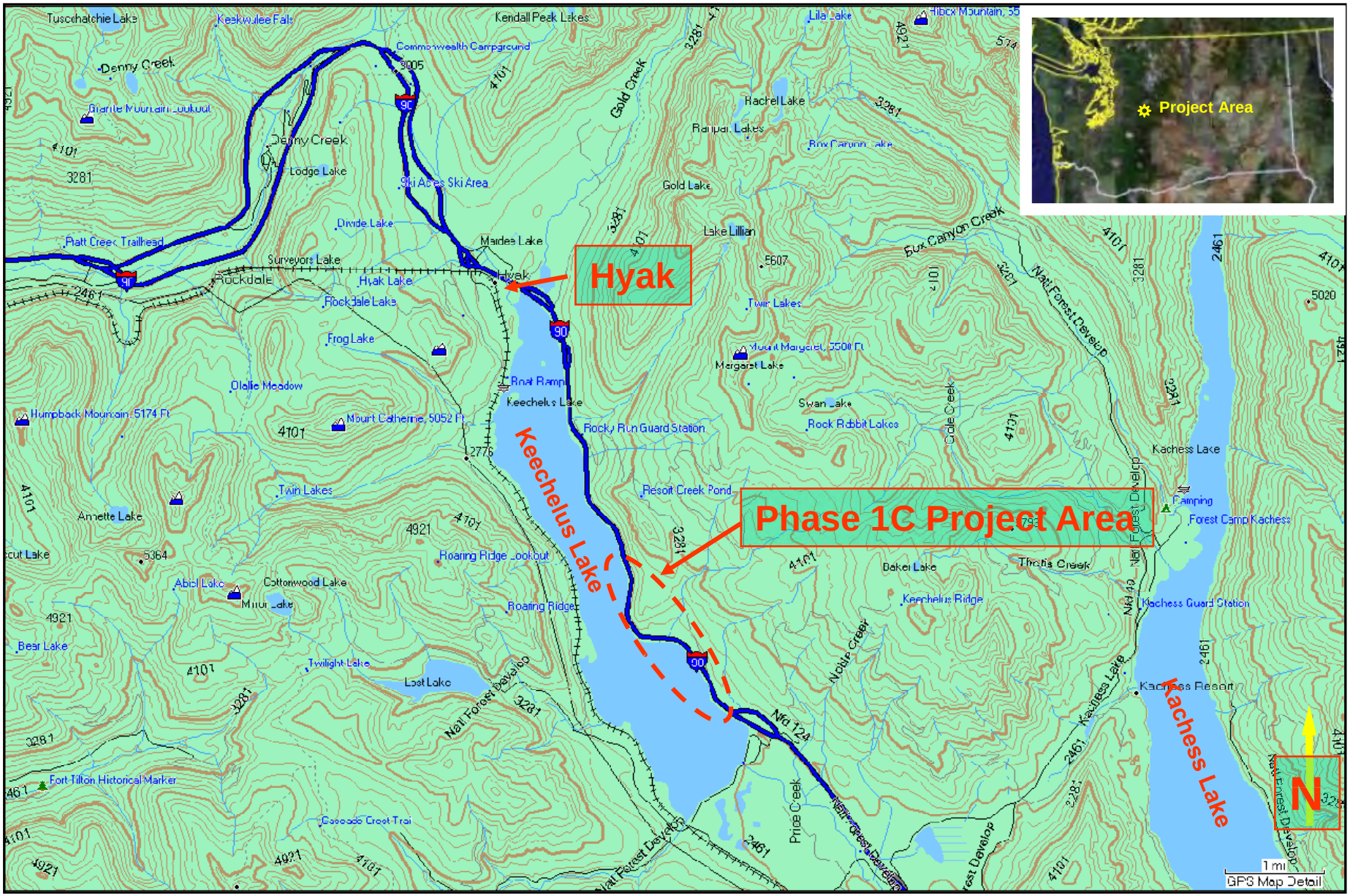


Project No. 062-2002 Date: January 2009

Figure 1

LOCATION MAP

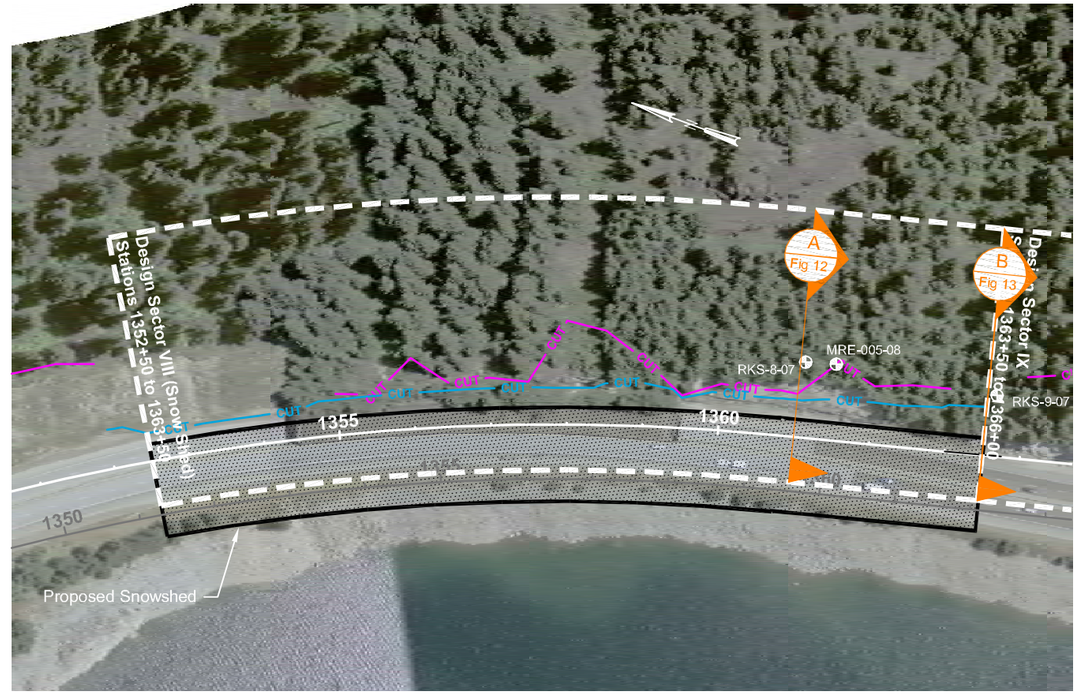
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

FIGURE **2**

SITE PLAN AND BOREHOLE LOCATIONS

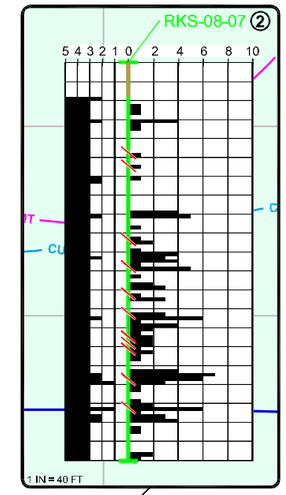
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

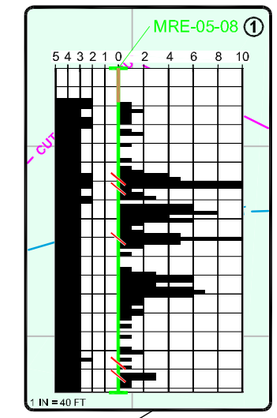
K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN- Phase 1C Figure 2 Site Plan.dwg 04/17/2009, 16:31 Layout: Figure 2 Site Plan

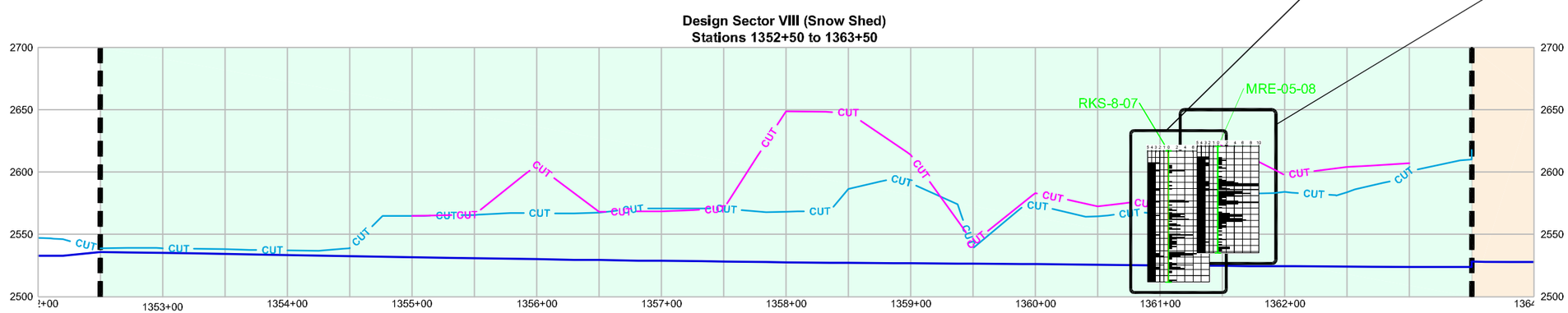


0 100 200
SCALE IN FEET

PLAN







0 50 100
SCALE IN FEET

PROFILE

Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- MInimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

Plan and Profile Explanation

- Borehole
- CUT — Catch Line of Top-of-Cut for Overburden Thickness
- CUT — Catch Line of Top-of-Cut for Rock
- Grade Line at Toe-of-Cut Slope

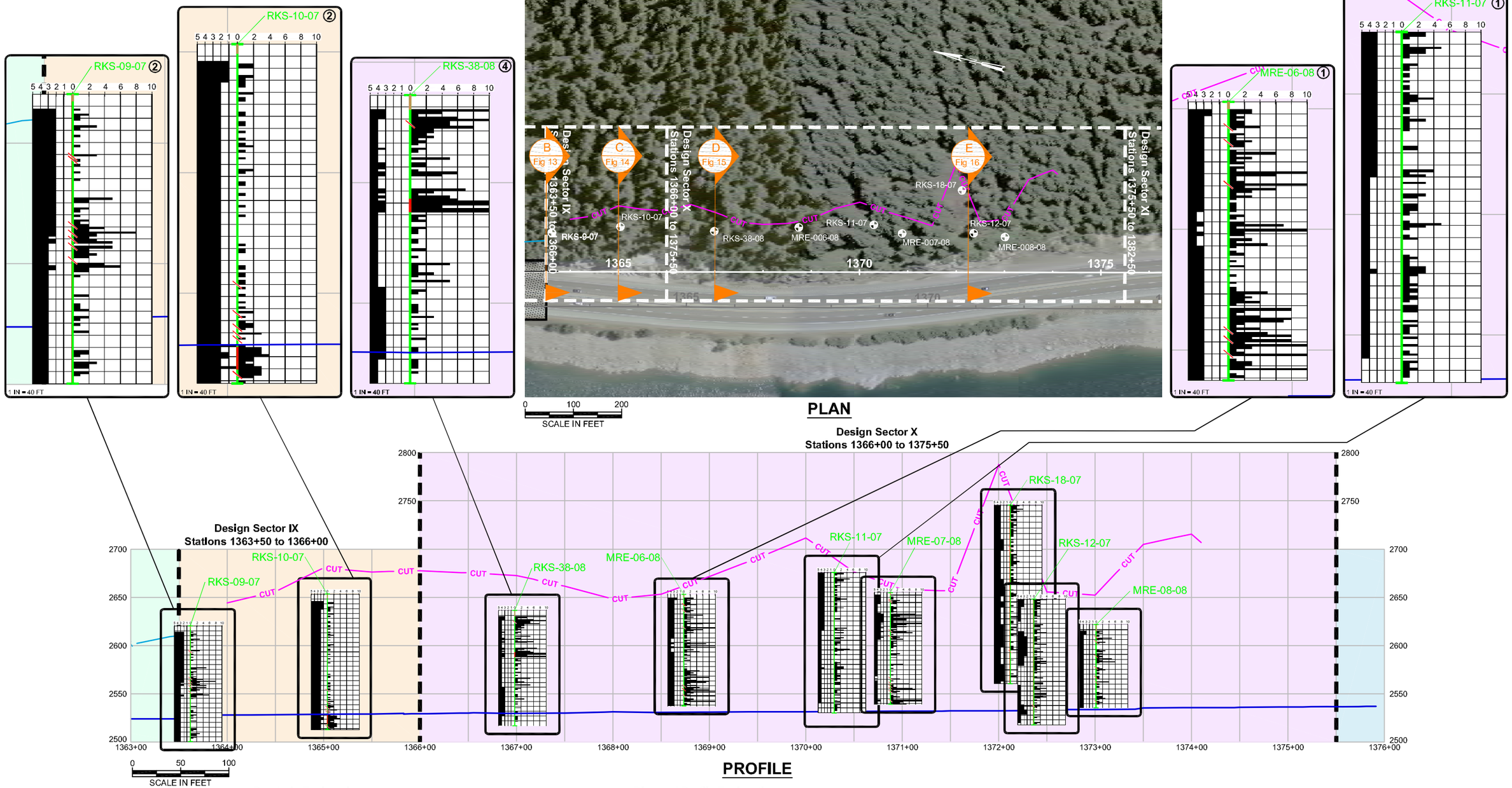
Note:
Dip direction data was not available for discontinuities from MRE-05-08 through MRE-08-08. This increases the number of significant discontinuities represented on the borehole logs.

Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

FIGURE **3**
DESIGN SECTOR VIII (SNOWSHED)

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN- Phase 1C Plan & Profile.dwg 04/21/2009, 09:56 Layout: Figure 3 (Sector VIII)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

Plan and Profile Explanation

- Borehole
- CUT — Catch Line of Top-of-Cut for Overburden Thickness
- CUT — Catch Line of Top-of-Cut for Rock
- Grade Line at Toe-of-Cut Slope

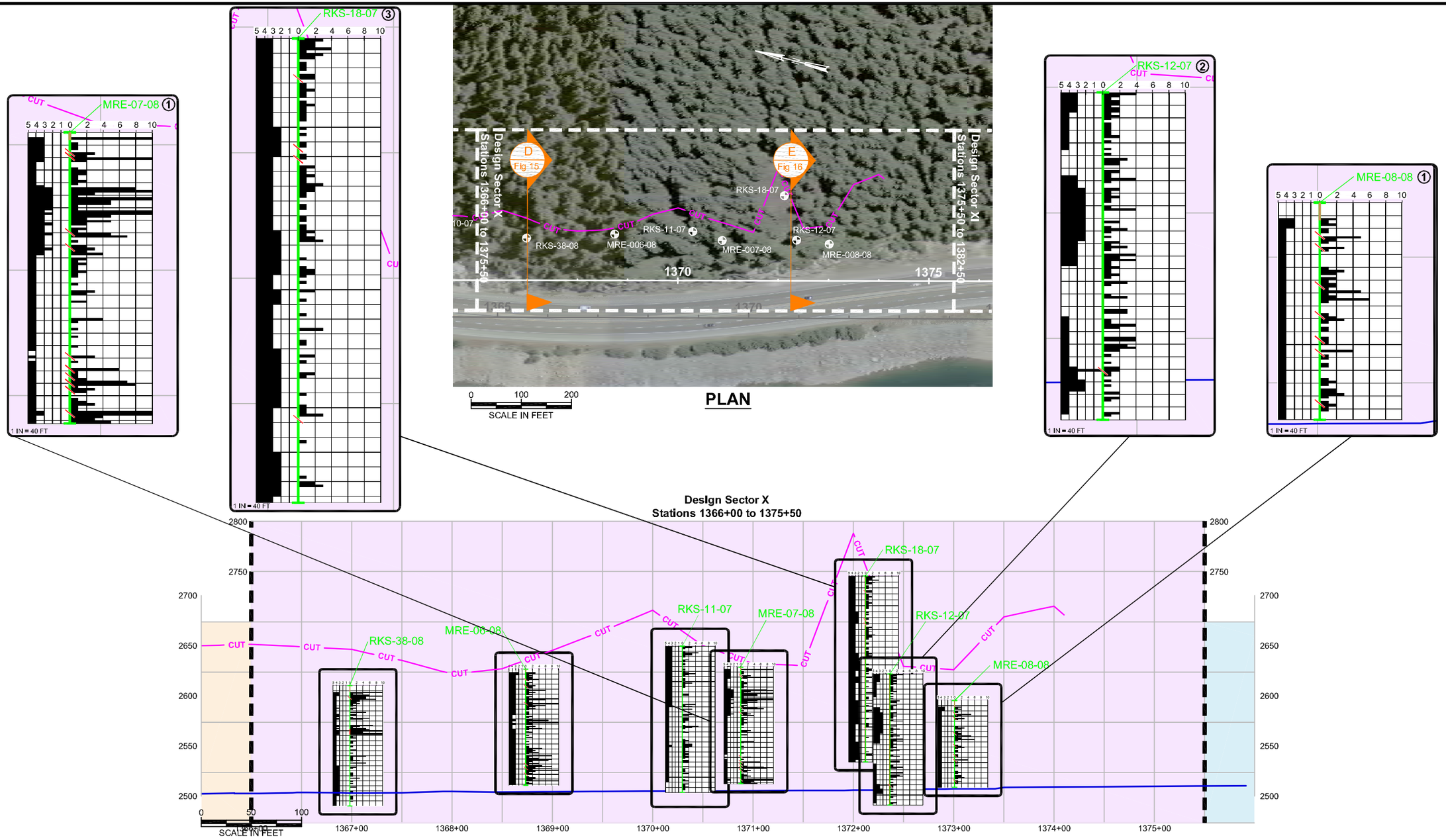
Note:
Dip direction data was not available for discontinuities from MRE-05-08 through MRE-08-08. This increases the number of significant discontinuities represented on the borehole logs.

Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

FIGURE 4
DESIGN SECTORS IX AND X

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Plan & Profile.dwg 04/21/2009, 09:57 Layout: Figure 4 (Sectors IX and X)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

Plan and Profile Explanation

- Borehole
- CUT — Catch Line of Top-of-Cut for Overburden Thickness
- CUT — Catch Line of Top-of-Cut for Rock
- Grade Line at Toe-of-Cut Slope

Note:
Dip direction data was not available for discontinuities from MRE-05-08 through MRE-08-08. This increases the number of significant discontinuities represented on the borehole logs.

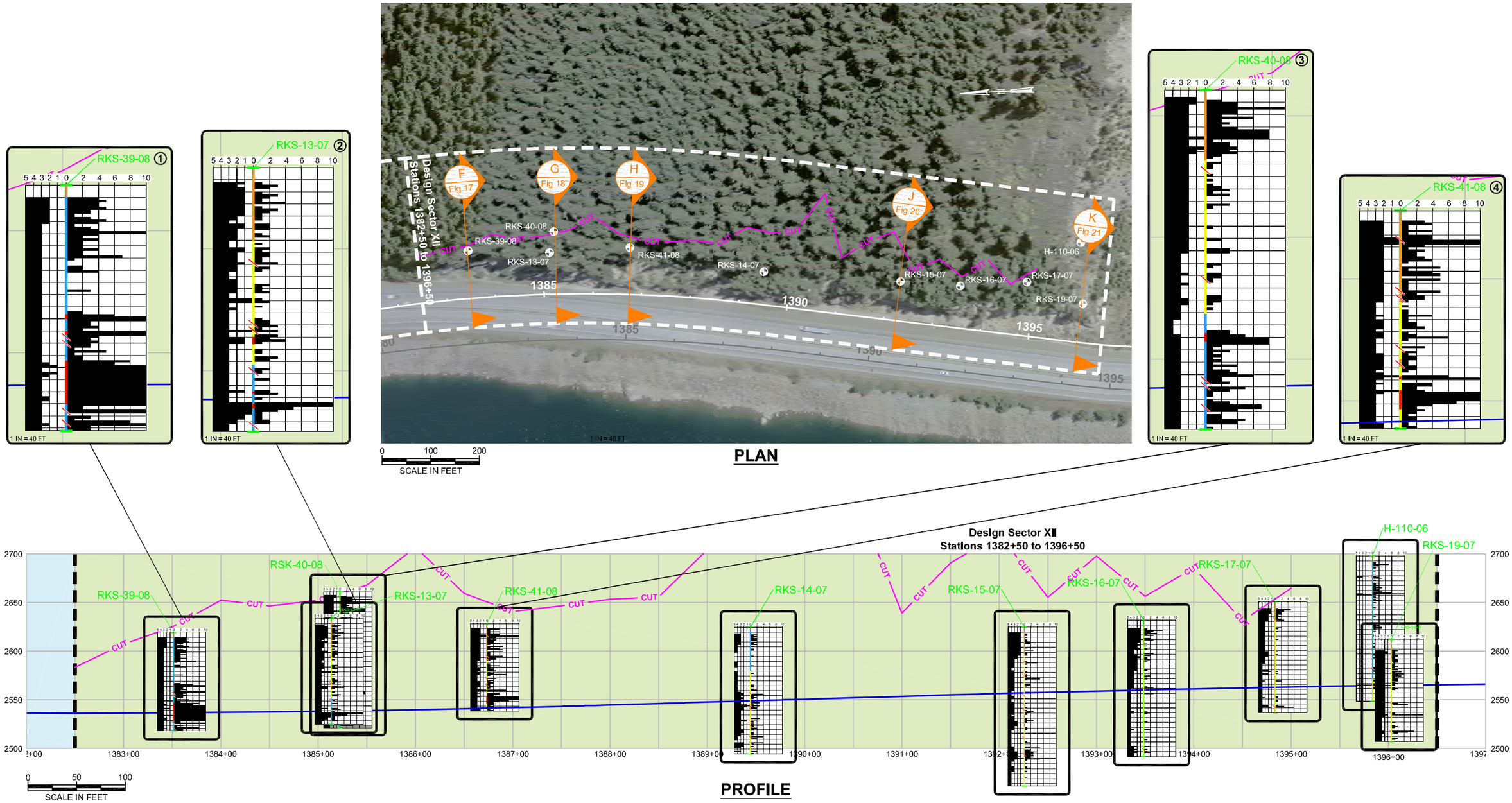
Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

FIGURE **5**

DESIGN SECTOR X

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\Sub Tasks\Phase 1C\WN - Phase 1C Plan & Profile.dwg 04/21/2009, 09:58 Layout: Figure 5 (Sector X)



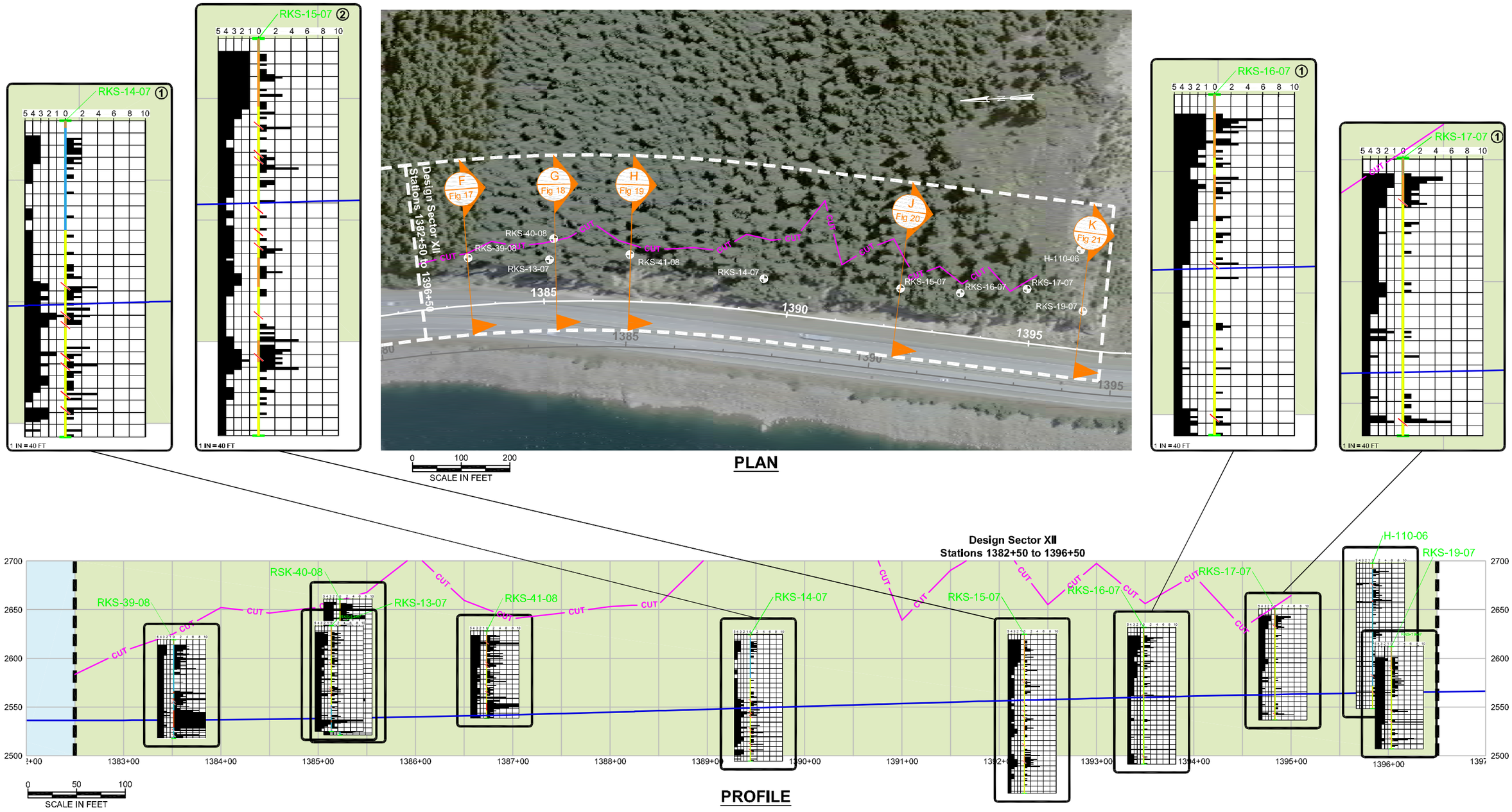
Note:
RKS-15-08 advanced at 80/029 degrees (Dip/Dip Direction), back into the slope.

Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

FIGURE 6
DESIGN SECTOR XII

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Plan & Profile.dwg 04/21/2009, 09:59 Layout: Figure 6 (Sector XII)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type: Overburden; Domain 1; Domain 2; Domain 3; Poor Rock Quality Interval; Adversely Dipping Significant Discontinuity

Piezometer: Minimum Water Depth; Instrument Depth

Instrumentation: ① No Instrumentation; ② VWPs Only; ③ VWPs and TDR; ④ TDR Only

Plan and Profile Explanation

Borehole

CUT — Catch Line of Top-of-Cut for Overburden Thickness

CUT — Catch Line of Top-of-Cut for Rock

Grade Line at Toe-of-Cut Slope

Note:
RKS-15-08 advanced at 80/029 degrees (Dip/Dip Direction), back into the slope.

Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

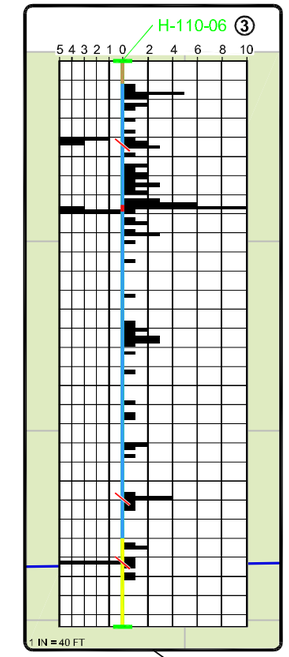
FIGURE 7
DESIGN SECTOR XII

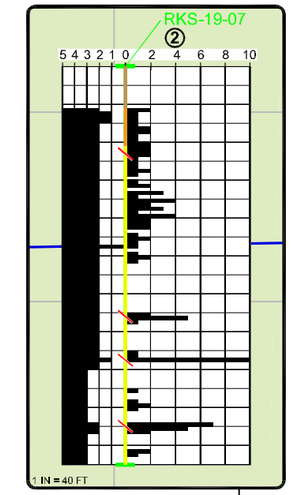
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

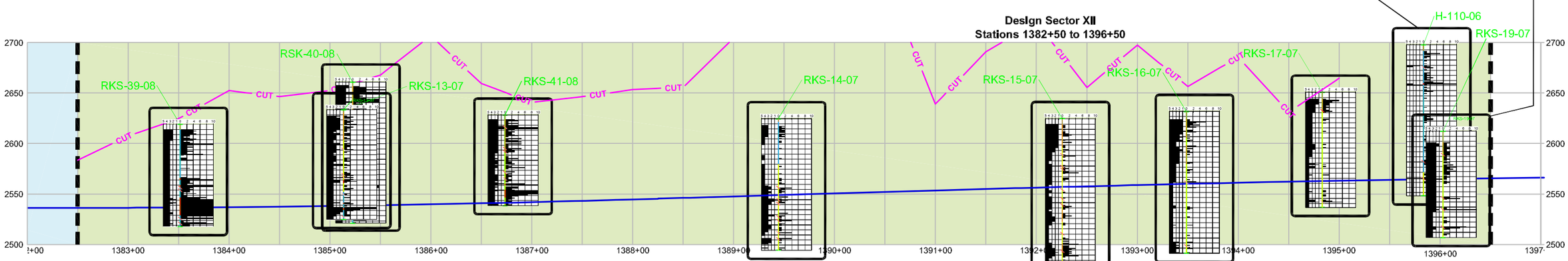
K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Plan & Profile.dwg 04/21/2009, 08:59 Layout: Figure 7 (Sector XII)

0 100 200
SCALE IN FEET

PLAN







0 50 100
SCALE IN FEET

PROFILE

Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
1. No Instrumentation
2. VWPs Only
3. VWPs and TDR
4. TDR Only

Plan and Profile Explanation

- Borehole
- CUT — Catch Line of Top-of-Cut for Overburden Thickness
- CUT — Catch Line of Top-of-Cut for Rock
- Grade Line at Toe-of-Cut Slope

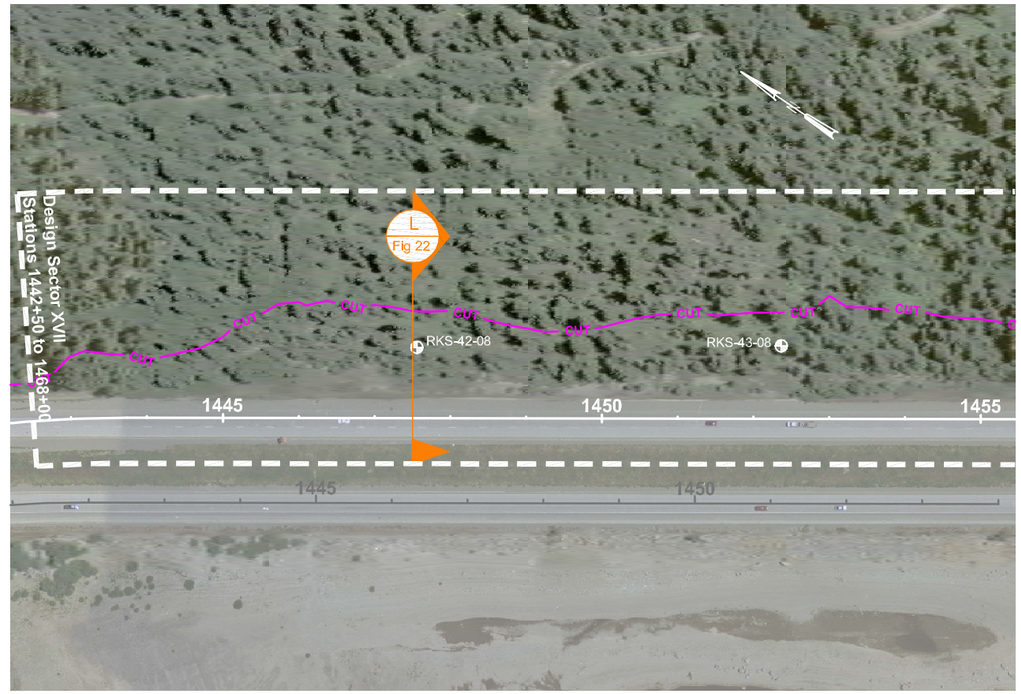
Note:
RKS-15-08 advanced at 80/029 degrees (Dip/Dip Direction), back into the slope.

Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

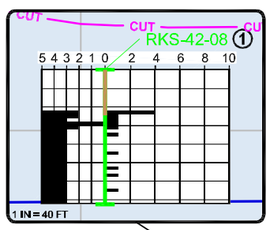
FIGURE 8
DESIGN SECTOR XII

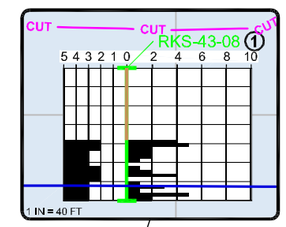
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

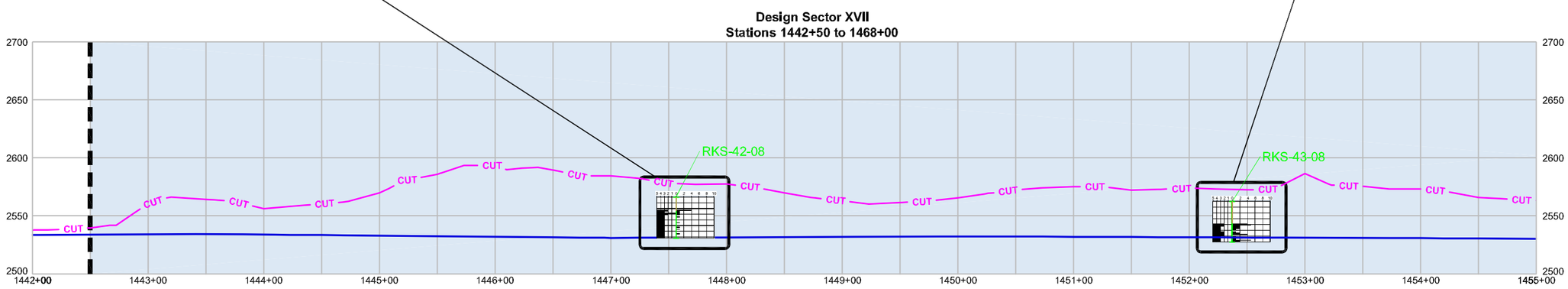
K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Plan & Profile.dwg 04/21/2009, 09:59 Layout: Figure 8 (Sector XII)



PLAN







PROFILE

Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- 1 No Instrumentation
- 2 VWPs Only
- 3 VWPs and TDR
- 4 TDR Only

Plan and Profile Explanation

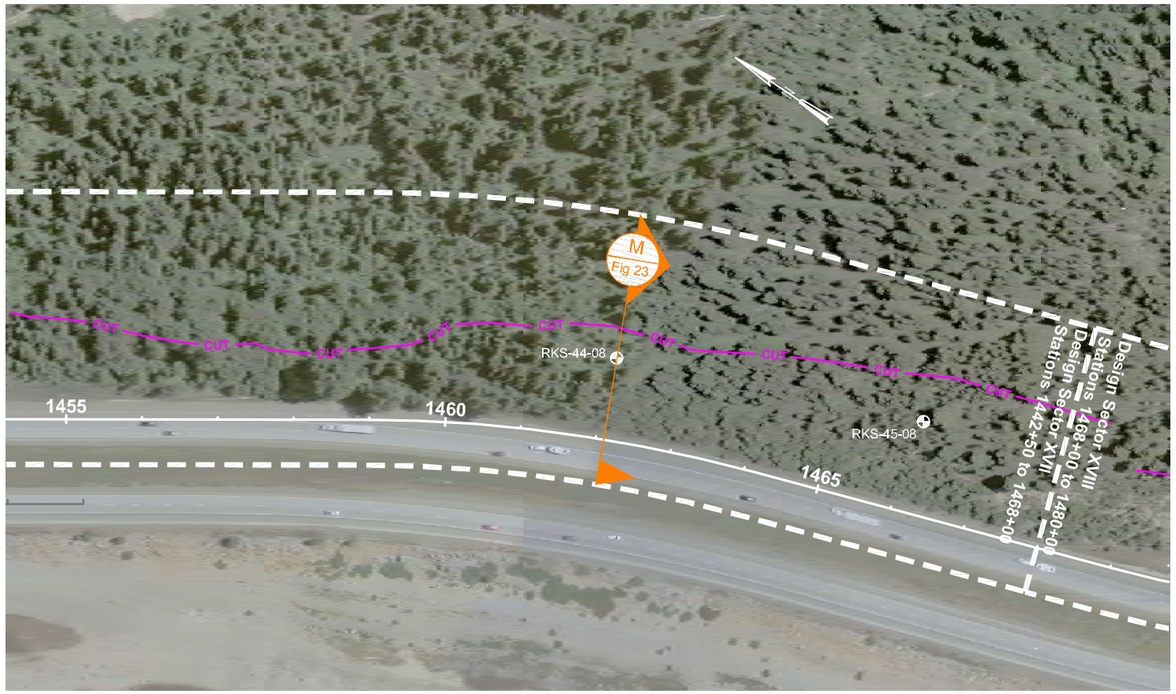
- Borehole
- CUT — Catch Line of Top-of-Cut for Overburden Thickness
- CUT — Catch Line of Top-of-Cut for Rock
- Grade Line at Toe-of-Cut Slope

Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

FIGURE 9
DESIGN SECTOR XVII

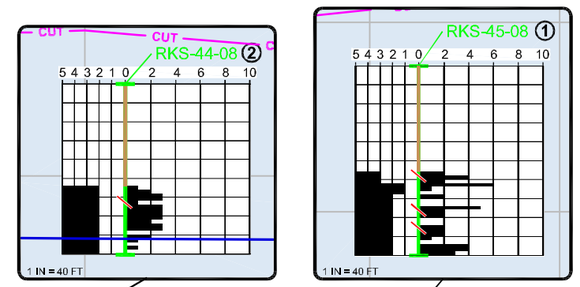
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

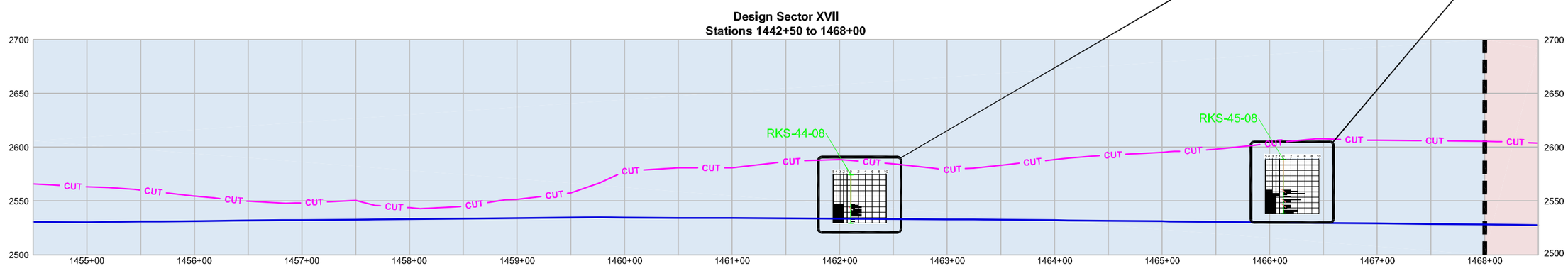
K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN- Phase 1C Plan & Profile.dwg 04/21/2009, 10:01 Layout: Figure 9 (Sector XVII)



0 100 200
SCALE IN FEET

PLAN





0 50 100
SCALE IN FEET

PROFILE

Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- MInImum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

Plan and Profile Explanation

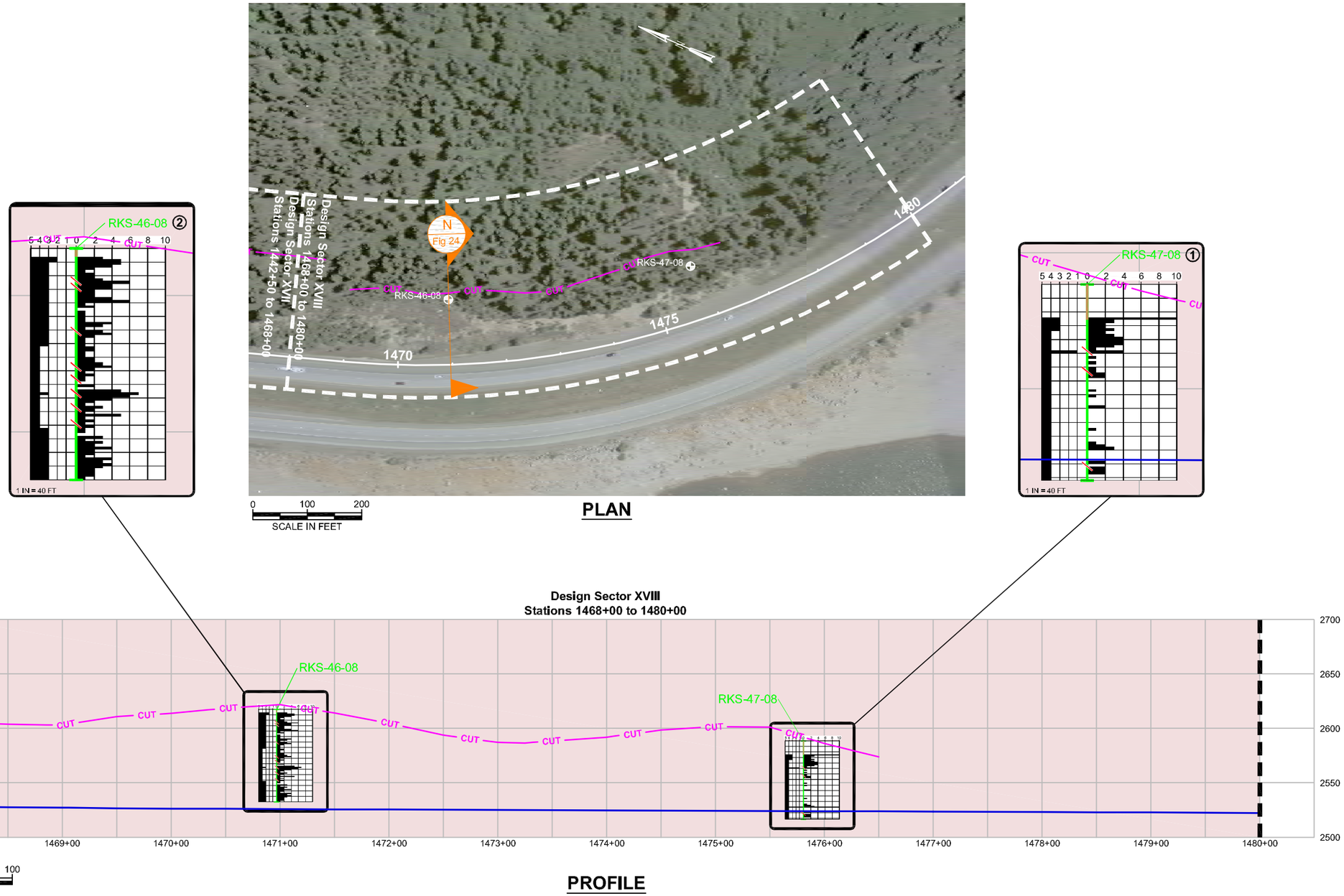
- Borehole
- CUT — Catch Line of Top-of-Cut for Overburden Thickness
- CUT — Catch Line of Top-of-Cut for Rock
- Grade Line at Toe-of-Cut Slope

Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

FIGURE **10**
DESIGN SECTOR XVII

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Plan & Profile.dwg 04/21/2009, 10:32 Layout: Figure 10 (Sector XVII)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

Plan and Profile Explanation

- Borehole
- CUT — Catch Line of Top-of-Cut for Overburden Thickness
- CUT — Catch Line of Top-of-Cut for Rock
- Grade Line at Toe-of-Cut Slope

Note:
Rock cut template continues for approximately 75 feet past WB station 1476+50. Overburden template is pending.

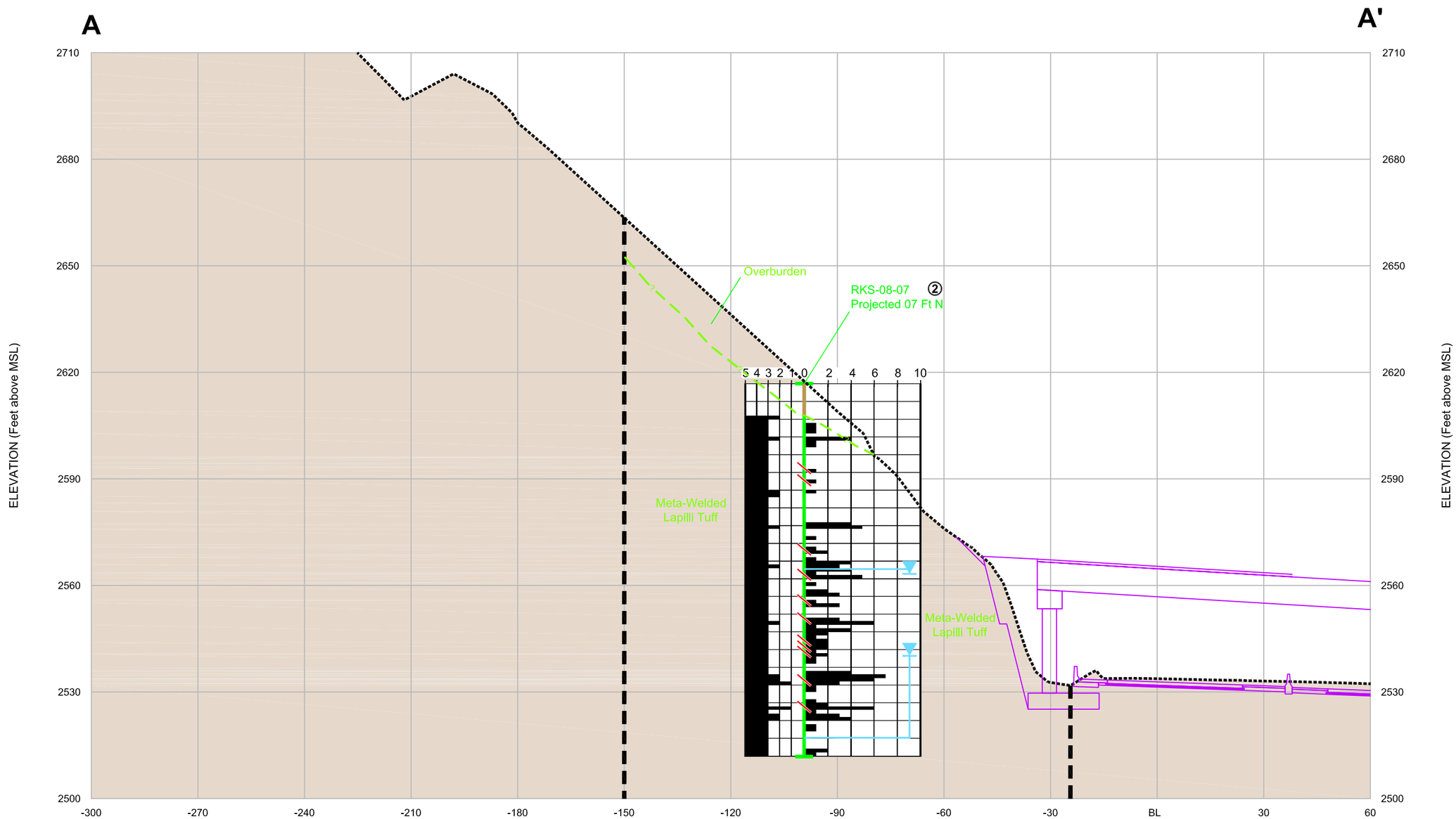
Source:
Profile, alignment and cut lines provided by WSDOT, April 15, 2009.

