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MEMORANDUM

June 5, 2026
To: Kate Drake, H.T. Harvey and Associates
From: Charles D. Anderson, PE
Subject: Synopsis of Structural and Geotechnical Design Approaches for Menlo SAFER Bay
Job #: MLPK.10.25

Introduction

This synopsis has been created to explain Menlo Park's approach to structural and geotechnical design for the Menlo SAFER Bay Project. Menlo Park is collaborating with the East Palo Alto design team and the San Francisquito Creek Joint Powers Authority to present material to the Bay Conservation and Development Commission's Engineering Criteria Review Board (BCDC ECRB).

General Engineering Criteria

Falling under the same SAFER Bay umbrella, both East Palo Alto and Menlo Park will use the same engineering criteria for flood protection design, whether earthen levees or structural floodwalls. Since subsurface conditions vary among jurisdictions, the engineering solutions to fulfill those criteria may differ.

Design Schedules

Both East Palo Alto and Menlo Park are advancing their designs. Menlo Park recently completed a 60% set of plans, specifications, and construction cost estimates. Due to this design schedule, Menlo Park has not yet completed a set of structural calculations or a geotechnical report, having recently met with the East Palo Alto design team to establish final engineering criteria and approach. Preliminary simplified methods have been used to establish the 60% project footprint, performance evaluation, and cost estimates. Menlo Park plans to complete structural calculations and a geotechnical report by August 2026, anticipating that we will provide more details at a second ECRB meeting to be held in September 2026.

Structural and Geotechnical Design Approach

SAFER Bay is taking a uniform and consistent approach to site specific seismic analysis rather than simplified methods for final design. The approach, which will be shared by Menlo Park and East Palo Alto, is to use advanced methods of nonlinear site response analysis and time history selection that are driven by USACE ER 1806 requirements for critical structures in high seismic zones and the presence of potentially liquefiable soils along the alignment. Since the East Palo Alto design team is ahead in terms of their design, they will develop the common ground motion inputs that both project reaches will use, while each team conducts their own soil-structure interaction analysis based on site-specific conditions.

Haley & Aldrich is the structural and geotechnical engineer of record for the Menlo Park portion of design. Their ongoing work plan entails the following:

- Update settlement analyses based on the 60% plan fill heights – with a level top of post-construction fill at 19 feet NAVD based on 100-year coastal flood hazards with 3.5 feet of future sea level rise and FEMA freeboard.

- Update liquefaction analyses based on new PGA requirements and ground improvement considerations.

- Update seepage and slope stability analyses based on fill heights and new seismic requirements related to pseudo-static analyses.

- Estimate potential lateral displacement based on pseudo-static stability analyses.

Haley & Aldrich will run more rigorous soil-structure interaction analysis, i.e. FLAC, once the ground-motion study lead by the East Palo Alto design team is available. Depending on the analytical results, additional seismic CPTs may be necessary but this would be done in concert with direction from the ECRB. We anticipate that the data that will be obtained by the East Palo Alto team will suffice for design and contract document completion.

Required Flood Protection Elevation

A coastal hazard study has established the one-percent storm surge plus wave crest elevation with 3.5 feet of future sea level rise as 17.3 feet NAVD. With an additional foot of FEMA-required coastal freeboard, the freeboard elevation is established at 18.3 feet NAVD. The design top of levee and floodwall elevation in Menlo Park is 19 feet NAVD.

Mitigation of Geotechnical Hazards in Menlo Park

Shoreline evolution based on prior urbanization has present-day project ramifications regarding the geotechnical feasibility of implementing a levee project. Generally, development within shoreline protection areas is built on often undocumented artificial fills placed over former Baylands and open water. Geotechnical hazards include flooding, shallow groundwater, non-engineered fills, expansive soils, consolidation settlement, corrosive soils, seepage, and slope stability.

Seismic Hazards

The project area is located within a CGS designated Liquefaction Zone. Preliminary analysis indicates that with an Operating Basis Earthquake (OBE or 475-year return period), liquefaction settlement due to sand layers below the Young Bay Mud might be as much as 5 inches. The OBE is paired with the one-percent flood hazard to evaluate the feasibility of sufficiently quick restoration prior to the next extreme flood event. Here, the post-slump flood protection elevation would be 18.5 feet NAVD, leaving 1.2 feet of 100-year coastal hazard freeboard, leaving time for levee restoration.

Assuming the approach describe, the SAFER Bay seismic deformation criteria are:

- OBE (475-year event): Maximum one foot of vertical displacement, maintaining protection against the 100-year flood hazard with sea level rise.

- MDE (2,475-year event): Deformation no lower than the 10-year water elevation with sea level rise, requiring repair but providing interim protection.

The maximum allowable vertical deformation is 3 feet based on 60% plan top of levee elevations and the 10-year water elevation with sea level rise. Since there are no readily available results for 10-year wave heights, the 100-year wave height paired with 10-year stillwater level and is considered conservative, defensible, and an accepted practice for interim risk assessment.

Anticipated vertical deformation from the maximum design earthquake (MDE) will be analyzed once the ground motion inputs are established using the Fast Lagrangian Analysis of Continua (FLAC) program, which will also be used to evaluate deformation under normal loads and consolidation settlement based on proposed levee improvement sections.

Consolidation Settlement

Project improvements will be constructed over fills above previously consolidated (stressed) YBM and directly over YBM that has never been consolidated. FLAC modeling will be used to evaluate deformation under load, but preliminary settlement estimates have been made for the grading plan and profile shown on the 60% plans using available consolidation test curves for the Project alignment. Table 1 summarizes these estimates and the additional fill height that must be placed at various Plan Stations for the constructed levee to settle at no less than 19 feet NAVD, assuming normal weight fill at 125 pounds per cubic foot.

