BGC ENGINEERING USA INC.
AN APPLIED EARTH SCIENCES COMPANY

CALIFORNIA DEPARTMENT OF TRANSPORTATION

LAST CHANCE GRADE

EXPERT-BASED RISK ASSESSMENT

FINAL

PROJECT NO.: 1776001 DATE: June 14, 2018

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June 14, 2018
Project No.: 1776001

Sebastian Cohen
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District 1
P.O. Box 3700
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Dear Mr. Cohen,

Re: Last Chance Grade Expert Based Risk Assessment – FINAL REPORT

This report presents the methodology and findings of the expert-based risk assessment BGC Engineering conducted for the Last Chance Grade portion of US 101 in Del Norte County. The drawings attached to the report were developed as part of this process and were instrumental in the expert panel review. The other content reviewed by the panel has been published previously and is not duplicated here.

We are pleased to have been able to assist Caltrans in this way. If we can be of further assistance, please let us know.

Yours sincerely,

BGC ENGINEERING USA INC.
per:

Scott A. Anderson, Ph.D., PE
Principal Geotechnical Engineer

EXECUTIVE SUMMARY

US Highway 101 crosses landslides along Last Chance Grade that have been actively moving and impacting the highway for decades. More recently, the highway has generally been a site of one-way controlled traffic and ongoing structural repairs. The annual maintenance and preservation cost of $2 to $5 million is increasing. Nearly continuous repair efforts have kept some access through the site, but they are not sustainable as a long-term approach, per findings of Caltrans and Federal Highway Administration (FHWA) reviews in 2016 and 2017.

Caltrans is considering a major capital investment, either generally along the existing alignment or along one of several possible new alignments. To estimate ownership risks with respect to cost, mobility, and closure for up to a 50-year project life, a panel was convened March 13-15, 2018 to complete an Expert-Based Risk Assessment (EBRA). The assessment compares the geotechnical risks for alternative alignments that include major improvements generally along the existing alignment, and previously determined alternatives that bypass the segment on entirely new alignments to the east. Assessment of construction cost and schedule risk was not part of the EBRA scope.

The independent expert panel was informed by a summary of published materials and project work compiled by BGC, by new conceptual design drawings, by mixed reality images viewed through the HoloLens, and by presentations by Caltrans staff in a panel meeting and in the field. With this understanding, they were able to reach a consensus opinion on all estimates of risk in the assessment.

The EBRA results show that alternative alignments are not equivalent with respect to risks of ownership and that the estimated risks vary by approximately two orders of magnitude between the alternatives. With respect to the risks estimated through this process, Alternative F has the lowest risk and highest "resistance," and Alternative C3 has the highest risk and lowest "resistance." Given that one reason for the high risk of Alternative C3 is its length, Alternatives C4 and C5, which are longer, would have an even higher risk and were not considered in the EBRA. The other alternatives considered here (X, L, A1, and A2) have risks that lie between these two extremes and are also expected to have lower construction cost, per previous Caltrans estimates.

The BGC experts engaged with the project were not tasked with making their own assessments of probability (risk) and did not do so. However, by way of their engagement with the project documents, the briefings by Caltrans and the deliberations of the panel, BGC staff were in a good position to recognize a surprising outcome if one did occur. In that way, BGC provided a type of independent review of the outcome – and BGC found the results to be reasonable. Caltrans can consider the estimated risks presented here for ownership cost, mobility impacts, and closure along with estimated construction costs and other important selection criteria when choosing the best alternative to meet their overall objectives. The findings will also help Caltrans plan site investigations and prepare for ownership of this part of US 101 for many years in the future.

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LIMITATIONS

BGC Engineering USA Inc. (BGC) prepared this document for the account of California Department of Transportation. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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1.0 INTRODUCTION

US 101 crosses landslides along Last Chance Grade that have been actively moving and impacting the highway for decades. More recently, the highway has generally been a site of one-way controlled traffic and ongoing structural repairs. The annual maintenance and preservation cost of $2 to $5 million is increasing. Nearly continuous repair efforts have kept some access through the site, but they are not sustainable as a long-term approach, per findings of Caltrans and Federal Highway Administration (FHWA) reviews in 2016 and 2017.

Caltrans is considering a major capital investment, either generally along the existing alignment or along one of several possible new alignments. Each alternative is in close proximity or contact with existing landslides on the current alignment, and each new alternative alignment crosses additional mapped landslides. The mapped landslides off the existing alignment have not been studied as carefully as those on it, but they are in the same geologic formations and climate, and thus might be active or easily reactivated. Concept-level cost estimates for the new alternative alignments vary from a few hundred million dollars to more than one billion dollars depending on the structures and lengths of highway involved. The trade-offs between alternatives have thus far been evaluated primarily on land use, cultural and environmental bases, and the estimated construction cost.

Because of the challenging geologic setting, and alignments selected based primarily on other criteria, Caltrans was concerned with making such a large investment and finding itself soon with a different set of geotechnical problems, but ones that have a similar long-term impact in terms of maintenance cost, impacts to mobility and road serviceability. Caltrans addressed this concern through a structured risk assessment that used information it had available to quantify an estimate of geotechnical risks for some alternative alignments. The risks estimated are with respect to the cost of ownership and maintenance, the possibility of future short-term closures and impacts to mobility when repairs are being made, and the possibility of a long-term or permanent closure.

BGC was contracted by Caltrans through a subcontract with GR Sundberg, Inc. to design, facilitate, report, and communicate the findings of this risk assessment. The scope of services is as prepared in BGC proposals to Caltrans dated June 2, 2017, and January 8, 2018, and the authorization via GR Sundberg Purchase Order P17171 dated June 19, 2017.

The work presented here includes opinions and estimates made by BGC, and subcontractors to BGC, who were members of an expert panel convened for this purpose. The panel's observations and estimates of risk, and the associated work products of BGC, are based only on the level of information conveyed through this process. This is believed to be sufficient to assist Caltrans with their project development process, but not for other purposes.

2.0 BASIS FOR THE RISK ASSESSMENT APPROACH

The risk assessment is based on expert opinion and the recognition that expert opinion can be quantified. Similar to probability estimates based on statistics or other logic, subjective probability estimates can be used to estimate risks for complex events. Background for this approach is nicely summarized in the following references, which span 50 years: Role of "calculated risk" in earthwork and foundation engineering – The Terzaghi Lecture, Arthur Casagrande, 1965, ASCE Journal of the Soil Mechanics and Foundation Division; Degrees of Belief – Subjective Probability and Engineering Judgment, Steven G. Vick, 2002, ASCE Press; Risk-Informed Decision Making (RIDM) – Risk Guidelines for Dam Safety, Federal Energy Regulatory Commission, Version 4.1, March 2016.

For complex problems or paths to failure, it is important to be able to decompose the problem into smaller steps because this allows a better assessment of probability for each step. The project can then be recomposed, and the probabilities combined in appropriate ways. Usually, this is done by considering conditional probabilities of failure, but other ways of decomposition for probability estimation are also acceptable.

Risk is the product of probability and consequence, and consequence can be defined in different ways. Caltrans' interest in the cost of maintenance, the possibility of having road and lane closures similar to what has been occurring recently on the highway, and the possibility of long-term closure, represents three different consequences. If each of these is defined by way of a threshold event, the consequence becomes simply that the threshold is crossed, and exactly what that means in terms of dollars, time or other measures is tied to the definition of the threshold. The estimated probability of the event of crossing a threshold is therefore equal to the risk of it occurring (consequence is given the value of unity (1.0), for example). The basis of the risk assessment is the expert opinion of these probabilities of crossing well-defined thresholds.

3.0 DESIGNING THE RISK ASSESSMENT

The risk assessment is designed to get the best possible estimates of the risk to achieving Caltrans' objective to build a low maintenance-cost and reliable highway to replace the existing US 101. This assessment is done for several different alignment alternatives, so the risks can then be considered with other objectives and used to help inform the selection of a preferred alternative. The quality of the estimate is limited at this stage by the information that is available on the geologic setting, the mechanisms and activity level of known landslides, and the limited, conceptual nature of the alternative alignment designs. Nevertheless, careful design of the process can lead to estimates of risk that are meaningful and objective, and helpful for the project.

The process relies on expert opinion and is therefore called an expert-based risk assessment (EBRA). The opinion of experts is formed by their past experiences as well as their interpretation of the current problem, so they can differ somewhat. The EBRA involves a panel of experts with complementary experience to capture this range of opinion and to encourage debate of contributing factors and risk estimates. Informing the panel on the current problem is done through providing access to published studies and information, and having the panel, who are experts in a 'global' sense meet with people who are experts on this project – those that have been working on it extensively.

It is important that all panel members have the same understanding of what they are estimating, so clear understanding of objectives and precise definitions are required. Caltrans is interested in short-term and long-term understanding of risk, so time periods of 10 and 50 years were established. To help panelists make logical extrapolations between these time periods, guidance was provided to allow consideration of the 10-year period as one 'Bernoulli trial' and to make judgments on how closely the actual processes would mimic a Bernoulli trial (the probability associated with each subsequent trial is independent of the outcome of any prior trial) and adjust their estimates accordingly.

The definitions representing Caltrans' performance objectives were more difficult, but it was possible to consider cost, mobility and closure separately and to give them precise definitions by defining four condition states and identifying three thresholds that represent the change from one condition state to another. The condition states and the transitions between them (the crossing of the thresholds) are described in Table 3-1.

Some assumptions are made to facilitate the risk assessment. There is an assumed hierarchy to the performance objectives in the sense that Caltrans will strive to protect a safe and long-lasting highway foremost, and they will sacrifice their mobility goal to do so - by closing the road or a lane for major repair, etc., when needed. Similarly, Caltrans will sacrifice their goal of maintaining a low-cost highway if additional investment will enable maintaining mobility, for example by using better and longer lasting materials and techniques during maintenance and routine repair, or by doing it more often (and resulting in greater cost).

Table 3-1. Description of condition states with representative maintenance and preservation actions, and examples.

Condition State	Description	Actions	Examples
A Routine Maintenance Work/ Average Maintenance Efforts for Type and Location of Highway	Highway segments that require no more than average maintenance for that type of highway lane mile. Average refers to the type, quantity, and frequency of application. Temporary lane and shoulder closures have frequency and duration consistent with other California highways requiring average maintenance, and work is scheduled to be minimally invasive. See Note 1.	Field Maintenance efforts include planned recurring work, such as vegetation, rock, and debris removal; minor ditch excavation; repair and resetting of guardrail; cleaning culverts; minor patching of potholes; repair of pavement sags and small embankment slumps; and other minor or routine work that's expected on California highways, including regularly programmed bridge and tunnel inspection and associated maintenance and traffic interruption.	Newer portions of US 101 near Arcata/Eureka/Trinidad/Redwood National Park Bypass; portions of highways recently built in stable areas, such as near Klamath (south of LCG); and US 101 between Crescent City and the northern margin of the Last Chance Grade Landslide (PM 15.5). These are areas that Field Maintenance would consider as requiring expected work/time/funds to maintain.
A-B Transition	*Frequency, magnitude, and type of maintenance and damage repair efforts/activities increase above average.*	*Field Maintenance resources become insufficient and other sources of support are sought.*	

B Above Routine Maintenance Work/Above Average Maintenance Efforts for Type and Location of Highway	Highway segments that require more than an average amount of resources to keep the highway safe and open. Maintenance and repairs require traffic control and short-duration lane closures and cause interruptions to mobility that are above average for similar California highways. See Note 1.	Requires above average Field Maintenance efforts, which approach or exceed the annual budget allocated or expected. Projects funded from various sources (Programs) often used to repair or construct improvements on a higher than average or expected frequency. Includes minor bridge repairs from ground movement or environmental factors, and portal and tunnel repair from drainage and minor ground movement.	The portion of US 101 in the Mélange Earth flow, between Wilson Creek bridge and the southern border of the Wilson Creek Wall Landslide (PM 14.35). This section requires paving, guardrail resetting and drainage repair of frequency and magnitude that other programs (e.g., Safety) are used to maintain the highway. Additional examples are portions of rural coastal highways where existing alignments were originally built utilizing non-engineered methodologies in non-analyzed geology, such that current highway conditions/designs trigger increased workload for Caltrans. These highways routes include US 1; US 96; and US 169. Bridges and structures may require crack and joint repair, repair of slightly deformed rails, and adjustment of foundation bearing pads, etc.
B-C Transition	*Maintenance activities are not effective, and facility demonstrates vulnerability to extreme events. Alternate methods are sought to preserve the highway (walls, drainage, minor alignment shifts, etc.)*	*Program dollars are needed to support the District and preserve the highway.*	

C Significant Damage Repair Work/ Emergency Projects Required	Highway segments that require significant emergency response actions and funding to keep the highway safe and open. Projects are large and substantial. (retaining walls, structures, minor realignments/retreats, bridge and tunnel structure mitigations, etc.). Mobility is impacted by restricted speeds and frequent lane closures, but a minimum of one lane is maintained open a majority of the time. Bridges and tunnels are distressed but still safe to allow traffic (with possibly some restrictions).	Programs of Emergency Relief, Safety and Pavement are accessed. Activities involve building structures, changing drainage, and construction activities that significantly interrupt traffic. Includes structural mitigation of bridges and tunnels/portals due to ground movement. Full, temporary closures from ground movement are rarely experienced. One-way Traffic Control measures, with delays of one to two hours, are sometimes required for damage repair activities. Weight restrictions might be imposed on distressed bridges.	The portion of US 101 through the Wilson Creek Wall and North and South Last Chance Grade landslides. This portion of highway has been in this state for many years. Since accelerated movement/damage began in 2011 this area may be nearing transition to Condition State D. This possibility is what has driven the need for alternatives evaluations, and, therefore, the need for this EBRA. Bridge decks and rails sometimes reach deteriorated conditions that necessitate contract repairs, which can be staged one lane at a time. Pier-isolation/retention structures and related mitigation for slope movements may be warranted.
C-D Transition	*Projects are short-lived and not reaching their design life. The lifecycle cost and impact of interventions escalate.*	*The stabilization projects, themselves, require maintenance, repair, in addition to the roadway. New attempts to perform on-alignment repairs or new alignments are investigated for feasibility and funding. All options are investigated, and stakeholders engaged for any proposed new Caltrans highway*	

D Long-term Full Closures/ Abandonment	Impractical to keep the highway open via emergency and other programs (Safety, Pavement, etc.), because the costs are too high. Closures that last more than a few weeks and may be permanent. Bridges, walls, and tunnels are significantly distressed and not safe to allow traffic.	Repair or stabilization of road, bridges, walls and/or tunnels require at least extended temporary road closure (traffic safety concerns, and not feasible to mitigate/repair facility/structure under traffic).	Recent California highways and structures that reached Condition State D are US 1 at Pfeiffer Canyon Bridge (2017), Devil's Slide (2005), and at Mud Creek (2017), US 140 at the Ferguson Slide (2006), and Confusion hill on US 101 (date 2005). US 101 at Last Chance Grade has not had a segment reach this condition state. Structural distress in Eddy C Bridge (US 20, Oregon) caused by landsliding during construction was closed to traffic for safety reasons (eventually demolished and replaced with embankment and culvert after concluding no feasible stabilization of bridge).

Note:

1. Review of Field Maintenance costs for District 1 suggests that the average cost per lane mile is 80% to 100% higher for a two-lane coastal highway than for other highways in the district. Thus, for US 101 through the project, the average cost that distinguishes Condition State A from Condition State B is this elevated amount: The A-B transition is not to distinguish coastal highways from others in the District.

This hierarchy means that during 10 or 50 years of ownership, Caltrans will first invest additional money, above an expected maintenance budget, to maintain their objective of keeping the road open and unrestricted. If necessary, Caltrans' interventions will escalate, and they will take steps that do compromise the mobility objective next, in order to preserve the road and keep it open. It follows from this logic is that there is essentially no mobility risk until money has been spent on unusually heavy maintenance, and there is no closure risk until interventions that have impacted mobility have been exhausted. The probability of a closure risk is therefore conditional on the probability of mobility and cost risks (thresholds) having been realized first, and the progression of changing condition and crossing thresholds could happen quickly or slowly. This simplification of conditional relationship is valuable and reasonable here, and it is a useful way to decompose the problem.

Another way this problem will be decomposed for risk estimation is through breaking alignments into construction segments. Construction segments have been selected based on the primary construction type in that part of an alignment – earthwork, bridge, or tunnel, and the geologic and topographic setting for a segment of alignment. With these considerations, eleven construction segments have been identified, and these will be the building blocks for the assessment. The panel will consider one of these eleven construction segments at a time and think only about the performance of that type of construction in that environment, in 10 and 50 years, and the risks of it advancing across three thresholds and four condition states.

The formulation of an event tree will be used to track the estimates and calculate conditional probabilities, and an event tree of this type is shown in Figure 3-1. The segment risk assessments will then be combined to build the alignments by treating each alignment as a system of segments.

In general, risks to the performance objectives of cost, mobility and closure can all be kept lower if there is an ability to observe what has been built and to augment or change a design efficiently. Some of these risk factors discussed are as follows:

- Landslide widths, lengths and depths
- Rate of movement for active landslides
- Triggers needed to initiate movement of inactive landslides
- Differential movement at landslide margins
- Incipient instability where no landslides are mapped now
- Impact of precipitation on landslide activity
- Impact of precipitation on design features (cuts, fills, tunnels, bridges)
- Impact of time on new design features and their environment
- Resilience of similar design features in similar environments
- Ability to observe incipient movement and distress
- Ability to act on observed movement and distress
- Ability to modify, augment or make large change to constructed works in the future.

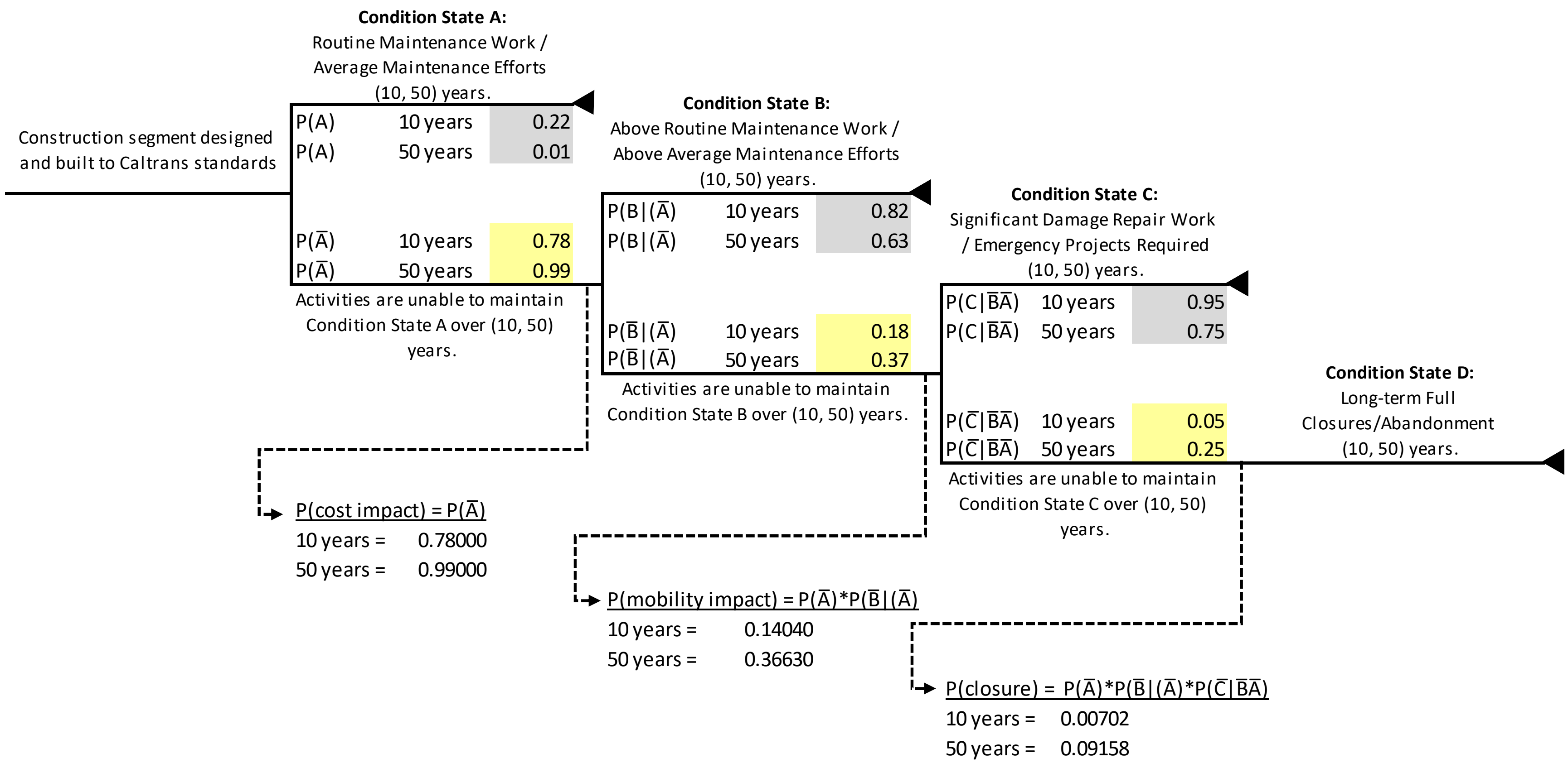

Figure 3-1. Representative event tree showing the estimated probability of each construction segment moving from Condition State A to B to C to D in 10 and 50 years.

4.0 CONDUCTING THE RISK ASSESSMENT

4.1. Assembling Site Information

Extensive writing on the Last Chance Grade project has accumulated over a long period of time and study. BGC curated the available information and condensed it into what is most important from a geotechnical standpoint and into what could be reviewed in an appropriate amount of time by a panel. This collection of information was part of a workbook that was presented to the panel: the main body introduced the risk assessment process, the general setting of Last Chance Grade, the alternative alignments, and the decomposition of the alternatives into construction segments, as explained here in Sections 1.0 through 3.0. Appendices and drawings provided the panelists with specific information relevant to each construction segment and each alignment. The final part of the workbook was a collection of memos and reports selected from the Last Chance Grade Project Study Report (Caltrans, 2016). Where possible, descriptions included in the workbook were excerpted from material available on the public www.lastchancegrade.com website or materials provided by Caltrans, and specific citations were provided where possible.