FIGURE **11**

DESIGN SECTOR XVIII

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CAD\D\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Plan & Profile.dwg 04/21/2009, 10:04 Layout: Figure 11 (Sector XVIII)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

General Explanation

- ? Geologic Inferred Contact
- Meta-Basalt Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figure 3 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

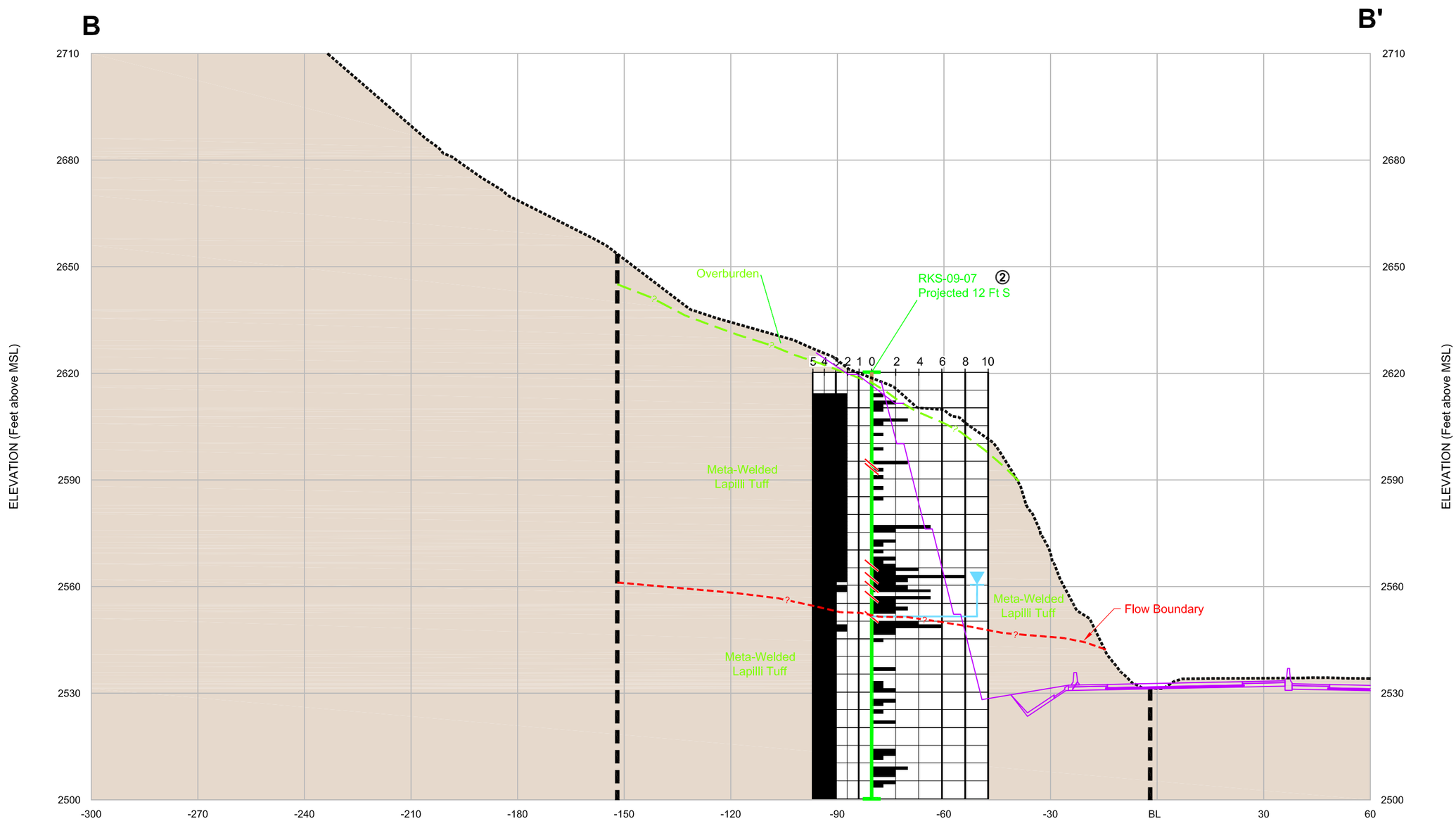
0 30 60
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **12**

DESIGN SECTOR VIII (SNOWSHED):
SECTION A-A' AT STATION 1361+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:41 Layout: Figure 12 (1361+00)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

General Explanation

- ? Geologic Inferred Contact
- Meta-Basalt Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figures 3 and 4 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

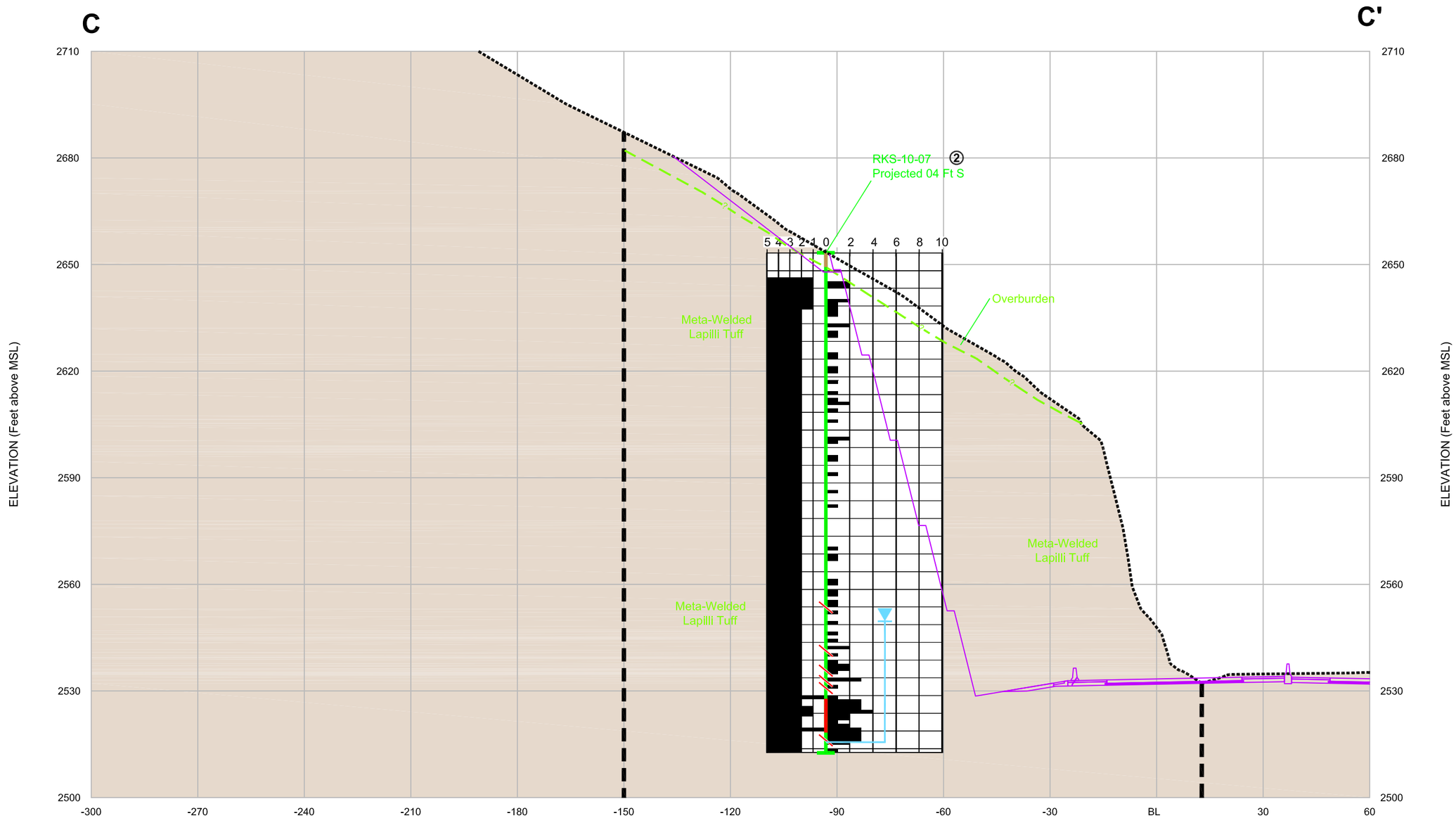
0 30 60
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **13**

DESIGN SECTOR IX:
SECTION B-B' AT STATION 1363+50

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:41 Layout: Figure 13 (1363+50)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

General Explanation

- ? Geologic Inferred Contact
- Meta-Basalt Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figure 4 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

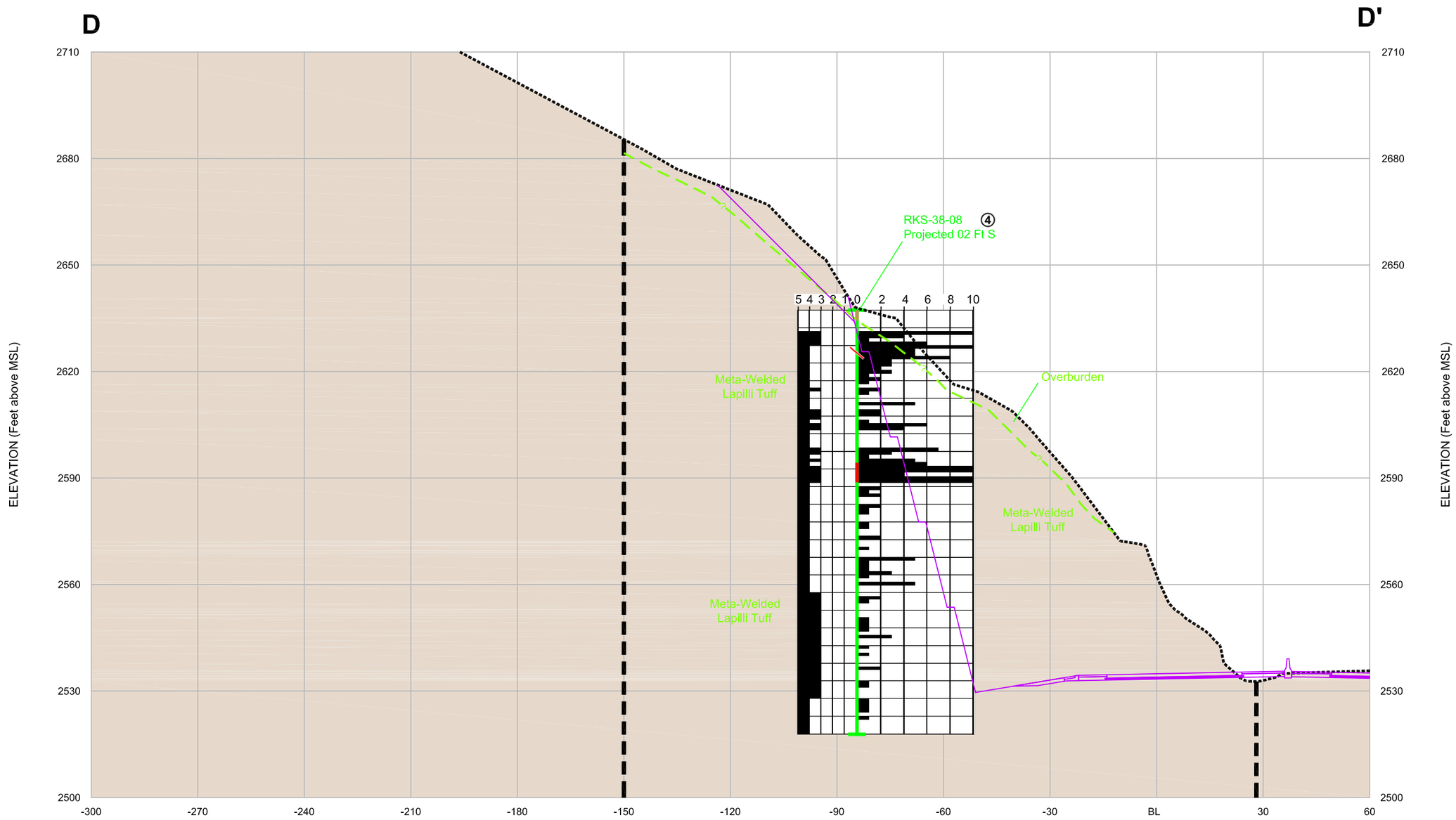
0 30 60
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **14**

DESIGN SECTOR IX:
SECTION C-C' AT STATION 1365+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg, 04/21/2009, 10:41, Layout: Figure 14 (1365+00)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

General Explanation

- ? Geologic Inferred Contact
- Meta-Basalt Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figures 4 and 5 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

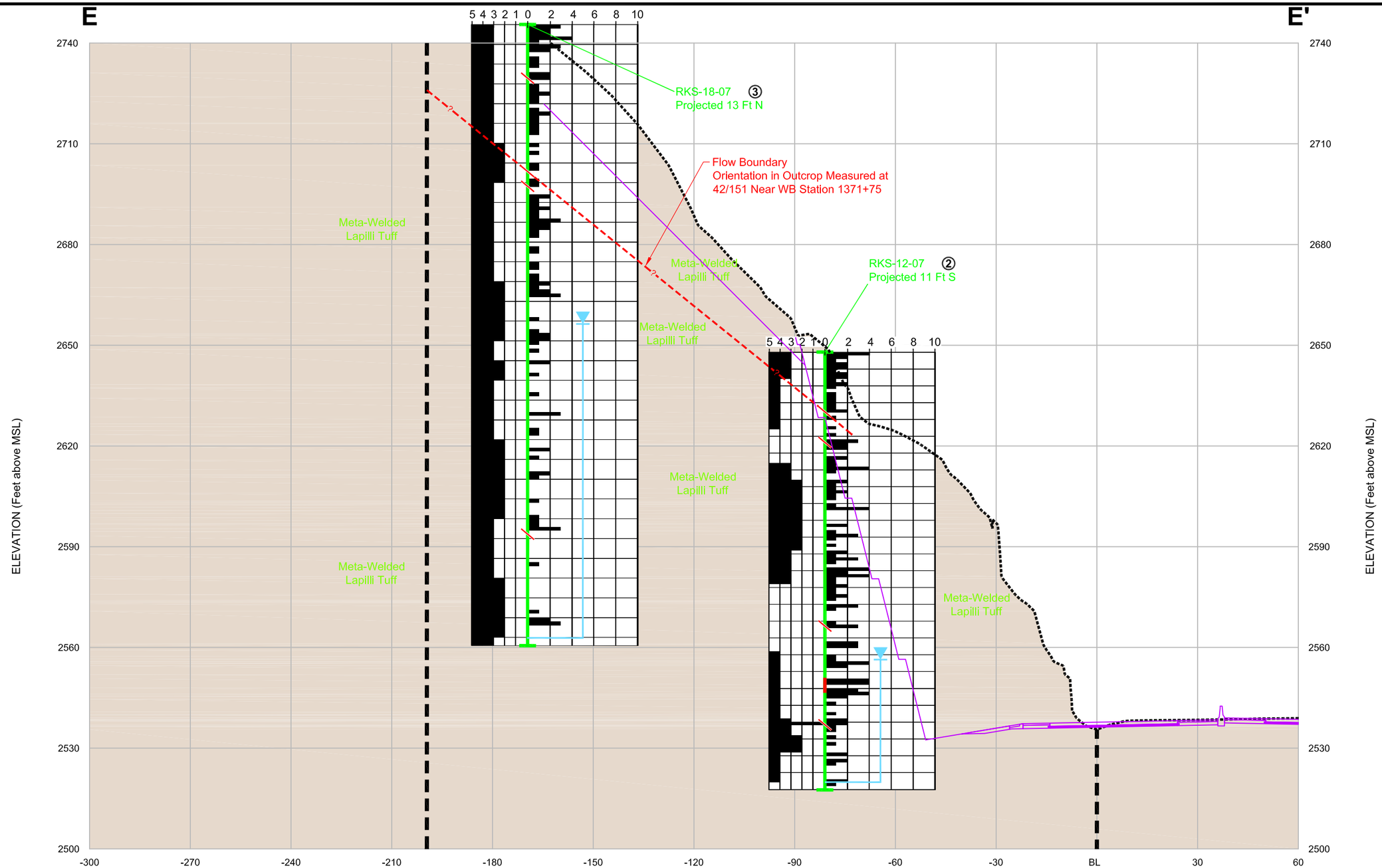
0 30 60
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **15**

