Memorandum

URS

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To:	David Cline, P.E. (Tetra Tech)	**CC:**	
From:	Rod DenHerder, P.E. (URS) Martin McCabe, Ph.D., P.E. (URS) Suren Balendra, P.E. (URS)	**Date:**	October 6, 2009
RE:	**Fisher Slough Restoration Final Design Recommendations**		
Job No.	**33760911**		

1.0 INTRODUCTION

This technical memorandum summarizes the final design analysis and recommendations for the Fisher Slough Floodgate, Big Ditch realignment and the proposed setback levee. Additional analysis was performed to evaluate the potential for “sand heave” and “boiling” on the downstream (Fisher Slough) side of the floodgate. The Big Ditch realignment analyses include ditch stability, ditch effects on Pioneer Highway, siphon pipe buoyancy and construction methods. The analyses of the setback levees included seepage, stability of the embankment, and settlement. Additional analysis included effects of the levee adjacent to the new Big Ditch alignment along Pioneer Highway. In addition to the above, potential construction issues were addressed and information provided for the final design report..

2.0 DESIGN REVIEW

2.1 INTRODUCTION

The purpose of the design review is to review the 50 % Design Report, drawings, and specifications to assure that they meet the recommendations listed in the Geotechnical Report (URS, 2009). The following sections present the analyses and the results of the review.

2.2 RAILROAD CAR BRIDGE ABUTMENT PRESSURES AND SETTLEMENT

The purpose of this study is to determine the allowable bearing pressures and estimated settlement for the abutment foundation pads for the four proposed access bridges. The bridges will consist of used railroad flatcars on concrete bearing pads for the abutments.

For the project, it is proposed that up to four (4) bridge crossings will be needed to provide access to adjacent properties as a result of the of the Big Ditch realignment. Those crossings are identified as:

- Smith A South access,
- Junquist South access,
- Junquist Northeast access, and
- Junquist North access.

The proposed bridges being considered are to be constructed using recycled railroad flatcars for structural support. The railcar bridge will rest directly on a concrete pad that is 8 to 10 feet long and up to 1 foot deep. The pad was assumed to be between 4 to 6 feet wide. The railcar bridge will span the width of the big ditch and where appropriate the width of the connecting existing or future embankment. The ultimate soil bearing capacity of the bridge pads took into consideration the variation of soil conditions at the site:

- Smith access – connecting from existing highway embankment to new dike,
- Junquist South access - connecting from existing highway embankment to existing dike,
- Junquist Northeast access – connecting from existing highway embankment to field/pasture, and
- North field access – connecting between field/pasture lands.

Further, the analysis considered the sloping ground which reduces the bearing capacity over that of a level ground surface.

The ultimate bearing capacities are recommended giving the following ground conditions:

- **Condition 1**
  Existing highway embankment fill (predominately granular soils, compacted):
  Soil friction – 40°
  Soil cohesion – 0 psf
  Unit weight – 130 pcf
  Ultimate bearing pressure: 46 kips/sf
- **Condition 2**
  Existing and future dike embankment fill (silt and sand mixtures, compacted):
  Soil friction – 36°
  Soil cohesion – 500 psf
  Unit weight – 120 pcf
  Ultimate bearing pressure: 17 kips/sf
- **Condition 3**
  Field/pasture land (predominately fine grained soils, identified in Geotechnical Report as Stratum 1, 2A & 2B):
  Soil friction – 0°
  Soil cohesion – 300 psf *
  Unit weight – 37 pcf **
  Ultimate bearing pressure: 1.7 kips/sf
  ** Calculated using weighted average influence depth (i.e. two times foundation width, 12 feet) of soil cohesion value of 500 psf for Stratum 1 and 250 psf for Stratum 2A & 2B, and assuming soil layer thickness of 4 feet for Stratum 1 not including embedment depth.*
  *** Assumes weighted average buoyant unit weight.*

Limitations of analysis:

- The bearing capacity analysis did not consider the groundwater effects for Condition 1 & 2, which assumed drained strength conditions.

The estimated settlement was calculated using Unisettle, a computer program, for two cases. The first case assumes that the abutments are on compacted fill, either existing highway fill or compacted levee fill. The second case assumes the bridge abutments are located in native silts and sands. The assumed applied stress was approximately 1000 psf from the dead load of the bridge plus one HS20 truck.

A summary of the values used for the two cases are:

- **Case #1:** Assumes somewhat better, more improved soil conditions over the native Stratum 1 soil layer. Referenced the UniSettle manual and choose the "m = 70" & "j = 0.5 " modulus value for a "compacted silt" when considering the higher strength contribution of the existing embankments or future levees that are planned.
- **Case #2:** Assumes abutment set on native Stratum 1 soil layer, m = 15 and j = 0.0.

Table 1 - Summary of Estimated Settlements of Railroad Car Bridges

CROSSING	ANALYSIS	SETTLEMENT (in)	
Smith A South	Case 1	1.7	
Junquist South Crossing	Case 2	5.7	
Junquist Northeast Crossing	Case 2	5.7	
Junquist North Crossing	Case 1	1.7	

Limitations of analysis:

- Global settlement may be controlling for the pads installed in the new dike embankments.

This magnitude of settlement is expected to be tolerable, although maintenance grading at the ends of the bridges may be needed to prevent a bump from occurring. Settlement may be reduce by proof rolling the excavated surface prior to placing the bearing pads and over-excavating and putting in a larger foundation of geotextile covered by 12 inches of crushed gravel before placing the bearing pads.

3.0 FLOODGATE SEEPAGE ANALYSIS

3.1 INTRODUCTION

This information was presented previously in a separate Memorandum. The purpose of the study was to evaluate the potential for "sand heave" and "boiling" on the downstream side of the new Fisher Slough floodgate. Sand heave is defined here to mean uplift of the downstream soil as an intact unit due to seepage pressures. Boiling is defined here to mean dispersion of soil grains at the bottom surface due to high seepage flow rates. The following sections present the analyses and the results of the seepage analysis.

3.2 ANALYSIS

SEEP/W (2007) is a finite element software product for analyzing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock. SEEP/W can model both saturated and unsaturated flow, a feature that greatly broadens the range of problems that can be analyzed. In addition to traditional steady-state saturated flow analysis, the saturated/unsaturated formulation of SEEP/W makes it possible to analyze seepage as a function of time and to consider such processes as the infiltration of precipitation.

Seepage analyses were performed to estimate the average and exit vertical hydraulic gradient on the downstream side of the floodgate. An exit hydraulic gradient exceeding a critical hydraulic gradient value indicates the potential for boiling for the conditions modeled. An average hydraulic gradient exceeding a critical hydraulic gradient value indicates the potential for sand heave for the conditions modeled. The critical hydraulic gradient (i_{cr}) is defined as follow:

$$i_{cr} = \frac{\gamma'}{\gamma_w}$$

where γ' is buoyant or effective unit weight of soil and γ_w is unit weight of water.

Factor of safety (FOS) against sand heave is defined as follow:

$FOS = \frac{i_{cr}}{i_{ave}}$, where i_{ave} is average vertical hydraulic gradient

Factor of safety (FOS) against boiling is defined as follow:

$FOS = \frac{i_{cr}}{i_e}$, where i_e is exit vertical hydraulic gradient

A seepage model using SEEP/W was developed for the floodgate using soil conditions encountered at borings B-1 and AB-4. Borings drilled near the bridge by WSDOT in 1984 indicate similar soil conditions.

The seepage analysis was conducted for the steady-state condition. A total head boundary condition was applied as described below:

- Upstream (Skagit River side of the floodgate): water surface elevation at 16.7 ft NAVD88.
- **Downstream:** water surface elevation at 10.7 ft NAVD88.

Hydraulic conductivity that was assumed for the stratum 2B material in the seepage model, and the way that this material was modeled, is as follows:

- Stratum 2B - Very loose to loose SILT/sandy SILT/silty SAND [ML/SM]
- Hydraulic conductivity - 1 x 10^{-3} cm/sec.
- Total unit weight – 100 pcf
- The soil was modeled as saturated only.

The hydraulic conductivity was obtained from laboratory data for this project, published literature for similar soils, and from URS geotechnical engineering judgment. The lab values of hydraulic conductivity measured for this project (approximately 10^{-6} cm/sec) were judged to be too low for accurate representation of field conditions. A conservative higher value was used for the analysis. Note that for conservatism, the hydraulic conductivity value selected for Stratum 2B is higher (higher rate of flow) for this floodgate evaluation than was used for seepage through the foundation of the new levee.

3.3 RESULTS:

A vertical hydraulic gradient contour output figure as shown on Figure 1 was generated using SEEP/W. Based on the seepage analysis; the maximum exit hydraulic gradient at the downstream side of the floodgate is 0.13 and results in a factor of safety against boiling of about 4.0. The average hydraulic gradient is 0.25 and results in a factor of safety against sand heave of about 2.0. This analysis indicates that the risk of sand heave and/or boiling alone is considered to be low.

4.0 BIG DITCH REALIGNMENT

4.1 INTRODUCTION

The purpose of this study was to analyze the stability of the new ditch cross-section, the required offset from Pioneer Highway, siphon pipe buoyancy, and new access road bridge abutment bearing pressure. The 50% Design Report and drawings were to be reviewed to determine that recommendations in the Geotechnical Report were followed.

4.2 EXISTING BIG DITCH ABANDONMENT

A substantial length of the existing Big Ditch will be realigned. The abandoned sections of Big Ditch will be filled with compacted non-organic soils obtained from the new ditch alignment, existing levee excavation and other sources as needed. Prior to placement of fill in the abandoned ditch, all vegetation and other organic material shall be removed. Soft sediment deposits shall also be removed within the ditch section along the old railroad grade (under the new setback levee fill location.

Compaction of ditch fill materials shall be 90 percent of maximum dry density per ASTM D-698, Standard Proctor Method, except along the old railroad grade section. In that section the ditch along the railroad grade, fill materials shall be the same as that required for the new setback levees. Compaction of fill material in that section of the abandoned ditch shall be 95 percent of maximum dry density per ASTM D-698, Standard Proctor Method.

4.3 DITCH STABILITY

The purpose of this study is to determine the stability of the new realigned Big Ditch. Included in this section is the calculation of the minimum offset from Pioneer Highway so that it does not impact the existing roadway. Results of the calculations (not attached here) indicate that a minimum offset of twenty (20) feet should be maintained from the toe of the Pioneer highway embankment to the edge of the Big Ditch excavation in the area south of the bridge at Fisher Slough. Because the highway embankment is not as high on the north side of the bridge, the minimum offset can be reduced to 10 feet. The analyses were performed for steady state conditions, and a minimum factor of safety of 1.25 was obtained, as required by the WSDOT Geotechnical Design Manual.

The minimum side slopes of the realigned ditch are recommended at 2.5 horizontal to 1 vertical. These slopes will be primarily in the Stratum 1 silt to sandy silt, which is medium stiff to very stiff in the upper 4 to 5 feet. Soils of that description could be excavated to stand vertically to 4 feet depth, although the presence of water in the ditch would soften and flatten the slopes over time. Slopes of this inclination are present now in the project area. Occasional sloughing could occur where the sand content of Stratum 1 is higher than elsewhere. Localized ditch widening may occur by that process, although re-construction of sloughing areas could be performed during the dry season.

4.4 INVERTED SIPHON BUOYANCY

The buoyant analysis performed on the siphon pipelines crossing the Fisher Slough shows that no significant uplift loading would occur under normal conditions when the pipeline is filled with water and buried with at least 3 feet of soil cover. The critical section is under Fisher Slough with a minimum of three feet of fill over the pipeline. The uplift buoyant force on an empty pipe are offset by the weight of the overlying soils, the shear strength of the soil materials along the cone of soil that would be displaced upward during a “floating” event, and the weight of the pipe material. Accordingly, the pipe is not expected to float when empty of water. Buoyant effects could be controlling only in the condition during soil liquefaction due to a large seismic event and when the pipeline is emptied of water, where the anticipated uplift is estimated at 100 pounds per linear feet of “affected” pipeline. The “affected” length can be considered the length which would lie within the Fisher Slough channel.

4.5 INVERTED SIPHON STRUCTURE EARTH LOADING

The vertical load on the sophon pipe for shallow burial depths is equal to the weight of soil over the pipe, i.e. the unit weight of the soil (total or buoyant as the case my be) times the depth to the top of the pipe. Lateral earth pressure against the sides of the pipe is assumed to be controlled by at-rest earth pressure conditions, and the lateral pressures would be the product of the unit weight of the soil times the at-rest earth pressure coefficient of the soil in question (see Table 1 – Summary of Recommended Parameters in the January 14, 2009 URS geotechnical report).

5.0 LEVEE SETBACK DESIGN

5.1 INTRODUCTION

The purpose of this section is to analyze the potential seepage under the levee, the stability of the levee, and the minimum offset from the Big Ditch and Pioneer Highway. As part of the seepage analysis, a determination will be made if additional seepage measures are required and configuration of the seepage control measures.

5.2 SEEPAGE ANALYSES OF LEVEE

Seepage analyses were performed to obtain pore water pressure generated in the soil elements which will be used in the slope stability program, SLOPE/W (2007), and to estimate exit hydraulic gradients at the toe of the levee.

Four cross sections (locations) were identified for seepage analyses. Sections for evaluation were selected based on geometry and foundation soil conditions and strata depths. Selected locations for seepage analyses are as follows:

- parallel to Pioneer Highway near B-1 (Station 10+00 to Station 16 + 00)
- parallel to Pioneer Highway near AB-1 (Station 16 + 00 to Station 17 +50)
- along the abandoned railroad embankment near B-2 (Station 17 +50 to Station 29 + 00)
- near east end of levee between GW-1 and B-4 (Station 29 + 00 to Station 48+00)

Seepage analyses were conducted for the steady-state and transient rapid drawdown. A total head boundary condition was applied for the following model cases:

- **Long Term Conditions (Static):** 1) Fisher Slough side of the new levee – water at El. 16.7 feet (maximum), Smith farm field side of the new levee – water at ground surface and 2) Fisher Slough side of the new levee – water at ground surface, Smith farm field side of the new levee – water at El. 16.7 feet (maximum).
- **End of Construction Conditions (Static):** water at El. 1 feet
- **Long Term Conditions (Seismic):** 1) Fisher Slough side of the new levee - water at El. 9.5 feet (average), Smith farm field side of the new levee – water at ground surface and 2) Fisher Slough side of the new levee – water at ground surface, Smith farm field side of the new levee – water at El. 9.5 feet (average).
- **Rapid Drawdown Conditions of Fisher Slough Side of New Levee:** Fisher Slough side of the new levee - water at El. 16.7, drop to 10.7 feet in twenty four hours; Smith farm field side of the new levee - water at ground surface.
- **Rapid Drawdown Conditions of Field Side of New Levee:** Fisher Slough side of the new levee- water at ground surface, Smith farm field side of the new levee - water at El. 16.7, drop to 10.7 feet in twenty four hours.

Materials and their permeabilities that were used in the seepage model are as follows:

- Stratum 1 Fill - SILT with a permeability of 1 x 10^{-5} cm/sec
- Stratum 2A – clayey SILT with a permeability of 1 x 10^{-5} cm/sec
- Stratum 2B – SILT/sandy SILT/silty SAND with a hydraulic conductivity of 1 x 10^{-4} cm/sec
- Stratum 3 – SILT/sandy SILT/silty SAND with a permeability of 1 x 10^{-3} cm/sec
- Existing Fill (Railroad Embankment)– SILT with a permeability of 5 x 10^{-5} cm/sec
- New Fill – sandy SILT/silty SAND with a permeability of 1 x 10^{-4} cm/sec
- Seepage Berm Fill–fill with permeability of 1 x 10^{-6} cm/sec

The permeability was obtained from laboratory data for this project, published literature for similar soils, and from URS geotechnical engineering judgment. The lab values of permeability measured for this project in strata 2A & 2B were judged to be too low for accurate representation of field conditions. A conservative higher value was used for the analysis.

For underseepage conditions, the current USACE criterion for the *average vertical exit gradient* through a levee's landside blanket is that it be less than or equal to 0.5 for the design floodwater level condition (see USACE, 2000 and USACE, 2005).

A vertical gradient contour output figure was generated using SEEP/W for case. This analysis indicates that seepage under the levee is not critical except along Big Ditch. The results of the seepage analysis are summarized in Table A2 in Appendix A. Based on the seepage analysis, the maximum localized exit hydraulic gradient at the toe of the levee is 0.7 and the maximum average vertical exit gradient is 0.6. In this section additional measures will be required to reduce the average vertical exit gradient to be equal or less than 0.5. In order to reduce the average vertical exit gradients it is recommended that a 12 foot wide seepage berm or blanket of low permeability material with a minimum thickness of 1 foot is required on both sides of the levee. The low permeability materials can be native soils such as clays with permeability no higher than 1 x 10^{-6} cm/sec or any combination of silt and sandy silts mixed with bentonite that achieves the same level of imperviousness. An acceptable alternative is to use approximately 1 foot of common fill material over a Geosynthetic Clay Liner (GCL). The seepage berm is required from the start of the setback levee at, Station 10 + 00 (Fisher Slough), to Station 16 + 00. Graphical results of the various seepage analysis cases are presented in Appendix A. Note that the figures list permeability (k) values in units of feet per second.

Alternative methods of controlling seepage, including toe drains, cutoff trenches and cutoff walls were evaluated. The minimum depth of cutoff walls considered was 20 feet deep, which would require that sheet piles or slurry trench be installed due to the soft soils and high groundwater. Results of a seepage analysis using a 20-foot deep sheetpile cutoff wall are shown in Appendix A. Similarly, a 10-foot deep cutoff trench was also evaluated assuming the permeability of the cutoff material is 10^{-6} cm/sec (about 3.3 x 10^{-8} feet per second). Toes drains have been used in other levee systems in Northwest Washington (Marshland and French Creek dikes along the Snohomish River) but may be difficult to maintain in this location where the water levels may frequently be high on both sides of the levee. Siltation of the toe drain may cause increased exit pressures right at the toe, exacerbating the problem.

5.3 STABILITY ANALYSES OF LEVEE

The proposed setback levee consists of a compacted earthfill with the following cross section: side slopes of 2.5H:1V on the Fisher Slough side, side slopes of 3H:1V on the Big Ditch side, with a top width of twelve feet. The results of the stability analysis indicate that the levee has an acceptable factor of safety according to guidelines in Table 2 except for a section of the levee along Big Ditch and Pioneer Highway near Fisher Slough (Station 10+00 to 16+00). Because of soil conditions near Fisher Slough additional measures are required for the levee to meet the stability requirements.

Slope stability analyses were performed using SLOPE/W (2007), which is a computer program for the general solution of slope stability problems by two-dimensional limiting equilibrium methods. The calculation of the factor of safety against instability of a slope can be performed using one of the following methods: Bishop Simplified Method (applicable to circular shaped failure surfaces), Ordinary Method, Janbu Simplified Method (applicable to failure surfaces of general shape), or Spencer's Method (applicable to any type of surface).

SLOPE/W features unique random techniques for generation of potential failure surfaces for subsequent determination of the more critical surfaces and their corresponding factors of safety. These techniques generate circular failure surfaces, surfaces of sliding block character, or more general irregular surfaces of random shape. For the purposes of these analyses, URS utilized Spencer’s Method. The pore pressure generated in the SEEP/W run was used in SLOPE/W program during stability analysis.

The same section locations and boundary conditions listed above in the seepage analysis section were used for the stability analysis. Soil parameters (friction angle, cohesion and unit weight) that were used in the analyses were based on field data, laboratory results, and engineering judgment, and are summarized in Table 2.

Table 2: Soil Parameters used in the Slope Stability Analyses

Soil Unit	Unit Weight (pcf)	Cohesion (psf)	Friction Angle (degrees)
Stratum 1[b], SILT	110	500 [a]	0
Stratum 2A[b], clayey SILT	95	250 [a]	0
Stratum 2B[b], SILT/sandy SILT/silty SAND	100	250 [a]	0
Stratum 3, silty SAND	110	0	28
Existing Railroad Fill	120	2000	0
New Fill	120	500	36

[a] used as minimum strength in this analyses
[b] S_u/p' ratio of 0.33 was used in this analyses

The minimum factors of safety (FS) for static conditions required by the US Army Corps of Engineers (USACE, 2000) are shown in Table 3.

Table 3: Minimum Factors of Safety Required for Levees under Static Conditions

Design Condition	Minimum Factor-of-Safety
End of Construction	1.3
Rapid Drawdown	1.0 to 1.2 *
Long Term (Steady Seepage)	1.4

* Sudden drawdown analysis. F.S. = 1.0 applies to pool levels prior to drawdown conditions where these water levels are unlikely to persist for long periods preceding drawdown. F.S. = 2.0 applies to pool level likely to persist for long periods prior to drawdown.

The required minimum FS under seismic conditions is generally 1.1 (WSDOT, 2008).

The results of the end of construction stability analyses are summarized in Table B3 in Appendix B. Representative graphical results are also presented in figures in Appendix B. The section of levee along Big Ditch and Pioneer Highway is in an area of soft silts and silty sands with low strengths. The maximum height of construction allowed in the first construction season is to Elevation 15.0 (approximately nine (9) feet of fill) with a minimum levee setback 15 feet from the edge of the Big Ditch excavation. The levee could be constructed up to Elevation 16 the first construction season if Big Ditch is not excavated until the second construction season. This reduced levee height would allow initial dike settlement to occur and some increase in foundation strength prior to completing the levee fill to the design elevation.

The results of the long term and rapid drawdown stability analyses are summarized in Tables 4 and 5, respectively. Tables B4 and B5 show that calculated FS met the minimum acceptable FS in all cases except along Big Ditch. The stability of the dike slope in this area can be improved by the following options:

- Reinforce the embankment (placing geotextile/geogrid layers at the base of the levee) with the existing 15 foot levee setback from Big Ditch.
- Maintain a 30 foot berm between the toe of the levee and Big Ditch

URS evaluated the two options in the analysis and both options will provide adequate factors of safety - FS of 1.4, for static.

URS estimated the seismic stability of the levee by considering the "post-shaking" factor of safety. In this analysis, a residual post-earthquake undrained strength was assigned to potentially liquefiable layer stratum 2B. A reduction of 15% for the shear strength for strata 2A due to shaking induced elevated pore pressures.

The residual post-earthquake undrained strengths of the Stratum 2B below the groundwater table were estimated based on equivalent Standard Penetration Test (SPT) blow counts (N). Based on Idriss and Boulanger (2008) approach, a residual post earthquake strength of 165 psf was estimated for the stratum 2B deposits.

The results of the post-shaking stability analyses are summarized in Table B6. The results indicate that calculated FS met the minimum acceptable FS in all cases except parallel to Pioneer Highway near the north end of the levee. At the north end of the setback levee where factors of safety of less than one were obtained for the "Post-shaking" stability analyses for the design seismic event, potentially large vertical and lateral deformations of the levee could occur due to liquefaction in the Stratum 2b sandy native foundation soil.

The liquefaction is likely to be discontinuous due to the variable fines content of this sublayer. Estimating the magnitude of deformations that could occur as a result of the liquefaction is beyond the scope of this effort. However, experience in California (Miller and Roycroft, 2004, "Seismic performance and deformation of levees: Four case histories", Journal of Geotechnical and Geoenvironmental Engineering, V 130, N4) and Japan (T. Kokusho, 2006, "Recent developments in liquefaction research learned form earthquake damage", Journal of Disaster Research, V1, N2) have shown that portions of the levee could settle and move laterally perhaps less than 10 to more than 30 percent of the height of the levee when foundation liquefaction occurs. The use of geogrid layer in the base of the levee is expected to reduce the seismic deformations. Substantial post-earthquake repair could be needed. Alternatively, ground improvement methods such as vibrocompaction, vibroreplacement or soil mixing could be employed during construction in the vulnerable zones of the foundation to minimize the magnitude of seismic displacement.

5.4 SETTLEMENT ANALYIS OF LEVEE

Due to the soft nature of the soil (Stratum 2A), the dike will experience considerable settlement, both during and after construction. The estimated settlements for a proposed new setback levee at three locations, are listed in Table 4..

Table 4. Estimate Levee Settlement

LEVEE SECTION	STATION RANGE	LOCATION WITHIN X-SECTION	SETTLEMENT	
			MAXIMUM	LIKELY
Along Pioneer Highway	Station 10+00 to 17 + 50	Center	3.9 ft	2.7 ft
		Toe - both	1.3 ft	0.9 ft
Along Railroad Grade	Station 17 +50 to Station 29 + 00	Center	2.3 ft	1.6 ft
		Toe – Field side	na	na
		Toe – Over old ditch	1.0 ft	0.7 ft
Southeast Section	Station 29+00 to 48+00	Center	2.3 ft	1.6 ft
		Toe - both	0.5 ft	0.4 ft

Approximately 50 to 60 percent of the above settlements are expected to occur within 12 months following the construction of the dike, with the remainder occurring over a period of roughly 6 to 10 years or more. The full levee cross-section can be constructed in one season for all sections of the setback levee except that area along Pioneer Highway and new ditch excavation.

The settlement evaluation assumed the settlement occurred at one time and did not consider phased construction described in the stability section above. One result of phased construction is that slightly reduced total settlements may occur.

5.5 SETTLEMENT OF PIONEER HIGHWAY

The purpose of this analysis is to evaluate the effect of settlement of the new levee and the excavation of Big Ditch on the Pioneer Highway embankment. Calculations show that the minimum distance between the toe of the levee and the toe of highway embankment must be 80 feet to limit the settlement of the highway embankment to less than 0.5 inch. This includes the assumed top distance of 45 feet for Big Ditch (2.5H:1V side slopes, 15 feet bottom width).

Based on stability calculations of Pioneer Highway, the minimum required offset of Big Ditch from Pioneer Highway is twenty (20) feet from the toe of the highway embankment to the edge of the Big Ditch excavation in the area south of the bridge at Fisher Slough. A minimum ten foot offset is required for Big Ditch from the Pioneer highway embankment to the north of the Fisher Slough bridge.

