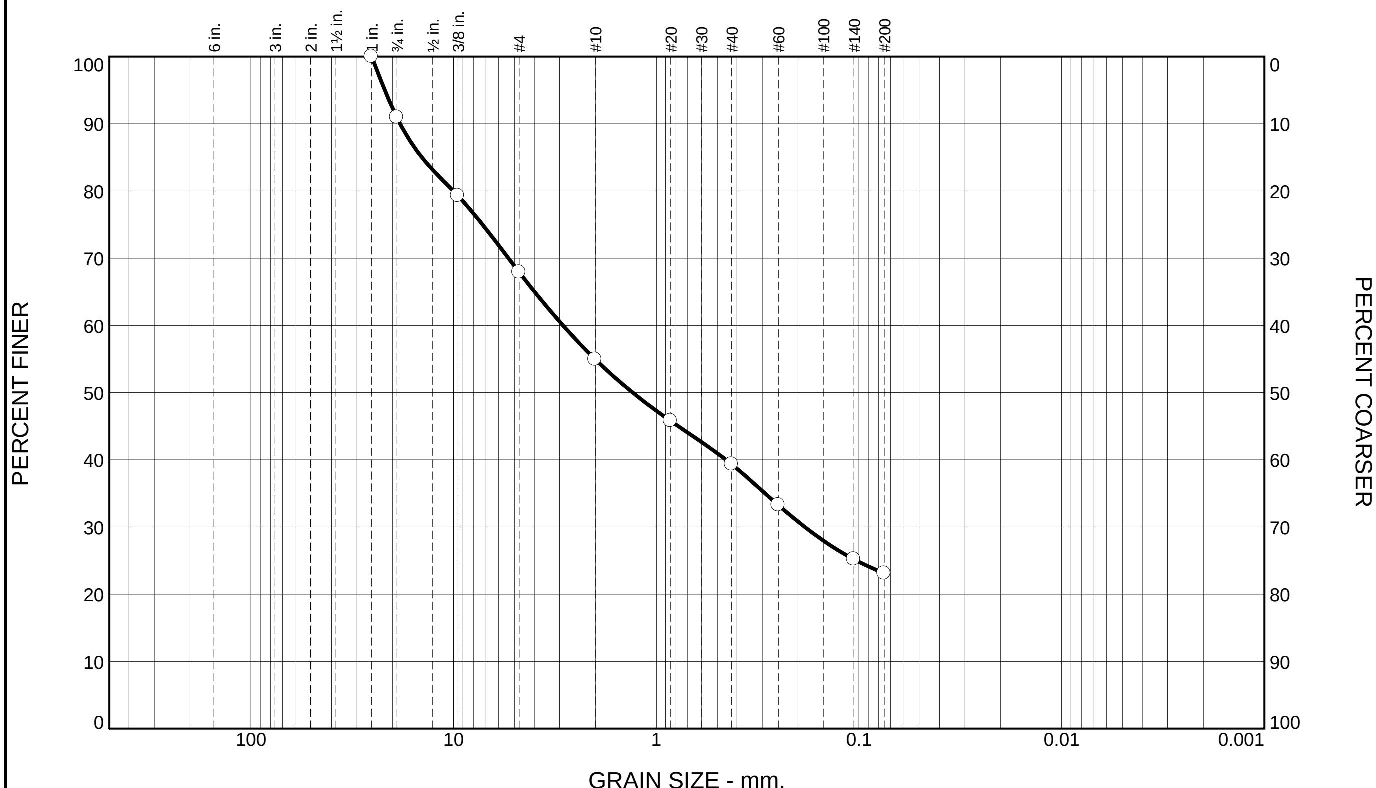
isi

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	9	23	13	16	16	23	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100		
3/4	91		
3/8	79		
#4	68		
#10	55		
#20	46		
#40	39		
#60	33		
#140	25		
#200	23		

* (no specification provided)

Soil Description

Grayish brown gravelly sand with clay

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 18.3756 D_{85}= 14.3593 D_{60}= 2.8886
D_{50}= 1.3079 D_{30}= 0.1852 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

