APPENDIX F
STATIC SLOPE STABILITY ANALYSIS

SLOPE STABILITY ANALYSIS

In this appendix we provide an explanation of methods and soil parameters used in our analysis of stability of the subject levee as well as computer model printouts of our stability analysis results. An explanation of analysis cross-sections and our results are included in the main report text.

Analysis Methods

Slope stability analyses were performed using SLOPE/W Version 7.12, developed by GEO-SLOPE International, Ltd. (2007). This program was used to perform automatic searches of different potential failure surfaces and to compute the lowest factor of safety (FOS) corresponding to a critical failure surface for a particular analysis condition to evaluate the global stability of landside and waterside slopes.

Slope stability analyses were performed to evaluate the global stability of the subject levee embankments. Design parameters input into the slope stability model include the embankment geometry and the approximate unit weight and shear strength properties of the native and engineered fill soils.

Failure surfaces defined by circular arcs were analyzed using Spencer's method. Spencer's method is a two-dimensional limit-equilibrium method that satisfies force equilibrium of slices and overall moment equilibrium of the potential sliding mass. The inclination of side forces between vertical slices is assumed to be the same for all slices and is calculated along with the FOS. This method uses the levee slope configuration, unit weight and shear strength properties of levee and foundation materials, and boundary and internal distribution of forces due to water pressures. After a potential failure surface has been assumed, the soil mass located above the failure surface is divided into a series of vertical slices. Forces acting on each slice include the slice weight, the pore pressure, the effective normal force on the base, the mobilized shear force (including both cohesion and friction), and the horizontal side forces due to earth pressures. Searches for critical failure surfaces were performed by specifying entry and exit ranges. The entry range defines where the failure surface initiates and the exit range defines where the failure surface ends.

The FOS is calculated by determining the ratio of the resisting force (cohesion and friction along the failure surface) to the driving forces about the center of the assumed failure surface. The computer program was used to perform automatic searches of different potential failure surfaces and to compute the lowest FOS corresponding to a critical failure surface for a particular analysis condition.

For the steady-state seepage conditions the piezometric surface was imported from the SEEP/W seepage analysis. For rapid drawdown analyses, the water level was assumed to drop quickly from the 100-year WSE to an assumed typical normal water level of +2.0 ft NAVD88.

Analysis Cases

Two slope stability conditions were analyzed:

Case II: Rapid Drawdown. This case represents the condition where the flood stage (100-year flood) fully saturates a majority of the levee embankment then falls faster before the soil can adequately drain.

Case III: Steady-State Seepage for 100-Year WSE. This condition occurs when the water remains at or near flood stage levels (100-year flood) thus fully saturating the embankment soils. A steady-state seepage condition then occurs.

LABORATORY TEST RESULTS

Laboratory test results are summarized in Appendix C of this report. Laboratory tests included sieve analysis, Atterberg Limits, unconfined compressive strength tests, organic contents and moisture contents. Additionally, field vane shear testing was performed at various depths during drilling operations. Test results along with normalized SPT blow counts and CPT results were used to develop strength parameters as described below.

STRENGTH SELECTION

As previously stated, drained and undrained strength parameters were developed using correlations from SPT $(N_1)_{60}$ blow counts, CPT results, field vane shear test results, and laboratory testing results. The selection of parameters for static slope stability at steady-state seepage conditions assumes the levee materials and foundation materials are in a drained state, or behave in a drained manner. The following correlations were used to develop the drained (effective stress) friction angles of the various materials:

Sands and Silts:

$$\phi' = \left(15.4 \cdot (N_1)_{60}\right)^{0.5} + 20° \text{ (Hatanakata \& Uchida, 1996, in FHWA NHI, 2002)}$$

$$\phi' = 17.6'' + 11.0 \cdot \log(q_{c1}) \text{ (Kulhawy and Mayne, 1990)}$$

Clays and Silts:

$$\phi' = \sin^{-1}\left(0.8 - 0.094 \cdot \ln\left(PI\right)\right) \text{ (Mitchell, 1976)}$$

Strengths were calculated using the normalized SPT blow counts and CPT tip resistance and were plotted by depth for each of the boring and CPT. Based on these calculated strengths, drained friction angles were determined for the sand and clay layers for each individual cross section.