In addition, LiDAR data collected in 2011 and 2016 was processed to create a bare-earth terrain model of the site. Creation of this model provided new insight into the geomorphology by allowing viewers to “see through” the vegetation to view the underlying landforms. To provide additional understanding, the alternative alignments with the proposed earthwork were merged with the topography to show the footprint of the road prisms. Geology and landslide maps (Wills, 2000) were added to the base maps to show where the proposed alignments intersect mapped landslides and where they cross geologic contacts. These data were presented in a series of maps and as 3D visualizations using Microsoft’s HoloLens mixed reality headsets and BGC’s Ada software.

4.2. Assembling the Panel

The value of the risk assessment depends on the expert opinions rendered, and this requires the coming together of the project information with people that have relevant experiences they can draw upon to make assessments. In this case, a panel of five experts was assembled. All panelists are leading geological or geotechnical experts and each person brought a unique and complementary perspective to the group. The panel members were:

- Tom Badger, LEG, LHG, PE, (Retired) Chief Engineering Geologist, Washington State Department of Transportation, Washington
- Scott Burns, Ph.D., RG, CEG, LG, Professor Emeritus, Department of Geology, Portland State University, Oregon
- John Duffy, P.G., CEG, Senior Engineering Geologist, Yeh and Associates (Retired Caltrans Engineering Geologist), California
- Kenneth Johnson, Ph.D., CEG, PE, Senior Geological Engineer, WSP USA, California
- George Machan, PE, Senior Associate Engineer, Landslide Technology, Oregon.

The panel represents more than 150 years of experience with highway, bridge and tunnel construction, and landslide study, on the Pacific coast of the US, and internationally. There is a balance of geologists and engineers, former DOT employees, academics and consultants, and a mutual respect for the experience that each brought to the panel. As explained further below, Caltrans expertise was shared with the panel, but Caltrans experts were not part of the panel, nor were they part of the panel deliberations. Thus, the opinions rendered by the panel are independent.

4.3. Facilitation

The panel of experts convened in Crescent City, California on March 13-15, 2018, a few days after they were given the workbook explaining the objective, process, and project background. The process from introduction to the project to the assessment of probability and risk moved quickly and at a pace appropriate for how much is known about the site conditions and alternative designs. The approximate total time commitment from each panelist was 50-60 professional hours, per person, for review, meeting, assessment, and summary. This time allotment means that not all available project material was reviewed and that additional research was not completed by any panelist. The limitation is appropriate given that the designs are currently conceptual, and that relatively little is known about the subsurface and site conditions for each specific alternative alignment. As more data become available, it will be possible to make better-informed judgments and it may be desired to do so for some of the alignments considered here, or possibly new versions of them.

The EBRA meeting took place over a period of the three days, following the agenda attached as Appendix A. The first day was spent familiarizing the panel with the site and the EBRA process. Caltrans presented the Last Chance Grade site history and BGC presented the history, scope, and structure of the EBRA process and laid out the meeting expectations. The focus of the meeting then transitioned from the existing US 101 alignment to the alternative alignments. BGC presented historical climate data, and then showed how the proposed alignments intersect the geology and landslide mapping using Drawings 01-09 presented here, and in three dimensions using the HoloLens mixed reality headsets.

The afternoon was spent in the field and along US 101, between Crescent City and Wilson Creek, along the Last Chance Grade. Caltrans and BGC led a tour along US 101 from Wilson Creek to Crescent City with a focus on the Last Chance Grade portion of the highway. Most of the tour was constrained to the highway corridor; however, the group was able to hike east of the highway where some of the alignments depart and reconnect with US 101.

The second day was spent reviewing the construction segments in detail and coming to a consensus on definitions of Condition States A, B, C, and D (as shown in Table 3-1). Caltrans staff were present during the morning session of Day 2 to answer questions about their experience on the project and to contribute to the condition state discussion. Caltrans staff left before the afternoon session began and did not return for the remainder of the EBRA, allowing it to be completed independently by the panel.

The remainder of the EBRA was dedicated to a working session during which the expert panel systematically reviewed all available information and as a group estimated the probability of each construction segment moving from Condition State A to B, and then to C and D, in both 10- and 50-year time periods. BGC facilitators used their expert experience and familiarity with the EBRA structure and process, and the Last Chance Grade project, to guide the discussion and the consideration of various inputs, but did not offer opinions, nor challenge estimates provided by panelists.

4.4. Alternative Alignments

Six alternative alignments were considered in the EBRA. Alternative Alignments A1, A2, C3, and F have been identified previously by Caltrans, and Alternative Alignments X and L are new. Alternative X was added so that the alternative alignments outside of the existing right of way could be compared to one within the right of way. Alternative L was added because it was recognized as a possible improvement to Alternative X from a geotechnical perspective, and with potentially less environmental impact than many other alternatives. Each alternative is summarized below, with the previously defined alternatives using descriptions excerpted from the Last Chance Grade Project Study Report (Caltrans 2016) and presented here in *italic*. Alternative alignments are shown conceptually in Figure 4-1 and in plan view on Drawings 01 and 02. Greater detail is provided on Drawings 03 to 09, which focus on individual construction segments.

4.4.1. Alternative Alignment A1

This alternative departs US 101 with an 850 foot radius horizontal curve at Rudisill Road (PM 13.47) and enters Redwood National Park (RNP) at an elevation of 380 feet. The alignment crosses the California Coastal Trail (CCT), exits RNP after 500 feet, and gains approximately 900 feet of elevation as it climbs the back side of the LCG hill. Connectivity to the CCT will need to be reestablished, possibly with an undercrossing where the fill prism is shallow and narrow. At 2.3 miles along the alignment it heads west and utilizes a 125-foot-high bridge (Bridge 1a) over an ephemeral tributary of Wilson Creek, and enters a tunnel (Tunnel 1) before reaching the eastern boundary of Del Norte Coast Redwoods State Park. Tunnel 1 is 2,425 feet long with a 2.6% grade and a northern portal near US 101 at PM 15.56. The alignment ties back into US 101 on a 900 foot radius horizontal curve. The alignment is 3.2 miles in length and eliminates a 2.1-mile-long segment of existing US 101.

4.4.2. Alternative Alignment A2

Alternative A2 is common to Alternative A1 for the initial 2.3 miles of the alignment, where the alignment then continues northeast from mile 2.3 and enters a large cut section before crossing an ephemeral tributary of Wilson Creek on a proposed 115-foot-high bridge (Bridge 2a). The alignment continues on a side-hill ascent through a small cut and enters a 1,100-foot-long bridge with a 7% grade (Bridge 2b) just prior to Del Norte Coast Redwoods State Park's eastern boundary and then passes through old growth forest. The alignment reconnects with existing US 101 within 450 feet of the viaduct at PM 15.92, south of the Damnation Creek Trailhead *pull-out. The alignment is also 3.2 miles in length and eliminates a 2.5-mile-long segment of existing US 101.*

4.4.3. Alternative Alignment C3

Alternative C3 is common to Alternatives A1 & A2 for the initial 2.3 miles of the alignment. At mile 2.3 the alignment continues north while remaining east of the Del Norte Coast Redwoods State Park and crosses three ephemeral tributaries of Wilson Creek utilizing two bridges (Bridge C1 & C2). At mile 3.25 the alignment enters the southern portal of a 1,680-foot-long tunnel (Tunnel 3) with a 3.9% grade. The tunnel in this alternative is used in lieu of a significant cut section through an unavoidable 1100-foot-high ridge. From the northern tunnel portal, the alignment continues north for 3,000 feet, crossing one ephemeral tributary of Wilson Creek on a bridge (Bridge C3), then swings to the east to avoid old growth forest within the State Park. Through this section, north of the tunnel, estimated cut and fill lines appear close to the Park boundary. Once survey information is available and design work begun, the alignment and/or profile will be adjusted, as necessary, to avoid direct impact to the Park. The alignment crosses two more ephemeral tributaries of Wilson Creek, turns north, and at mile 4.9, enters previously harvested State Park forest land. At mile 5.4, the alignment extends through a low gap in the ridge while transitioning from the Wilson Creek watershed to the West Branch (WB) Mill Creek/Smith River watershed. The alignment continues northwest crossing a tributary of WB Mill Creek with a bridge (Bridge C4) at mile 6.6. It continues northwest crossing another tributary (no bridge) to mile 6.7. Bridge C4 was added to the alternative after completion of the Advance Planning Study as discussed in Section 14.4 (of that report). At mile 6.7, at an elevation of approximately 800 feet, the alignment extends northwest and crosses a drainage of WB Mill Creek on a 1,100-foot-long bridge (Bridge 3a) before ascending at 6.9% through a large cut. At mile 7.8, the alignment reconnects with existing US 101 at PM 19.81, approximately 0.4 miles south of the Mill Creek Campground Road intersection, at an elevation of 1,100 feet. The alignment is 7.8 miles in length and eliminates a 6.3-mile-long segment of existing US 101.

4.4.4. Alternative Alignment F

Alternative F proposes a complete tunnel option to realign US 101. The alternative departs US 101 at PM 14.24 with a northeast bearing in order to go behind the landslide failure planes. The alignment extends 750 feet before entering the southern tunnel portal (Tunnel 2) at an elevation of approximately 610 feet. The tunnel maintains a grade of 4% until reaching its northern portal at an elevation of approximately 840 feet. Upon leaving the northern portal, the alignment extends approximately 450 feet while ascending at a grade of 5.6% before reconnecting to existing US 101 at PM 15.56. The proposed tunnel is 5,600 feet in length and would generate approximately 200,000 cubic yards of excess excavation material. In the event a location near the alignment cannot be identified, an off-site location will need to be found. The alignment is 1.3 miles in length and eliminates a 1.3-mile segment of US 101. The tunnel's feasibility has not yet been proven and is complicated by the fact that it passes between the boundary separating *the Franciscan Complex Broken Formation and the Mélange. Extensive geotechnical studies will be needed to determine if this is a viable alternative.*

4.4.5. Alternative Alignment X

Alternative X is generally on the existing US 101 alignment, with two areas that straighten curves and one that retreats inland approximately 130 feet. This alternative has only minor impact outside the presumed right of way, and the alignment changes are more for highway geometric design than geotechnical stability or longevity. It is assumed, however, that Caltrans will have the opportunity to study the mechanisms of instability more globally than it has been able to in the past, and that Alternative X will have considerable capital investment in the form of new and modified structures, surface and subsurface drainage, and roadway prism reconstruction where recommended by this future study. A cost estimate has not been prepared, but it is assumed by Caltrans and understood by the panel that to create the desired change from the current condition, this alternative will cost more than $100 million. It is also assumed to be considerably less cost than the previously identified alternatives.

4.4.6. Alternative Alignment L

Alternative L is a retreat of up to 650 feet inland from the existing US 101 alignment and it results in significant highway grade changes, as well as changes in plan. In contrast to Alternative X, the alignment changes here are made specifically for geotechnical stability and longevity. This alternative will bring the highway higher on the slope, where it will be closer to stable ground and farther from coastal erosion-based retreat. The alignment will include cuts, structures, surface and subsurface drainage, and a resilient roadway prism. A cost estimate has not been prepared, but it is assumed by Caltrans and understood by the panel that this alternative will cost considerably more than Alternative X, and less than the previously identified alternatives.

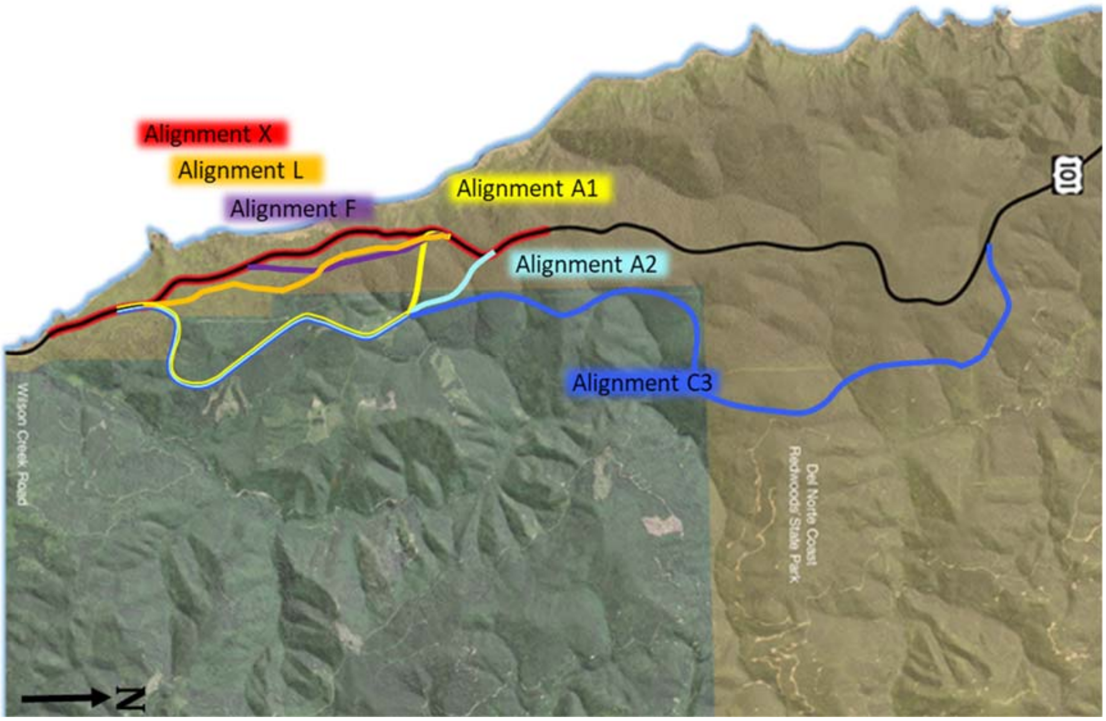

Figure 4-1. Schematic of Alternative Alignments A1, A2, C3, F, X, and L.

4.5. Construction Segments

Construction segments have been identified as a way to decompose the complex problem and to help with the assessment of risk. Each construction segment is identified based on dominant characteristics of construction: large earthwork, significant bridges, or tunnels, with the idea that the long-term performance and the maintenance and preservation activities and costs can be visualized while thinking of one of these construction types. The segments generally exist within certain geologic and topographic terrains, so they have internally consistent conditions in that respect, as well. The construction segments are the building blocks of each alignment.

Using the criteria of characteristic design features and unique setting, the following eleven construction segments have been defined:

1. Mélange Earth Flow (X and F).
2. Mélange Earth Flow (L).
3. Last Chance Grade Landslides (X).
4. Last Chance Grade Landslides (L).
5. Existing 101 Approach.
6. New Wilson Creek Grade.
7. A1 Connection.
8. A2 Connection.
9. C3 Connection (Earthwork.)
10. C3 Connection (Structures).
11. Last Chance Grade Tunnel F.

The decomposition of alignments into construction segments is shown schematically in Figure 4-2 and the segments are listed in Table 4-1. Also shown in Figure 4-2 are two zones where no construction segments exist. Zone 1 is an area common to all alternative alignments, so although it is in the Mélange Earth Flow, and poses some additional risk to performance, it doesn't help to differentiate alternatives and is not considered further. Zone 2 is a transition zone where several alternative alignments are coming together. For simplicity, it is not considered explicitly in this analysis, rather, risk from this area was attributed to adjacent segments as they were assessed.

The eleven construction segments combine in different ways to form the six different alignments being considered. The EBRA process involves considering each segment individually and then combining them later. The design features associated with each construction segment are shown in Table 4-2 and a summary of each construction segment is presented in the following subsections. The panel addressed the segments in the order they are listed in Table 4-2, which is generally in order of increasing work and complexity.

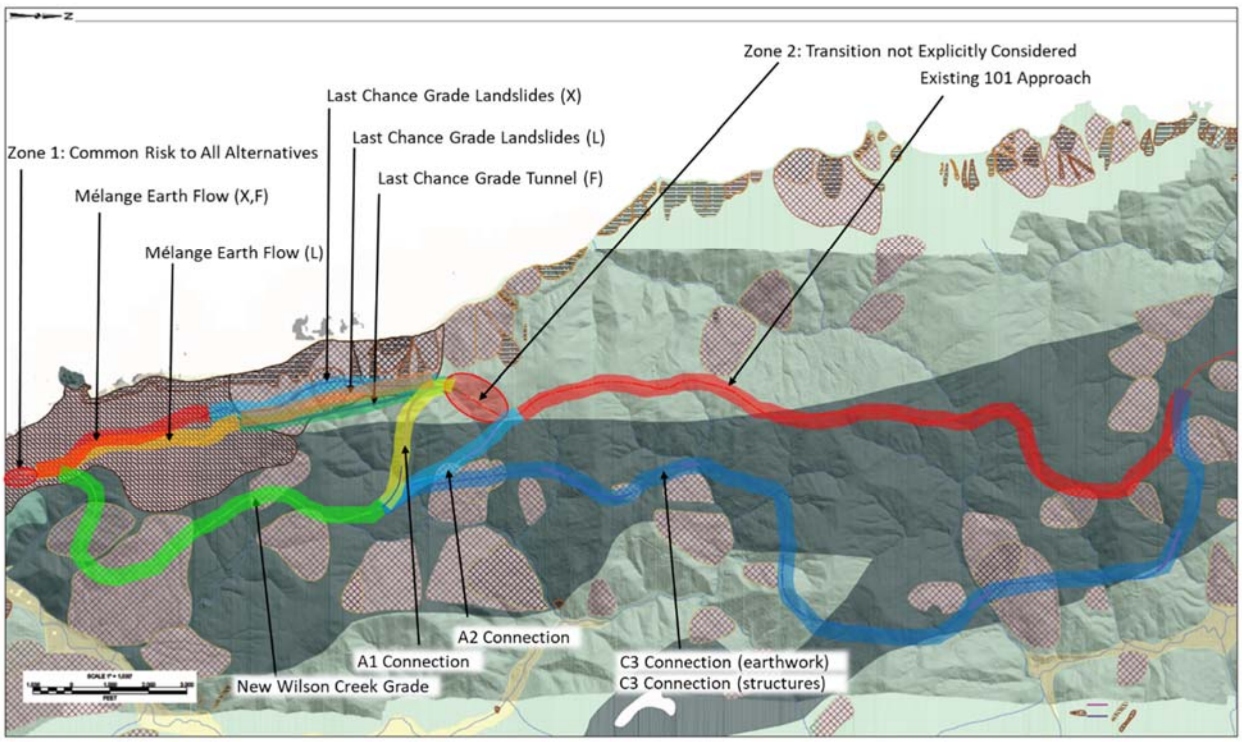

Figure 4-2. Schematic of alternative alignments decomposed into construction segments.

Table 4-1. Alternative alignments and their component construction segments.

Construction Segment	Alignment					
	X	L	F	A1	A2	C3
Mélange Earth Flow (X, F)	✓		✓			
Mélange Earth Flow (L)		✓				
LCG Landslides (X)	✓					
LCG Landslides (L)		✓				
Existing 101 Approach	✓	✓	✓	✓	✓	
New Wilson Creek Grade				✓	✓	✓
A1 Connection				✓		
A2 Connection					✓	
C3 Connection (Earthwork)						✓
C3 Connection (Structures)						✓
Last Chance Grade Tunnel (F)			✓			

Table 4-2. Construction segment design feature summary.

Construction Segment	DWG[1]	Primary Design Features							
		Drainage	Cut	Fill	Wall	Portal	Tunnel	Bridge (Abut.)	Bridge Pier (multi-span)
Mélange Earth Flow (X, F)	08	✓							
Mélange Earth Flow (L)	08	✓	✓	✓					
LCG Landslides (X)	09	✓	✓		✓				
LCG Landslides (L)	08	✓	✓		✓				
Existing 101 Approach	02								
New Wilson Creek Grade	03		✓	✓	✓				
A1 Connection	04					✓	✓	✓	✓
A2 Connection	05		✓	✓				✓	✓
C3 Connection (Earthwork)	06		✓	✓					
C3 Connection (Structures)	06					✓	✓	✓	✓
Last Chance Grade Tunnel (F)	07					✓	✓		

Note:
1. The Overview Plan and the Geology and Landslide Plan are shown on Drawings 01 and 02, respectively.

4.5.1. Mélange Earth Flow (X and F) Construction Segment

The Mélange Earth Flow Construction Segment of Alternative Alignments X and F is characterized by having no substantial new work. For both X and F, the panel assumed this section of road would be reconstructed with a reinforced roadway prism and drainage measures to combat the effects of the slow-moving Mélange earth flow; however, there will not be any new large cuts or fills. The panel drove and walked this section of highway and viewed a 3D oblique aerial photogrammetry (OAP) model of the site. The panel had the benefit of learning the performance history of this section of US 101 from Caltrans staff.

4.5.2. Mélange Earth Flow (L) Construction Segment

The Mélange Earth Flow Construction Segment of Alternative Alignment L is characterized by cuts and fills on the order of 25-feet high in Franciscan Mélange. The panel assumed 1.5H:1V cut and 2H:1V fill slope angles. The panel also assumed this section of road would be constructed with a reinforced roadway prism and necessary drainage measures. The panel was not able to walk directly along the alignment; however, it was assumed that ground conditions were similar to those observed on the existing US 101 alignment through this section.

4.5.3. Last Chance Grade Landslides (X) Construction Segment

The Last Chance Grade Landslides Construction Segment of Alternative Alignment X is characterized by cuts for its entire length. Alignment X is generally on the existing Highway 101 alignment, with areas that retreat inland up to approximately 130 feet. The panel assumed that 1H:1V cut slopes would be built, drainage would be added, and some structures would be preserved, while others would be augmented, removed or replaced.

The Last Chance Grade Landslides Construction Segment was the most extensive portion of the panel's site visit, largely because of the ease of access and the abundance of activity at the site. The panel walked this entire section of the highway and looked at many phases of slope failure above and below the existing road and observed current wall-building activities. They also had the opportunity to ask questions of Caltrans staff about the long site history, current mitigation efforts, and how the site has evolved. Walking along the highway afforded the panel views immediately above and below the road; however, in most cases, a view of the base of the slope was obstructed by vegetation. This is where the oblique aerial photogrammetry (OAP) model was useful. One month before the panel convened, an OAP model was created by BGC from a US Coast Guard helicopter flight organized by Caltrans. The photos were processed to create a 3D model of the slope which allows the viewer to zoom in, rotate, and pan across the slope. A fly-by video of this model was shown to the panel which allowed them to view the toe of the slope below Last Chance Grade and to see how erosion may be affecting the stability of the road. The HoloLens 3D visualization tool was also very useful for this construction segment because it allowed the panel to view the slope from all angles, and was free of vegetation in the LiDAR scene.

