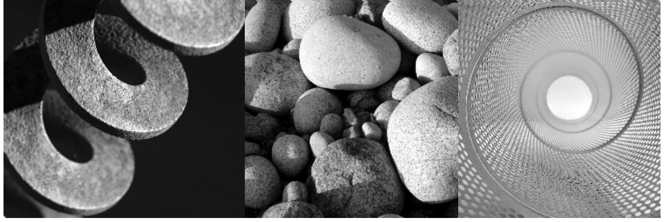
Remedial Alternatives Report

NOVATO CREEK LEVEE EVALUATION

PREPARED FOR:

Marin County Flood Control and Water Conservation District

January 2020



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Remedial Alternatives Report

Novato Creek Geotechnical Evaluation
Marin County, California

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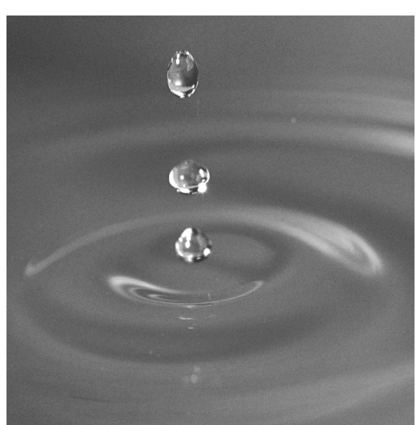
January 2020
Project 1805153



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1.0 Introduction

This Remedial Alternative Report (RAR) was prepared by GEI Consultants, Inc. (GEI) for Marin County Flood Control & Water Conservation District (District to present GEI's geotechnical assessment of the Novato Creek levee system (Figure 1-1).

1.1 Purpose and Scope

The overall goal of the evaluation is to provide a comprehensive assessment of the current condition of the levee system and develop initial recommendations for both short- and long-term improvements for future assessment and/or implementation. Recommendations vary based on the considered flood risk reduction goal. Improvement alternatives which provide options for maintaining or increasing the level of protection provided by the Project are developed and assessed with consideration of both their initial engineering feasibility and cost-effectiveness.

GEI completed an existing conditions evaluation of the Novato Creek levee system in order to provide a geotechnical assessment of the current levee condition. The work conducted under the existing conditions levee evaluation was the basis for development of remedial alternatives to address any areas not meeting design criteria discussed herein. The results of the geotechnical analyses for existing levee conditions have been presented in a GEI report entitled *Geotechnical Evaluation Report (GER)*, dated January 2020, which is a companion document to this *Remedial Alternatives Report (RAR)*. Its contents are referred to but not reproduced herein.

The purpose of this Alternatives Evaluation Report is to summarize the results of the existing conditions analyses, provide an assessment of potential remedial alternatives, and develop concept-level costs for the analyzed remedial measures. This report includes results for a series of screening-level geotechnical analyses of remediated sections. The remediated conditions analyses include a seepage evaluation, slope stability analysis under steady-state seepage conditions, slope stability analysis under rapid drawdown conditions, and settlement.

Additional evaluation and consideration would be needed to further develop and select a preferred improvement alternative or alternatives prior to their design and implementation. Furthermore, the extent of analyses performed for the evaluation does not constitute final design assessments or construction-stage cost estimates. Construction limits and final designs addressing segments of levee that do not meet design criteria should follow standard professional practices including conducting additional field investigations, additional laboratory testing, implementing detailed design analyses, and corresponding cost estimating procedures.

A total of three reaches were designated for the Novato Creek levees (Figures 1-2 and 1-3):

1) Novato Creek Left Bank (Reach NCLB),
2) Lynwood Levee (Reach LL), and
3) Pacheco Pond Levee (Reach PP).

The reaches were selected such that each reach can be adequately represented in terms of geotechnical characterization and analysis by one longitudinal soil profile, one associated transverse cross section, and one set of associated geotechnical analysis input parameters.

1.2 System Overview

The Novato Creek levees are located within Marin County Flood Control District Zone No. 1, which was formed in 1955 to address flooding issues in downtown Novato and surrounding areas and encompasses the entire City of Novato as well as a sizeable amount of unincorporated area around the City, making it the District's largest flood control zone. The Zone includes the entire watershed tributary to Novato and Rush Creeks, which includes the project levees (Novato Creek Left Bank Upstream SR-37 [Novato Creek LB us 37], Lynwood Levee [Lynwood], and Pacheco Pond Levee [Pacheco]). This area has regularly experienced significant flooding, especially in the areas of Novato where two major creeks converge (Novato and Warner Creeks). In 1984, the residents of Novato voted to fund the Novato Flood Control Project (NFCP). The NFCP was implemented in eight phases that began in 1985 and was completed in 2006. In addition to these improvements, maintenance of lower Warner, Arroyo Avichi, and Novato Creek has required the District to conduct sediment removal operations comprising a range of 25,000-75,000 cubic yards of sediment removal every 4-years to provide the design-level (50-year) flood protection.

1.3 Project Datum and Stationing

The vertical datum used for this Study is the 1988 North American Vertical Datum (NAVD88).

The stationing presented in this report was developed for this project and is intended to be used by the District moving forward. The stationing increases looking upstream for Novato Creek LB us 37 and Lynwood. For Pacheco, the stationing increases starting from north to south.

1.4 Water Surface Elevations

The water surface elevations (WSEs) used for analysis in this project are the District provided 50-year peak flow and the 100-year flow based on FEMA Flood Insurance Study (FIS). These will be referred to in this report at the 50-year WSE and 100-year WSE respectively. The water surface elevation data was provided in the hydraulic evaluation report (Stetson, 2019).

Both the 50-year and 100-year WSE's for Pacheco are approximately 0.5 feet higher than the physical top of levee at the analysis cross section. Therefore, the top of levee was analyzed in place of the 50-year and 100-year WSE's. Overtopping of the Pacheco levee is expected and necessary. Raising the levee would result in flooding of the businesses on the west side of Pacheco Pond (Stetson, 2019).

2.0 Summary of Existing Conditions Evaluation

The investigation was performed to assess existing conditions of the Novato Creek levee system. The existing conditions investigation is presented in the GER (GEI 2020). The GER characterized levee conditions and includes geotechnical seepage, stability, erosion, and settlement analyses. Based on the results presented in the GER details for each reach are summarized below.

2.1 Novato Creek Left Bank Upstream SR-37

The Novato Creek LB us 37 levee seepage analyses results indicate that the levee meets criteria for underseepage and through seepage. The phreatic surface does breakout above the levee toe, but the embankment material is predominantly clay (CH) and not considered erodible.

Based on the stability analyses results, we conclude that the Novato Creek LB us 37 levee reach does not meet criteria for landside slope stability. Rapid drawdown waterside stability criteria are met for this reach.

Evaluation of the erosion risk, including assessment of the levee geometry, embankment material, and peak flow velocity, indicates that the Novato Creek LB us 37 levee is not considered at risk of erosion-driven failure. However, it is possible that there are portions of the levee (outside of the discrete points sampled by the borings) that contain more sandy material and could potentially be susceptible to erosion. Monitoring of the slopes should be performed as part of the ordinary operations and maintenance to ensure no areas of erosion develop in the future.

Evaluation of freeboard (Stetson 2019) indicates that portions of the Novato Creek LB us 37 levee do not meet freeboard criteria by an average of approximately 2 feet.

2.2 Lynwood

The Lynwood seepage analyses results indicate that the levee does not meet criteria for underseepage due to a leaker condition and does not meet criteria for through seepage due to the breakout of the phreatic surface in a potentially erodible SM layer at the base of the embankment.

Based on the stability analyses results, we conclude that the Lynwood reach does not meet criteria for landside slope stability. Rapid drawdown waterside stability criteria are met for this reach.

Evaluation of the erosion risk, including assessment of the levee geometry, embankment material, and peak flow velocity, indicates the downstream portion of Lynwood (approximately 4,500 feet) is at risk of erosion-driven failure. Additionally, it should be noted, that while the boring logs indicate that the upstream portion is largely clay and resistant to erosion, it is possible that there are portions of the upstream levee (outside of the discrete points sampled by the borings) that contain more sandy material and could potentially be susceptible to erosion as well.

Evaluation of freeboard (Stetson 2019) indicates that Lynwood is does not meet the criteria for freeboard between Station LL 310+00 and Station LL 307+50 and between Station LL 298+00 and Station LL 260+00, where it is below criteria by an average of approximately 1-foot. Additionally, between Station LL 260+00 and Station LL 242+16 the levee does not meet criteria by and average of approximately 3 feet.

2.3 Pacheco Pond

The Pacheco seepage analyses results indicate that the levee meets criteria for underseepage but does not meet criteria for through seepage due to the breakout of the phreatic surface in a potentially erodible MH layer in the embankment.

Based on the stability analyses results, we conclude that the Pacheco reach does not meet criteria for landside slope stability. Rapid drawdown waterside stability criteria are met for this reach.

Evaluation of the erosion risk, including assessment of the levee geometry, embankment material, and peak flow velocity, the Pacheco levee is not considered at risk of erosion-driven failure, specifically because the estimated velocities that fill Pacheco Pond are expected to be negligible.

Areas that do not meet freeboard criteria along the Pacheco Pond levee are not considered for geometric remediation (i.e. levee raise) because, as was discussed in the GER (GEI 2020), it is our understanding that increasing the levee height could result in increased flooding to the adjacent areas. Slope protection for the landside of the levee in the event of overtopping will be discussed in Section 5.

3.0 Geotechnical Seepage and Slope Stability Design Criteria

This section summarizes the criteria used to evaluate seepage and slope stability geotechnical analyses results for alternatives and design analyses. The criteria for the analyzed water surface elevation based on USACE's design guidelines are consistent with DWR's ULDC. The design criteria for the different analyses are described below.

3.1 Underseepage

Underseepage may occur when a levee is subjected to a differential hydraulic head caused by a river or channel stage that is higher than the ground surface elevation along the landside of the levee. The severity of underseepage depends on several factors, such as the magnitude of the hydraulic head differential; duration of the high-water event; hydraulic conductivity of aquifer layers underlying the levee; thickness, weight, and hydraulic conductivity of any foundation blanket layer; and waterside seepage entrance conditions. The differential hydraulic head leads to seepage flow beneath the levee toward the landside.

When aquifer layers underlie a less pervious top stratum, the seepage in the aquifer layer initially is confined and a blanket condition exists. During high water stages, if the hydraulic pressure in the aquifer layer landward of the levee becomes high enough, the pressure will cause uplift of the blanket. This uplift may lead to rupture at weak spots or low areas, generating a concentration of seepage flow and sand boils. The concentrated seepage may result in channelization of flow across the blanket and underlying aquifer layer, which also may lead to piping. Where seepage flow is concentrated to the extent that turbulent flow conditions exist, the flow may cause erosion of the foundation material, which can undermine the levee. Progressive underseepage piping and boils may lead to levee failure. Underseepage also may negatively affect slope stability by reducing effective stresses in the foundation soils.

Underseepage conditions generally are expressed by an average exit gradient, i. The average exit gradient is calculated using the following equation:

$$i = \frac{\text{total head differential in feet across a blanket layer}}{\text{total thickness in feet of the blanket layer}}$$

The gradient required to cause uplift is called the critical gradient (i_c). The critical gradient is the ratio of the unit weight of water to the total submerged unit weight of the blanket layer. For a saturated unit weight of 100 pounds per cubic foot (pcf), the critical gradient is 0.6. The ratio of the critical gradient to the average exit gradient is the uplift factor of safety. The following Engineer Manuals (EM) or guidance documents were used to evaluate underseepage and through-seepage for the Novato Creek study area levees:

- EM 1110-2-1913, *Design and Construction of Levees* (USACE, 2000)
- Engineer Technical Letter 1110-2-569, *Design Guidance for Levee Underseepage* (USACE, 2005)
- *Geotechnical Levee Practice* (USACE, 2008a)
- EM 1110-2-1901, *Seepage Analysis and Control for Dams* (USACE, 1993)
- ULDC (DWR, 2012)

According to these publications, the average hydraulic exit gradient must be equal to or less than the following values for the WSE analyzed (50-year and 100-year):

- Landside levee toe: ≤ 0.37 (FS ≥ 1.6)

The average exit gradients summarized above are based on the assumption that the unit weights of the in-situ landside blanket soils (Young Bay Mud) are approximately 100 pcf.

Where no fine-grained blanket material is present beneath the levee, the condition is referred to in this report as a "leaker" condition. Where this scenario is present, a Creep Ratio has been identified for different soil types as described in Section 3.2. For purposes of this study a creep factor of 15 was selected consistent with the recommendations in Bligh (1927) for a fine sandy material. This indicates that if a site's (structures) base width/net head ratio is less than the 15, it would be susceptible to backward erosion and piping (assuming no flow through the overlying structure) (CIRIA, 2013). The overlying structural element protects the soil from backwards erosion and piping and increases the seepage path length to the edge of the protecting structure, where backwards erosion and piping could occur. By increasing the structure base width, and lengthening the seepage path, the potential for backwards erosion and piping in the underlying soil is reduced.

For the remedial alternatives described in this RAR, the base width of a structure is also assumed to be increased by lengthening a seepage berm with a drainage layer and graded filter above the potentially erosible soil, also protecting the underlying soil from backwards erosion and piping.

3.2 Through Seepage

Through seepage may cause removal of materials from levee embankments because of piping through erodible low-plasticity to non-plastic soils. Through seepage also usually is accompanied by a reduced factor of safety against slope stability failure because of high internal water pressures within the landside slope.

The presence of rodent holes and animal burrows was not explicitly analyzed as part of this study; however, it should be noted that their presence increases the through seepage risk and could potentially lead to piping, erosion, or levee failure especially if the holes are observed on both the waterside and landside slope at the same location.

The USACE design manuals do not provide specific criteria for through seepage. Accordingly, the levees were evaluated by considering historical performance observations and numerical seepage analyses, based on the location of the phreatic surface break-out on the landside levee slope and the composition of the levee. During the existing conditions analysis phase, levees shown to have a phreatic line emerging on the landside levee slope were evaluated for piping potential and potential for through seepage induced sloughing of the landside slope. Levees with erodible soils that may be prone to piping or through seepage induced sloughing are considered to require remediation

3.3 Landside Slope Stability

The requirement for a minimum factor of safety for landside stability in EM 1110-2-1913, *Manual for Levee Design and Construction* (USACE, 2000) is the same as the minimum factor of safety in the ULDC (DWR, 2012). Minimum required factor of safety for the Novato Creek LB us 37, Lynwood, and Pacheco levees is 1.4 at the 100-year WSE.

3.4 Rapid Drawdown Slope Stability

Design criteria under rapid drawdown conditions are based on EM 1110-2-1913, *Design and Construction of Levees* (USACE, 2000), which requires a minimum factor of safety between 1.0 and 1.2, depending on the duration of pool levels before drawdown. A minimum factor of safety of 1.0 is required for rapid drawdown analyses where pool levels before drawdown are unlikely to persist for long periods. A minimum factor of safety of 1.2 is required when the pool levels before drawdown are likely to persist for long periods.

Because the water surface elevations in the Novato Creek Study Area are flashy and unlikely to persist for long periods of time, a minimum required factor of safety of 1.0 was adopted for the Novato Creek Study Area.

4.0 Geotechnical Evaluations Methodology

Geotechnical analysis of remedial alternatives involved modifying the existing conditions cross sections to include remedial alternatives (i.e. embankment raise, cutoff walls, etc.), where needed based on identified levee segments not meeting design criteria discussed in Section 2.0. The layering and material properties of the existing conditions cross sections, as presented in the GER (GEI 2020), were only modified where required to incorporate needed fixes. The process for selecting material properties and performing the geotechnical analyses described in the GER will not be reproduced in this report, but rather referenced herein.

Seepage and stability analyses were performed at the selected cross sections in general accordance with USACE EM 1110-2-1913, Design and Construction of Levees (USACE, 2000), EM 1110-2-1902, Slope Stability (USACE, 2003), ETL 1110-2-569, Design Guidance for Levee Underseepage (USACE, 2005), EM 1110-2-1901, Seepage Analysis of Dams (USACE, 1993), and EM 1110-2-2502.

4.1 Geotechnical Parameter Characterization

Recommended material properties were developed for each stratigraphic layer for each modeled cross section as part of the GER (GEI 2020). The following new material types were modeled for the remediated conditions analysis:

- Clay Fill: Clay material used for levee raise, widening, and reconstruction
- Berm Fill: Cohesive material used for construction of seepage and stability berms at the landside toe of the levee
- Berm Drainage Material: Highly permeable material at the base of the berm and extending up the landside slope of the embankment. This material will need to be designed considering filter compatibility with the embankment and shallow foundation material as well as the berm fill. Filter compatibility will be considered during the design phase.
- Soil-Cement-Bentonite (SCB) Cutoff Wall: A combination of soil, cement, and bentonite to create an impermeable cutoff wall beneath the levee embankment

Hydraulic conductivities and strength parameters for seepage analyses were selected for each material based on historically accepted values for the various material types based on construction of a number of similar projects. The selected hydraulic conductivity and strength values are presented in Appendix A.

4.2 Methodology for Steady-State Seepage Analyses

Seepage analyses were performed using SEEP/W, a two-dimensional finite element modeling computer program, developed by GEO-SLOPE International, Ltd (2018). SEEP/W was used to calculate the steady-state phreatic surface and pore water pressure within the levee and foundation soils at the100-year WSE.

Boundary conditions and model extents were kept consistent with the existing conditions analysis as outlined in the GER (GEI, 2020).

4.2.1 Underseepage

Underseepage analyses were performed assuming steady-state seepage conditions develop during the flood condition being analyzed. Underseepage for steady-state conditions is evaluated by calculating the average vertical exit gradient across at the landside levee toe and at the landside toe of the berm (when applicable). The calculated average vertical exit gradient is compared to the maximum allowable gradient for the location under consideration. Alternatively, the potential for underseepage problems can be expressed as a factor of safety against uplift by dividing the critical gradient associated with the blanket soil by the calculated gradient. The critical gradient is determined by taking the buoyant weight of the soil and dividing it by the unit weight of water, and it represents the gradient at which uplift of the blanket might be initiated.

Maximum allowable vertical exit gradients and factor of safety criteria used for this Study are consistent with the ULDC and are tabulated below.

Condition	Max. Allowable Exit Gradient(1)*	Minimum FS(1)
Landside Levee Toe	0.37	1.6
Landside Levee Toe with Seepage Berm (min width = 4 x height, max 300 ft.)	0.37	1.6
Seepage Berm Toe (min width = 4 x height, max 300 ft.)	0.6 (Note 2)	1.0
Ditch, Canal or Depression (at the levee toe)	0.37	1.6
Ditch, Canal or Depression (150 ft. from the levee toe)	0.6 (Note 3)	1.0

1. The saturated unit weights of the “in-situ” landside blanket soils must be at or above 100 pcf to use these exit gradient criteria.
2. Instances where the toe exit gradient exceeds 0.6 at the toe of a 300-ft-wide seepage berm are considered unlikely to affect levee performance during a flood event since seepage-related issues, such as sand boils, would occur 300 ft from the landside levee toe. Thus, the seepage berm is truncated at a width of 300 ft.
3. Exit gradient criteria are linearly interpolated from 0.37 at the landside levee toe to 0.6 at a distance of 150 ft from the landside levee toe.

Additionally, if no fine-grained blanket material was present beneath the levee, referred to in this report as a “leaker” condition, a Creep Ratio calculation was performed where sandy soil layers exist in the upper foundation. Creep Ratio is a metric for evaluating the risk of backward erosion of a sandy layer below a structure such as a levee embankment or a berm with a filter and drainage layer, which is considered not erodible. Creep Ratios were originally based on observations of piping occurring from foundations supporting masonry dams, but the use of Creep Ratios for evaluation of levees provides an indication of conditions that may lead to piping and backward erosion of the foundation. The calculation compares the seepage flow distance, or the levee base width (including the berm with when applicable) (W), to the Net Head (h_{cr}).

Specific critical Creep Ratios, or creep factors, have been identified for different soil types, with more erodible soils (i.e. fine sands or silt) requiring a greater base width for a given hydraulic head. Bligh (1927) provides a creep factor based on the grain size and material type of layer and if the base width/net head ratio is less than this value, it would be susceptible to backward erosion and piping (assuming no flow through the overlying structure (CIRIA, 2013). The use of Creep Ratios for this evaluation provides a relative indication of conditions that may be more vulnerable to "leaker" seepage and/piping.

As discussed in Section 3.1, for the remedial alternatives described in this RAR, the base width of a structure is assumed to be increased by lengthening a seepage berm with a drainage layer and graded filter above the potentially erosible soil, also protecting the underlying soil from backwards erosion and piping.

4.2.2 Through Seepage

In the case where through seepage is determined to exit on the landside levee slope, the effects of levee through seepage need to be evaluated. For the case of levee through seepage, or "face-exiting" seepage, when the levee did not meet criteria, the remediations modeled in the analyses included a cutoff wall (to cutoff seepage flow), or a berm with a drainage layer to capture any potential seepage.

4.3 Methodology for Steady-State Slope Stability Analyses

Slope stability analyses were performed on the same analysis cross sections evaluated for seepage using SLOPE/W, a slope stability analysis software program developed by GEO-SLOPE International, Ltd (2018). Slope stability was evaluated using the Spencer limit equilibrium method of analysis, which satisfies both moment and force equilibrium by assuming that the resultant interslice forces are of constant slope throughout the sliding mass. Circular slip surfaces were evaluated and defined using the entry-and-exit method. Non-circular surfaces and wedge analyses were not considered for this Study. The slope stability parameters and loading conditions considered for the analyses are discussed below.

Critical slip surfaces were identified for each water surface elevation. Slip surfaces less than three-feet-deep were not considered to be indicative of failed criteria, since they can be categorized as localized sloughing failures that are a maintenance concern rather than a levee safety issue. These shallow, localized failures are considered to repairable between flood events. Failure surfaces were limited to circles that would impact the levee crown creating instability of the entire levee structure, and a potential levee safety issue.

It is assumed that the duration of the flood is sufficient to establish steady-state seepage conditions through the levee embankment, in accordance with USACE guidelines. The phreatic surfaces and pore water pressures from the seepage analyses were used in the stability evaluations. Because steady-state seepage is a long-term condition, drained strengths were assigned to both coarse- and fine-grained soils.

Earthquake Loading evaluations are only required for development of an Emergency Action Plan and are not required for evaluating the need for or design of remedial mitigation measures. This is because the Novato Creek levees have been classified as only "Intermittently Loaded" levees per ULDC, which are levees that do not experience a water surface elevation of one foot or higher above the elevation of the levee toe at least once a day for more than 36 days per year on average. Since the water surface against the Novato Creek levees exceeds one foot above the toe of the levees for less than 36 days per year on average, earthquake stability evaluations are not part of the evaluation of existing conditions presented in this report.

4.4 Methodology for Rapid Drawdown Slope Stability Analyses

The waterside rapid drawdown stability condition of a levee slope is evaluated when a drop in water level is relatively quick, so that soils within the slope do not have sufficient time to completely drain. Rapid drawdown analysis results depend on the embankment and foundation materials, drop level, and waterside slope geometry.

Water level drop rates for rapid drawdown analyses were estimated using available hydrographs prepared by Stetson Engineering for the project. The height of water level drop rates used for Novato Creek LB us 37 and Lynwood were based on the difference between the 100-year water surface and the Mean Lower Low Water elevation of 2.96 feet. Based on an evaluation of this information, a drop of 10.8 feet is considered appropriate for rapid drawdown analysis along Novato Creek LB us 37 and a drop of 9.5 feet for Lynwood. Due to the ponding condition along Pacheco Pond Levee, a drop from the Physical top of levee (PTOL) to the waterside toe was used. A drop of 7.3 feet was considered appropriate for this levee segment. Analyses were performed assuming that the drop occurred from the 100-year WSE or PTOL, whichever was lower.

Rapid drawdown analyses were performed in accordance with the three-stage rapid drawdown procedure as outlined in the GER (GEI 2020). Rapid drawdown analysis is being performed on the remediated conditions because, although the existing conditions analyses all meet criteria, some of the remedial alternatives involved raising the levee which could influence the waterside rapid drawdown stability results. The analysis was performed where applicable to ensure that the remediated condition meets rapid drawdown criteria.

Similar to steady-state stability analysis, rapid drawdown analyses were also performed using SLOPE/W software. SLOPE/W software is an acceptable tool to perform three-stage rapid drawdown analyses, in accordance with the Duncan, Wright, and Wong (1990) procedure.

4.5 Methodology for Settlement Analysis

Primary and secondary settlements were estimated for remediated conditions at the most critical location to provide an upper bound estimate of anticipated settlements due to levee remediation construction. The largest settlements were expected for remedial alternatives resulting in the greatest increase in overburden pressure where the bay mud was thickest and had the lowest overconsolidation ratios. Primary settlement refers to the consolidation settlement that occurs in saturated fine-grained soils after construction (loading), and secondary settlement refers to the long-term settlement. Secondary settlement, for soils with organics present, is considered to occur directly after loading and occur at a logarithmic rate until additional loading is applied, at which point secondary settlement starts again (Feng, 2013).

The amount of primary settlement is dependent on the thickness of the layer, the initial void ratio (e_o), the change in stress, the compression ratio (CR), and the recompression ratio (RR). CR and RR are dependent on the initial void ratio (e_o) and the compression index (C_c) or the recompression index (C_r). The field consolidation curve was corrected using Schmertmann's procedure to obtain a corrected C_c value. Consolidation settlement calculations were performed on the bay mud layers using Terzaghi's One-Dimensional Consolidation Theory (1968). Osterberg's stress distribution under a continuous embankment was used to compute the stress increase with depth (Osterberg, 1957). The water level was conservatively assumed to be at the natural ground surface.

Primary and secondary settlements were assumed to occur in the bay mud layer. Soil parameters used in the analysis were obtained through evaluation of the laboratory test results and also compared to well-established parameters in literature (Bonaparte and Mitchell, 1979). Maximum past pressures estimated from the consolidation test data and obtained from correlations with CPT data indicate the bay mud layers are generally normally to slightly overconsolidated. The soil layers were assumed to be normally consolidated in the settlement calculations. The CR and RR values were calculated based on the average of the seven consolidation tests performed within the Coyote Creek system in Marin County (GEI, 2015). The CR and RR value were estimated to be 0.27 and 0.04 respectively. The soil layers were assumed to act "double drained" (drainage occurs at the top and bottom of the layer) based on the assumption that the underlying sand layer will serve as the lower drainage boundary. The secondary settlement parameter $C_{\alpha\varepsilon}$ was assumed to be equal to 0.004 for the bay mud. This is consistent with literature from Bonaparte and Mitchell (1979) for an initial void ratio equal to 2.6, which is in the range of measured void ratios of the bay mud laboratory tests.

5.0 Evaluation of Remediated Conditions

5.1 Identification of Remedial Alternatives

Up to two remedial alternatives were generally considered for each reach that did not meet analysis criteria under existing conditions analysis. Steady-state seepage and slope stability analyses were performed on the same analysis cross sections used for the existing conditions analyses, but with remedial alternatives incorporated. The analysis of remediated conditions involved modifying the existing conditions cross sections from the GER (GEI 2020) to include remedial alternatives (i.e., cutoff walls, and seepage/stability berms), where needed, and iteratively revising the geometries/properties of the improvements until seepage and stability criteria were met. The layering and material properties of the existing conditions cross sections were only modified where required to incorporate the improvements.

Material types considered for the analyses of remedial alternatives include: Cohesive Berm Fill, Berm Drainage Material (for seepage and stability berms), Clay Fill for levee raises, widening, and reconstruction, and SCB material for cutoff walls. A summary of the material properties used for the seepage and stability analyses are presented in Appendix A.

The analyses were performed using the same methods and for the same 100-year WSE used in the existing conditions analyses described in the GER (GEI 2020). Existing conditions analysis indicate that the existing waterside slopes meet stability criteria; therefore, no remediation measures were evaluated for waterside slope stability. Seepage and stability results for the remedial alternatives are presented in Appendix A.

Based on the results of remedial alternatives analyses, conceptual costs were then developed for the alternatives found to meet design criteria. Costs were estimated based on dimensions of the alternative with typical material types and unit costs derived from comparable projects. A detailed discussion of the cost estimating approach is provided in Section 6.0.

Areas along Novato Creek LB us 37 and Lynwood that do not meet freeboard criteria identified in the Hydraulic Evaluations Report (Stetson 2019) were also addressed in the remedial alternatives analyses and were also included in development of cost estimates. Rapid drawdown analysis was still performed in cases where a levee raise was considered to ensure that the section still met waterside stability criteria. Based on Hydraulic Evaluations Report (Stetson 2019), Pacheco Pond is designed to overtop to keep the businesses on the west side of the pond from flooding. Therefore, no levee raise was included in the remedial analysis model of Pacheco. To address the potential overtopping of Pacheco at the 100-year WSE, the cost estimate included in Section 6 will include rock slope protection for the landside slope.

The alternatives and analyses described herein are consistent with conceptual-level design. Additional site investigations and evaluations are required to confirm extent of potential areas of remediation and perform detailed design.

5.2 Selection of Remedial Measures

Results of the seepage and stability analyses of existing conditions were presented in the GER (GEI 2020). The following remediation alternatives have been selected for further evaluation.

1. Levee raise and widening: Addition of material to levee crest to increase freeboard, and where necessary to support the levee raise, addition of material to the landside slope, which effectively widens the levee prism.

2. Levee rebuild: The levee is degraded to the waterside toe and rebuilt with compacted levee fill material. The new levee fill consists of fine-grained material that is less erodible.

3. Cutoff walls: Cutoff walls are vertical low-permeability barriers that reduce seepage through pervious layers in the levee and foundation and key into a low-permeable layer.

4. Landside Seepage berms: Seepage berms mitigate underseepage by the addition of weight to counteract underseepage uplift pressures by collecting and conveying seepage flows through a drainage layer at the base of the berm. Additionally, the seepage berm can buttress the waterside slope providing additional stability to the slope.

5. Shallow drainage and stability berms: Shallow drainage and stability berms address through-levee seepage and landside slope stability by providing a filtered exit to prevent the movement of fine soil particles, lower the phreatic surface by providing a drainage layer to capture seepage flows, and provide weight to buttress the landside slope of the levee.

6. Combination seepage and stability berms: Including both seepage and stability berms where necessary to buttress the landside slope and mitigate potential underseepage

At a minimum, the remedial measure or combination of measures selected must mitigate areas that do not meet seepage criteria (i.e. through seepage) identified in the existing conditions analyses. Additional considerations of each alternative's accomplishments and drawbacks (i.e., pros and cons) include:

- Performance (durability, adaptability);
- Impacts (environmental, aesthetics, residents, property);

- Schedule/ ease of implementation;
- Considerations (geotechnical, hydraulic, freeboard constructability, operational and maintenance);
- Regulatory acceptance (permitting issues)

The remedial alternatives included in the analyses include a combination of levee raises, drained stability berms, drained seepage berms, and cutoff walls.

5.3 Analysis Results

Steady-state seepage analyses, steady-state stability analyses and rapid drawdown stability analyses were performed on the three analysis cross sections developed to represent Novato Creek Left Bank, Lynwood Levee, and Pacheco Pond as detailed in the GER (GEI, 2020). Each cross section was analyzed at the 100-year WSE consistent with the existing conditions analysis. The results of the analyses are discussed below and summarized in Table 5-1 by reach. The analysis results are presented by reach in Appendix A.

