Memorandum

To: Scott Golbek (WSDOT), Steve Lowell (WSDOT)

Cc: Dave Walker (URS Corporation)

From: Norman I. Norrish, P.E. (Wyllie & Norrish Rock Engineers Inc.)

Norman I Norrish

Date: August 16, 2010

Re: Phase 1C Rock Slopes
I-90 Snoqualmie Pass East Snowshed

Background

As part of URS Corporation Work Order number 33758664.00003 Task DQ, Wyllie & Norrish Rock Engineers Inc. (W&N) is providing support to WSDOT for the preparation of Plans, Specifications and Estimates (PS&E) for the Phase 1C Project. The scope of work is primarily concerned with accurate incorporation of recommendations contained in the Geotechnical Report ("Phase 1C – Rock Slope Engineering Report, April, 2009) into the PS&E. Subsequent to the submittal of the aforementioned report, multiple alternatives for the cut slope template between Stn 1384+00 LW and Stn 1394+ 00 LW were analyzed by WSDOT South Central Region. These analyses were concerned with optimizing the rock slope templates to:

1. Provide sufficient ditch width to meet hydraulic and snow storage requirements.
2. Provide sight distance in accordance with highway design speed, profile and grade.
3. Provide rockfall catchment in accordance with WSDOT design standards.
4. Meet stability margins as recommended in W&N, 2009.
5. Satisfy constructability constraints imposed by traffic scheduling / routing.
6. Optimize construction cost through minimizing excavation volume while meeting constructability limitations imposed by difficult slope access.

These design objectives led to the consideration of two broad categories of rock cuts; those deemed "sliver cuts" that required minimal excavation volume and precluded access to the top-of-cut, and "conventional" top-down excavation of cuts with a reasonable construction width, typically 20 feet.

Following discussions with SC Region and WSDOT Geotechnical Division, it was agreed that W&N would solicit the opinions of specialty rock excavation contractors regarding constructability, reanalyze rock slope stability requirements taking into account the constructability recommendations, and summarize the results in a technical memorandum for final design guidance to SC Region.

Approach

Two specialty contractors were invited to the site; one with expertise in rock slope drilling, blasting, and reinforcement in steep mountainous terrain, and the second with previous experience performing mechanical excavation for high rock slopes on the I-90 corridor in the vicinity of the project site. The site reviews involved inspection of existing rock slopes from the current I-90 grade, review of alternative slope templates, and discussions relating to fatal flaws and or construction risk.

Constructability Assessments

Both contractors were of the definite opinion that the slopes were constructible utilizing their specific excavation methodologies. That is, the drill, blast and reinforcing contractor was of the opinion that conventional top-down construction methods were workable provided an adequate width was removed. Similarly, the mechanical excavation contractor felt that sliver cuts could be developed to the required heights using mechanical excavation techniques.

To further analyze these excavation approaches, a decision matrix was developed utilizing input from the contractors as well as issues pertaining to rock slope stability and highway geometry. The results are presented in the form of an advantage/disadvantage listing in Table 1. Based on the tabular comparison and contractor discussions, each approach has critical issues:

Conventional Cuts

The steep natural terrain above the proposed cuts slopes will preclude the explore and refine approach for establishing the contact between overburden soils and the bedrock. As shown in Figure 1, the contractor will be required to pioneer just below the top-of-cut using slash drilling techniques, thereby precluding overburden exploration higher up the slope. Slash drilling refers to a drilling and blasting technique in which short blast holes (nominally less than 14 ft) are drilled horizontally into an advancing face, much like tunnel blasting. The slopes in Phase 1C are amenable to this approach because the overburden depths are minimal (WSDOT, 2010). However, WSDOT must be prepared to stake the catch point in advance of construction and to accept the risk for any substantive deviations if the top-of-rock is not encountered as predicted. Small, mobile drilling equipment such as that shown above must be employed to successfully access the steep terrain.