4.5.4. Last Chance Grade Landslides (L) Construction Segment

The Last Chance Grade Landslides Construction Segment of Alternative Alignment L is characterized by a steep grade and large cut. Alignment L is a major retreat of up to 650 feet inland from the existing Highway 101 alignment. The panel assumed 1H:1V cut and 1.5H:1V fill slope angles would be built. The panel also assumed the alignment will be adjusted and redesigned to some extent to get close to the head of the global sliding, and out of it where possible, and to reduce the grade. With that said, most of the alignment would still be within the mapped Last Chance Grade Landslides.

The panel was not able to walk this alignment; however, the panel members were informed by much of the same information as they were for Alternative X.

4.5.5. Existing 101 Approach Construction Segment

The Existing 101 Approach Construction Segment starts at PM 16.0, where Alternative A2 reconnects with US 101, and continues north to the point where Alternative C3 reconnects with US 101. This segment is characterized by having no substantial new work. The panel drove slowly through this section of highway observing pavement, and embankment condition, apparent past repairs, and roadwork, and were informed on the history of maintenance by Caltrans.

4.5.6. New Wilson Creek Grade Construction Segment

The New Wilson Creek Grade (NWCG) Construction Segment is 2.33 miles in length and is part of alternative alignments A1, A2, and C3. This segment is characterized by its large cuts and fills in area mapped as the Franciscan Mélange and landslide deposits, and its steep grade. The panel assumed 1.5H:1V cut and 2H:1V fill slope angles and that excavated material will be used to build embankments. They also assumed that the footprint of large cuts and fills may be reduced with reinforced soil slopes and walls in the case of embankments, and rock bolts and draped mesh in the case of cut slopes; however, earthwork would not be replaced by structures such as bridges or viaducts. The final alignment for NWCG and all other construction segments would be optimized based on exploration to avoid unnecessarily large cuts and fills and avoidable construction on landslides.

Relatively little is known about this construction segment. The panel based their assessment on LiDAR, geology and landslide mapping, their collective experience in building in similar geology, and a view of the terrain from an overlook in the field at the beginning the segment. The HoloLens was especially useful for visualizing the magnitude of the large cuts and fills proposed to be built on large mapped landslides.

The panel also reviewed early geologic mapping from Caltrans and had a presentation on findings from this ongoing work. The panel was informed that there is some difference between the Wills (2000) landslide mapping and Caltrans' preliminary landslide mapping, and that the Caltrans mapping is just beginning.

4.5.7. A1 Connection Construction Segment

The A1 Connection Construction Segment begins at the north end of the NWCG Segment. The A1 connection segment heads west and uses a 125-foot high, 350 feet long, 2-span bridge over an ephemeral tributary of Wilson Creek, and then enters a tunnel before reaching the eastern boundary of Del Norte Coast Redwoods State Park. The 2-span bridge and the tunnel are the design elements that characterize this construction segment. The tunnel is 2,425 feet long with a 2.6% grade. Original concepts showed a single-bore tunnel, but it is assumed that a twin-bore tunnel may be constructed. There also is a through cut with an approximate maximum height of 150 feet; however, this cut slope was attributed to the NWCG construction segment.

There is no performance history at this site, so the assessment was based solely on desktop-level information and a brief field visit to the location of the northern portal of the A1 tunnel. LiDAR, geology and landslide mapping, HoloLens 3D visualization, and structural drawings from the

Caltrans Project Study Report (2016) were the key pieces of information used to assess this segment.

4.5.8. A2 Connection Construction Segment

The A2 Connection Construction Segment begins at the north end of the NWCG segment. The A2 Connection segment continues northeast and enters a large cut section before crossing an ephemeral tributary of Wilson Creek on a proposed 345-foot-long bridge (Bridge 2a). The alignment continues on a side-hill ascent through a cut and fill section and enters a 1,100-foot-long bridge (Bridge 2b) just prior to Del Norte Coast Redwoods State Park’s eastern boundary, and then passes through old growth redwood forest. The alignment reconnects with existing US 101 within 450 feet of the viaduct at PM 15.92, and south of the Damnation Creek Trailhead pull-out.

Bridge 2a and Bridge 2b are the design elements that characterize this construction segment, though there is also an embankment near the head of a mapped landslide in between the bridges and a through cut with an approximate maximum height of 180 feet near where this segment abuts NWCG; however, risks associated with this cut slope were attributed to the NWCG construction segment.

There is no performance history at this site, so the assessment was based solely on desktop-level information. LiDAR, geology and landslide mapping, HoloLens 3D visualization, and structural drawings from the Caltrans Project Study Report (2016) were the key pieces of information used to assess this segment.

4.5.9. C3 Connection (Earthwork) Construction Segment

The C3 Connection Construction Segment begins at the north end of the NWCG Segment, and it is different from the other construction segments because it is longer and has essentially all of the design features shown in Table 4-2. The total length of the C3 Connection segment is 5.60 miles, and it is almost all within the Franciscan Mélange. Due to the length of the segment, the continuity of geology, and the even distribution of work elements, two superimposed construction segments are considered separately here. The “C3 Connection Earthwork” Construction Segment is defined to include all the earthwork over the entire length of the segment and “C3 Connection Structures” is a superimposed segment that includes all the bridges and the tunnel.

The C3 Connection (Earthwork) Construction Segment is characterized by large cuts and fills. There are two large through cuts with approximate maximum heights of 200 feet, and various earthwork crossing 9 mapped landslides. The assessment for this construction segment was based solely on desktop-level information. LiDAR and geology and landslide mapping were the key pieces of information used to assess this segment. The panel assumed 1.5H:1V cut and 2H:1V fill slope angles and that excavated material will be used to build embankments. It was also assumed that the footprint of large cuts and fills may be reduced with reinforced soil slopes and walls in the case of embankments, and rock bolts and draped mesh in the case of cut slopes; however, earthwork would not be replaced by structures such as bridges or viaducts. The final alignment for C3 and would be optimized based on exploration to avoid unnecessarily large cuts and fills. Regardless, there would be many sections of highway with large earthwork components that would inevitably cross large mapped landslides and there would be large valley fills which would require large culverts.

4.5.10. C3 Connection (Structures) Construction Segment

Bridges C1, C2, C3, C4, 3a and Tunnel 3 are significant design elements that characterize the C3 Connection (Structures) Construction Segment. The panel recognized bridge abutments within mapped landslides or landslide morphology identified in LiDAR, and the tunnel's northern portal is within a mapped landslide. LiDAR, geology and landslide mapping, and structural drawings from the Caltrans Project Study Report (2016) were the key pieces of information used to assess this segment.

4.5.11. Last Chance Grade Tunnel (F) Construction Segment

The Last Chance Grade Tunnel (F) Construction Segment is comprised of a complete tunnel option (Tunnel 2) to realign US 101 beneath and behind the Last Chance Grade Landslide. The proposed tunnel is a 5,600-foot-long single-bore tunnel; however, it is anticipated that the final design may arrive at a twin-bore configuration. The tunnel's feasibility has not yet been proven and is complicated by the fact that it passes between the boundary separating the Franciscan Complex Broken Formation and Mélange (Caltrans, 2016), but feasibility was assumed for the EBRA purpose. LiDAR, geology and landslide mapping, and structural drawings from the Caltrans Project Study Report (2016) were the key pieces of information used to assess this segment. The panel also visited the south and north portal locations in the field.

4.6. Assembling the Results

Construction segments were evaluated against one another during the process, in order to benchmark relative judgments, but alignments were not. The panel estimated the probability of each construction segment moving from Condition State A to B to C to D in 10 and 50 years. BGC recorded the probability estimates in event trees, as shown in Figure 3-1. Only after the meeting concluded were the construction segment results combined into alignments to be compared as systems. Results of segment assessments and alignment calculations were subsequently reviewed by the panel for apparent contradictions or unexplainable outcomes. One outcome with respect to the A2 connection was debated and revised slightly, but other results remained unchanged.

5.0 RESULTS

5.1. Construction Segment Results

The panel was asked to estimate the probability of each construction segment moving from Condition State A to B, B to C, and C to D in both 10 and 50 years (see Table 3-1 for the definitions and examples of each condition state). When a construction segment moves from Condition State A to Condition State B, a cost impact is realized; when it moves from Condition State B to C, mobility is impacted; and, when it moves from Condition State C to D a construction segment experiences long-term full closure and/or abandonment. This concept is illustrated in Figure 3-1 and explained in Table 5-1.

Table 5-1. Cost impact, mobility impact, and closure with respect to transitioning from one condition state to another.

Impact	Condition State Transitions	Probability Formulas
Cost	Transition from Condition State A to Condition State B	$P(\text{cost impact}) = P(\overline{A})$
Mobility	Transition from Condition State B to Condition State C	$P(\text{mobility impact}) = P(\overline{A})*P(\overline{B}\|(\overline{A})$
Closure	Transition from Condition State C to Condition State D	$P(\text{closure}) = P(\overline{A})*P(\overline{B}\|(\overline{A})*P(\overline{C}\|\overline{B}\overline{A})$

BGC recorded the panel's probability estimates in event trees and calculated the conditional probability of each construction segment experiencing a cost impact, mobility impact, and closure in both 10 and 50 years. The calculated results are shown in Table 5-2. Each cell in this table is a unique, consensus opinion made by the panel, and this is their primary work product. The assessments represented in each cell were challenged by the panel as the work was completed, and reviewed subsequently, and confirmed as the panel's best judgment based on the data available to them and the process described herein. As facilitators, BGC guided the work and reminded the panel of information to consider the significance of assumptions such as the conditional probability assumptions, and how the decomposed estimates will be recomposed for each alignment alternative.

It is difficult to assign subjective probability estimates to events that are either very unlikely or very likely, and that is one reason why the EBRA process relies on decomposition of a problem, and then using conditional probability rules to estimate low probability events. An example of this is shown for the probability of closure for the Existing US 101 Approach in Table 5-2. Essentially, the panel believed the routine earthwork and lack of structures in this construction segment, meant that the risk of crossing any threshold was low, and when these were multiplied to solve for the conditional probability, the value got quite low.

Table 5-2. Probability of cost impact, mobility impact, and closure for each construction segment.

Construction Segments	Probability of Cost Impact		Probability of Mobility Impact		Probability of Closure	
	10-year	50-year	10-year	50-year	10-year	50-year
Mélange Earth Flow (X, F)	0.75	0.99	0.08	0.30	0.001	0.03
Mélange Earth Flow (L)	0.78	0.99	0.14	0.37	0.01	0.09
LCG Landslides (X)	0.95	0.999	0.71	0.998	0.21	0.80
LCG Landslides (L)	0.85	0.99	0.51	0.94	0.10	0.42
Existing 101 Approach	0.01	0.05	0.00001	0.0003	0.00000001	0.000001
New Wilson Creek Grade	0.80	0.99	0.60	0.94	0.15	0.47
A1 Connection	0.05	0.10	0.0003	0.001	0.000001	0.00001
A2 Connection	0.45	0.95	0.41	0.86	0.36	0.77
C3 Connection (earthwork)	0.93	0.999	0.84	0.99	0.46	0.91
C3 Connection (structures)	0.90	0.99	0.81	0.98	0.73	0.97
Last Chance Grade Tunnel (F)	0.10	0.40	0.02	0.24	0.0002	0.01

Given that the probability of something "not happening" is equal to "1 minus the probability of something happening", the probability of "not experiencing a cost impact" is equal to "1 minus the probability of experiencing a cost impact", for example. This inverse can be considered as a resistance to change (resistance to an impact); is an easier reference from which to consider the results and is used from here forward. Furthermore, these probabilities are quite small, and it is convenient to multiply by 100 to make them more comprehensible, and thereby presentable as percent, so this is also done. The estimated probability of 'not changing', presented as percent, is herein termed "Resistance". With these changes, a value of 100% Resistance means that there will be no change, and a value of 50% Resistance means change is as likely as not, etc.

The converted results are shown in Table 5-3 and are plotted in Figure 5-1, Figure 5-2, and Figure 5-3. As seen in the table, no construction segments are 100% resistant to change and none are 0% resistant to change. This is a natural outcome of the process of estimating conditional probabilities. The precise values in the table are useful for understanding how the results were obtained but the relative scale of bars in the figures is a more appropriate way of comparing results. Given the early stages of understanding the geotechnical conditions and conceptual designs, small differences in calculated values are not particularly meaningful. Thus, the discussion of results is based on the general trends recognizable in the bar charts of the figures.

Table 5-3. Resistance to cost impact, mobility impact, and closure for each construction segment.

Construction Segments	Resistance to Cost Impact		Resistance to Mobility Impact		Resistance to Closure	
	10-year	50-year	10-year	50-year	10-year	50-year
Mélange Earth Flow (X, F)	25%	1.0%	93%	70%	99.9%	97%
Mélange Earth Flow (L)	22%	1.0%	86%	63%	99%	91%
LCG Landslides (X)	5%	0.1%	29%	0.2%	79%	20%
LCG Landslides (L)	15%	1.0%	49%	6%	90%	58%
Existing 101 Approach	99%	95%	99.999%	99.98%	99.999999%	99.9999%
New Wilson Creek Grade	20%	1.0%	40%	6%	85%	53%
A1 Connection	95%	90%	99.98%	99.9%	99.9999%	99.999%
A2 Connection	55%	5%	60%	15%	64%	23%
C3 Connection (earthwork)	7%	0.1%	16%	1.1%	54%	9%
C3 Connection (structures)	10%	1.0%	19%	2%	27%	3%
Last Chance Grade Tunnel (F)	90%	60%	98%	76%	99.98%	98.8%

5.1.1. Resistance to Cost Impact

The resistance to cost impact for each construction segment over 10 and 50 years is shown in Figure 5-1. Results for the 10-year time period are represented by solid blue bars, and the 50-year by dotted-pattern blue bars. These results show that the panel anticipates that most construction segments will move from Condition State A to Condition State B and will thus become a higher than average cost highway segment for maintenance within 10 years and, of course, will be less resistant to advance to Condition State B in 50 years. In the figure, a high bar (%) is desired and a low bar (%) is not.

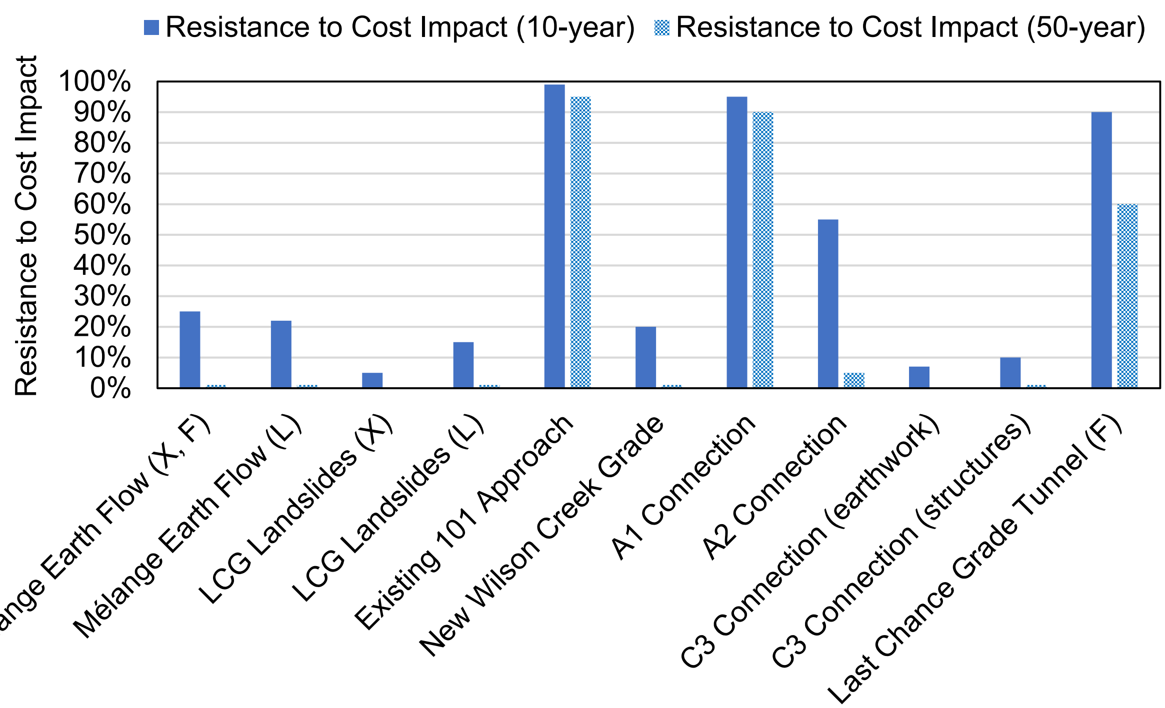

Figure 5-1. Resistance to cost impact for each construction segment (transition from Condition State A to B).

5.1.2. Resistance to Mobility Impact

The resistance to mobility impact for each construction segment over 10 and 50 years is shown in Figure 5-2. These results show that the estimated resistance to moving from Condition State B to Condition State C, and the resulting mobility impact, is quite high for some construction segments and quite low for others. This differentiation can be used to better understand where the panel sees the risk to performance and envisions there may be future efforts, like those going on today on the Last Chance Grade, to preserve the highway.

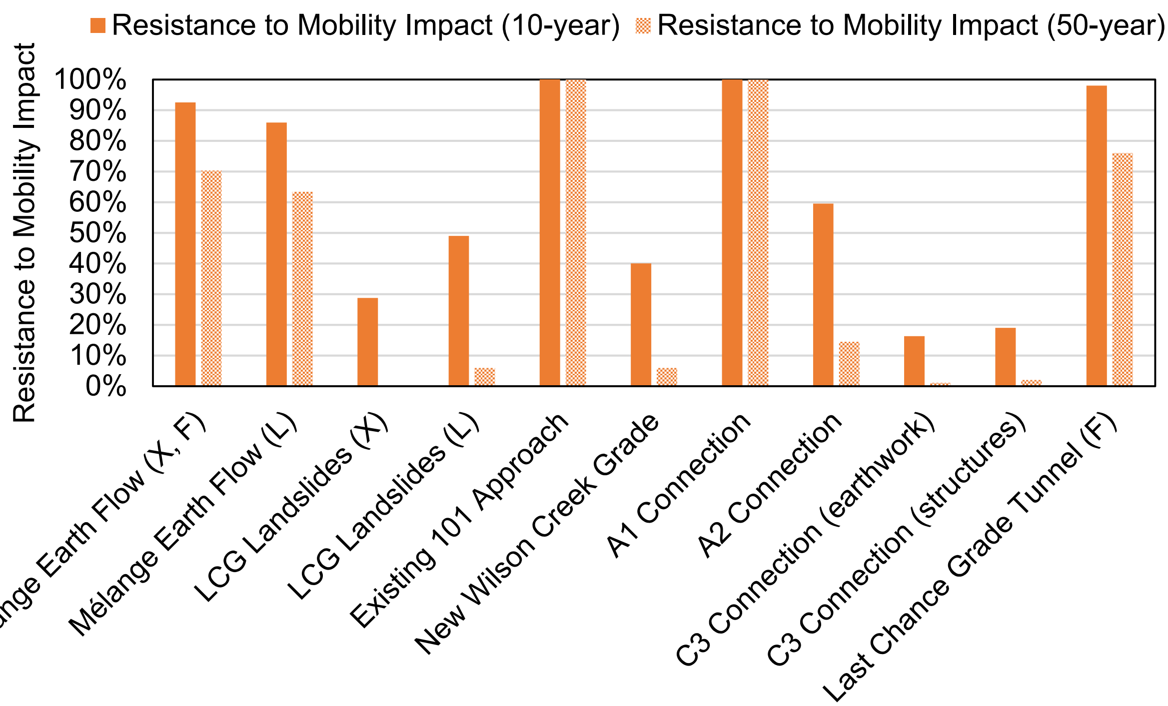

Figure 5-2. Resistance to mobility impact for each construction segment (transition from Condition State B to C).

5.1.3. Resistance to Closure

The resistance to closure for each construction segment over 10 and 50 years is shown in Figure 5-3. These results show that some construction segments are judged to be vulnerable to closure in 10 to 50 years (a change in Condition State from C to D). Others are quite resistant to closure, as would be expected for new highway construction. This is further differentiation and identification of where the perceived challenges lie. Greater discussion on this is presented later, as these segments are combined into the conceptual alternative alignments.

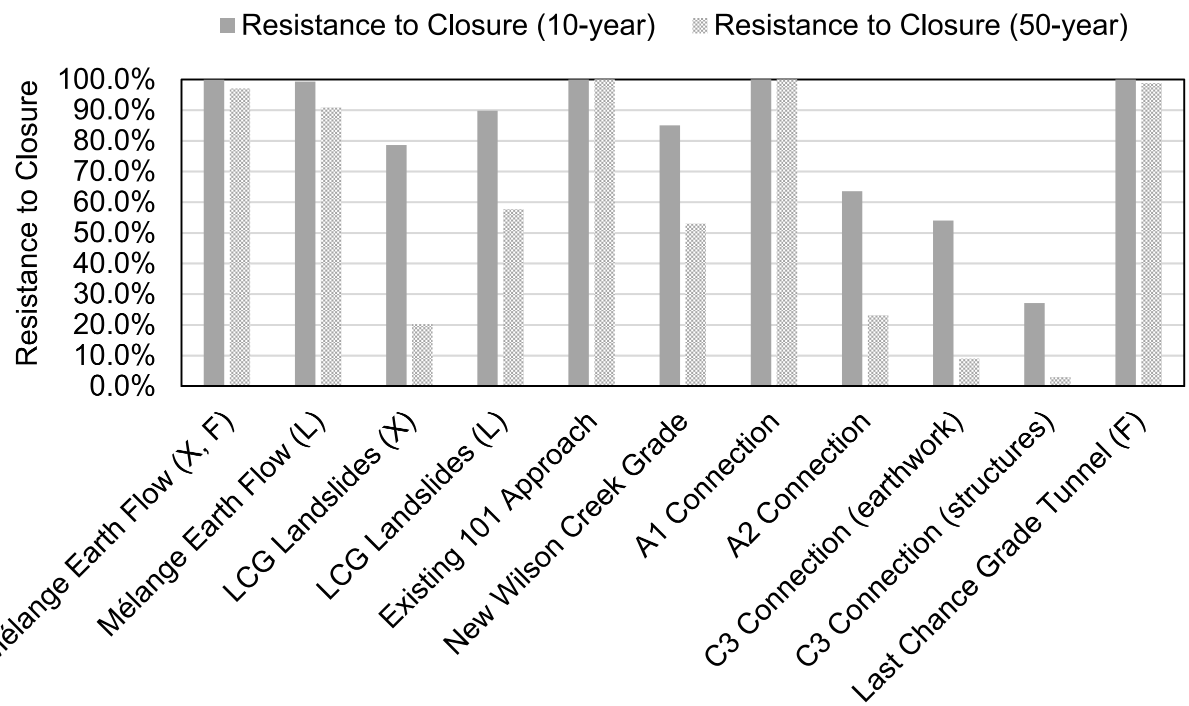

Figure 5-3. Resistance to closure for each construction segment (transition from Condition State C to D).