6.0 REFERENCES

USACE, US Army Corps of Engineers, *Design and Construction of Levees*, EM 1110-2-1913, April 2000

USACE, US Army Corps of Engineers, *Design Guidance for Levee Underseepage*, ETL 1110-2-569, 2005

WSDOT Washington State Department of Transportation, Geotechnical Design Manual.

ATTACHMENTS:

Figure 1- Floodgate Seepage - Vertical Gradient Contours

APPENDIX A - Results of Seepage Analyses

APPENDIX B - Selected Results of Stability Analyses

FIGURES

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-005 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Sheet Pile Model: (none)

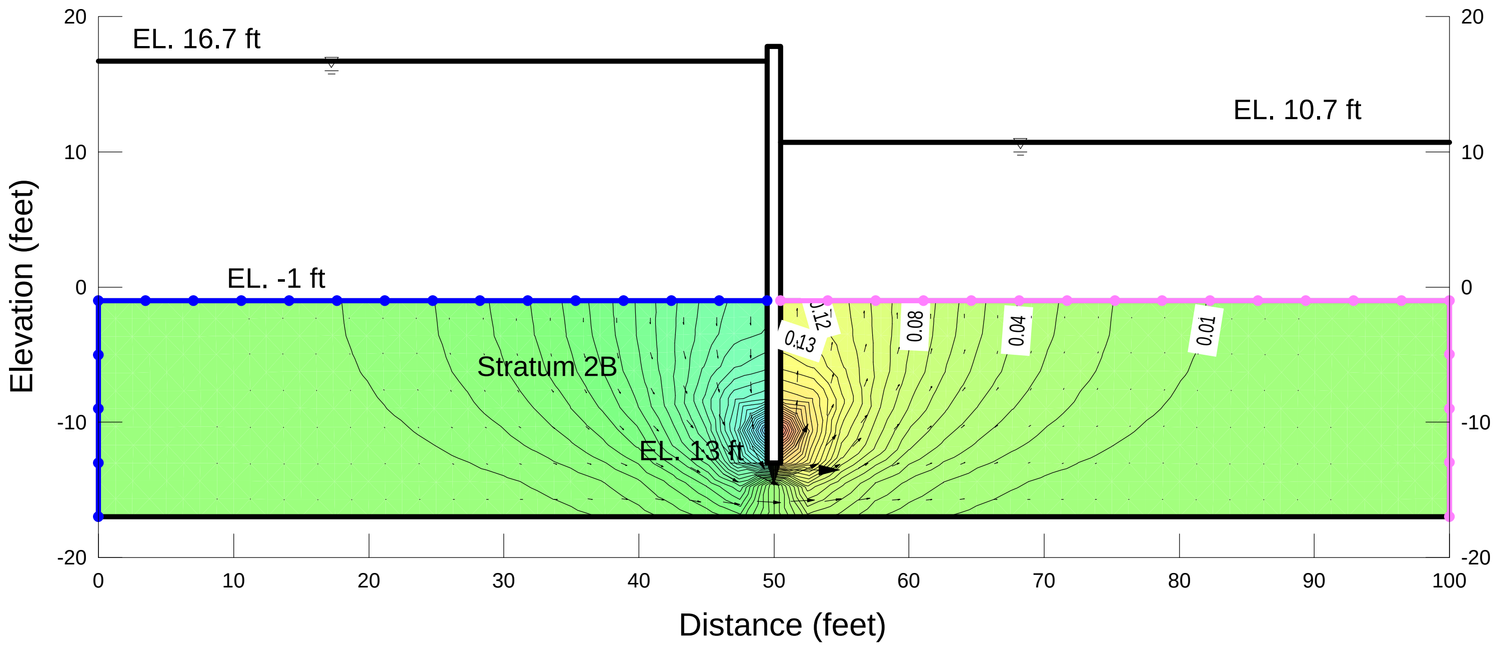

Figure 1

Job No. 33760911

Floodgate Seepage - Vertical Gradient Contours

URS

Fisher Slough Restoration Project
Skagit County, Washington

APPENDIX A - Results of Seepage Analyses

Table A2: Summary of Seepage Gradient at Toe

Section	Water Level EL. (ft)		Maximum Exit Vertical Gradient (i_{max})	Average Exit Vertical Gradient (i_{avg})	Figure No
	Fisher Slough Side	Ditch/Smith Field Side			
parallel to Pioneer Highway near AB-1[b]	16.7	6	0.35	0.31	A-1
	6	16.7	0.40	0.35	A-2
parallel to Pioneer Highway near B-1[b]	16.7	6	0.60	0.54	A-3 & A-4
	6	16.7	0.70	0.66	A-5
parallel to Pioneer Highway near B-1[b & c]	16.7	6	0.60	0.36	A-6 & A-7
	6	16.7	1.00	0.46	A-8
parallel to Pioneer Highway near B-1[b & d]	16.7	6	0.45	0.43	A-9
	6	16.7	0.55	0.50	A-10
parallel to Pioneer Highway near B-1[b & e]	16.7	6	0.50	0.48	A-11
	6	16.7	0.65	0.58	A-12
along the abandoned railroad embankment near B-2	16.7	6	0.30	0.21	A-13
	6	16.7	0.40	0.32	A-14
near east end of levee between GW-1 and B-4	16.7	7	0.40	0.38	A-15
	7	16.7	0.45	0.36	A-16

[b] with geogrid & [c] with a low permeability 1-foot thick blanket on the 12-foot wide on both side of the toe of the levee

[d] with sheet pile & [e] with a 10-foot deep cutoff trench

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0

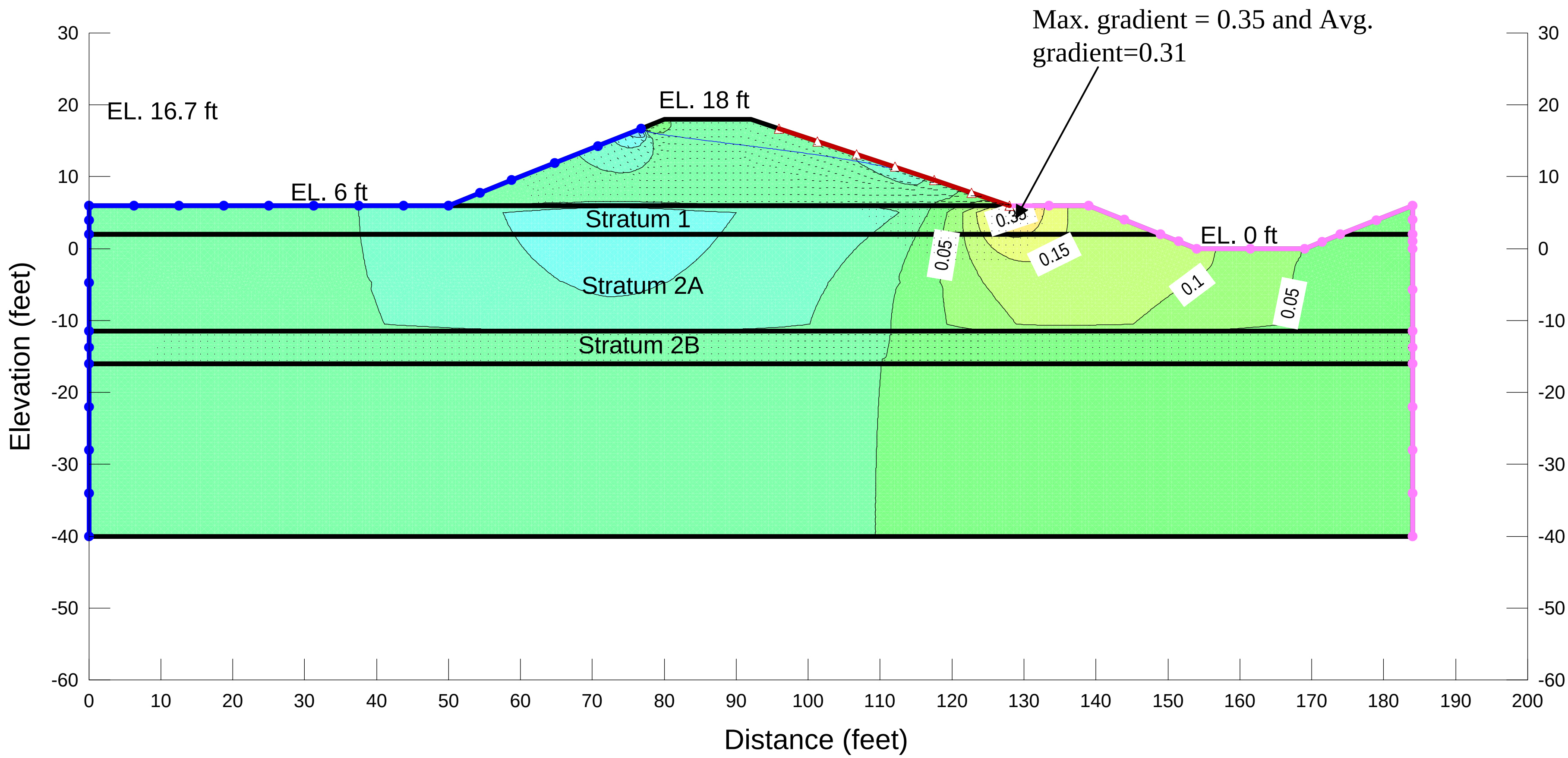

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Figure A-1

Job No. 33760911

Vertical Gradient Contours

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B   Model: Saturated Only   K-Sat: 3.28084e-006   Volumetric Water Content: 0   Mv: 0   K-Ratio: 1   K-Direction: 0
Name: Stratum 2A   Model: Saturated Only   K-Sat: 3.28084e-007   Volumetric Water Content: 0   Mv: 0   K-Ratio: 1   K-Direction: 0
Name: Stratum 1   Model: Saturated Only   K-Sat: 3.28084e-007   Volumetric Water Content: 0   Mv: 0   K-Ratio: 1   K-Direction: 0
Name: Fill   Model: Saturated / Unsaturated   K-Function: New Fill   Vol. WC. Function: Silt   K-Ratio: 1   K-Direction: 0

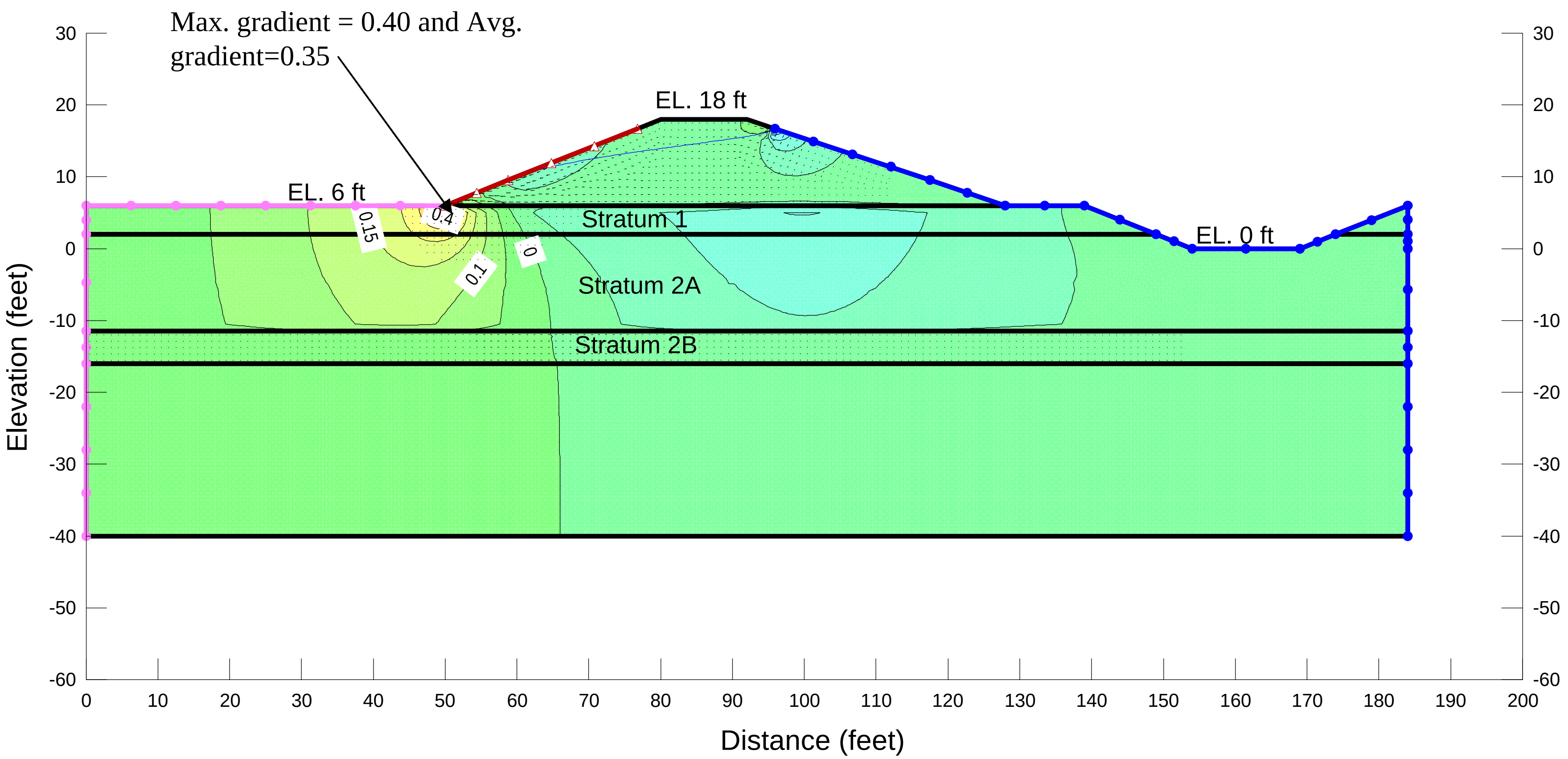

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Figure A-2

Job No. 33760911

Vertical Gradient Contours

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0

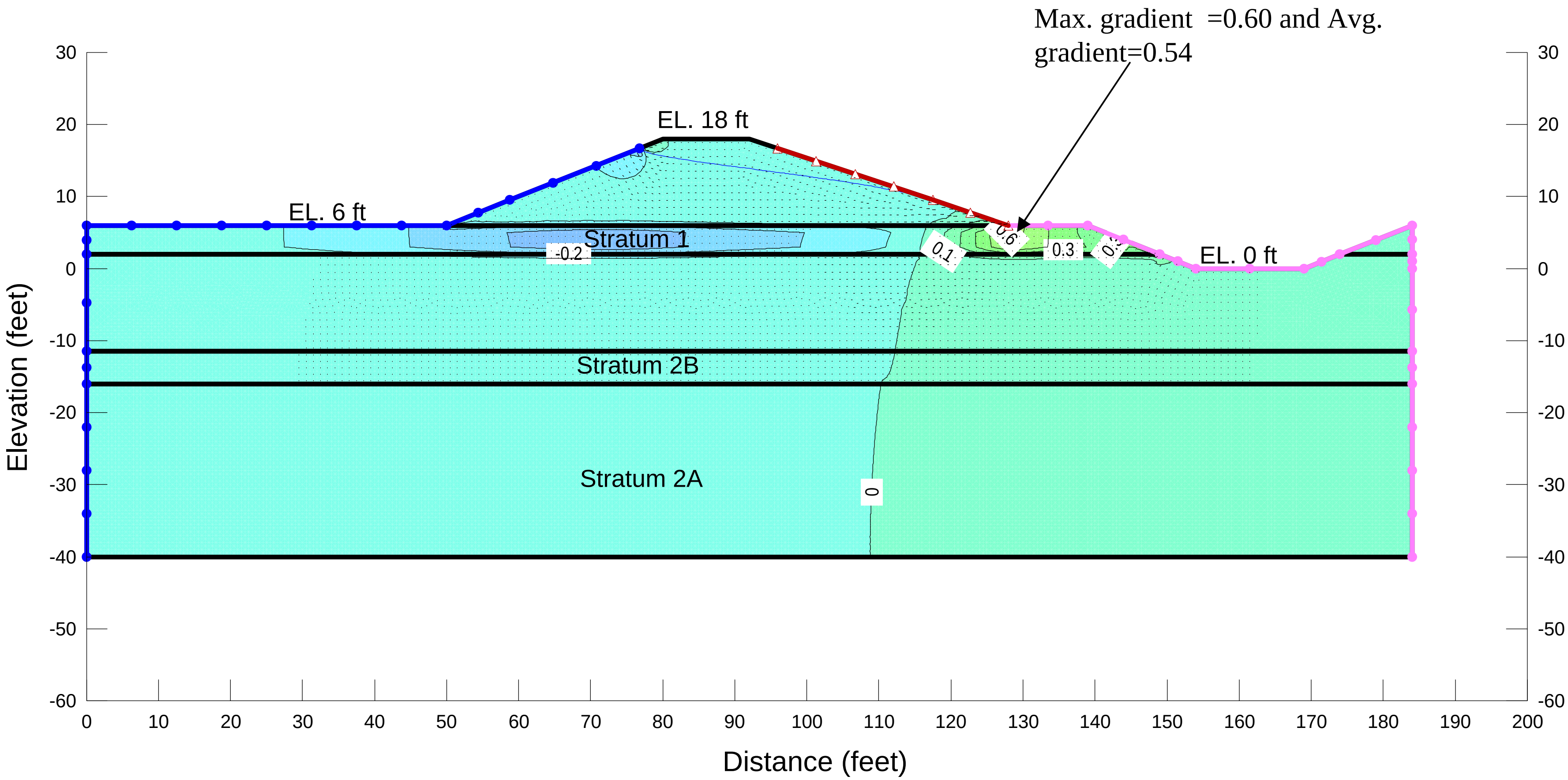

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Figure A-3

Job No. 33760911

Vertical Gradient Contours without Blanket Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

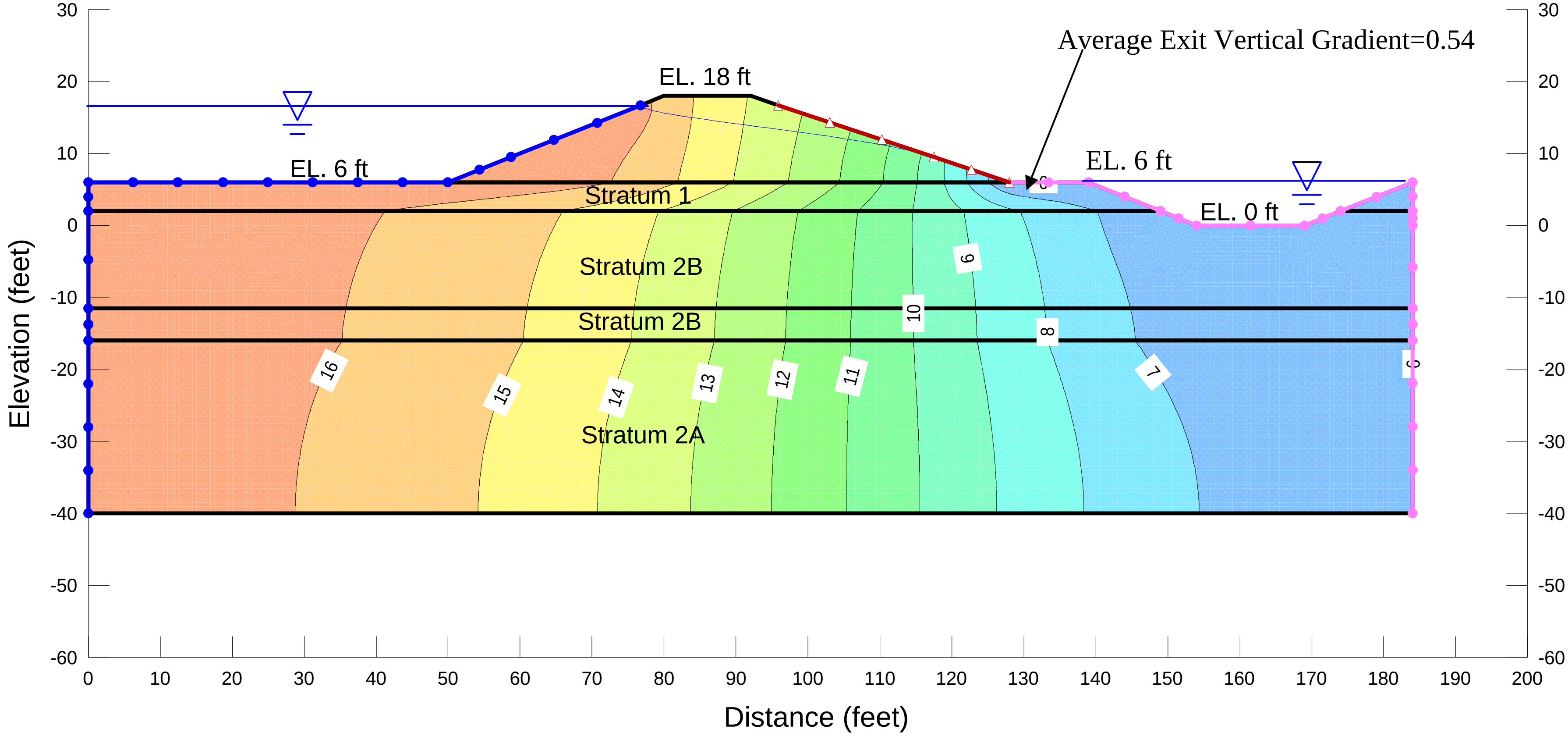

Figure A-4

Job No. 33760911

Total Head Contours without Blanket Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0

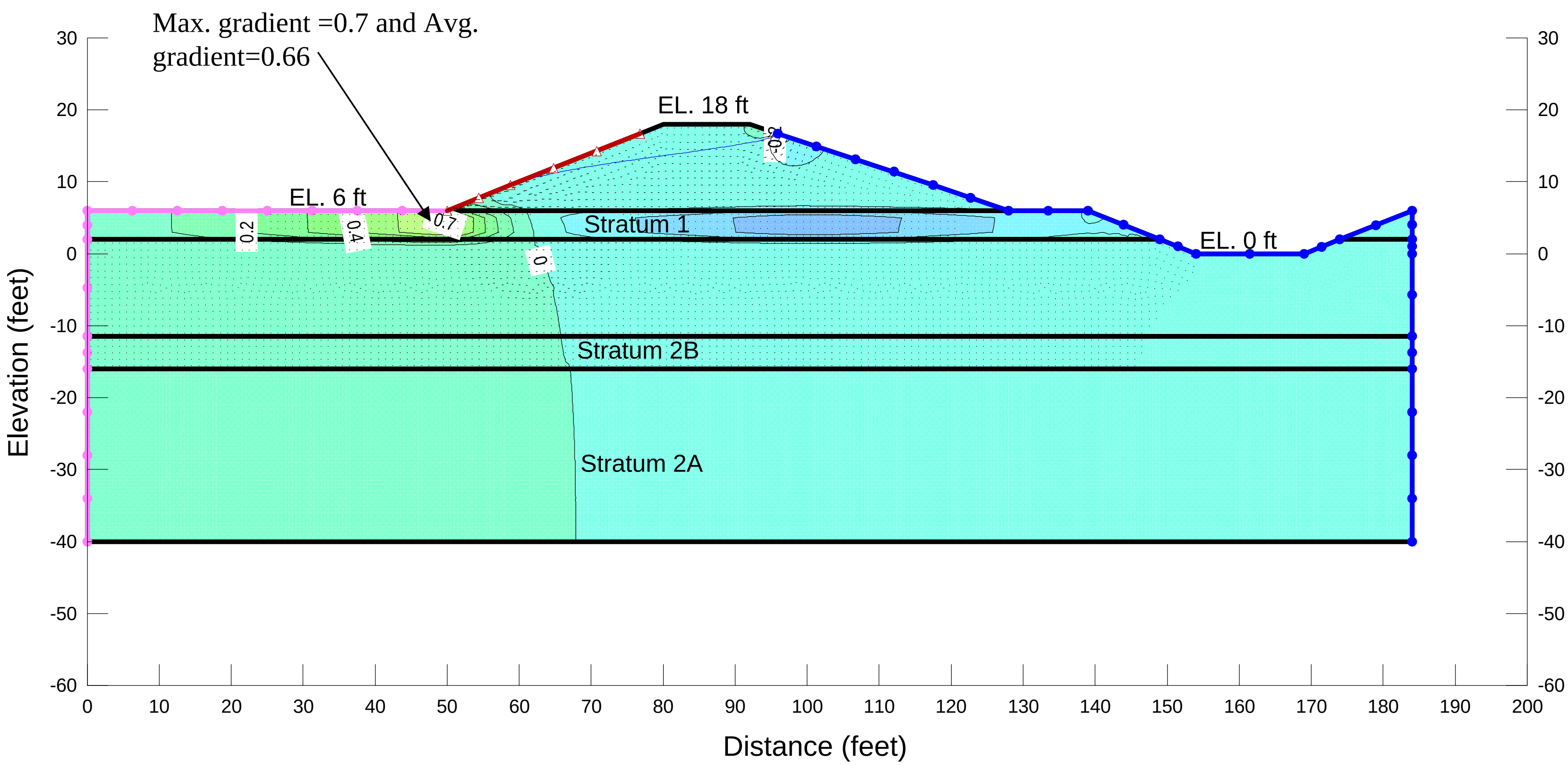

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Figure A-5

Job No. 33760911

Vertical Gradient Contours without Blanket Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0
Name: Blanket Model: Saturated / Unsaturated K-Function: Blanket Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0