Table 1: Consolidation Settlement Estimates Based on Soil Testing

Plan Station	Boring Number	YBM	Initial Fill Elevation	Fill Height	Consolidation
188+00	B24-05	4 to 34 feet bgs (30 feet thick)	24.5 feet NAVD	21.5 feet	63.0”
201+00	B24-06	11 to 36 feet (25 feet thick)	21.5 feet NAVD	17.5 feet	27.0”
220+00	B24-07	14 to 34 ft bgs (20 feet thick)	21.5 feet NAVD	16.5 feet	29.3”
243+00	B24-08	4 to 24 ft bgs (20 feet thick)	21.0 feet NAVD	12.0 feet	18.5”
276+00	B24-09	14 to 23 ft bgs (9 feet thick)	n/a	n/a	No Curve
336+00	B24-10	9 to 16 ft bgs (7 feet thick)	19.5 feet NAVD	17.5 feet	2.1”
366+50	B24-11	8 to 18 ft bgs (10 feet thick)	20.0 feet NAVD	8.0 feet	9.2”

This variability in YBM thickness across the levee alignment, which is not entirely open to subsurface exploration along the Project control line, could be problematic in terms of differential design settlement mitigation. The foundation soils are not of uniform compressibility, ranging from thin, near pinch-out zones to thick basin deposits. This indicates irregular Bay Mud basin geometry due to paleochannels, marsh variability, and alluvial deposits.

Ground Improvement

Ground improvement is preferred over conventional surcharge/settlement programs for this Project due to schedule, performance reliability, and reduced risk of post-construction deformation in the soft foundation soils. Surcharge methods rely on time-dependent consolidation and require extended durations, significant preload heights, and careful observational management, with residual settlement risk remaining particularly in thick deposits of soft cohesive soils.

Ground improvements like rigid inclusions and deep soil mixing (DSM), however, provide immediate enhancement of stiffness, strength, and deformation control, enabling earlier construction of levee loads and improved predictability consistent with USACE risk-informed design. For the site-specific condition of Young Bay Mud (YBM) ranging from approximately 5 feet to 35 feet below ground surface (bgs), DSM is expected to outperform rigid inclusion systems such as rammed aggregate columns.

The YBM is characterized by very low shear strength, high compressibility, and limited lateral confinement, which reduces the effectiveness of rigid inclusions that rely on mobilization of surrounding soil to provide confinement and load transfer. In contrast, DSM creates a continuous soil-cement matrix, significantly increasing undrained shear strength, reducing compressibility, and providing both bearing support and seepage reduction independent of native soil confinement. Additionally, DSM is less sensitive to variability in stratum thickness and can be designed to form cutoff or stiffness zones compatible with levee stability and seepage control requirements. As such, DSM provides a robust and reliable ground improvement solution for thick YBM deposits in a coastal levee system.

Deep soil mixing can also significantly reduce long-term subsidence locally, albeit without eliminating regional subsidence. The ground improvement technique fundamentally alters the soil behavior by reducing compressibility since the soft clay is converted into a soil-cement composite. This dramatically lowers both the compression index (C_c) and secondary compression index (C_α). Creep mechanisms are eliminated within the DSM treatment zone since the injection of cementitious material locks soil particles and prevents viscous rearrangement to effectively suppress the secondary compression. Loads are transferred deeper and the DSM columns act as stiff inclusions and load-sharing elements that reduce the effective stress carried by untreated YBM, thus minimizing consolidation settlement.

Cost estimates presented with this Basis of Design assume that the entire levee base footprint will be treated with DSM through the YBM to the stiffer material below, except for the structural floodwall along Highway 84 and the east side of Meta which will be founded on a grade beam and deep pile foundation. Should even more cost-effective settlement mitigation measures be employed toward the Bedwell Park end of the system, overall Project costs could be further reduced.

FLAC modeling for a DSM supported embankment focuses on simulating soil-cement columns and the surrounding soft foundation. This requires a coupled mechanical-fluid flow approach in either FLAC2D (plane-strain) or FLAC3D. The analysis determines settlement, overall stability, and load-transfer mechanisms between the embankment and the columns. However, based on the value engineering completed to date, DSM appears to be a viable and cost-effective settlement mitigation strategy in lieu of a lengthy surcharge program during and after construction.

Design Loading Conditions

Design will follow the risk-informed framework of ER 1110-2-1806 and applicable USACE guidance, including EM 1110-2-1913 (Levees), EM 1110-2-2502 (Floodwalls), EM 1110-2-6050 (Seepage), and the Coastal Engineering Manual (EM 1110-2-1100).

The system is intended to achieve FEMA accreditation (44 CFR 65.10) and must withstand the one percent annual chance coastal flood, including storm surge, wave effects, and associated erosion processes. Numerical analyses will be performed using FLAC-based modeling to capture coupled hydraulic, geotechnical, and structural response. There are two major loading cases that are not assumed to be coincident:

1) ***Hydraulic Loading Conditions***

   - Storm surge elevation and wave setup
   - Hydrostatic and hydrodynamic forces on floodwalls
   - Seepage gradients under surge conditions
   - Long-duration steady-state seepage
   - Underseepage
   - Uplift, exit gradients, and piping
   - “Rapid” drawdown (tide cycles)

2) ***Seismic Loading Conditions***

   - OBE and MDE events
   - Pseudo-static stability
   - Dynamic deformation analysis (FLAC)
   - Liquefaction potential
   - Post-liquefaction deformation

Load combinations will explicitly include coincident surge, wave, and tidal conditions, consistent with USACE guidance. The levee crest elevation will be maintained considering wave runup and erosion within acceptable deformation limits under cyclic and dynamic loading, demonstrating that the system meets the stability and seepage safety factors per USACE criteria, which FEMA requires for accreditation.