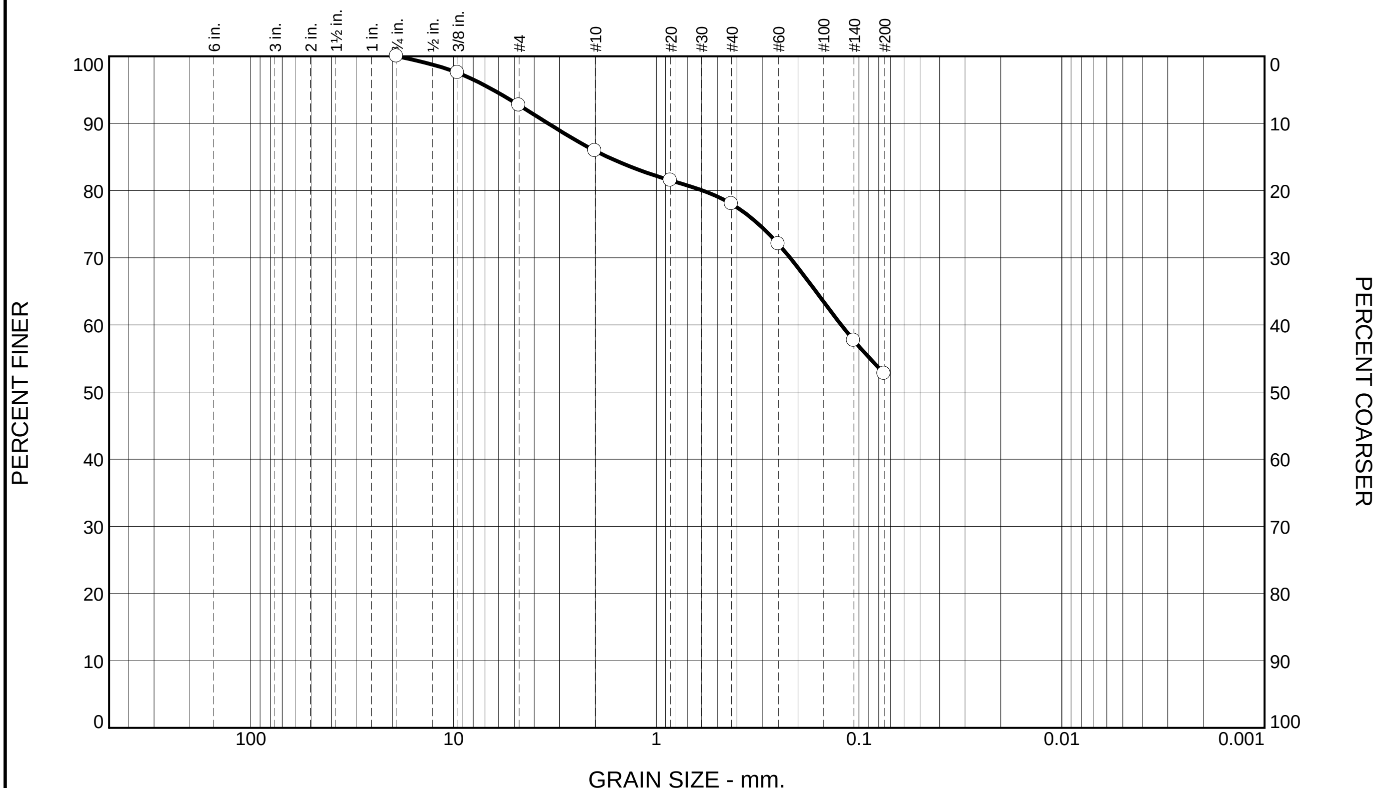
Source of Sample: B-3 **Depth:** 35-36.5
Sample Number: 7

Date: 6-5-17

Client: AECOM
Project: Bolinas Lagoon
60393194
Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	7	7	8	25	53	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4	100		
3/8	98		
#4	93		
#10	86		
#20	82		
#40	78		
#60	72		
#140	58		
#200	53		

* (no specification provided)