For clays, the drained friction angle was capped at a maximum of 31 degrees. For the remaining soil types, the drained friction angle was capped at 35 degrees.

For rapid drawdown, two sets of parameters are required, both total stress (c, ϕ) and effective stress (c′, ϕ') strength parameters. Cohesionless soils can be assumed to behave in a drained manner and the effective strength parameters are used. These parameters can be estimated using the correlations given. The effective strength parameters for cohesive soils can also be estimated using the correlations above. For total strength parameters, triaxial consolidated undrained testing and experience with similar materials were used to estimate or determine the parameters.

The strength properties selected for the stability analyses including seismic evaluation are summarized in Table F-1.

Table F-1. Section C Strength Parameters Selection

Material No. In Slope/W Model	Soil Type	Unit Weight (pcf)	Drained Strength		Undrained Strength	
			C (psf)	ϕ (degree)	C (psf)	ϕ (degree
1	Fat Clay	115	200	24	300	22
2	Silt	115	100	27	200	25
3	Organic Silt/Fat Clay	100	100	24	100	22
4	Lean Clay	115	150	26	200	24
5	Sandy Silt	115	50	28	100	26
6	Sandy Lean Clay	115	100	26	150	24
7	Silty Sand	120	0	30	N/A	N/A

SLOPE STABILITY RESULTS

The results of the slope stability analyses showing the failure surfaces resulting from these analyses are presented in Table F-2, below.

Table F-2. Summary of Slope Stability Analyses

Reach	Section	Analysis Condition	Factor of Safety	
			Waterside Rapid Drawdown (Case II)	Landside Steady-State Seepage (Case III)
1	C	Existing condition	1.4	1.33
1	C	Assuming Slope Fails and Scarp Is Flattened		1.29
1	C	Assuming Slope Is Flattened To 2:1 After Initial Failure		1.48

LIST OF ATTACHMENTS

The following plates are attached as part of this appendix and include graphical presentations of the stability analyses:

Plate F-1	Section C, Steady-State Stability Analysis
Plate F-2	Section C, Steady-State Stability Analysis After Slope Failure And Head Scarp Flattened To 2:1
Plate F-3	Section C, Steady-State Stability Analysis After Slope Failure And Slope Flattened To 2:1 From Water Surface To Crown
Plate F-4	Section C, Sudden Drawdown Stability Analysis

Dad's Point Levee — Section C, Steady State Stability Analysis

File Name: Section C_Stability_Steady State_100yr Flood_Head Differential.gsz
Last Saved Date: 1/5/2010
Analysis Type: SLOPE/W
Analysis View: 2D

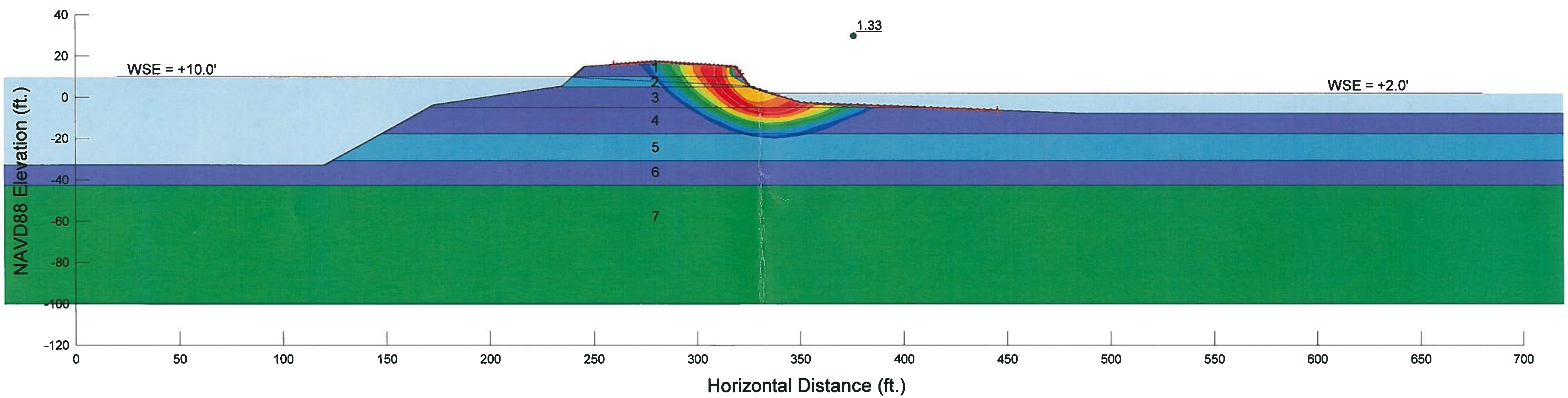
Material Number, Description, Unit Weight, Cohesion, Friction Angle