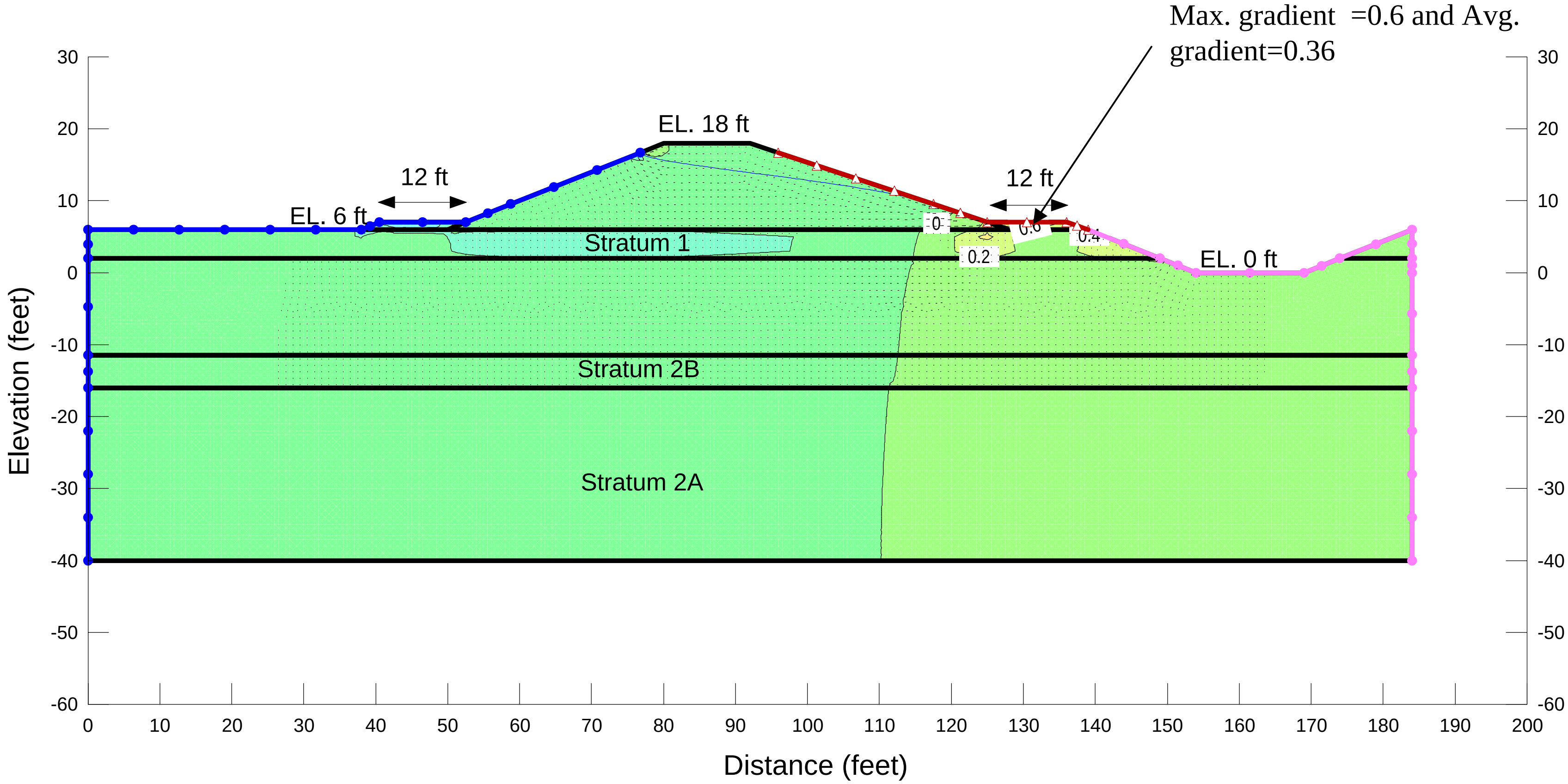

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Figure A-6

Job No. 33760911

Vertical Gradient Contours with Blanket Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

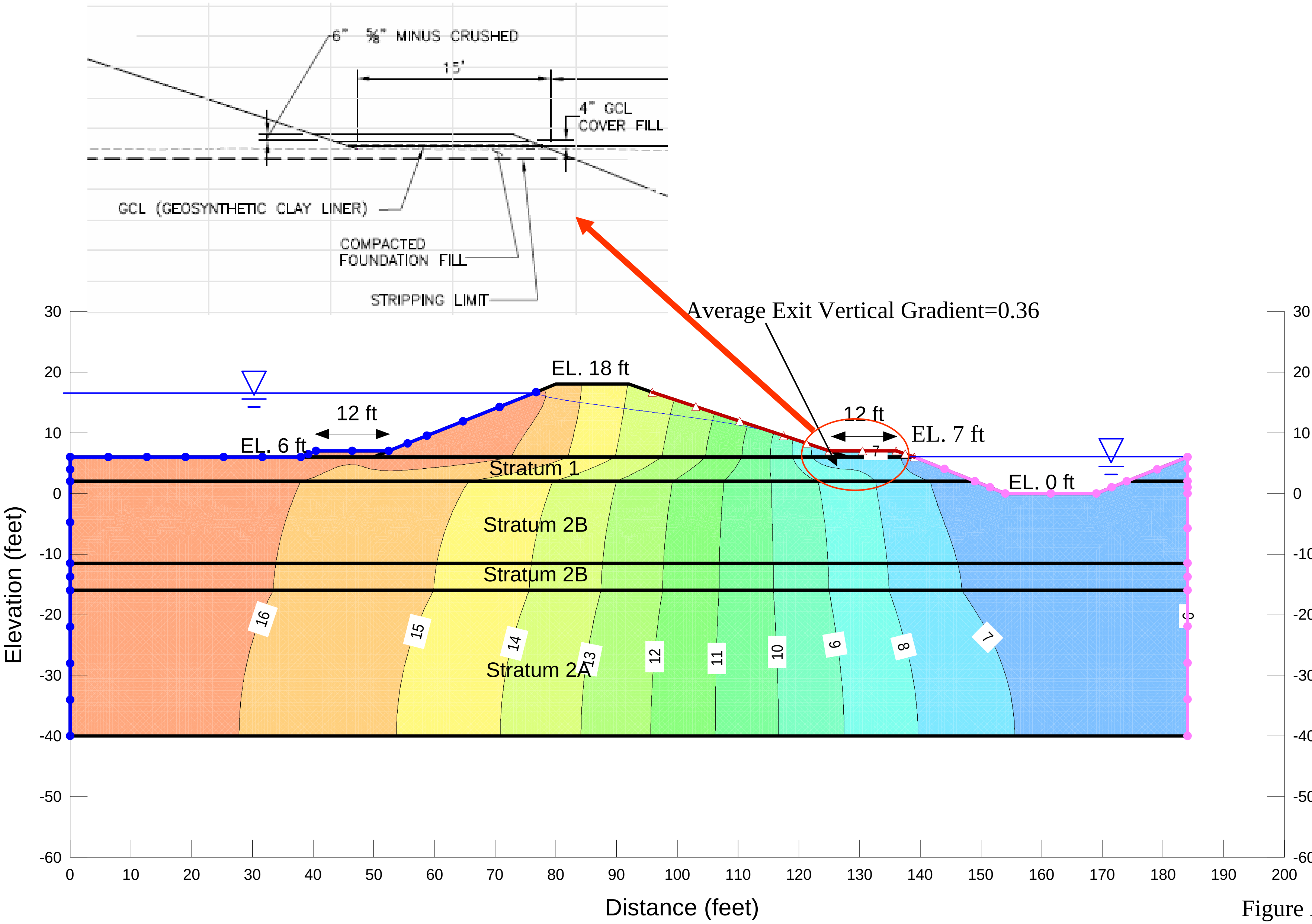

Figure A-7

Job No. 33760911

Total Head Contours for with Blanket Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0
Name: Blanket Model: Saturated / Unsaturated K-Function: Blanket Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0

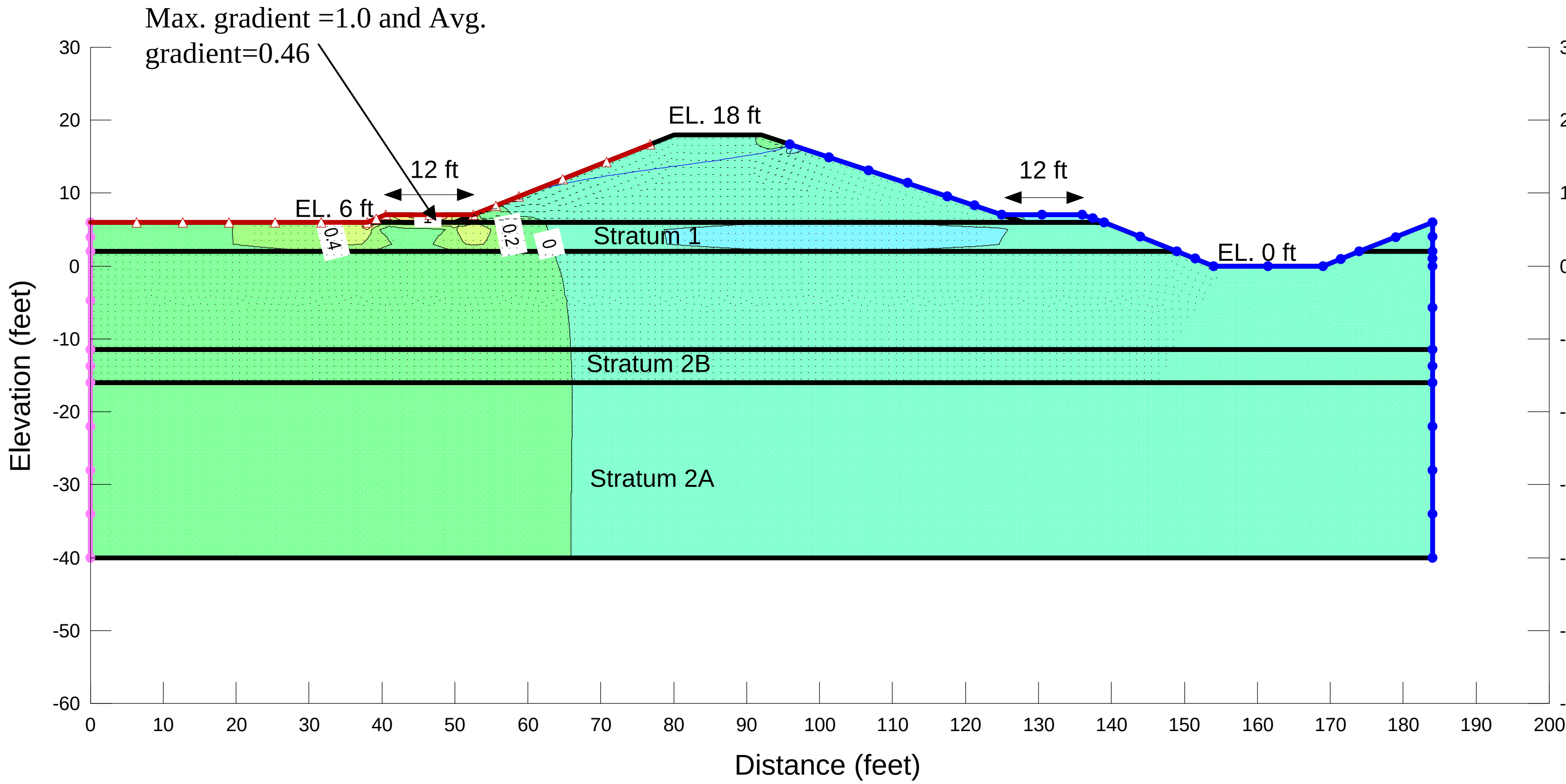

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Figure A-8

Job No. 33760911

Vertical Gradient Contours with Blanket Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0

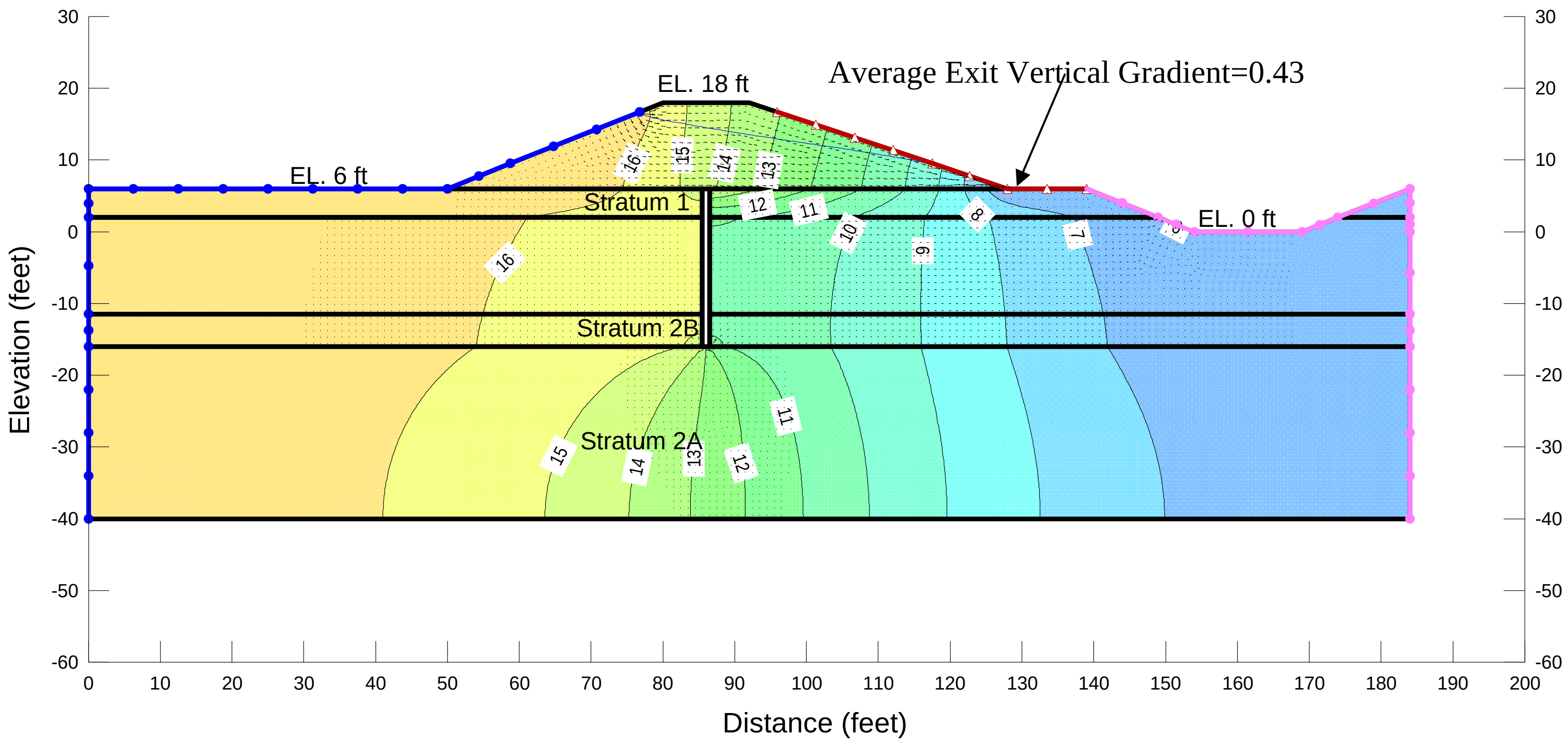

Figure A-9
Total Head Contours with Cutoff Wall Case
Fisher Slough Restoration Project
Skagit County, Washington

Job No. 33760911

URS

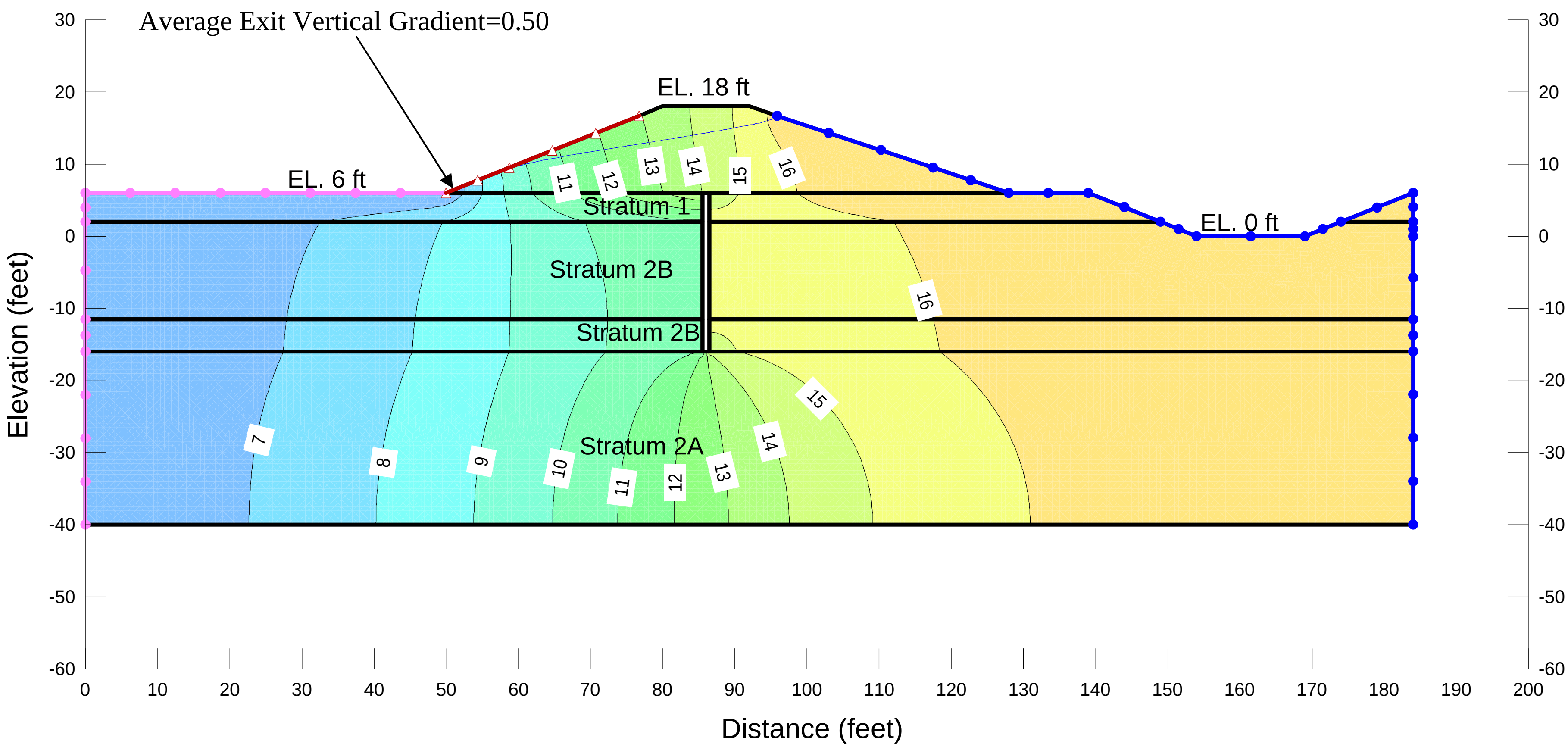

Figure A-10

Job No. 33760911

Total Head Contours with Cutoff Wall Case

URS

Fisher Slough Restoration Project

Skagit County, Washington

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill Vol. WC. Function: Silt K-Ratio: 1 K-Direction: 0
Name: Cutoff Trench Model: Saturated Only K-Sat: 3.28084e-008 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0

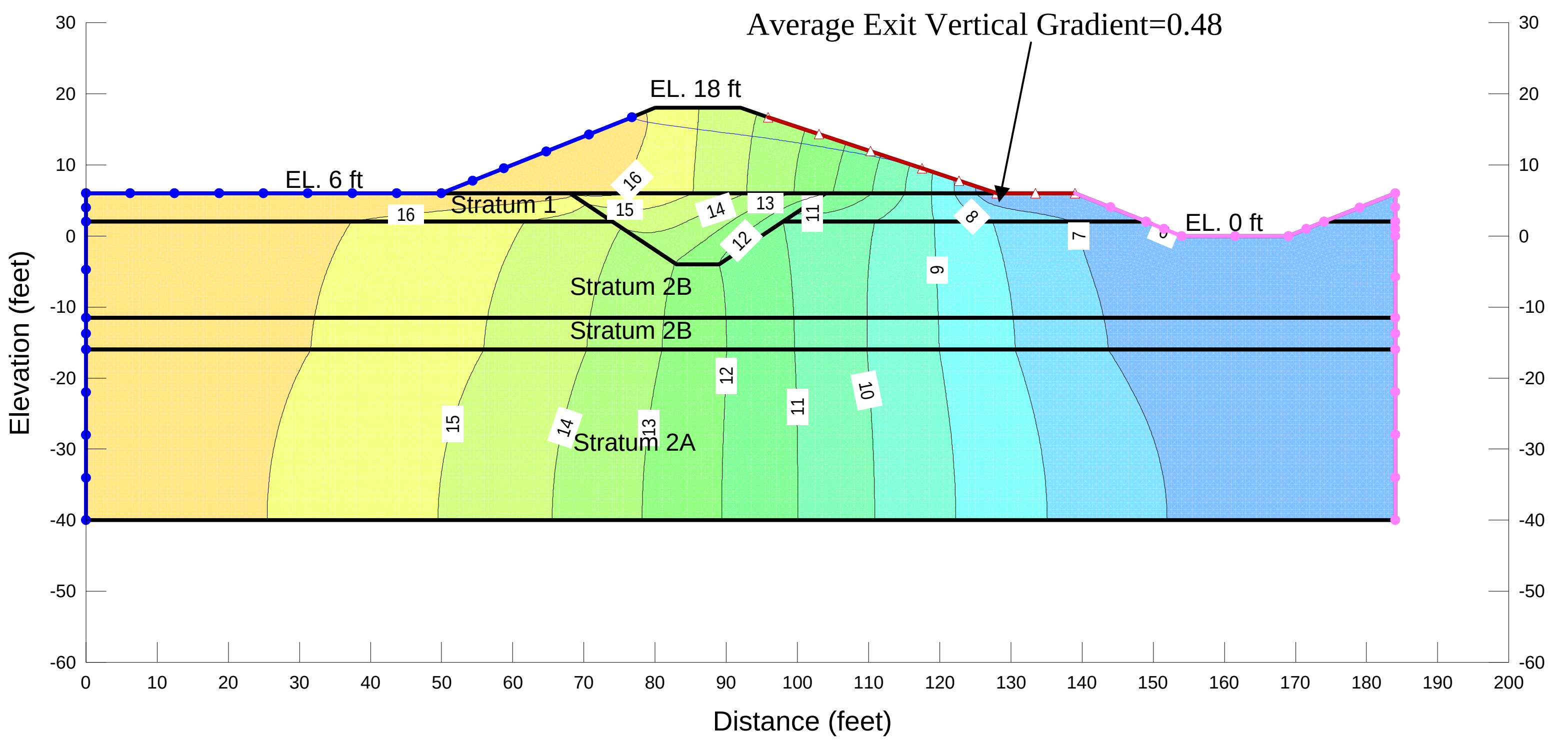

Figure A-11

Job No. 33760911

Total Head Contours with Cutoff Trench Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

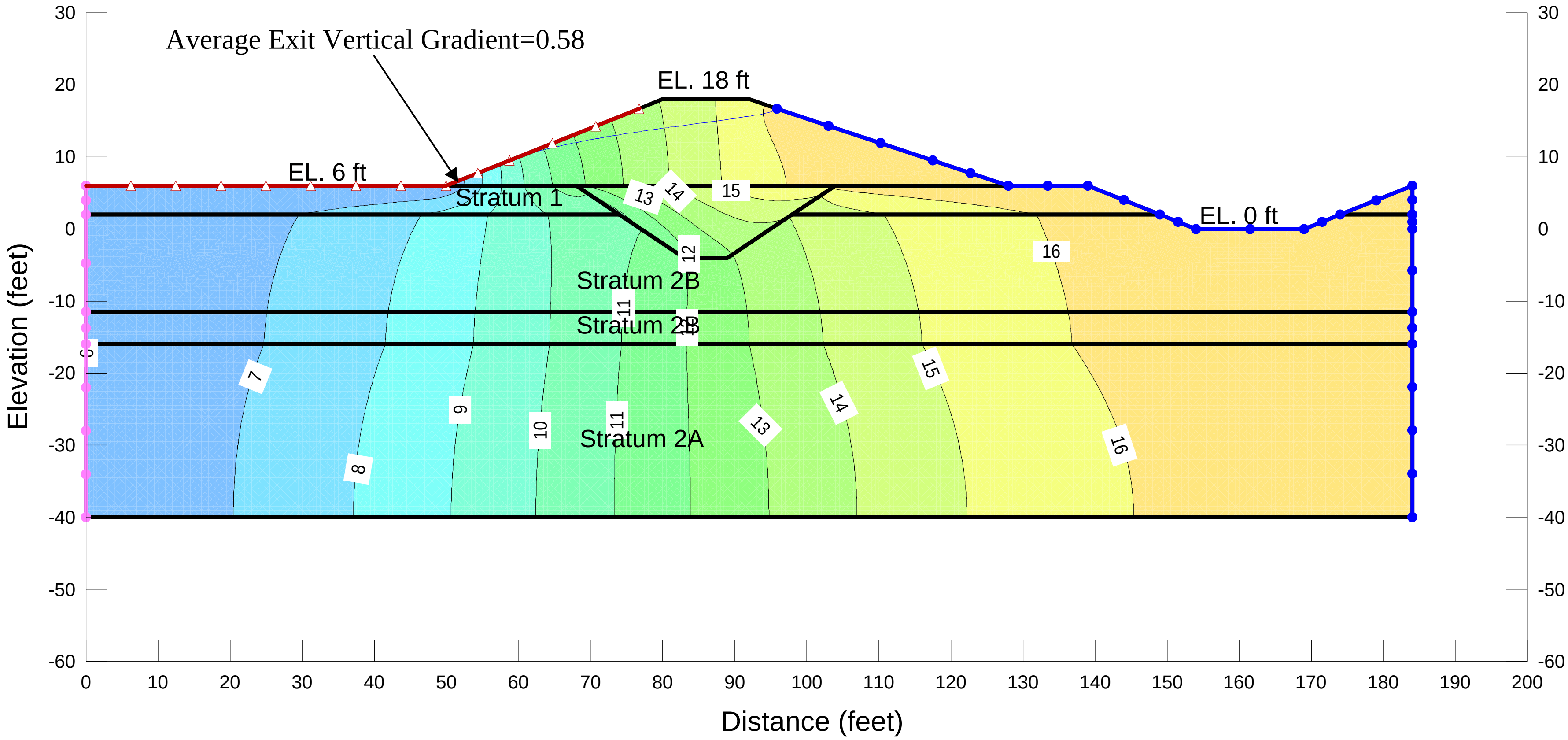

Figure A-12

Job No. 33760911

Total Head Contours with Cutoff Trench Case

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill K-Ratio: 1 K-Direction: 0
Name: Existing Fill Model: Saturated / Unsaturated K-Function: Existing Fill K-Ratio: 1 K-Direction: 0