For each cross section, the seepage analysis results are illustrated in figures in Appendix A that show the seepage model with soil layering and total head contours for the 100-year WSE. Exit gradients were estimated at the levee toe and at the remedial berm toe (where applicable) for each cross section and are annotated on the figures. Likewise, the stability analysis results are illustrated in figures in Appendix A that show the soil layering, amount of water level drop (rapid drawdown), analysis search limits, and critical failure surface with corresponding factors of safety. The analysis sections were evaluated to assess which remediation alternatives meet seepage and stability criteria.

End of construction safety factors were not analyzed as part of this study. As landside improvements will potentially be founded on non-free-draining and potentially soft soils (Bay Muds), this should be considered as the project proceeds to a design level. End of construction safety factor non meeting criteria would not indicate the analyzed alternative is infeasible. The analyses instead would indicate that construction should be performed in multiple stages rather than a single stage to allow for further consolidation of and strength gain of Bay Mud materials under gradual loading or indicate that other ground improvement measures should be considered. Construction sequencing or site preparation (i.e. pre-loading with wick drains) should be considered during detailed design of improvements to address end of construction stability and settlement.

The alternatives considered for each reach are detailed below and the seepage and slope stability analysis are included in Appendix A.

One of the through seepage concerns was the presence of rodent holes and animal burrows in the embankment. The holes and burrows in the levee increase the through seepage failure risk and should be mitigated. Mitigation measures can include grouting the holes, backfilling the holes with levee fill material, and keeping the vegetation mowed so the animals have a less likely place to hide. Keeping the vegetation mowed also allows for any holes to be seen easily during routine inspections. In addition to repairing the existing holes, a plan to keep animals from creating more holes and burrows in the future is recommended (e.g. baiting program or owl boxes).

Review of the subsurface profiles and analyzed remedial alternatives indicated the largest settlements would likely occur under the remediation for Novato Creek LB us 37 with drained crown raise and levee widening (essentially acting as a full levee height stability berm). This reach was found to have the largest increase in overburden stress due to fill placement for the levee widening and a relatively thick bay mud layer (approximately 60 feet thick). The Lynwood reach with crown raise and widening was also considered because it has a slightly thicker bay mud layer (approximately 70 feet thick), however, it was not selected for further analysis because it was estimated to have lower settlement than the Novato Creek LB us 37 section. The height of fill placement (and the corresponding increase in overburden pressure) was lower and this was found to have the largest influence on settlement due to the thick bay mud layers and the limited zone of increasing stress with depth.

The estimated primary (consolidation) settlement occurred beneath the 10.5 feet of fill at the landside levee toe was estimated to be between 3 and 4 feet over a duration of approximately 175 years, as shown in Figure 5-1. The estimated additional secondary settlement at the centerline was estimated to be approximately 2.5 inches after a period of approximately 750 years. The primary and secondary settlements would decrease moving either landward or waterward of the maximum fill thickness as the height of fill decreases.

5.3.1 Novato Creek Left Bank Upstream SR-37

For Novato Creek LB us 37, the first remedial alternative was a drained crown raise and levee widening (stability berm) as shown on Appendix A Figures A-1 through A-6. The crown raise addresses areas that do not meet freeboard criteria while the levee widening and drain addresses the stability of the landside slope.

The second remedial alternative was a levee reconstruction and widening as shown on Appendix A Figures A-7 through A-12. The levee would be degraded to the waterside toe and reconstructed with engineered levee fill to a height that creates the necessary freeboard. The corresponding widening addresses the stability of the landside slope.

5.3.2 Lynwood

For Lynwood the first remedial alternative was a drained seepage berm to address the underseepage (leaker condition) as shown on Appendix A Figures A-13 through A-18. The width of the seepage berm was calculated to meet the creep ratio criteria outlined in Section 2.1. The resulting berm was approximately 55 feet wide. The berm also serves to buttress the landside slope addressing the slope instability while the drain addresses the through seepage.

To address areas that do not meet freeboard criteria the levee would be raised with engineered fill. For the majority of the reach the crest width is sufficient for the levee to be raised without the need to widen the levee. However, from approximately Station LL 260+00 to Station LL 242+16 would require a levee widening to accommodate the necessary levee raise.

The second remedial alternative was a shallow cutoff wall as shown on Appendix A Figures A-19 through A-24. For the construction of the cutoff wall the levee be degraded by half to create a working platform to install the wall. The wall would extend to an elevation of approximately 6.5 feet (5 feet into the underlying CH layer) cutting off the shallow SM leaker layer as well as the through seepage in the lower portion of the levee embankment. The upper portion of the levee would then be reconstructed with engineered levee fill to a height that creates the necessary freeboard. The cutoff wall lowers the phreatic surface through the levee and this combined with the strength properties of the engineered fill address the landside slope instability.

5.3.3 Pacheco Pond

For Pacheco levee the first remedial alternative was a drained combination berm as show on Appendix A Figures A-25 through A-28. The drainage layer in the stability would address the through seepage in upper silt portion of the levee embankment and the relatively short seepage berm provides additional buttressing of the landside slope addressing the slope instability. No freeboard remediation is considered for the Pacheco Pond levees as discussed in the GER (GEI, 2020), due to increased risk of flooding to surrounding properties.

The second remedial alternative is the reconstruction of the upper portion of the levee combined with the construction a narrow, drained seepage berm at the levee toe as shown on Appendix A Figures A-29 through A-32. The reconstruction of the upper portion of the levee would involve the degrade of the embankment to remove the potentially erodible silt layer (to approximately the elevation of the waterside toe). This portion would then be reconstructed with engineered fill which would not be susceptible to internal erosion, thus addressing the through seepage. The narrow, drained seepage berm placed at the landside toe would buttress the landside slope addressing potential slope instability.

6.0 Cost Estimates for Remedial Alternatives

6.1 Cost Estimating Process

The cost estimates for this Study are intended to be Class 4 according to the guidance of the Association for the Advancement of Cost Engineering International (AACEI). A Class 4 Estimate is prepared based on limited information where the preliminary engineering is from 1 to 15 percent complete. Strategic planning, project screening, alternative scheme analysis, confirmation of economic and technical feasibility, and preliminary budget constraints will be considered in future design phases.

Class 4 estimates include allowances for changes due to the level of detail that typically occurs between the feasibility level and the issuance of final design documents. The expected accuracy ranges for this project are -15 percent on the low side and +50 percent on the high side. The cost estimates in this document should be considered planning-level estimates.

6.2 Conceptual Cost Estimates

Levee remediation alternatives are described in Section 5. Material quantities were estimated for each alternative based on the typical remediated section for that reach. Using the quantities obtained, costs were prepared by for each evaluation alternative. Conceptual sections of the levee improvement alternatives are identified in Appendix B Figures B-1 through B-6.

Depending on the levee improvement alternative selected, the following items are included in the cost estimates:

- Clearing and grubbing: Clearing all vegetation and debris (trees, shrubs, stumps, major roots, and rubbish) near the ground surface within the remediated levee embankment footprint.
- Stripping: Stripping the original ground surface a minimum of 12 inches within the remediated levee embankment and berm footprint to remove roots and other organic matter. The combination seepage and stability berm alternatives assume a stripping depth of 1-foot will be sufficient to remove existing trees and associated root balls in the area the berm will be installed. Further investigation will be needed to determine the existing conditions and depth of stripping actually required.
- Proof compacting: Proof compacting the surface within the extents of the levee footprint including ripping, moisture conditioning and compaction of the existing ground surface prior to placement of select levee fill or berm fill.

- SCB cutoff wall: Foundation conditions along select reaches require the installation of a SCB wall to address underseepage concerns for the relatively shallow cutoff wall depths (<50 feet) considered in this RAR. SCB cutoff walls can be constructed by standard open-trench methods (i.e., excavator and slurry trench, etc.).
- Select levee fill: Select levee fill used for all levee embankment construction including geometry improvements. No grading on the waterside slope will be performed. Local sources of select levee fill have not been identified. For the purpose of this RAR, it is assumed that select levee fill shall be purchased from a commercial source and imported to the site. As sources for select levee fill are identified, unit costs for embankment fill can be re-evaluated. It is assumed that no levee degrade material will be used as select levee fill, and degraded material will be trucked off and disposed of within 10 miles of the site.
- Berm fill: No available borrow site is known at this time; therefore, it is assumed that the berm fill will be the same cost as the select levee fill. Future analysis to identify local borrow sites may provide significant reductions in this unit cost. Berm fill may also be acquired from any levee degrade which occurs, but this was not considered for this RAR. Cost includes preparation of the area to receive fill, placement of the fill to the appropriate loose thickness, and compaction of the fill.
- Aggregate Base: A 6-inch-thick aggregate base road will be constructed on the levee crown for all cutoff wall alternatives and/ or levee raise alternatives as they include removing the existing crown.
- Hydroseeding: Hydroseeding for erosion protection will occur along both the landside and waterside slopes of the levee as well as all disturbed areas impacted by levee construction activities.
- Right-of-way (ROW) acquisition: ROW quantities are based only on the additional real estate required for the widened levee embankment footprint based on the typical section for each reach. Costs assume an additional 10 ft of ROW acquisitions for landside berms are needed beyond the remediated levee footprint. All acquisitions are assumed to be permanent.
- Utility relocations: The impact of known utilities to be relocated is considered minimal to the larger scope of the project. Unidentified utility relocations are assumed part of the allowance for unlisted items costs. Costs do not include removal and relocation of any existing structure on the landside of the levee, including but not limited to pump stations, residences, etc. The impact of utility crossings on the stability of the levee foundation, embankments and refinements to associated costs for mitigation and / or relocation of these crossings will need to be considered during the project design phase.

6.2.1 Development of Unit Costs and Other Costs

Unit costs were developed by evaluating costs presented in previous cost estimating efforts for levee improvements and bid abstracts from local and regional levee improvement projects. Prior to comparison, all unit costs were escalated to December 2019 using the 20-city average from the *Engineering News-Record* (ENR) Construction Cost Index, as provided in Table 6-1. All unit costs include materials, labor, placement, and delivery to site. The unit costs used for this study are provided in Table 6-2.

Cost estimates and bid abstracts from the following projects were referenced for unit costs comparisons:

- Feather River West Levee Project Phase 1, Projects B, C and D, bid in 2013 and 2014;
- Non-Urban Levee Evaluations (NULE) Project Remediation Alternative and Cost Estimates Report (RACER), North NULE Study Area. Prepared by URS for DWR in 2011 (URS, 2011);
- North Area Streams (NAS) Levee Improvement Project, cutoff wall along the waterside toe of the NEMDC East Levee, bid in 2017;
- Sacramento Area Flood Control Agency (SAFCA) Sacramento River East Levee Improvement Project – IFA Construction Cost Estimate; and
- Three Rivers Levee Improvement Authority (TRLIA) levee improvement Segments 1 and 3, bid in 2007, and setback levee Segment 2, bid in 2008.

Other costs have been defined as percentages of construction activities from previous similar-level cost estimating efforts and have been compared and evaluated to establish appropriate percentages to account for additional costs not explicitly quantified in this estimate. For this RAR, Other Costs are broken down into two categories, *Other Construction Costs* and *Other Owner Costs*. Percentages and descriptions for these items are characterized below.

- *Other Construction Costs* (as percentage of the Major Construction Items Subtotal)
    - Mobilization and Demobilization (5%). Includes the contractor's mobilization and demobilization of equipment, personnel, field offices, etc. to and from the site in support of the construction.
    - Allowance for unlisted, or unanticipated, items (20%). This allowance is not a contingency; rather it is an attempt to acknowledge (and quantify) the "known unknowns" in the project as they relate to bid items that have yet to be identified in this early development stage for design, and regulatory compliance and construction items and that will likely increase project costs. Construction items not addressed at the current feasibility level of design include but are not limited to items such as utility relocations, pipe relocations unknown at the time these cost estimates were prepared.

- *Other, Owner Costs* (as percentage of the Construction Total)
    - Environmental documentation and permitting, and environmental compliance monitoring during construction (7%). Includes all studies and report preparation, documentation necessary to complete an EIR, EIS and any other

environmental permits for the project. Does not include any environmental mitigation costs or environmental construction monitoring.

- Design and engineering costs (15%). Includes investigations, design and engineering of project including surveying, geotechnical investigation, utility investigation and coordination, preparation of plans, specifications and cost estimates along with all other items necessary to complete the design of the project for bidding.
- Legal costs (2%). Includes all Owner legal costs to implement the project.
- Engineering during construction (2%). Includes engineering during construction activities including review of submittals, RFI's, bidder questions, changes, etc.
- Construction management (15%). Includes management and oversight of the construction project, including quality assurance inspection and testing.

Other Construction Costs are applied as a percentage of the Major Construction Item Costs. Summing the Major Construction Item and *Other Construction Costs* together presents the Total Construction Cost representing the physical construction components of the work. *Other Owner Costs* are applied as a percentage to the Total Construction Cost and are meant to represent additional costs to the Owner may expect through the construction of a project. A -15 percent to +50 percent program contingency has been included in the estimate, in addition to the subtotal of estimated total construction costs and other owner costs. This contingency is included to address uncertainties as the project continues through development, including but not limited to design changes, regulatory requirements, pricing/bid uncertainties, environmental uncertainties, and changes and uncertainties during construction,

6.2.1.1 Right-of-Way Acquisition

The base construction cost includes provisions to purchase new right-of-way for each remedial measure alternative. Site-specific conditions will need to be assessed and individual conditions evaluated before any design decisions are finalized.

An easement is typically present along existing levees. For the purposes of this study it is assumed that purchasing the strip of land needed for new construction (base width of berms or widened levees) will leave the existing levee easement adjacent to the new construction. It is assumed that all the berms will require an additional 10 feet of right of way beyond the berm toe to allow construction equipment adequate construction surfaces.

Permanent right-of-way acquisition for this study is assumed to be wetlands. Mitigation measures for impacting habitat, such as wetlands, can involve significant variations based on location and the type of habitat impacted. For this study it was assumed that mitigation credits, which are typically the most expensive form of mitigation, would need to be purchased to offset the additional right-or-way needed to construct the levee improvements.

Future studies can look at refinements to minimize the impact or do onsite or offsite mitigation activities. Burdell Ranch representatives were contacted for an estimate for the cost of wetland credits in the project area. Only a limited number of credits are currently available, but freshwater wetland credits would potentially be available at a cost of $983,000 per acre (2019 costs). Additionally, typically mitigation requires a 2:1 mitigation ratio (i.e., 1.0 acre of impact requires 2.0 acres of mitigation), thus the estimate for right-of-way acquisition for this project is assumed to be $1,966,000 per acre.

6.3 Remediation Alternatives Cost Summary

The estimated costs for each remedial alternative considered in each reach analyzed for this Study are summarized in Table 6-3.

7.0 Conclusions and Recommendations

7.1 Summary of Selected Remedial Alternatives

Geotechnical alternatives analysis for steady-state seepage and landside stability were performed at three cross sections. Two alternatives were evaluated for each cross section where geotechnical conditions did not meet the current study established design criteria. Table 7-1 summarizes the results, proposed alternatives, advantages, constraints, conceptual cost, and recommended alternative. Appendix A contains a geologic cross section, parameter table, analysis summary information, and analyses results.

Novato Creek LB us 37 has slope stability and freeboard conditions which do not meet the current study design criteria along the entire reach. The preferred alternative for this reach is the levee reconstruction and widening. Reconstructing and widening the levee and replacing the embankment with engineered fill will improve the levee stability.

Lynwood has through seepage and slope stability conditions which do not meet the current study design criteria along the entire reach. Approximately 5,830 feet of this levee does not meet freeboard criteria. The preferred alternative was chosen primarily based on the cost difference and consists of a cutoff wall and crown raise. The cutoff wall will mitigate the through seepage issue, as well as draw down the phreatic surface which will help with the stability issues driven by excess pore pressures. The second alternative was a seepage berm with a crown raise with an overall project cost about six times more than the preferred alternative. The high costs are due to the cost to acquire land delineated as wetlands.

Pacheco has through seepage and slope stability conditions which do not meet the current study design criteria. The levee does not meet freeboard criteria; however, the levee is designed to overtop to keep the businesses on the west side of Pacheco from flooding during high water events. The preferred alternative is a levee reconstruction and seepage berm with rock slope protection on the landside. Removing the erodible silt material in the embankment material and replacing it with engineered fill will result in through seepage meeting criteria. The seepage berm is to help with the landside stability due to the soft bay mud in the foundation.

8.0 Limitations

The levee system evaluations were performed in accordance with the standard of care and skill ordinarily exercised by members of our profession. Standard of care is defined as the ordinary diligence exercised by fellow practitioners in the same or similar area performing the same services under similar circumstances during the same period.

Discussions of subsurface conditions and improvement alternatives summarized in this report are based on the assumption that subsurface soil and groundwater conditions between the subsurface explorations will not appreciably deviate from those disclosed at the locations of the site-specific explorations. Subsurface explorations may not disclose all adverse conditions in a levee and its foundation. No warranty, either express or implied, is made that actual encountered site and subsurface conditions will conform to the conditions described herein.

A compilation of prior geotechnical borings and other subsurface data developed by others has been utilized in preparing this report. GEI has relied upon the prior geotechnical information in developing subsurface stratigraphic profiles and strength and hydraulic conductivity parameters for geotechnical analyses of the levee. Inaccuracies in some of the geotechnical data developed by others could lead to incomplete or faulty analyses or interpretations of geotechnical conditions and levee behavior during high water events. GEI does not attest to the accuracy, completeness, or reliability of geotechnical borings and other subsurface data by others that are included in this report; an independent validation or verification of data by others has not been performed.

The analyses results do not constitute a final opinion about the condition of a levee reach relative to levee performance and the ability of a levee reach to provide reliable flood protection, because such determinations can be affected by conditions beyond the scope of work. The findings of this report may be refined as design of remedial measures are developed during the design and review process.

Any data presented in this report are time sensitive in that they apply solely to locations and conditions existing at the time of exploration and during preparation of this report. Data should not be applied to any other projects in or near the area of this study, nor should it be applied at a future time without appropriate verification.

This report is for the use and benefit of the District and its consultants. Use by any other party is at their own discretion and risk.

9.0 References

GEI Consultants, Inc. (GEI), 2015, Coyote Creek Levee Evaluation Project Geotechnical Data Report. May.

GEI, 2020, Geotechnical Evaluation Report, Marin County, California, December.

GEO-SLOPE International, Ltd., 2018, GeoStudio 2018 Edition, Calgary, Alberta, Canada.

Stetson Engineers, Inc. (Stetson), 2019, Hydraulic Evaluation of Novato Creek Levees. September.

Tables

Table 5-1. Remedial Alternatives Analysis Results Summary

Levee	Station	Model	WSE	WSE	Under-Seepage	Through-Seepage	Slope Stability	Rapid Drawdown
					Gradient	Seepage Breakout above Toe (ft)	FS	FS
Pacheco Pond	*PP 33+22*	*Existing Conditions*	*9.32*	*Top of Levee*	*0.26*	*9.53*	*0.5*	*1.5*
Pacheco Pond	PP 33+22	Alternative 1 - Combination Seepage and Stability Berm	9.32	Top of Levee	0.23	N/A	1.7	1.5
Pacheco Pond	PP 33+22	Alternative 2 - Levee Reconstruction with Seepage Berm	9.32	Top of Levee	0.24	N/A	1.4	1.7
Novato Creek Left Bank Levee upstream of SR-37	*NCLB 300+89*	*Existing Conditions*	*13.56*	*50-Year*	*0.06*	*2.74*	*1.2*	*N/A*
Novato Creek Left Bank Levee upstream of SR-37	*NCLB 300+89*	*Existing Conditions*	*13.76*	*100-Year*	*0.06*	*2.74*	*1.2*	*1.8*
Novato Creek Left Bank Levee upstream of SR-37	NCLB 300+89	Alternative 1 - Levee Widening and Crown Raise	13.56	50-Year	0.05	N/A	1.5	N/A
Novato Creek Left Bank Levee upstream of SR-37	NCLB 300+89	Alternative 1 - Levee Widening and Crown Raise	13.76	100-Year	0.05	N/A	1.5	1.8
Novato Creek Left Bank Levee upstream of SR-37	NCLB 300+89	Alternative 2 - Levee Reconstruction and Widening	13.56	50-Year	0.05	0.60	1.5	N/A
Novato Creek Left Bank Levee upstream of SR-37	NCLB 300+89	Alternative 2 - Levee Reconstruction and Widening	13.76	100-Year	0.06	0.60	1.4	2.1
Lynwood Levee	*LL 260+68*	*Existing Conditions*	*12.36*	*50-Year*	*N/A*	*1.00*	*1.3*	*N/A*
Lynwood Levee	*LL 260+68*	*Existing Conditions*	*12.49*	*100-Year*	*N/A*	*1.00*	*1.3*	*1.3*
Lynwood Levee	LL 260+68	Alternative 1 - Seepage Berm and Crown Raise	12.36	50-Year	N/A	N/A	1.7	N/A
Lynwood Levee	LL 260+68	Alternative 1 - Seepage Berm and Crown Raise	12.49	100-Year	N/A	N/A	1.7	1.3
Lynwood Levee	LL 260+68	Alternative 2 - Cutoff Wall and Crown Raise	12.36	50-Year	N/A	N/A	1.6	N/A
Lynwood Levee	LL 260+68	Alternative 2 - Cutoff Wall and Crown Raise	12.49	100-Year	N/A	N/A	1.6	1.3

Red = Does not meet criteria

Results of Italicized Analyzes can be found in Appendix C of the GER (GEI 2020)

Table 6-1. ENR Average Annual Cost Escalation to July 2019, as Percentage

Year	Escalation (%)
2007	30.0%
2008	27.0%
2009	24.7%
2010	22.7%
2011	20.3%
2012	18.2%
2013	16.1%
2014	13.8%
2015	11.8%
2016	9.2%
2017	5.7%
2018	2.8%
2019	0%

Table 6-2. Class 4 Unit Cost Estimates

Item	Item Description	Unit	Unit Cost	Notes
1	Clearing and Grubbing - Flat Terrain	AC	**$6,467**	Cost from ULE/NULE, 2010 selected. The ULE/NULE cost was in line with similar clearing grubbing efforts for SBFCA. Includes removal of trees, vegetation, and other debris above the ground surface.
2	Stripping - <1'	AC	**$7,039**	Cost from NAS, 2017 selected. As the most recent project cost available. Assumed to be 1 foot stripping. Cost includes removal from site.
3	Stripping - >1'	CY	**$5.61**	Cost from TRLIA S2, 2008 selected; cost was in line with the other stripping costs compared.
4	Excavation - Levee Degrade	CY	**$5.87**	Cost from SBFCA Proj D, 2014 selected. The SBFCA Proj D cost is in line with the other degrade excavation costs compared. Cost includes excavation of the existing levee and does not include disposal.
5	Unsuitable Fill Disposal	CY	**$18.14**	Cost from SBFCA Proj C, 2013 selected. Cost includes loading and disposal of unsuitable material off site with a round trip of 20 miles. Cost assumes no payment to dispose of soil.
6	Select Levee Fill Import for Existing Levee Improvement - Import (> 3 mi)	CY	**$22.02**	Cost from TRLIA-WPIC, 2018 selected. Cost includes import from non-local borrow site; site preparation to receive fill; and fill moisture conditioning, placement to appropriate lift thickness, and compaction.
7	Berm Fill - Misc.	CY	**$22.02**	Cost from TRLIA-WPIC, 2018. Berm fill assumed not locally available and hauling costs are significant portion of total cost. Cost includes import from non-local borrow site; site preparation to receive fill; and fill moisture conditioning, placement to appropriate lift thickness, and compaction.
8	Drain Layers (Geotextile, Filter Sand, Drain Aggregate)	CY	**$77.61**	Cost from ULE/NULE, 2010 selected. When compared to the individual costs of the geotextile, filter sand and drain aggregate within similar bids, the costs were similar. Cost includes placement of geotextile, filter sand, and drain aggregate for internal drainage features.
9	Aggregate Base	TN	**$38.53**	Cost from TRLIA-WPIC, 2018 selected. Cost selected for aggregate base was similar to other bid abstract costs in the project area. Cost includes placement and compaction of aggregate base material.
10	SB Cutoff Wall, Open Trench Method (<40')	SF	**$8.14**	Cost from TLRLIA S1&3, 2007 selected. Cost includes excavation, preparation of slurry, placement, and curing efforts for cutoff wall.
11	Hydroseeding	AC	**$4,693**	Cost from SBFCA Proj B & D, 2014 selected. SBFCA Proj B & D costs were approximately average of the data available. Cost includes hydroseeding and irrigation for establishing native grass vegetation.
12	Rock Slope Protection	CY	**$150**	Cost developed from estimated local rock source (Dutra Construction) and adding estimate for trucking distance to project site, and equipment to place rip-rap

Table 6-3. Summary of Remedial Alternatives Cost Estimates

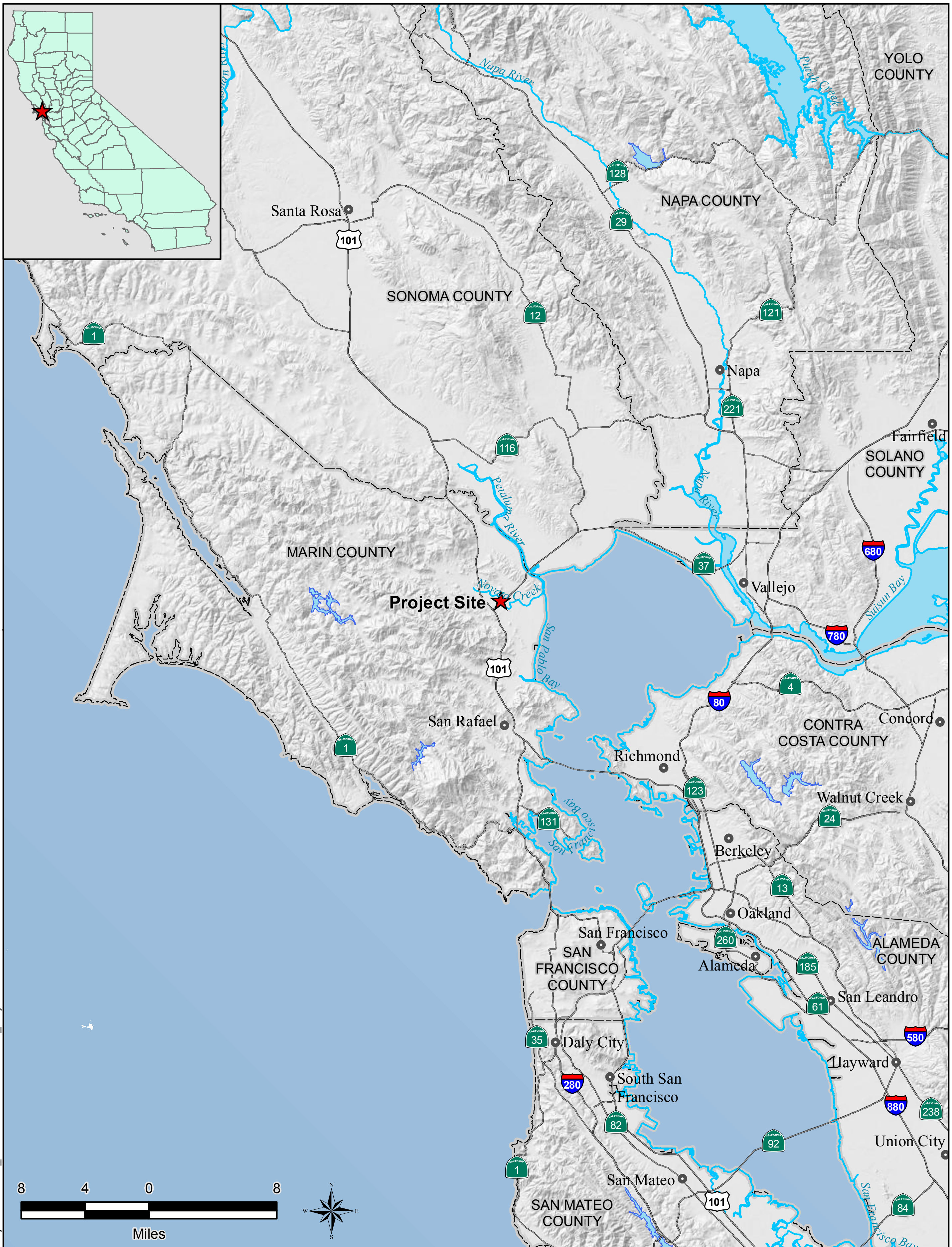
Construction Activity	**Novato Creek Alt. 1**	**Novato Creek Alt. 2**	**Lynwood Levee Alt. 1**	**Lynwood Levee Alt. 2**	**Pacheco Pond Alt. 1**	**Pacheco Pond Alt. 2**
Stability Berm	*$7,430,000*	*$0*	*$0*	*$0*	*$0*	*$0*
Seepage Berm	*$0*	*$0*	*$7,961,000*	*$0*	*$0*	*$943,000*
Combination Berm	*$0*	*$0*	*$0*	*$0*	*$3,244,000*	*$0*
Cutoff Wall	*$0*	*$0*	*$0*	*$4,813,000*	*$0*	*$0*
Geometry Repair	*$1,021,000*	*$8,781,000*	*$587,000*	*$469,000*	*$0*	*$2,195,000*
Rock Slope Protection	*$0*	*$0*	*$1,645,000*	*$0*	*$2,987,000*	*$1,992,000*
Permanent Right-of-Way- Wetlands	*$14,516,000*	*$18,489,000*	*$14,530,000*	*$644,000*	*$5,722,000*	*$2,907,000*
Total Project Baseline Cost =	**$22,967,000**	**$27,270,000**	**$24,723,000**	**$5,926,000**	**$11,953,000**	**$8,038,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)	**$19,522,000 to $34,451,000**	**$23,180,000 to $40,905,000**	**$21,015,000 to $37,085,000**	**$5,037,000 to $8,889,000**	**$10,160,000 to $18,737,000**	**$6,832,000 to $12,057,000**