Material Description

Grayish brown sandy clay

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 3.4148 D_{85}= 1.7348 D_{60}= 0.1225
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: B-3 **Depth:** 45-46.5
Sample Number: 9-1

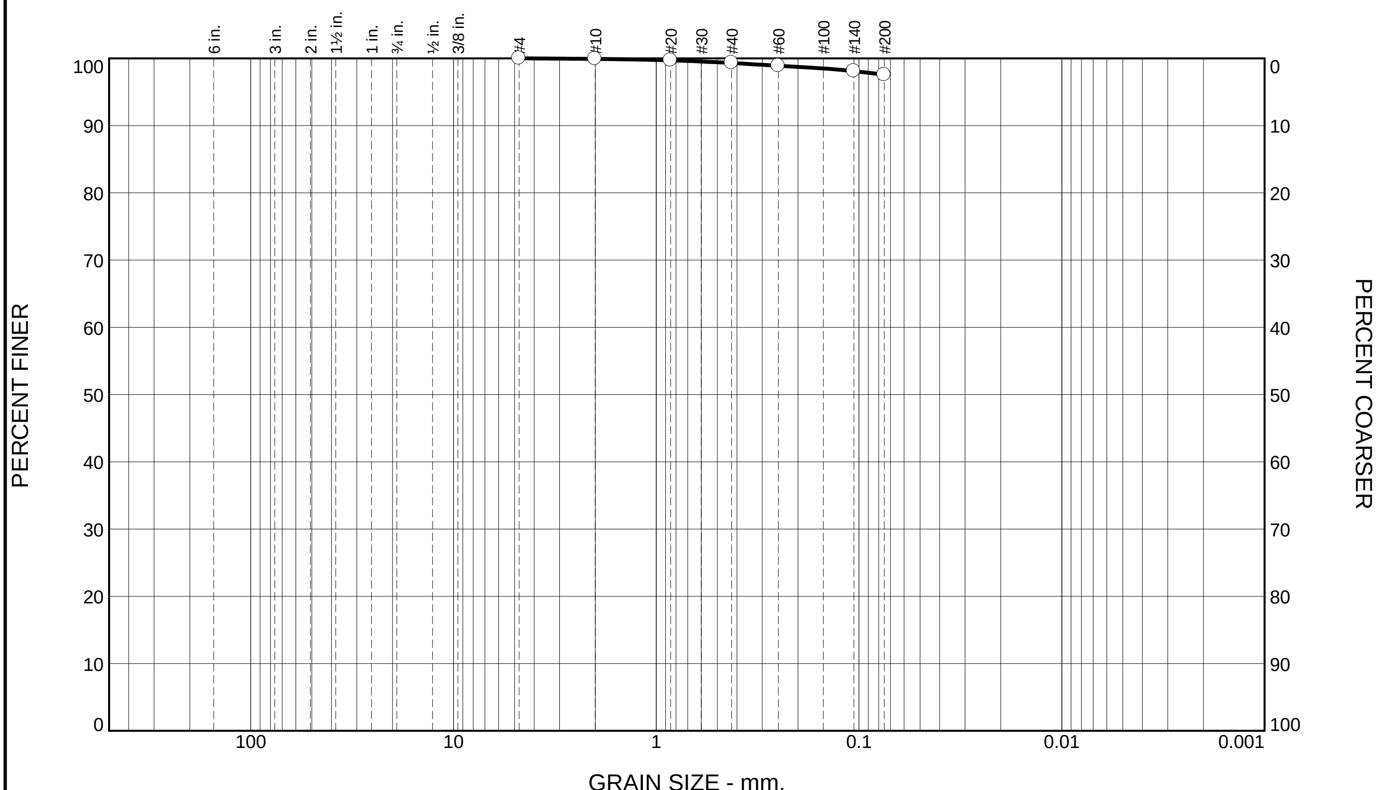
Date: 6-13-17

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	0	1	1	98	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100		
#10	100		
#20	100		
#40	99		
#60	99		
#140	98		
#200	98		

* (no specification provided)

Soil Description

Gray clay with organics

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: B-4 **Depth:** 20-21.5
Sample Number: 5-2