5.2. Alternative Alignment Results

Each alternative alignment is made up of three construction segments and there are multiple ways the estimates can be combined. With respect to mobility impact and closure impact, it is easy to visualize the three segments as links in a chain, where if one link fails, the chain fails. Thus, the construction segments work as a system, and the probability of system failure can be calculated using Equation 5-1, where p_1, p_2, and p_3 are the probabilities associated with the three construction segments making up an alignment. An example of the probability of cost impact for Alternative Alignment X in 10 years is shown in Equation 5-2.

$$\mathrm{P}(\text{cost impact, mobility impact, or closure}) = 1 - (1 - p_1) \times (1 - p_2) \times (1 - p_3) \qquad \text{[Eq. 5-1]}$$

$$\mathrm{P}(\text{cost impact}) = 1 - (1 - 0.75) \times (1 - 0.95) \times (1 - 0.01) = 0.988 \qquad \text{[Eq. 5-2]}$$

The logic of the segments working together as a system is not as representative for the cost impact as for the others, but since cost is not found to be a valuable differentiator (see Figures 5-1, 5-4, and 5-5), the system logic is adopted and used to combine segments into alignments and to compare alignments. The calculations of system failure probabilities are shown in Tables 5-4, 5-5, 5-6, and 5-7, and the resulting probabilities are summarized in Table 5-8. The conversion to “Resistance” (as %) is made as it was in Section 5.1 and the resulting values are shown in Table 5-9. As discussed in Section 5.1, the precise values are useful for understanding how calculations were made, but they imply a precision in findings that is not appropriate given the uncertainties incorporated. Bar graphs are used in Figures 5-4 and 5-5 to display the results, and these two figures convey the summary findings of the risk assessment.

Table 5-4. Alignments X, L, and F system failure probability estimates for cost impact, mobility impact, and closure (10-year).

Construction Segment	Performance (10 years)	Alignment		
		X	L	F
Mélange Earth Flow (X, F)	P(cost impact) = $P(\overline{A})$	0.750		0.750
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\|\overline{A})$	0.075		0.075
	P(closure) = $P(\overline{A})*P(\overline{B}\|\overline{A})*P(\overline{C}\|\overline{B}\overline{A})$	0.001		0.001
Mélange Earth Flow (L)	P(cost impact) = $P(\overline{A})$		0.780	
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\|\overline{A})$		0.140	
	P(closure) = $P(\overline{A})*P(\overline{B}\|\overline{A})*P(\overline{C}\|\overline{B}\overline{A})$		0.007	
LCG Landslides (X)	P(cost impact) = $P(\overline{A})$	0.950		
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\|\overline{A})$	0.713		
	P(closure) = $P(\overline{A})*P(\overline{B}\|\overline{A})*P(\overline{C}\|\overline{B}\overline{A})$	0.214		
LCG Landslides (L)	P(cost impact) = $P(\overline{A})$		0.850	
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\|\overline{A})$		0.510	
	P(closure) = $P(\overline{A})*P(\overline{B}\|\overline{A})*P(\overline{C}\|\overline{B}\overline{A})$		0.102	
Existing 101 Approach	P(cost impact) = $P(\overline{A})$	0.010	0.010	0.010
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\|\overline{A})$	0.00001	0.00001	0.00001
	P(closure) = $P(\overline{A})*P(\overline{B}\|\overline{A})*P(\overline{C}\|\overline{B}\overline{A})$	0.00000001	0.00000001	0.00000001
Last Chance Grade Tunnel (F)	P(cost impact) = $P(\overline{A})$			0.100
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\|\overline{A})$			0.020
	P(closure) = $P(\overline{A})*P(\overline{B}\|\overline{A})*P(\overline{C}\|\overline{B}\overline{A})$			0.0002
System Failure	P(cost impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.988	0.967	0.777
	P(mobility impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.734	0.579	0.094
	P(closure) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.214	0.108	0.001

Table 5-5. Alignments A1, A2, and C3 system failure probability estimates for cost impact, mobility impact, and closure (10-year).

Construction Segment	Performance (10 years)	Alignment		
		A1	A2	C3
Existing 101 Approach	P(cost impact) = $P(\overline{A})$	0.010	0.010	
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$	0.00001	0.00001	
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$	0.00000001	0.00000001	
New Wilson Creek Grade	P(cost impact) = $P(\overline{A})$	0.800	0.800	0.800
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$	0.600	0.600	0.600
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$	0.150	0.150	0.150
A1 Connection	P(cost impact) = $P(\overline{A})$	0.050		
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$	0.0003		
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$	0.000001		
A2 Connection	P(cost impact) = $P(\overline{A})$		0.450	
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$		0.405	
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$		0.365	
C3 Connection (earthwork)	P(cost impact) = $P(\overline{A})$			0.930
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$			0.837
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$			0.460
C3 Connection (structures)	P(cost impact) = $P(\overline{A})$			0.900
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$			0.810
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$			0.729
System Failure	P(cost impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.812	0.891	0.999
	P(mobility impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.600	0.762	0.988
	P(closure) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.150	0.460	0.876

Table 5-6. Alignment X, L, and F system failure probability estimates for cost impact, mobility impact, and closure (50-year).

Construction Segment	Performance (50 years)	Alignment		
		X	L	F
Mélange Earth Flow (X, F)	P(cost impact) = $P(\overline{A})$	0.990		0.990
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$	0.297		0.297
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$	0.030		0.030
Mélange Earth Flow (L)	P(cost impact) = $P(\overline{A})$		0.990	
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$		0.366	
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$		0.092	
LCG Landslides (X)	P(cost impact) = $P(\overline{A})$	0.999		
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$	0.998		
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$	0.798		
LCG Landslides (L)	P(cost impact) = $P(\overline{A})$		0.990	
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$		0.941	
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$		0.423	
Existing 101 Approach	P(cost impact) = $P(\overline{A})$	0.050	0.050	0.050
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$	0.0003	0.0003	0.0003
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$	0.000001	0.000001	0.000001
Last Chance Grade Tunnel (F)	P(cost impact) = $P(\overline{A})$			0.400
	P(mobility impact) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})$			0.240
	P(closure) = $P(\overline{A})*P(\overline{B}\mid(\overline{A})*P(\overline{C}\mid\overline{B}\overline{A})$			0.012
System Failure	P(cost impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.99999	0.9999	0.994
	P(mobility impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.999	0.962	0.466
	P(closure) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.804	0.476	0.041

Table 5-7. Alignments A1, A2, and C3 system failure probability estimates for cost impact, mobility impact, and closure (50-year).

Construction Segment	Performance (50 years)	Alignment		
		A1	A2	C3
Existing 101 Approach	P(cost impact) = P($\overline{A}$)	0.050	0.050	
	P(mobility impact) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)	0.0003	0.0003	
	P(closure) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)*P($\overline{C}$|$\overline{BA}$)	0.000001	0.000001	
New Wilson Creek Grade	P(cost impact) = P($\overline{A}$)	0.990	0.990	0.990
	P(mobility impact) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)	0.941	0.941	0.941
	P(closure) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)*P($\overline{C}$|$\overline{BA}$)	0.470	0.470	0.470
A1 Connection	P(cost impact) = P($\overline{A}$)	0.100		
	P(mobility impact) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)	0.001		
	P(closure) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)*P($\overline{C}$|$\overline{BA}$)	0.00001		
A2 Connection	P(cost impact) = P($\overline{A}$)		0.950	
	P(mobility impact) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)		0.855	
	P(closure) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)*P($\overline{C}$|$\overline{BA}$)		0.770	
C3 Connection (earthwork)	P(cost impact) = P($\overline{A}$)			0.999
	P(mobility impact) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)			0.989
	P(closure) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)*P($\overline{C}$|$\overline{BA}$)			0.910
C3 Connection (structures)	P(cost impact) = P($\overline{A}$)			0.990
	P(mobility impact) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)			0.980
	P(closure) = P($\overline{A}$)*P($\overline{B}$|($\overline{A}$)*P($\overline{C}$|$\overline{BA}$)			0.970
System Failure	P(cost impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.991	0.9995	0.9999999
	P(mobility impact) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.941	0.991	0.99999
	P(closure) = $1-(1-p_1)*(1-p_2)*(1-p_3)$	0.470	0.878	0.999

Table 5-8. Summary of Alignment system failure probability estimates for cost impact, mobility impact, and closure.

Alignments	Cost Impact		Mobility Impact		Closure	
	10-year	50-year	10-year	50-year	10-year	50-year
X	0.988	0.99999	0.734	0.999	0.214	0.804
L	0.967	0.9999	0.579	0.962	0.108	0.476
F	0.777	0.994	0.094	0.466	0.001	0.041
A1	0.812	0.991	0.600	0.941	0.150	0.470
A2	0.891	0.9995	0.762	0.991	0.460	0.878
C3	0.999	0.9999999	0.988	0.99999	0.876	0.999

Table 5-9. Summary of resistance to cost impact, mobility impact, and closure.

Alignments	Resistance to Cost Impact		Resistance to Mobility Impact		Resistance to Closure	
	10-year	50-year	10-year	50-year	10-year	50-year
X	1.2%	0.001%	27%	0.1%	79%	20%
L	3%	0.01%	42%	4%	89%	52%
F	22%	0.6%	91%	53%	99.9%	96%
A1	19%	0.9%	40%	6%	85%	53%
A2	11%	0.05%	24%	0.9%	54%	12%
C3	0.1%	0.00001%	1.2%	0.001%	12%	0.1%

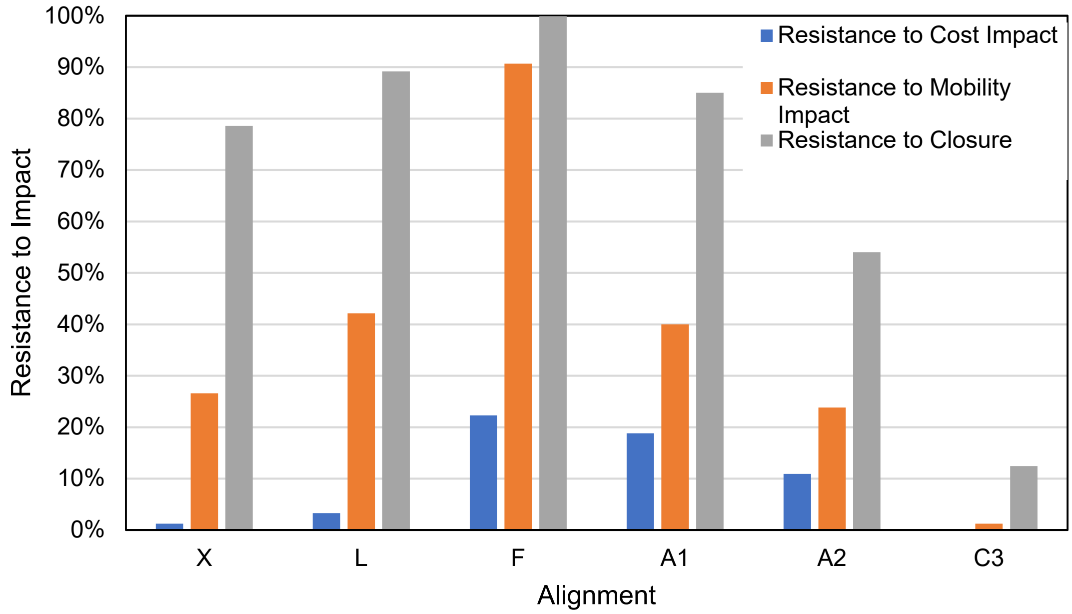

Figure 5-4. Resistance to cost impact, mobility impact, and closure at 10 years.

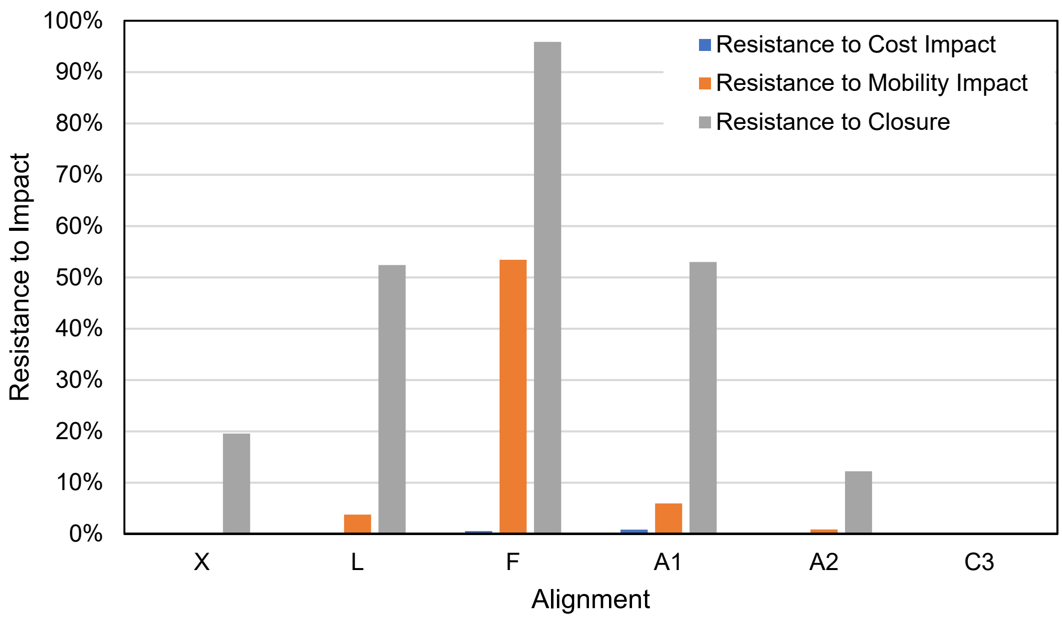

Figure 5-5. Resistance to cost impact, mobility impact, and closure at 50 years.

6.0 OBSERVATIONS AND CONCLUSION

6.1. Observations

The risk assessment was useful in contrasting the different alignment alternatives and the different performance objectives, and high-level observations are summarized here. The resistance to cost impact is very low: it is expected that each alternative alignment would move from Condition State A to B within 10 years and is nearly certain to do so within 50 years. The resistance to mobility impact is also low but shows greater differentiation between the alternatives. Within 50 years' time, only Alternative F is more likely than not to resist the change from Condition State from B to C. For the other alternatives, it is nearly certain. In other words, based on the available information now, the panel believes it is nearly certain that within 50 years this highway will transition into Condition State C, unless it is routed through the tunnel of Alternative F. This means that the level of effort to maintain these other alternatives (other than F) is nearly certain to cost more than average for a coastal highway with similar bridges and structures, and nearly certain to experience impacts to mobility, as described in Table 3-1.

Three of the alternatives (L, F and A1) are very likely to avoid closure (Condition State D) within 10 years, and more likely than not to avoid closure within 50 years. The other alternatives are very likely to result in closure within this time.

These results mean that the risks to the performance objectives of low cost, relatively unimpeded mobility, and avoiding closure are high. Indeed, they are higher than one would expect for any new construction. One reason for this is the uncertainty that exists now. As exploration is conducted, the site understanding improved, and concepts developed in recognition of the geotechnical challenges, it is expected the estimated risks will come down. However, it is also expected that the ranking of alternatives will stay approximately the same, with the possible exception being the relative positions of Alternatives A2 and L with respect to one another. The reasons for this are presented below in paragraphs summarizing key observations related to each alternative and the risks to mobility and for closure.

The following paragraphs present some observations from the panel on where the risks and uncertainties lie, and some ideas on how they could potentially be reduced.

Alternative Alignments X and L:

The risks for Alternative Alignments X and L come primarily from the Last Chance Grade Landslides construction segment. Although there has been a great deal of work on this section of highway, it has mostly been focused on relatively small-scale failures and repairs. There has not been an all-encompassing study focused on defining the global and surficial slide mechanisms and rates, especially above the existing US 101 alignment, or understanding the groundwater conditions. The panel also recognized the apparent vulnerability of the highway at the northern margin of the construction segment and saw this as an area where further study could reduce uncertainty.

Alternative Alignment F:

The risks for this alternative alignment come primarily from the Mélange Earth Flow segment and the tunnel portals. They can be addressed in the future through better understanding of the depth of the Mélange Earthflow at the south portal and the vulnerability of the highway at the north portal. In addition to the portal locations, the tunnel alignment is controlled by the geometry of the deepest global slip surface in the Last Chance Grade landslides. The panel assumed the proposed alignment is behind and below the deepest landslide slip surface; however, this is something that will need to be verified by geotechnical investigation, and the alignment modified if needed to make this assumption valid.

Alternatives Alignments A1 and A2:

The risks for alternatives A1 and A2 come primarily from the New Wilson Creek Grade Construction Segment. They can be addressed in the future through better understanding of the extent and activity of mapped landslides along the alignment, recognition of other landslides or marginally stable slopes, and whether optimization of layout can significantly avoid these areas.

There is also risk associated with tunnel portals and bridge abutments and the consideration that slope movement could more quickly jeopardize structures than earthwork. These risks can be addressed in the future through better understanding of the stability of the slopes containing bridge piers and abutments and conditions at tunnel portals. This was thought to be especially important for the northern abutment of the northern bridge (Bridge 2b) of Alternative A2.

Alternative Alignment C3:

The risks for this alternative come from all three construction segments. They can be addressed in the future through better understanding of the geology, landslide activity and subsurface conditions. However, given the length of new construction in Franciscan Mélange, the size of cuts and embankments, and the size and location of bridges, the panel's expectation is that uncertainty and risks will remain high, even with careful and thorough investigation.

6.2. Conclusion

The independent expert panel was informed by a summary of published materials and project work compiled by BGC, by new conceptual design drawings, by mixed reality images viewed through the HoloLens, and by presentations by Caltrans staff in a panel meeting and in the field. With this understanding, they were able to reach consensus opinion on all estimates of risk in the assessment.

These results show that alternatives are not equivalent with respect to risks of ownership, and that the estimated risks vary by approximately two orders of magnitude between the alternatives. With respect to the risks estimated through this process, Alternative F has the least risk and highest "resistance," and Alternative C3 has the highest risk and lowest "resistance." Given that one reason for the high risk of Alternative C3 is its length, other C alternatives, which are longer, would have even higher risk. The other alternatives considered here (X, L, A1 and A2) have risks that lie between these two extremes and are also expected to have lower construction cost per previous Caltrans estimates.

The BGC staff engaged with the project were not tasked with making their own assessments of probability (risk) and did not do so. However, by way of their engagement with the project documents, the briefings by Caltrans and the deliberations of the panel, BGC staff were in a good position to recognize a surprising outcome if one did occur. In that way, BGC provided a type of independent review of the outcome – and BGC found the results to be reasonable. Caltrans can consider the estimated risks presented herein for ownership cost, mobility impacts and closure, along with estimated construction costs, and other important selection criteria, when choosing the best alternative to meet their overall objectives. The findings will also help Caltrans with planning of site investigations and preparing for ownership of this part of US 101 for many years in the future.

7.0 CLOSURE

We trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

BGC ENGINEERING USA INC.
per:

Scott A. Anderson, Ph.D., PE
Principal Geotechnical Engineer

Cole Christiansen, M.Sc., PE
Geological Engineer

Reviewed by:

Michael Porter, M.Eng., P.Eng., LEG
Director, Principal Geological Engineer

SA/MP/hwn/mm

Attachments: Appendix A - EBRA Agenda
Drawings

REFERENCES

California Department of Transportation. June 2016. Project Study Report, Permanent Restoration, Last Chance Grade. File: 01-DN-101 PM 12.0/15.5. EA: 01-0F280K/EFIS. EFIS ID: 0115000099. Program Code: 20.XX.201.131. URL: http://www.lastchancegrade.com/files/managed/Document/208/lcg_psr_final_s.pdf

Wills, C.J. 2000. Landslides in the Highway 101 Corridor Between Wilson Creek and Crescent City, Del Norte County, California. Department of Conservation, California Geological Survey, Special Report 184.

APPENDIX A
EBRA AGENDA

BGC	**MEETING AGENDA**	
	Project: 1776-001 Risk Assessment for Highway 101 Last Chance Grade, Del Norte County, CA	

Venue: Crescent City, California **Date:** March 13-15, 2018

Attendees: **BGC:** Scott Anderson, Cole Christiansen

Panel: Tom Badger, Scott Burns, John Duffy, Kenneth Johnson, George Machan

Caltrans: Sebastian Cohen, Marietta James, Jaime Matteoli, Charlie Narwold, Eric Wilson

FHWA: Keaton Browder, Daniel Alzamora

Subject: Expert-based risk assessment (EBRA) for Highway 101 at Last Chance Grade, Del Norte County, CA

Day 1 - Morning Session (8:00 AM – 12:00 PM)

1. PROJECT BACKGROUND (75 minutes – led by BGC then Caltrans)
   - 1.1. Introductions and general business
   - 1.2. Project history through contracting of EBRA
   - 1.3. Noteworthy events since contracting EBRA (technical, and non-technical?)