Sliver Cuts

The critical issue in this case is the approach to excavating localized areas where the rock mass strength is sufficiently high to reduce the efficiency of mechanical excavation. In such cases the mechanical excavation contractor may require the assistance of a drill and blast operation to loosen or remove the stronger rock. Such trim blasting could occur at elevated locations on the slope face mandating hand drilling from ropes or crane-assisted drilling. Controlled blasting would not be feasible and flyrock should be anticipated. The final face developed by mechanical excavation would be highly irregular in response to local structural control (joints, flows etc). Localized stabilization with rock bolts or dowels would require the use of rope or crane supported work platforms.

Table 1. COMPARISON MATRIX
Phase 1C Rock Slopes

	Conventional Rock Cut Excavation	Sliver Cut Rock Excavation
Equipment	Small track drill Excavator	"High reach" hydraulic boom Impact hammer
Constructability		
Requires top-of-cut access	Yes	No
Ability to handle variable rock quality	High	May need local blast assist
Requires minimum width	Yes ± 20 ft	No
Site suitability for equipment	Difficult	Good
Requires pre-defined catch point for cut	Yes	No
Contractor confidence	High	High
Slope Stability / Rockfall		
Removal of existing poor quality rock face	Yes	Partial
Integrity of new cut face	Good (with controlled blasting)	Good
Uniformity of final face	Good	Poor
Compatibility with top-down reinforcement	Good - spyder assist	Good - crane assist
Other Issues		
Minimizes excavation volume	No	Yes
Rate of excavation	Moderate	Slow
Availability of Qualified Contractors	Moderate	Low
Traffic issues	Periodic interruption for blasting	Live traffic with net protection
Collateral benefits from enhanced ditch volume	Yes	No
Advisory Specification for "special excavation" zone	Yes	Yes

Based on the foregoing discussion, it is the considered opinion of W&N that conventional top-down rock excavation be employed for the Phase 1C rock cuts between Stations 1384+00 and 1394+00 LW. This assertion is conditional on the following:

1. WSDOT will stake the catch points in advance of construction based on the best available exploration data.

2. Contractual language can be incorporated into the PS&E that require the rock drilling, rock excavation and rock reinforcement activities to be performed by a single company with demonstrated experience with similar projects in mountainous terrain.

3. The successful bidder will be required to submit a construction plan for rock excavation and reinforcement, including specifications for proposed equipment, for prior review by WSDOT. Such review by WSDOT should examine whether the contractor's means and methods demonstrate an understanding of the advisory specification for this specific station interval that will be included in the contract documents.

Revised Stabilization Recommendations

Slope stability analyses previous performed for W&N (2009) demonstrated that the nominal 100-foot high existing slopes between 1884+00 and 1894+00 LW have a margin of stability less than 1.25. To improve stability margins for new cuts it was previously recommended that the station interval be pattern doweled with large diameter dowels (#20 bars 15ft horizontal x 12 ft vertical pattern). The oversize bars included sacrificial steel to obviate the need for corrosion protection. Given the limitations imposed by either the "conventional" or "sliver" cut approaches discussed above, it is necessary to revise the reinforcement plan to accommodate smaller drills and restricted access. Accordingly, the dowels above the crest and the upper two rows of pattern dowels have been limited to #9 bars with an ultimate strength of 100 kips. The crest dowels should 25 feet long and the upper two rows of pattern dowels should be 40 feet long. Such bars could be installed in boreholes advanced with bencher or other difficult access drills as shown below. Alternatively, crane-supported work platforms could be utilized.

Bencher drill and spyder cage – 2 ½ inch diameter hole, 40-foot depth limitation.

After the uppermost one or two rows when the bench width attains about 20-foot width, it is assumed that larger diameter drill holes could be advanced using down hole hammers. Thus the bar size and bar length for the design has been increased to #14 bar (225 kip ultimate) for the third and subsequent rows to provide greater stability. Figure 2 summarizes the revised stability analyses.

The recommended stabilization layout is shown conceptually in Figure 3. It consists of the following:

1. A row of crest dowels installed in advance of blasting for the first excavation lift. The crest dowels should be epoxy coated #9 bars (100 kip ultimate), spaced at 10 feet and inclined at -15°.

2. One or two rows (depending on access width) of pattern dowels consisting of epoxy coated #9 bars (100 kip ultimate), spaced at 10 feet horizontally by 6 feet vertically and inclined at -15°. These are designated rows "A" and "B" on Figure 2 and 3.