Date: 6-8-17

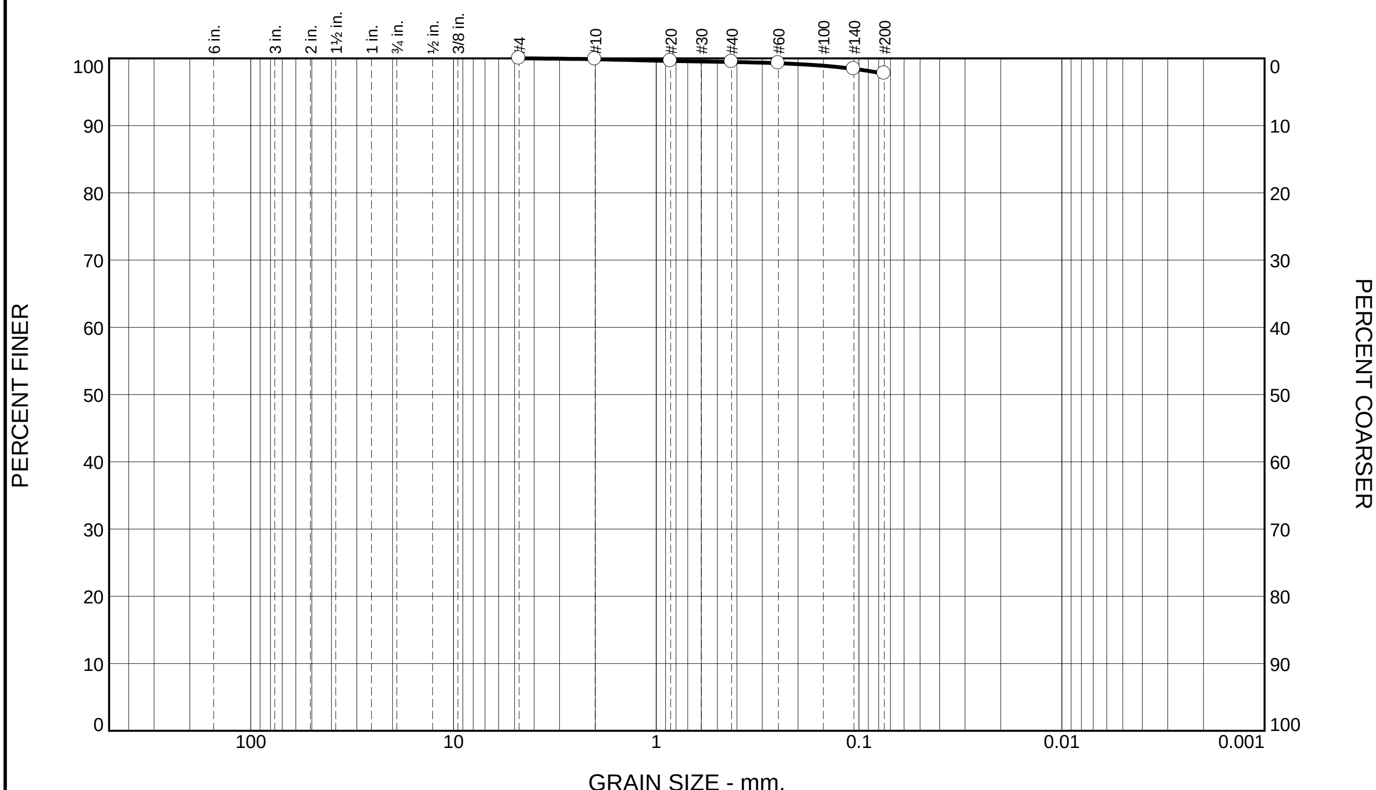
isi

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	0	1	1	98	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100		
#10	100		
#20	100		
#40	99		
#60	99		
#140	98		
#200	98		

* (no specification provided)