DESIGN SECTOR X:
SECTION D-D' AT STATION 1367+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CADD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:41 Layout: Figure 15 (1367+00)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

General Explanation

- Geologic Inferred Contact
- Meta-Basalt — Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figures 4 and 5 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

0 30 60
SCALE IN FEET
(Horizontal & Vertical)

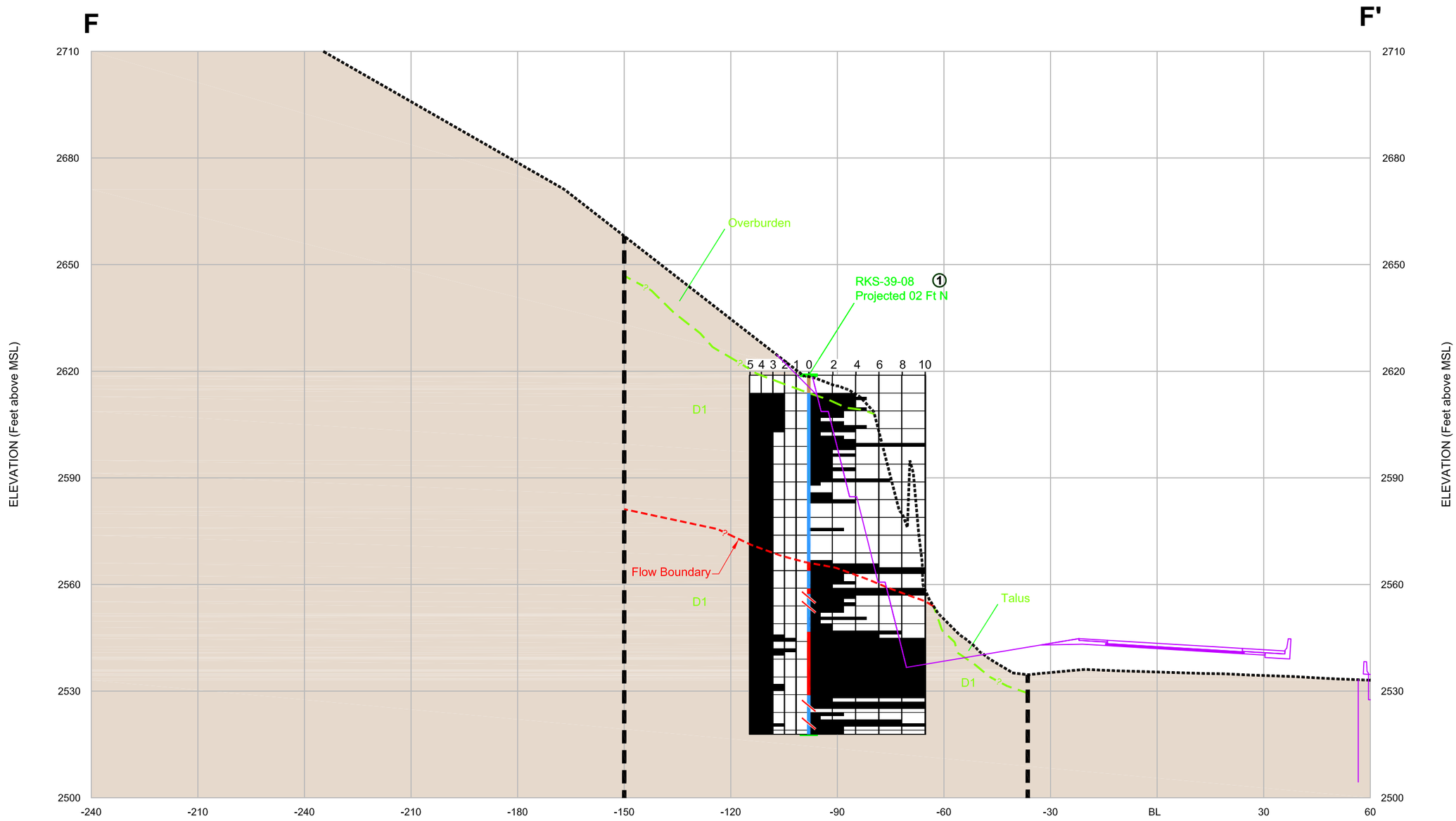
FIGURE **16**

DESIGN SECTOR X:

SECTION E-E' AT STATION 1372+25

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:41 Layout: Figure 16 (1372+25)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type: Overburden; Domain 1 (D1); Domain 2 (D2); Domain 3 (D3); Poor Rock Quality Interval; Adversely Dipping Significant Discontinuity

Piezometer: Minimum Water Depth; Instrument Depth

Instrumentation: ① No Instrumentation; ② VWPs Only; ③ VWPs and TDR; ④ TDR Only

General Explanation

? Geologic Inferred Contact

D1 Inferred Rock Type

Proposed Roadway

Mapping Boundary

Notes:

1. See Figures 6, 7 and 8 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:

Sections provided by WSDOT, April 15, 2009.

Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

0 30 60

SCALE IN FEET (Horizontal & Vertical)

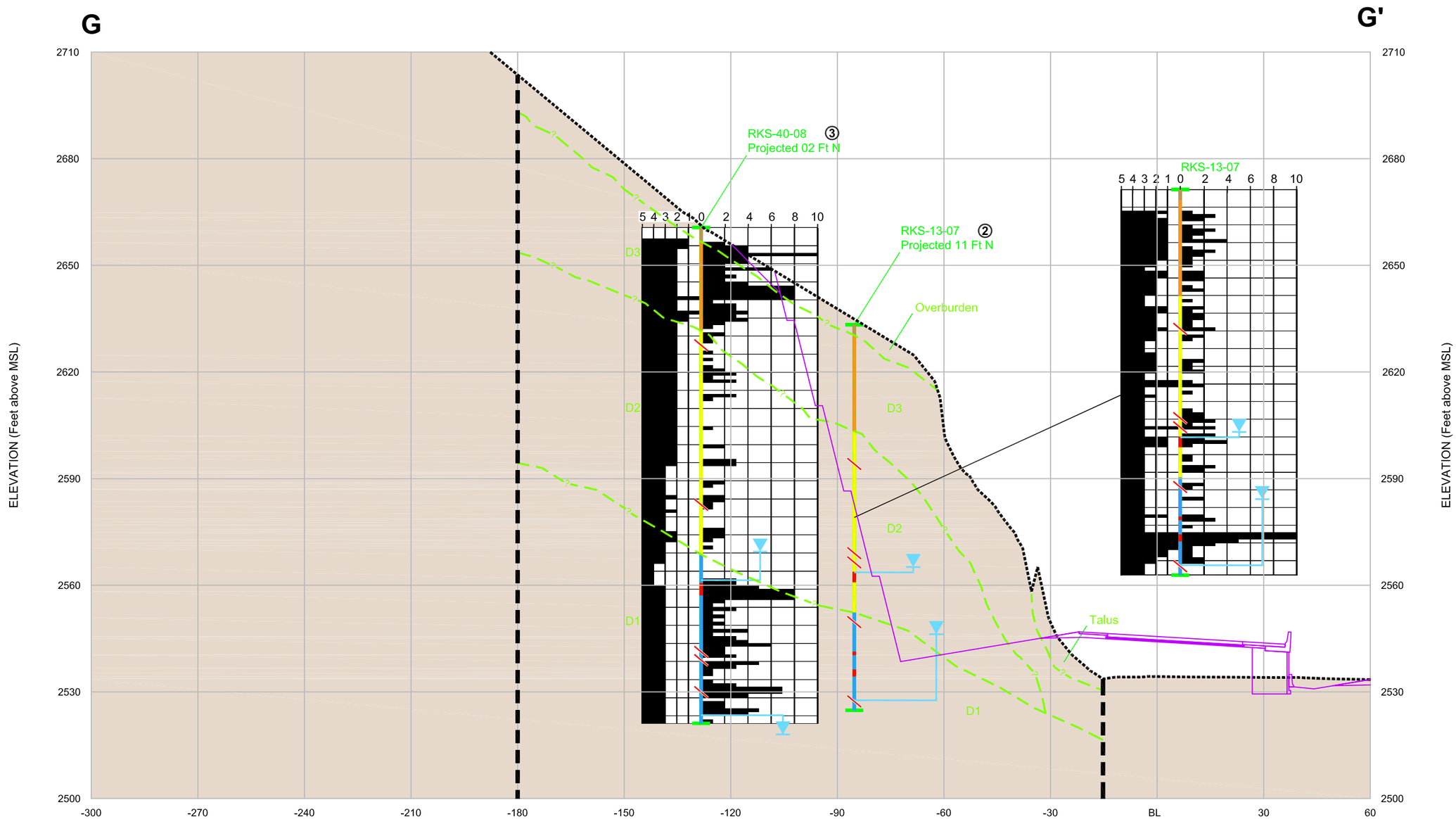
FIGURE **17**

DESIGN SECTOR XII:

SECTION F-F' AT STATION 1383+50

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:41 Layout: Figure 17 (1383+50)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type

- Overburden
- Domain 1 (D1)
- Domain 2 (D2)
- Domain 3 (D3)
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer

- Minimum Water Depth
- Instrument Depth

Instrumentation

1. No Instrumentation
2. VWPs Only
3. VWPs and TDR
4. TDR Only

General Explanation

- ? Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:

1. See Figures 6, 7 and 8 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:

Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

0 30 60
SCALE IN FEET
(Horizontal & Vertical)

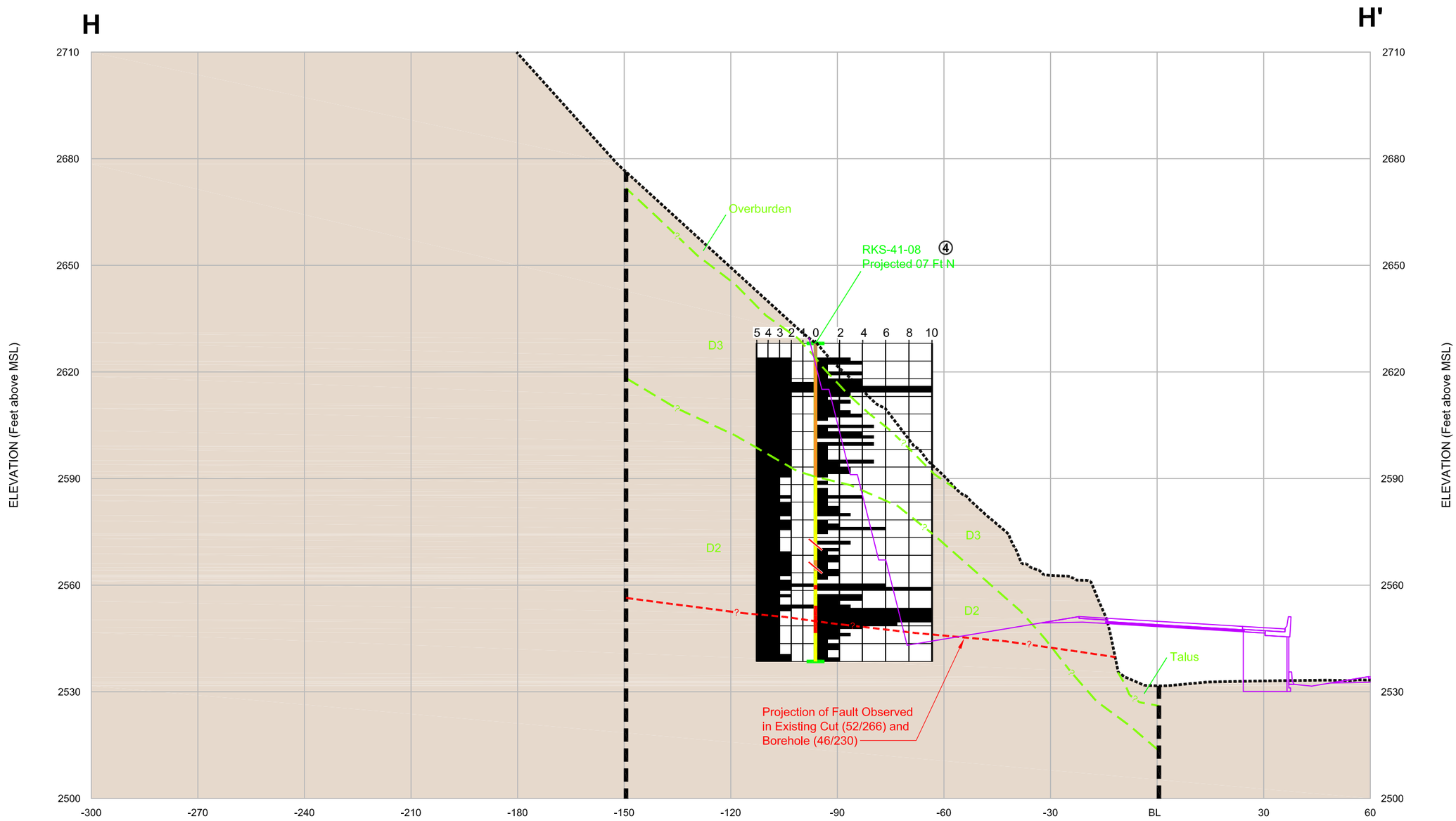
FIGURE **18**

DESIGN SECTOR XII:

SECTION G-G' AT STATION 1385+25

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:41 Layout: Figure 18 (1385+25)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type

- Overburden
- Domain 1 (D1)
- Domain 2 (D2)
- Domain 3 (D3)
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer

- Minimum Water Depth
- Instrument Depth

Instrumentation

1. No Instrumentation
2. VWPs Only
3. VWPs and TDR
4. TDR Only

General Explanation

- ? Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:

1. See Figures 6, 7 and 8 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:

Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

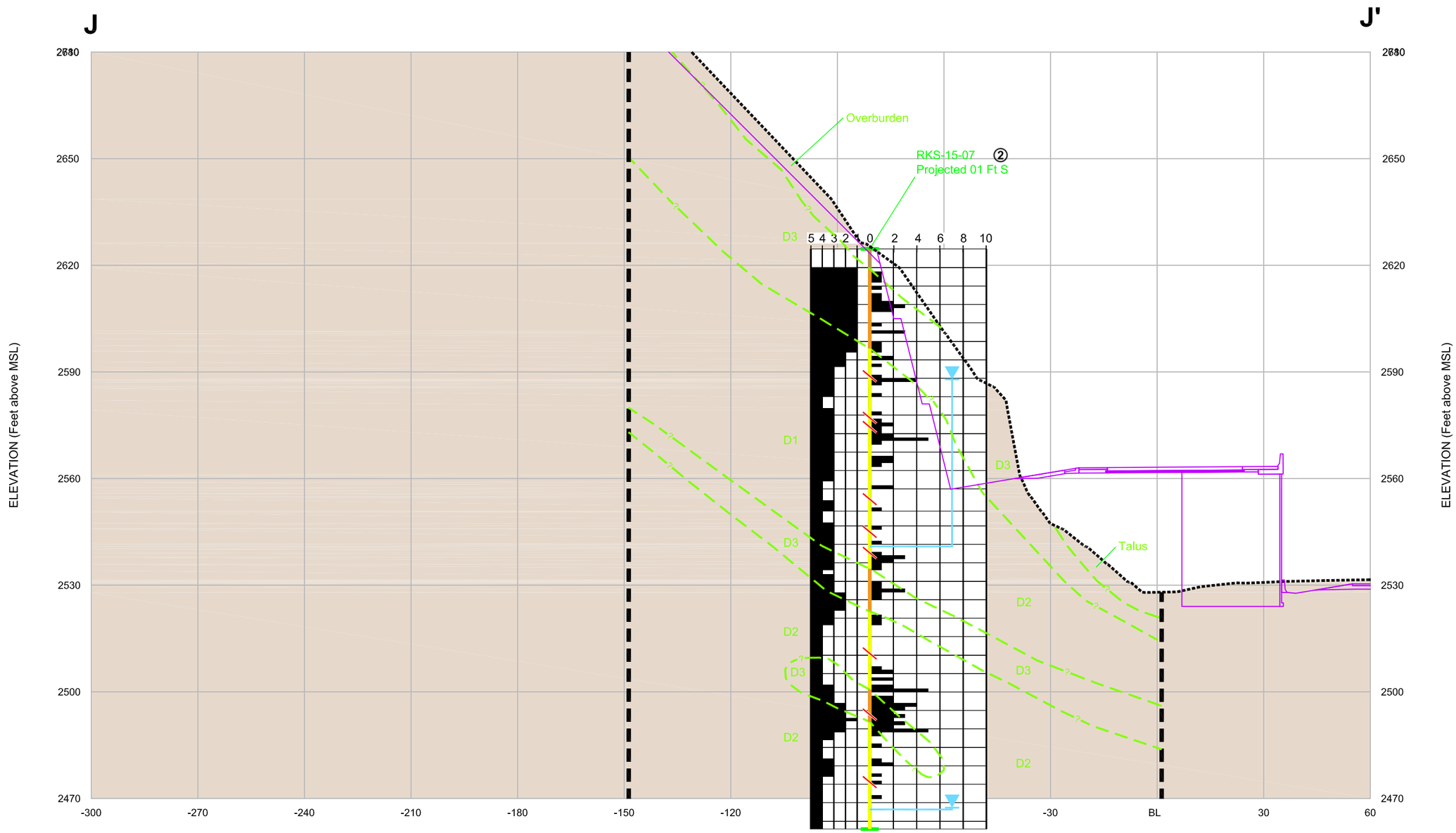
0 30 60
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **19**