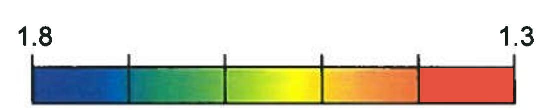
Material # 1: Fat Clay Unit Weight: 115 pcf; Cohesion: 200 psf; Friction Angle: 24 degrees
Material # 2: Silt Unit Weight: 115 pcf; Cohesion: 100 psf; Friction Angle: 27 degrees
Material # 3: Organic Silt/Fat Clay Unit Weight: 100 pcf; Cohesion: 200 psf; Friction Angle: 24 degrees
Material # 4: Lean Clay Unit Weight: 115 pcf; Cohesion: 150 psf; Friction Angle: 26 degrees
Material # 5: Sandy Silt Unit Weight: 115 pcf; Cohesion: 50 psf; Friction Angle: 28 degrees
Material # 6: Sandy Lean Clay Unit Weight: 115 pcf; Cohesion: 100 psf; Friction Angle: 26 degrees
Material # 7: Silty Sand Unit Weight: 120 pcf; Cohesion: 0 psf; Friction Angle: 30 degrees

Top of Levee Elevation: +17.4 Feet (NAVD88)
Landside Toe Elevation: -2.6 Feet (NAVD88)
Landside Elevation 150 Feet From Toe: -7.6 Feet (NAVD88)

Waterside Water Surface Elevation: +10.0 Feet (NAVD88)
*Note: The water elevation used on the waterside of the model was equal to the 100-yr flood elevation.

Landside Water Surface Elevation: +2.0 Feet (NAVD88)
*Note: The water elevation used on the landside of the model was assumed as a 8 foot head differential from the waterside.





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PROJECT NO.	92459.G02
DATE:	9.28.09
DRAWN BY:	S. Wiesner
CHECKED BY:	R. Heinzen

Dad's Point Levee
Steady State Stability Analysis

LEVEE EVALUATION
DAD'S POINT LEVEE CERTIFICATION
STOCKTON, CALIFORNIA

PLATE
F-1

Dad's Point Levee — Section C, Steady State Stability Analysis After Slope Failure And Head Scarp Flattened To 2:1

File Name: Section C_Stability_Steady State_100yr Flood_Flattened Slope.gsz
Last Saved Date: 1/8/2010
Analysis Type: SLOPE/W
Analysis View: 2D