Soil Description

Greenish gray clay

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

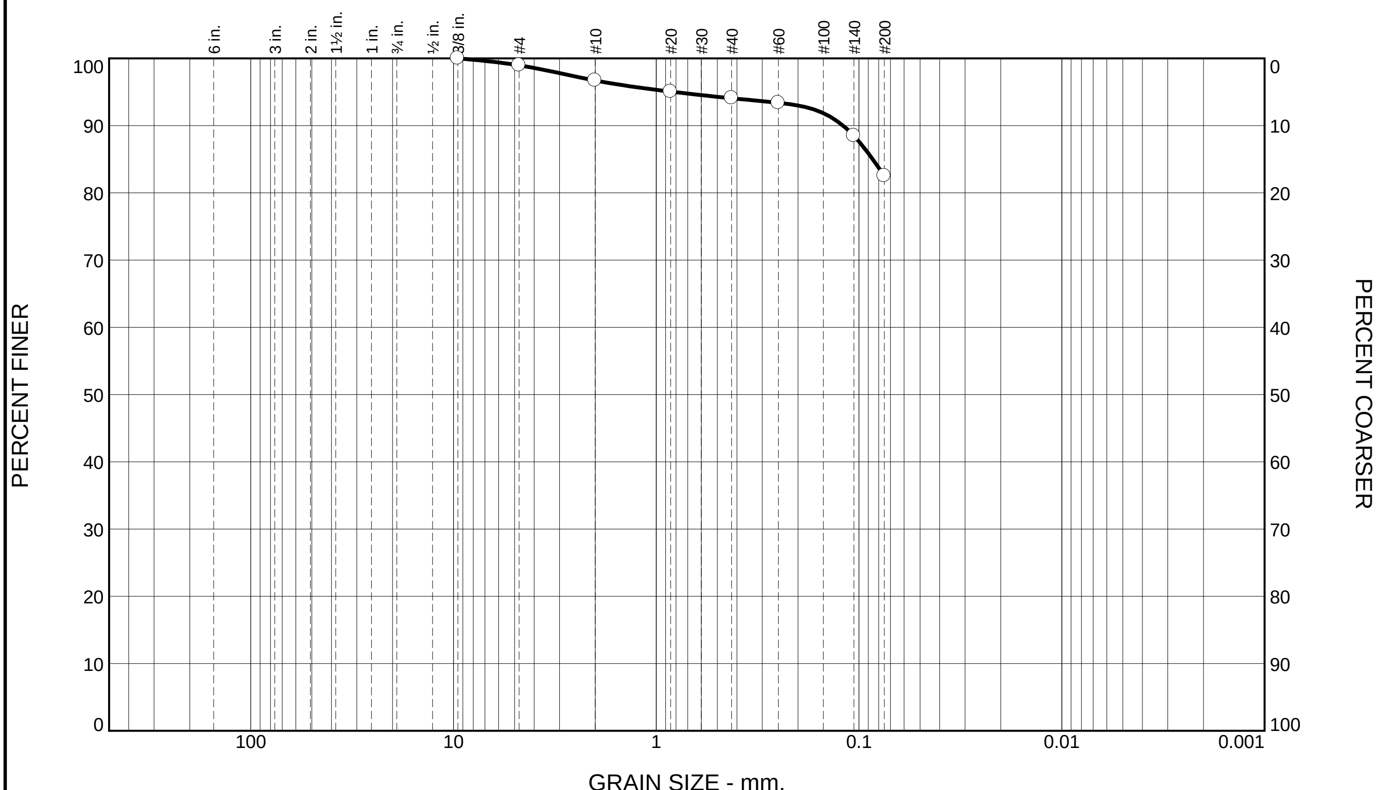
Source of Sample: B-5 **Depth:** 5-6.5
Sample Number: 1

Date: 6-5-17

Client: AECOM
Project: Bolinas Lagoon
60393194
Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	1	2	3	11	83	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8	100		
#4	99		
#10	97		
#20	95		
#40	94		
#60	93		
#140	88		
#200	83		

* (no specification provided)

Soil Description

Grayish brown silty clay with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.1200 D_{85}= 0.0857 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: B-5 **Depth:** 10-11.5
Sample Number: 2-1