3. Up to six rows, depending on cut height, of pattern dowels consisting of epoxy coated #14 bars (225 kip ultimate), spaced at 10 feet horizontally by 12 feet vertically and inclined at -15˚. These rows are designated rows "C" through "H" on Figures 2 and 3. (Note that if the access width is adequate, rows "A" and/or "B" can be substituted with the larger bar at the 12-foot vertical spacing instead of the lighter bar at 6-foot vertical spacing.)

4. Application of a minimum 3-inch thick layer of fiber-reinforced shotcrete extending to elevation 2590 MSL. Field observations may change the lower shotcrete limit or indicate the need for spot application below the limit.

5. Two rows of 50-foot long horizontal drains installed at the nominal ditch grade + 3 feet and at the nominal ditch grade +27 feet. The drains in each row should be spaced at 50 feet with the centers offset between rows.

References Cited:

WSDOT, 2010. Memorandum titled "SR-90, MP 58 to 59 Vicinity, XL-2779, Snoqualmie Pass East – Phase 1C, Overburden Thickness and Cut Slope Recommendations", authored by T.M. Allen and RT.C. Badger, January 6, 2010.

W&N, 2009. "Phase 1C – Rock Slope Engineering Report – 2008 Geotechnical program. I-90 Snoqualmie Pass East Project" authored by Wyllie & Norrish Rock Engineers Inc.