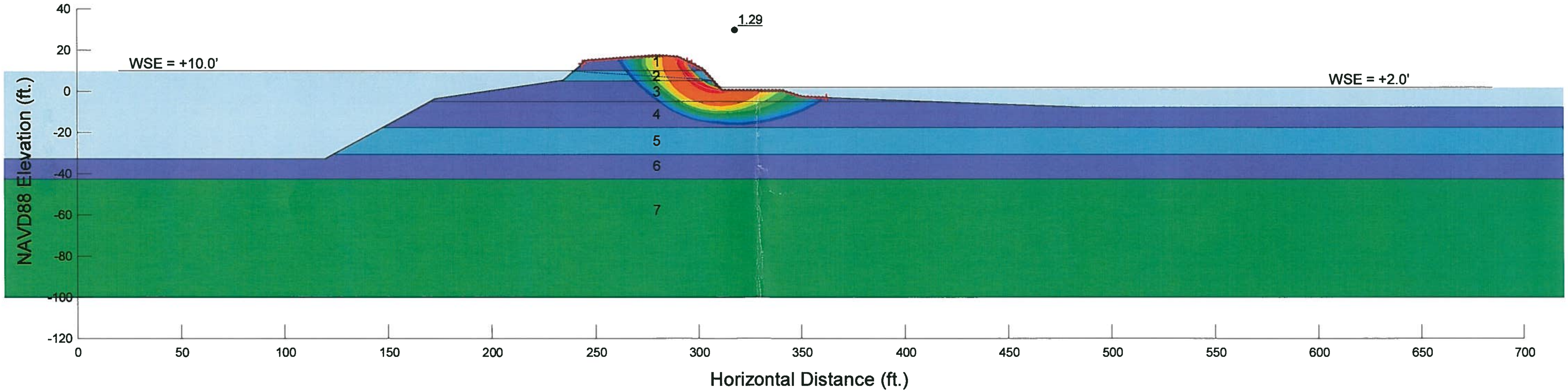
Material Number, Description, Unit Weight, Cohesion, Friction Angle

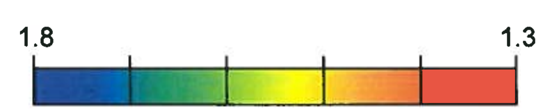
Material # 1: Fat Clay Unit Weight: 115 pcf; Cohesion: 200 psf; Friction Angle: 24 degrees
Material # 2: Silt Unit Weight: 115 pcf; Cohesion: 100 psf; Friction Angle: 27 degrees
Material # 3: Organic Silt/Fat Clay Unit Weight: 100 pcf; Cohesion: 200 psf; Friction Angle: 24 degrees
Material # 4: Lean Clay Unit Weight: 115 pcf; Cohesion: 150 psf; Friction Angle: 26 degrees
Material # 5: Sandy Silt Unit Weight: 115 pcf; Cohesion: 50 psf; Friction Angle: 28 degrees
Material # 6: Sandy Lean Clay Unit Weight: 115 pcf; Cohesion: 100 psf; Friction Angle: 26 degrees
Material # 7: Silty Sand Unit Weight: 120 pcf; Cohesion: 0 psf; Friction Angle: 30 degrees

Top of Levee Elevation: +17.4 Feet (NAVD88)
Landside Toe Elevation: -2.6 Feet (NAVD88)
Landside Elevation 150 Feet From Toe: -7.6 Feet (NAVD88)

Waterside Water Surface Elevation: +10.0 Feet (NAVD88)
*Note: The water elevation used on the waterside of the model was equal to the 100-yr flood elevation.

Landside Water Surface Elevation: +2.0 Feet (NAVD88)
*Note: The water elevation used on the landside of the model was assumed as a 8 foot head differential from the waterside.





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Dad's Point Levee
Steady State Stability Analysis

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PLATE
F-2

Dad's Point Levee — Section C, Steady State Stability Analysis After Slope Failure And Slope Flattened To 2:1 From Water Surface To Crown

File Name: Section C_Stability_Steady State_100yr Flood_Flattened Slope_1.gsz
Last Saved Date: 1/12/2010
Analysis Type: SLOPE/W
Analysis View: 2D