2. MEETING PURPOSE (45 minutes – led by BGC, Break TBD)
   - 2.1. History of EBRA process
   - 2.2. Scope of EBRA
   - 2.3. Structure of EBRA
   - 2.4. Expectations from this meeting

3. SITE UNDERSTANDING (75 minutes – led by Caltrans then BGC)
   - 3.1. Geology
   - 3.2. Climate
   - 3.3. Drawings (Geology and Landslides)
   - 3.4. HoloLens Session 1

4. RECAP (15 minutes – led by BGC)
   - 4.1. Morning parking lot items, Q&A

Day 1 - Lunch (12:00 PM – 1:00 PM)

Day 1 - Afternoon Session (1:00 PM – 5:00 PM)

5. SITE UNDERSTANDING (field) (4 hours – led by Caltrans)
    5.1. Site Visit
    5.2. Q/A Session with Caltrans (field or back in office)

Day 2 - Morning Session (8:00 AM – 12:00 PM)

6. CONCEPTUAL ENGINEERING
    6.1. Discussion of alternatives and concept designs (design drawings) (45 minutes – led by Caltrans/BGC)
    6.2. Similar construction experience, and associated performance (45 minutes - led by Caltrans)
    BREAK
    6.3. Discussion on Construction Segments and Condition States (90 minutes – led by BGC)
    6.4. HoloLens (30 minutes - repeat opportunity)

Day 2 - Afternoon Session (1:00 PM – 5:00 PM)

7. GETTING STARTED
    7.1. Rules of EBRA (60 minutes – led by BGC)
    7.2. Practice example (30 minutes – led by BGC)
    BREAK
    7.3. Working session (90 minutes – led by BGC)
    7.4. Recap, with parking lot and Q&A (15 minutes – led by BGC)

Day 3 - Morning Session (8:00 AM – 12:00 PM)

8. WORKING SESSION
   8.1. Refresher (15 minutes – led by BGC)
   8.2. Resume working session (180 minutes – led by BGC)
   8.3. Recap, with parking lot and Q&A (15 minutes – led by BGC)

Day 3 - Early Afternoon Session (1:00 PM – 3:00 PM)

9. WORKING SESSION
   9.1. Resume working session (60 minutes – led by BGC)
   9.2. Planning for follow up homework (45 minutes – led by BGC)
   9.3. Recap, with parking lot and Q&A (15 minutes – led by BGC)

- Option to revisit site (after 3:00)

DRAWINGS

THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

NOTES:

1. ALL DIMENSIONS ARE IN FEET UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT", AND DATED JUNE 2018.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY CALIFORNIA DEPARTMENT OF TRANSPORTATION, (CALTRANS) DATED 2011 AND 2016.
4. PROJECTION IS STATE PLANE CALIFORNIA ZONE 1 NAD83 US FEET.
5. ALIGNMENTS A1, A2, C3 AND F ARE AS IDENTIFIED IN THE LAST CHANCE GRADE PROJECT STUDY REPORT (CALTRANS 2016).
6. PROPOSED NEW WILSON CREEK GRADE (NWCG) ALIGNMENT IS PART OF ALIGNMENTS A1, A2 AND C3.
7. PROPOSED ALTERNATIVE X ALIGNMENT AND ALTERNATIVE L ALIGNMENT CREATED FEBRUARY 2018 BY CALTRANS.
8. DESIGN TEMPLATES USED FOR THE DIFFERENT ALIGNMENTS WERE PROVIDED BY CALTRANS; SHOULDER WIDTH AND CUT AND FILL SLOPE ANGLE VARY AND WILL BE REVISED AS DESIGNS ARE FURTHER DEVELOPED.
9. WHERE SHOWN, MAPPED GEOLOGY AND LANDSLIDES, INCLUDING TERMINOLOGY, LEGEND AND HATCHING, ARE REPRODUCED FROM "LANDSLIDES IN THE HIGHWAY 101 CORRIDOR BETWEEN WILSON CREEK AND CRESCENT CITY, DEL NORTE COUNTY, CALIFORNIA" (WILLS 2000).
10. PM IS DESIGNATION OF APPROXIMATE POST MILE, PROVIDED BY CALTRANS.
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DATE:	JUN 2018
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AN APPLIED EARTH SCIENCES COMPANY

CLIENT: CALIFORNIA DEPARTMENT OF TRANSPORTATION

PROJECT: LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE: GENERAL ARRANGEMENT - OVERVIEW PLAN

PROJECT No.:	DWG No.:
1776-001	01

X:\Projects\1776\CAD\Production\Report-Memo\20171211_LAST_CHANCE_GRADE_EXPERT-BASED_RISK_ASSESSMENT\01.dwg Layout: 01 Plot Date Jun 7 18 Time: 10:07 PM

LEGEND - GEOLOGY

QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

LEGEND - LANDSLIDE

DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			

THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

NOTES:

1. ALL DIMENSIONS ARE IN FEET UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT", AND DATED JUNE 2018.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS), DATED 2011 AND 2016. CONTOUR INTERVAL IS 50.0 FT.
4. PROJECTION IS STATE PLANE CALIFORNIA ZONE 1 NAD83 US FEET.
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SCALE:	1" = 1,000'
DATE:	JUN 2018
DRAWN:	AH
CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
GENERAL ARRANGEMENT - GEOLOGY AND LANDSLIDE PLAN

PROJECT No.:	DWG No.:
1776-001	02

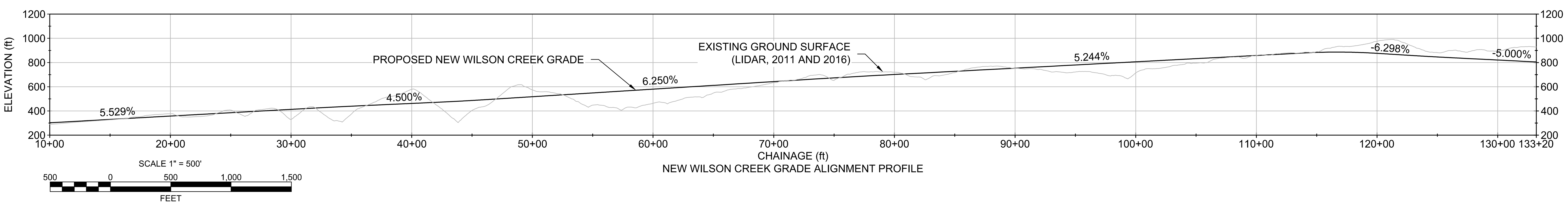
X:\Projects\1776\CAD\Production\Report-Memo\20171211_LAST_CHANCE_GRADE_EXPERT-BASED_RISK_ASSESSMENT\02.dwg Layout: 02 Plot Date Jun 7 18 Time: 10:10 PM

LEGEND - CUT/FILL VOLUME	
CUT	1.7 M Cu.Yd
FILL	4.2 M Cu.Yd

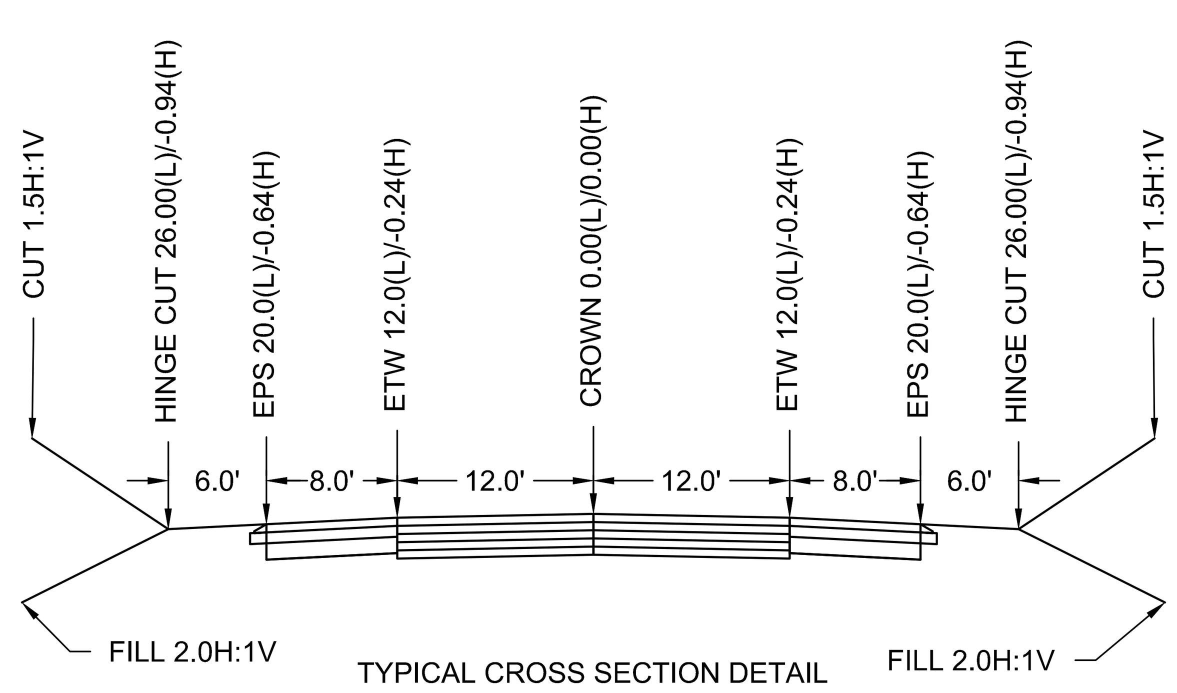
LEGEND - GEOLOGY		
QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

LEGEND - LANDSLIDE

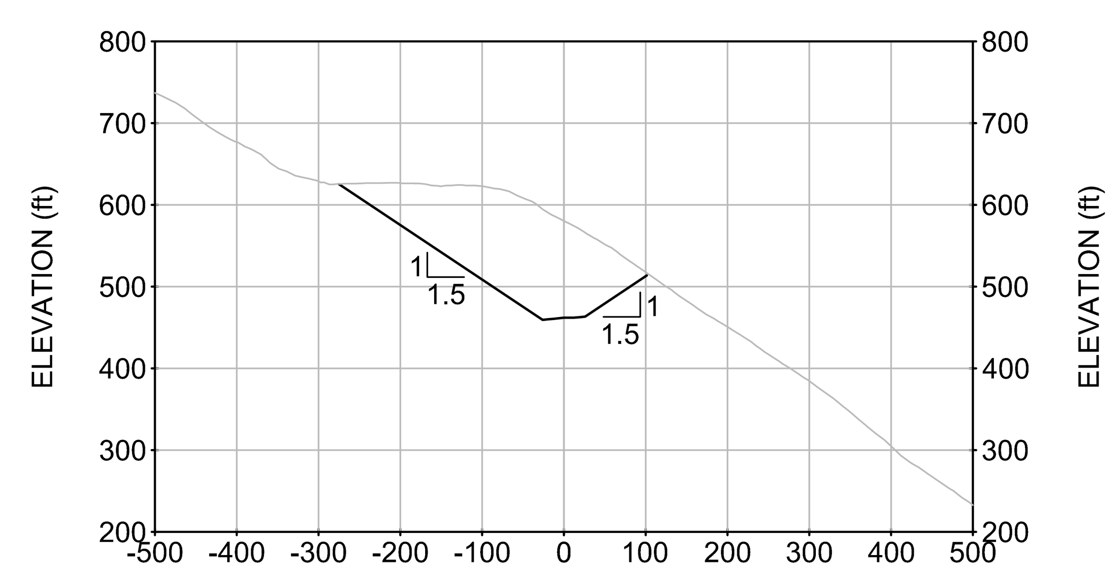
DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			



NEW WILSON CREEK GRADE ALIGNMENT PROFILE



TYPICAL CROSS SECTION DETAIL
NTS



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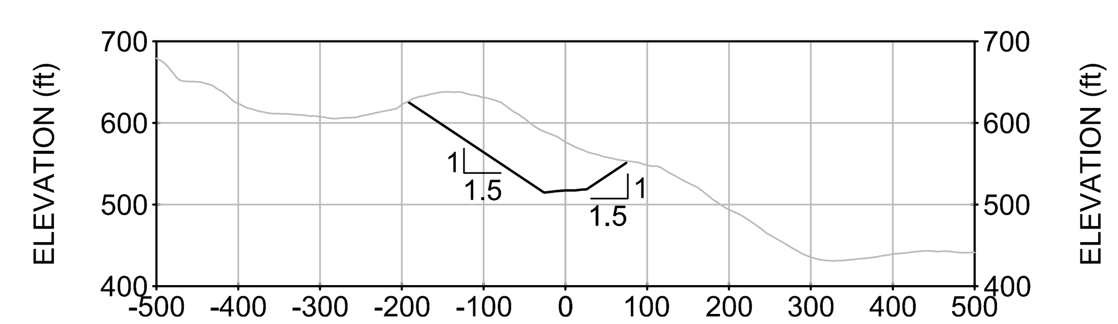
SCALE: 1" = 200'



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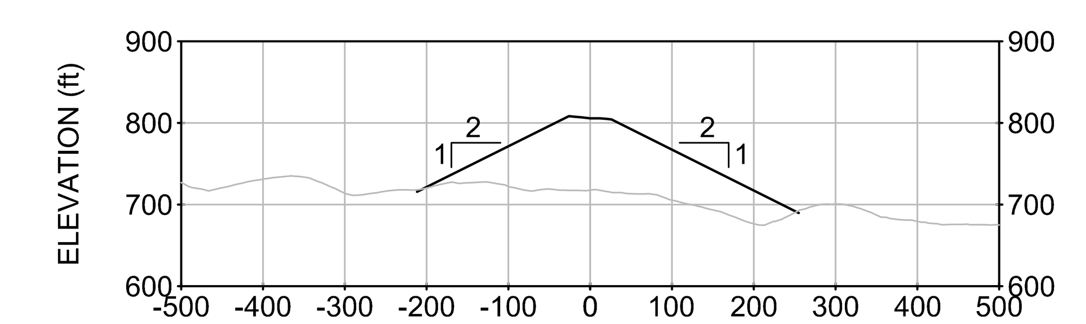
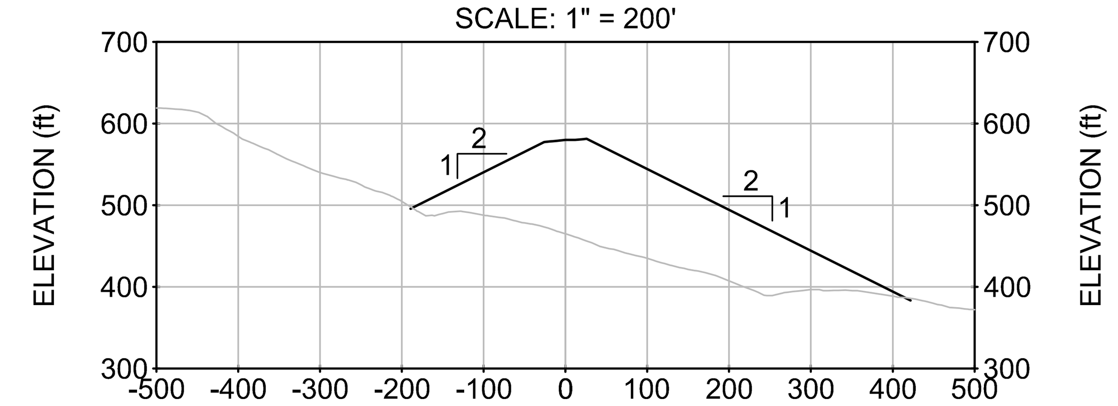
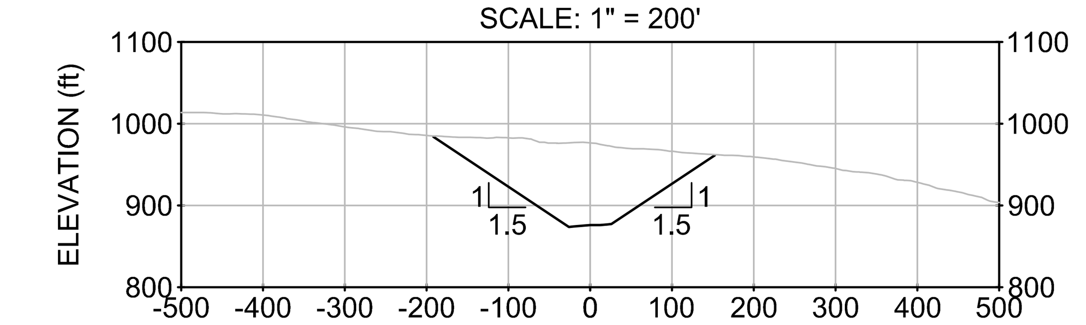
SCALE: 1" = 200'



CROSS-SECTION 100+00
SCALE: 1" = 200'



CROSS-SECTION 60+00
SCALE: 1" = 200'



CROSS-SECTION 120+00
SCALE: 1" = 200'

NOTES:
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SCALE:	AS SHOWN
DATE:	JUN 2018
DRAWN:	AH
CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
NEW WILSON CREEK GRADE CONSTRUCTION SEGMENT
CONCEPTUAL DESIGN, GEOLOGY, AND LANDSLIDE PLAN

PROJECT No.:	DWG No.:
1776-001	03

THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

X:\Projects\1776\CAD\Production\Report-Memo\20171211_LAST_CHANCE_GRADE_EXPERT-BASED_RISK_ASSESSMENT\03.dwg Layout: 03 Plot Date Jun 7 18 Time: 10:17 PM

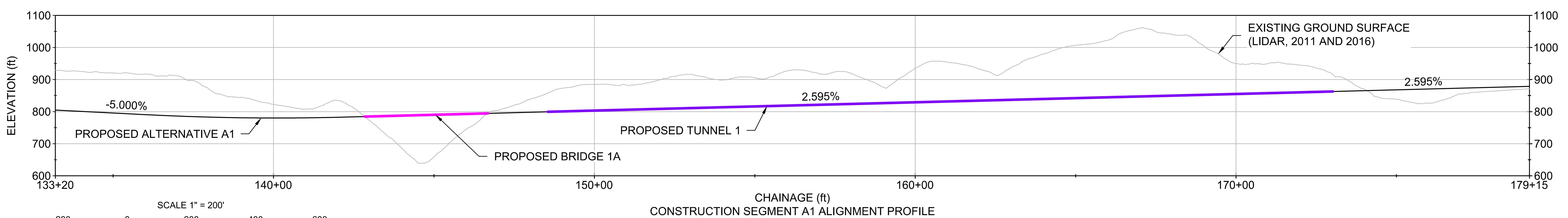
THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

LEGEND - CUT/FILL VOLUME	
CUT	786,850 Cu.Yd
FILL	28,300 Cu.Yd

LEGEND - GEOLOGY		
QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

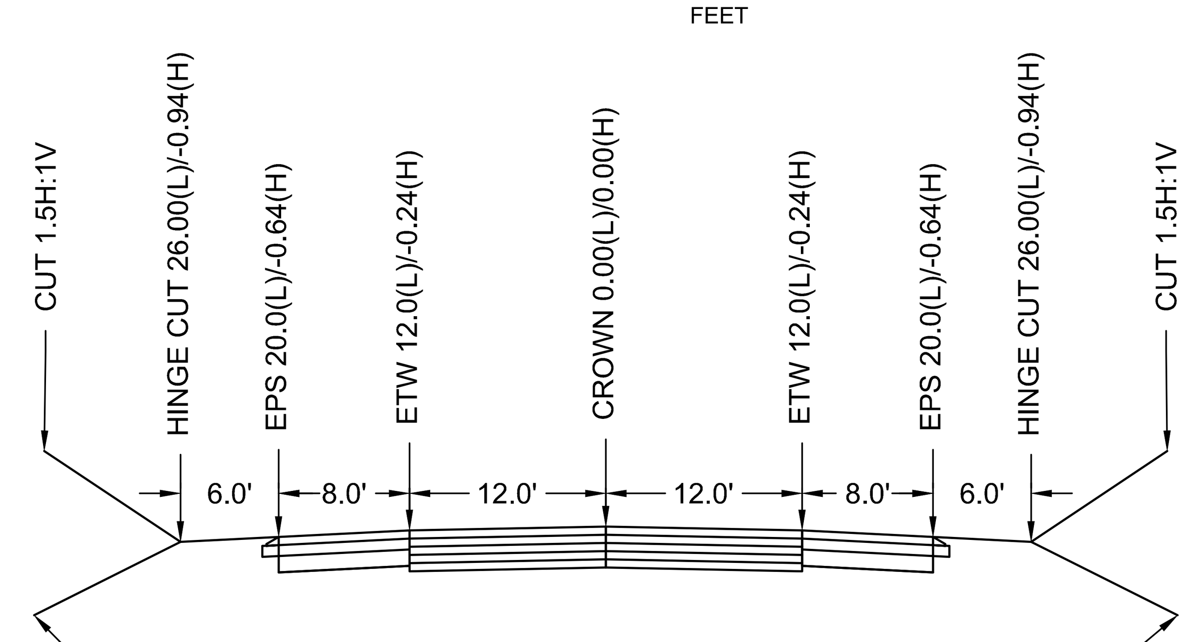
LEGEND - LANDSLIDE

DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			

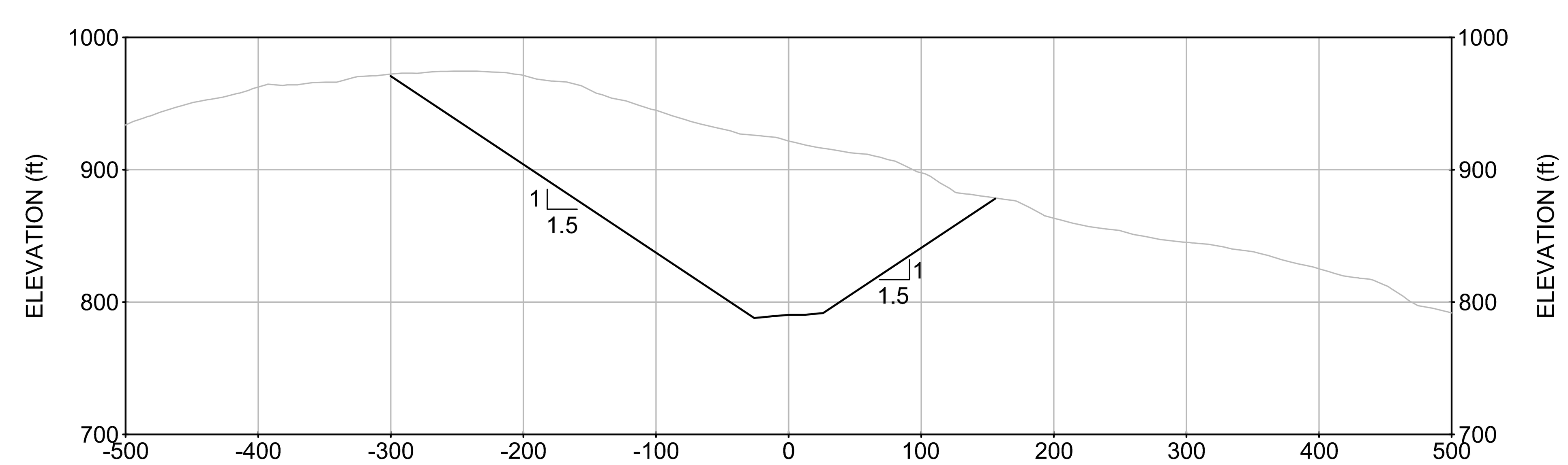


CONSTRUCTION SEGMENT A1 ALIGNMENT PROFILE

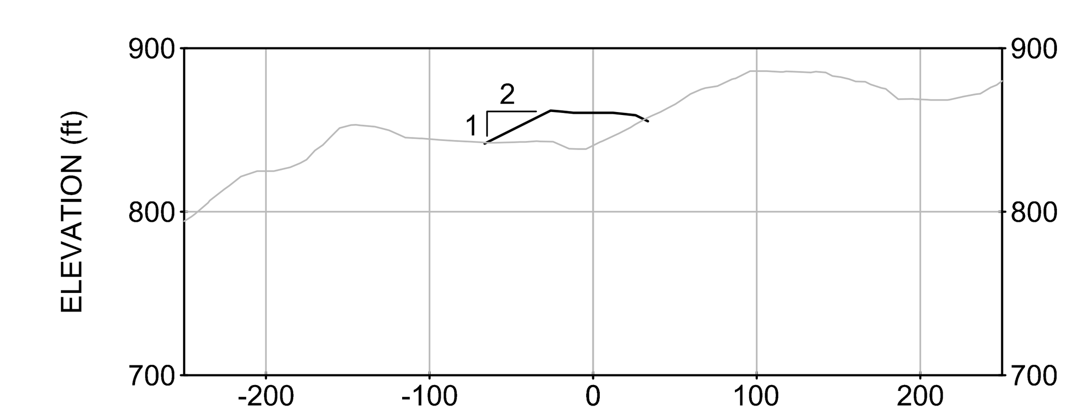
SCALE 1" = 200'