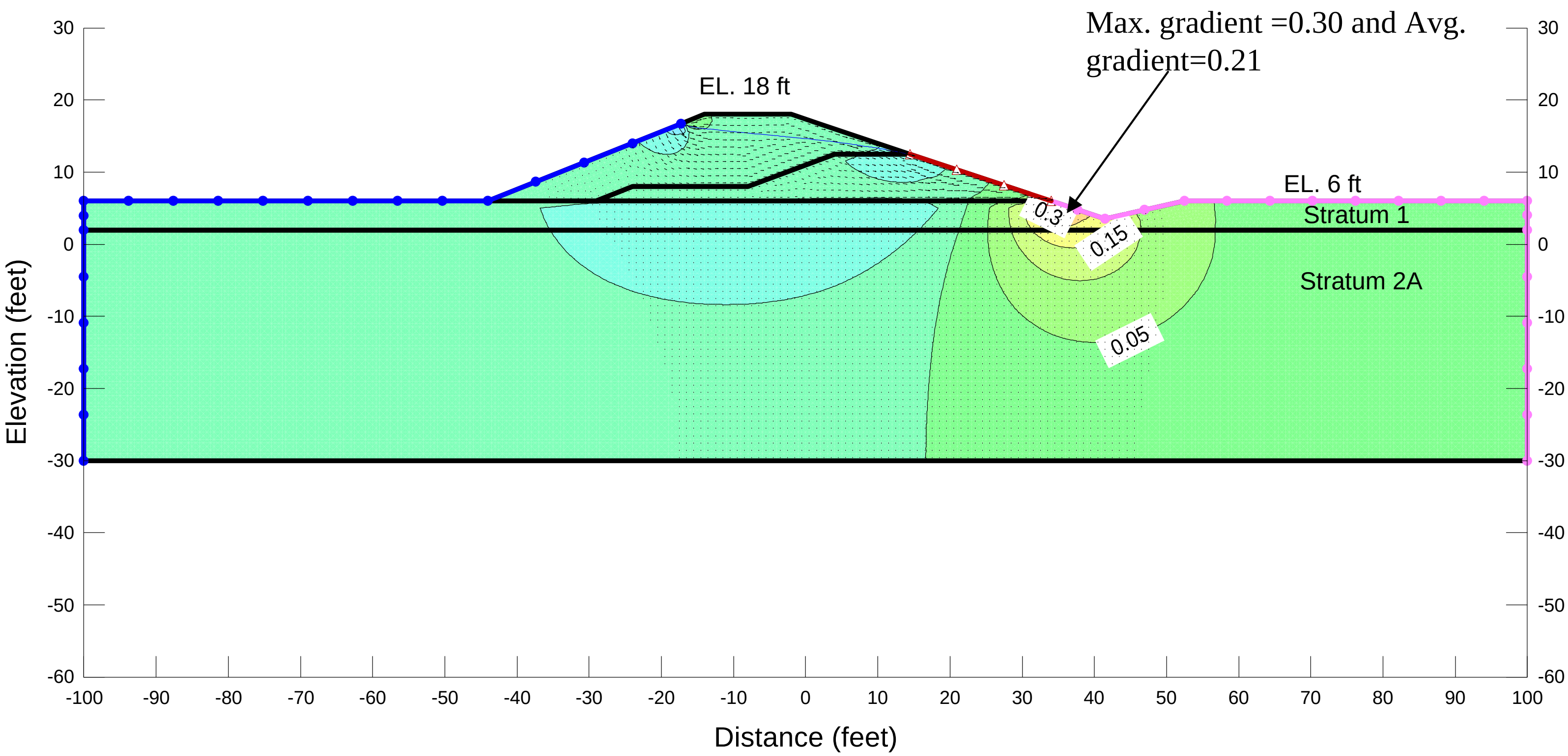

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Figure A-13

Job No. 33760911

Vertical Gradient Contours

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill K-Ratio: 1 K-Direction: 0
Name: Existing Fill Model: Saturated / Unsaturated K-Function: Existing Fill K-Ratio: 1 K-Direction: 0

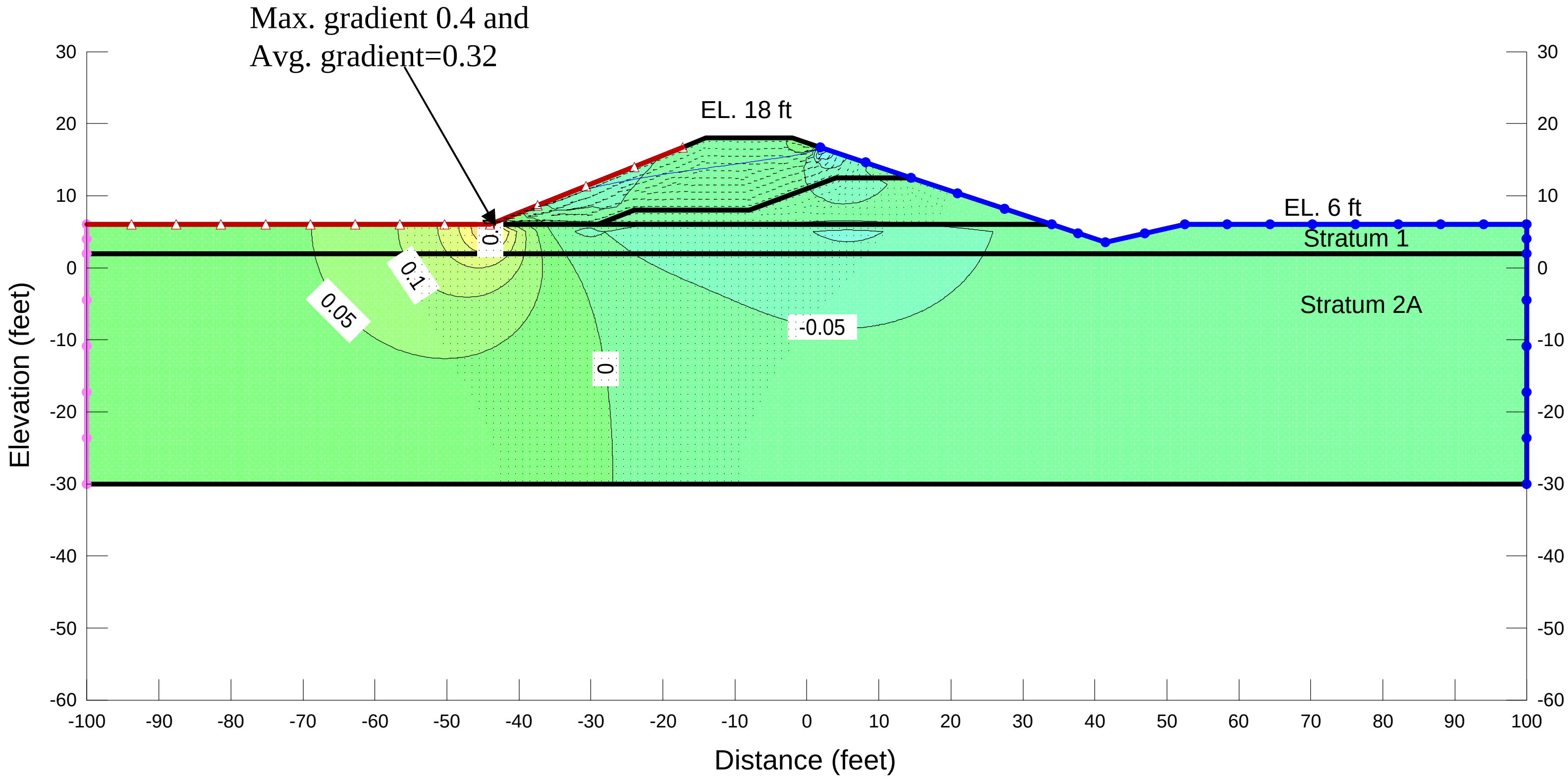

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Figure A-14

Job No. 33760911

Vertical Gradient Contours

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 38+00

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill K-Ratio: 1 K-Direction: 0
Name: Stratum 3 Model: Saturated Only K-Sat: 3.28084e-005 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0

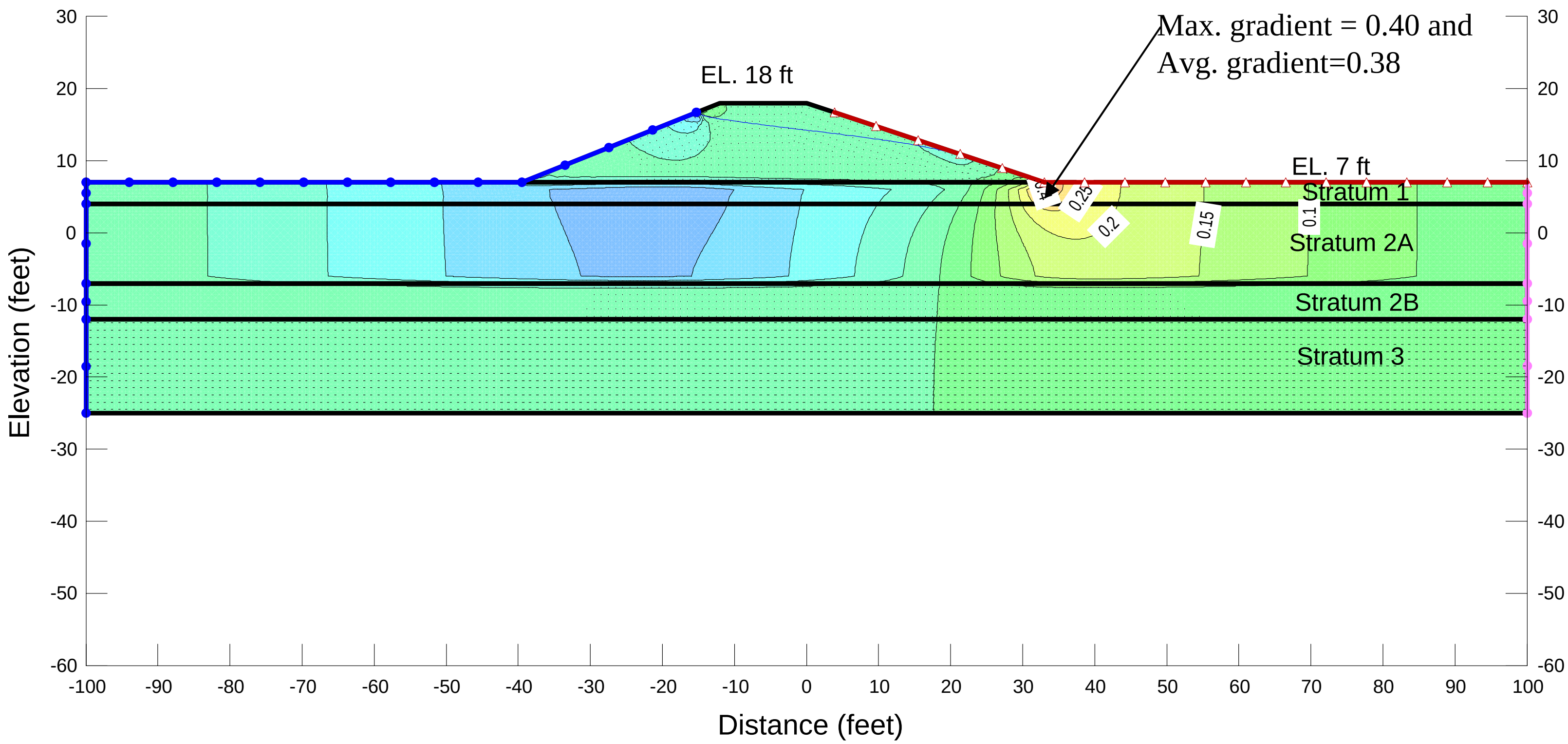

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Figure A-15

Job No. 33760911

Vertical Gradient Contours

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 38+00

Name: Stratum 2B Model: Saturated Only K-Sat: 3.28084e-006 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 2A Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Stratum 1 Model: Saturated Only K-Sat: 3.28084e-007 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0
Name: Fill Model: Saturated / Unsaturated K-Function: New Fill K-Ratio: 1 K-Direction: 0
Name: Stratum 3 Model: Saturated Only K-Sat: 3.28084e-005 Volumetric Water Content: 0 Mv: 0 K-Ratio: 1 K-Direction: 0

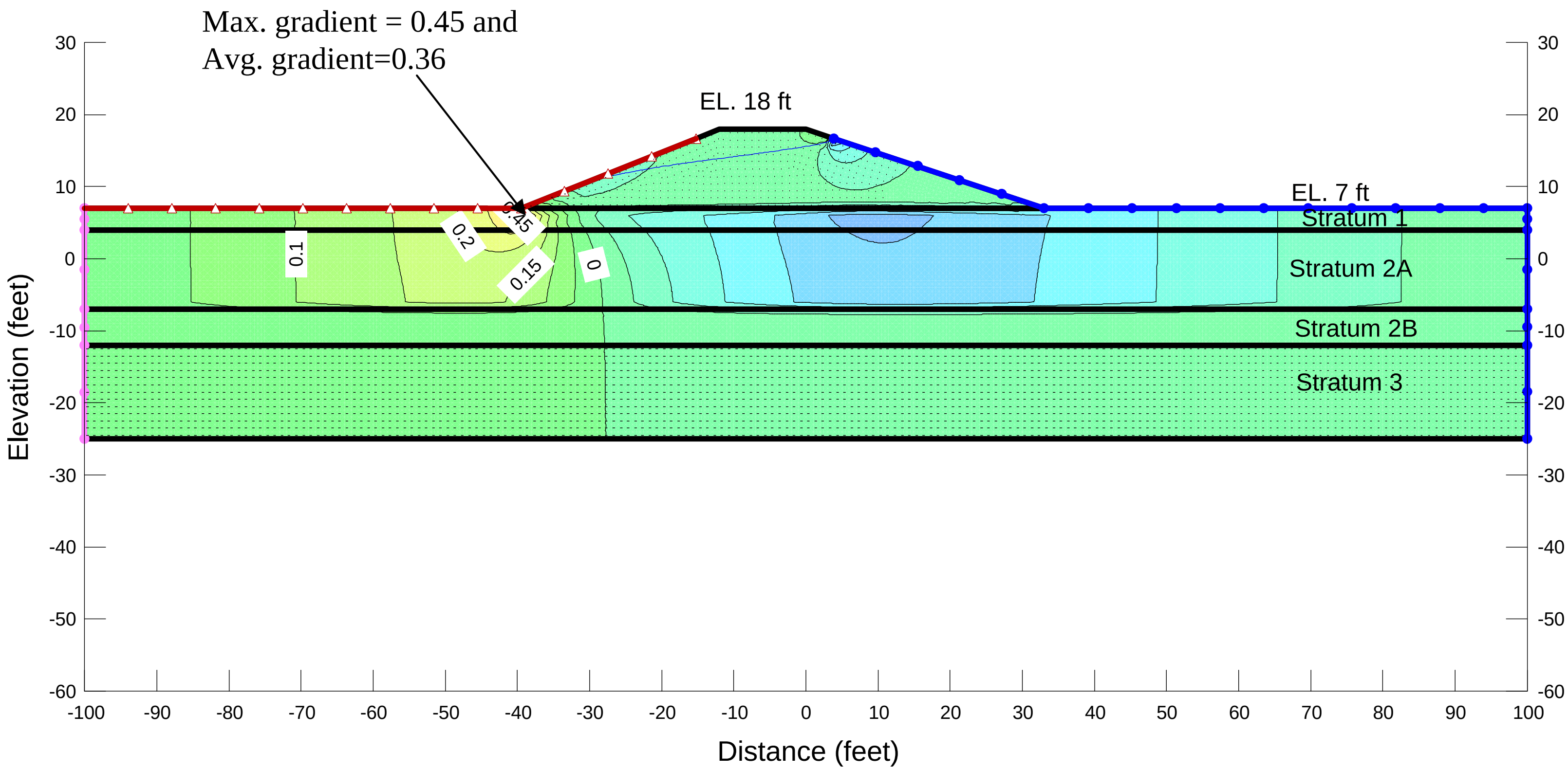

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Figure A-16

Job No. 33760911

Vertical Gradient Contours

URS

Fisher Slough Restoration Project
Skagit County, Washington

APPENDIX B - Selected Results of Stability Analyses

Table B3: Summary of End of Construction Condition Factor of Safety (FOS)

Section	Max. Levee Height (ft) [Crest EL. (ft)]	Water Level EL. (ft)		FOS		Figure No
		Fisher Slough Side	Ditch/Smith Field Side	Fisher Slough Side	Ditch/Smith Field Side	
parallel to Pioneer Highway near AB-1[a]	9 [15]	1	1	1.79	1.39	B-1
parallel to Pioneer Highway near B-1[a]	9 [15]	1	1	1.79	1.40	B-2
along the abandoned railroad embankment near B-2	12 [18]	1	1	1.36	1.33	B-3
near east end of levee between GW-1 and B-4	11 [18]	1	1	1.39	1.44	B-4

[a] with geogrid

Table B4: Summary of Long Term Condition Factor of Safety (FOS)

Section	Water Level EL. (ft)		FOS		Figure No
	Fisher Slough Side	Ditch/Smith Field Side	Fisher Slough Side	Ditch/Smith Field Side	
parallel to Pioneer Highway near AB-1[a]	16.7	6	3.35	1.40	B-5
	6	16.7	1.64	2.66	B-6
parallel to Pioneer Highway near B-1[a]	16.7	6	3.44	1.45	B-7
	6	16.7	1.68	2.72	B-8
along the abandoned railroad embankment near B-2	16.7	6	3.29	1.52	B-9
	6	16.7	1.54	3.13	B-10
near east end of levee between GW-1 and B-4	16.7	7	3.14	1.57	B-11
	7	16.7	1.55	3.28	B-12

[a] with geogrid

Table B5: Summary of Rapid Drawdown Condition Factor of Safety (FOS)

Section	Water Level EL. (ft)		FOS		Figure No
	Fisher Slough Side	Ditch/Smith Field Side	Fisher Slough Side	Ditch/Smith Field Side	
parallel to Pioneer Highway near AB-1[a]	16.7 to 10.7	6	2.14	1.46	B-13
	6	16.7 to 10.7	1.70	1.84	B-14
parallel to Pioneer Highway near B-1[a]	16.7 to 10.7	6	2.21	1.51	B-15
	6	16.7 to 10.7	1.75	1.91	B-16
along the abandoned railroad embankment near B-2	16.7 to 10.7	6	1.99	1.50	B-17
	6	16.7 to 10.7	1.56	1.94	B-18
near east end of levee between GW-1 and B-4	16.7 to 10.7	7	1.94	1.66	B-19
	7	16.7 to 10.7	1.62	2.00	B-20

[a] with geogrid

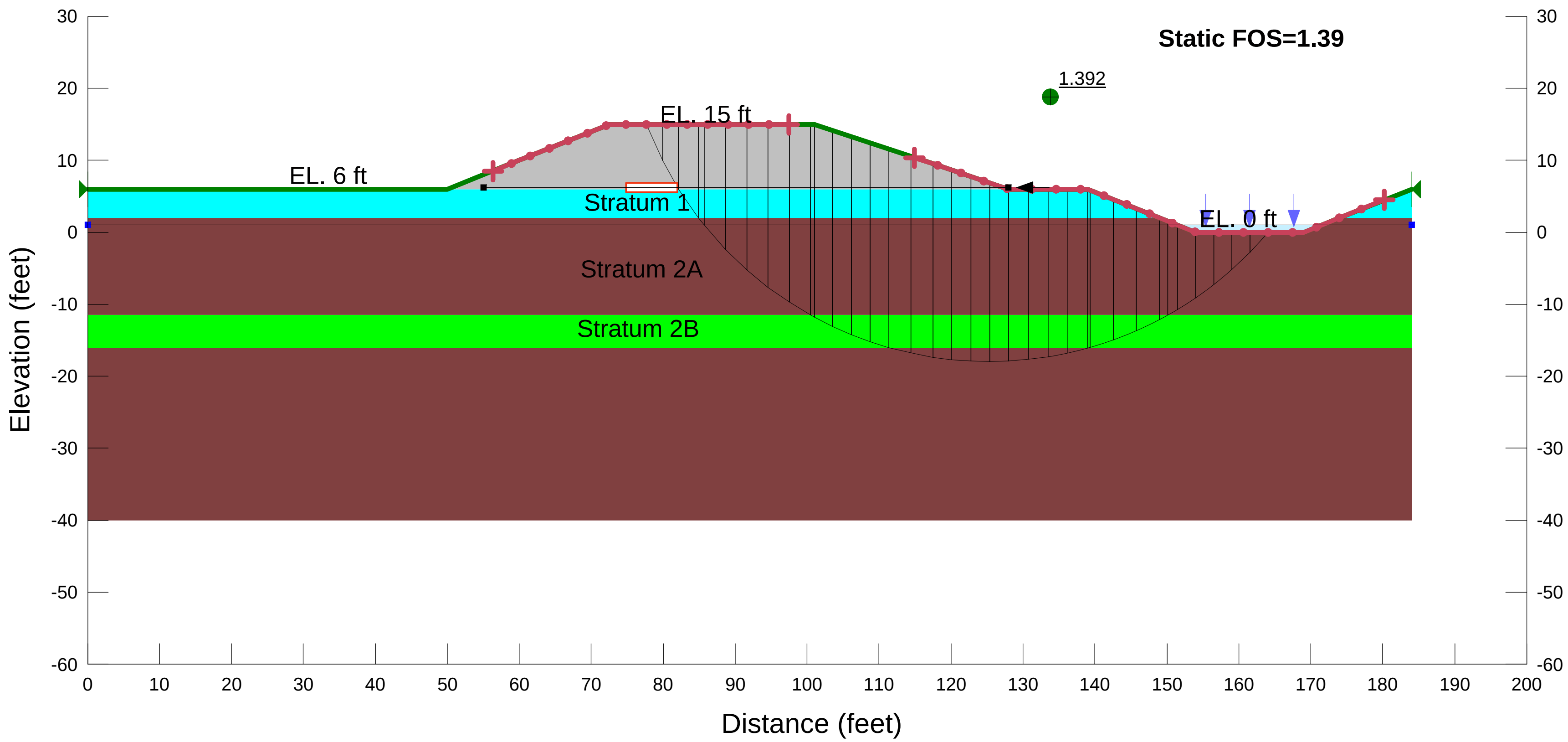
Table B6: Summary of Post-Shaking Factor of Safety (FOS)-15% reduction in strength for Stratum 2A

Section	Water Level EL. (ft)		FOS		Figure No
	Fisher Slough Side	Ditch/Smith Field Side	Fisher Slough Side	Ditch/Smith Field Side	
parallel to Pioneer Highway near AB-1[a]	9.5	6	1.66	1.19	B-21
	6	9.5	1.37	1.45	B-22
parallel to Pioneer Highway near B-1[a]	9.5	6	1.18	0.86	B-23
	6	9.5	0.98	1.05	B-24
along the abandoned railroad embankment near B-2	9.5	6	1.80	1.47	B-25
	6	9.5	1.52	1.73	B-26
near east end of levee between GW-1 and B-4	9.5	7	1.40	1.25	B-27
	7	9.5	1.25	1.39	B-28

[a] with geogrid

For S_r=165 psf

Name: Stratum 2B Model: S=f(depth) Unit Weight: 100 C-Top of Layer: 310 C-Rate of Increase: 12.4 Limiting C: 1000 Piezometric Line: 1
Name: Stratum 2A Model: Mohr-Coulomb Unit Weight: 95 Cohesion: 250 Phi: 0 Piezometric Line: 1
Name: Stratum 1 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 500 Phi: 0 Piezometric Line: 1
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36 Piezometric Line: 1
Name: Stratum 2A-Bottom Model: S=f(depth) Unit Weight: 95 C-Top of Layer: 365 C-Rate of Increase: 10.75 Limiting C: 1000 Piezometric Line: 1