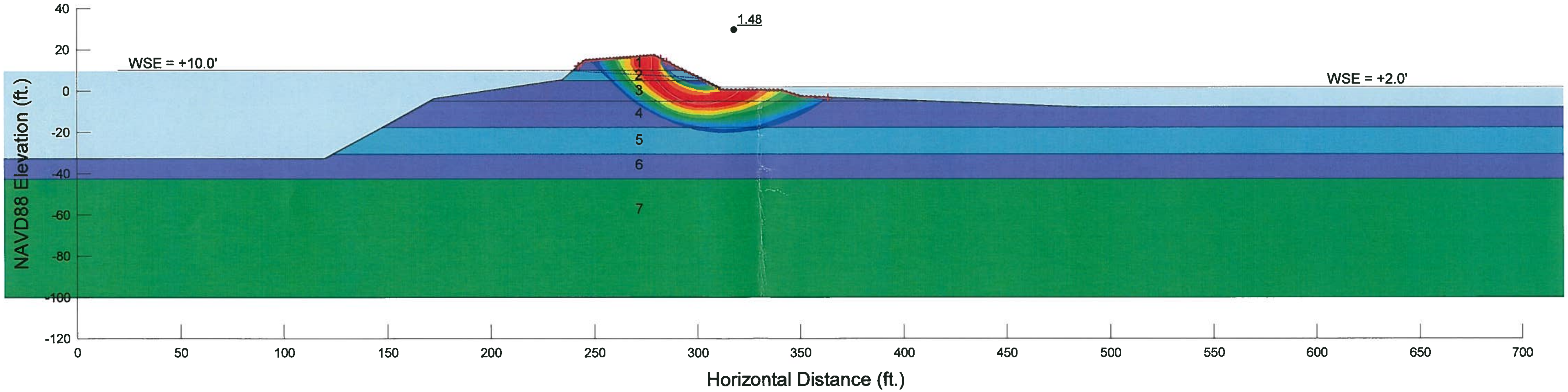
Material Number, Description, Unit Weight, Cohesion, Friction Angle

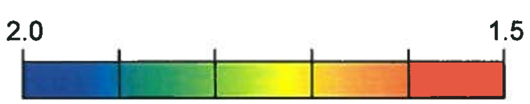
Material # 1: Fat Clay Unit Weight: 115 pcf; Cohesion: 200 psf; Friction Angle: 24 degrees
Material # 2: Silt Unit Weight: 115 pcf; Cohesion: 100 psf; Friction Angle: 27 degrees
Material # 3: Organic Silt/Fat Clay Unit Weight: 100 pcf; Cohesion: 200 psf; Friction Angle: 24 degrees
Material # 4: Lean Clay Unit Weight: 115 pcf; Cohesion: 150 psf; Friction Angle: 26 degrees
Material # 5: Sandy Silt Unit Weight: 115 pcf; Cohesion: 50 psf; Friction Angle: 28 degrees
Material # 6: Sandy Lean Clay Unit Weight: 115 pcf; Cohesion: 100 psf; Friction Angle: 26 degrees
Material # 7: Silty Sand Unit Weight: 120 pcf; Cohesion: 0 psf; Friction Angle: 30 degrees

Top of Levee Elevation: +17.4 Feet (NAVD88)
Landside Toe Elevation: -2.6 Feet (NAVD88)
Landside Elevation 150 Feet From Toe: -7.6 Feet (NAVD88)

Waterside Water Surface Elevation: +10.0 Feet (NAVD88)
*Note: The water elevation used on the waterside of the model was equal to the 100-yr flood elevation.

Landside Water Surface Elevation: +2.0 Feet (NAVD88)
*Note: The water elevation used on the landside of the model was assumed as a 8 foot head differential from the waterside.





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PROJECT NO.	92459.G02	**Dad's Point Levee** **Steady State Stability Analysis**	PLATE
DATE:	9.28.09		**F-3**
DRAWN BY:	S. Wiesner	LEVEE EVALUATION DAD'S POINT LEVEE CERTIFICATION STOCKTON, CALIFORNIA	
CHECKED BY:	R. Heinzen		

Dad's Point Levee — Section C, Sudden Drawdown Stability Analysis

File Name: Section C_Stability_Sudden Drawdown.gsz
Last Saved Date: 1/12/2010
Analysis Type: SLOPE/W
Analysis View: 2D