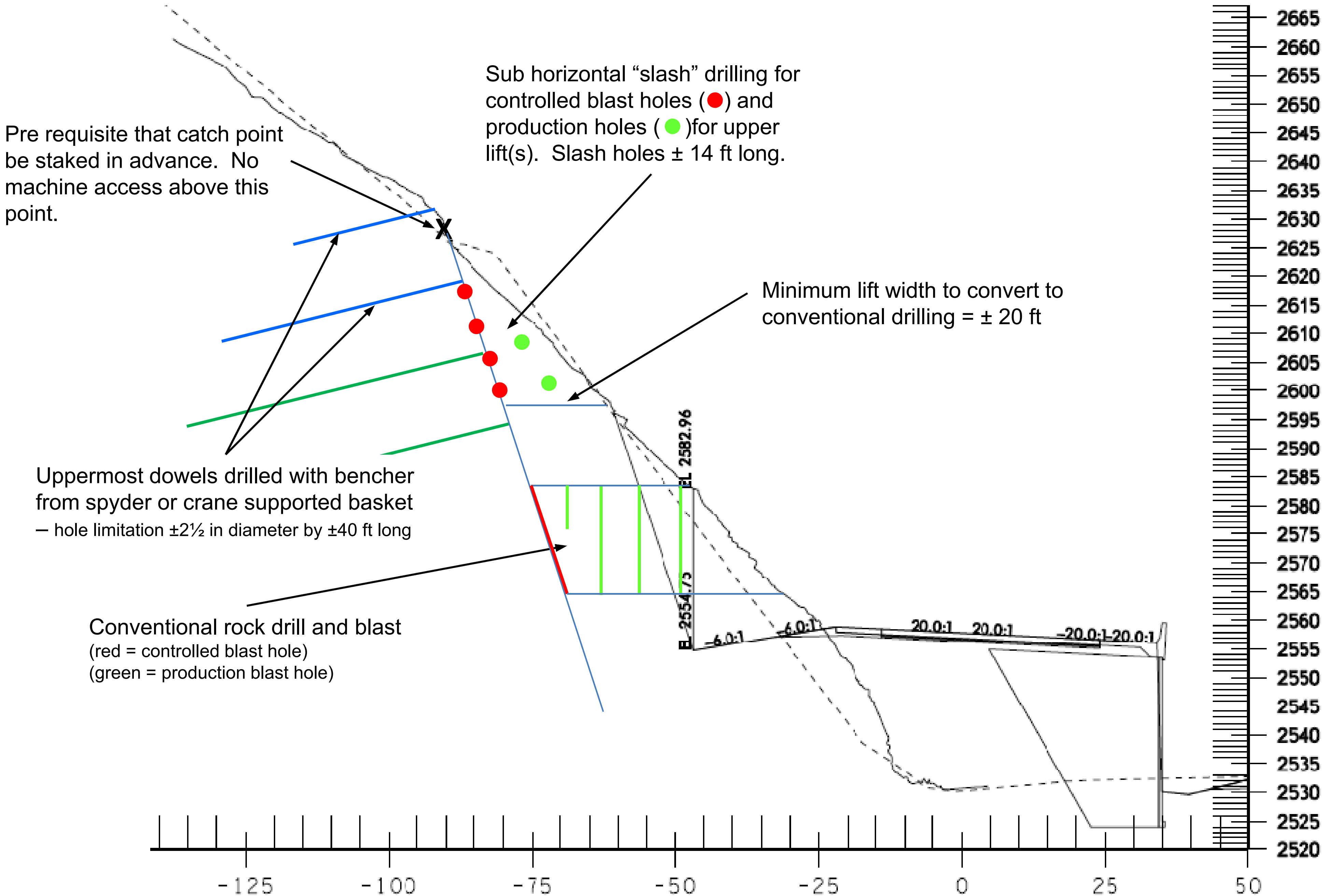
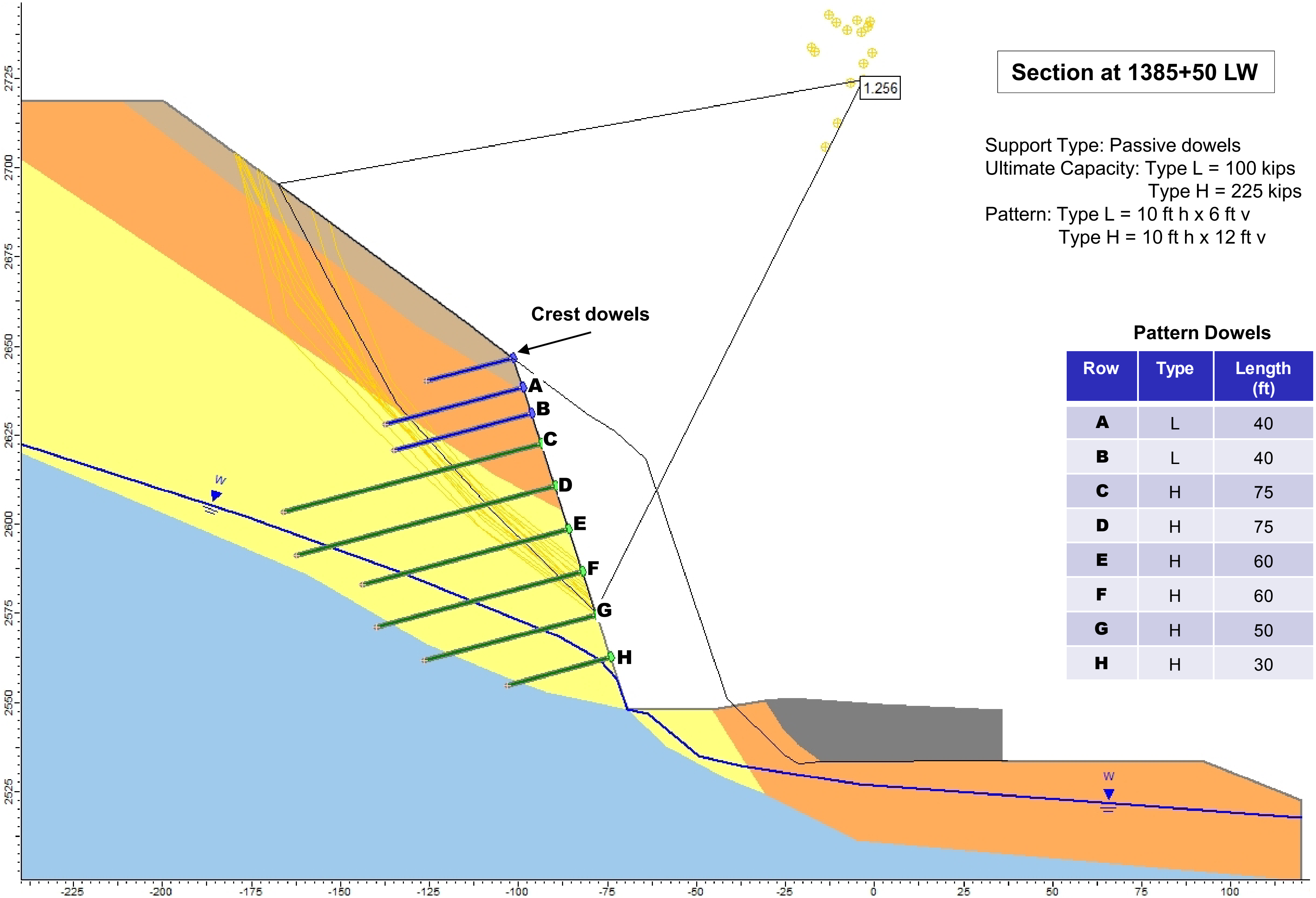