DESIGN SECTOR XII:
SECTION H-H' AT STATION 1386+75

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:42 Layout: Figure 19 (1386+75)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type:
- Overburden
- Domain 1 (D1)
- Domain 2 (D2)
- Domain 3 (D3)
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer:
- Minimum Water Depth
- Instrument Depth

Instrumentation:
1. No Instrumentation
2. VWPs Only
3. VWPs and TDR
4. TDR Only

General Explanation

- Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figures 6, 7 and 8 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.
3. Borehole advanced at 80/029 degrees (Dip/Dip Direction) back into the slope.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

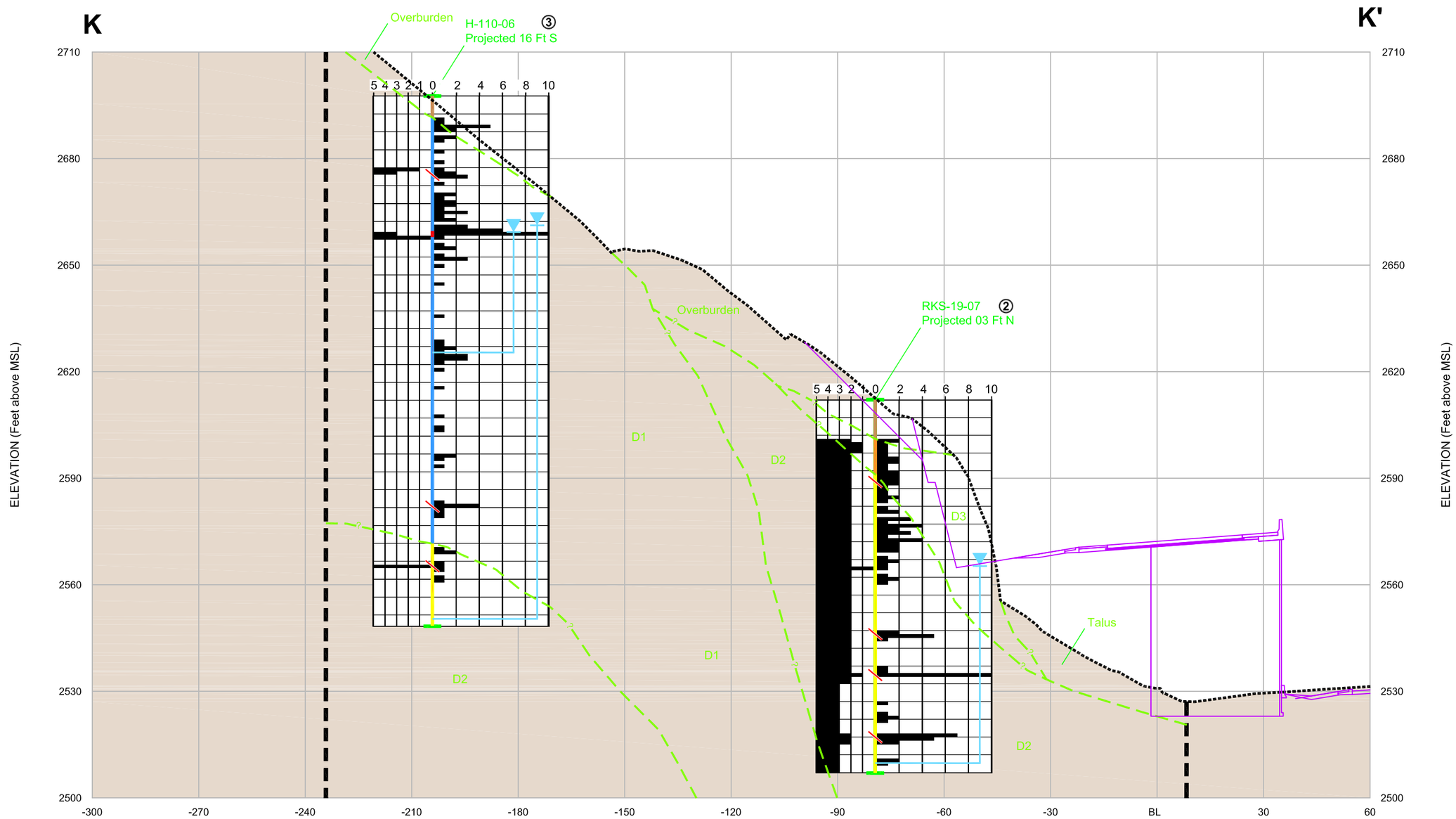
0 30 60
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **20**

DESIGN SECTOR XII:
SECTION J-J' AT STATION 1392+25

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:42 Layout: Figure 20 (1392+25)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type: Overburden; Domain 1 (D1); Domain 2 (D2); Domain 3 (D3); Poor Rock Quality Interval; Adversely Dipping Significant Discontinuity

Piezometer: Minimum Water Depth; Instrument Depth

Instrumentation: ① No Instrumentation; ② VWPs Only; ③ VWPs and TDR; ④ TDR Only

General Explanation

Geologic Inferred Contact

D1 Inferred Rock Type

Proposed Roadway

Mapping Boundary

Notes:
1. See Figures 6, 7 and 8 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

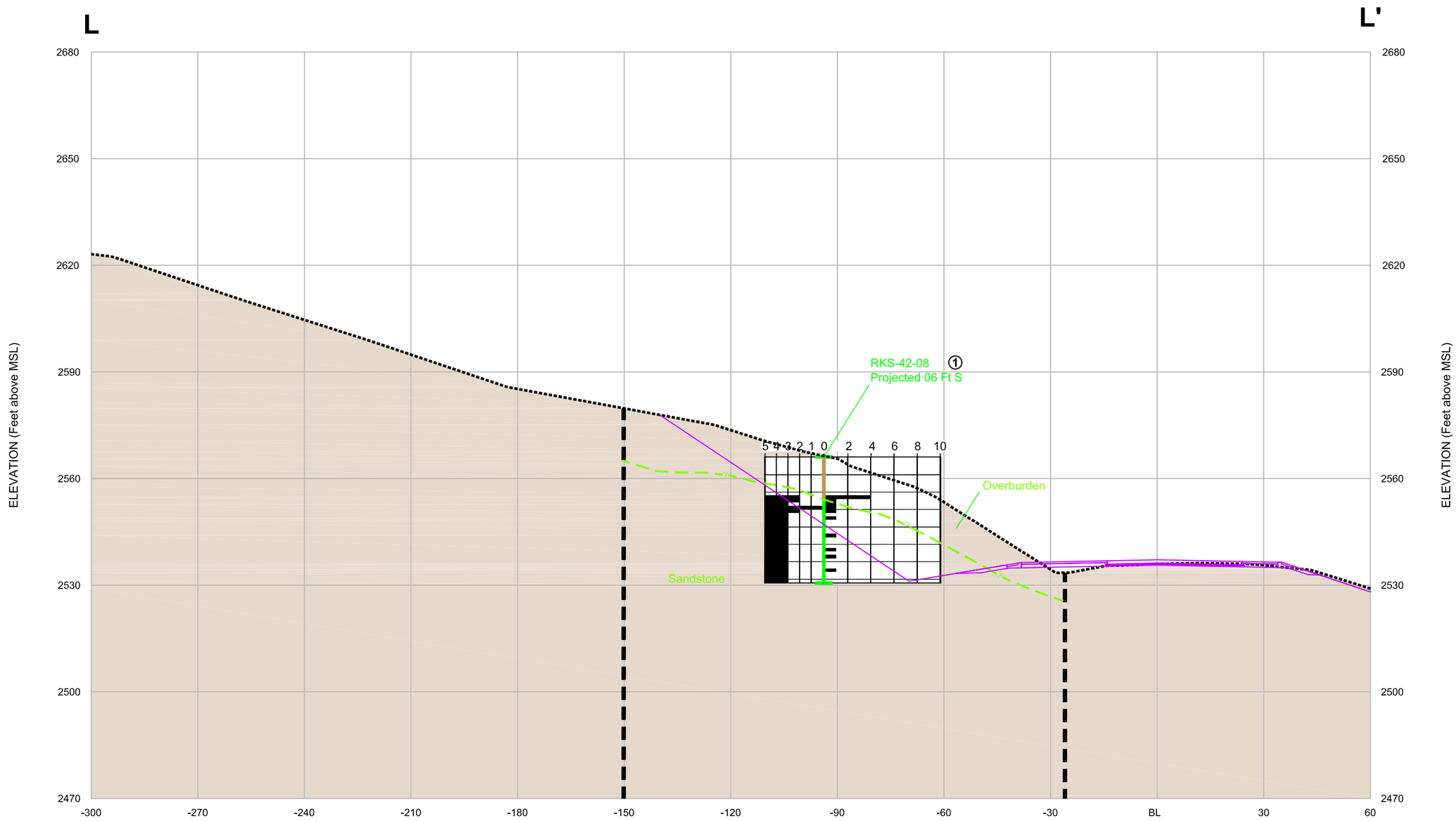
0 30 60
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **21**

DESIGN SECTOR XII:
SECTION K-K' AT STATION 1396+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:42 Layout: Figure 21 (1396+00)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- 1 No Instrumentation
- 2 VWPs Only
- 3 VWPs and TDR
- 4 TDR Only

General Explanation

- ? Geologic Inferred Contact
- Meta-Basalt Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figure 9 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

0 30 60
SCALE IN FEET
(Horizontal & Vertical)

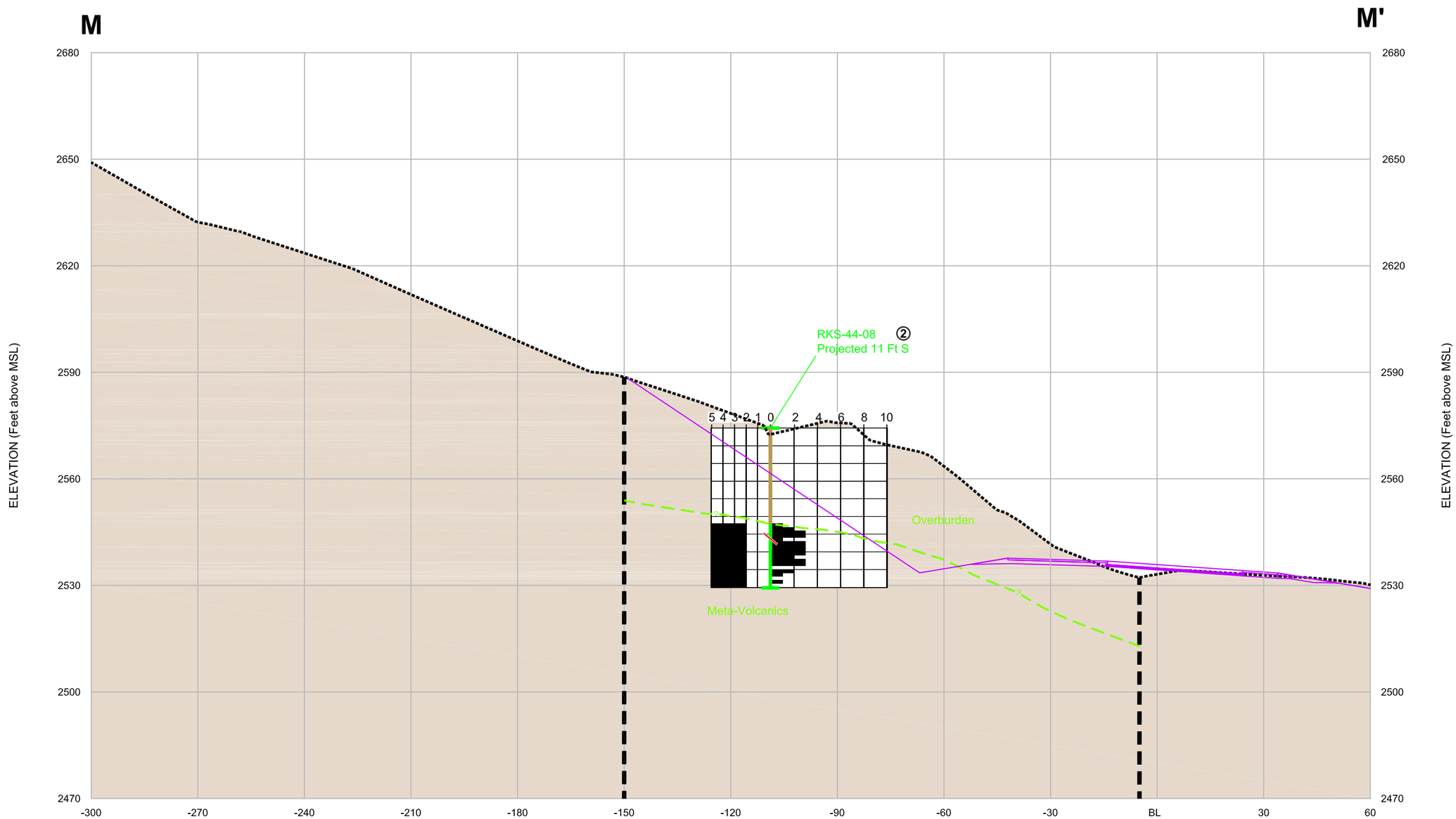
FIGURE **22**

DESIGN SECTOR XVII:

SECTION L-L' AT STATION 1447+50

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:42 Layout: Figure 22 (1447+50)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

General Explanation

- ? Geologic Inferred Contact
- Meta-Basalt Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figure 10 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.
3. No groundwater data available from the VWPs at the time of this report.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

0 30 60
SCALE IN FEET
(Horizontal & Vertical)