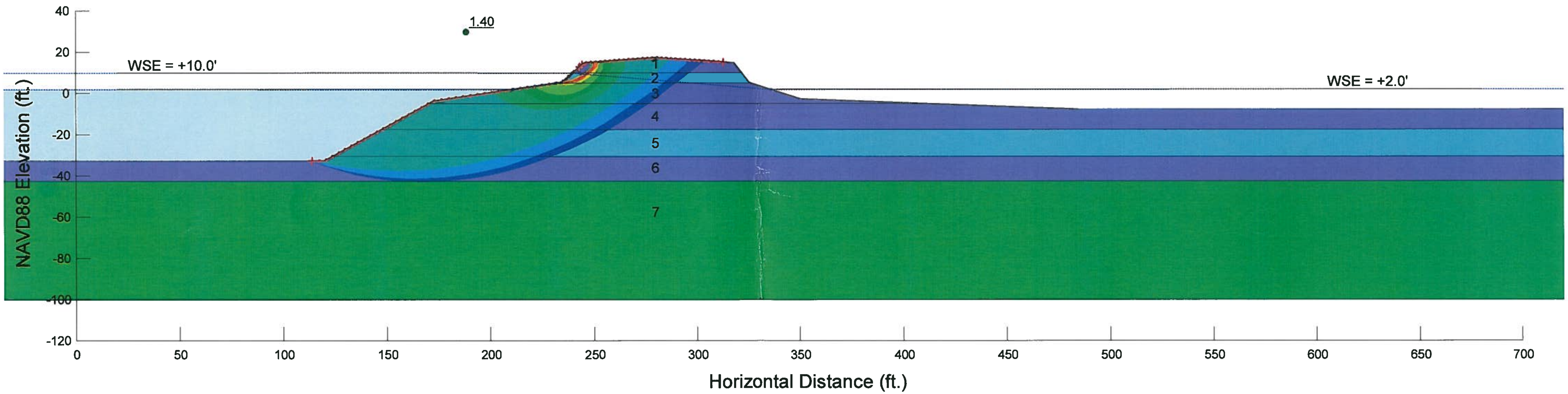
Material Number, Description, Unit Weight, Drained Cohesion, Drained Friction Angle, Undrained Cohesion, Undrained Friction Angle

Material # 1: Fat Clay - Unit Weight: 115 pcf, Drained C: 200 psf, Drained Phi: 24 °, Undrained C: 300 psf, Undrained Phi: 22 °
Material # 2: Silt - Unit Weight: 115 pcf, Drained C: 100 psf, Drained Phi: 27 °, Undrained C: 200 psf, Undrained Phi: 25 °
Material # 3: Organic Silt/Fat Clay - Unit Weight: 100 pcf, Drained C: 200 psf, Drained Phi: 24 °, Undrained C: 300 psf, Undrained Phi: 22 °
Material # 4: Lean Clay - Unit Weight: 115 pcf, Drained C: 150 psf, Drained Phi: 26 °, Undrained C: 200 psf, Undrained Phi: 24 °
Material # 5: Sandy Silt - Unit Weight: 115 pcf, Drained C: 50 psf, Drained Phi: 28 °, Undrained C: 100 psf, Undrained Phi: 26 °
Material # 6: Sandy Lean Clay - Unit Weight: 115 pcf, Drained C: 100 psf, Drained Phi: 26 °, Undrained C: 150 psf, Undrained Phi: 24 °
Material # 7: Silty Sand - Unit Weight: 120 pcf, Drained C: 0 psf, Drained Phi: 30 °, Undrained C: 0 psf, Undrained Phi: 30 °

Top of Levee Elevation: +17.4 Feet (NAVD88)
Landside Toe Elevation: -2.6 Feet (NAVD88)
Landside Elevation 150 Feet From Toe: -7.6 Feet (NAVD88)

Waterside Water Surface Elevation:
Dropped From +10.0 Feet To +2.0 Feet (NAVD88)
*Note: The water elevations used on the waterside of the model were equal to the 100-yr flood and normal water elevation.

Landside Water Surface Elevation: +2.0 Feet (NAVD88)
*Note: The water elevation used on the landside of the model was assumed as a 8 foot head differential from the waterside.



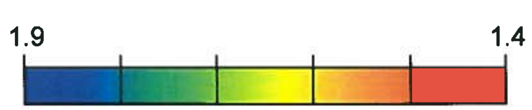


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PLATE
F-4