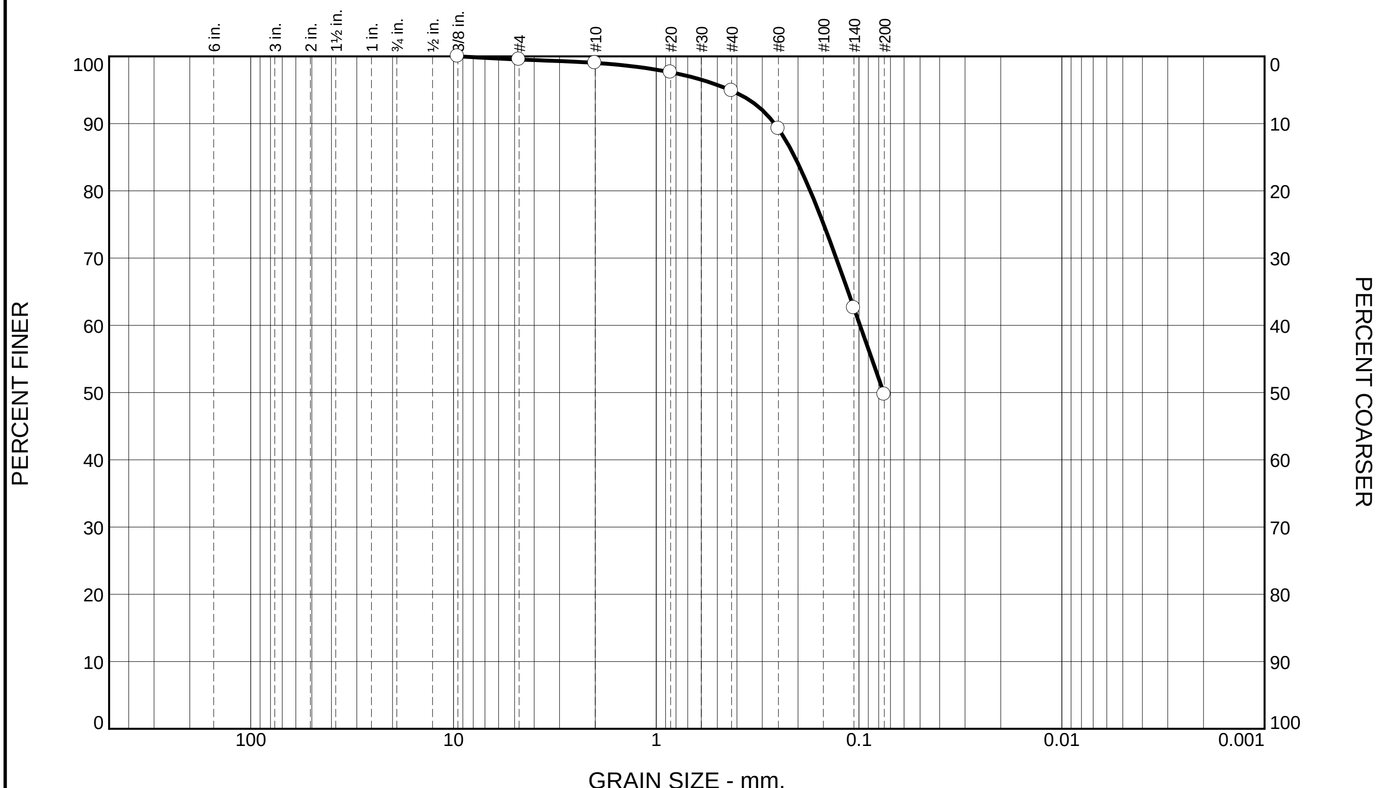
Date: 6-7-17

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	1	4	45	50	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8	100		
#4	100		
#10	99		
#20	98		
#40	95		
#60	89		
#140	63		
#200	50		

* (no specification provided)

Material Description

Gray clayey sand with organics

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2611 D_{85}= 0.2073 D_{60}= 0.0989
D_{50}= 0.0756 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: B-6 **Depth:** 14.5-15
Sample Number: 4-2