TYPICAL CROSS SECTION DETAIL
NTS



OFFSET DISTANCE (ft)
CROSS-SECTION 135+00
SCALE: 1" = 100'



OFFSET DISTANCE (ft)
CROSS-SECTION 175+00
SCALE: 1" = 100'

NOTES:
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SCALE:	AS SHOWN
DATE:	JUN 2018
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CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

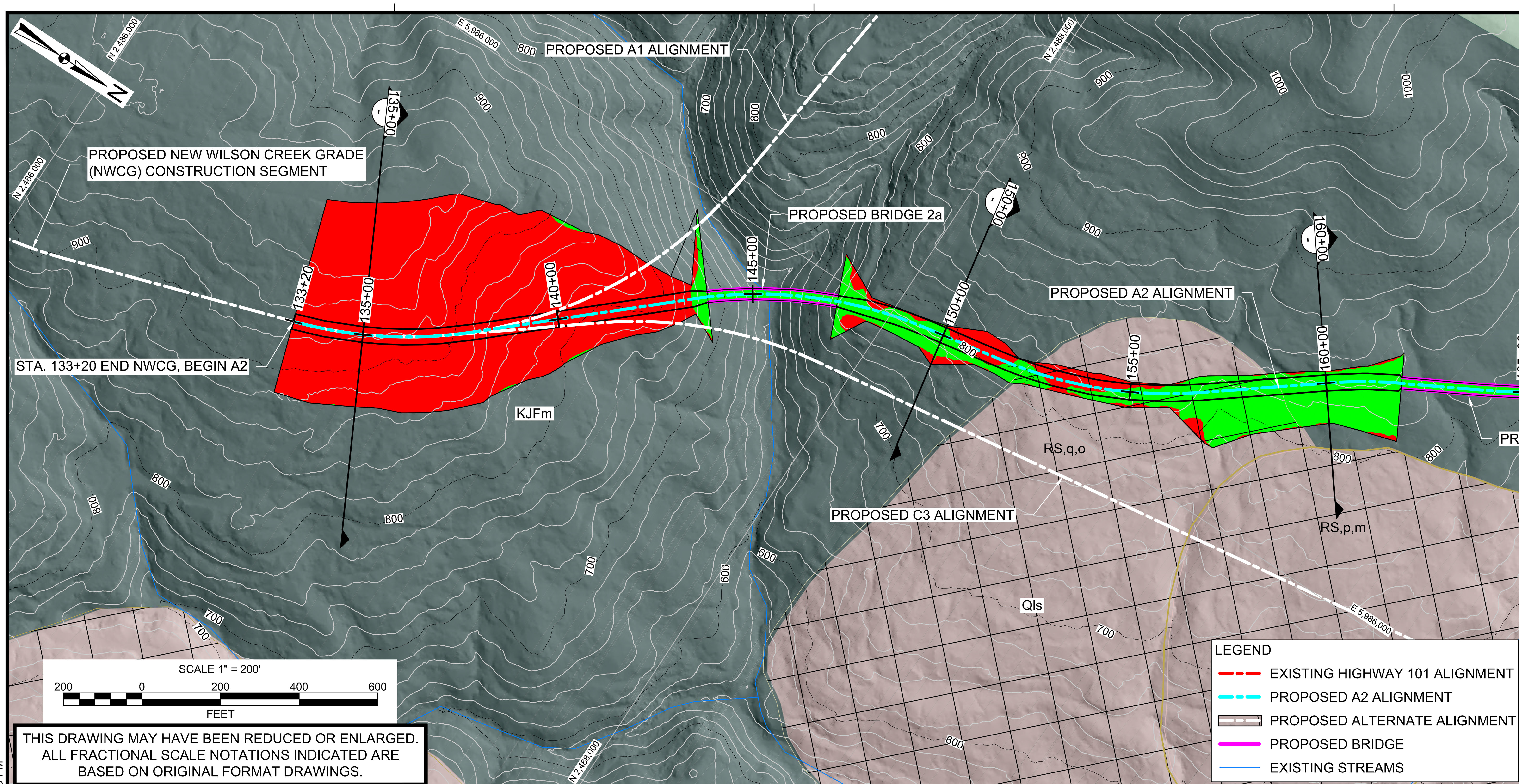
PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
A1 CONNECTION CONSTRUCTION SEGMENT
CONCEPTUAL DESIGN, GEOLOGY, AND LANDSLIDE PLAN

PROJECT No.: 1776-001
DWG No.: 04

THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

X:\Projects\1776\CAD\Production\Report-Memo\20171211_LAST_CHANCE_GRADE_EXPERT-BASED_RISK_ASSESSMENT\04.dwg Layout: 04 Plot Date Jun 7 18 Time: 10:24 PM



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LEGEND

EXISTING HIGHWAY 101 ALIGNMENT	
PROPOSED A2 ALIGNMENT	
PROPOSED ALTERNATE ALIGNMENT	
PROPOSED BRIDGE	
EXISTING STREAMS	

LEGEND - CUT/FILL VOLUME	
CUT	120,000 Cu.Yd
FILL	66,250 Cu.Yd

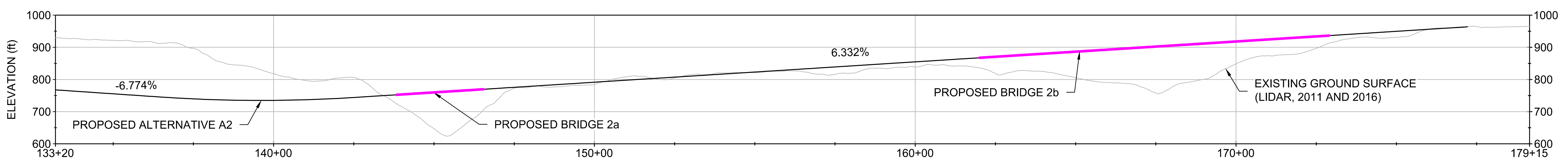
LEGEND - GEOLOGY

QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

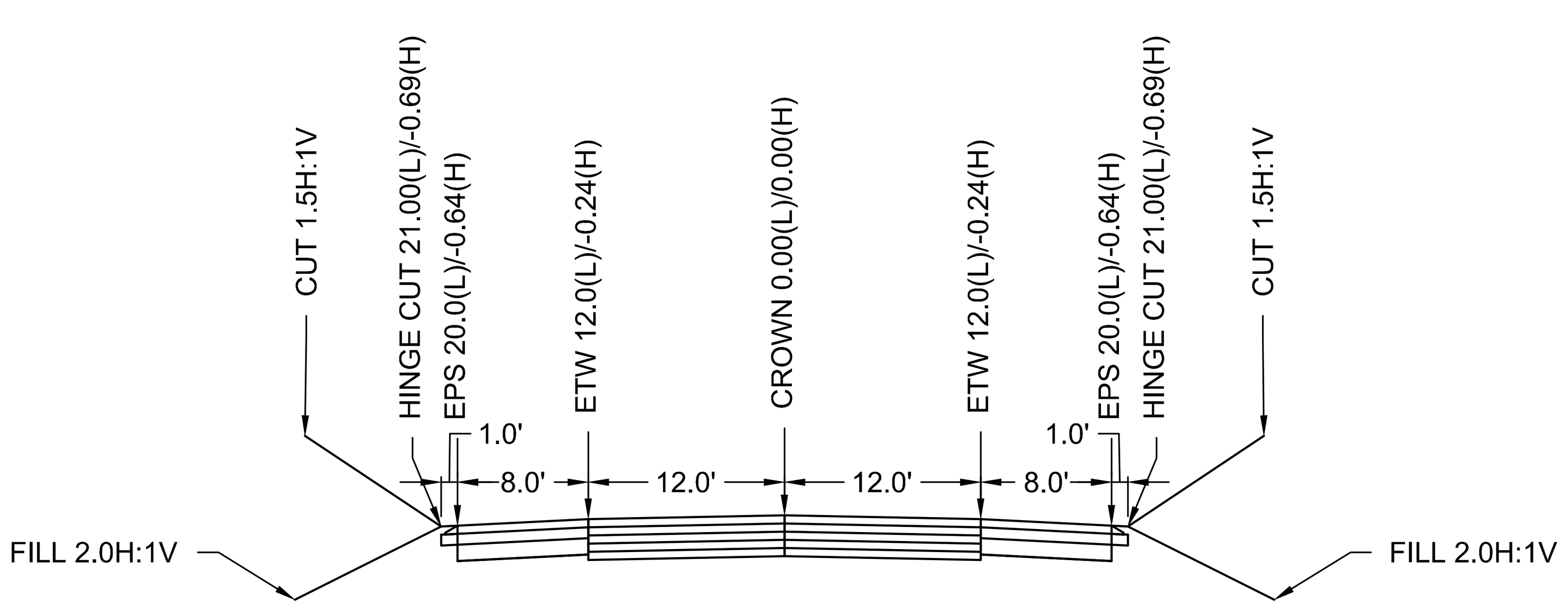
LEGEND - LANDSLIDE

DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			

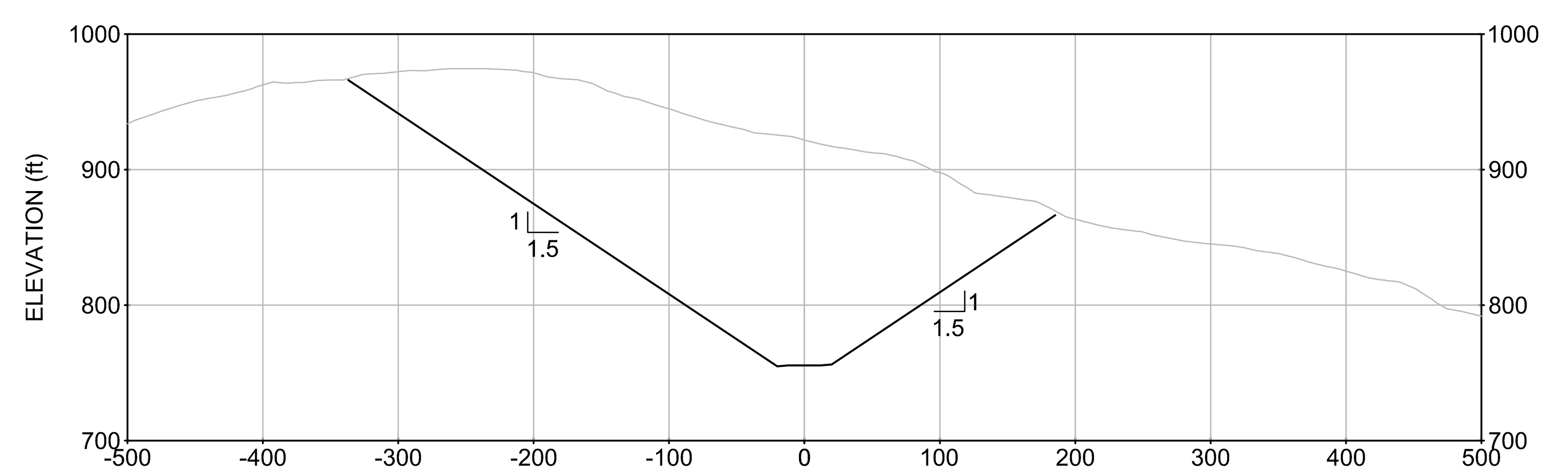
THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.



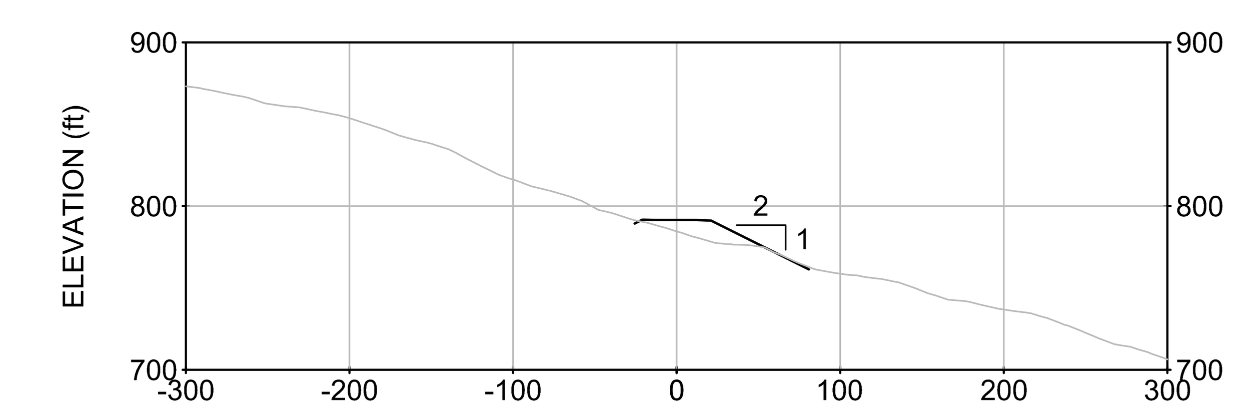
CHAINAGE (ft)
ALTERNATIVE A2 ALIGNMENT PROFILE



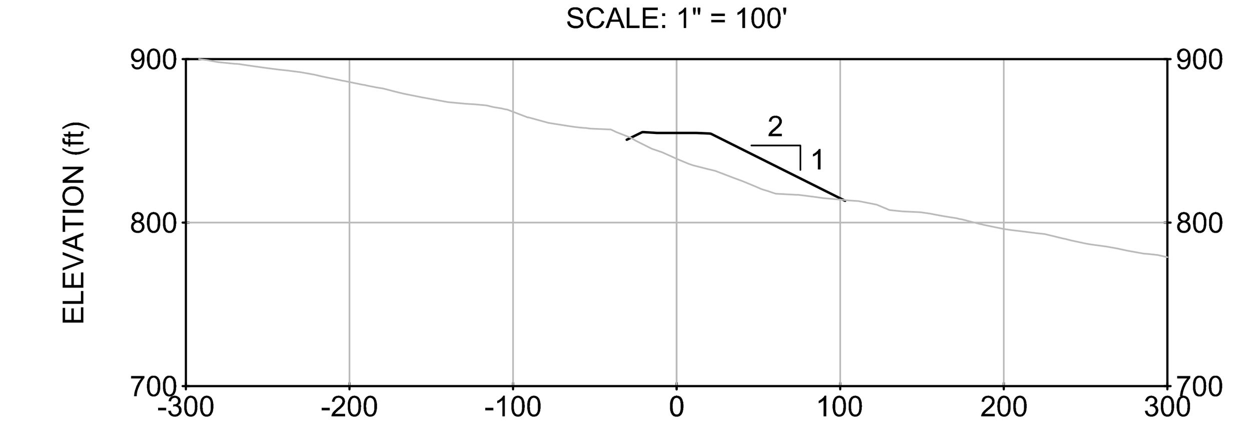
TYPICAL CROSS SECTION DETAIL
NTS



OFFSET DISTANCE (ft)
CROSS-SECTION 135+00
SCALE: 1" = 100'



OFFSET DISTANCE (ft)
CROSS-SECTION 150+00
SCALE: 1" = 100'



OFFSET DISTANCE (ft)
CROSS-SECTION 160+00
SCALE: 1" = 100'

NOTES:
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SCALE:	AS SHOWN
DATE:	JUN 2018
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CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
A2 CONNECTION CONSTRUCTION SEGMENT
CONCEPTUAL DESIGN, GEOLOGY, AND LANDSLIDE PLAN

PROJECT No.:	DWG No.:
1776-001	05

X:\Projects\1776\CAD\Production\Report-Memo\20171211_LAST_CHANCE_GRADE_EXPERT-BASED_RISK_ASSESSMENT\05.dwg Layout: 05 Plot Date Jun 7 18 Time: 10:29 PM

THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

LEGEND - CUT/FILL VOLUME	
CUT	8.12 M Cu.Yd
FILL	8.07 M Cu.Yd

LEGEND - GEOLOGY

QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

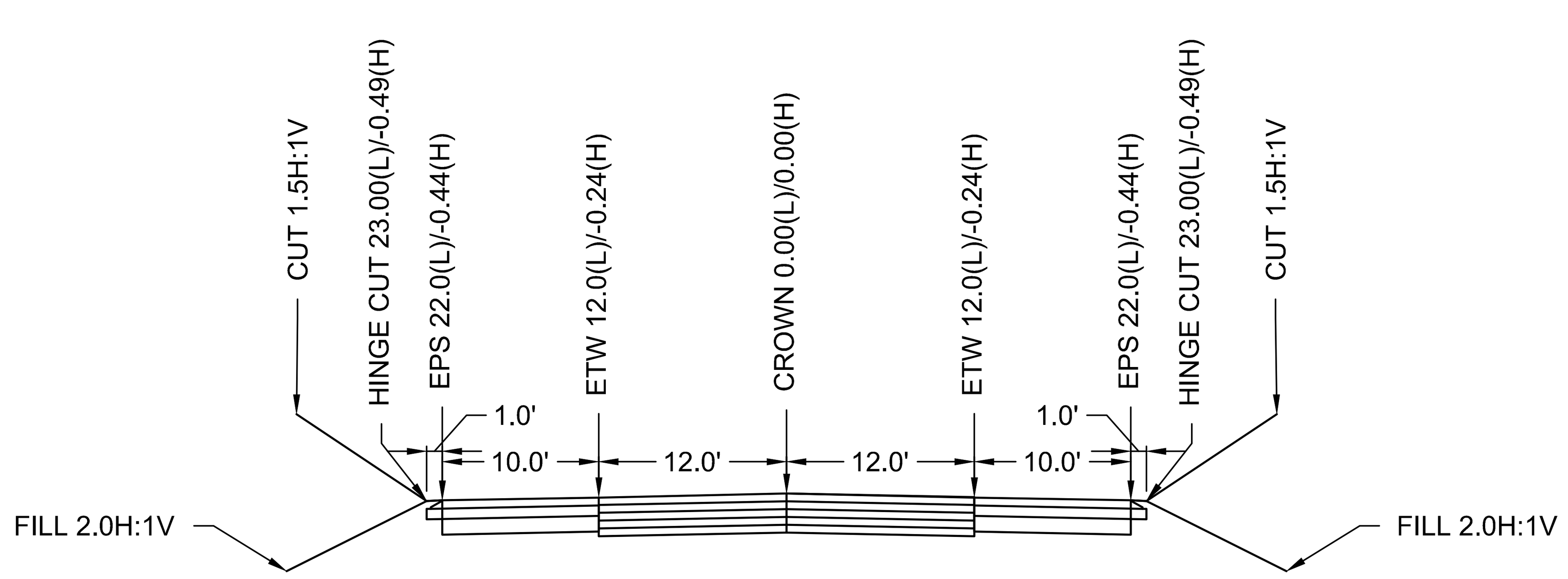
LEGEND - LANDSLIDE

DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			

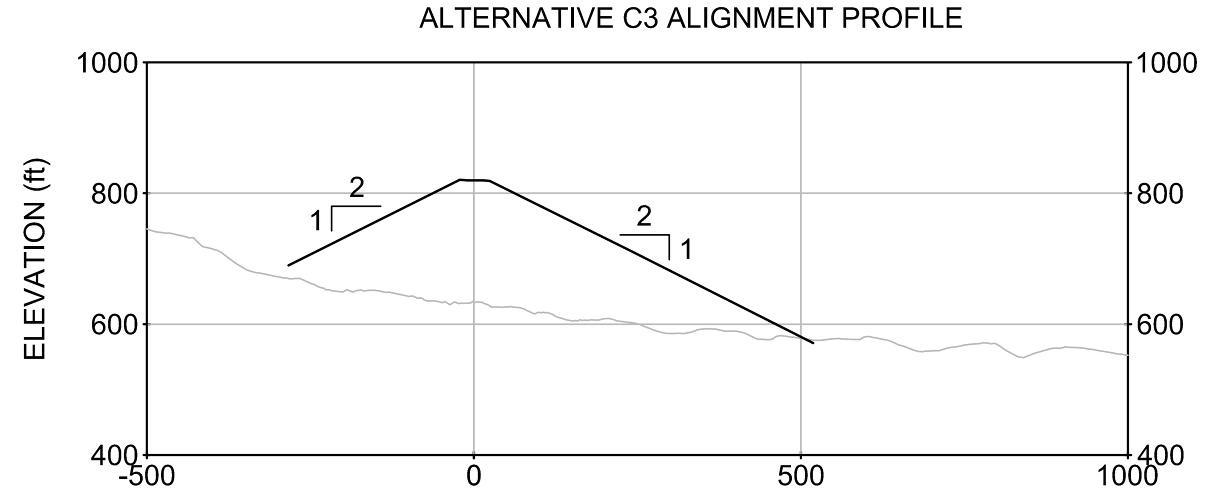
ALTERNATIVE C3 ALIGNMENT PROFILE

SCALE 1" = 1,000'