Figure 1

Conceptual "Slash" Drilling Concept



Section at 1385+50 LW

Support Type: Passive dowels
Ultimate Capacity: Type L = 100 kips
Type H = 225 kips
Pattern: Type L = 10 ft h x 6 ft v
Type H = 10 ft h x 12 ft v

Pattern Dowels

Row	Type	Length (ft)
A	L	40
B	L	40
C	H	75
D	H	75
E	H	60
F	H	60
G	H	50
H	H	30

Notes:
1. *Material properties per Figure 53, Wyllie & Norrish, 2009.*

Figure 2

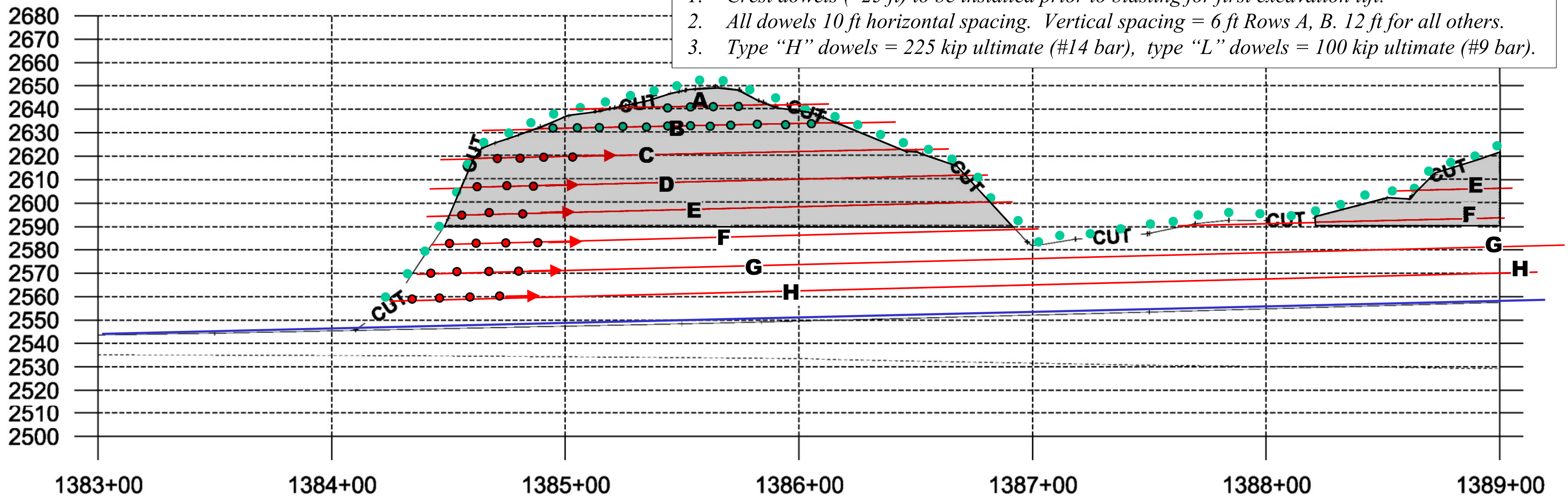
STABILITY ANALYSIS: Sta 1384+00 to 1394+00 LW