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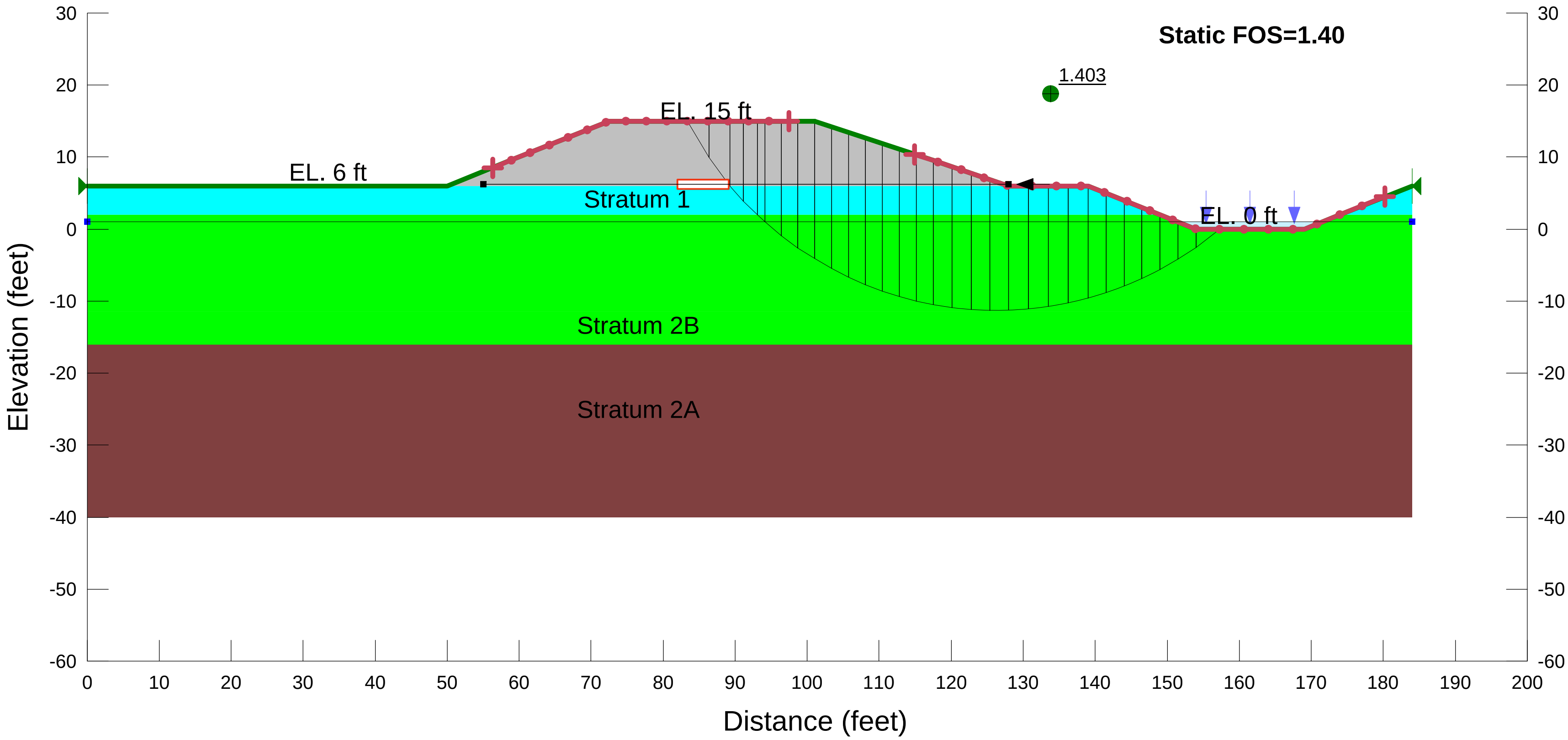
Job No. 33760911

Figure B-1

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B-Bottom Model: S=f(depth) Unit Weight: 100 C-Top of Layer: 330 C-Rate of Increase: 12.4 Limiting C: 1000 Piezometric Line: 1
Name: Stratum 2B Model: Mohr-Coulomb Unit Weight: 100 Cohesion: 250 Phi: 0 Piezometric Line: 1
Name: Stratum 1 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 500 Phi: 0 Piezometric Line: 1
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36 Piezometric Line: 1
Name: Stratum 2A Model: S=f(depth) Unit Weight: 95 C-Top of Layer: 385 C-Rate of Increase: 10.75 Limiting C: 1000 Piezometric Line: 1



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Job No. 33760911

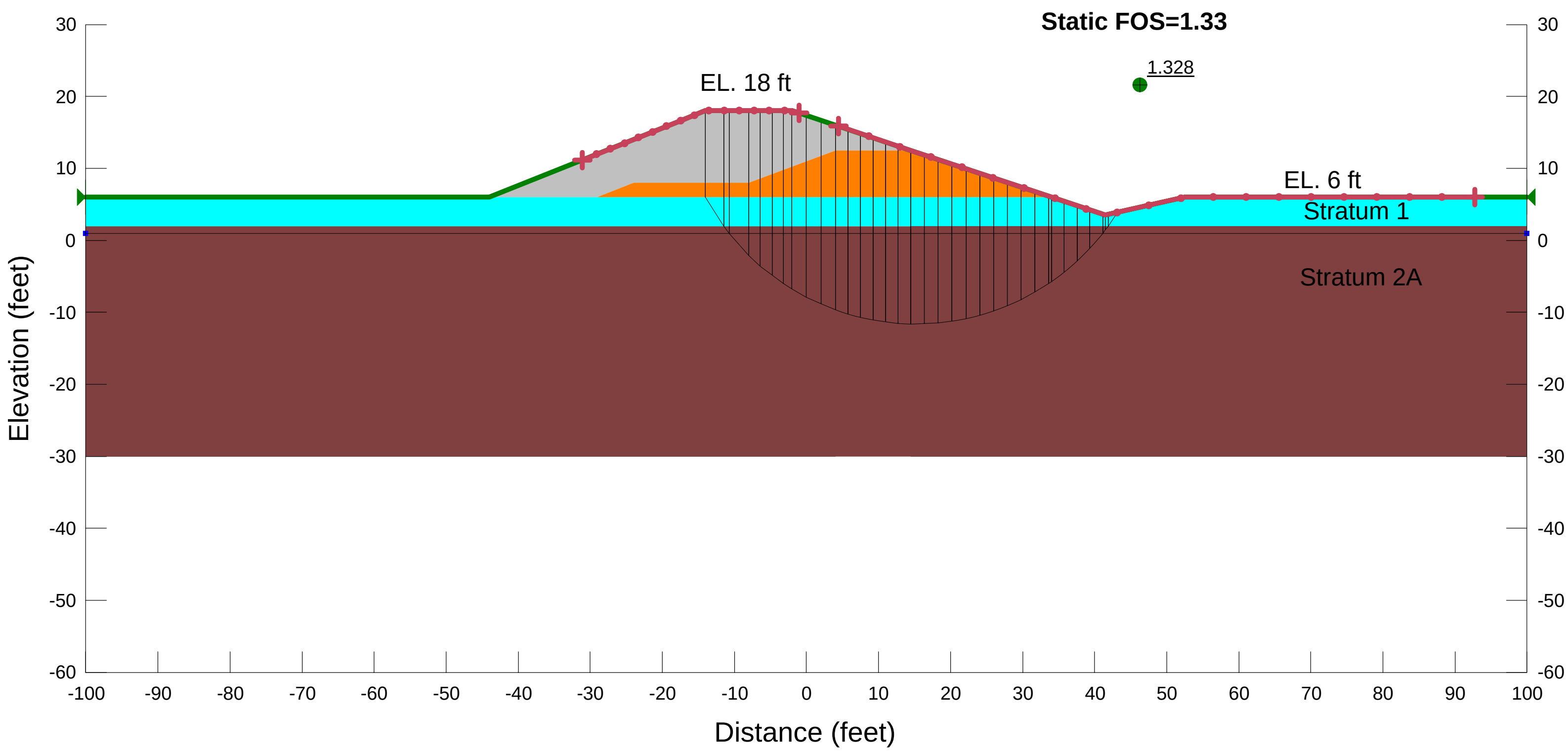
Figure B-2

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 2A Model: Mohr-Coulomb Unit Weight: 95 Cohesion: 250 Phi: 0 Piezometric Line: 1
Name: Stratum 1 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 500 Phi: 0 Piezometric Line: 1
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36 Piezometric Line: 1
Name: Existing Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 2000 Phi: 0 Piezometric Line: 1
Name: Stratum 2A-Bottom Model: S=f(depth) Unit Weight: 95 C-Top of Layer: 250 C-Rate of Increase: 10.758 Limiting C: 0 Piezometric Line: 1
Name: Stratum 2A-Middle Model: S=f(depth) Unit Weight: 95 C-Top of Layer: 400 C-Rate of Increase: 10.758 Limiting C: 0 Piezometric Line: 1



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Job No. 33760911

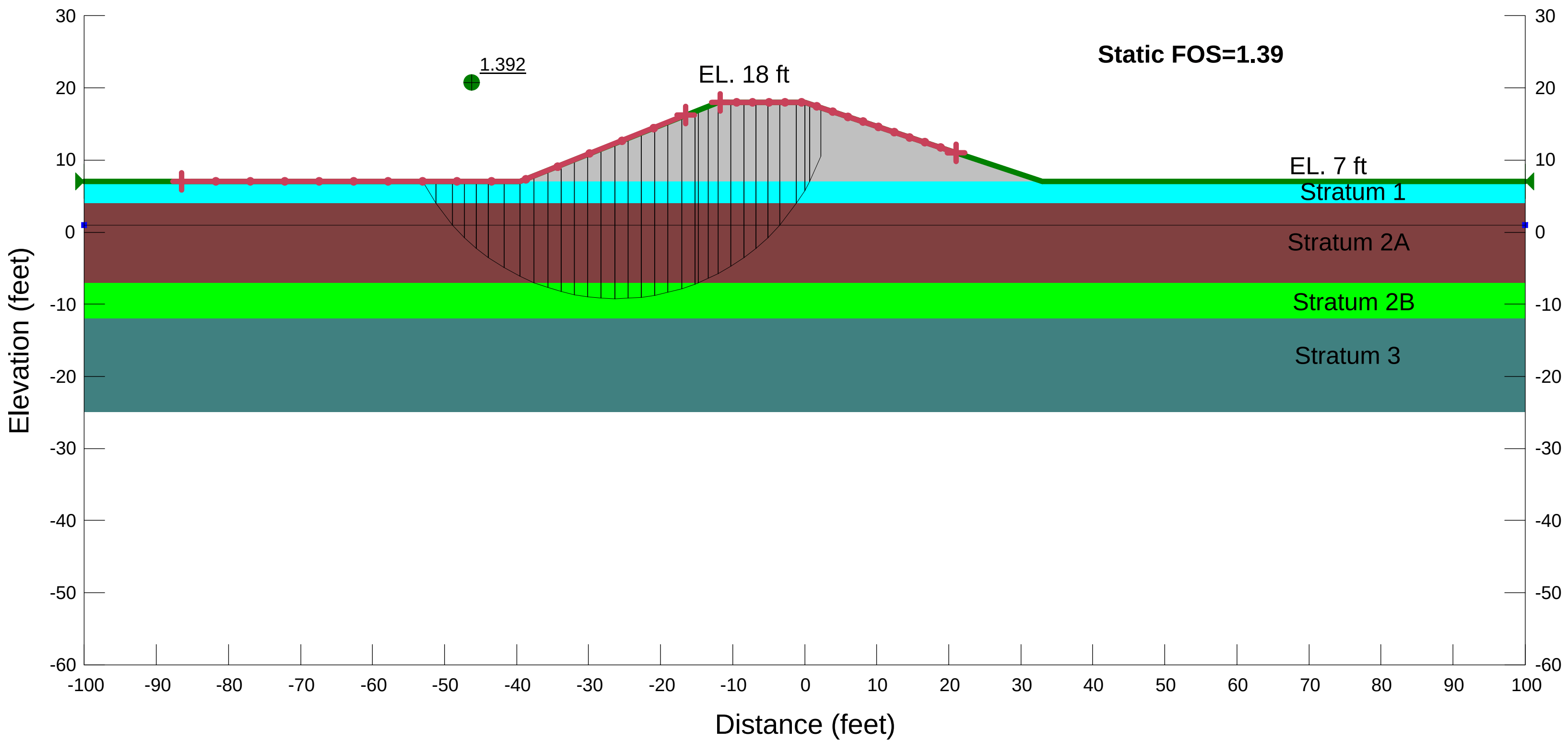
Figure B-3

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station 38+00

Name: Stratum 2B   Model: S=f(depth)   Unit Weight: 100   C-Top of Layer: 285   C-Rate of Increase: 12.4   Limiting C: 1000   Piezometric Line: 1
Name: Stratum 2A   Model: Mohr-Coulomb   Unit Weight: 95   Cohesion: 250   Phi: 0   Piezometric Line: 1
Name: Stratum 1   Model: Mohr-Coulomb   Unit Weight: 110   Cohesion: 500   Phi: 0   Piezometric Line: 1
Name: Fill   Model: Mohr-Coulomb   Unit Weight: 120   Cohesion: 500   Phi: 36   Piezometric Line: 1
Name: Stratum 3   Model: Mohr-Coulomb   Unit Weight: 110   Cohesion: 0   Phi: 28   Piezometric Line: 1
Name: Stratum 2A-Bottom   Model: S=f(depth)   Unit Weight: 95   C-Top of Layer: 250   C-Rate of Increase: 10.758   Limiting C: 1000   Piezometric Line: 1



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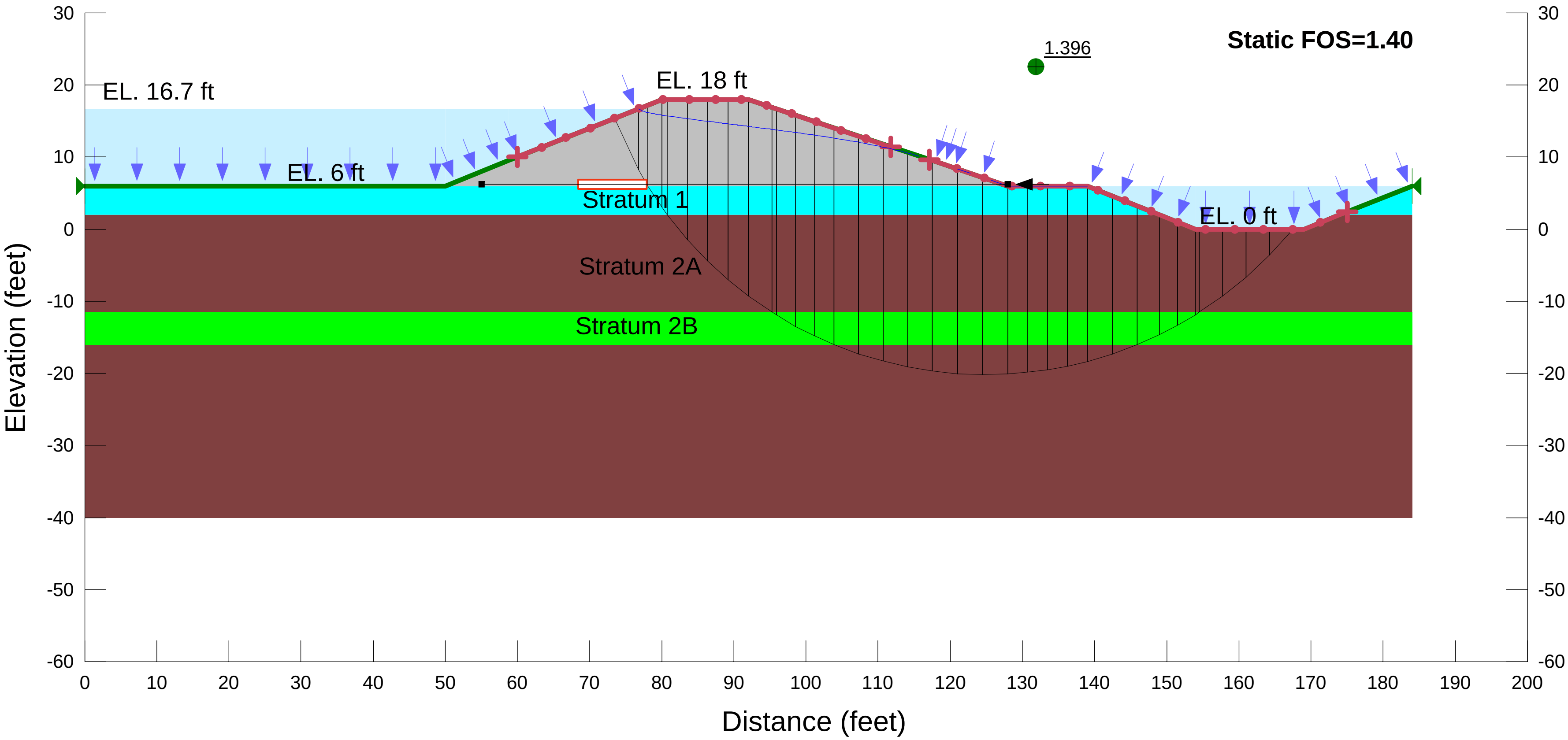
Job No. 33760911

Figure B-4

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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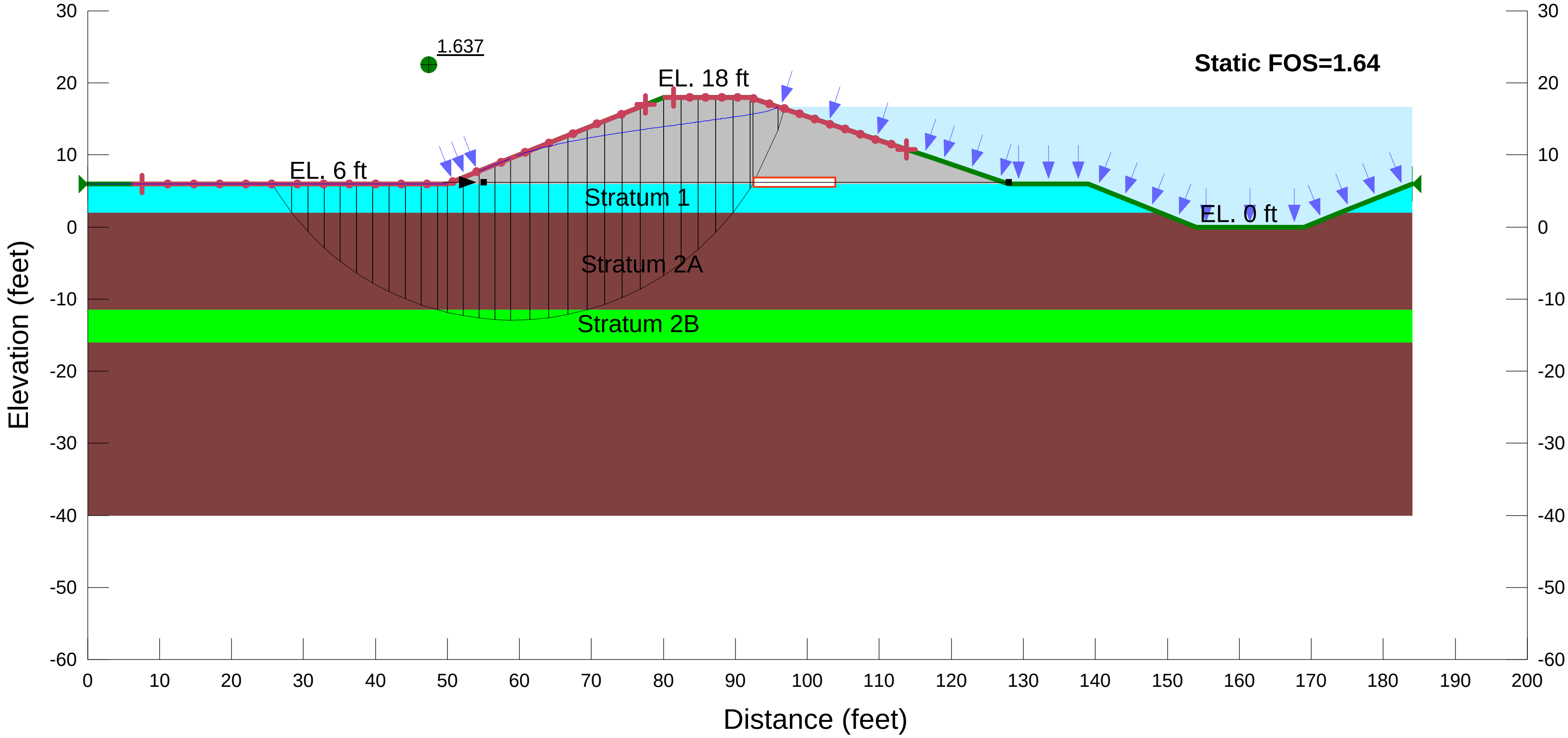
Job No. 33760911

Figure B-5

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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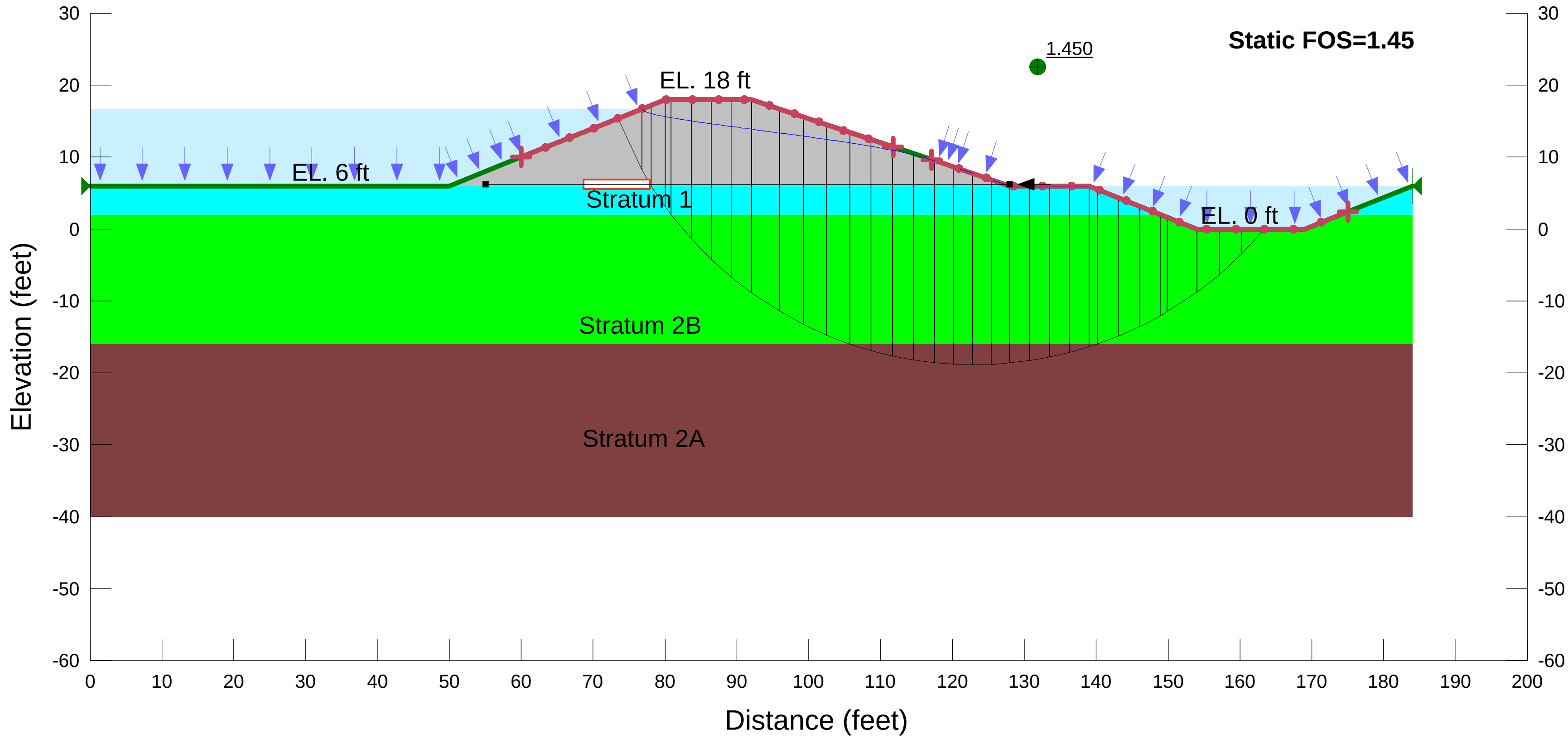
Job No. 33760911

Figure B-6

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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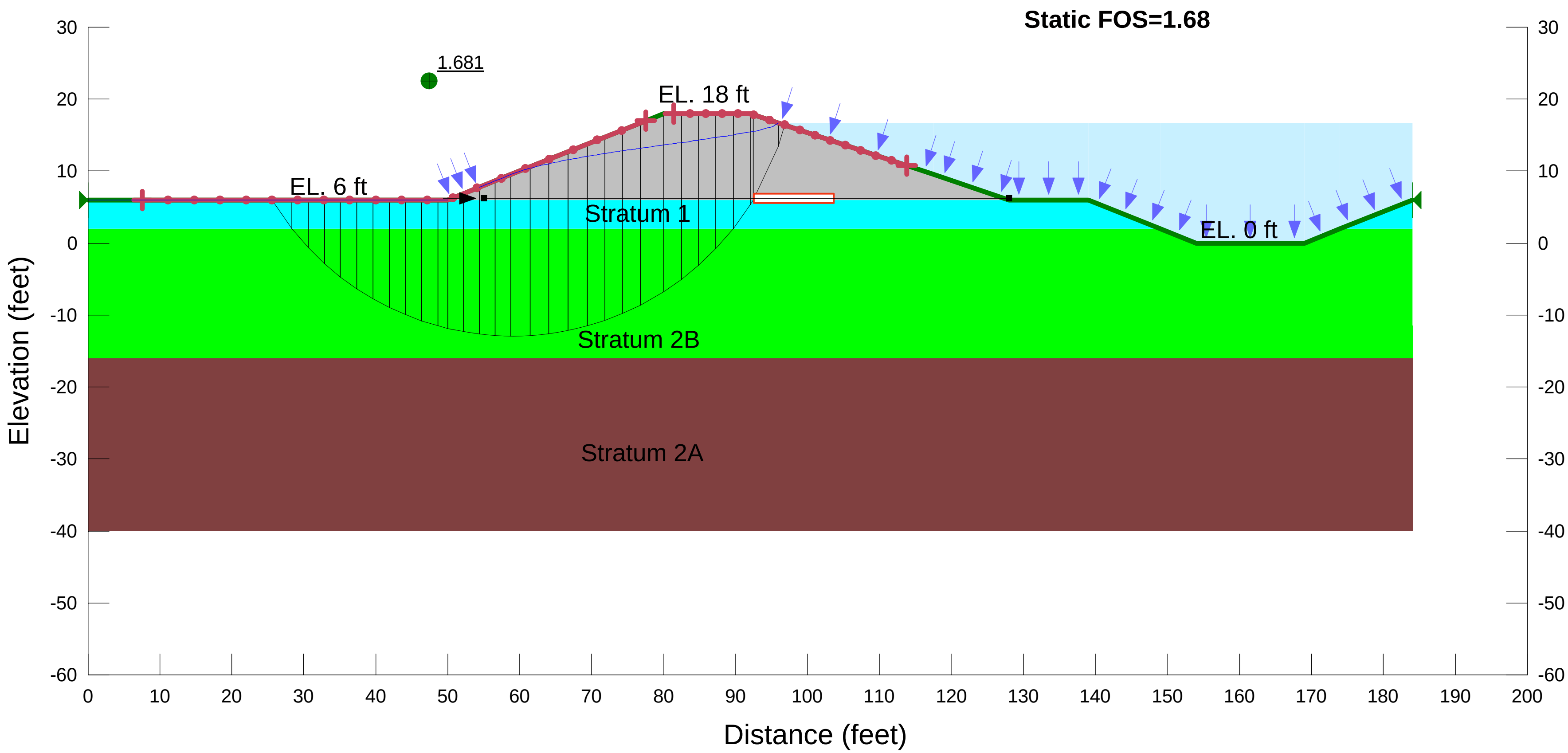
Job No. 33760911