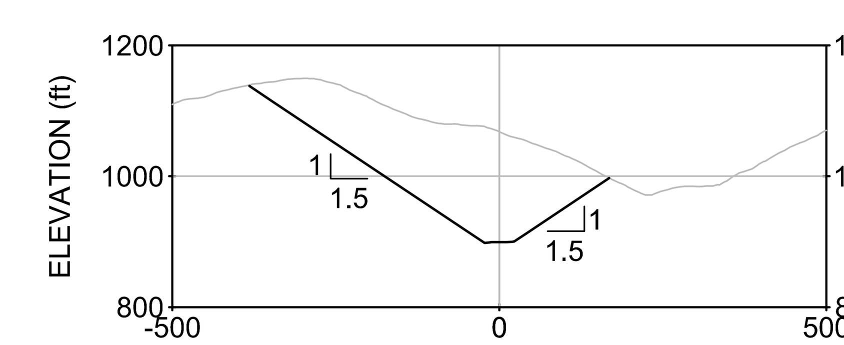
1,000 0 1,000 2,000 3,000 FEET



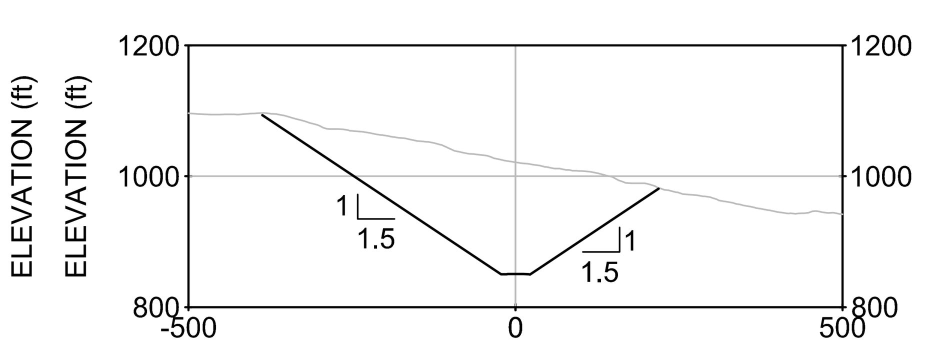
TYPICAL CROSS SECTION DETAIL
NTS



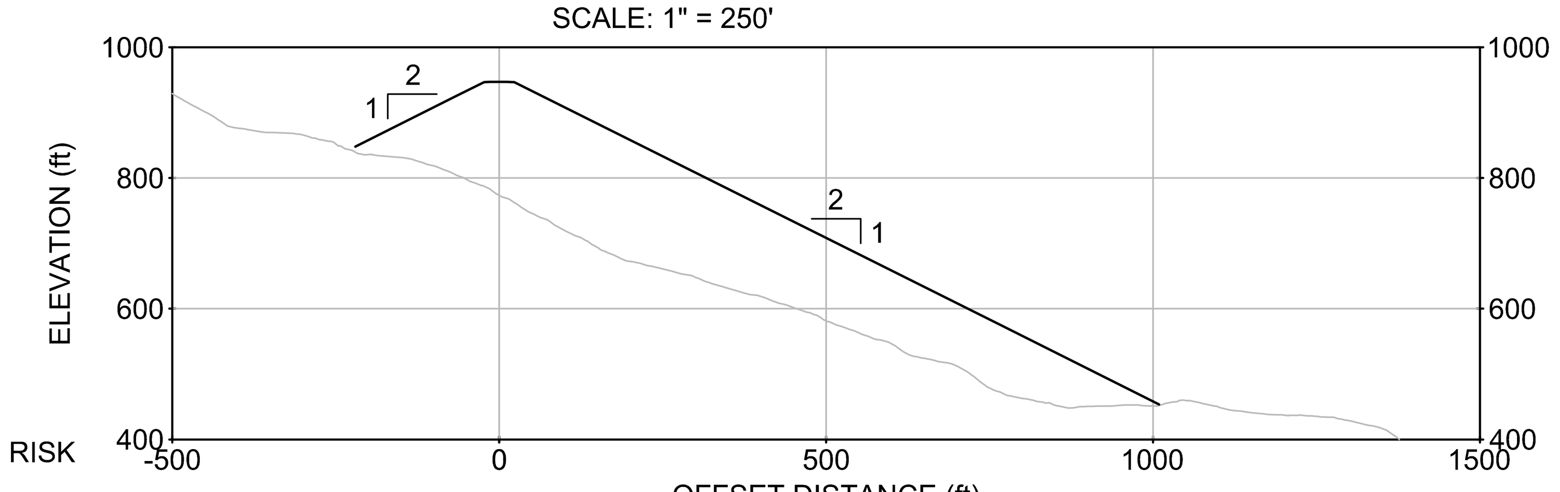
CROSS-SECTION 246+50
SCALE: 1" = 250'



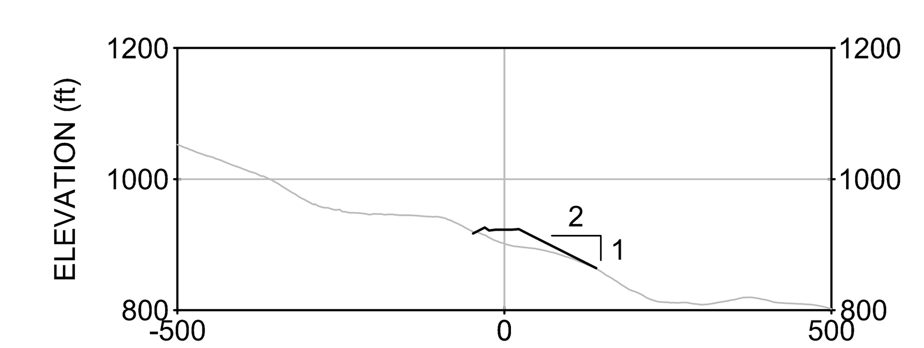
CROSS-SECTION 310+00
SCALE: 1" = 250'



CROSS-SECTION 343+00
SCALE: 1" = 250'



CROSS-SECTION 265+00
SCALE: 1" = 250'



CROSS-SECTION 405+50
SCALE: 1" = 250'

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SCALE:	AS SHOWN
DATE:	JUN 2018
DRAWN:	AH
CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

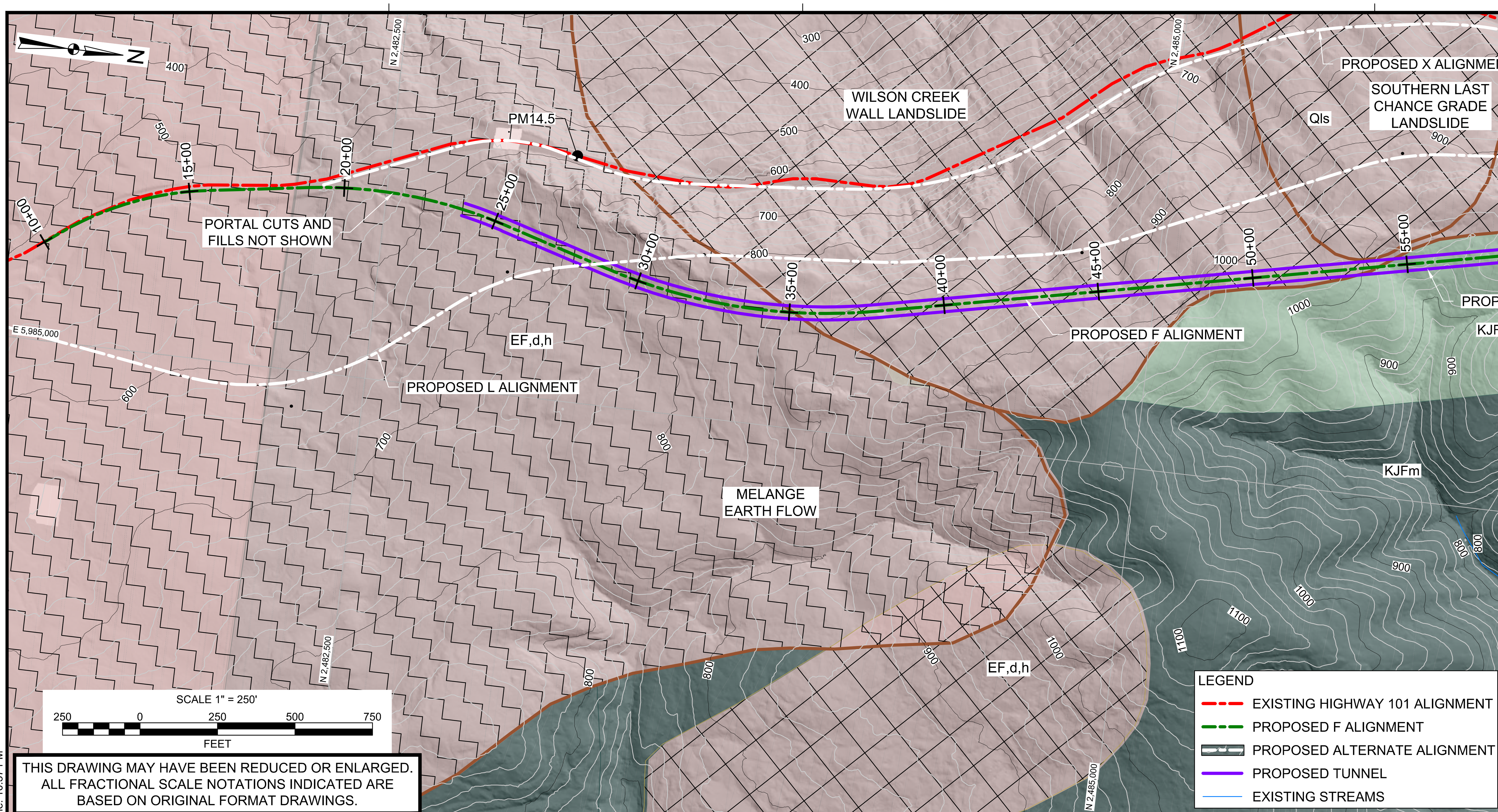
PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
C3 CONNECTION CONSTRUCTION SEGMENTS
CONCEPTUAL DESIGN, GEOLOGY, AND LANDSLIDE PLAN

PROJECT No.:	DWG No.:
1776-001	06

THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

X:\Projects\1776\CAD\Production\Report-Memo\20171211_LAST_CHANCE_GRADE_EXPERT-BASED_RISK_ASSESSMENT\06.dwg Layout: 06 Plot Date Jun 7 18 Time: 10:33 PM



THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

LEGEND - CUT/FILL VOLUME	
CUT	NA
FILL	NA

LEGEND - GEOLOGY		
QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

LEGEND - LANDSLIDE

DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			

ALTERNATIVE F ALIGNMENT PROFILE

SCALE 1" = 250'
250 0 250 500 750
FEET

NOTES:

1. ALL DIMENSIONS ARE IN FEET UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT", AND DATED JUNE 2018.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS), DATED 2011 AND 2016. CONTOUR INTERVAL IS 20.0 FT.
4. PROJECTION IS STATE PLANE CALIFORNIA ZONE 1 NAD83 US FEET.
5. SEE DRAWING 01 NOTES FOR ADDITIONAL EXPLANATION AND REFERENCE FOR THIS DRAWING.
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SCALE:	AS SHOWN
DATE:	JUN 2018
DRAWN:	AH
CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
LAST CHANCE GRADE TUNNEL F CONSTRUCTION SEGMENT CONCEPTUAL DESIGN, GEOLOGY, AND LANDSLIDE PLAN

PROJECT No.:	DWG No.:
1776-001	07

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THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

LEGEND - CUT/FILL VOLUME	
CUT	889,185 Cu.Yd
FILL	74,450 Cu.Yd

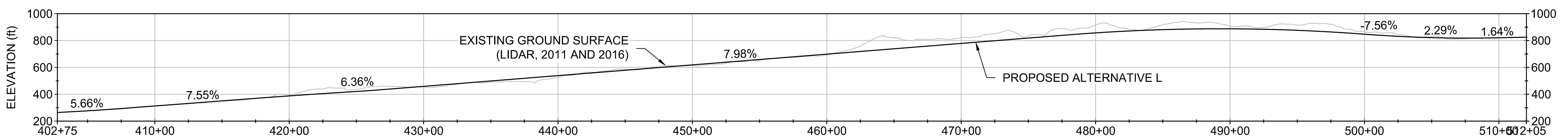
THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.

LEGEND - GEOLOGY

QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

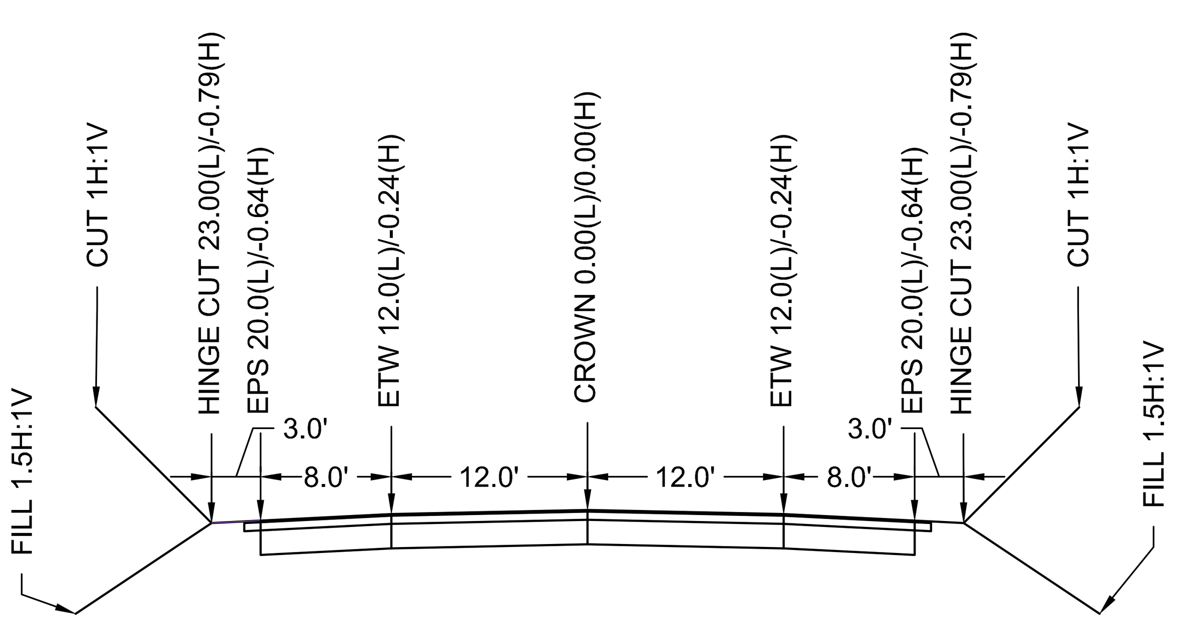
LEGEND - LANDSLIDE

DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			

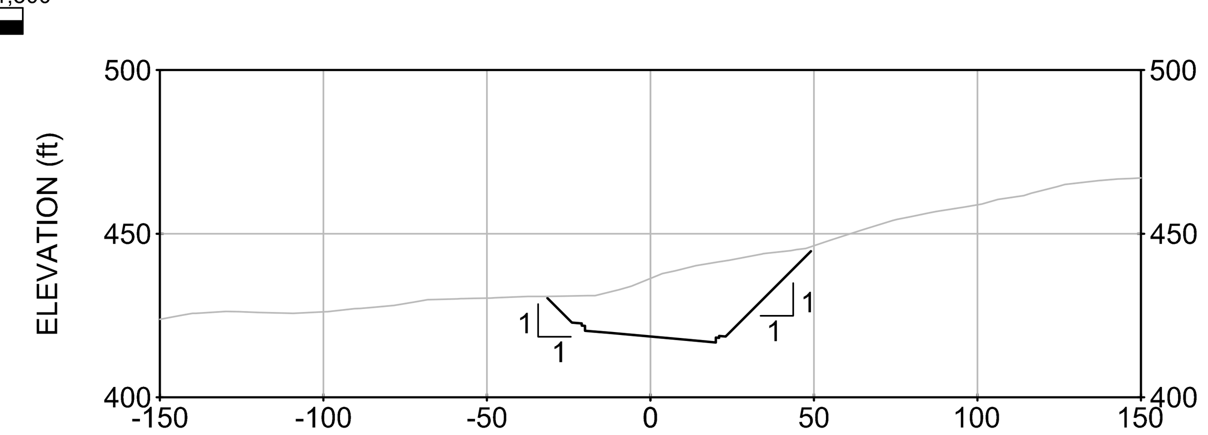


CHAINAGE (ft)
ALTERNATIVE L ALIGNMENT PROFILE

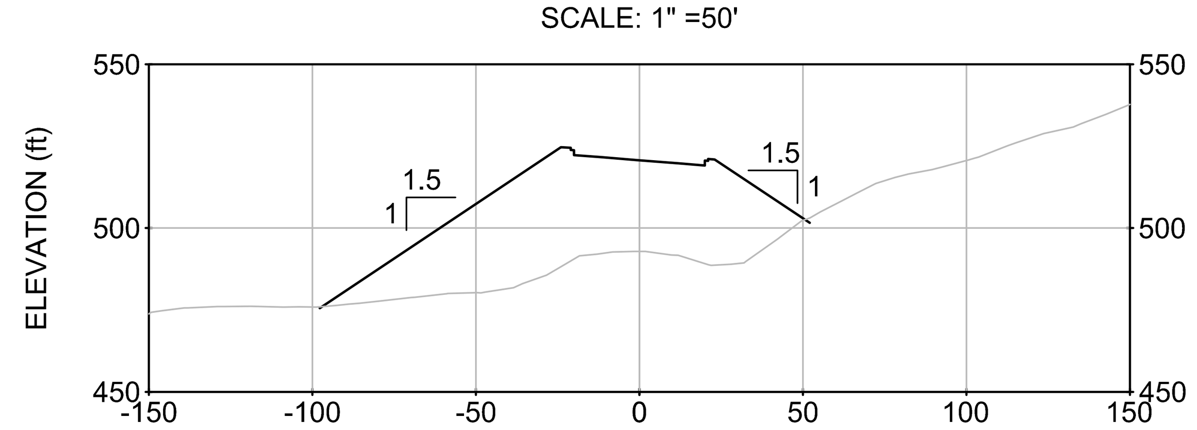
SCALE 1" = 500'
500 0 500 1,000 1,500
FEET



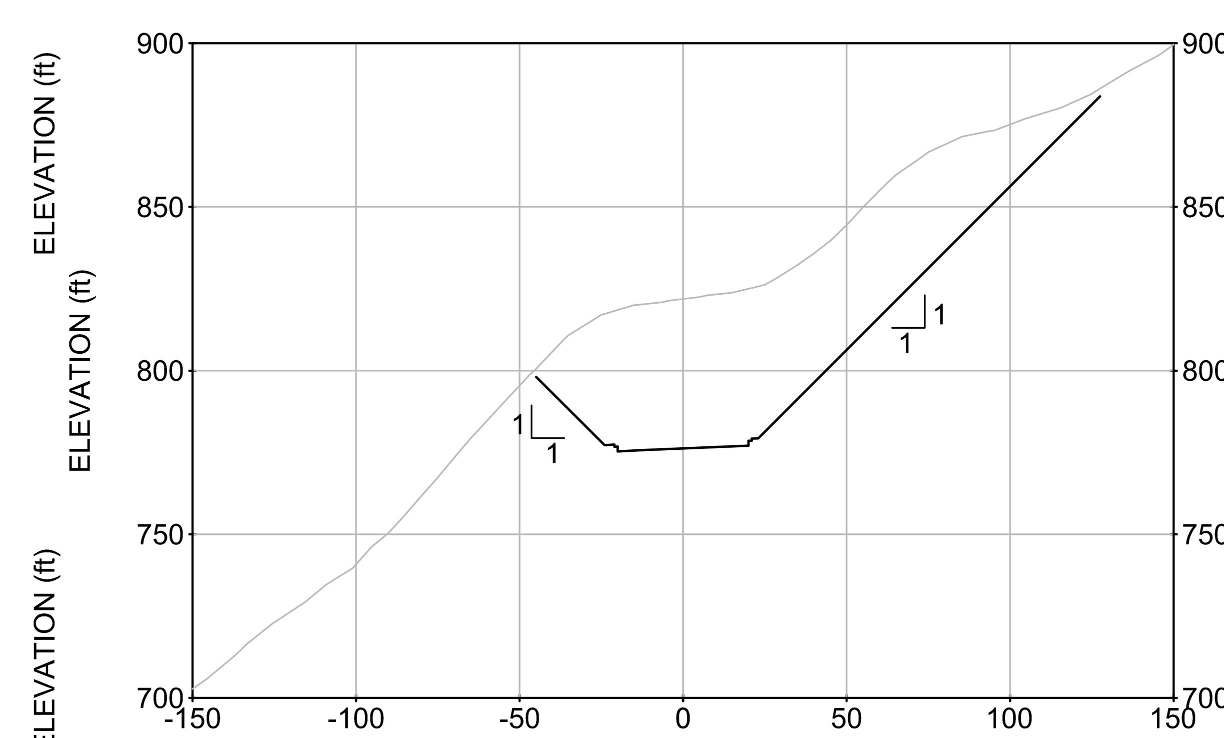
TYPICAL CROSS SECTION DETAIL
NTS



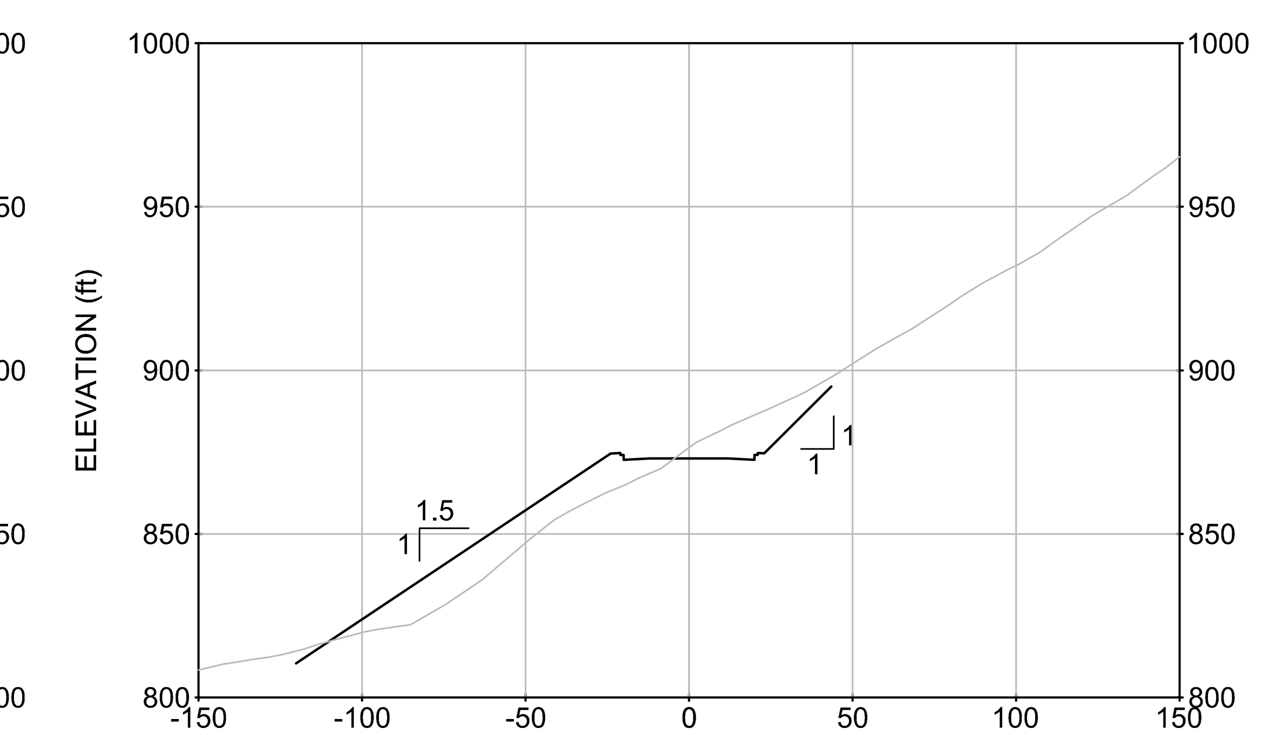
OFFSET DISTANCE (ft)
CROSS-SECTION 425+00
SCALE: 1" =50'