Table 7-1. Comparison of Proposed Remedial Alternatives

Reach	Station Limits	Length of Repair (ft)	Deficiencies	Alternatives	Advantages	Constraints	Conceptual Construction Cost Range	Preferred Alternative
NCLB	NCLB 225+36 to NCLB 310+00	8,464	Slope Stability Freeboard	Alternative 1: Levee widening (stability berm) and crown raise	• Construction does not require specialty equipment. • Size can be varied along the length of the levee as conditions require. • Readily accepted by regulatory agencies for structural improvement.	• Added embankment fill will lead to additional settlement. • Requires appropriate borrow for levee widening and raise. • Would require use of large, earth-moving equipment.	$19.5M to $34.5M	The preferred alternative for Novato Creek LB us 37 is the levee widening and crown raise. The stability berm will improve on the landside instability of the levee and this alternative has a lower cost.
				Alternative 2: Levee reconstruction and widening (geometry repair)	• Construction does not require specialty equipment. • Improves the slope stability with placement of engineered fill. • Readily accepted by regulatory agencies for structural improvement. • Widening adds additional crest width for operations and maintenance access.	• Added embankment fill will lead to additional settlement. • Requires appropriate borrow for levee reconstruction. • Landward expansion of the levee would incur high right-of-way/environmental costs. • Impacts wetlands adjacent to the levee increase regulatory challenges and could dramatically impact the project construction schedule.	$23.2M to $40.9M	
LL	LL 242+16 to LL 310+00	6,784	Through Seepage Slope Stability Freeboard*	Alternative 1: Seepage berm and crown raise (geometry repair)	• Can effectively address through seepage in the embankment. • Construction does not require specialty equipment. • Does not require significant structural modification of the existing levee embankment. • Provides buttressing at the toe of the waterside slope. • Raise can be varied along the length of the levee as conditions require.	• Added embankment fill will lead to additional settlement. • Requires appropriate borrow for crown raise. • Landward expansion of the levee would incur high right-of-way/environmental costs. • Impacts wetlands adjacent to the levee increase regulatory challenges and could dramatically impact the project construction schedule.	$21.0M to $37.1M	The preferred alternative for Lynwood is the cutoff wall and crown raise because of the lower cost. The cutoff wall has a smaller footprint than constructing a seepage berm, which would require land acquisition.
				Alternative 2: Cutoff wall and crown raise (geometry repair)	• Can effectively reduce through seepage when constructed to proper depths. • Small overall footprint once constructed, and improves embankment stability in cases where stability issues are driven by excess pore pressures.	• May require dewatering or use of bentonite slurry, which requires mixing plant. • Crown raise adds embankment fill which leads to additional settlement.	$5M to $8.9M	
PP	PP 10+00 to PP 43+90	3,390	Through Seepage Slope Stability	Alternative 1: Combination seepage and stability berm	• Can effectively address through seepage at any height on the landside face of the embankment and/or shallow underseepage • Construction does not require specialty equipment. • Does not require significant structural modification of the existing levee embankment.	• Landward expansion of the levee would incur high right-of-way/environmental costs. • Impacts wetlands adjacent to the levee increase regulatory challenges and could dramatically impact the project construction schedule.	$10.1M to $17.9M	The preferred alternative for Pacheco is the levee reconstruction and seepage berm. This alternative removes the erodible embankment material and replaces it with engineered fill. The drained seepage berm helps draw down the phreatic surface, but also helps with the stability of the levee. This alternative also has a lower cost. The conceptual cost includes rock slope protection on the landside for planned overtopping.
				Alternative 2: Levee reconstruction (geometry repair) and seepage berm	• Can effectively address through seepage in the lower portion of the embankment. • Construction does not require specialty equipment. • The seepage berm provides buttressing at the toe of the waterside slope. • Levee reconstruction improves both through seepage and slope stability with placement of engineered fill	• Landward expansion of the levee would incur high right-of-way/environmental costs. • Impacts wetlands adjacent to the levee increase regulatory challenges and could dramatically impact the project construction schedule. • Added embankment fill for levee reconstruction will lead to additional settlement. • Requires appropriate borrow for levee reconstruction. • Would require use of large, earth-moving equipment.	$6.8M to $12.1M	

*Freeboard repair on Lynwood levee is only applicable to a portion of the repair length shown

Figures



Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control and Water Conservation District

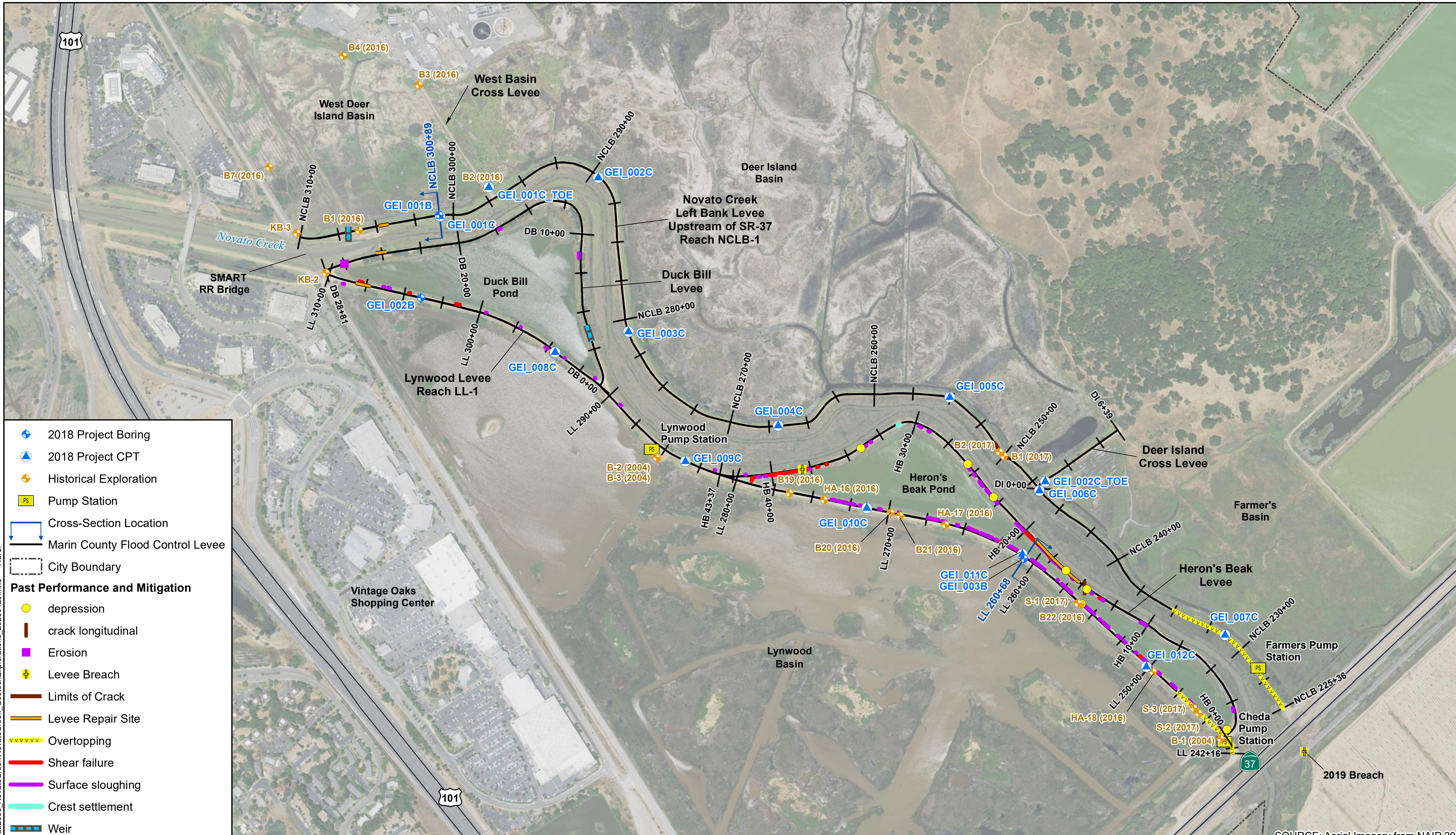
GEI Consultants

Project Location

DECEMBER 2019

FIGURE 1-1

27Nov2019 Z:\Projects\1802696_NovatoCreek\NovatoCreek_ProjectLocation.mxd RS



20-Jan-2020 Z:\Projects\1802696_NovatoCreek\NovatoCreek_GeotechExplorations_20200120.mxd RS/SI

0 300 600 1,200

Feet

N E S W

Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control
and Water Conservation District

GEI Consultants

GEOTECHNICAL EXPLORATIONS
NOVATO CREEK AND LYNWOOD BASIN LEVEES

JANUARY 2020

FIGURE 1-2

0 250 500 1,000

Feet

Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control
and Water Conservation District

GEI Consultants

GEOTECHNICAL EXPLORATIONS
PACHECO POND LEVEE

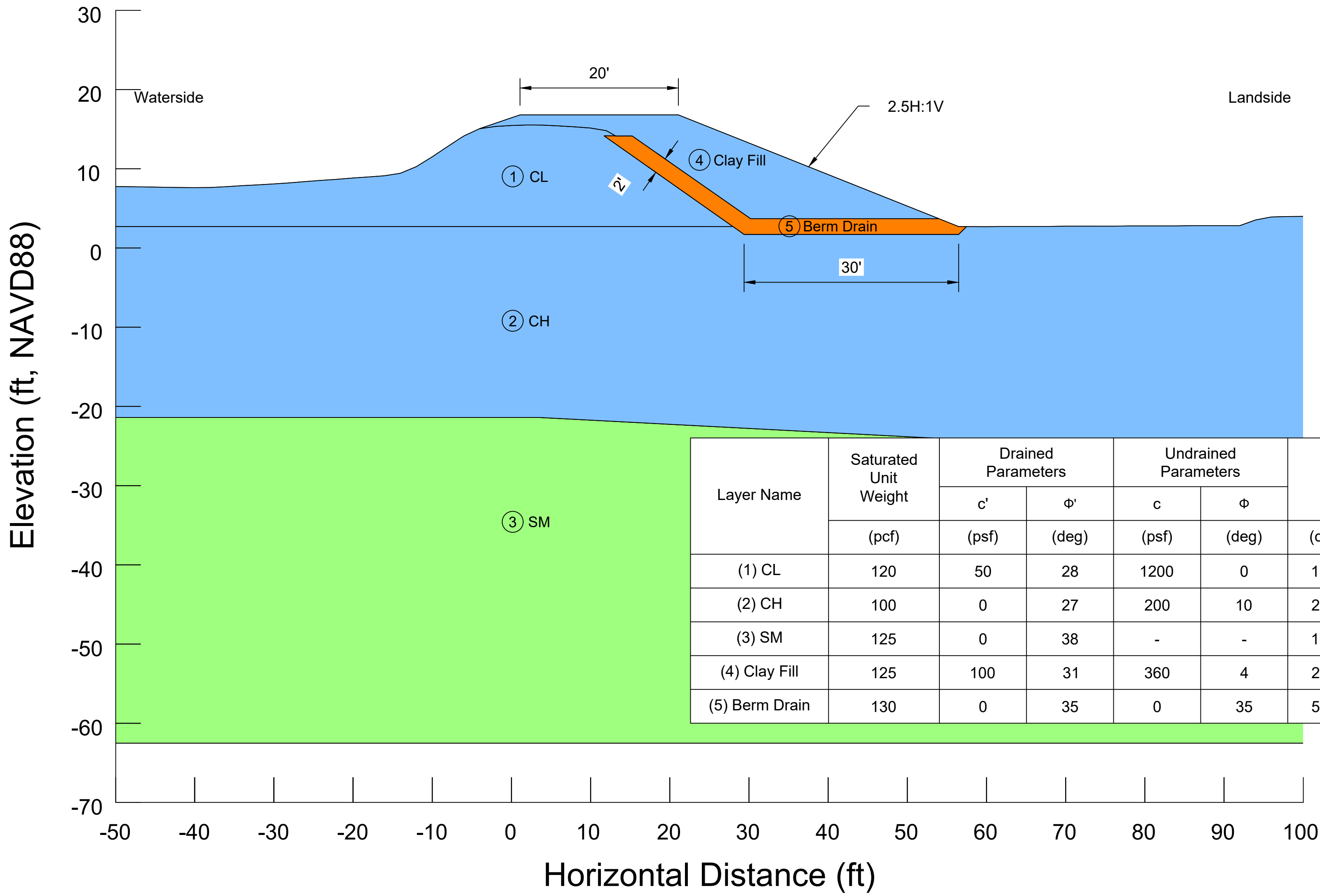
JANUARY 2020

FIGURE 1-3

07-Jan-2020 Z:\Projects\1802696_NovatoCreek\PachecoPond_GeotechExplorations_20200107.mxd RS/SI

Novato Creek Levee Evaluation Project Novato, California	GEI Consultants	SETTLEMENT ANALYSIS RESULTS NCLB STA. 231+50 FILL HEIGHT = 10.5 FT
Marin County Flood Control and Water Conservation District	Project 1900493	December 2019 Figure 5-1

Appendix A
Results of Analysis of Remediated Conditions Analyses



Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters		K_v	K_h
		c'	Φ'	c	Φ		
	(pcf)	(psf)	(deg)	(psf)	(deg)	(cm/sec)	(cm/sec)
(1) CL	120	50	28	1200	0	$1.0x10^{-6}$	$4.0x10^{-6}$
(2) CH	100	0	27	200	10	$2.5x10^{-6}$	$1.0x10^{-5}$
(3) SM	125	0	38	-	-	$1.5x10^{-4}$	$6.0x10^{-4}$
(4) Clay Fill	125	100	31	360	4	$2.5x10^{-7}$	$1.0x10^{-6}$
(5) Berm Drain	130	0	35	0	35	$5.0x10^{-2}$	$5.0x10^{-2}$

Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.
2. Dimensions are approximate and should not be used for design purposes.

Novato Creek Levee Evaluation Project
Novato, CA

Marin County Flood Control and Water Conservation District

GEI Consultants

ALTERNATIVE 1
BASE MODEL
NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-17
STATION NCLB 300+89

January 2020 | Project #1802696 | Figure A-1

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\NC_300+89_Alt1.dwg

Novato Creek Levee Evaluation Project
Seepage and Slope Stability Analysis Results

Levee: **Novato Creek Left Bank Levee upstream of SR-37**

Station: **NCLB 300+89**

Analysis Run: **Alternative 1 -Levee Widening and Crown Raise**

Analyzed by: E. Cerna Alvarez
Date: 12/3/2019

Gradient is calculated at: Landside Toe (landside toe, low point at x ft from toe)

Water Surface: 50-Year

Water Surface Elevation 13.56 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	57.50 feet	2.70 feet	2.70 feet	**0.05**
Bottom of Blanket	58.02 feet	-24.24 feet	4.01 feet	

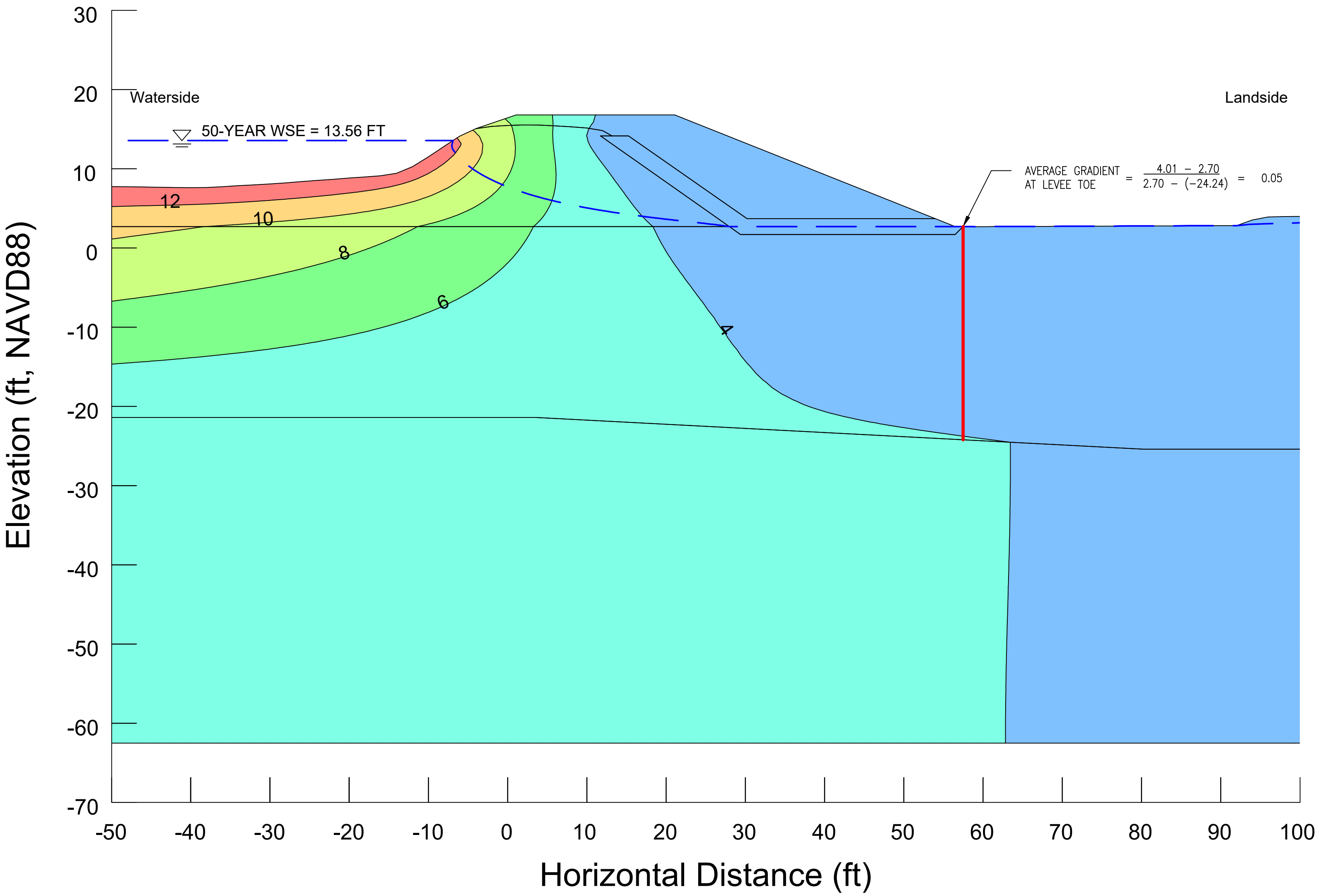
Seepage Breakout above Toe, ft N/A ft
Steady State Landside Slope Stability, FS 1.5 (circular)

Water Surface: 100-Year

Water Surface Elevation 13.76 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	57.50 feet	2.70 feet	2.70 feet	**0.05**
Bottom of Blanket	58.02 feet	-24.24 feet	4.04 feet	

Seepage Breakout above Toe, ft N/A ft
Steady State Landside Slope Stability, FS 1.5 (circular)
Rapid Draw Down Slope Stability, FS 1.8 (circular)



Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **50-YEAR WSE - SEEPAGE RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-17 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-2

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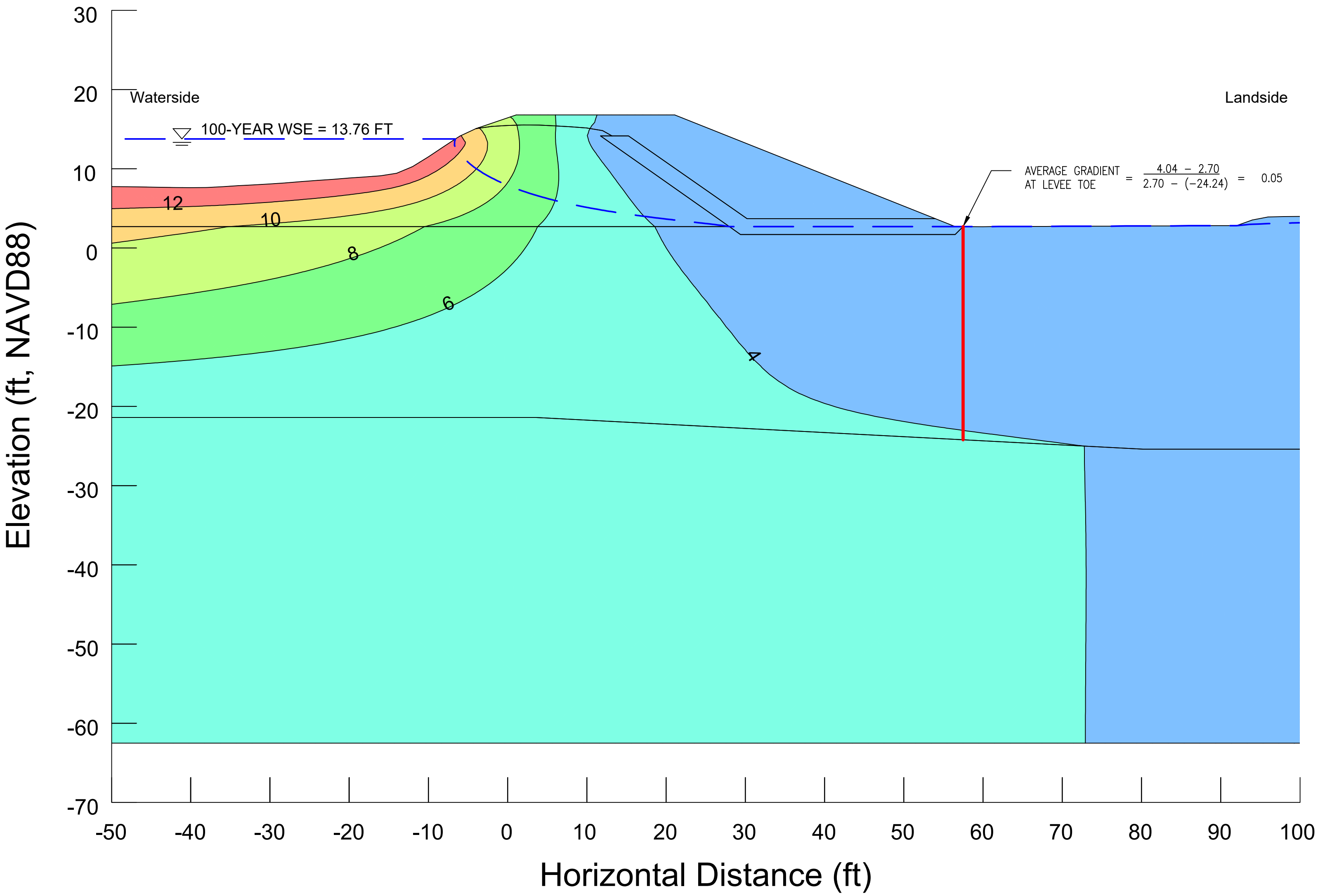

Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **100-YEAR WSE - SEEPAGE RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-17 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-3

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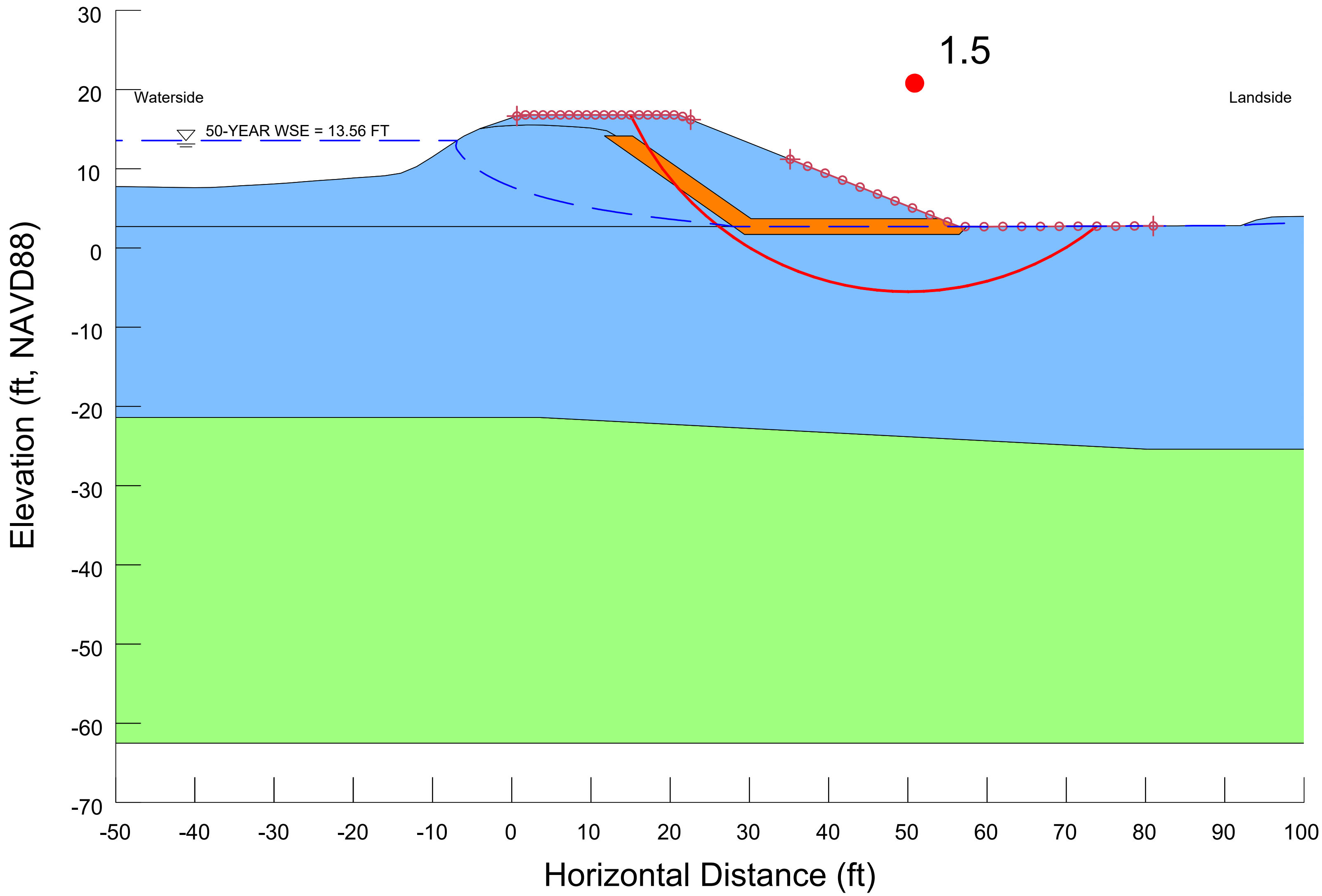
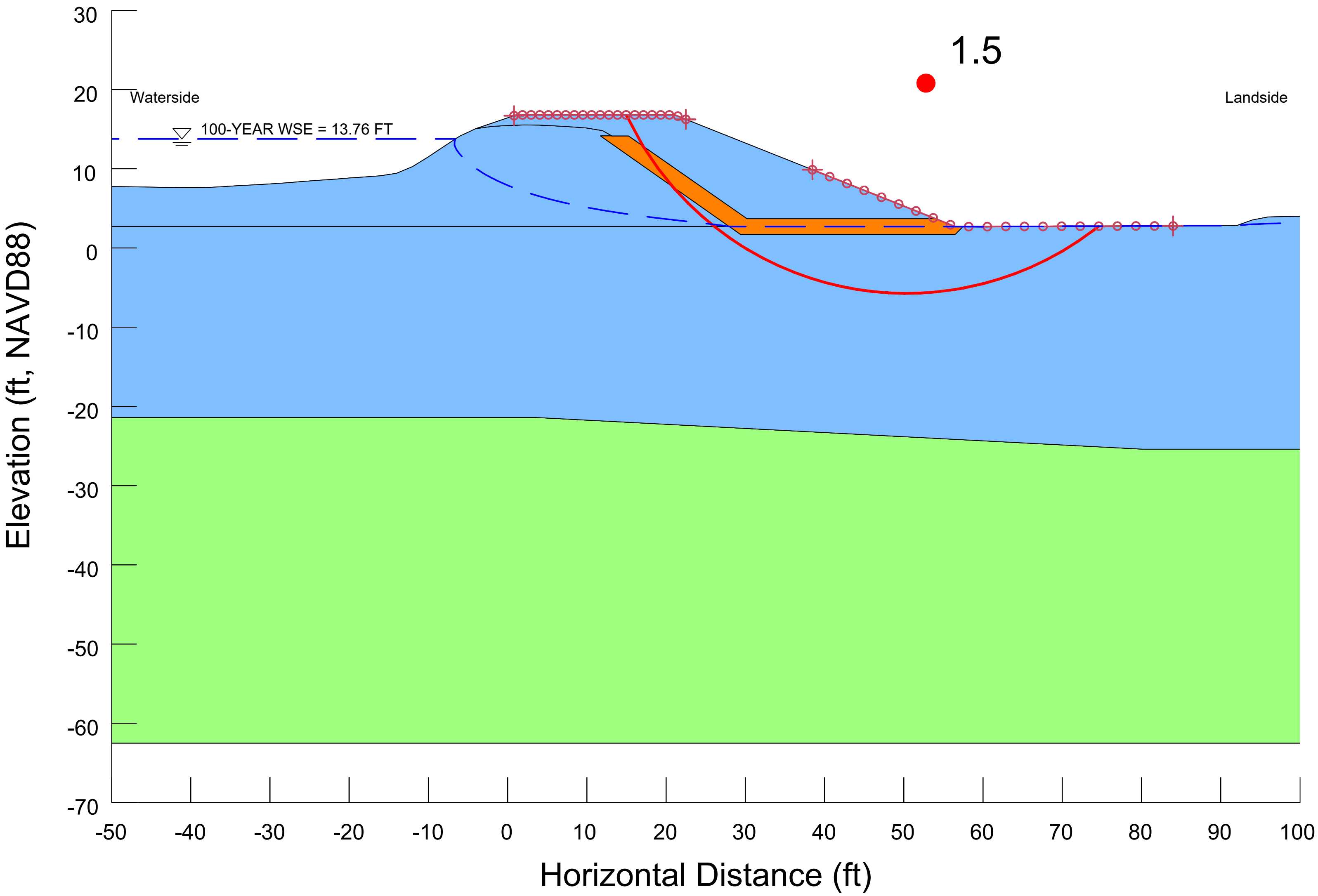


Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **50-YEAR WSE - STABILITY RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-17 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-4

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\NC_300+89_Alt1.dwg

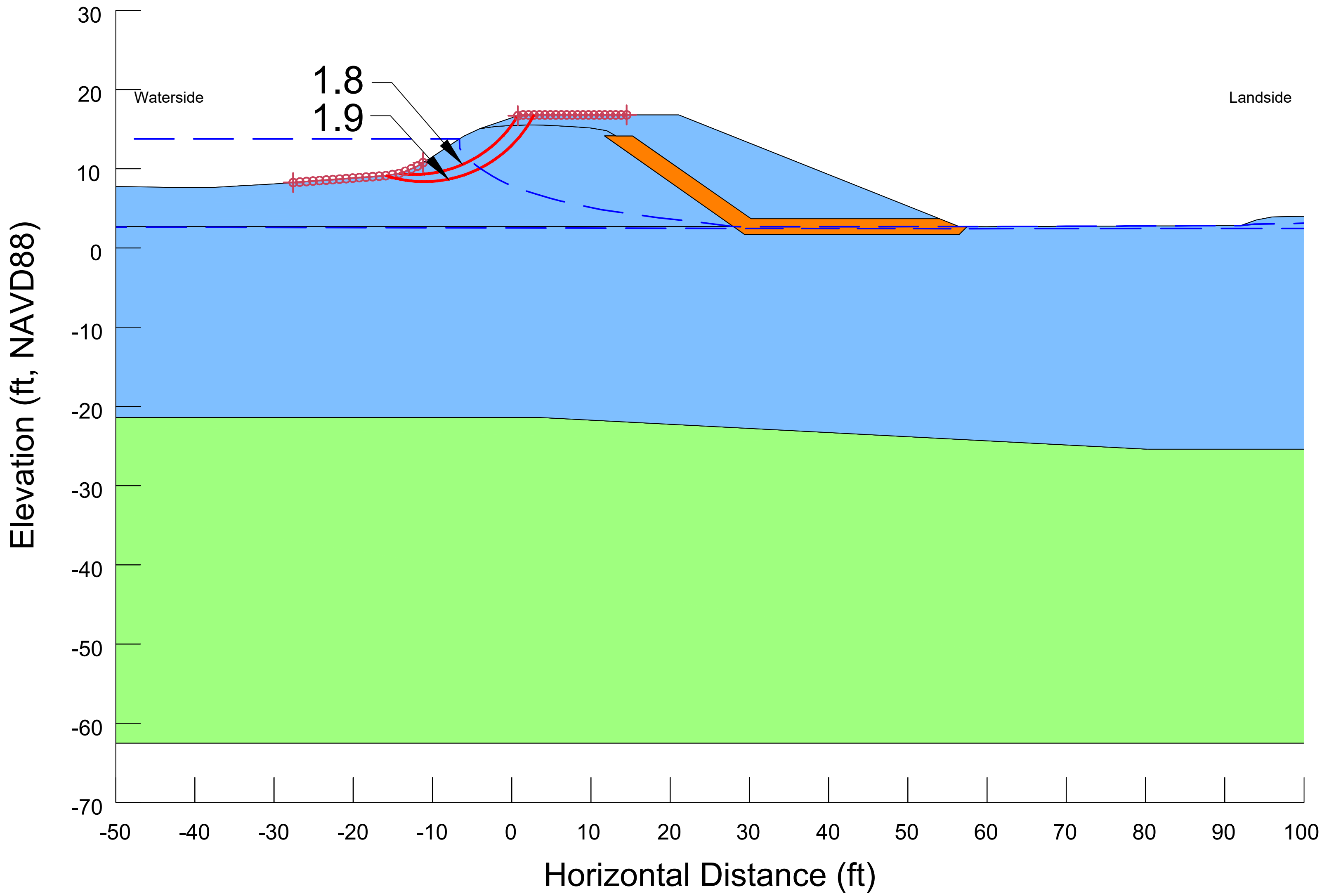


Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **100-YEAR WSE - STABILITY RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-17 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-5