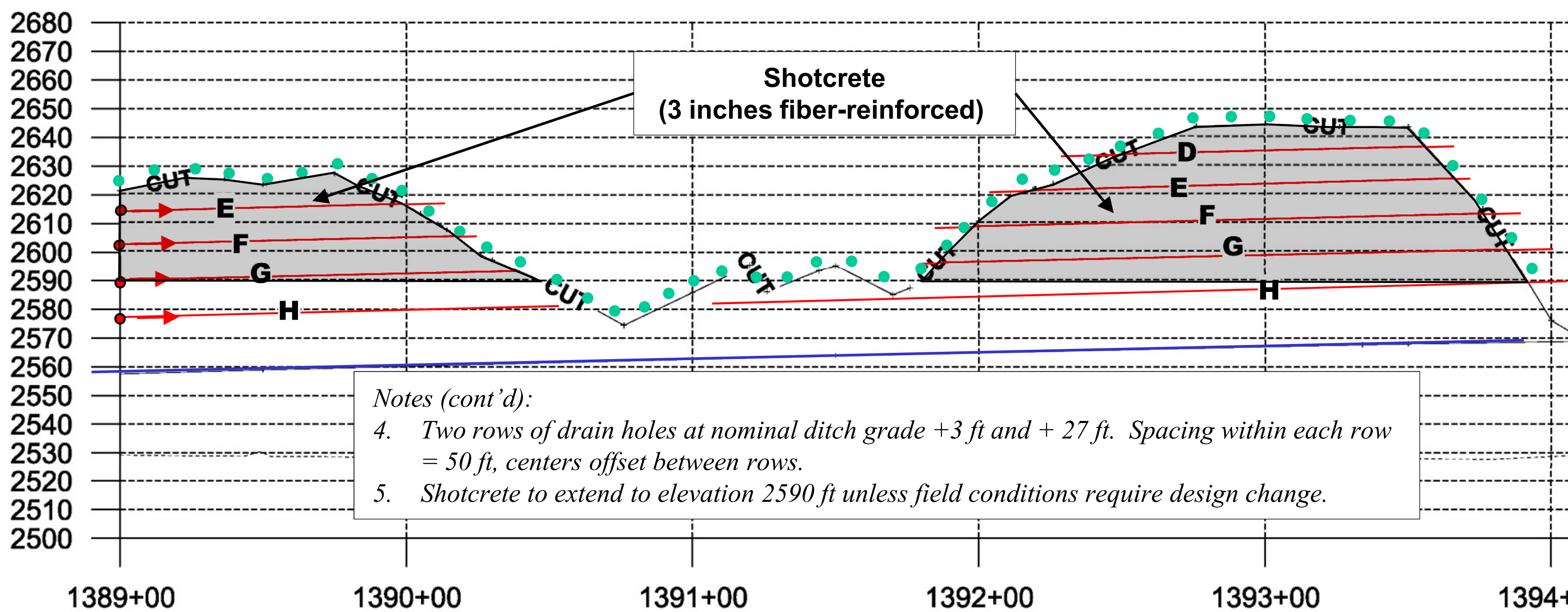
Project No. 062-2002 **Date:** August 2010

I-90 Snoqualmie Pass East
Phase 1C Rock Slopes

Notes:

1. *Crest dowels (● 25 ft) to be installed prior to blasting for first excavation lift.*
2. *All dowels 10 ft horizontal spacing. Vertical spacing = 6 ft Rows A, B. 12 ft for all others.*
3. *Type "H" dowels = 225 kip ultimate (#14 bar), type "L" dowels = 100 kip ultimate (#9 bar).*





Row	Type	Length (ft)
A ●	L	40
B ●	L	40
C ●	H	75
D ●	H	75
E ●	H	60
F ●	H	60
G ●	H	50
H ●	H	30

Notes (cont'd):

4. *Two rows of drain holes at nominal ditch grade +3 ft and + 27 ft. Spacing within each row = 50 ft, centers offset between rows.*
5. *Shotcrete to extend to elevation 2590 ft unless field conditions require design change.*

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Figure 3

CONCEPTUAL STABILIZATION DESIGN : Sta 1384+00 to 1394+00 LW

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