Figure B-7

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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Job No. 33760911

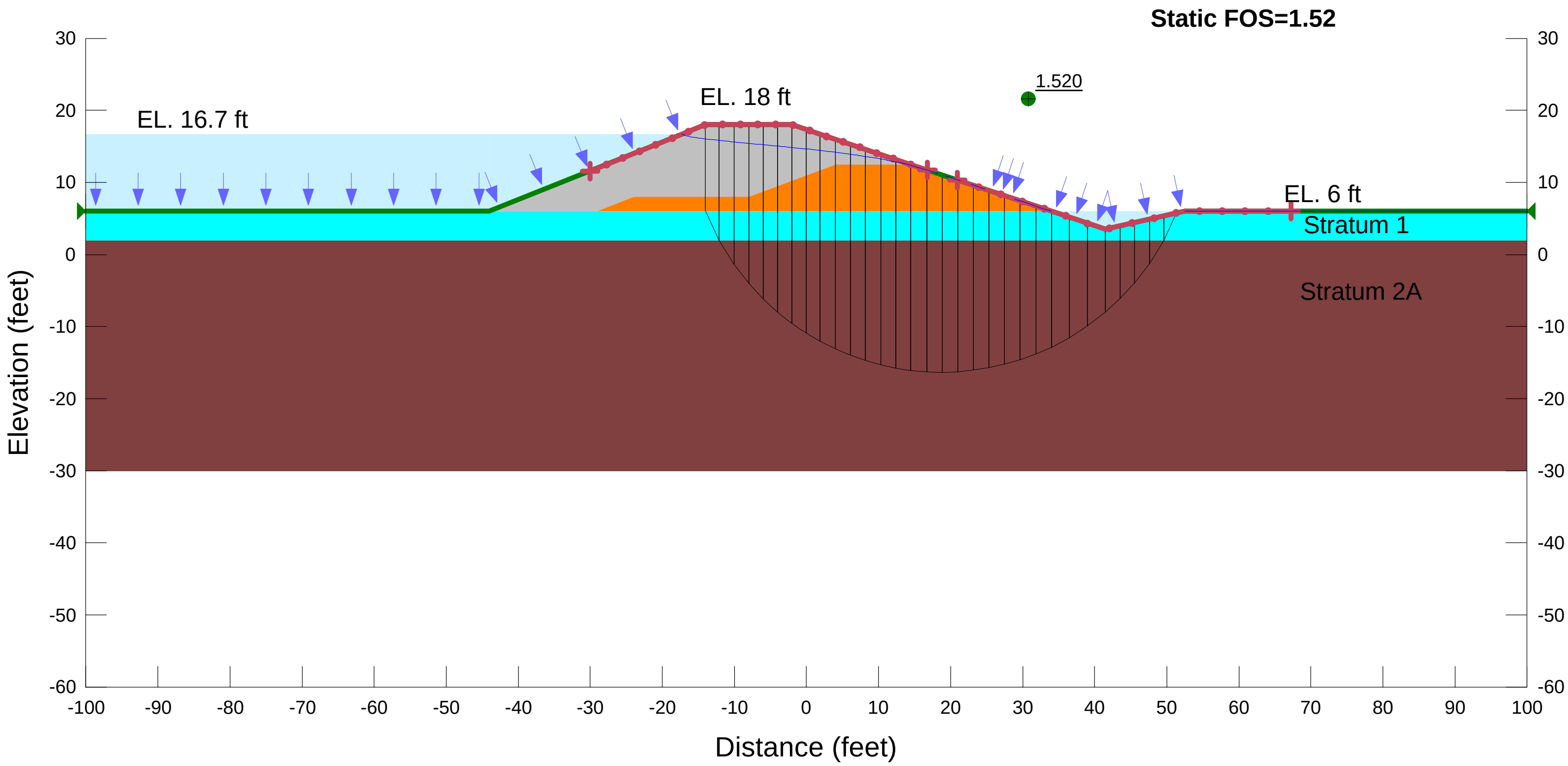
Figure B-8

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Existing Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 2000 Phi: 0



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Job No. 33760911

Figure B-9

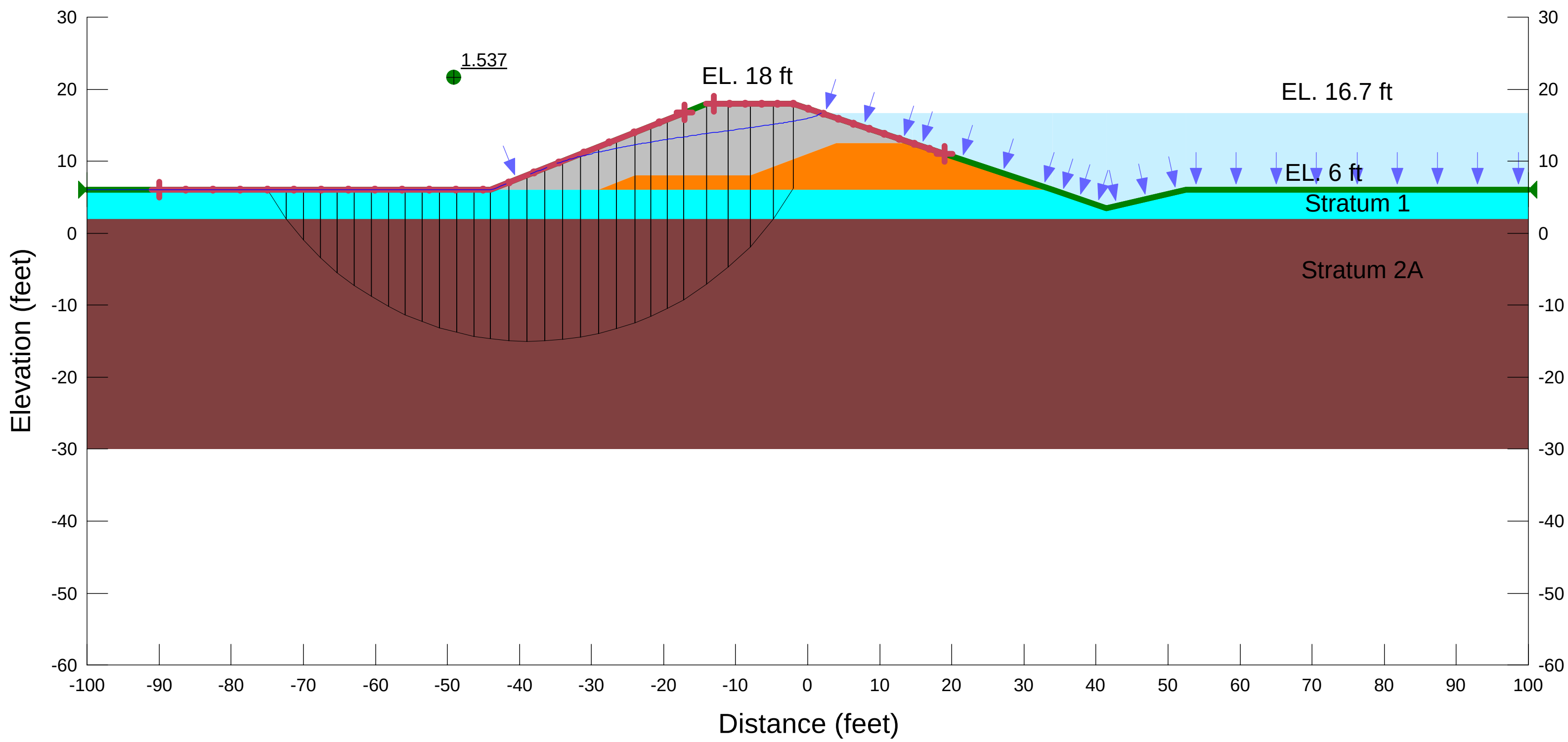
URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Existing Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 2000 Phi: 0

Static FOS=1.54



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Job No. 33760911

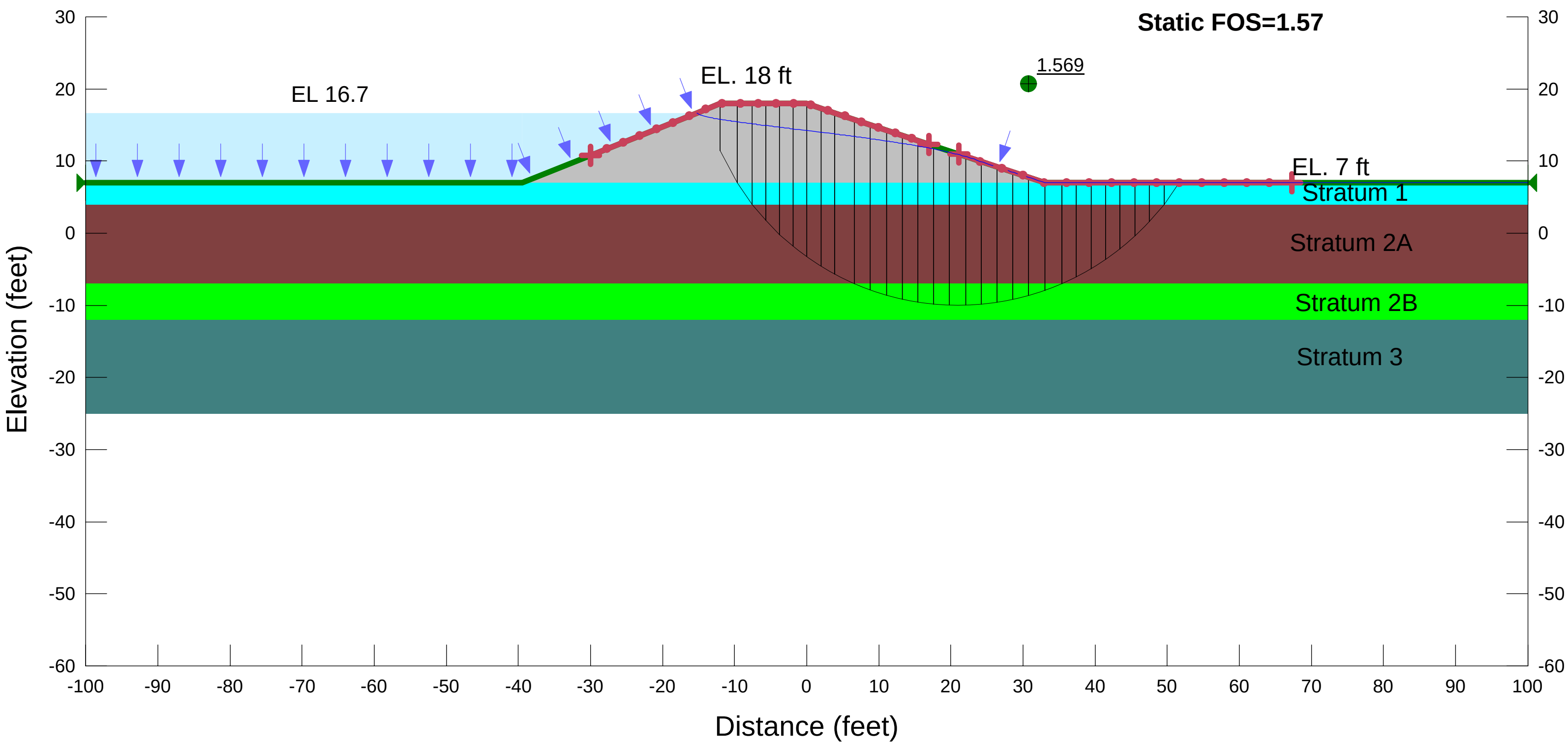
Figure B-10

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 38+00

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 3 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 0 Phi: 28



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Job No. 33760911

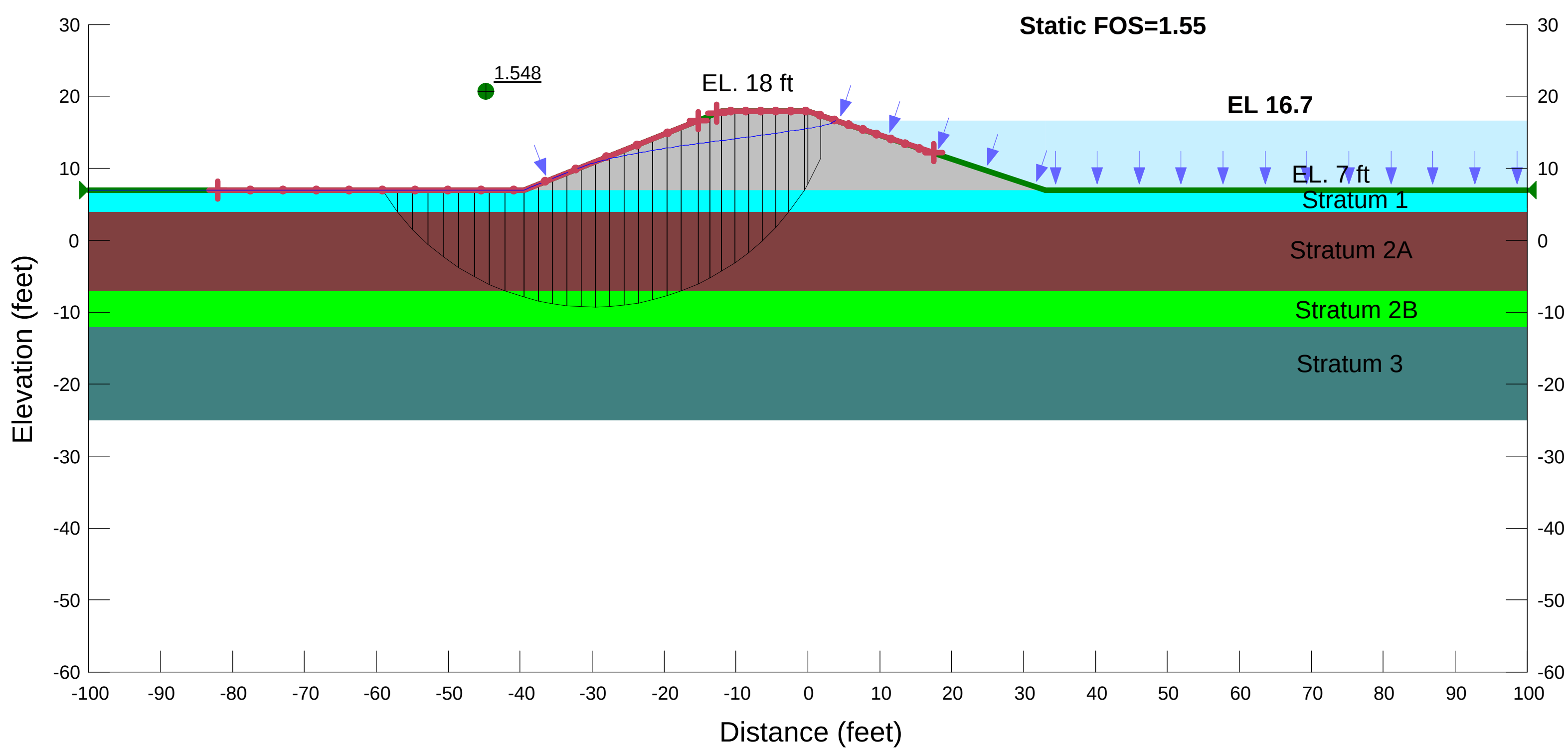
Figure B-11

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 38+00

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 3 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 0 Phi: 28



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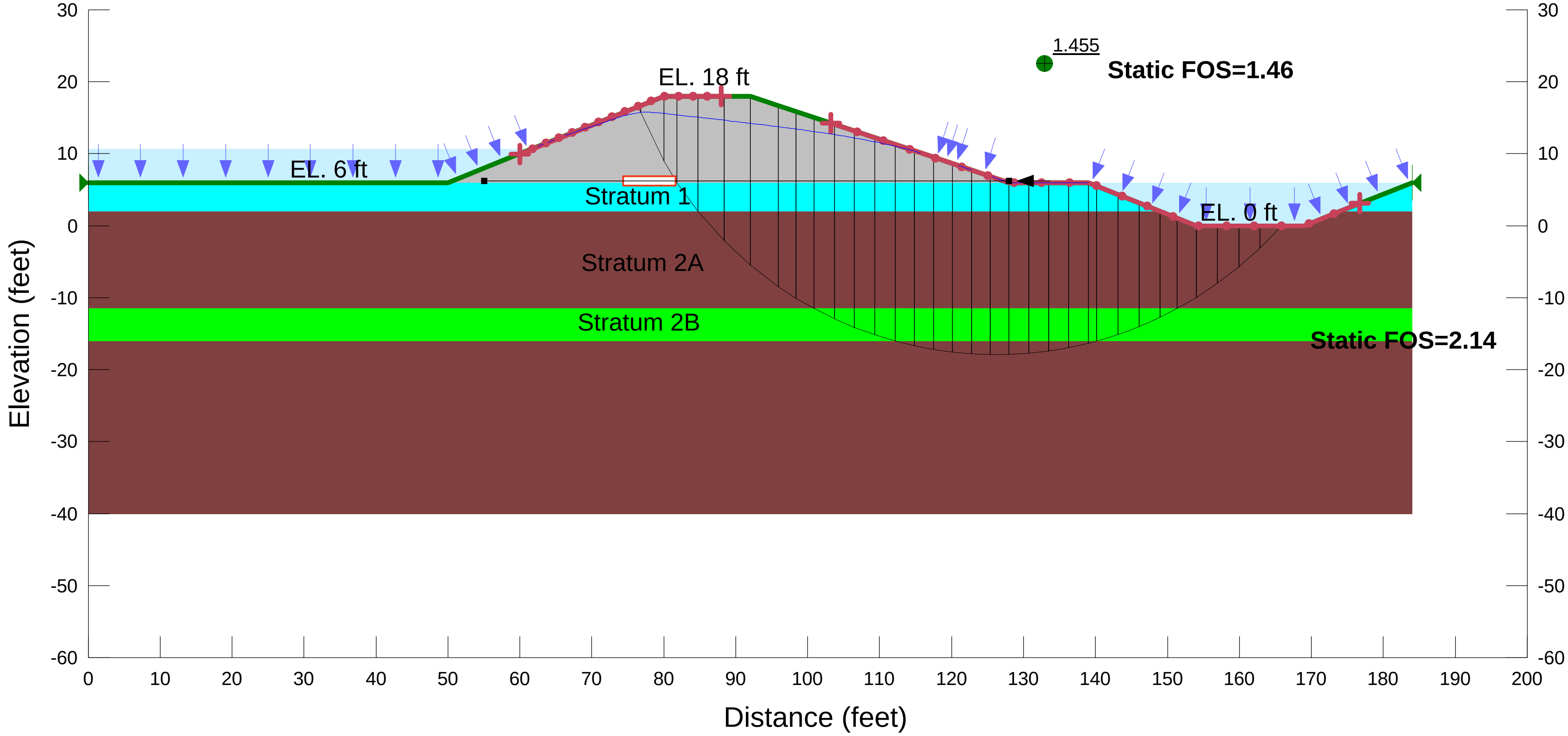
Job No. 33760911

Figure B-12

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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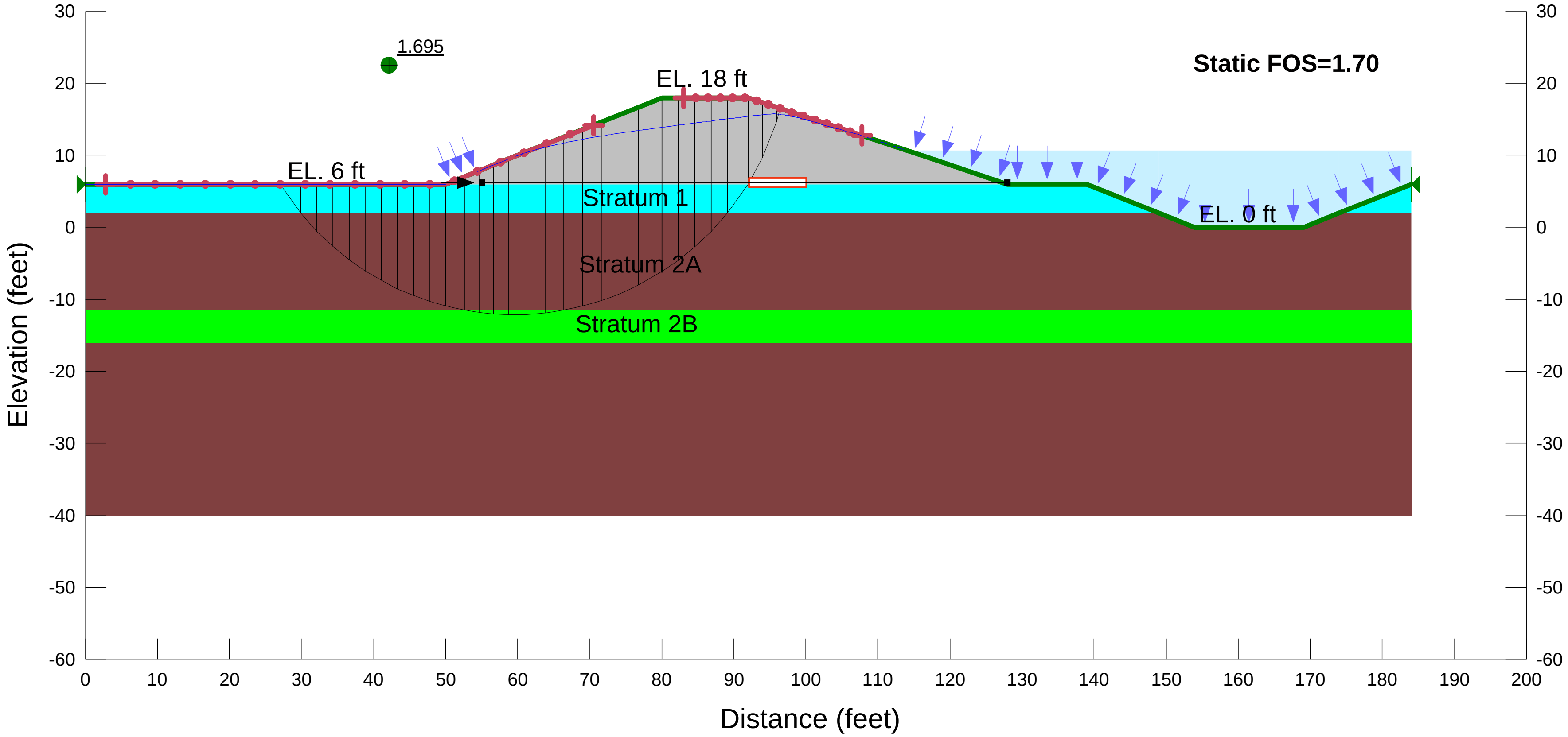
Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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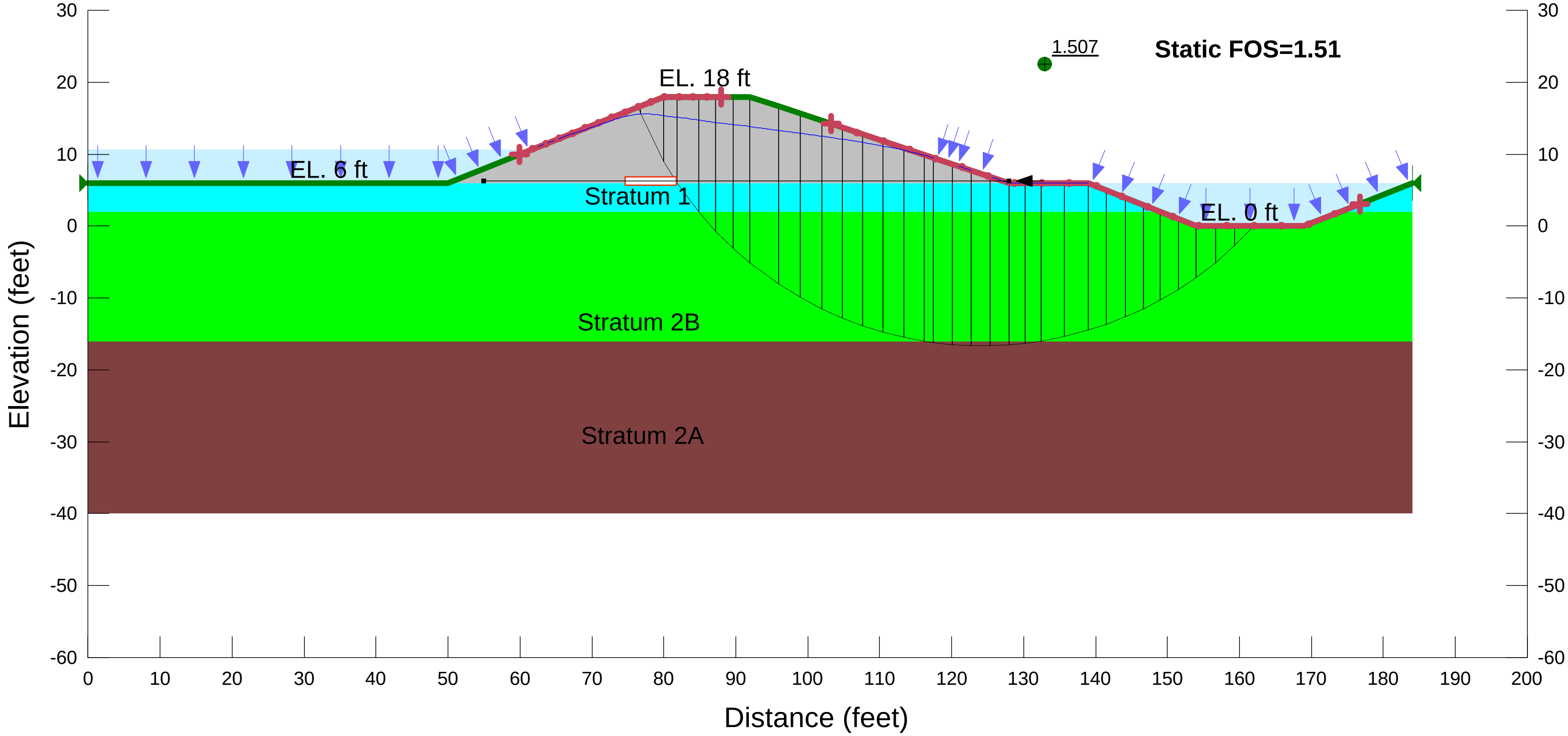
Job No. 33760911