Date: 6-14-17

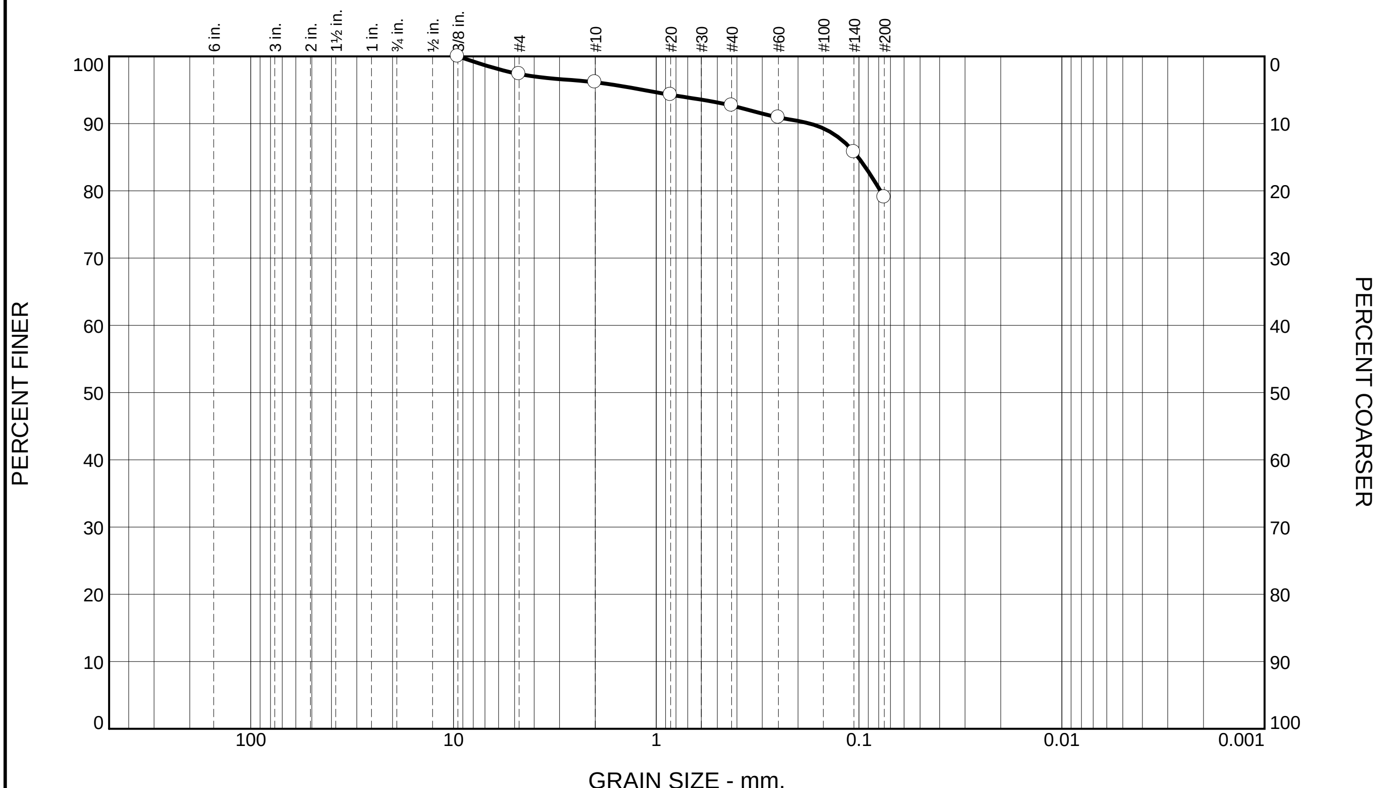
isi

Client: AECOM
Project: Bolinas Lagoon
60393194

Project No: **Figure**

Tested By: JH **Checked By:** JH

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	3	1	3	14	79	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8	100		
#4	97		
#10	96		
#20	94		
#40	93		
#60	91		
#140	86		
#200	79		

* (no specification provided)

Material Description

Brown clay with sand and organics

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.1753 D_{85}= 0.1011 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: B-7 **Depth:** 5.5-6
Sample Number: 1-2

Date: 6-13-17

Client: AECOM
Project: Bolinas Lagoon
60393194
Project No: **Figure**

Tested By: JH **Checked By:** JH

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