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\NC_300+89_Alt1.dwg

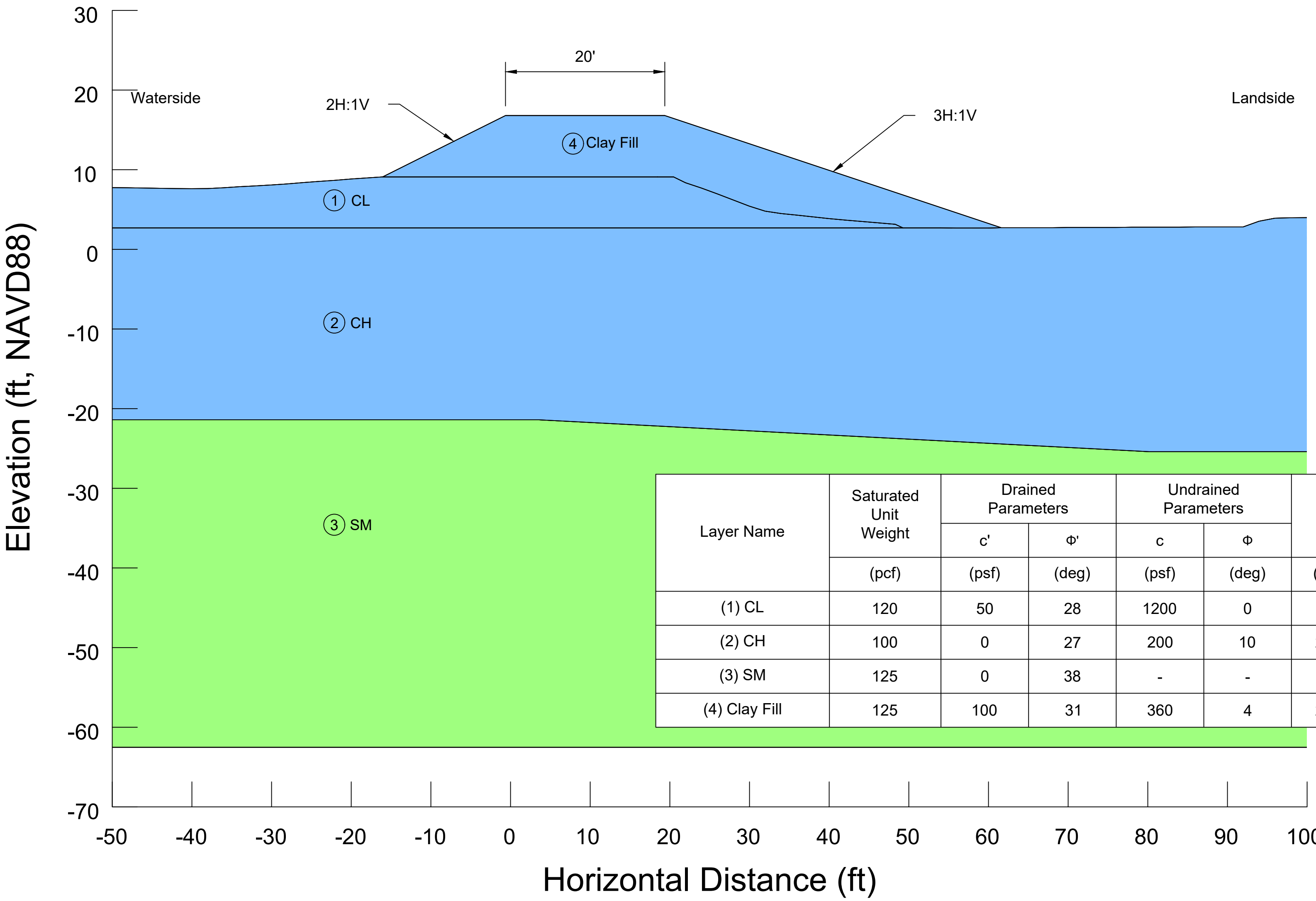


Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **100-YEAR WSE - RAPID DRAWDOWN RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-17 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-6

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\NC_300+89_Alt1.dwg



Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters		K_v	K_h
		c'	Φ'	c	Φ		
	(pcf)	(psf)	(deg)	(psf)	(deg)	(cm/sec)	(cm/sec)
(1) CL	120	50	28	1200	0	1.0×10^{-6}	4.0×10^{-6}
(2) CH	100	0	27	200	10	2.5×10^{-6}	1.0×10^{-5}
(3) SM	125	0	38	-	-	1.5×10^{-4}	6.0×10^{-4}
(4) Clay Fill	125	100	31	360	4	2.5×10^{-7}	1.0×10^{-6}

Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.
2. Dimensions are approximate and should not be used for design purposes.

Novato Creek Levee Evaluation Project
Novato, CA

Marin County Flood Control and Water Conservation District

GEI Consultants

ALTERNATIVE 2
BASE MODEL
NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-37
STATION NCLB 300+89

January 2020 | Project #1802696 | Figure A-7

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\NC_300+89_Alt2.dwg

Novato Creek Levee Evaluation Project
Seepage and Slope Stability Analysis Results

Levee:	**Novato Creek Left Bank Levee upstream of SR-37**
Station:	**NCLB 300+89**

Analysis Run: **Alternative 2 -Levee Reconstruction and Widening**

Analyzed by: E. Cerna Alvarez
Date: 12/13/2019

Gradient is calculated at: Landside Toe (landside toe, low point at x ft from toe)

Water Surface: 50-Year

Water Surface Elevation 13.56 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	61.64 feet	2.71 feet	2.71 feet	**0.05**
Bottom of Blanket	62.06 feet	-24.45 feet	4.20 feet	

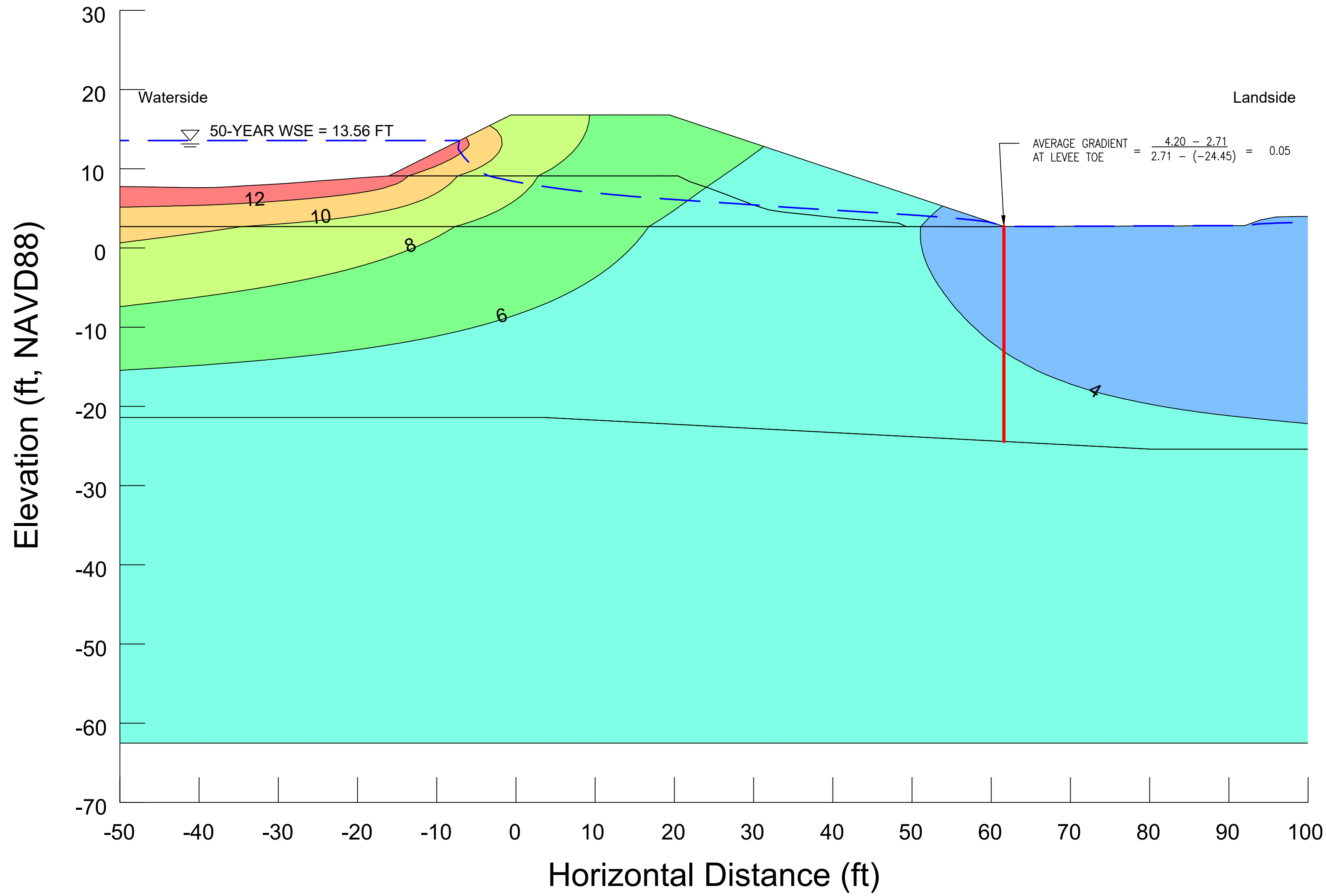
Seepage Breakout above Toe, ft 0.6 ft
Steady State Landside Slope Stability, FS 1.5 (circular)

Water Surface: 100-Year

Water Surface Elevation 13.76 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	61.64 feet	2.71 feet	2.71 feet	**0.06**
Bottom of Blanket	62.06 feet	-24.45 feet	4.23 feet	

Seepage Breakout above Toe, ft 0.6 ft
Steady State Landside Slope Stability, FS 1.4 (circular)
Rapid Draw Down Slope Stability, FS 2.1 (circular)



Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **50-YEAR WSE - SEEPAGE RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-37 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-8

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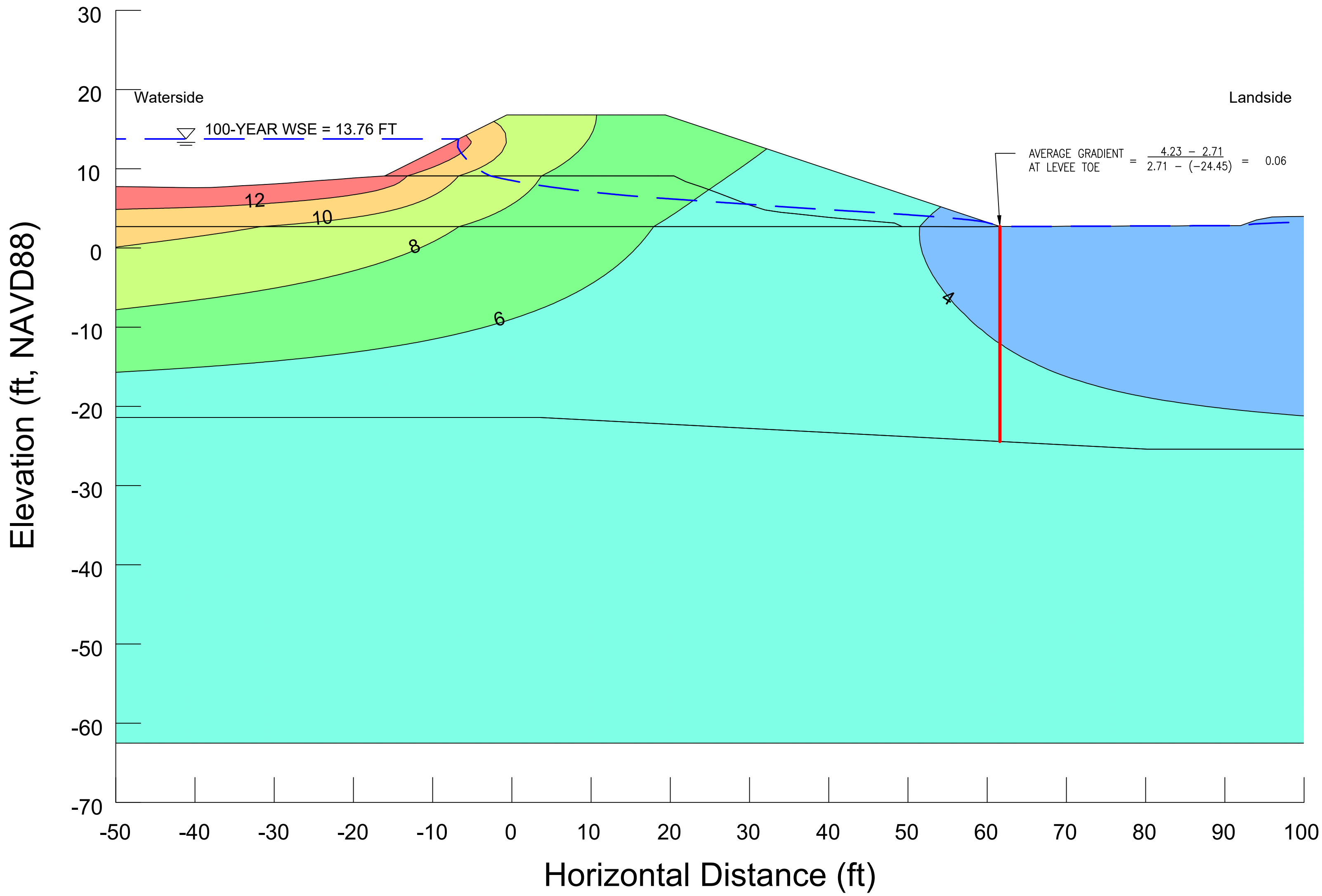

Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **100-YEAR WSE - SEEPAGE RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-37 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-9

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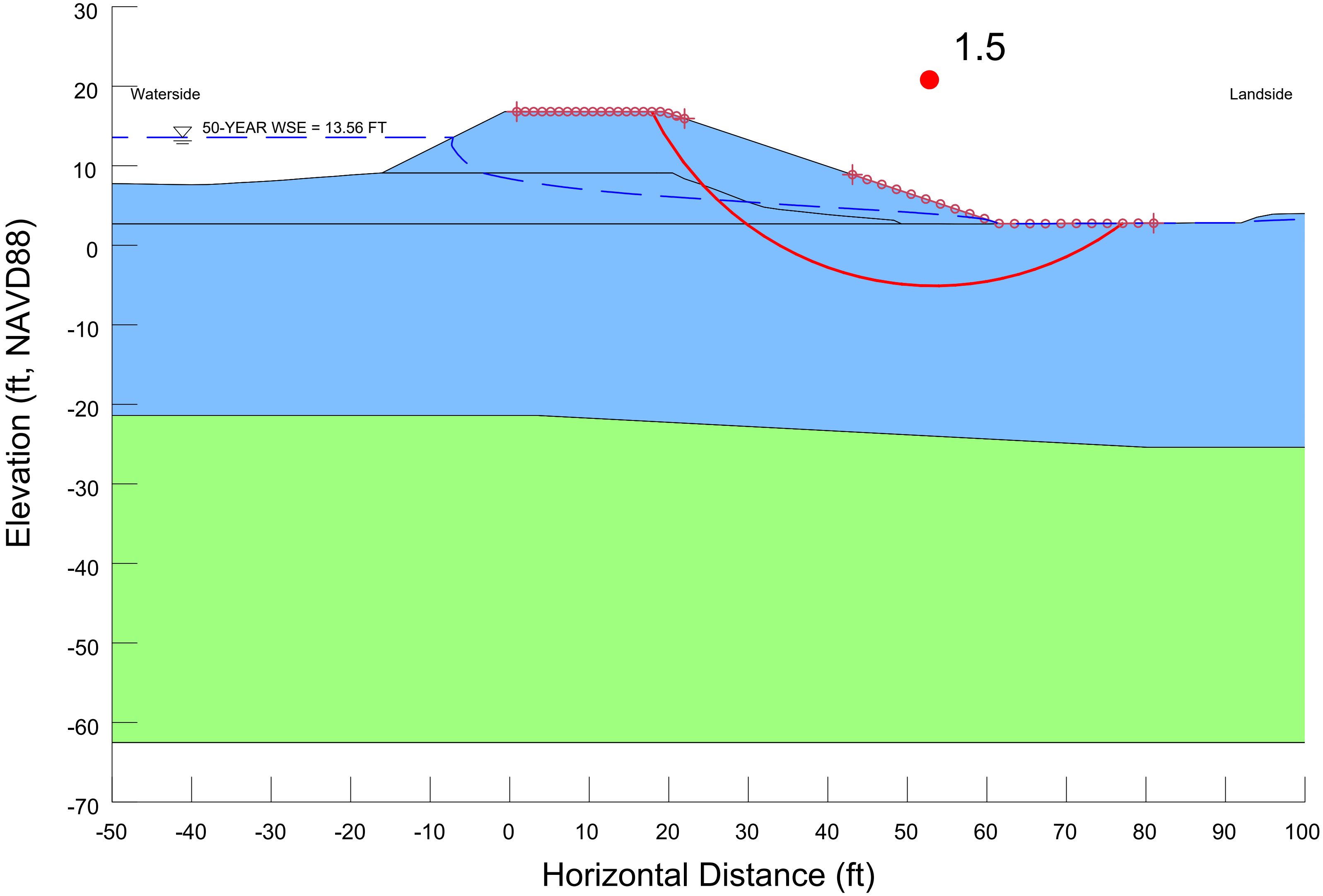
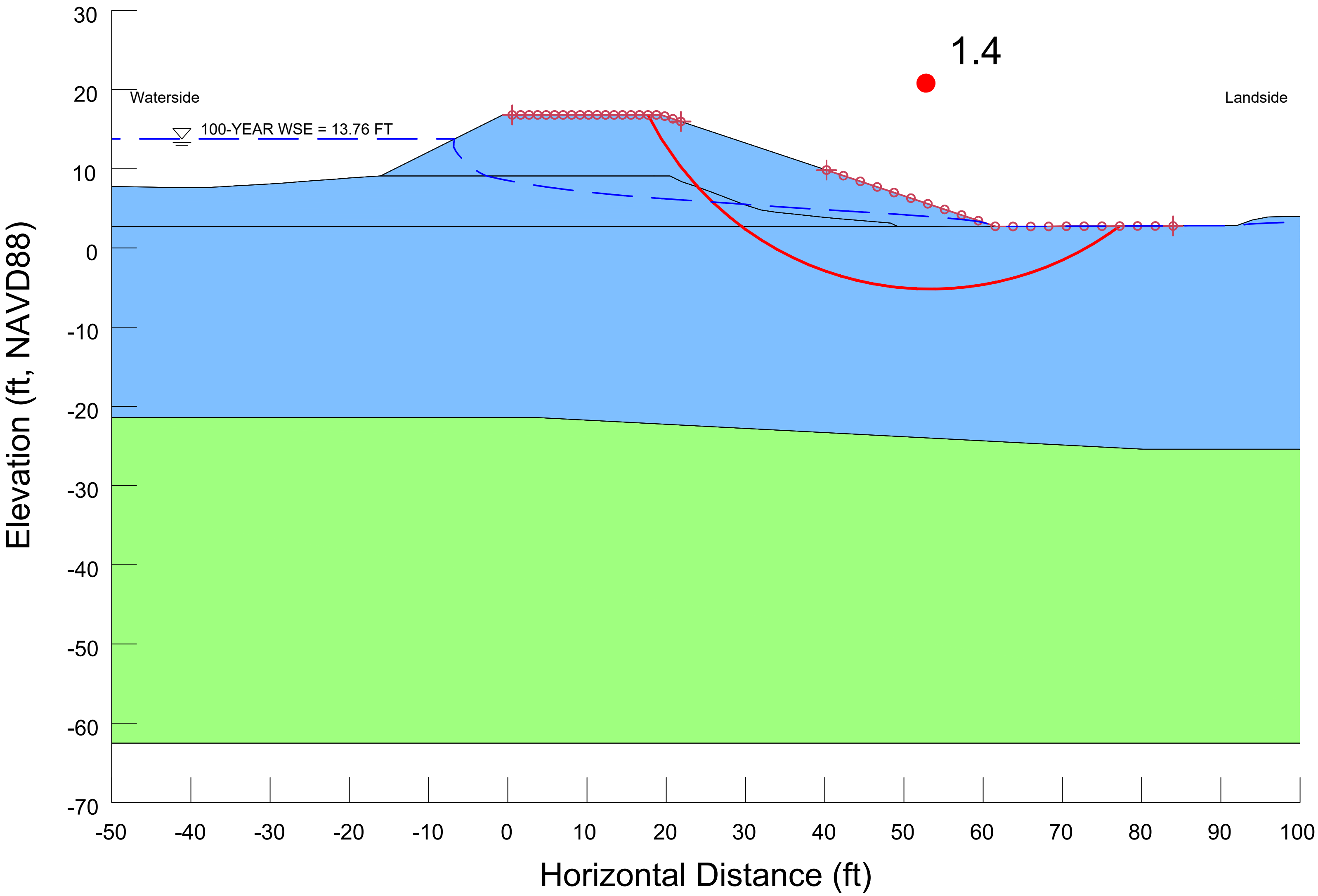


Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **50-YEAR WSE - STABILITY RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-37 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-10

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\NC_300+89_Alt2.dwg



Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **100-YEAR WSE - STABILITY RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-37 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-11

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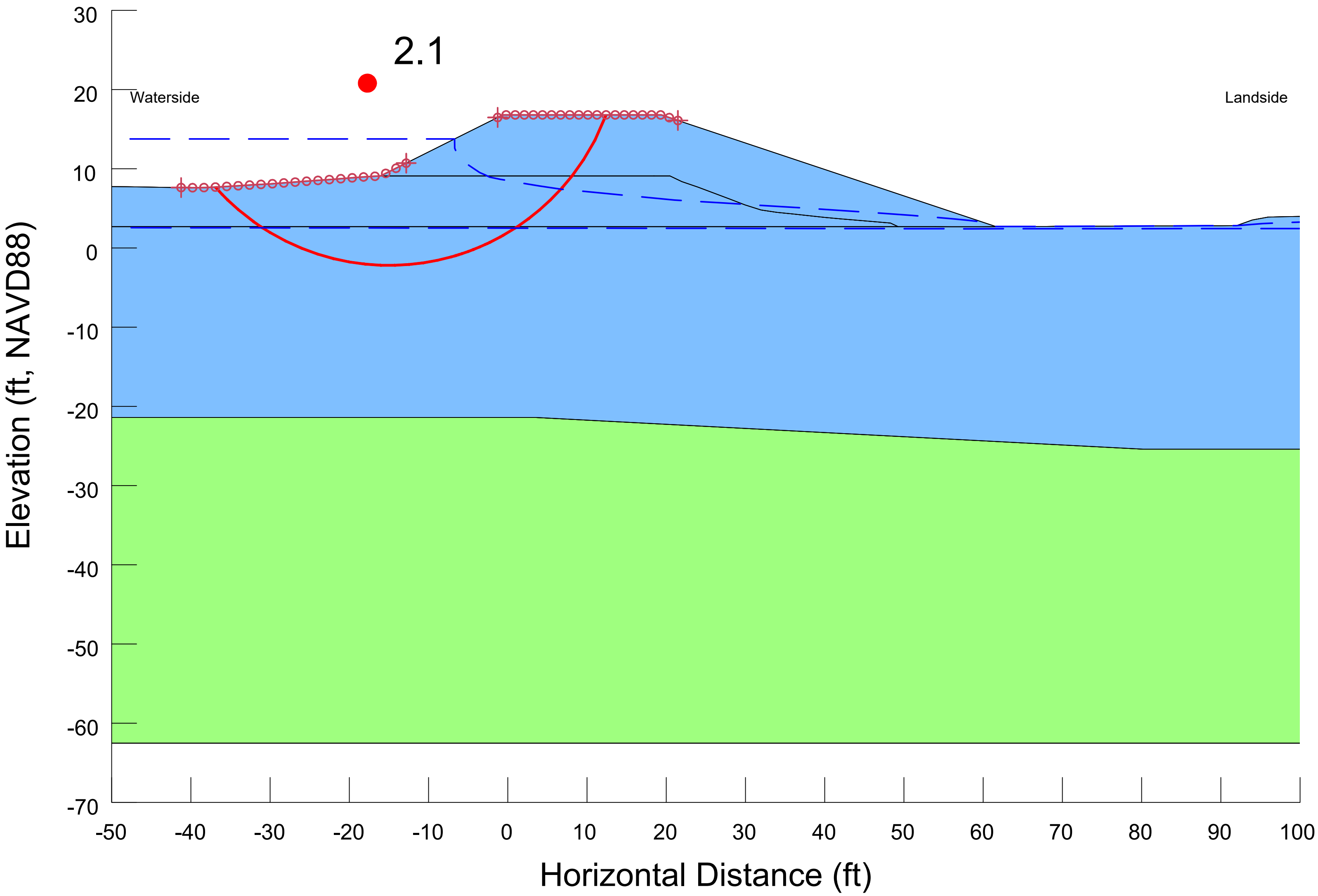


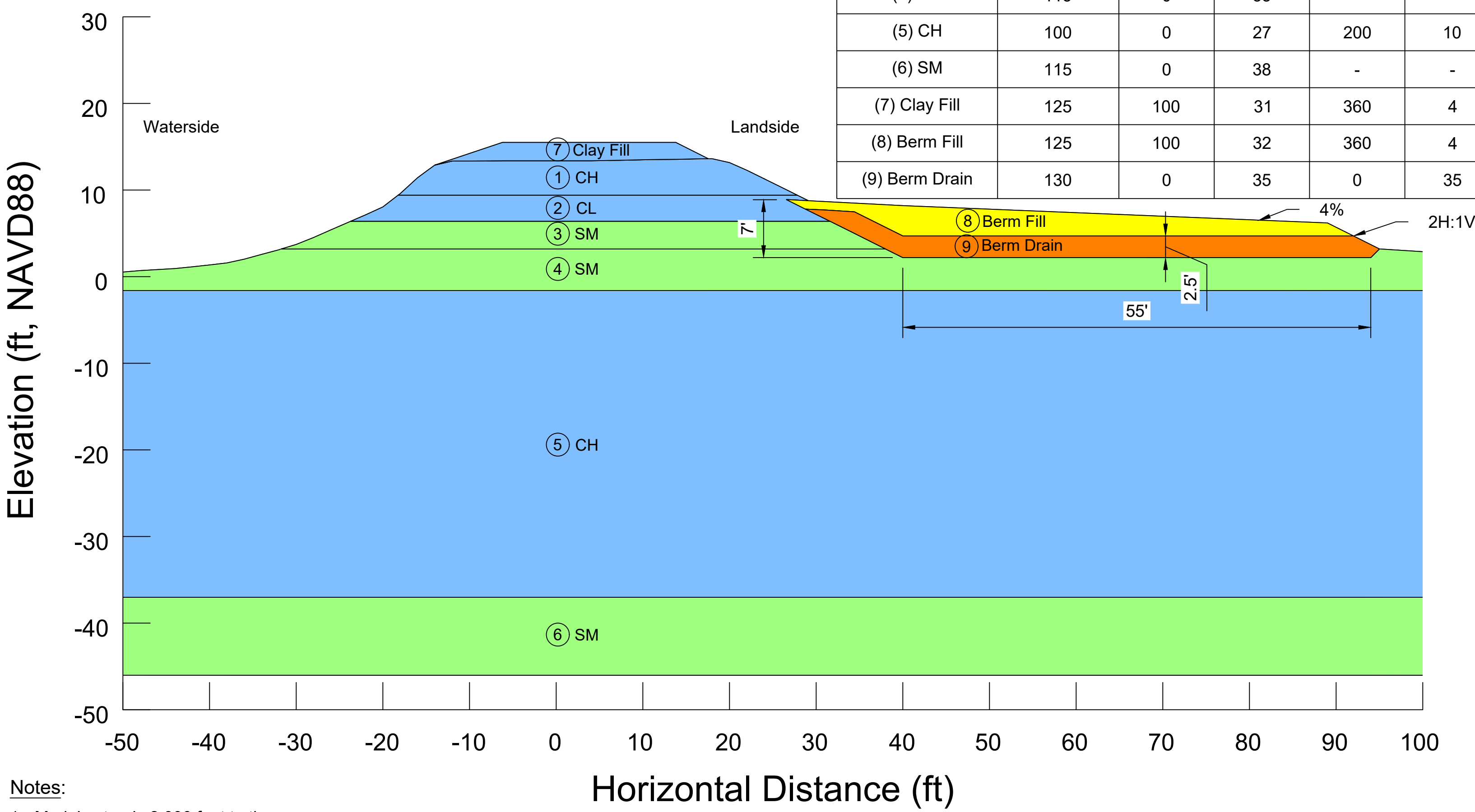
Notes:

1. Model extends 735 feet to the landside and 100 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **100-YEAR WSE - RAPID DRAWDOWN RESULTS** NOVATO CREEK LEFT BANK LEVEE UPSTREAM OF SR-37 STATION NCLB 300+89
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-12

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\NC_300+89_Alt2.dwg

Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters		K_v	K_h
		c'	Φ'	c	Φ		
	(pcf)	(psf)	(deg)	(psf)	(deg)	(cm/sec)	(cm/sec)
(1) CH	120	0	27	500	0	$1.0x10^{-6}$	$4.0x10^{-6}$
(2) CL	120	50	28	1500	0	$1.0x10^{-6}$	$4.0x10^{-6}$
(3) SM	115	0	36	-	-	$5.0x10^{-4}$	$2.0x10^{-3}$
(4) SM	115	0	33	-	-	$1.5x10^{-4}$	$6.0x10^{-4}$
(5) CH	100	0	27	200	10	$2.5x10^{-6}$	$1.0x10^{-5}$
(6) SM	115	0	38	-	-	$1.5x10^{-4}$	$6.0x10^{-4}$
(7) Clay Fill	125	100	31	360	4	$2.5x10^{-7}$	$1.0x10^{-6}$
(8) Berm Fill	125	100	32	360	4	$3.0x10^{-7}$	$1.0x10^{-6}$
(9) Berm Drain	130	0	35	0	35	$5.0x10^{-2}$	$5.0x10^{-2}$



Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.
2. Dimensions are approximate and should not be used for design purposes.