Figure B-14

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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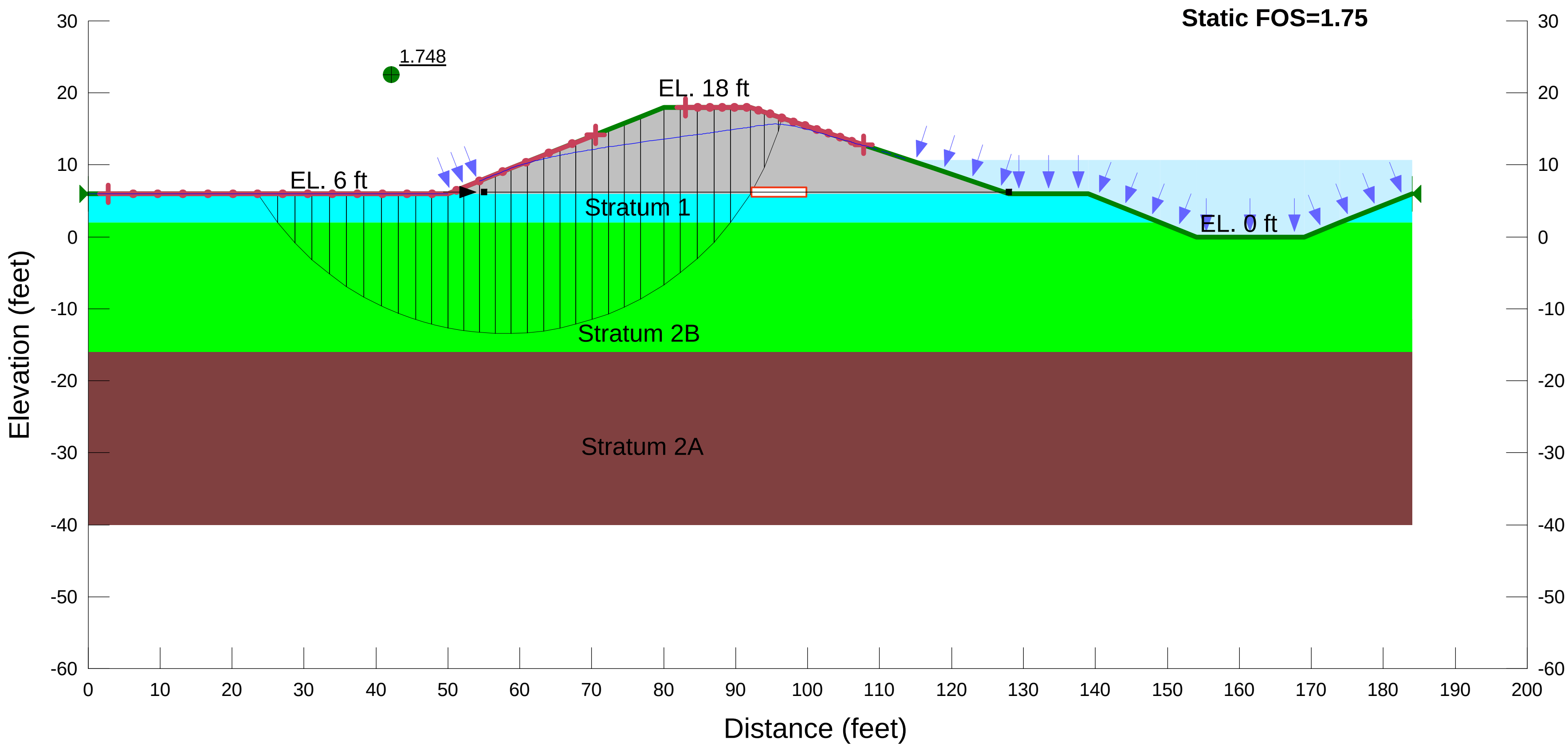
Job No. 33760911

Figure B-15

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36



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Job No. 33760911

Figure B-16

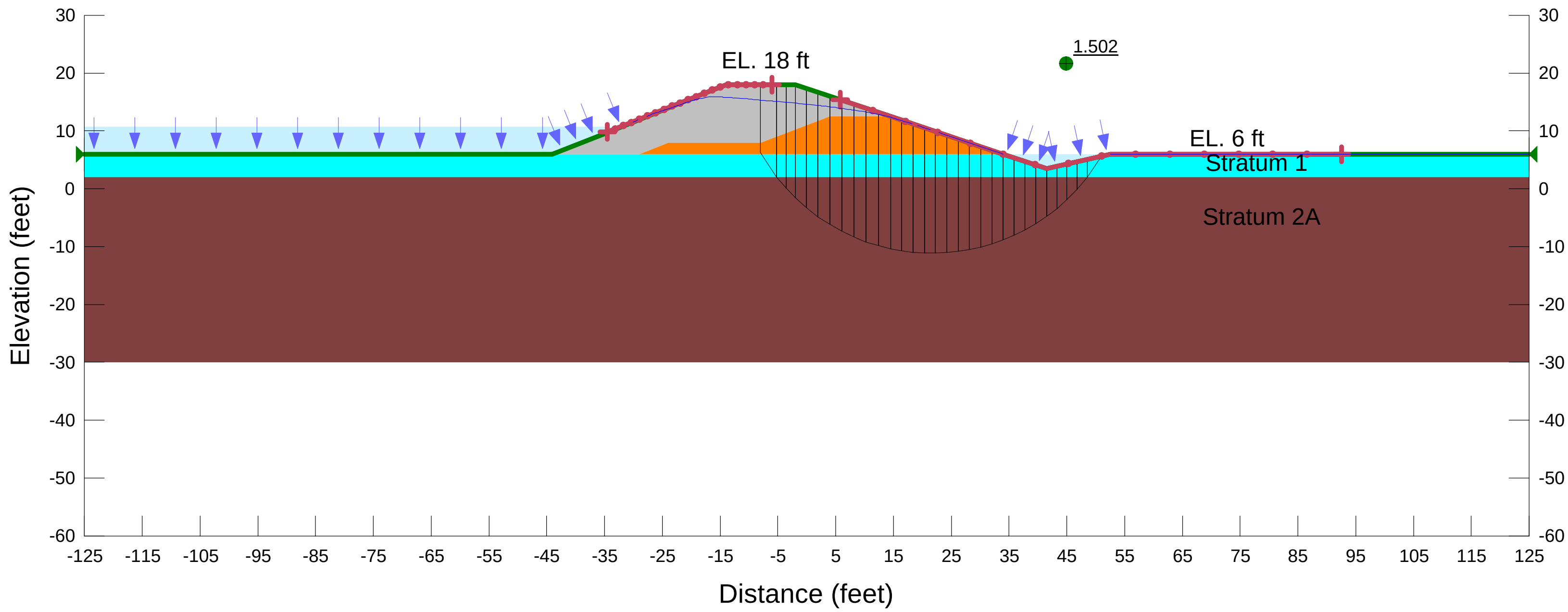
URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 2A   Model: S=f(overburden)   Unit Weight: 95   Tau/Sigma Ratio: 0.33   Minimum Strength: 250
Name: Stratum 1   Model: S=f(overburden)   Unit Weight: 110   Tau/Sigma Ratio: 0.33   Minimum Strength: 500
Name: Fill   Model: Mohr-Coulomb   Unit Weight: 120   Cohesion: 500   Phi: 36
Name: Existing Fill   Model: Mohr-Coulomb   Unit Weight: 120   Cohesion: 2000   Phi: 0

Static FOS=1.50



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Job No. 33760911

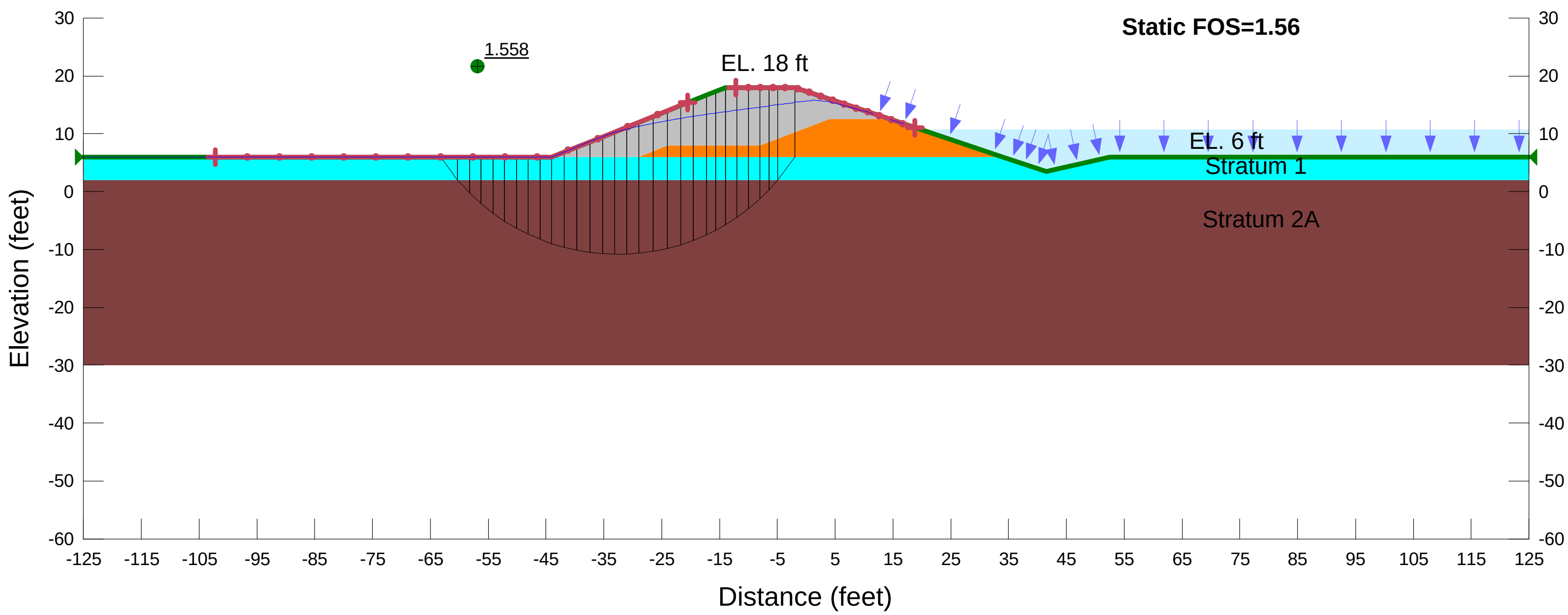
Figure B-17

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Existing Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 2000 Phi: 0



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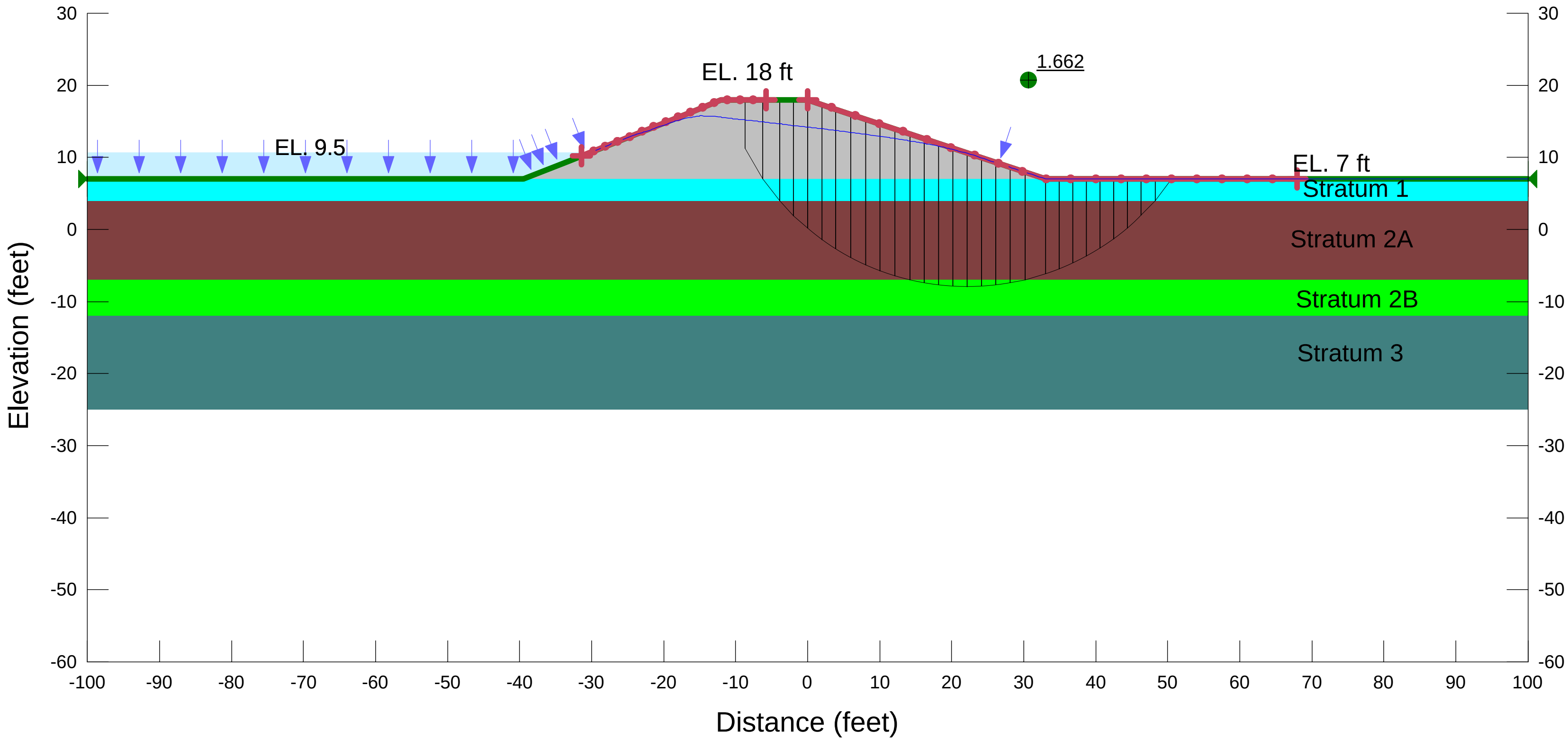
Station: 38+00

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 3 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 0 Phi: 28

Static FOS=1.66



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Job No. 33760911

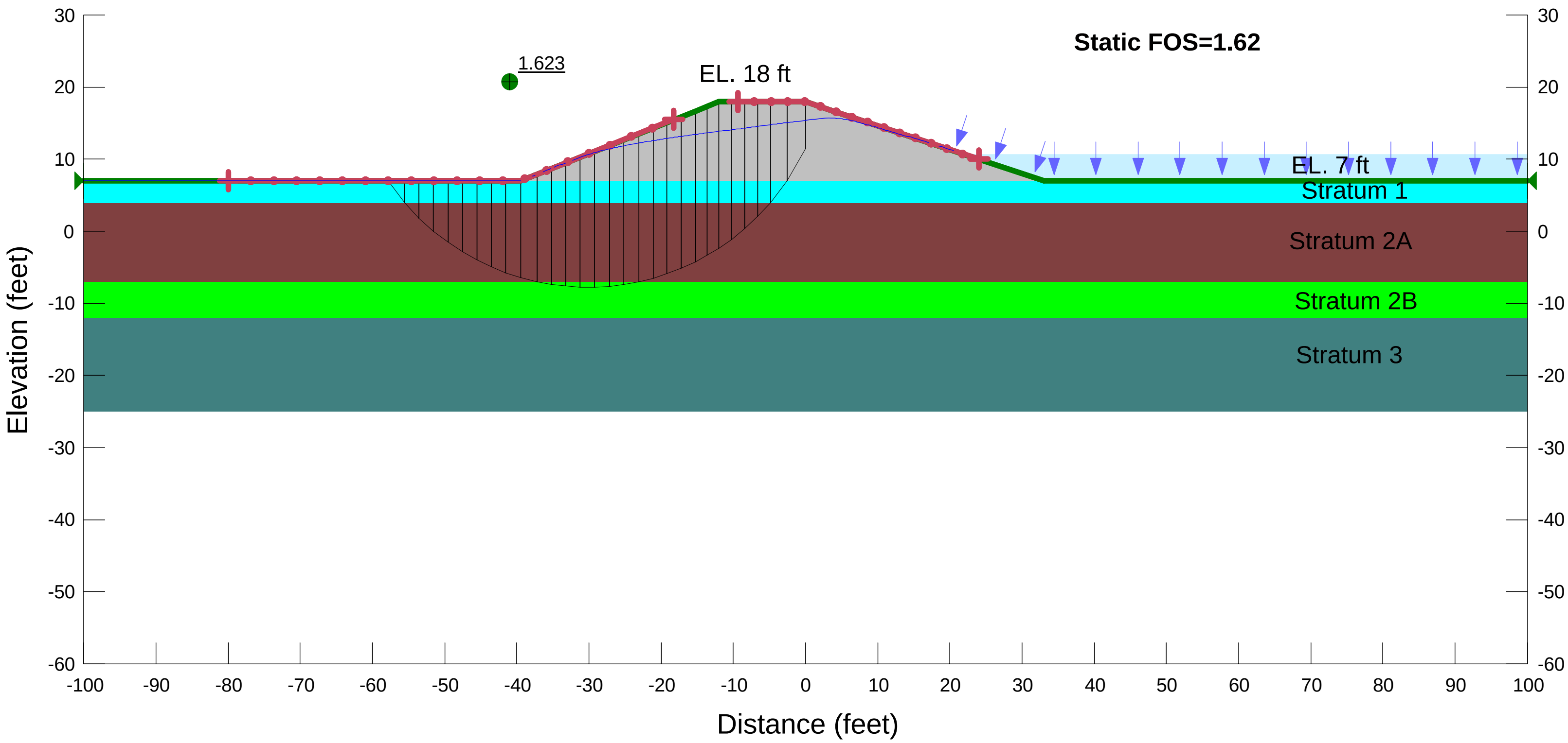
Figure B-19

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 38+00

Name: Stratum 2B Model: S=f(overburden) Unit Weight: 100 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 2A Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.33 Minimum Strength: 250
Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 3 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 0 Phi: 28



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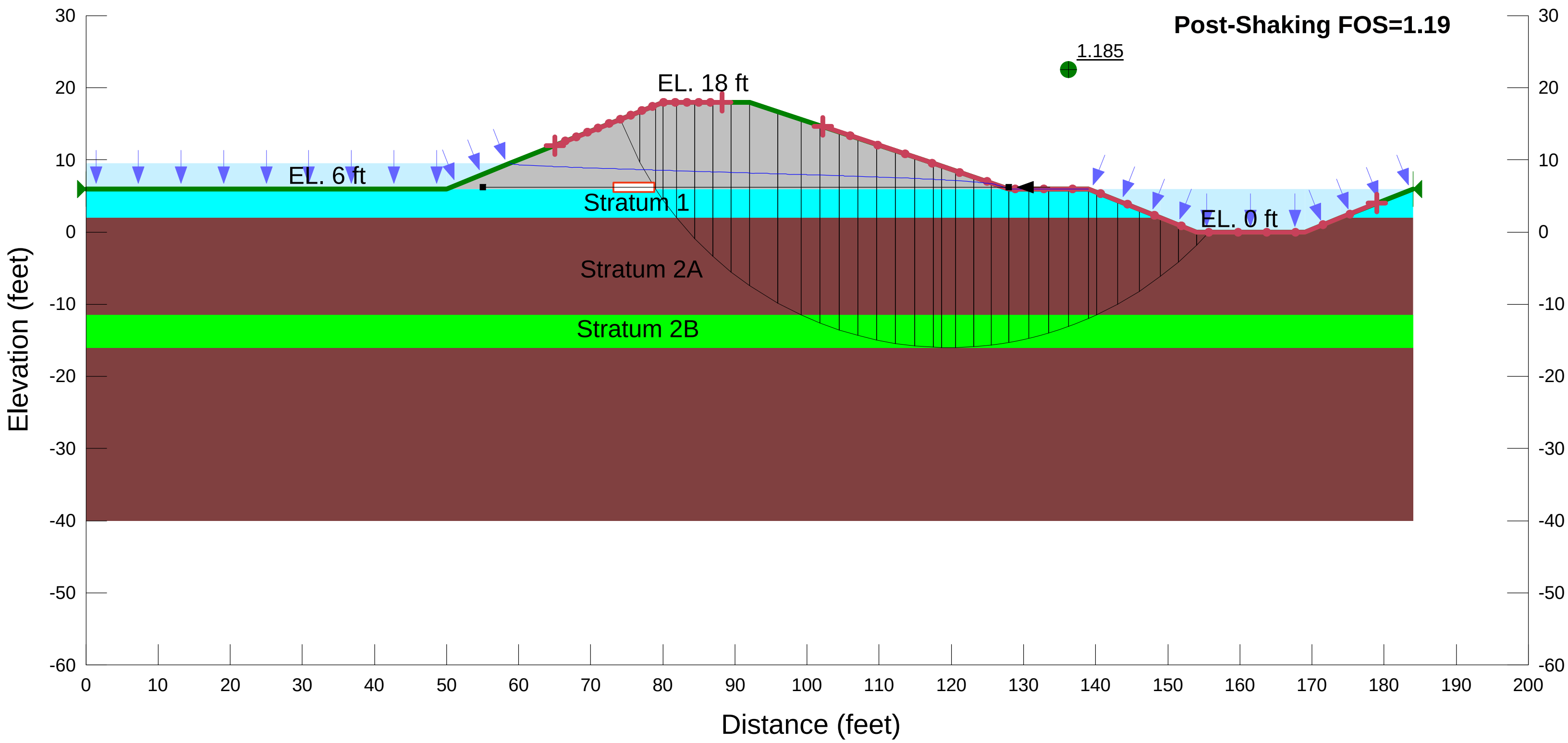
Job No. 33760911

Figure B-20

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 1   Model: S=f(overburden)   Unit Weight: 110   Tau/Sigma Ratio: 0.33   Minimum Strength: 500
Name: Fill   Model: Mohr-Coulomb   Unit Weight: 120   Cohesion: 500   Phi: 36
Name: Stratum 2A-Reduced   Model: S=f(overburden)   Unit Weight: 95   Tau/Sigma Ratio: 0.2805   Minimum Strength: 212.5
Name: Stratum 2B-Residual-sr   Model: Mohr-Coulomb   Unit Weight: 100   Cohesion: 165   Phi: 0