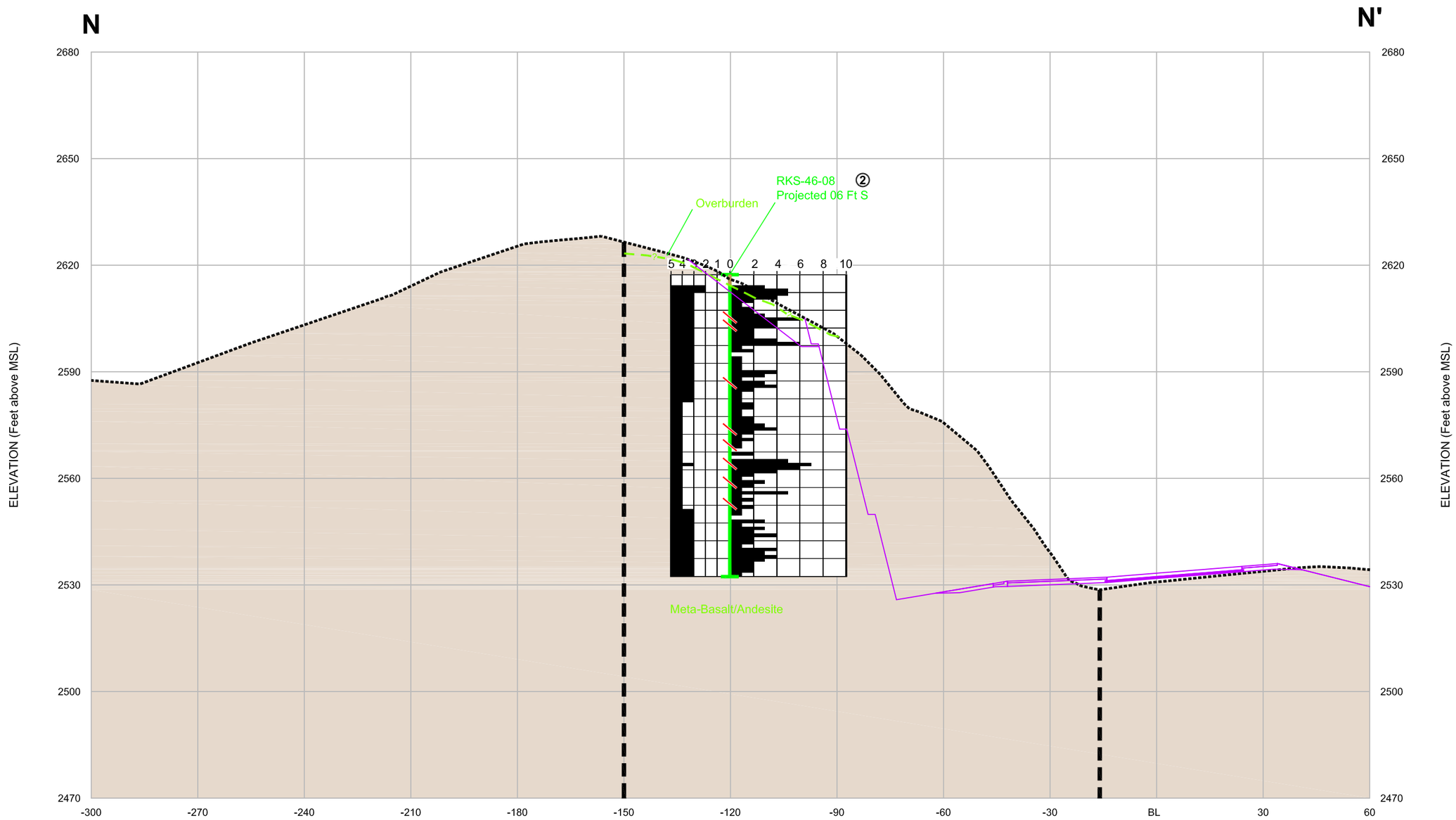
FIGURE **23**

DESIGN SECTOR XVII:

SECTION M-M' AT STATION 1462+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CADD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:42 Layout: Figure 23 (1462+00)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Poor Rock Quality Interval
- Adversely Dipping Significant Discontinuity

Piezometer
- Minimum Water Depth
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ TDR Only

General Explanation

- ? Geologic Inferred Contact
- Meta-Basalt Rock Type
- Proposed Roadway
- Mapping Boundary

Notes:
1. See Figure 11 for section location.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.
3. No groundwater data available from the VWPs at the time of this report.

Source:
Sections provided by WSDOT, April 15, 2009.
Elevation inconsistencies noted at several locations on the project datum and may affect actual elevation data presented on the sections.

0 30 60
SCALE IN FEET
(Horizontal & Vertical)

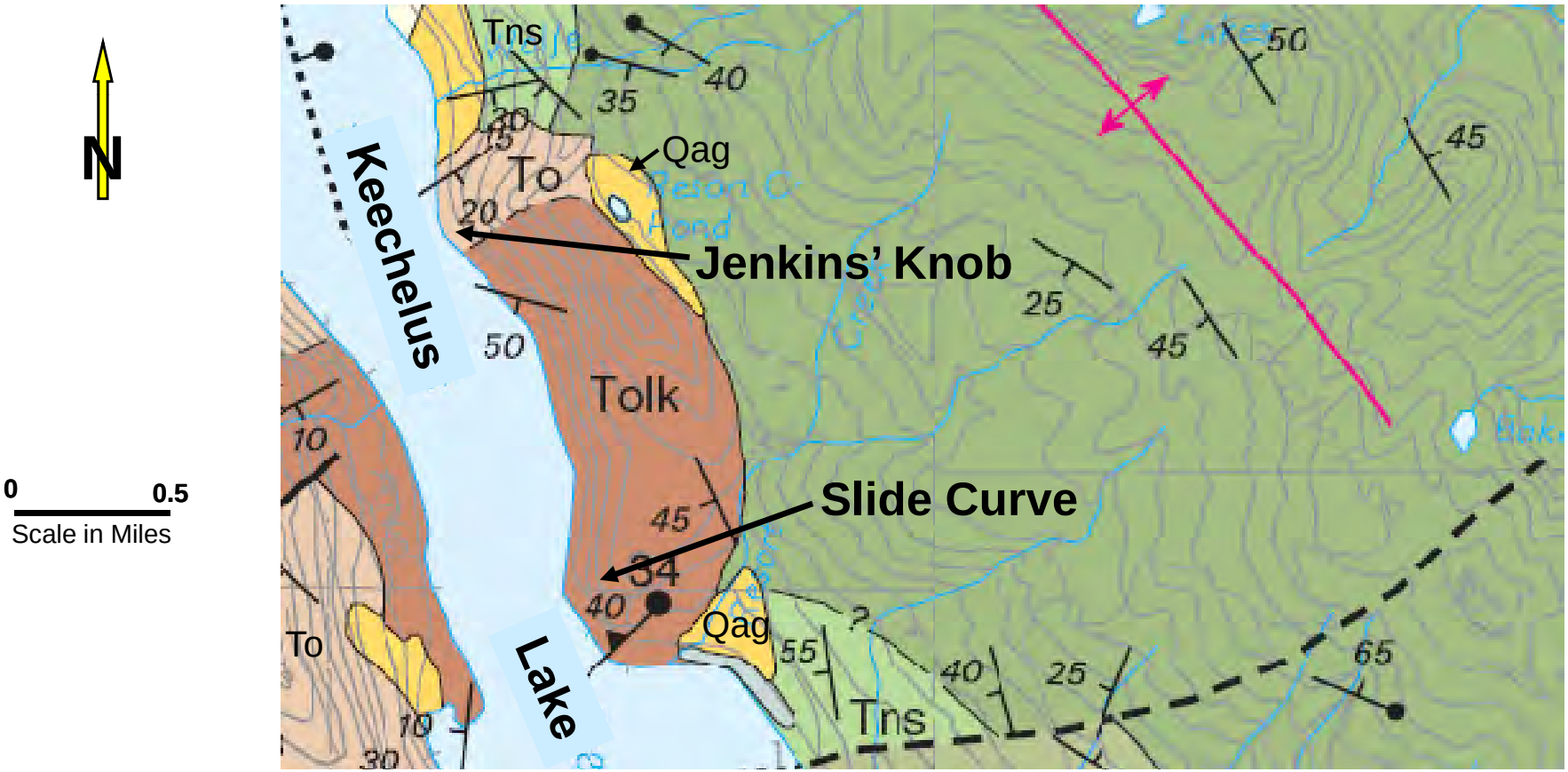
FIGURE **24**

DESIGN SECTOR XVIII:

SECTION N-N' AT STATION 1471+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam
Phase 1C Rock Slope Engineering Report

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\Phase 1C\WN - Phase 1C Sections.dwg 04/21/2009, 10:42 Layout: Figure 24 (1471+00)



From Tabor, R.W, et al, 2000

Qag — Alpine glacial deposits (Pleistocene)

To — Ohanapecosh Formation (Oligocene)

Tolk — Tuff member of Lake Keechelus

Tns — Glomeroporphyritic basalt (late and middle Eocene)

Tnbg — Feldspathic sandstone and volcanic rocks (late to middle Eocene)

Fault dotted where covered, dashed where location approximate

25 — Strike and dip on bedding, dot indicates top known

Anticline

34 — 30.4+/-1.2 my F-T age

Strike and dip on foliation or igneous fabric

Project No. 062-2002 Date: March 2009

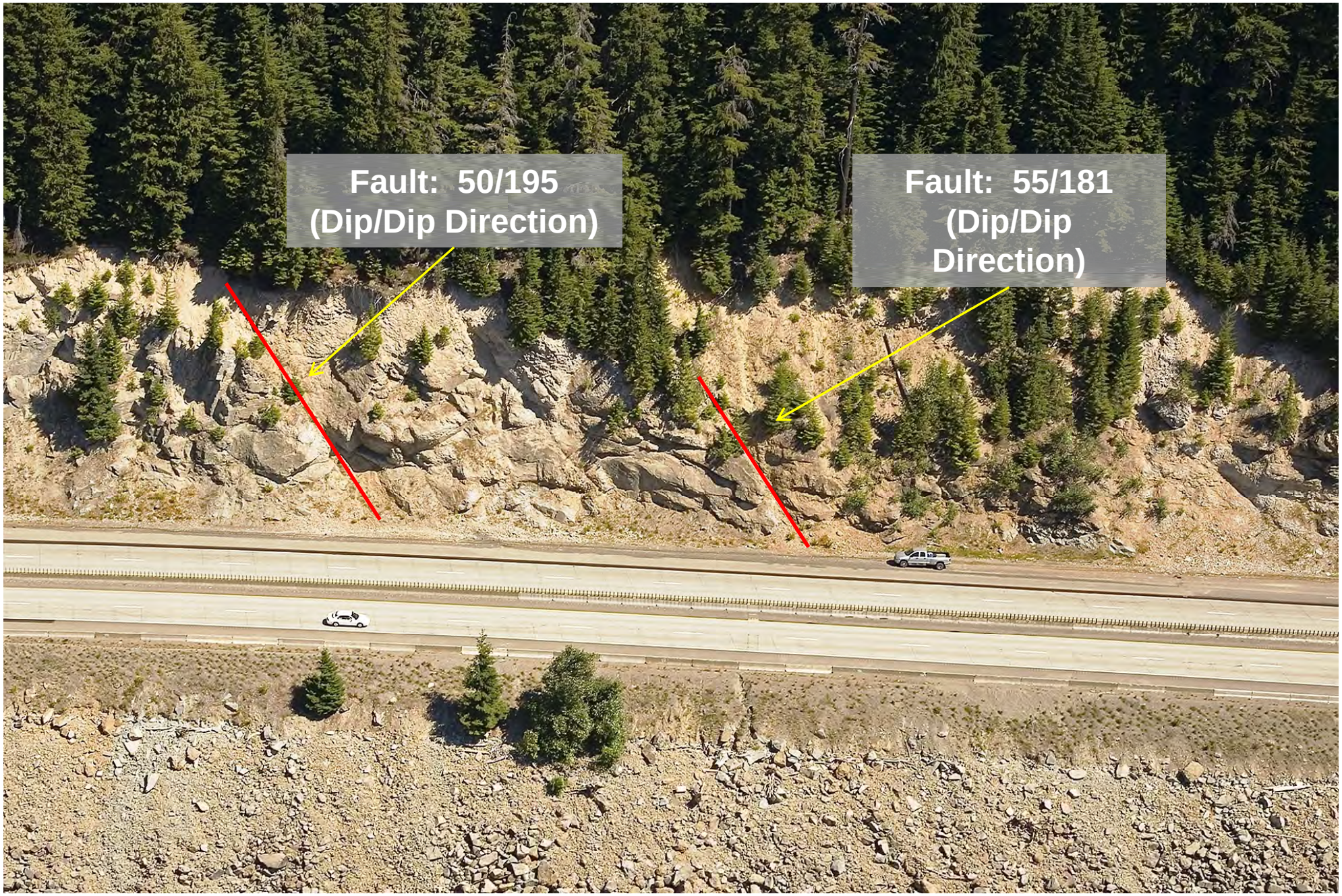
Figure 25

Regional Geologic Map

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

Figure 26

Discontinuities in Meta-Lapilli Ash Tuff (Sector X)

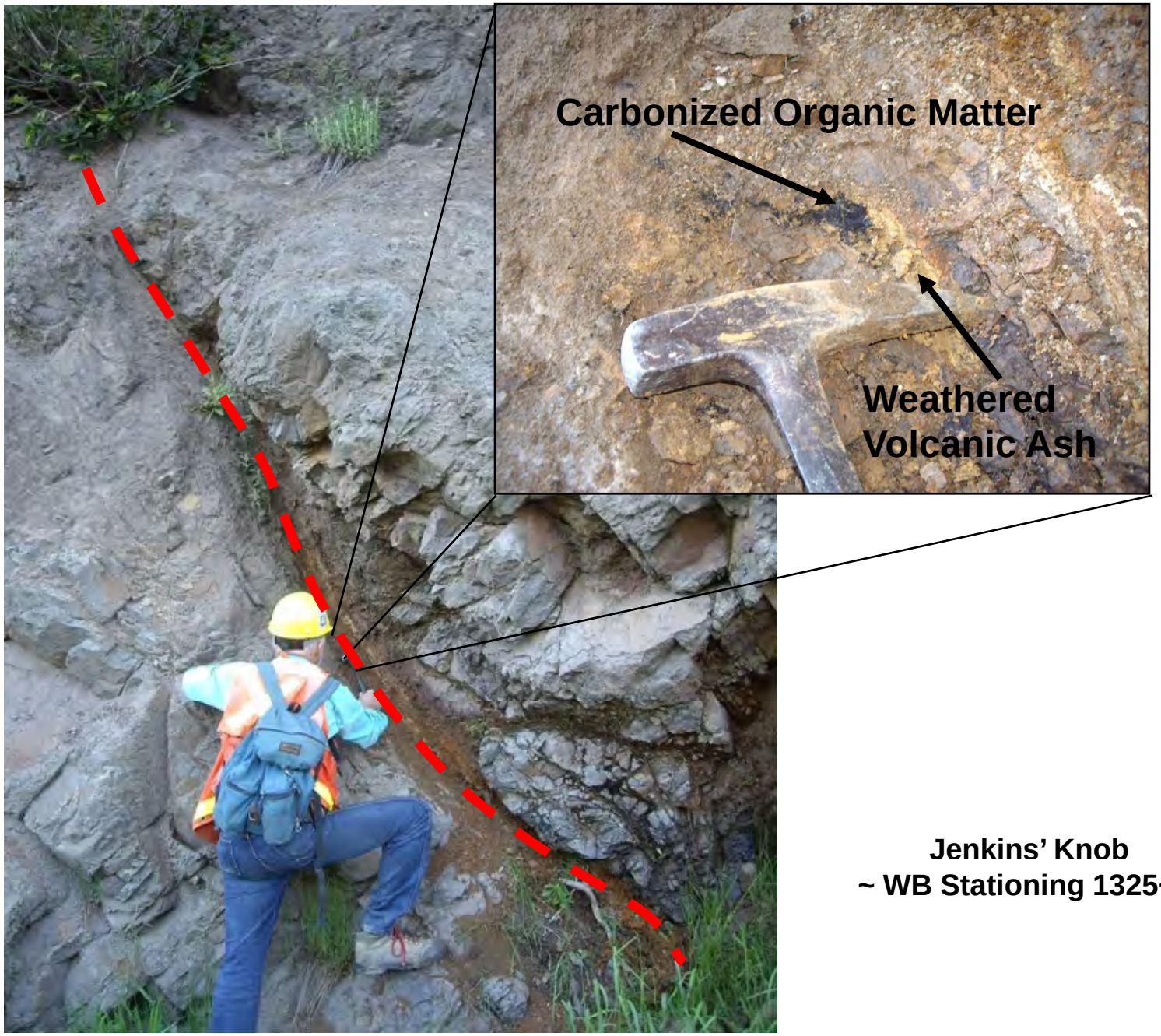


Project No. 062-2002 Date: March 2009

Figure 27

Fault Discontinuities (Sector XII)