Novato Creek Levee Evaluation Project
Novato, CA

Marin County Flood Control and Water Conservation District

GEI Consultants

ALTERNATIVE 1
BASE MODEL
LYNWOOD LEVEE
STATION LL 260+68

January 2020 | Project #1802696 | Figure A-13

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt1.dwg

Novato Creek Levee Evaluation Project
Seepage and Slope Stability Analysis Results

Levee:	**Lynwood Levee**
Station:	**LL 260+68**

Analysis Run: **Alternative 1 -Seepage Berm and Crown Raise**

Analyzed by: E. Cerna Alvarez
Date: 12/4/2019

Gradient is calculated at: Landside Toe (landside toe, low point at x ft from toe)

Water Surface: 50-Year

Water Surface Elevation 12.36 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	N/A feet	N/A feet	N/A feet	**N/A**
Bottom of Blanket	N/A feet	N/A feet	N/A feet	

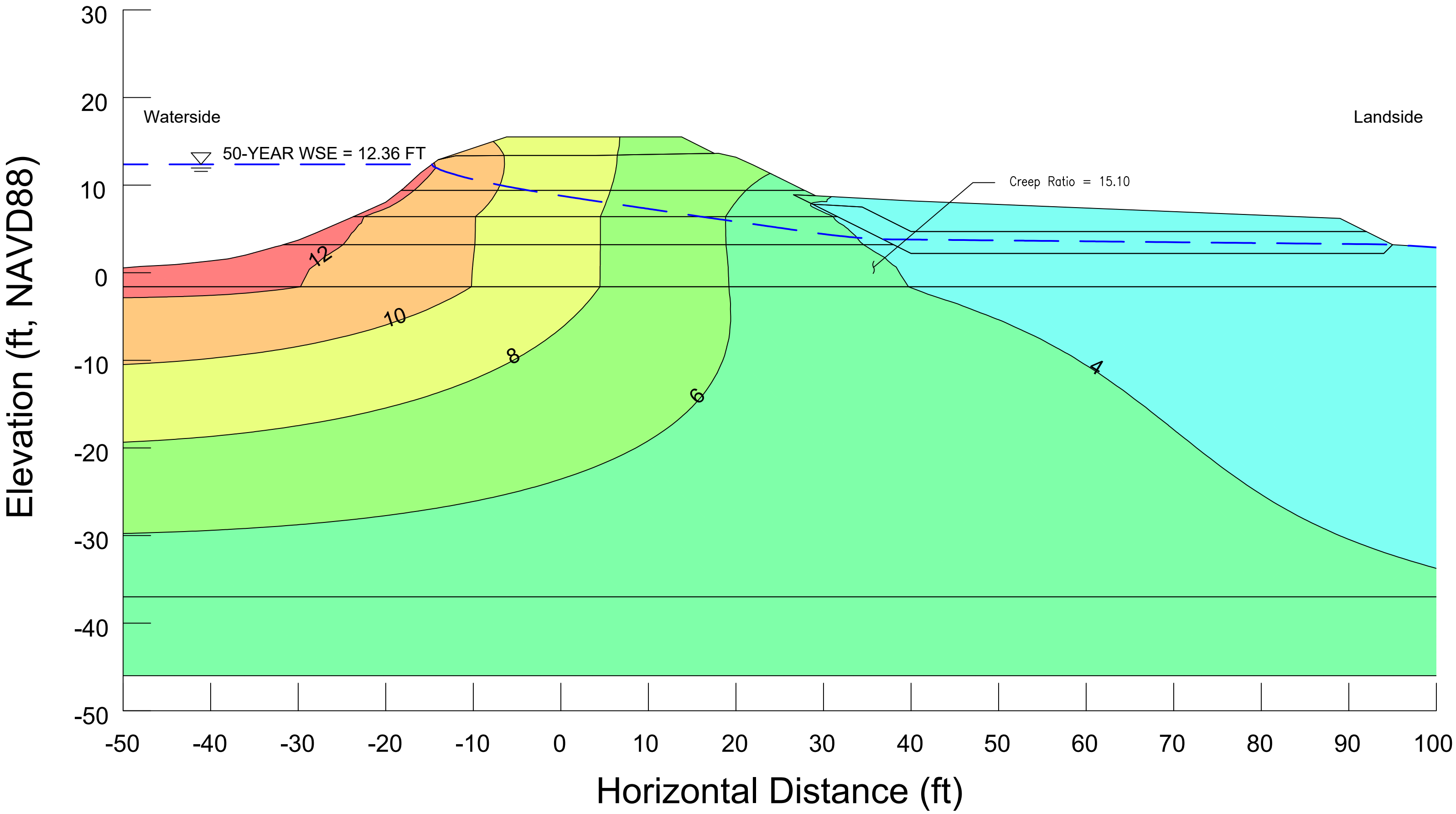
Seepage Breakout above Toe, ft N/A ft
Steady State Landside Slope Stability, FS 1.7 (circular)

Water Surface: 100-Year

Water Surface Elevation 12.49 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	N/A feet	N/A feet	N/A feet	**N/A**
Bottom of Blanket	N/A feet	N/A feet	N/A feet	

Seepage Breakout above Toe, ft N/A ft
Steady State Landside Slope Stability, FS 1.7 (circular)
Rapid Draw Down Slope Stability, FS 1.3 (circular)



Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **50-YEAR WSE - SEEPAGE RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-14

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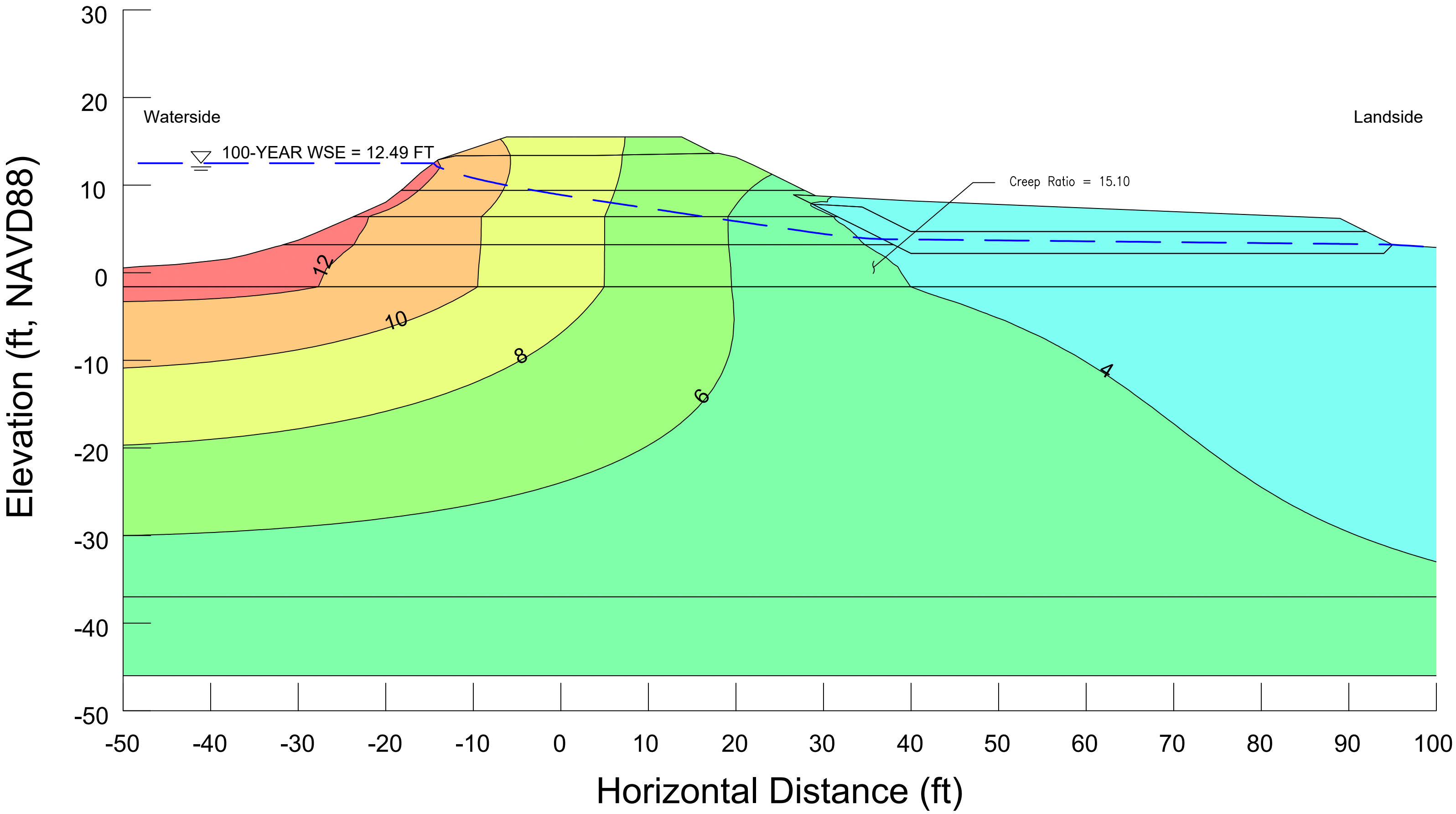

Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **100-YEAR WSE - SEEPAGE RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-15

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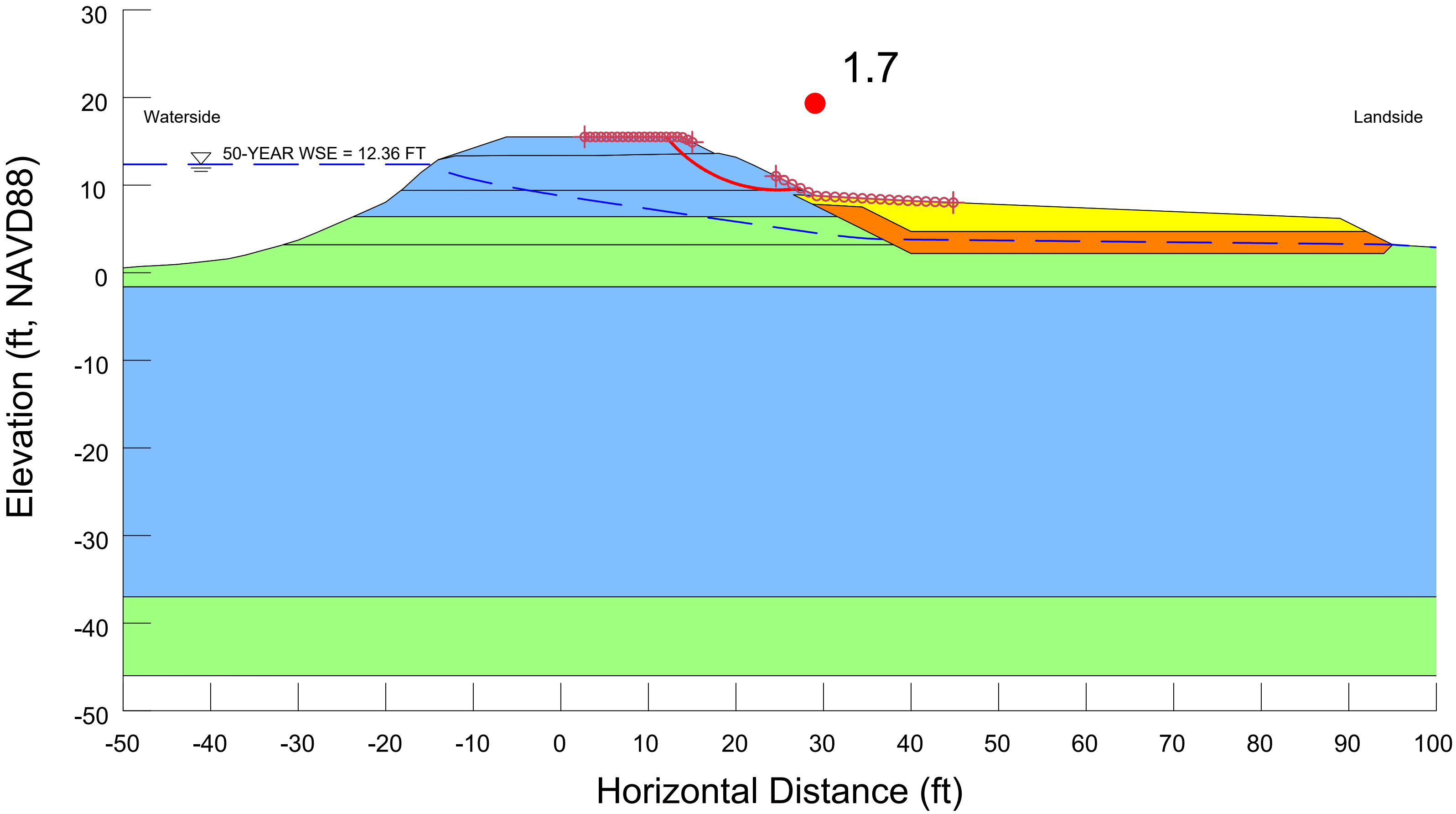

Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **50-YEAR WSE - STABILITY RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-16

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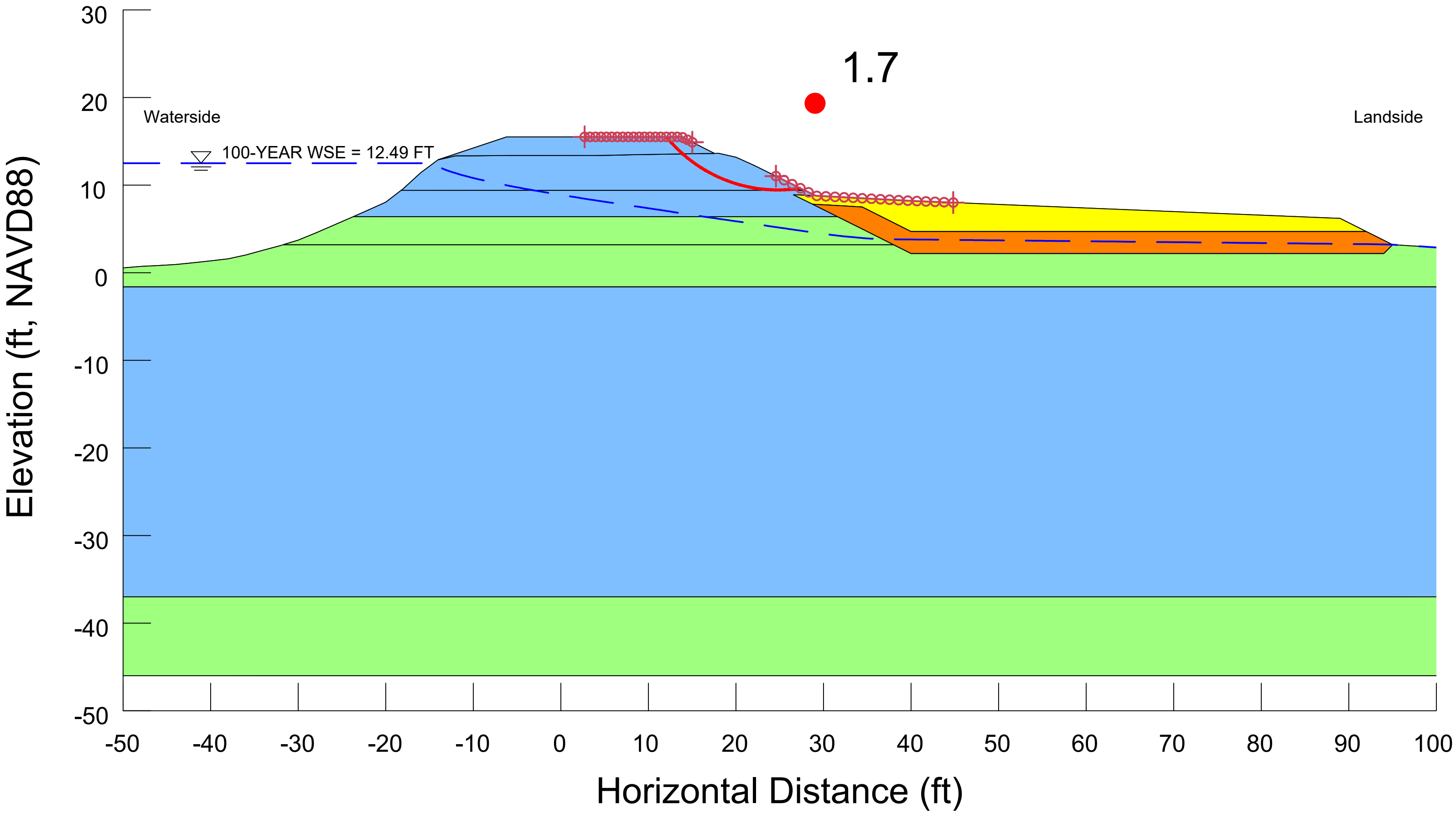
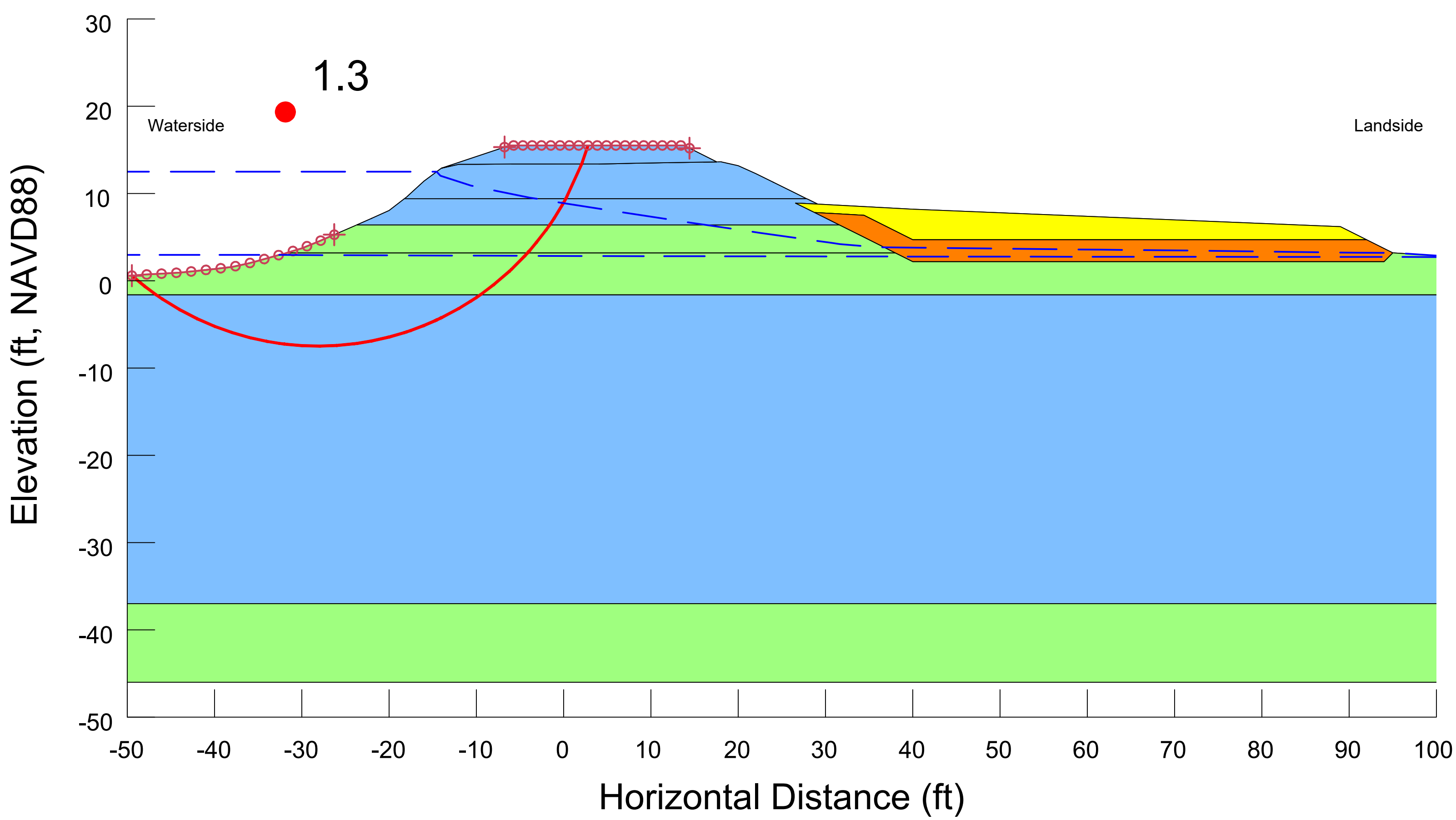


Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **100-YEAR WSE - STABILITY RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-17

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt1.dwg



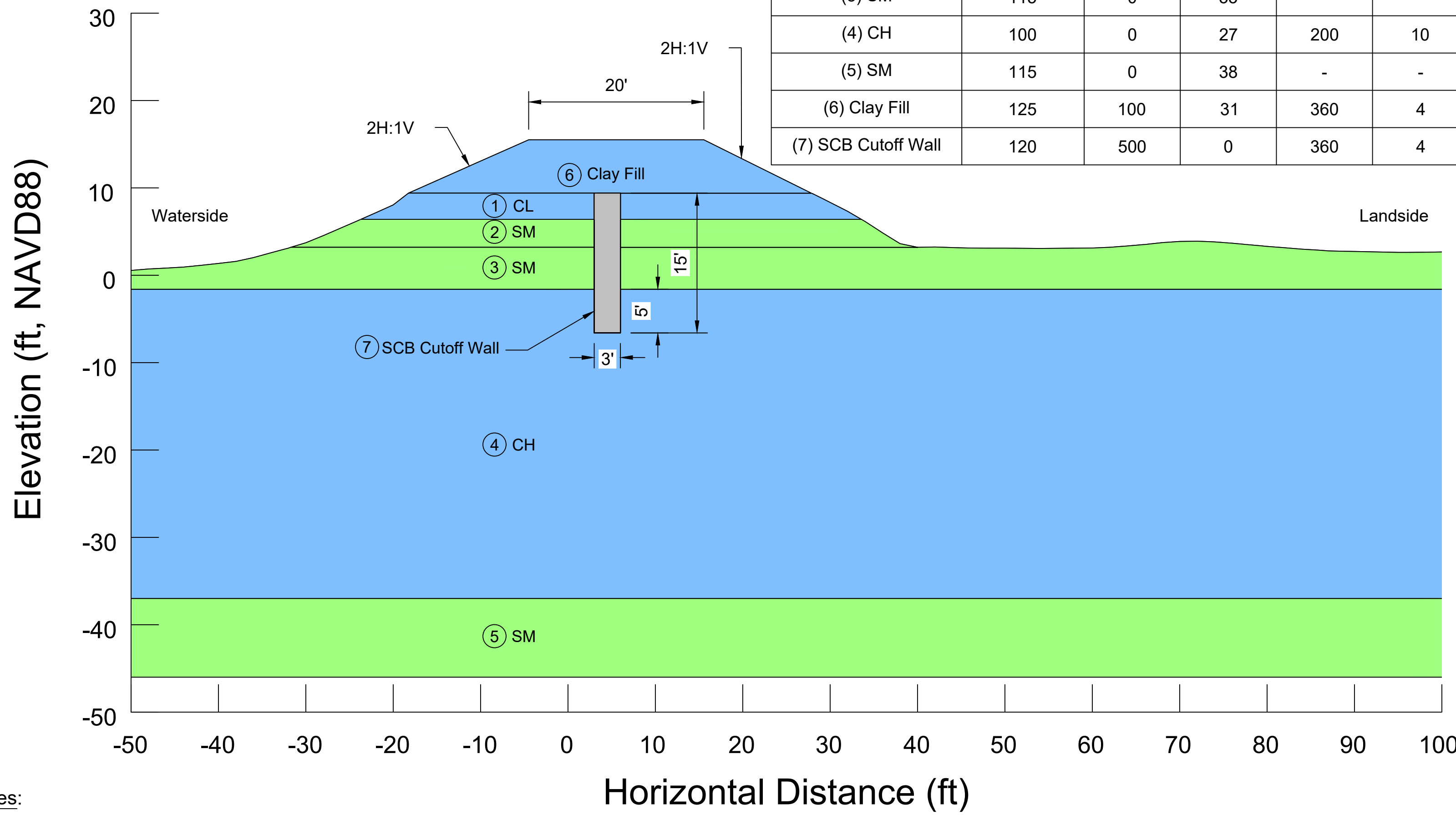
Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **100-YEAR WSE - RAPID DRAWDOWN RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-18

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt1.dwg

Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters		K_v	K_h
		c'	Φ'	c	Φ		
	(pcf)	(psf)	(deg)	(psf)	(deg)	(cm/sec)	(cm/sec)
(1) CL	120	50	28	1500	0	1.0×10^{-6}	4.0×10^{-6}
(2) SM	115	0	36	-	-	5.0×10^{-4}	2.0×10^{-3}
(3) SM	115	0	33	-	-	1.5×10^{-4}	6.0×10^{-4}
(4) CH	100	0	27	200	10	2.5×10^{-6}	1.0×10^{-5}
(5) SM	115	0	38	-	-	1.5×10^{-4}	6.0×10^{-4}
(6) Clay Fill	125	100	31	360	4	2.5×10^{-7}	1.0×10^{-6}
(7) SCB Cutoff Wall	120	500	0	360	4	1.0×10^{-7}	1.0×10^{-7}



Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.
2. Dimensions are approximate and should not be used for design purposes.

Novato Creek Levee Evaluation Project
Novato, CA

Marin County Flood Control and Water Conservation District

GEI Consultants

ALTERNATIVE 2
BASE MODEL
LYNWOOD LEVEE
STATION LL 260+68

January 2020 | Project #1802696 | Figure A-19

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt2.dwg

Novato Creek Levee Evaluation Project
Seepage and Slope Stability Analysis Results

Levee: **Lynwood Levee**
Station: **LL 260+68**

Analysis Run: **Alternative 2 - Cutoff Wall and Crown Raise**

Analyzed by: E. Cerna Alvarez
Date: 12/3/2019

Gradient is calculated at: Landside Toe (landside toe, low point at x ft from toe)

Water Surface: 50-Year

Water Surface Elevation 12.36 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	N/A feet	N/A feet	N/A feet	**N/A**
Bottom of Blanket	N/A feet	N/A feet	N/A feet	

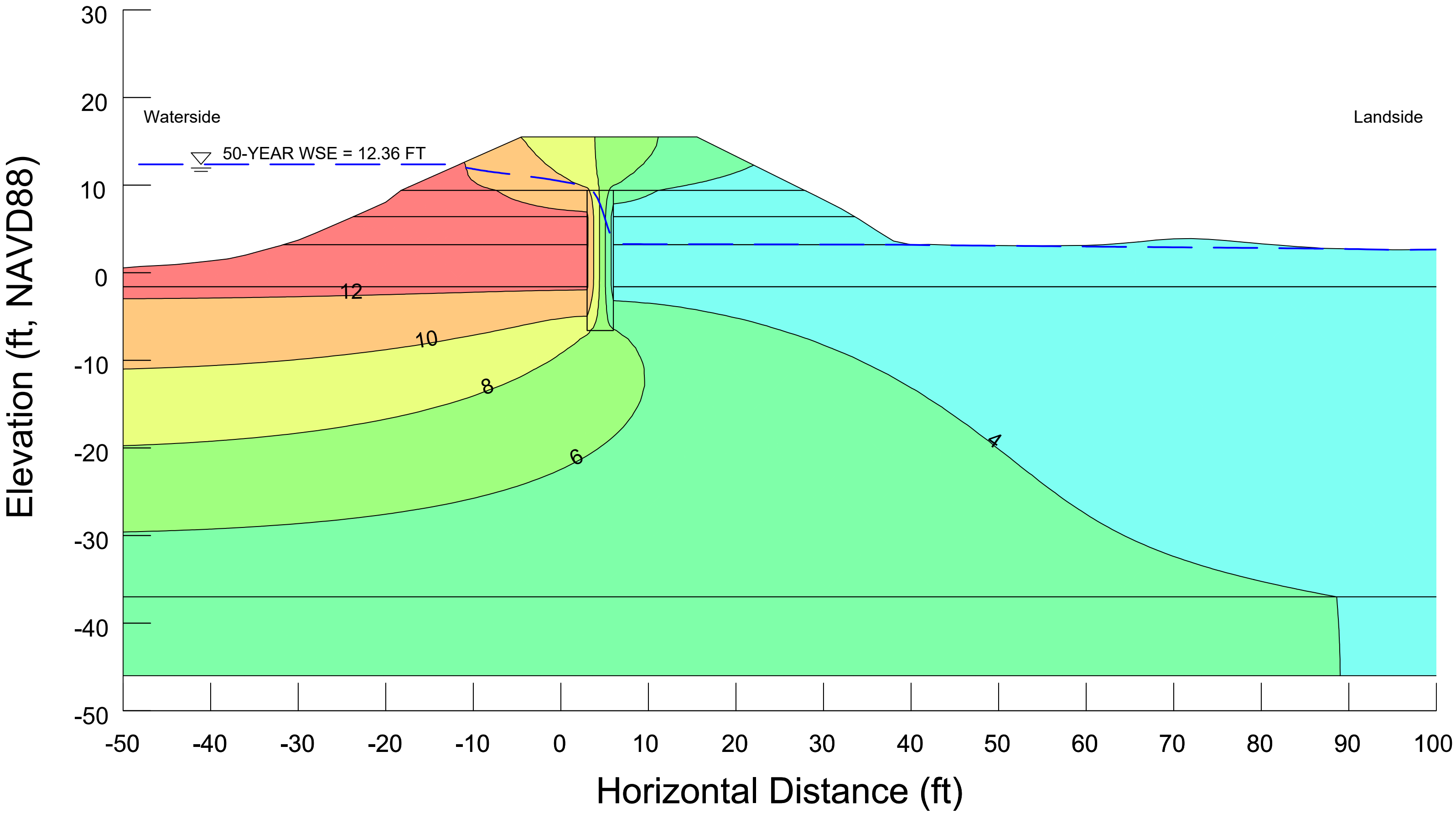
Seepage Breakout above Toe, ft N/A ft
Steady State Landside Slope Stability, FS 1.6 (circular)

Water Surface: 100-Year

Water Surface Elevation 12.49 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Toe	N/A feet	N/A feet	N/A feet	**N/A**
Bottom of Blanket	N/A feet	N/A feet	N/A feet	