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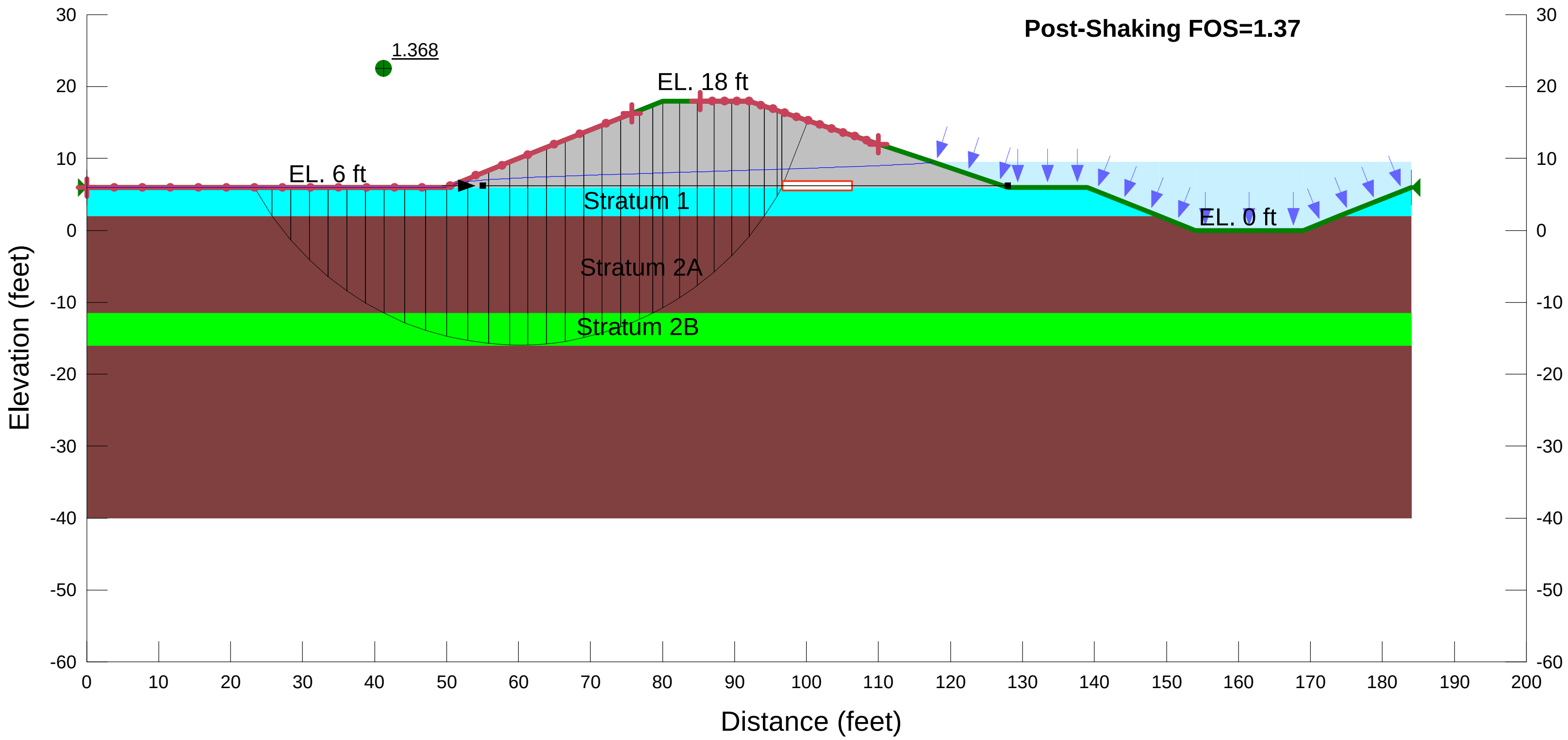
Job No. 33760911

Figure B-21

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 2A-Reduced Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.2805 Minimum Strength: 212.5
Name: Stratum 2B-Residual-sr Model: Mohr-Coulomb Unit Weight: 100 Cohesion: 165 Phi: 0



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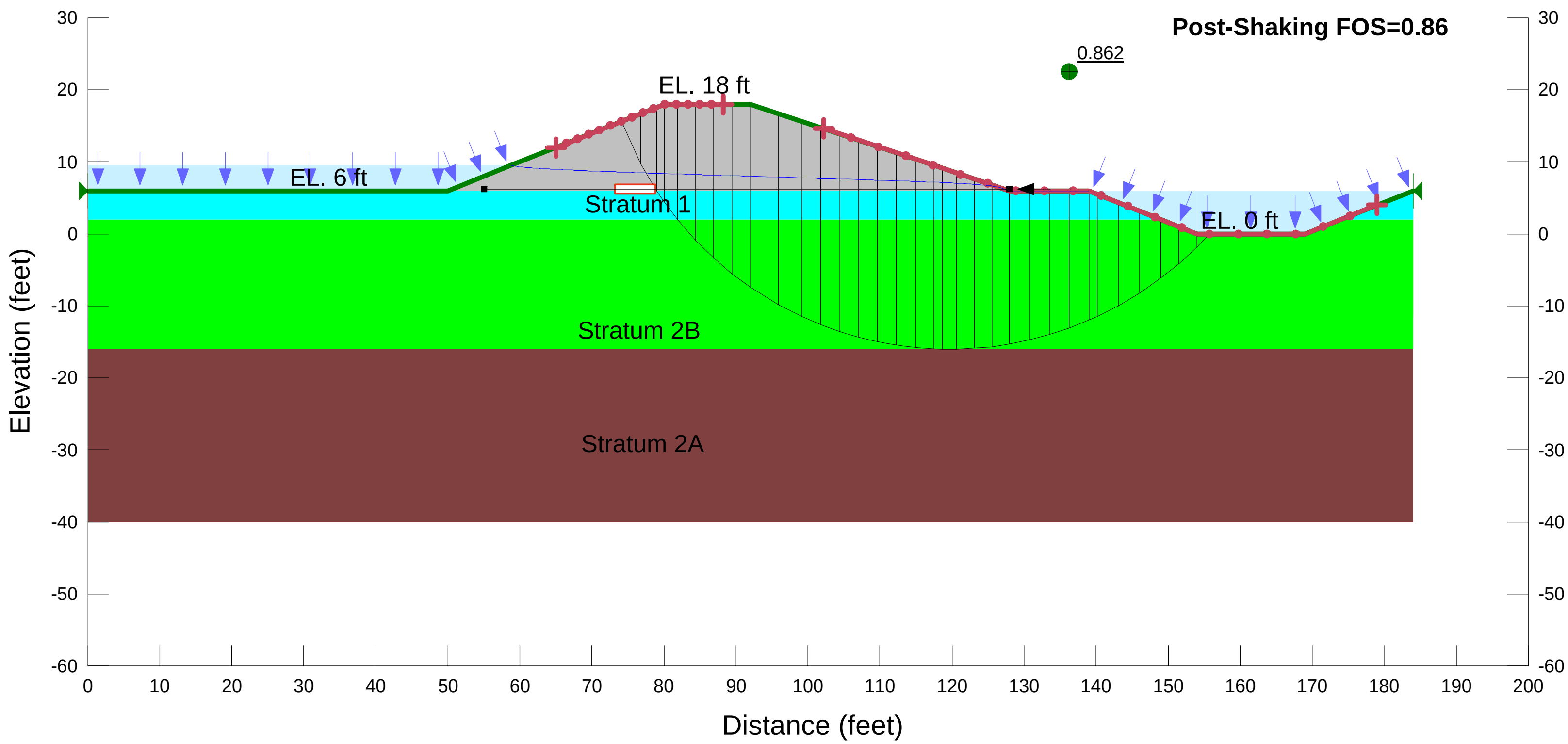
Job No. 33760911

Figure B-22

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 2B-Residua-Sr Model: Mohr-Coulomb Unit Weight: 100 Cohesion: 165 Phi: 0
Name: Stratum 2A-Reduced Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.2805 Minimum Strength: 212.5



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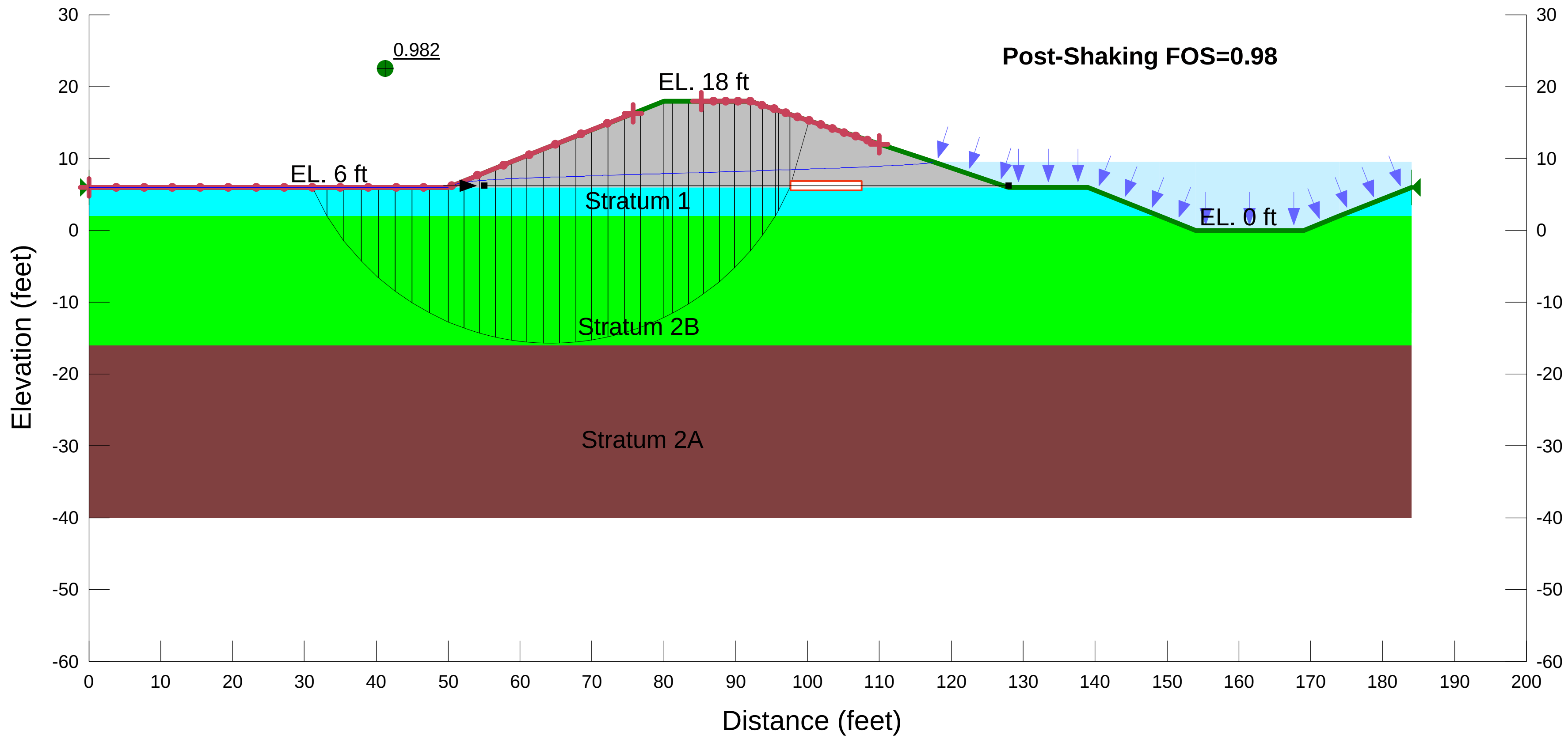
Job No. 33760911

Figure B-23

URS

Fisher Slough Restoration Project
Skagit County, Washington

Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 2B-Residua-Sr Model: Mohr-Coulomb Unit Weight: 100 Cohesion: 165 Phi: 0
Name: Stratum 2A-Reduced Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.2805 Minimum Strength: 212.5



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Job No. 33760911

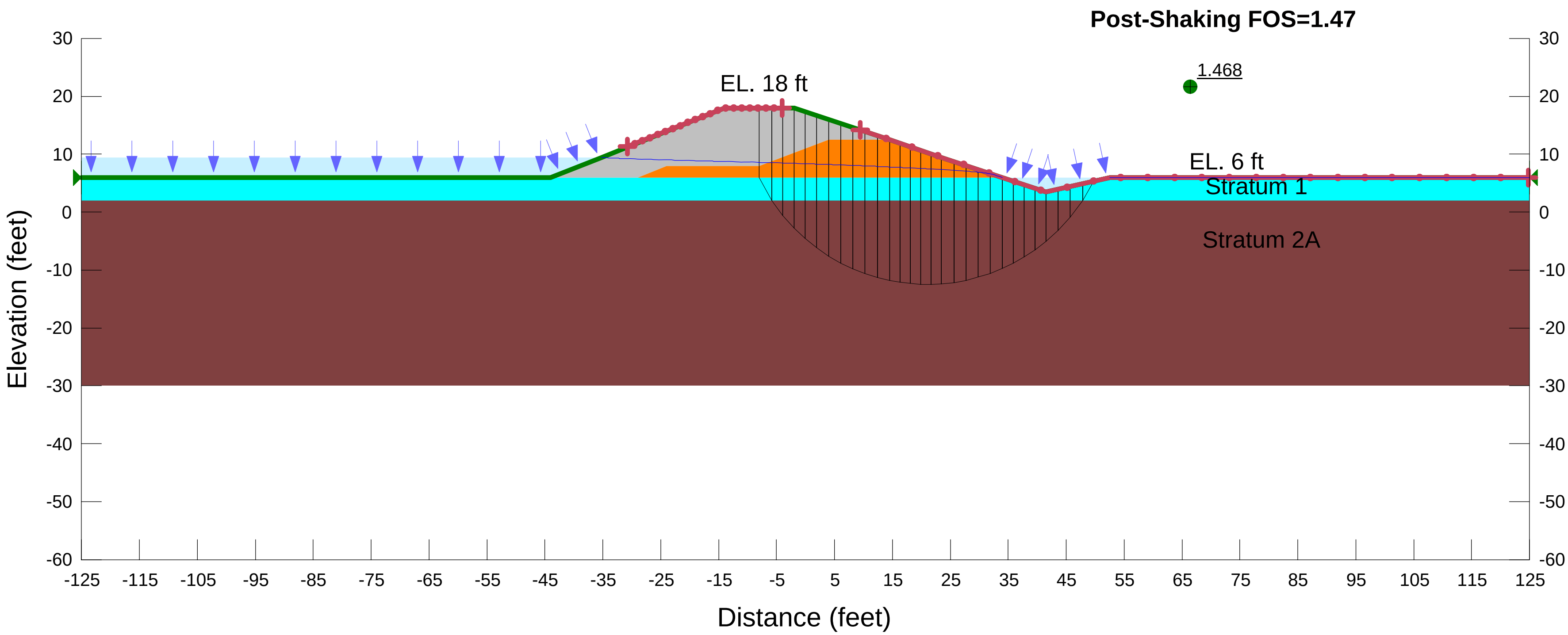
Figure B-24

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Existing Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 2000 Phi: 0
Name: Stratum 2A-Reduced Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.2805 Minimum Strength: 212.5



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Job No. 33760911

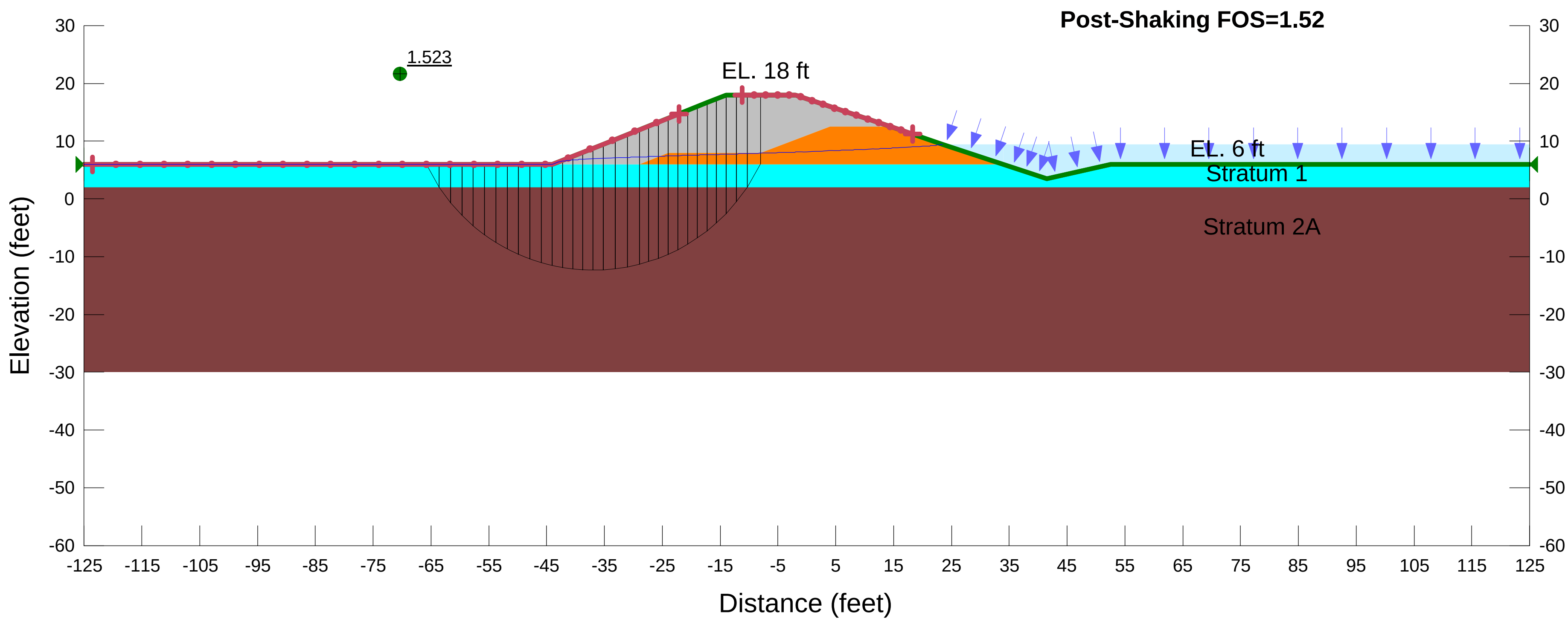
Figure B-25

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 22+00

Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Existing Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 2000 Phi: 0
Name: Stratum 2A-Reduced Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.2805 Minimum Strength: 212.5



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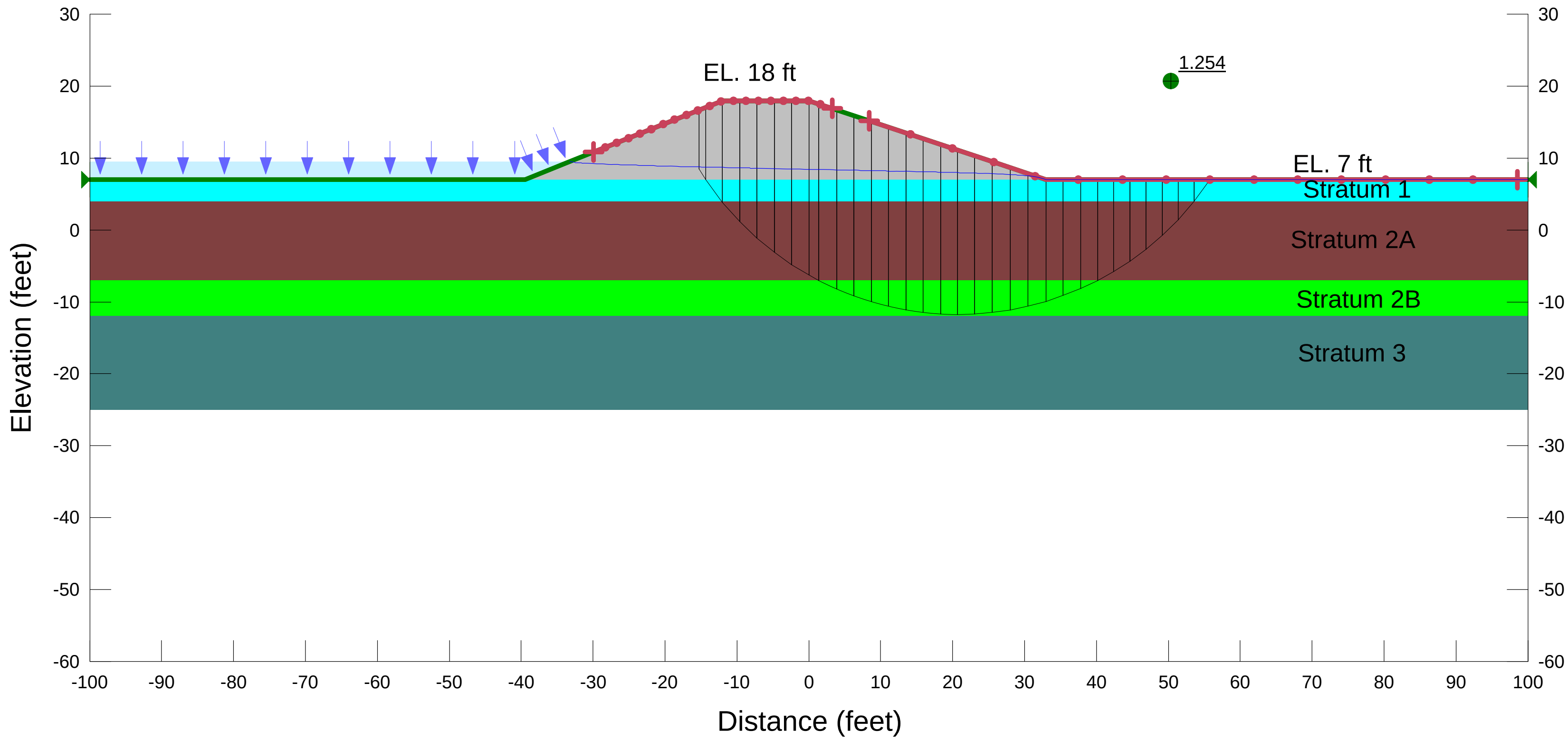
Station: 38+00

Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 3 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 0 Phi: 28
Name: Stratum 2A-Reduced Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.2805 Minimum Strength: 212.5
Name: Stratum 2B-Residuaal-sr Model: Mohr-Coulomb Unit Weight: 100 Cohesion: 165 Phi: 0

Post-Shaking FOS=1.25



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Job No. 33760911

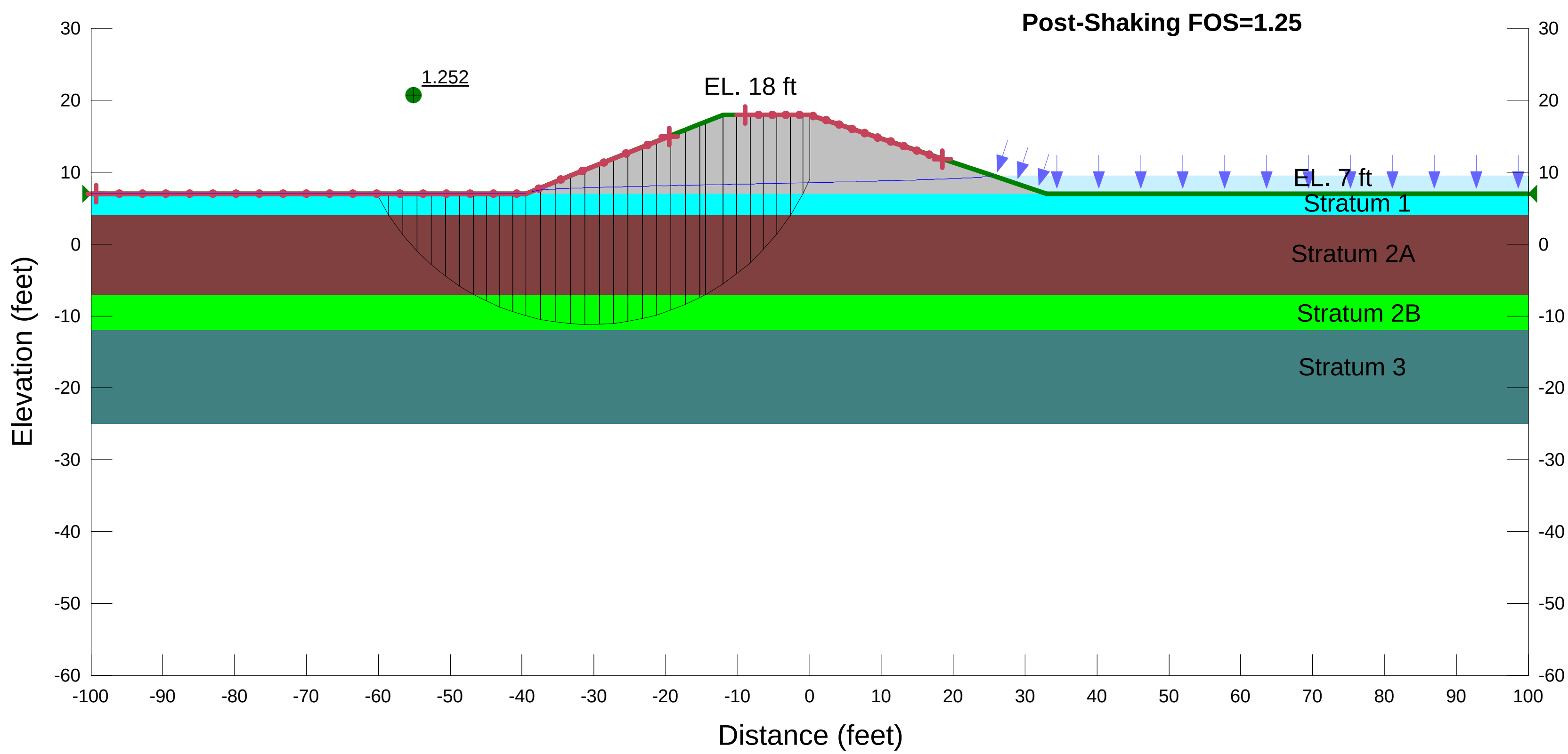
Figure B-27

URS

Fisher Slough Restoration Project
Skagit County, Washington

Station: 38+00

Name: Stratum 1 Model: S=f(overburden) Unit Weight: 110 Tau/Sigma Ratio: 0.33 Minimum Strength: 500
Name: Fill Model: Mohr-Coulomb Unit Weight: 120 Cohesion: 500 Phi: 36
Name: Stratum 3 Model: Mohr-Coulomb Unit Weight: 110 Cohesion: 0 Phi: 28
Name: Stratum 2A-Reduced Model: S=f(overburden) Unit Weight: 95 Tau/Sigma Ratio: 0.2805 Minimum Strength: 212.5
Name: Stratum 2B-Residuaal-sr Model: Mohr-Coulomb Unit Weight: 100 Cohesion: 165 Phi: 0



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Job No. 33760911

Figure B-28

URS

Fisher Slough Restoration Project
Skagit County, Washington