OFFSET DISTANCE (ft)
CROSS-SECTION 438+00
SCALE: 1" =50'



OFFSET DISTANCE (ft)
CROSS-SECTION 470+00
SCALE: 1" =50'



OFFSET DISTANCE (ft)
CROSS-SECTION 483+50
SCALE: 1" =50'

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3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY CALIFORNIA STATE TRANSPORTATION (CALTRANS), DATED 2011 AND 2016. CONTOUR INTERVAL IS 20.0 FT.
4. PROJECTION IS STATE PLANE CALIFORNIA ZONE 1 NAD83 US FEET.
5. SEE DRAWING 01 NOTES FOR ADDITIONAL EXPLANATION AND REFERENCE FOR THIS DRAWING.
6. CONCEPTUAL DESIGN INCLUDES SURFACE AND SUBSURFACE DRAINAGE NOT SHOWN HERE. ANTICIPATED ELEMENTS INCLUDE LINED DITCHES AND DRILLED DRAINS, AND POSSIBLY SHAFTS AND TUNNELS, TO CONTROL SHALLOW, PERCHED, AND REGIONAL WATER LEVELS WITHIN AND BELOW SLIP SURFACES. SCOPE OF INSTALLED DRAINAGE IS ASSUMED TO BE PRECEDENT-SETTING FOR HIGHWAY WORK.
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SCALE:	AS SHOWN
DATE:	JUN 2018
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CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

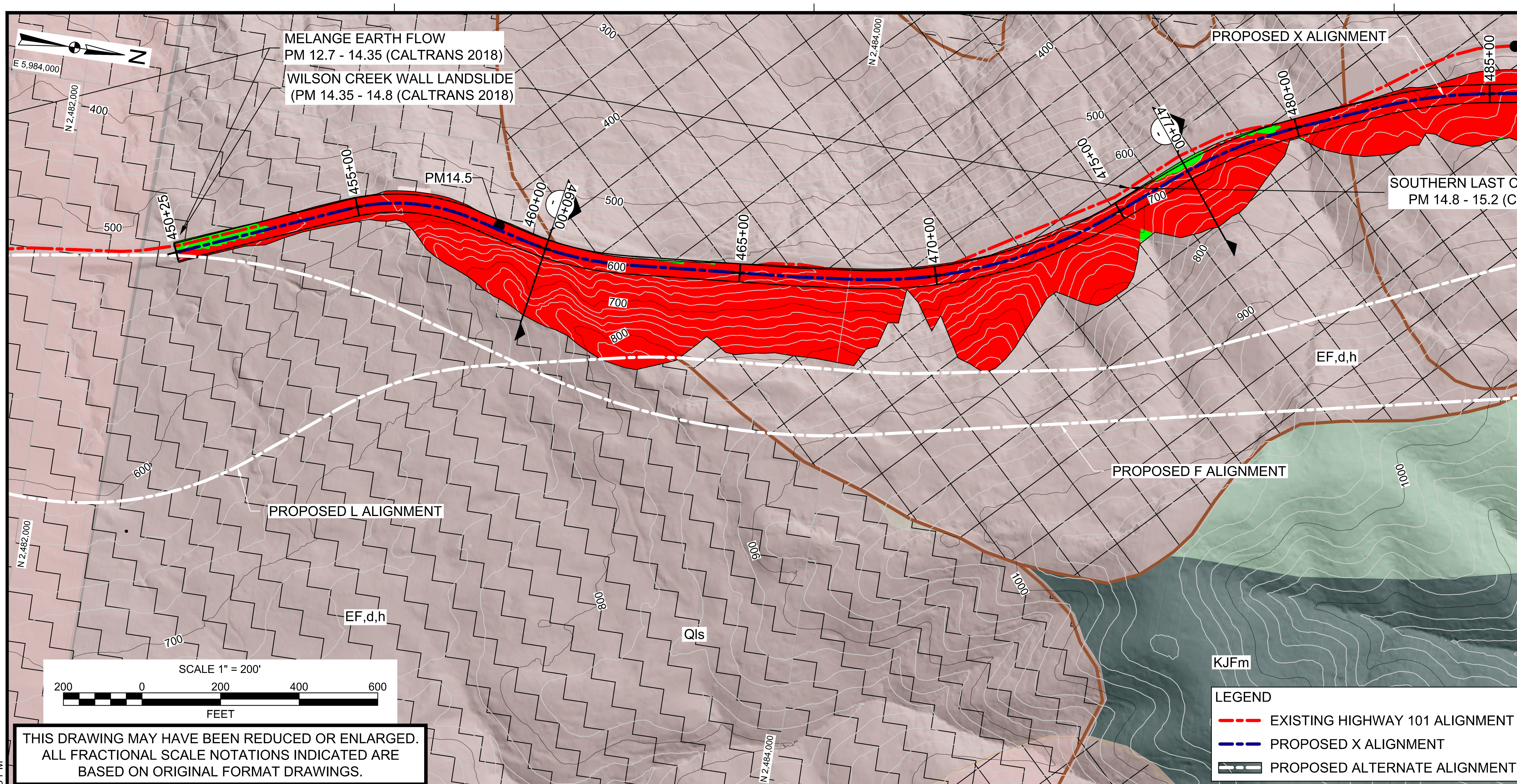
CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
MÉLANGE EARTH FLOW (L) AND LAST CHANCE GRADE LANDSLIDES (L) CONSTRUCTION SEGMENTS CONCEPTUAL DESIGN, GEOLOGY, AND LANDSLIDE PLAN

PROJECT No.:	DWG No.:
1776-001	08

X:\Projects\1776\CAD\Production\Report-Memo\20171211_LAST_CHANCE_GRADE_EXPERT-BASED_RISK_ASSESSMENT\08.dwg Layout: 08 Plot Date Jun 7 18 Time: 10:52 PM



THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

LEGEND - CUT/FILL VOLUME	
CUT	751,245 Cu.Yd
FILL	3,370 Cu.Yd

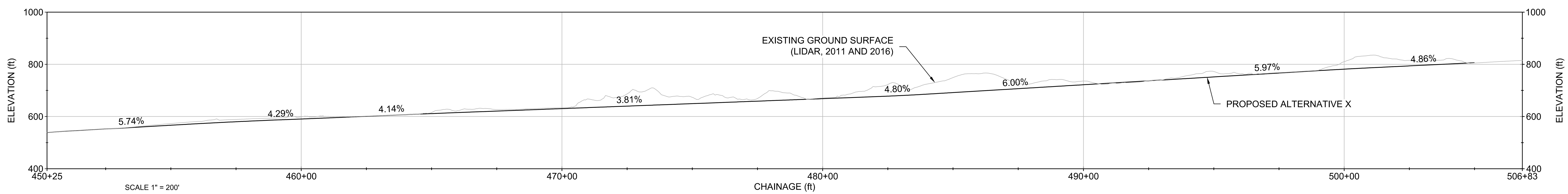
LEGEND - GEOLOGY

QUATERNARY	Qal	ALLUVIUM, UNCONSOLIDATED SAND AND GRAVEL IN ACTIVE STREAM CHANNELS AND FLOODPLAINS
	Qb	BEACH DEPOSITS, SAND ON ACTIVE AND OLDER BEACH AREAS
	Qls	LANDSLIDE DEPOSITS, DISRUPTED WEATHERED BEDROCK AND DEBRIS
CRETACEOUS	KJFm	MELANGE, HIGHLY SHEARED SHALE AND ARGILLITE
	KJFbf	BROKEN FORMATION, HARD SANDSTONE AND SHEARED SHALE
	Fbm	BLOCKS OF DISTINCT ROCK TYPES WITHIN MELANGE MAY INCLUDE SANDSTONE, SERPENTINE, GREENSTONE AND CHERT

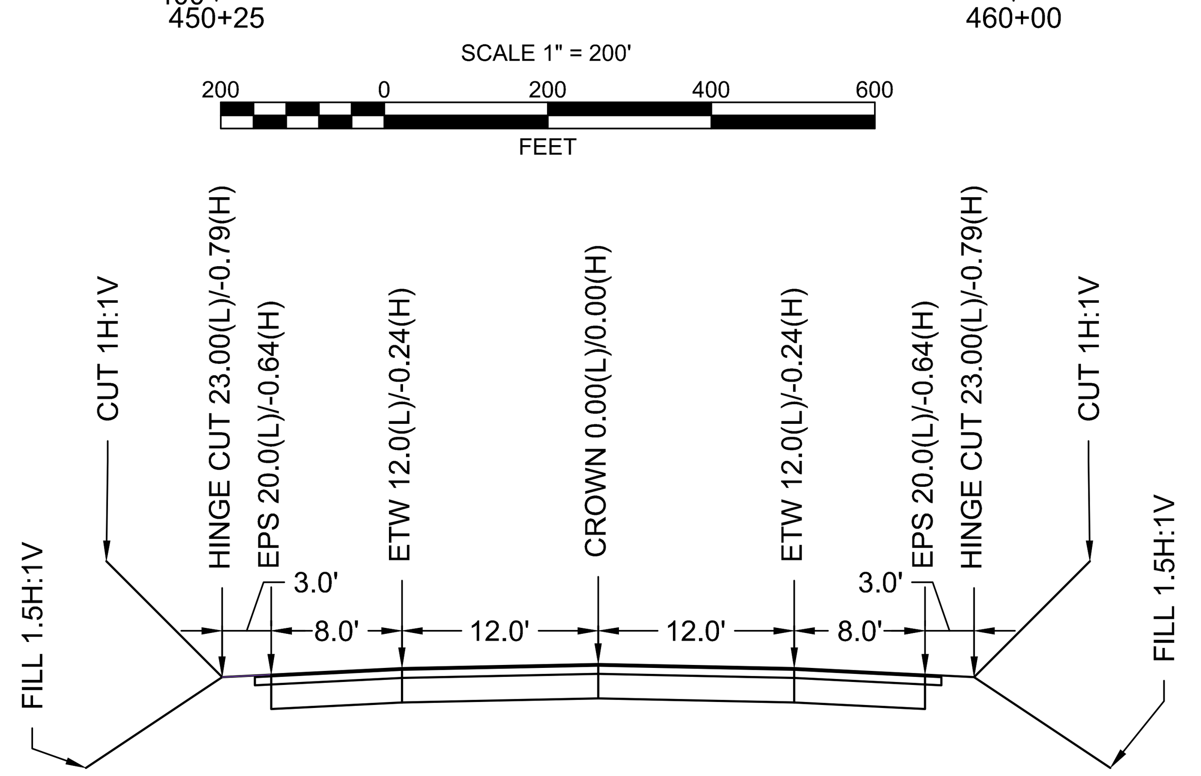
LEGEND - LANDSLIDE

DEFINITE (D)	HISTORIC (H)	YOUNG (Y)	PROBABLE (P)	HISTORIC (H)	YOUNG (Y)	MATURE (M)	QUESTIONABLE (Q)	YOUNG (Y)	MATURE (M)	OLD (O)
DEBRIS FLOW (DF)			DEBRIS FLOW (DF)				DEBRIS FLOW (DF)			
DEBRIS SLIDE (DS)			DEBRIS SLIDE (DS)				DEBRIS SLIDE (DS)			
ROCK SLIDE (RS)			ROCK SLIDE (RS)				ROCK SLIDE (RS)			
EARTH FLOW (EF)			EARTH FLOW (EF)				EARTH FLOW (EF)			

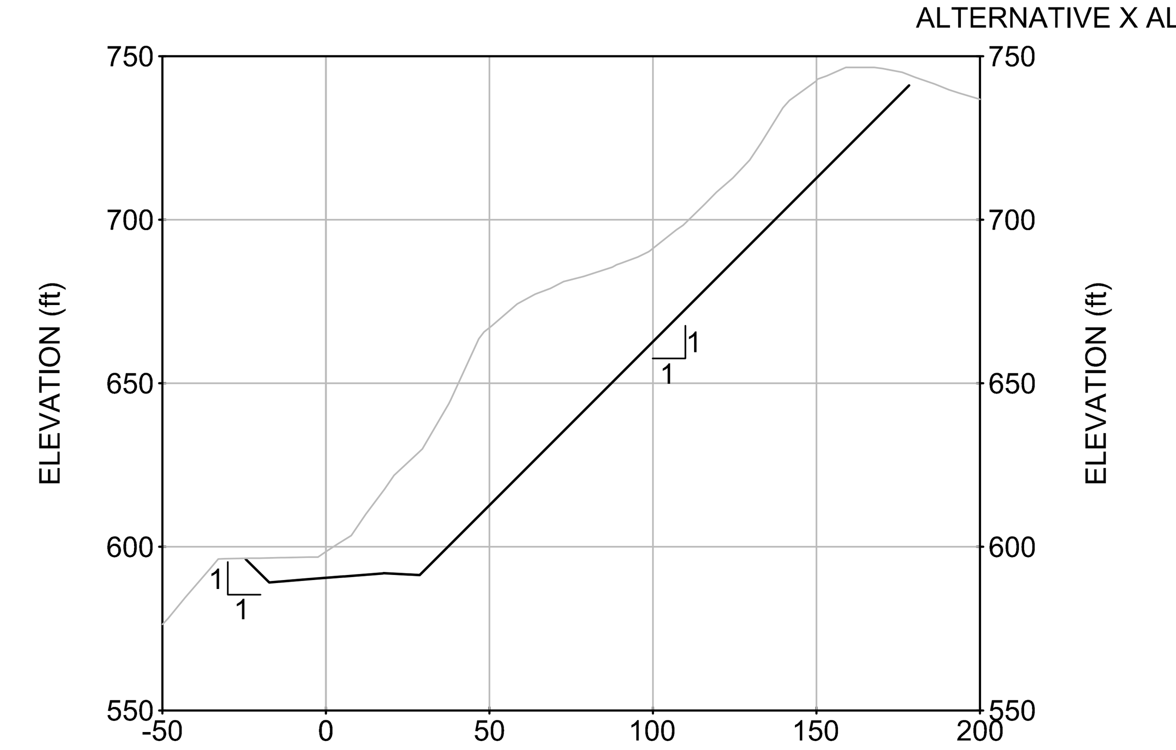
THIS BAR MEASURES 100 mm AT FULL SIZE. ALL SCALES REFERENCED TO FULL SIZE.



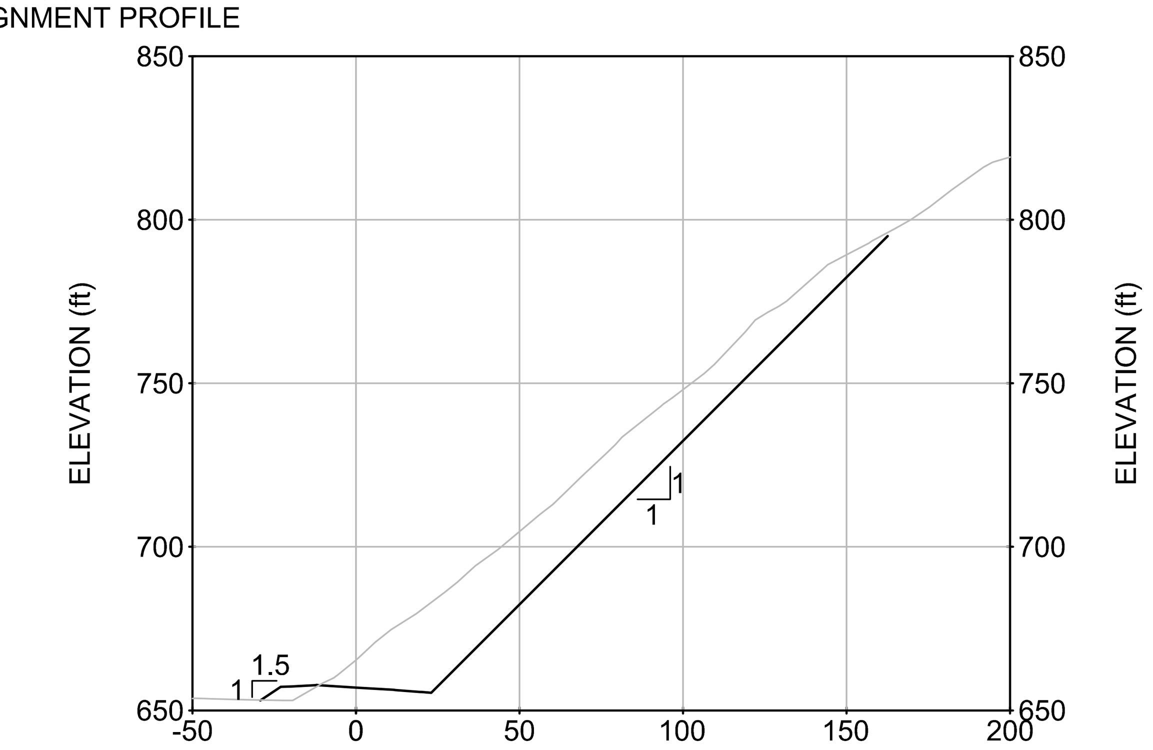
ALTERNATIVE X ALIGNMENT PROFILE



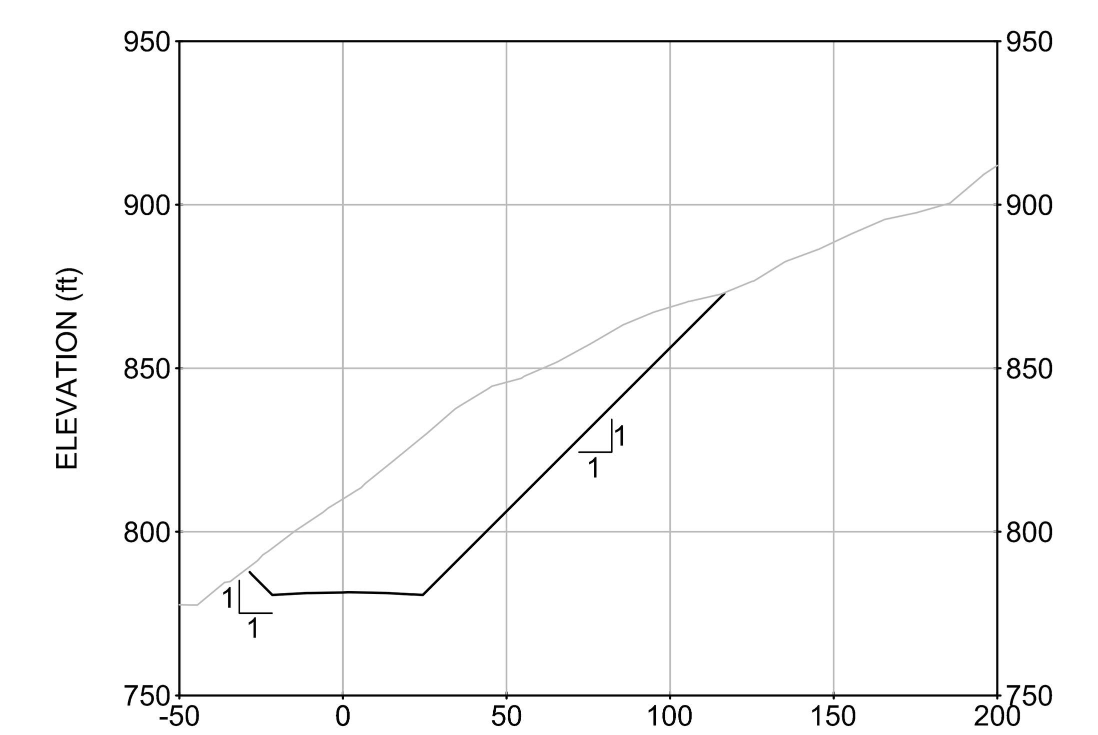
TYPICAL CROSS SECTION DETAIL
NTS



CROSS-SECTION 460+00
SCALE: 1" =50'



CROSS-SECTION 477+00
SCALE: 1" =50'



CROSS-SECTION 500+00
SCALE: 1" =50'

NOTES:
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SCALE:	AS SHOWN
DATE:	JUN 2018
DRAWN:	AH
CHECKED:	CC
APPROVED:	SA

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

PROJECT:
LAST CHANCE GRADE EXPERT-BASED RISK ASSESSMENT

TITLE:
LAST CHANCE GRADE LANDSLIDES (X) CONSTRUCTION SEGMENT CONCEPTUAL DESIGN, GEOLOGY, AND LANDSLIDE PLAN

PROJECT No.:	DWG No.:
1776-001	09