Seepage Breakout above Toe, ft N/A ft
Steady State Landside Slope Stability, FS 1.6 (circular)
Rapid Draw Down Slope Stability, FS 1.3 (circular)

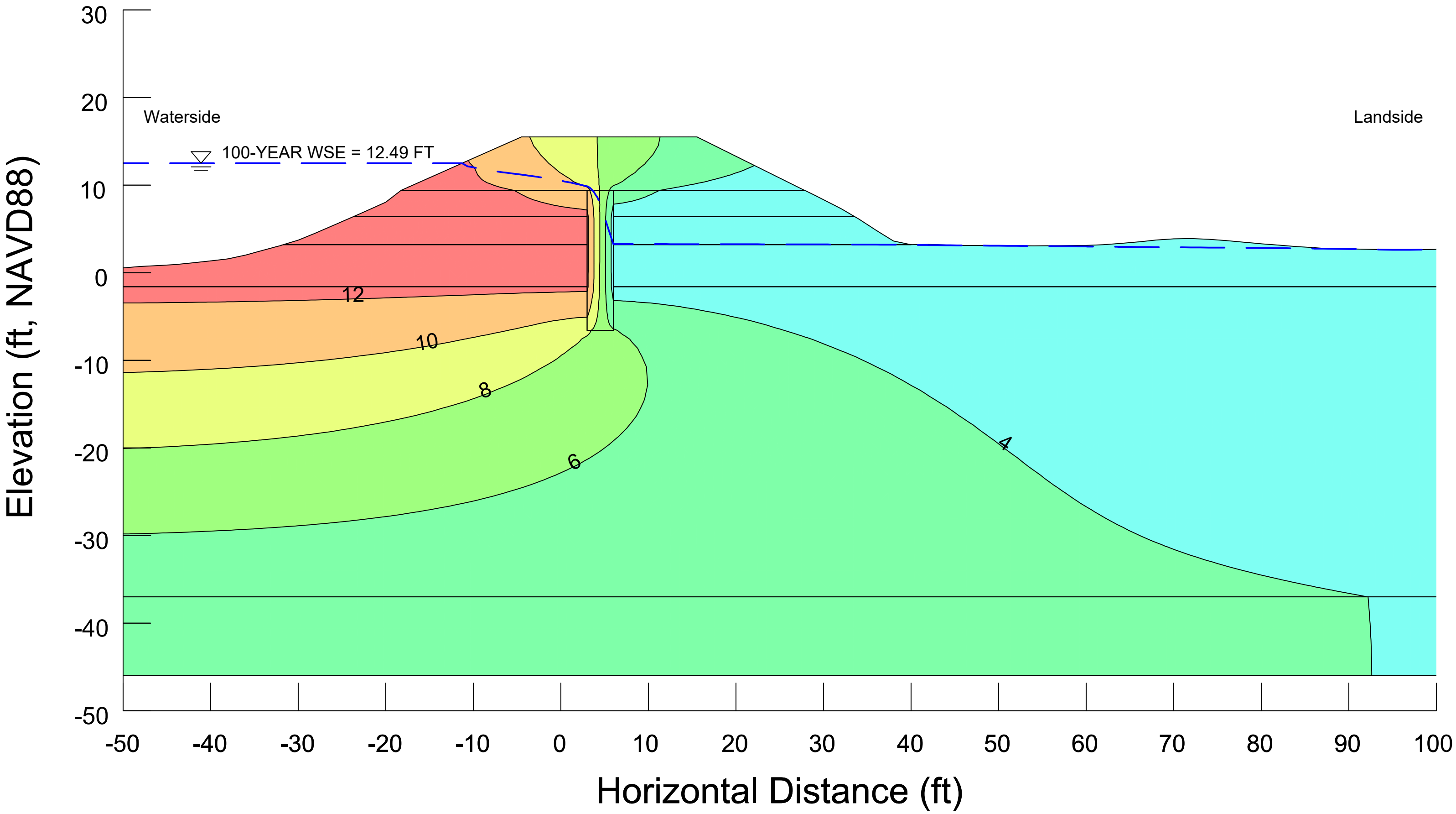


Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **50-YEAR WSE - SEEPAGE RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-20

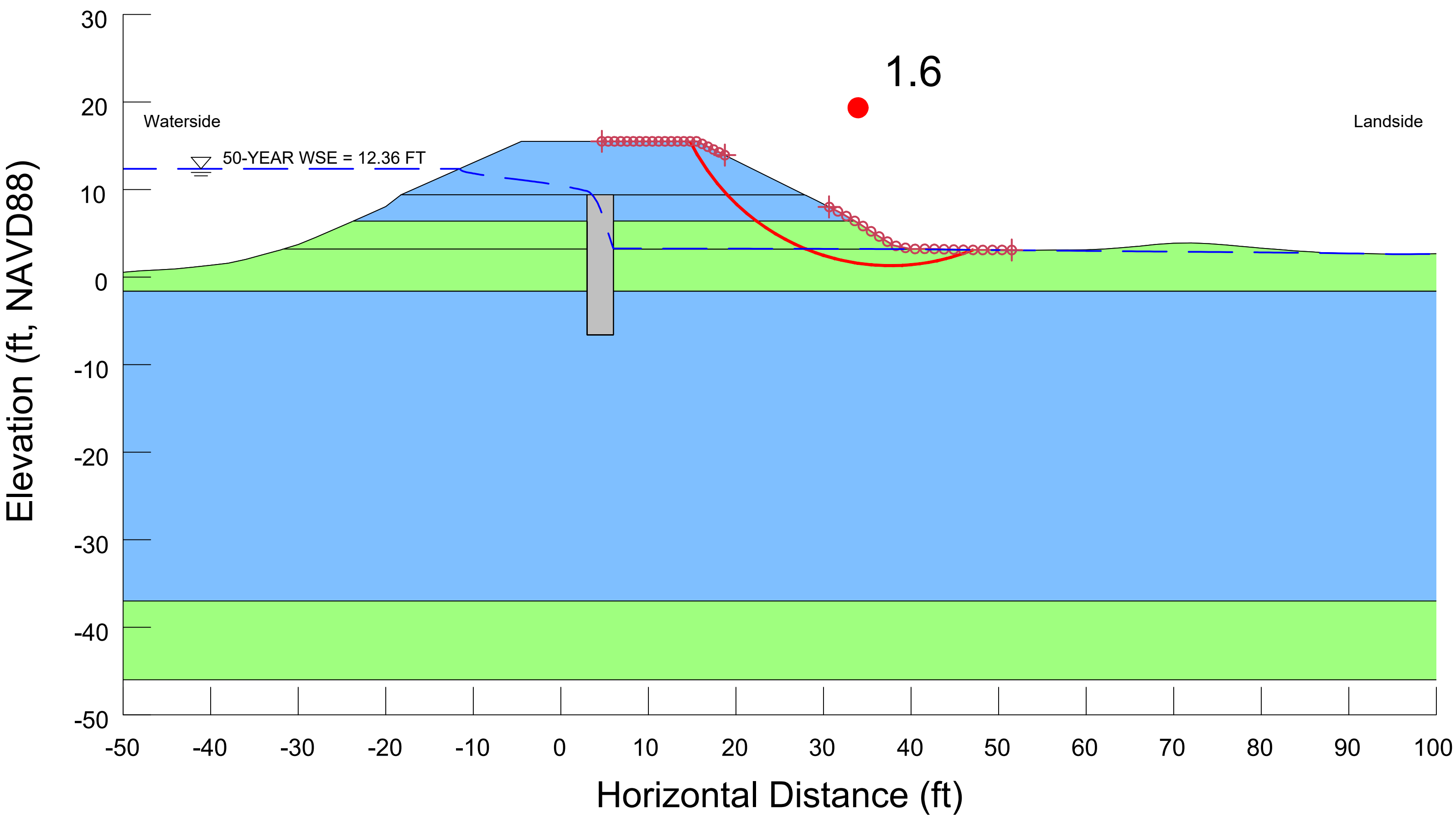
DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt2.dwg



Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **100-YEAR WSE - SEEPAGE RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-21

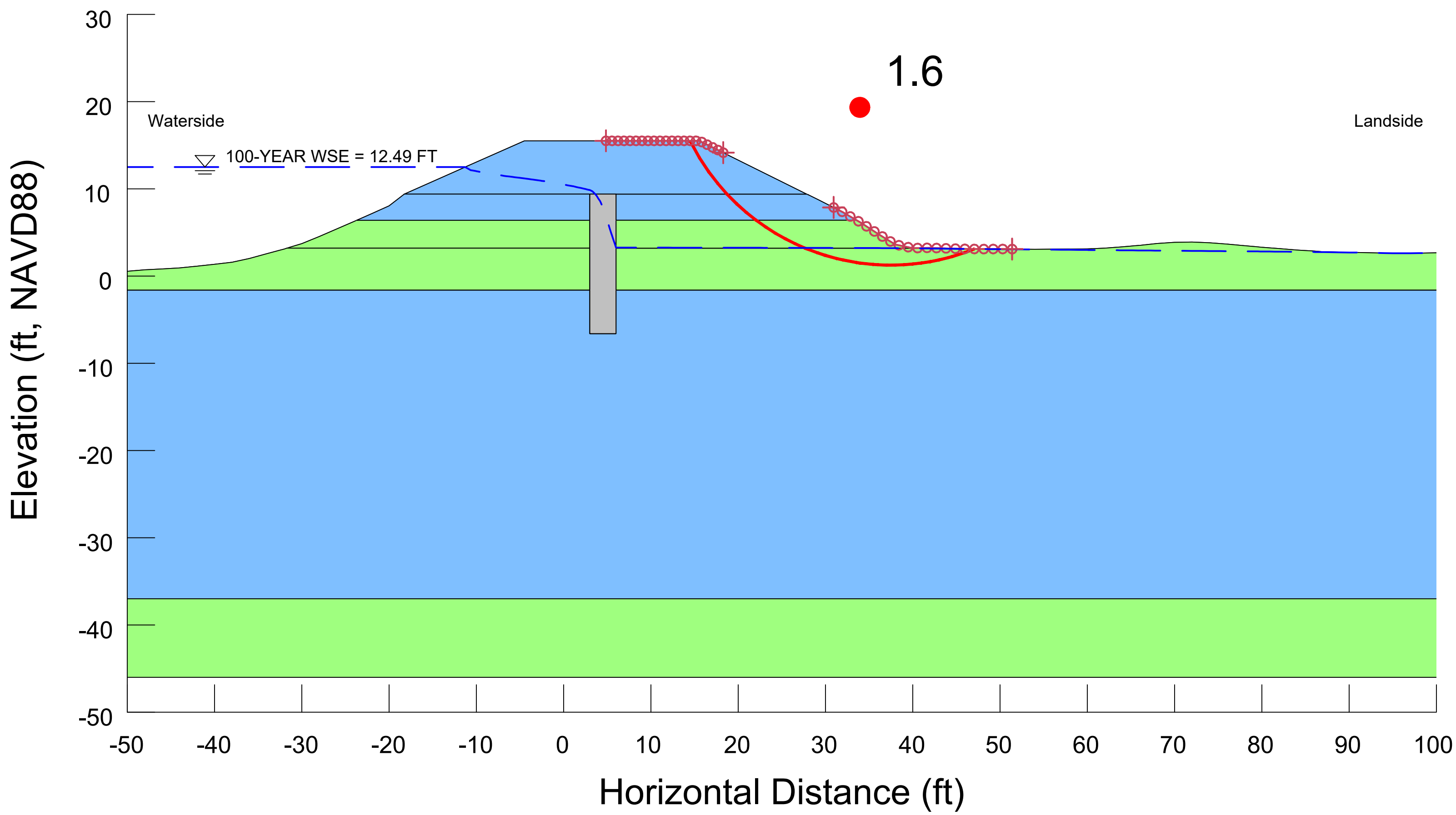


Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **50-YEAR WSE - STABILITY RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-22

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt2.dwg

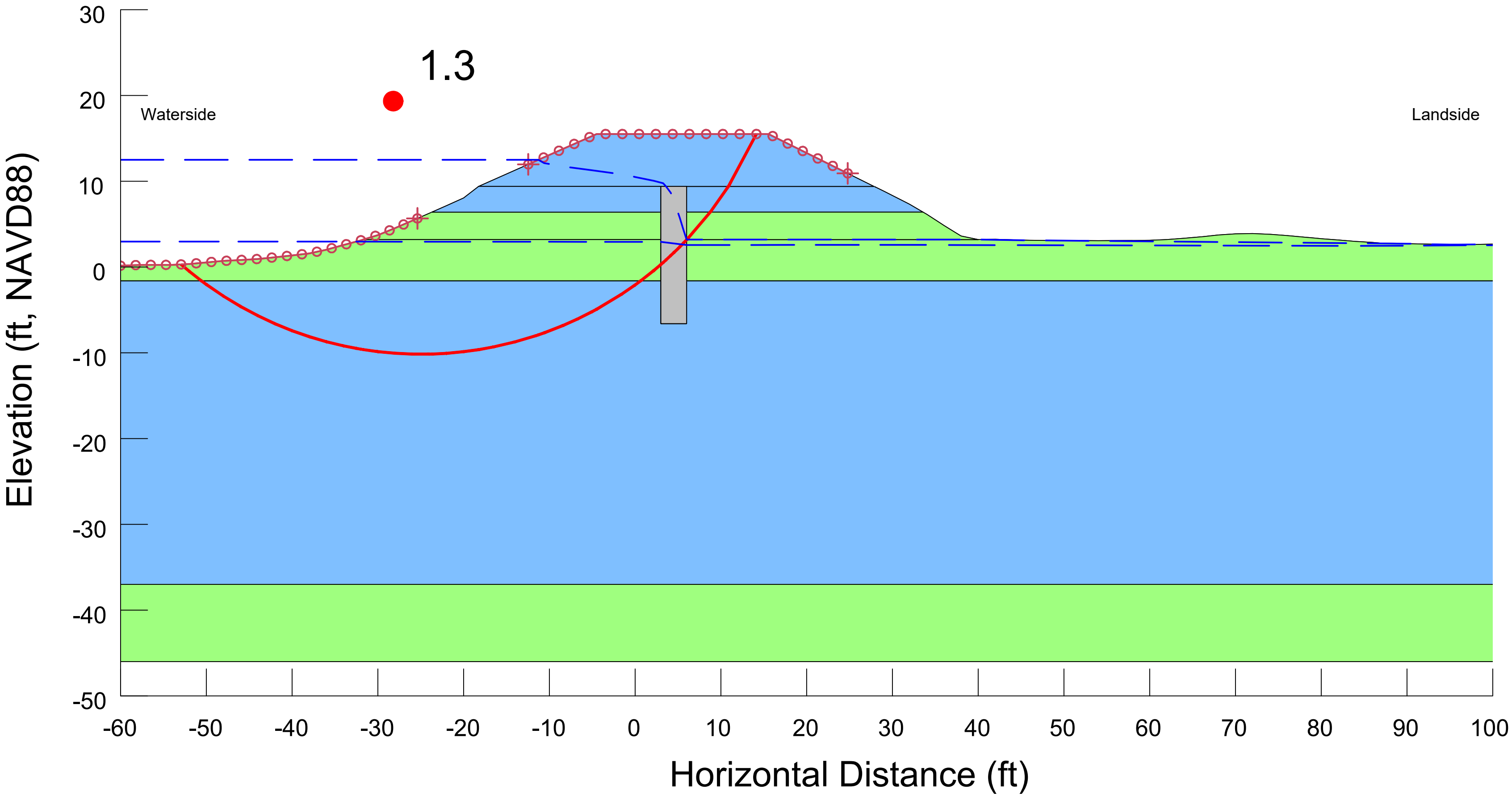


Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **100-YEAR WSE - STABILITY RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-23

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt2.dwg



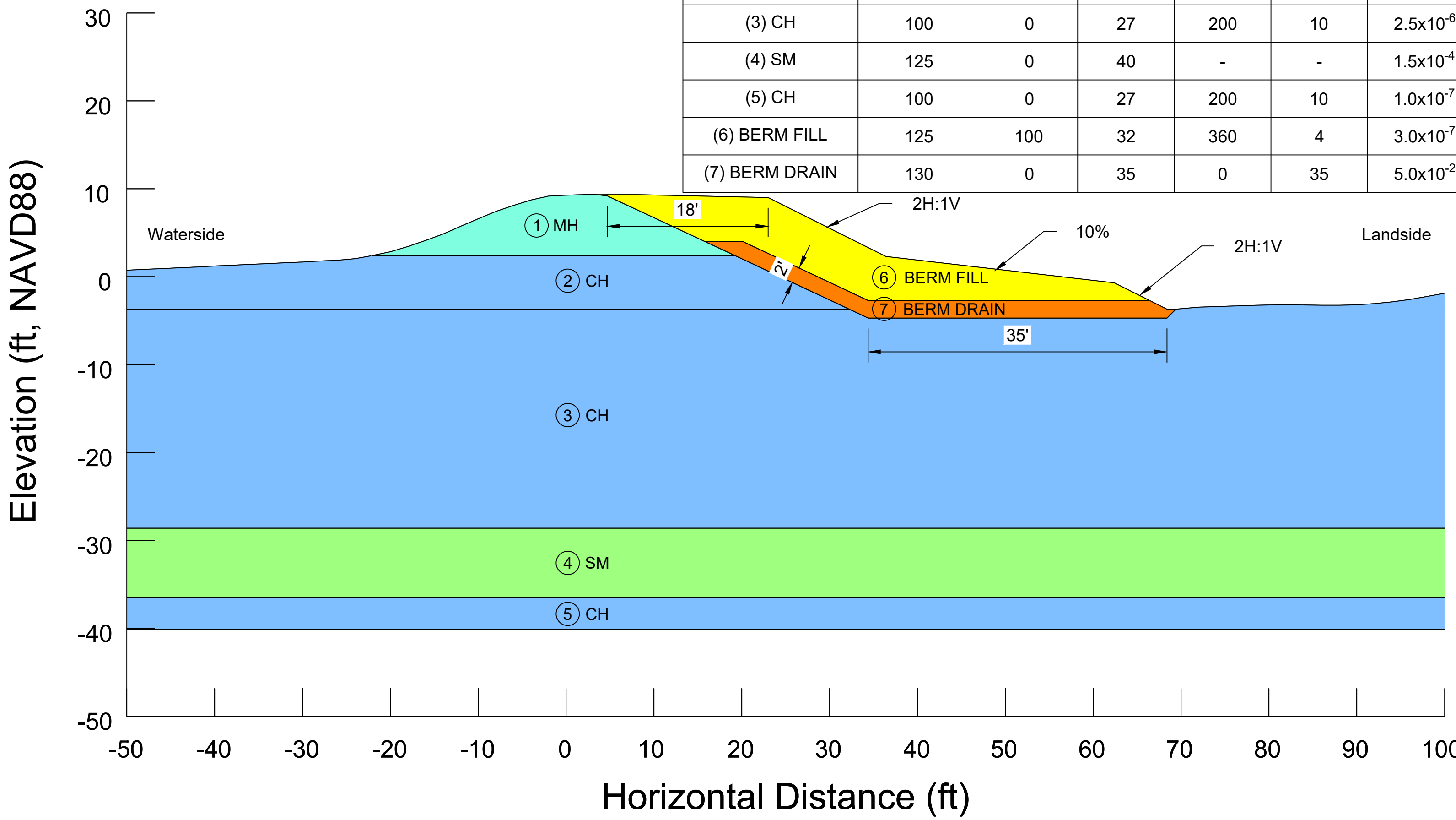
Notes:

1. Model extends 2,000 feet to the landside and 60 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **100-YEAR WSE - RAPID DRAWDOWN RESULTS** LYNWOOD LEVEE STATION LL 260+68
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-24

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\LL_260+68_Alt2.dwg

Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters		K_v	K_h
		c'	Φ'	c	Φ		
	(pcf)	(psf)	(deg)	(psf)	(deg)	(cm/sec)	(cm/sec)
(1) MH	120	0	27	1000	0	5.0×10^{-6}	2.0×10^{-5}
(2) CH	115	0	27	400	0	1.0×10^{-6}	4.0×10^{-6}
(3) CH	100	0	27	200	10	2.5×10^{-6}	1.0×10^{-5}
(4) SM	125	0	40	-	-	1.5×10^{-4}	6.0×10^{-4}
(5) CH	100	0	27	200	10	1.0×10^{-7}	2.0×10^{-7}
(6) BERM FILL	125	100	32	360	4	3.0×10^{-7}	1.0×10^{-6}
(7) BERM DRAIN	130	0	35	0	35	5.0×10^{-2}	5.0×10^{-2}



Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.
2. Dimensions are approximate and should not be used for design purposes.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **BASE MODEL** PACHECO POND LEVEE STATION PP 33+22
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-25

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt1.dwg

Novato Creek Levee Evaluation Project
Seepage and Slope Stability Analysis Results

Levee: **Pachecho Pond Levee**
Station: **PP 33+22**

Analysis Run: **Alternative 1 -Combination Seepage and Stability Berm**

Analyzed by: E. Cerna Alvarez
Date: 12/18/2019

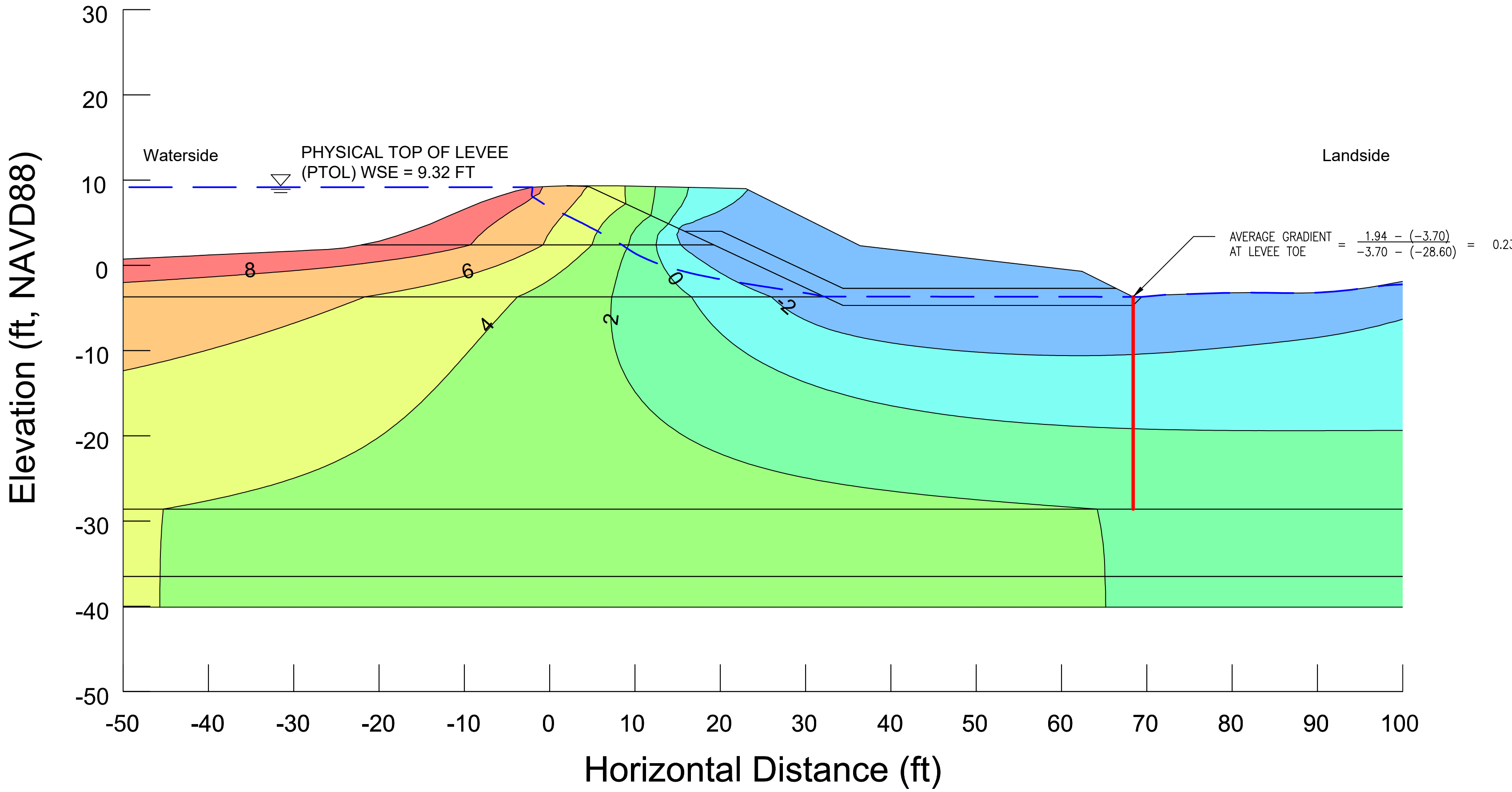
Gradient is calculated at: Landside Toe (landside toe, low point at x ft from toe)

Water Surface: Physical Top of Levee

Water Surface Elevation 9.3 feet

Exit Gradient (i) Calculation	x-Coordinate		y-Coordinate		Total Head		i
Landside Toe	68.40	feet	-3.70	feet	-3.70	feet	**0.23**
Bottom of Blanket	68.00	feet	-28.60	feet	1.94	feet	

Seepage Breakout above Toe, ft N/A ft
Steady State Landside Slope Stability, FS 1.7 (circular)
Rapid Draw Down Slope Stability, FS 1.5 (circular)

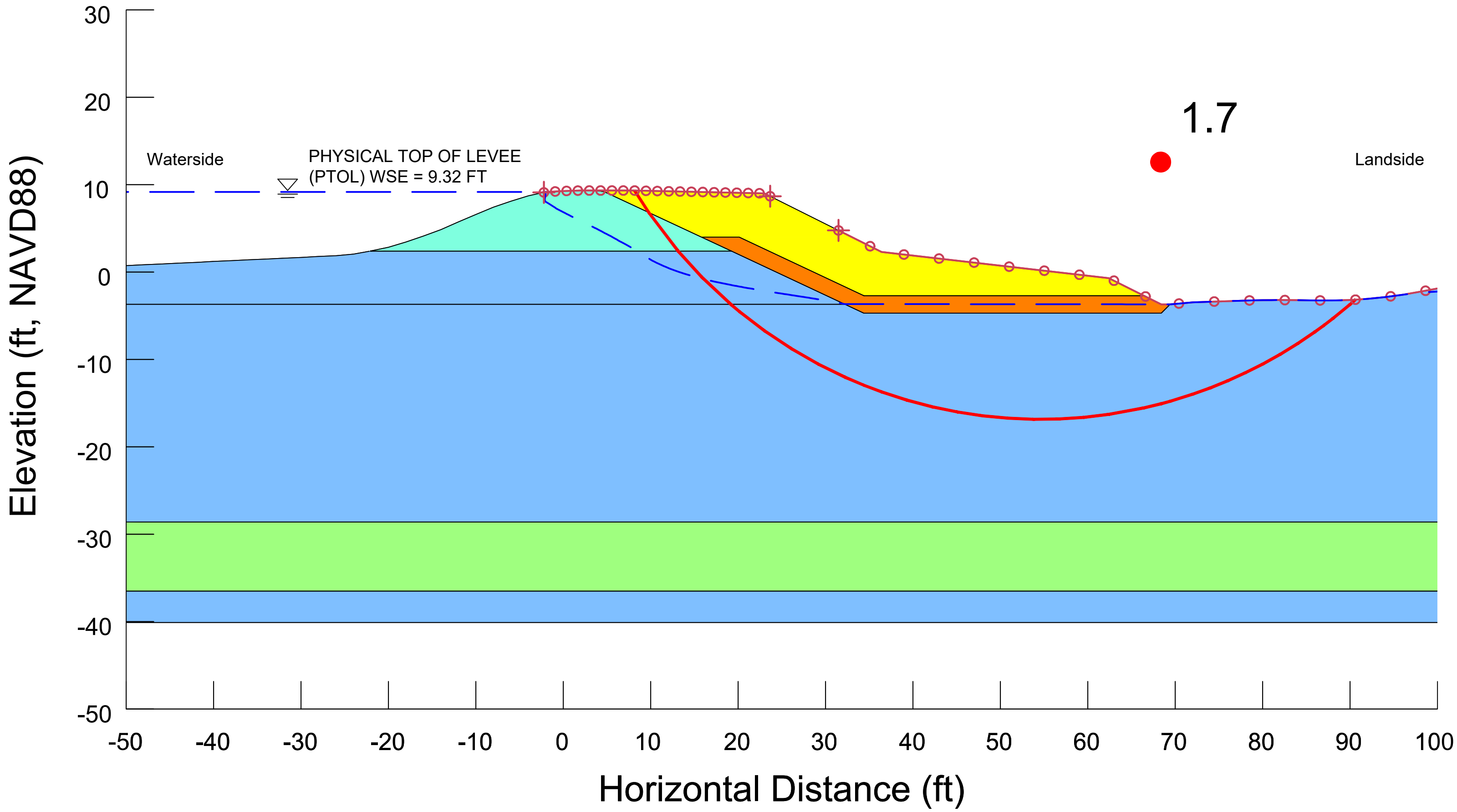


Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **PTOL WSE - SEEPAGE RESULTS** PACHECO POND LEVEE STATION PP 33+22
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-26

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt1.dwg

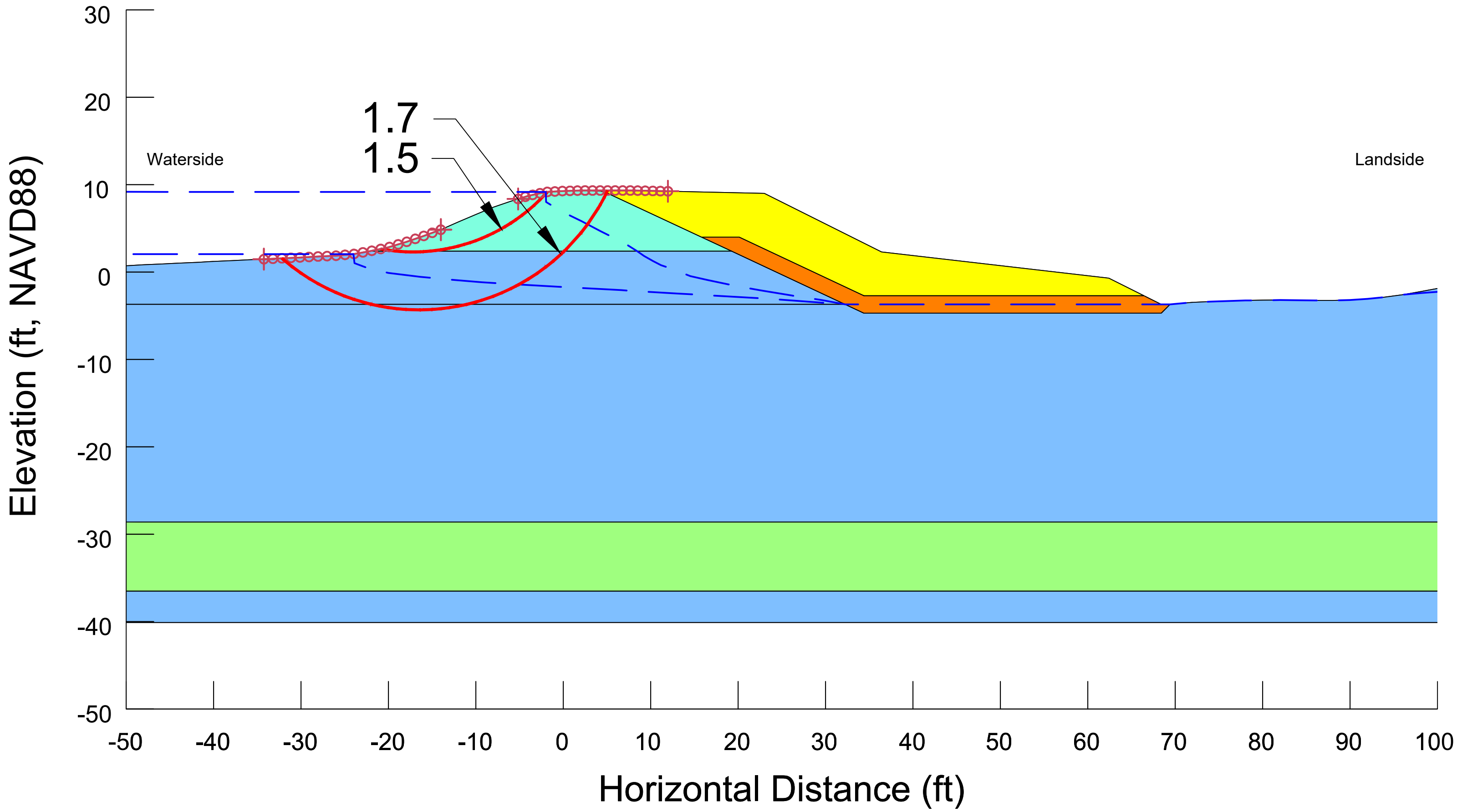


Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **PTOL WSE - STABILITY RESULTS** PACHECO POND LEVEE STATION PP 33+22
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-27

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt1.dwg



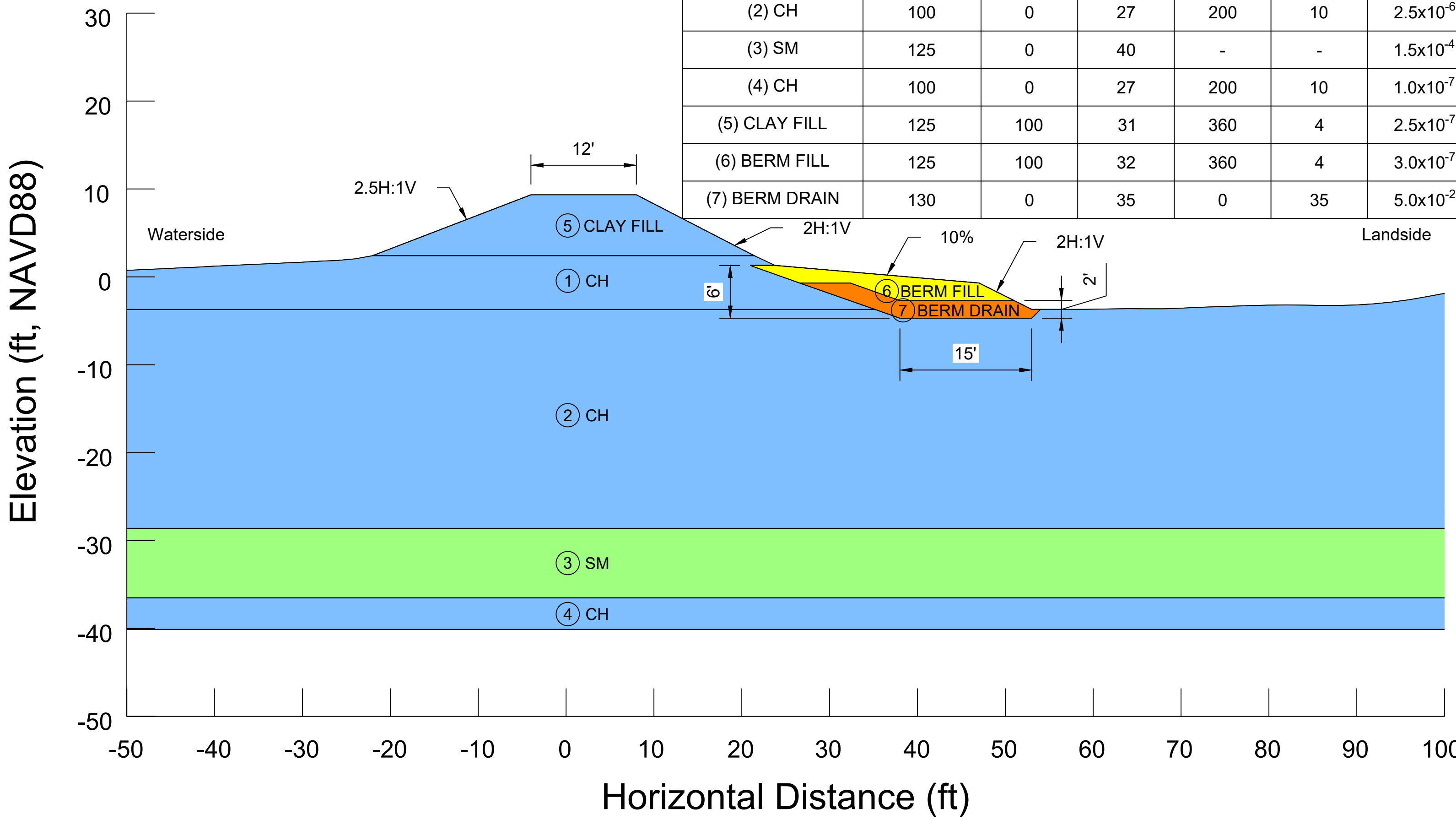
Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 1** **PTOL WSE - RAPID DRAWDOWN RESULTS** PACHECO POND LEVEE STATION PP 33+22
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-28

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt1.dwg

Layer Name	Saturated Unit Weight	Drained Parameters		Undrained Parameters		K_v	K_h
		c'	Φ'	c	Φ		
	(pcf)	(psf)	(deg)	(psf)	(deg)	(cm/sec)	(cm/sec)
(1) CH	115	0	27	400	0	1.0×10^{-6}	4.0×10^{-6}
(2) CH	100	0	27	200	10	2.5×10^{-6}	1.0×10^{-5}
(3) SM	125	0	40	-	-	1.5×10^{-4}	6.0×10^{-4}
(4) CH	100	0	27	200	10	1.0×10^{-7}	2.0×10^{-7}
(5) CLAY FILL	125	100	31	360	4	2.5×10^{-7}	1.0×10^{-6}
(6) BERM FILL	125	100	32	360	4	3.0×10^{-7}	1.0×10^{-6}
(7) BERM DRAIN	130	0	35	0	35	5.0×10^{-2}	5.0×10^{-2}



Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.
2. Dimensions are approximate and should not be used for design purposes.

Novato Creek Levee Evaluation Project
Novato, CA

Marin County Flood Control and Water Conservation District

GEI Consultants

ALTERNATIVE 2
BASE MODEL
PACHECO POND LEVEE
STATION PP 33+22

January 2020 | Project #1802696 | Figure A-29

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt2.dwg

Novato Creek Levee Evaluation Project
Seepage and Slope Stability Analysis Results

Levee: **Pachecho Pond Levee**
Station: **PP 33+22**

Analysis Run: **Alternative 2 -Levee Reconstruction with Seepage Berm**

Analyzed by: E. Cerna Alvarez
Date: 12/12/2019

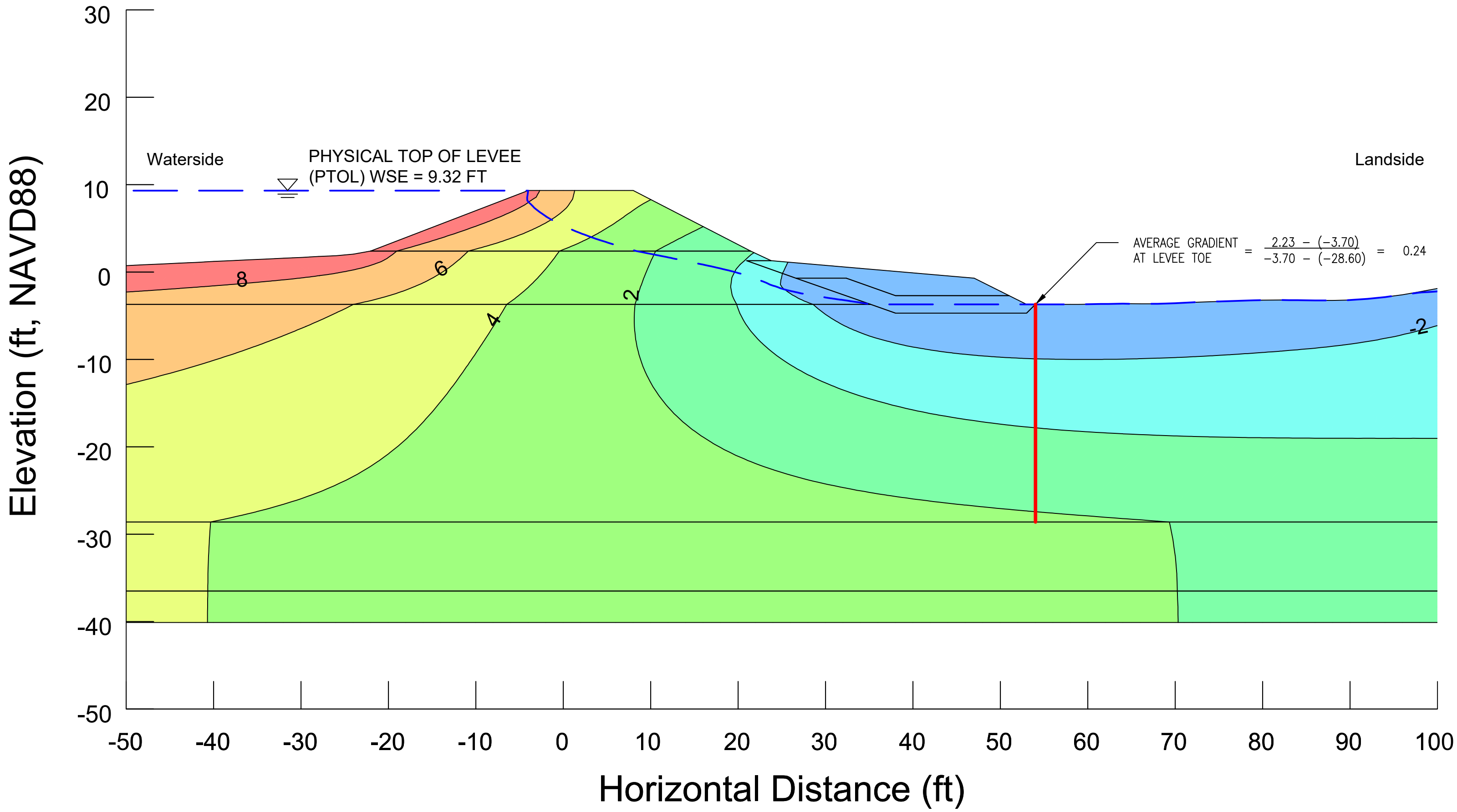
Gradient is calculated at: Landside Berm Toe (landside toe, low point at x ft from toe)

Water Surface: Physical Top of Levee

Water Surface Elevation 9.3 feet

Exit Gradient (i) Calculation	x-Coordinate	y-Coordinate	Total Head	i
Landside Berm Toe	54.00 feet	-3.70 feet	-3.70 feet	**0.24**
Bottom of Blanket	54.00 feet	-28.60 feet	2.23 feet	

Seepage Breakout above Toe, ft	N/A	ft
Steady State Landside Slope Stability, FS	1.4	(circular)
Rapid Draw Down Slope Stability, FS	1.7	(circular)

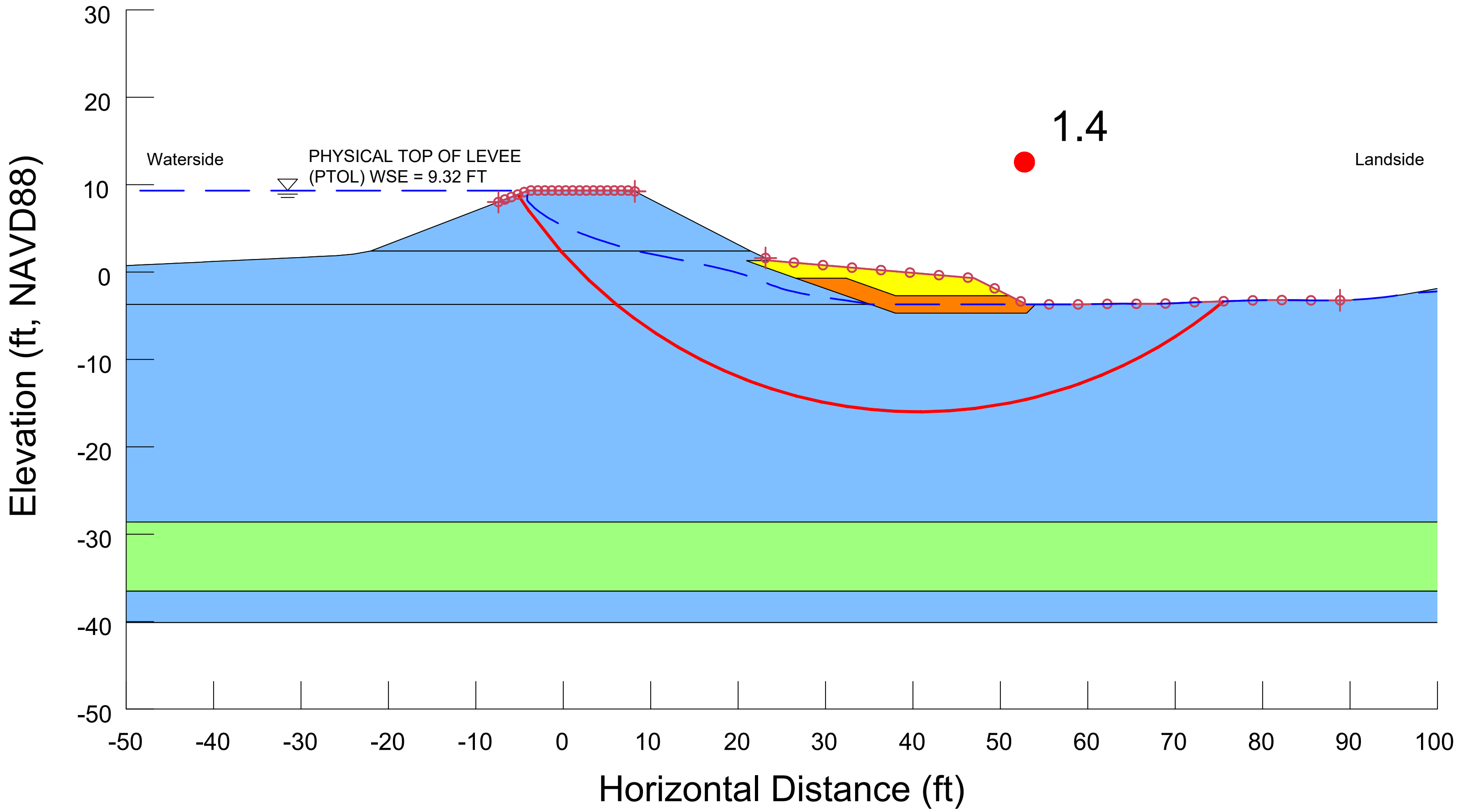


Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **PTOL WSE - SEEPAGE RESULTS** PACHECO POND LEVEE STATION PP 33+22		
Marin County Flood Control and Water Conservation District		January 2020	Project #1802696	Figure A-30

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt2.dwg

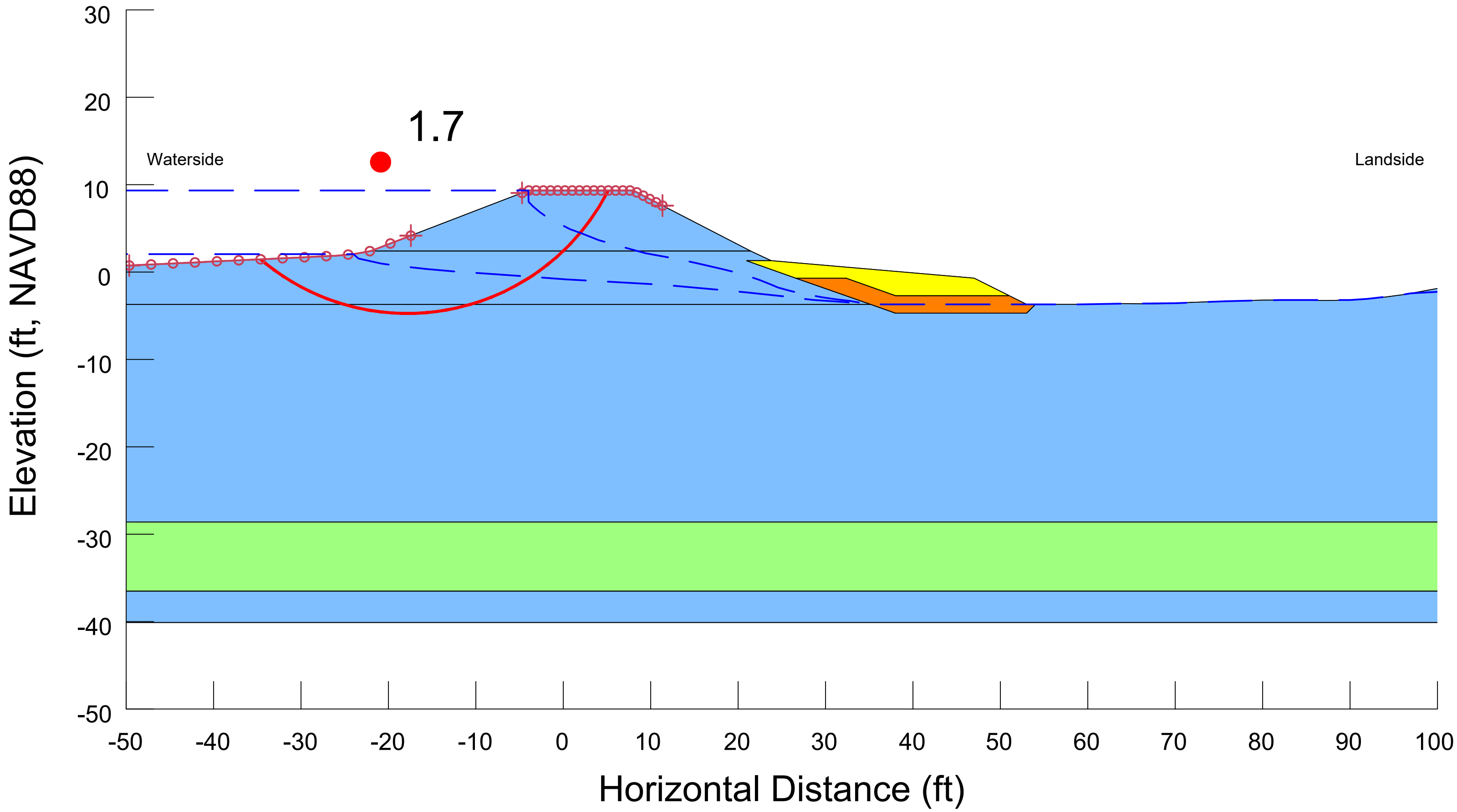


Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **PTOL WSE - STABILITY RESULTS** PACHECO POND LEVEE STATION PP 33+22
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-31

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt2.dwg



Notes:

1. Model extends 1,775 feet to the landside and 500 feet to the waterside of the alignment.

Novato Creek Levee Evaluation Project Novato, CA	GEI Consultants	**ALTERNATIVE 2** **PTOL WSE - RAPID DRAWDOWN RESULTS** PACHECO POND LEVEE STATION PP 33+22
Marin County Flood Control and Water Conservation District		January 2020 Project #1802696 Figure A-32

DRAWING: J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 4 - Remedial Alternatives\CADD\PP_33+22_Alt2.dwg

Appendix B
Remedial Alternative Conceptual Cost Estimates

Appendix B: Remedial Alternative Conceptual Cost Estimates

This appendix presents the results of the conceptual costs estimated for each of the remedial alternatives considered for Reaches along Novato Creek Left Bank, Lynwood Levee, and Pacheco Pond. The cost estimates are summarized in Table B-1 for each reach and for each alternative. The remedial alternatives analyzed included:

- Novato Creek Left Bank
  - Alternative 1: Drained crown raise and levee widening
  - Alternative 2: Levee reconstruction and widening
- Lynwood
  - Alternative 1: Drained Seepage berm and crown raise
  - Alternative 2: Shallow cutoff wall
- Pacheco Pond
  - Alternative 1: Drained Combination berm and riprap placement
  - Alternative 2: Partial levee reconstruction and drained seepage berm

The conceptual costs are presented and discussed by reach in this appendix.

Table B-1. Summary of Remedial Alternatives Cost Estimates

Construction Activity	Novato Creek Alt. 1	Novato Creek Alt. 2	Lynwood Levee Alt. 1	Lynwood Levee Alt. 2	Pacheco Pond Alt. 1	Pacheco Pond Alt. 2
Stability Berm	*$7,430,000*	*$0*	*$0*	*$0*	*$0*	*$0*
Seepage Berm	*$0*	*$0*	*$7,961,000*	*$0*	*$0*	*$943,000*
Combination Berm	*$0*	*$0*	*$0*	*$0*	*$3,244,000*	*$0*
Cutoff Wall	*$0*	*$0*	*$0*	*$4,813,000*	*$0*	*$0*
Geometry Repair	*$1,021,000*	*$8,781,000*	*$587,000*	*$469,000*	*$0*	*$2,195,000*
Rock Slope Protection	*$0*	*$0*	*$1,645,000*	*$0*	*$2,987,000*	*$1,992,000*
Permanent Right-of-Way- Wetlands	*$14,516,000*	*$18,489,000*	*$14,530,000*	*$644,000*	*$5,722,000*	*$2,907,000*
Total Project Baseline Cost =	**$22,967,000**	**$27,270,000**	**$24,723,000**	**$5,926,000**	**$11,953,000**	**$8,038,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)	**$19,522,000 to $34,451,000**	**$23,180,000 to $40,905,000**	**$21,015,000 to $37,085,000**	**$5,037,000 to $8,889,000**	**$10,160,000 to $18,737,000**	**$6,832,000 to $12,057,000**

Novato Creek Left Bank

Novato Creek left bank extends from station 225+36 to 310+00 for a total length of 8,464 feet. Typical remedial cross sections for Alternative 1 and Alternative 2 are included in Figure B-1 and B-2. The proposed remedial alternatives include:

- Alternative 1: Alternative 1 is remediated with a drained stability berm and a raised crown. The stability berm is 17 ft wide, the height of the levee, has a landside slope of 2H:1V and a 2-foot -thick drainage layer at the base of the berm and on the levee slope. The entire levee is raised by an average of 2 feet including the existing crown and the widened drained stability berm. A cost summary is provided in Table B-2.

- Alternative 2: Alternative 2 is remediated with a degrade of the existing levee, and reconstruction of a widened levee. The existing levee would be degraded by 6 feet. The levee is then reconstructed to an average of 2 feet above the existing crown elevation and is widened to accommodate a 20’ crown width. A cost summary is provided in Table B-3.

Table B-2: Novato Creek Alternative 1

Construction Activity	Units	Quantity	Unit Cost	Cost
Stability Berm				
Clearing and Grubbing	AC	11.8	$6,467	$76,200
Stripping - Existing Levee and ground	AC	9.8	$7,039	$69,300
Drain Layers	CY	30,600	$77.61	$2,375,000
Berm Fill	CY	74,500	$22.02	$1,640,000
Hydroseeding	AC	11.6	$4,693	$54,300
Geometry Repair				
Select Levee Fill	CY	20,800	$22.02	$458,000
Aggregate Base Levee Crown	CY	3,135	$38.53	$121,000
Major Construction Items Subtotal =				**$4,794,000**
Other Construction Costs**				
Unallocated Items in Construction Costs	20%			$959,000
Mobilization and Demobilization	5%			$240,000
Construction Total =				**$5,993,000**
Other Owner Costs***				
Environmental Documentation and Permitting	7%			$420,000
Design and Engineering Costs	15%			$899,000
Legal Costs	2%			$120,000
Engineering during Construction	2%			$120,000
Construction Management	15%			$899,000
Other Owner Costs Subtotal =				**$2,458,000**
Permanent Right-of-Way (fee Title)- Wetlands	AC	7.4	$1,966,000	**$14,516,000**
Total Project Baseline Cost =				**$22,967,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)			**$19,522,000**	**to $34,451,000**

*Other Construction Costs are a percentage of the Major Construction Items Subtotal.

** Other Owner Costs are a percentage of the Construction Total.

Numbers may not add up exactly due to rounding errors

Table B-3: Novato Creek Alternative 2

Construction Activity	Units	Quantity	Unit Cost	Cost
Geometry Repair				
Levee Degrade	CY	55,700	$5.87	$327,000
Levee Degrade Spoil Disposal	CY	55,700	$18.14	$1,010,000
Clearing and Grubbing	AC	8.4	$6,467	$54,000
Stripping - Existing Levee and ground	AC	8.4	$7,039	$59,000
Select Levee Fill	CY	153,300	$22.02	$3,376,000
Hydroseeding	AC	7.4	$4,693	$35,000
Aggregate Base Levee Crown	CY	3,135	$38.53	$121,000
Major Construction Items Subtotal =				**$4,982,000**
Other Construction Costs**				
Unallocated Items in Construction Costs	20%			$996,000
Mobilization and Demobilization	5%			$249,000
Construction Total =				**$6,227,000**
Other Owner Costs***				
Environmental Documentation and Permitting	7%			$436,000
Design and Engineering Costs	15%			$934,000
Legal Costs	2%			$125,000
Engineering during Construction	2%			$125,000
Construction Management	15%			$934,000
Other Owner Costs Subtotal =				**$2,554,000**
Permanent Right-of-Way (fee Title)- Wetlands	AC	9.4	$1,966,000	$18,489,000
Total Project Baseline Cost =				**$27,270,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)			**$23,180,000**	**to $40,905,000**

*Other Construction Costs are a percentage of the Major Construction Items Subtotal.

** Other Owner Costs are a percentage of the Construction Total.

Numbers may not add up exactly due to rounding errors

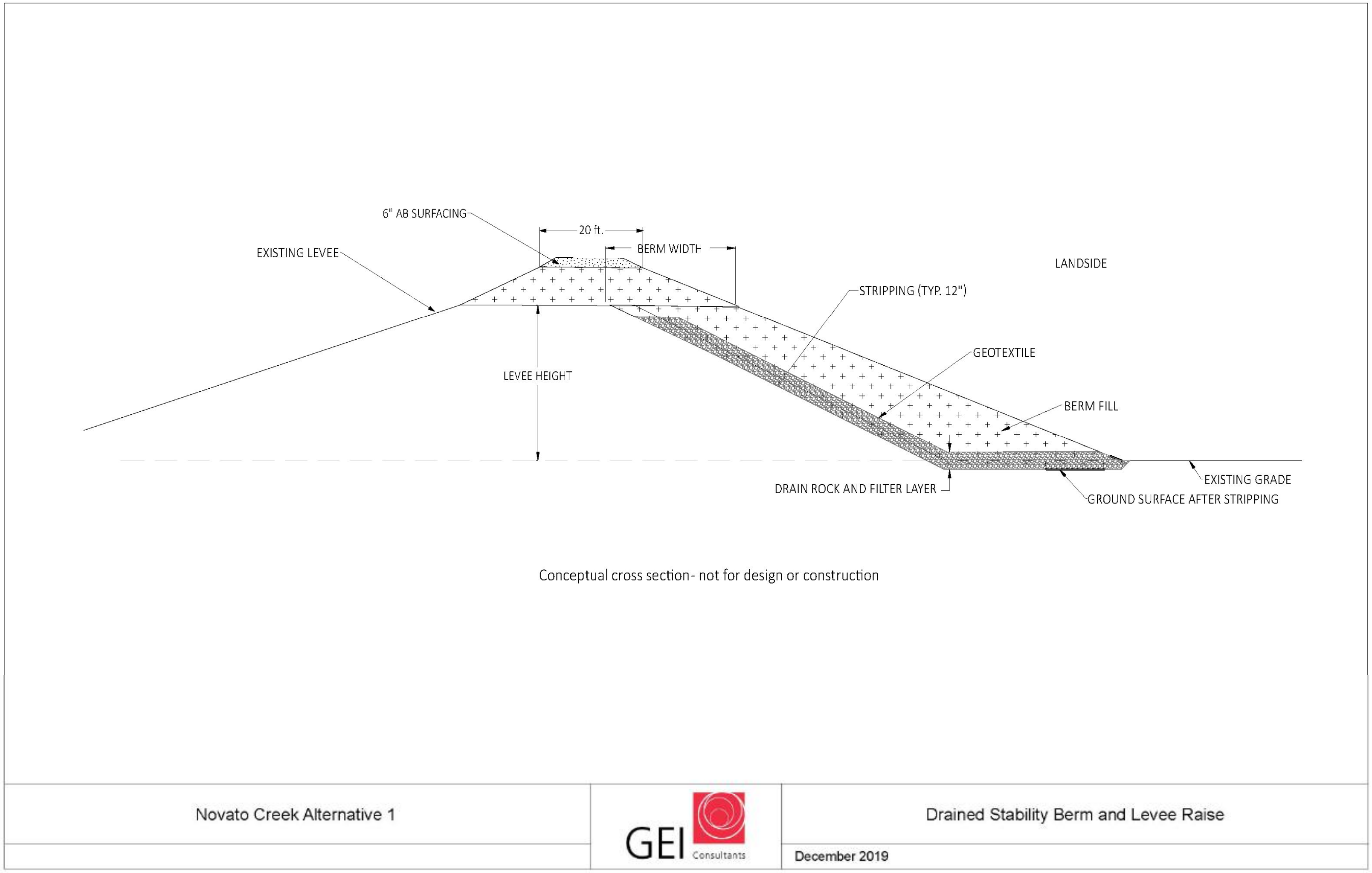
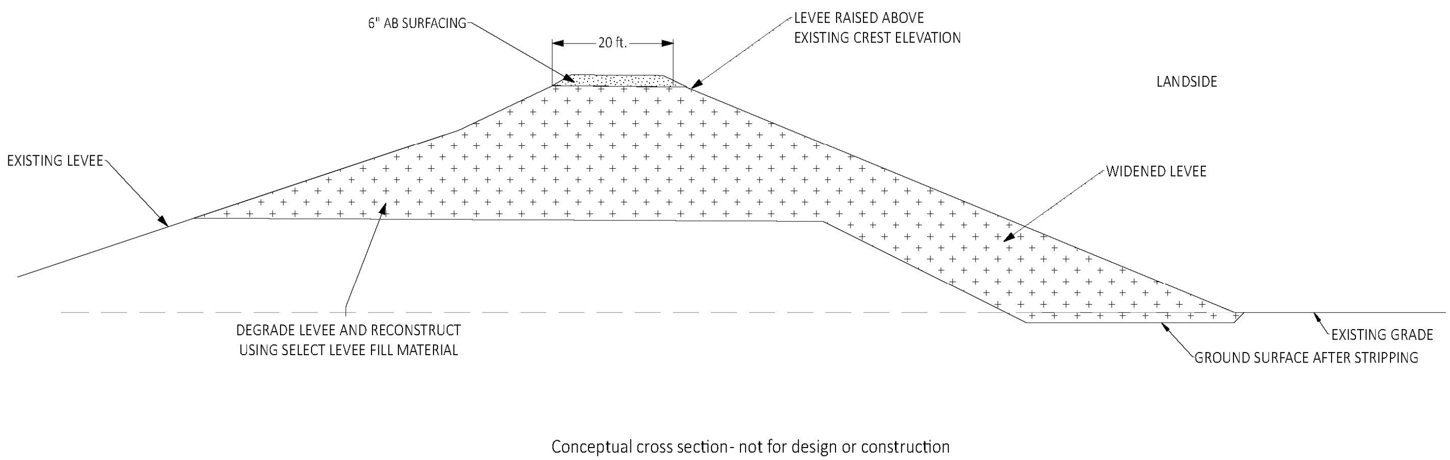


Figure B-1: Novato Creek Alternative 1



Novato Creek Alternative 2	GEI Consultants	Levee Reconstruction, Raising and Widening
		December 2019

Figure B-2: Novato Creek Alternative 2

Lynwood Levee

Lynwood Levee extends from station 242+16 to 310+00 for a total length of 6,784 feet. Typical remedial cross sections for Alternative 1 and Alternative 2 are included in Figure B-3 and B-4. The proposed remedial alternatives include:

- Alternative 1: Alternative 1 is remediated with a drained seepage berm and a raised crown. The seepage berm is 55 feet wide, varies from 6 feet tall at the existing levee toe to 4 feet tall at the berm landside hinge, and has a 2-foot -thick drainage layer at the base of the berm and on the levee slope. From Station 310+00 to Station 307+50, the existing levee crown is raised by an average of approximately 1-foot. From Station 298+00 to Station 260+00, the existing levee crown is raised by an average of approximately 1-foot. From Station 260+00 to Station 242+16, the existing levee crown is raised by an average of approximately 3 feet. The raise from 260+00 to 242+16 also requires levee widening by 8 feet to accommodate the levee raise. A 2-foot thick rock slope protection is also included along the waterside of the existing levee to protect the erodible embankment material. The rock slope protection is approximately 30 feet wide. A cost summary is provided in Table B-4.

- Alternative 2: Alternative 2 is remediated with a degrade of the existing levee, a shallow SCB cutoff wall and reconstruction of a widened levee. In order to provide an adequate working surface for the construction equipment the existing levee needs to be degraded by 5 feet. A SCB cutoff wall is then constructed at the degraded levee elevation to a depth of 16 feet. From Station 310+00 to Station 307+50 the levee is then reconstructed to an average of approximately 1-foot above the existing crown elevation. From Station 298+00 to Station 260+00, the levee is then reconstructed to an average of approximately 1-foot above the existing crown elevation. From Station 260+00 to Station 242+16, the levee is then reconstructed to an average of approximately 3 feet above the existing crown elevation. The raise from 260+00 to 242+16 also requires levee widening by 8 feet to accommodate the levee raise. A cost summary is provided in Table B-.

Table B-4: Lynwood Levee Alternative 1

Construction Activity	Units	Quantity	Unit Cost	Cost
Seepage Berm				
Clearing and Grubbing	AC	7.8	$6,467	$50,200
Stripping - Existing Levee and ground	AC	7.8	$7,039	$54,600
Drain Layers	CY	31,286	$77.61	$2,428,000
Berm Fill	CY	44,242	$22.02	$974,000
Hydroseeding	AC	7.7	$4,693	$36,400
Geometry Repair				
Stripping - Existing Levee and ground	AC	5.0	$7,039	$35,000
Select Levee Fill	CY	21,600	$22.02	$476,000
Hydroseeding	AC	1	$4,693	$6,000
Aggregate Base Levee Crown	CY	1,827	$38.53	$70,000
Rock Slope Protection				
Riprap	CY	10,964	$150.00	$1,645,000
Major Construction Items Subtotal =				**$5,781,000**
Other Construction Costs**				
Unallocated Items in Construction Costs	20%			$1,157,000
Mobilization and Demobilization	5%			$289,000
Construction Total =				**$7,227,000**
Other Owner Costs***				
Environmental Documentation and Permitting	7%			$506,000
Design and Engineering Costs	15%			$1,085,000
Legal Costs	2%			$145,000
Engineering during Construction	2%			$145,000
Construction Management	15%			$1,085,000
Other Owner Costs Subtotal =				**$2,966,000**
Permanent Right-of-Way (fee Title)- Wetlands	AC	7.4	$1,966,000	$14,530,000
Total Project Baseline Cost =				**$24,723,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)			**$21,015,000**	**to $37,085,000**

*Other Construction Costs are a percentage of the Major Construction Items Subtotal.

** Other Owner Costs are a percentage of the Construction Total.

Numbers may not add up exactly due to rounding errors

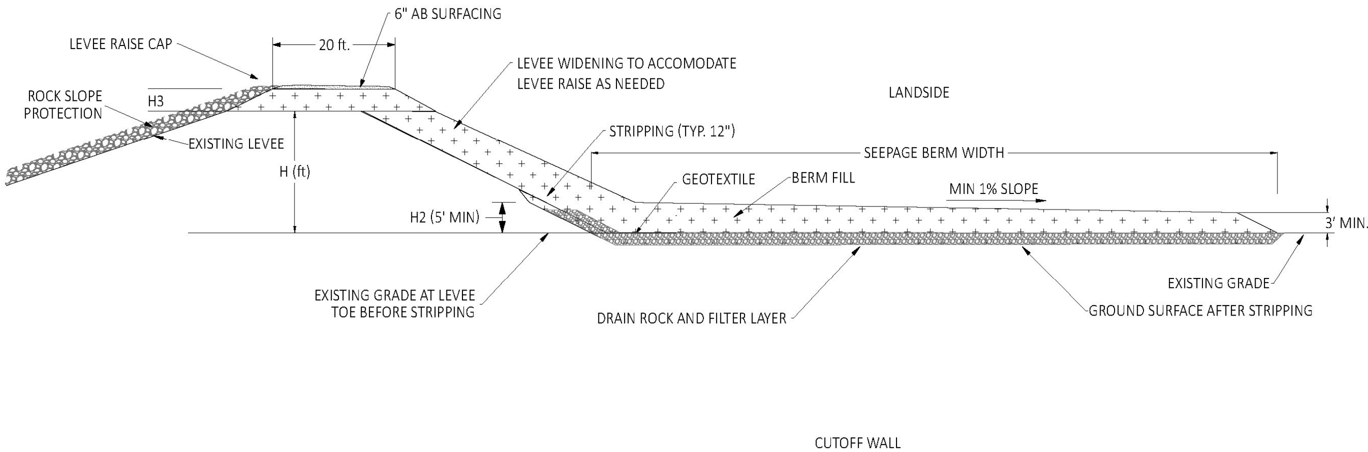
Table B-5: Lynwood Levee Alternative 2

Construction Activity	Units	Quantity	Unit Cost	Cost
Cutoff Wall				
Levee Degrade	CY	39,300	$5.87	$231,000
Levee Degrade Spoil Disposal	CY	39,300	$18	$713,000
Cutoff Wall	SQFT	78,900	$8.14	$643,000
Levee Rebuild	CY	45,200	$22.02	$995,000
Aggregate Base Levee Crown	CY	1,800	$77.07	$139,000
Hydroseeding	AC	2.2	$4,693	$10,000
Geometry Repair				
Stripping - Existing Levee and ground	AC	1.2	$7,039	$9,000
Select Levee Fill	CY	11,300	$22.02	$249,000
Hydroseeding	AC	0.4	$4,693	$2,000
Major Construction Items Subtotal =				**$2,997,000**
Other Construction Costs**				
Unallocated Items in Construction Costs	20%			$599,000
Mobilization and Demobilization	5%			$150,000
Construction Total =				**$3,746,000**
Other Owner Costs***				
Environmental Documentation and Permitting	7%			$262,000
Design and Engineering Costs	15%			$562,000
Legal Costs	2%			$75,000
Engineering during Construction	2%			$75,000
Construction Management	15%			$562,000
Other Owner Costs Subtotal =				**$1,536,000**
Permanent Right-of-Way (fee Title)- Wetlands	AC	0.3	$1,966,000	$644,000
Total Project Baseline Cost =				**$5,926,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)			**$5,037,000**	**to $8,889,000**

*Other Construction Costs are a percentage of the Major Construction Items Subtotal.

** Other Owner Costs are a percentage of the Construction Total.

Numbers may not add up exactly due to rounding errors



Conceptual cross section- not for design or construction

Lynwood Levee Alternative 1	GEI Consultants	Seepage Berm and Freeboard Raise
		December 2019

Figure B-3: Lynwood Levee Alternative 1

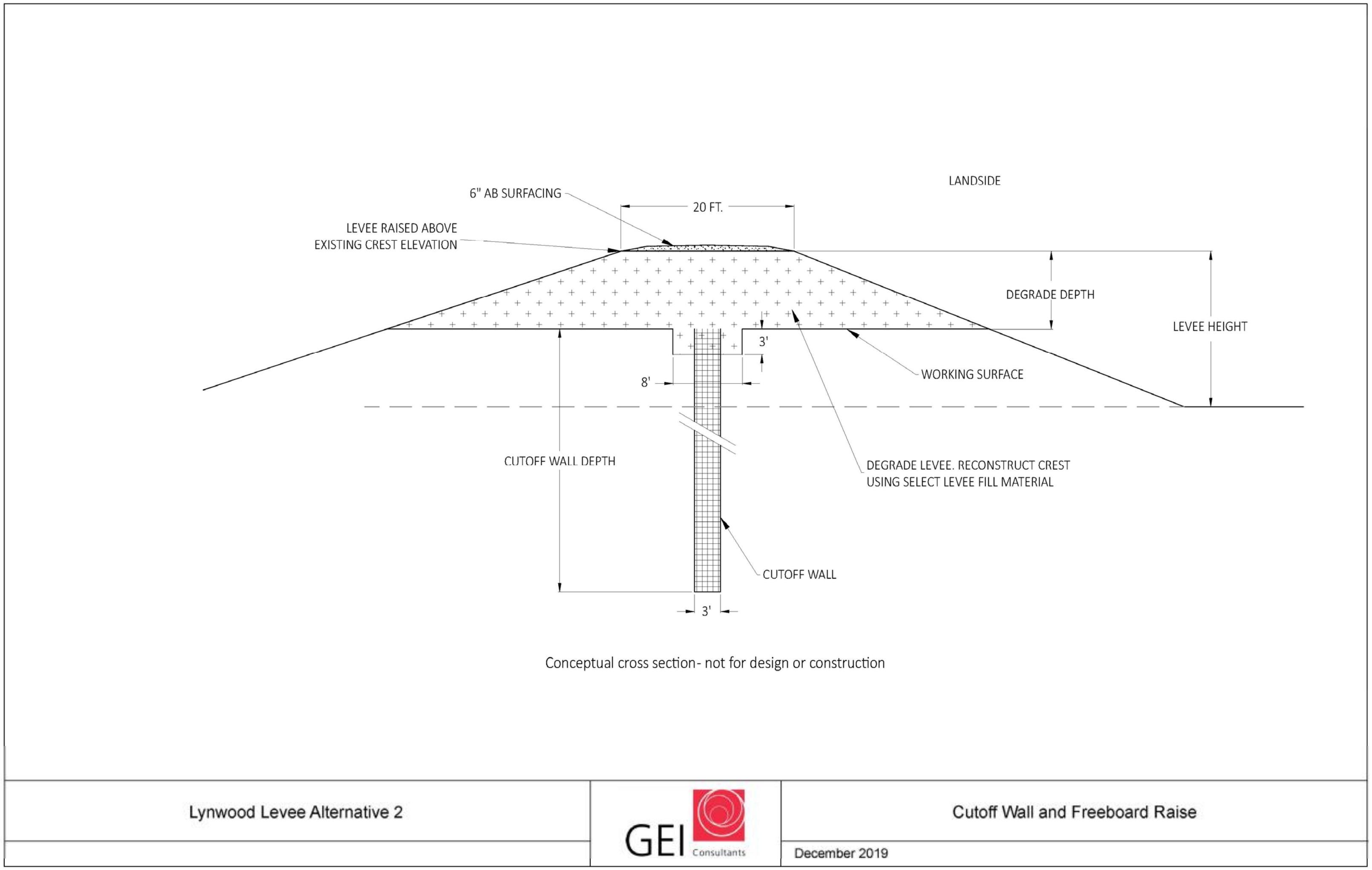


Figure B-4: Lynnwood Levee Alternative 2

Pacheco Pond Levee

Pacheco Pond Levee extends from station 10+00 to 43+90 for a total length of 3,390 feet. Typical remedial cross sections for Alternative 1 and Alternative 2 are included in Figure B-5 and B-6. The proposed remedial alternatives include:

- Alternative 1: Alternative 1 is remediated with a drained combination berm. The stability berm portion is 18 feet wide, and has a height equal to the existing levee. The seepage berm portion is 30 feet wide, varies from 7 feet at the stability berm to 4 feet at the berm hinge. The combination berm has a 2-foot thick drainage layer at the base of the berm and on the levee slope. A 2-foot thick rock slope protection is also included on the landside levee and berm to prevent erosion when overtopping. The rock slope protection is approximately 45 feet wide. A cost summary is provided in Table B-6.

- Alternative 2: Alternative 2 is remediated with a degrade of the existing levee reconstruction of the existing levee prism, and construction of a narrow seepage berm. In order to remove the erodible material present the existing levee embankment needs to be degraded by 7 feet. The levee is then reconstructed to the existing crown elevation. The seepage berm is 10 feet wide, varies from 5 feet at the existing levee to 4 feet at the berm hinge. The seepage berm includes a 2-foot thick drainage layer. A 2-foot thick rock slope protection is also included on the landside levee and berm to prevent erosion when overtopping. The rock slope protection is approximately 30 feet wide. A cost summary is provided in Table B-7.

Table B-6: Pacheco Pond Levee Alternative 1

Construction Activity	Units	Quantity	Unit Cost	Cost
Combination Berm				
Clearing and Grubbing	AC	5.6	$6,467	$35,900
Stripping - Existing Levee	AC	2.2	$7,039	$15,800
Stripping - Ground	CY	11,300	$6	$63,000
Drain Layers	CY	14,800	$77.61	$1,149,000
Berm Fill	CY	38,900	$22.02	$857,000
Hydroseeding	AC	5.5	$4,693	$25,600
Rock Slope Protection				
Riprap	CY	11,300	$150.00	$1,695,000
Major Construction Items Subtotal =				**$3,841,000**
Other Construction Costs**				
Unallocated Items in Construction Costs	20%			$768,000
Mobilization and Demobilization	5%			$192,000
Construction Total =				**$4,801,000**
Other Owner Costs***				
Environmental Documentation and Permitting	7%			$336,000
Design and Engineering Costs	15%			$720,000
Legal Costs	2%			$96,000
Engineering during Construction	2%			$96,000
Construction Management	15%			$720,000
Other Owner Costs Subtotal =				**$1,968,000**
Permanent Right-of-Way (fee Title)- Wetlands	AC	2.9	$1,966,000	$5,722,000
Total Project Baseline Cost =				**$12,491,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)			**$10,617,000**	**to $18,737,000**

*Other Construction Costs are a percentage of the Major Construction Items Subtotal.

** Other Owner Costs are a percentage of the Construction Total.

Numbers may not add up exactly due to rounding errors

Table B-7: Pacheco Pond Levee Alternative 2

Construction Activity	Units	Quantity	Unit Cost	Cost
Seepage Berm				
Clearing and Grubbing	AC	1.6	$6,467	$10,600
Stripping - Existing Levee and ground	AC	1.6	$7,039	$11,500
Drain Layers	CY	5,294	$77.61	$411,000
Berm Fill	CY	4,269	$22.02	$94,000
Hydroseeding	AC	1.6	$4,693	$7,700
Geometry Repair				
Levee Degrade	CY	26,600	$5.87	$156,000
Levee Degrade Spoil Disposal	CY	26,600	$18.14	$483,000
Levee Rebuild	CY	24,400	$22.02	$537,000
Aggregate Base Levee Crown	CY	800	$77.07	$62,000
Hydroseeding	AC	1.5	$4,693	$7,000
Rock Slope Protection				
Riprap	CY	7,533	$150.00	$1,130,000
Major Construction Items Subtotal =				**$2,910,000**
Other Construction Costs**				
Unallocated Items in Construction Costs	20%			$582,000
Mobilization and Demobilization	5%			$146,000
Construction Total =				**$3,638,000**
Other Owner Costs***				
Environmental Documentation and Permitting	7%			$255,000
Design and Engineering Costs	15%			$546,000
Legal Costs	2%			$73,000
Engineering during Construction	2%			$73,000
Construction Management	15%			$546,000
Other Owner Costs Subtotal =				**$1,493,000**
Permanent Right-of-Way (fee Title)- Wetlands	AC	1.5	$1,966,000	$2,907,000
Total Project Baseline Cost =				**$8,038,000**
Cost Estimate Range (AACE Class 4, -15% to +50%)			**$6,832,000**	**to $12,057,000**

*Other Construction Costs are a percentage of the Major Construction Items Subtotal.

** Other Owner Costs are a percentage of the Construction Total.

Numbers may not add up exactly due to rounding errors

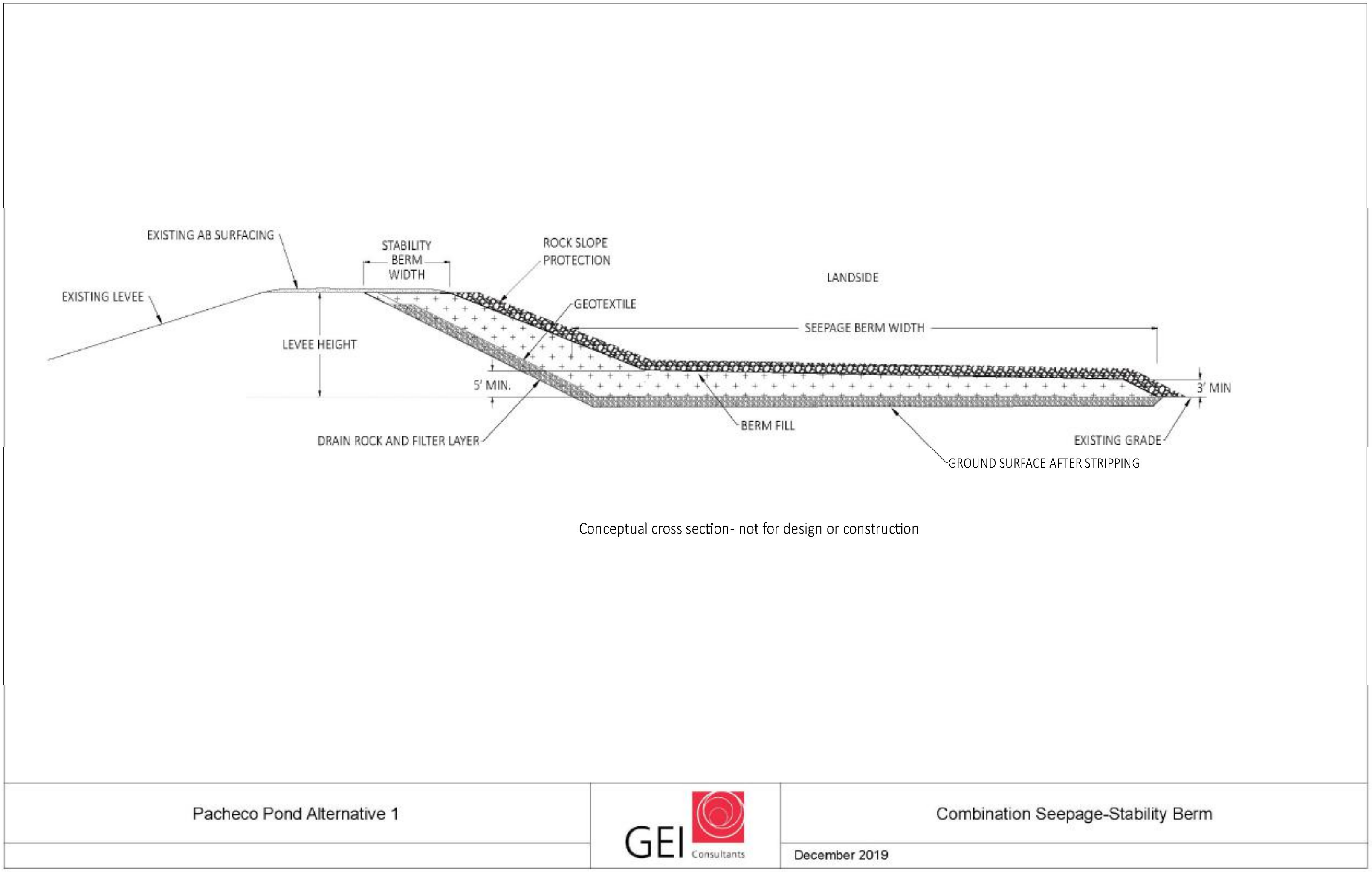


Figure B-5: Pacheco Pond Alternative 1

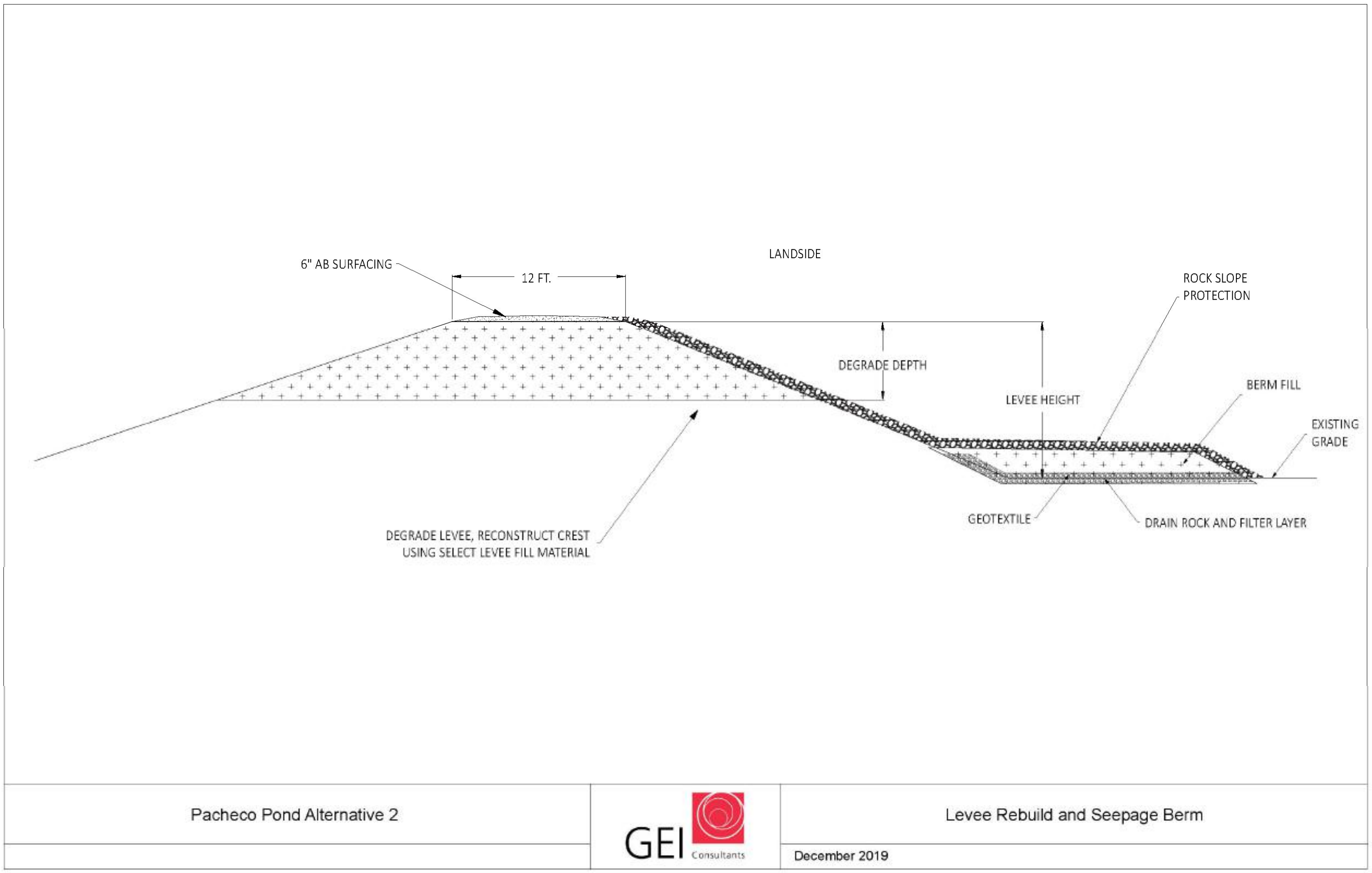


Figure B-6: Lynnwood Levee Alternative

Right-of-Way Identification

As was identified in the RAR, an easement is typically present along existing levees. For the purposes of this study it is assumed that purchasing the strip of land needed for new construction (base width of berms or widened levees) will leave the existing levee easement adjacent to the new construction. It is assumed that all the berms will require an additional 10 feet of right of way beyond the berm toe to allow construction equipment adequate construction surfaces. All acquisitions are assumed to be permanent.

The base construction costs include right-of-way acquisition for each remedial measure alternative. Site-specific conditions will need to be assessed and individual conditions evaluated before any design decisions are finalized. The approximate real estate acquisition requirements are included below. A plan view of the approximate real estate footprint is included for the largest right-of-way acquisition alternative for each location in figures B-7 and B-8.

- Novato Creek Left Bank Alternative 1: 17 ft wide stability berm, with an additional 10 ft beyond the berm toe for construction access, for a total of 27 ft from the existing levee toe.

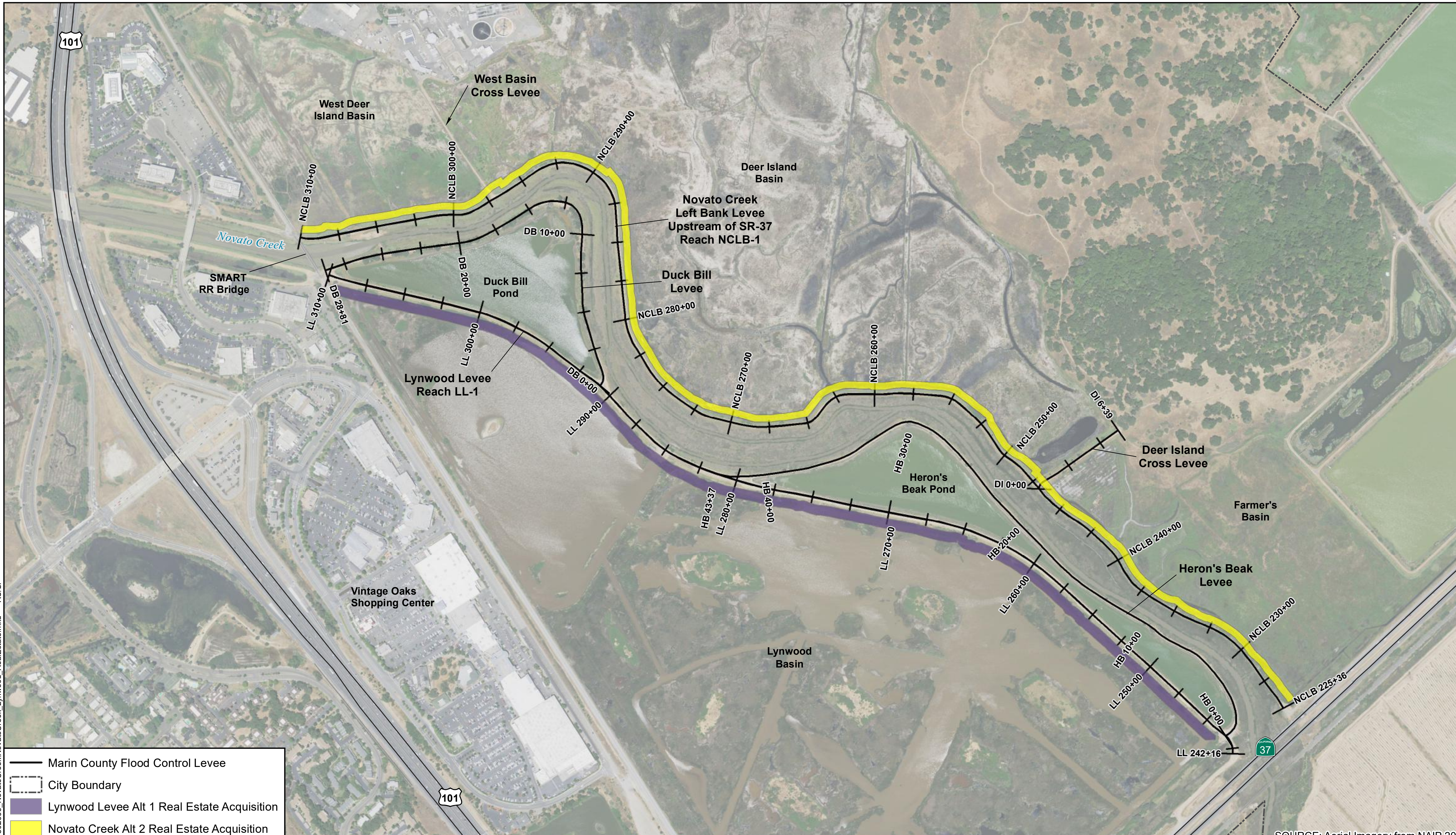
- Novato Creek Left Bank Alternate 2: 38 ft wider levee to accommodate levee rebuild and slope flattening, with an additional 10 ft beyond the berm toe for construction access, for a total of 48 ft from the existing levee toe.

- Lynwood Levee Alternative 1: 55 ft wide seepage berm, with an additional 10 ft beyond the berm toe for construction access, for a total of 65 ft from the existing levee toe.

- Lynwood Levee Alternative 2: Only the portion of levee from 260+00 to 242+16 requires levee widening by 8 feet to accommodate the levee raise with an additional 10 ft beyond the berm toe for construction access, for a total of 18 ft from the existing levee toe.

- Pacheco Pond Levee Alternative 1: 30 ft wide combo berm, with an additional 10 ft beyond the berm toe for construction access, for a total of 40 ft from the existing levee toe.

- Pacheco Pond Levee Alternative 2: 10 ft wide seepage berm, with an additional 10 ft beyond the berm toe for construction access, for a total of 20 ft from the existing levee toe.



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Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control
and Water Conservation District

GEI Consultants

REAL ESTATE REQUIREMENTS
NOVATO CREEK AND LYNWOOD BASIN LEVEES

JANUARY 2020

FIGURE B-7

0 250 500 1,000
Feet

Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control
and Water Conservation District

GEI Consultants

REAL ESTATE REQUIREMENTS
PACHECO POND LEVEE

JANUARY 2020

FIGURE B-8

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