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Jenkins' Knob
~ WB Stationing 1325+25

Figure **28**

Flow Boundary Discontinuity (Sector V)

Project No. 062-2002 **Date:** March 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

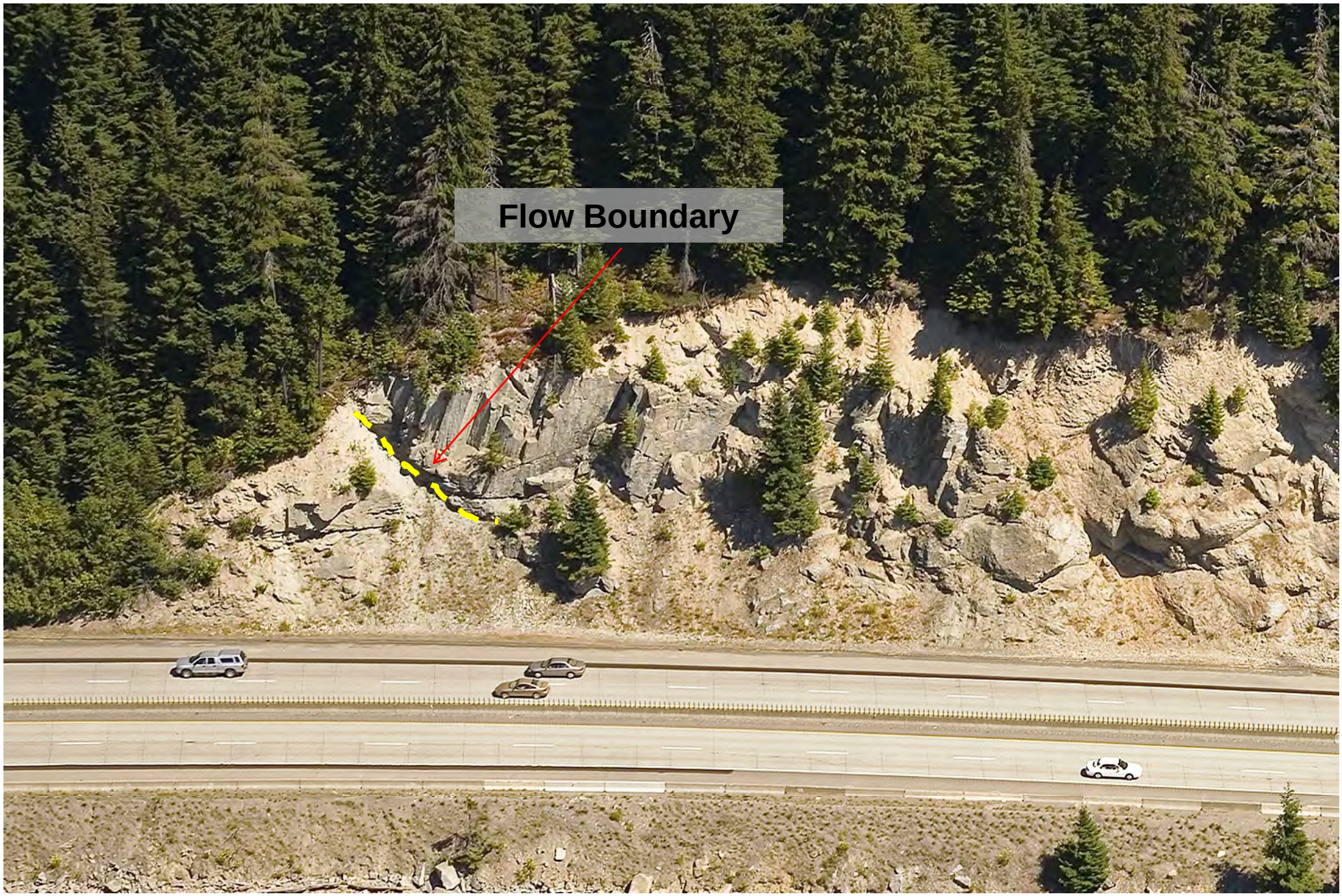


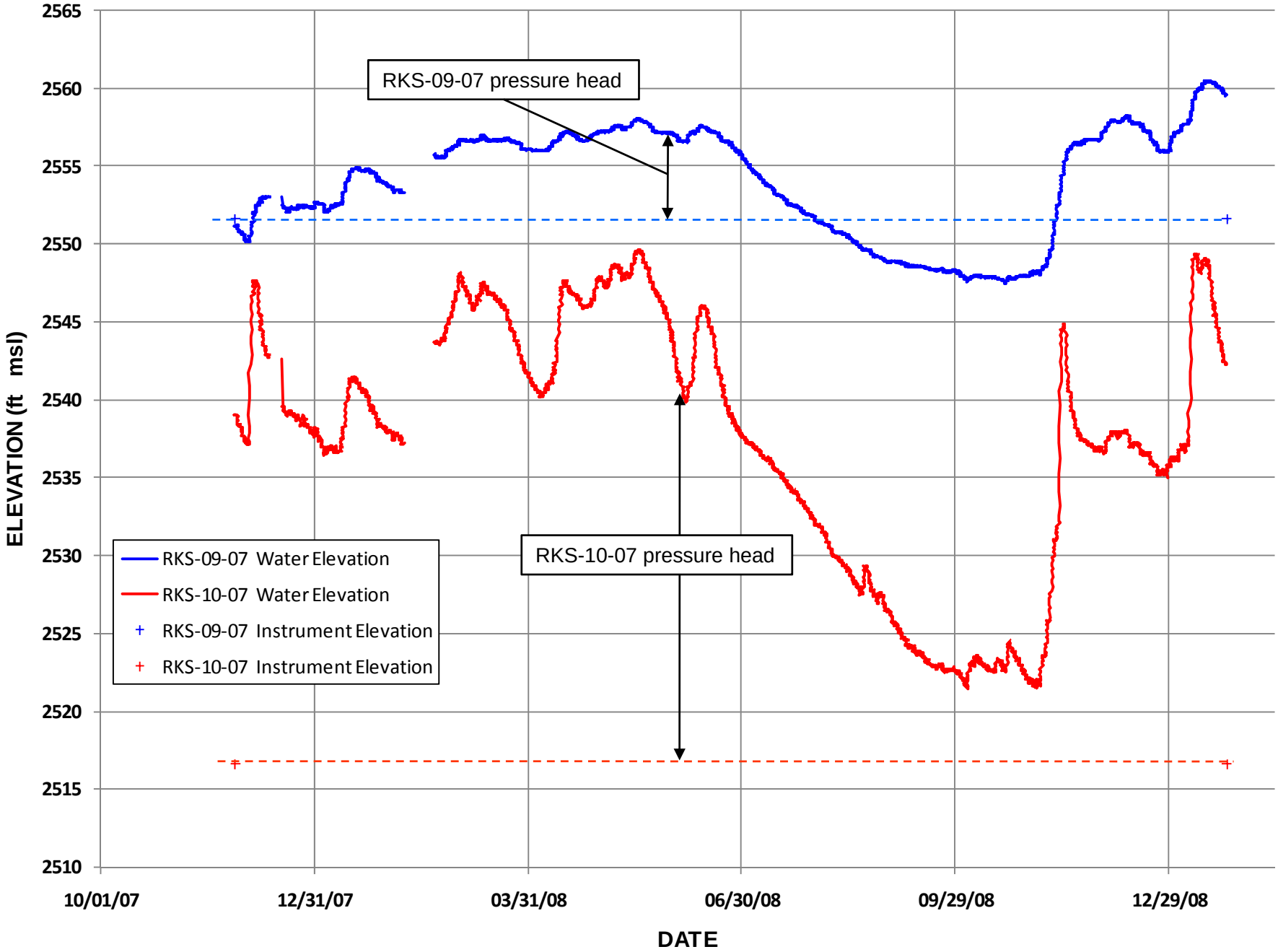
Figure 29

Flow Boundary Discontinuity (Sector XII)

WB Station 1383+75

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

Project No. 062-2002 **Date:** March 2009



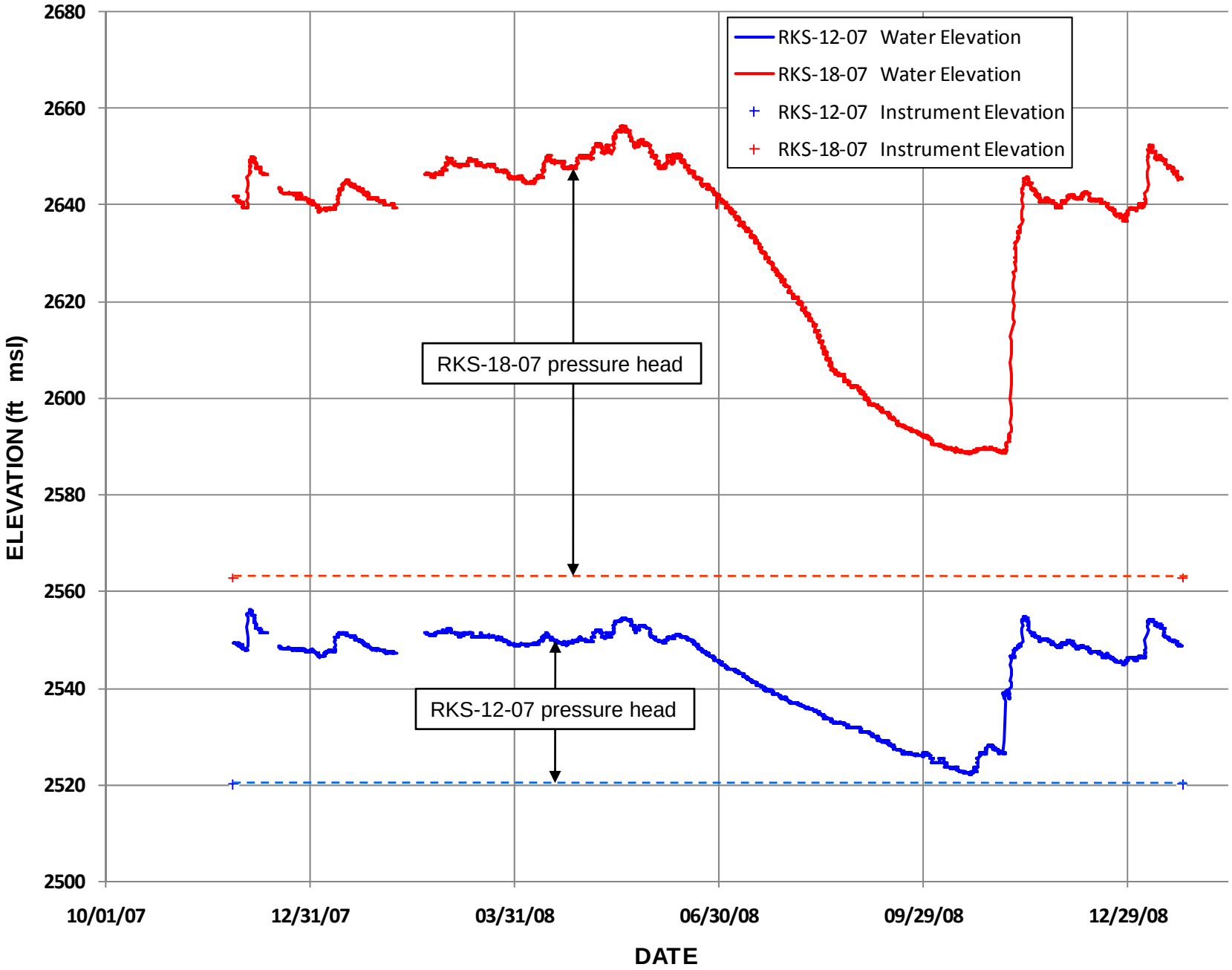
Project No. 062-2002 Date: January 2009

Piezometric data provided by WSDOT

Figure 30

Piezometeric Data for Design Sector IX

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



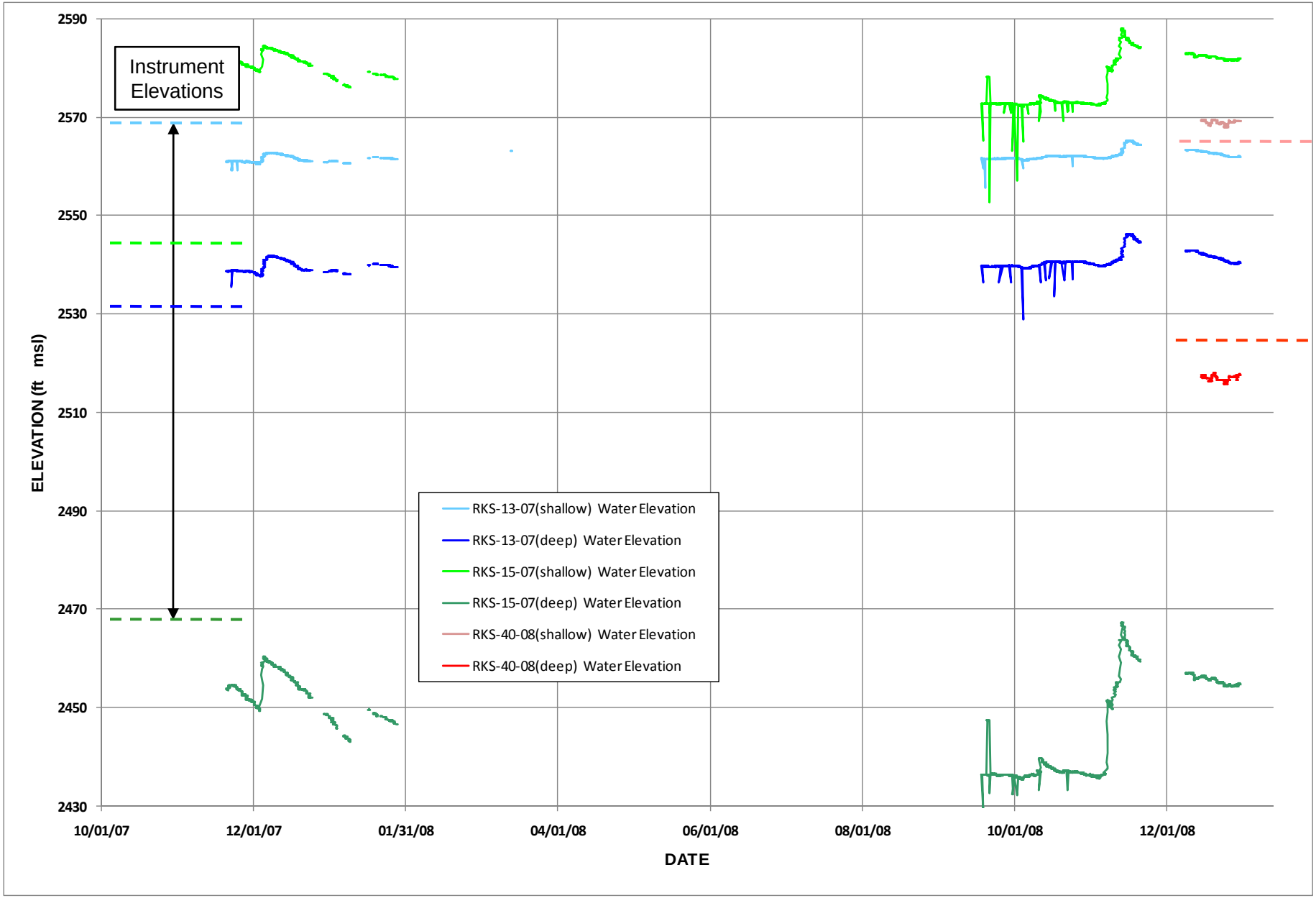
Project No. 062-2002 Date: January 2009

Figure 31

Piezometeric Data for Design Sector X

Piezometric data provided by WSDOT

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Project No. 062-2002 Date: January 2009

Figure 32

Piezometric data provided by WSDOT

Piezometeric Data for Design Sector XII (Western)

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

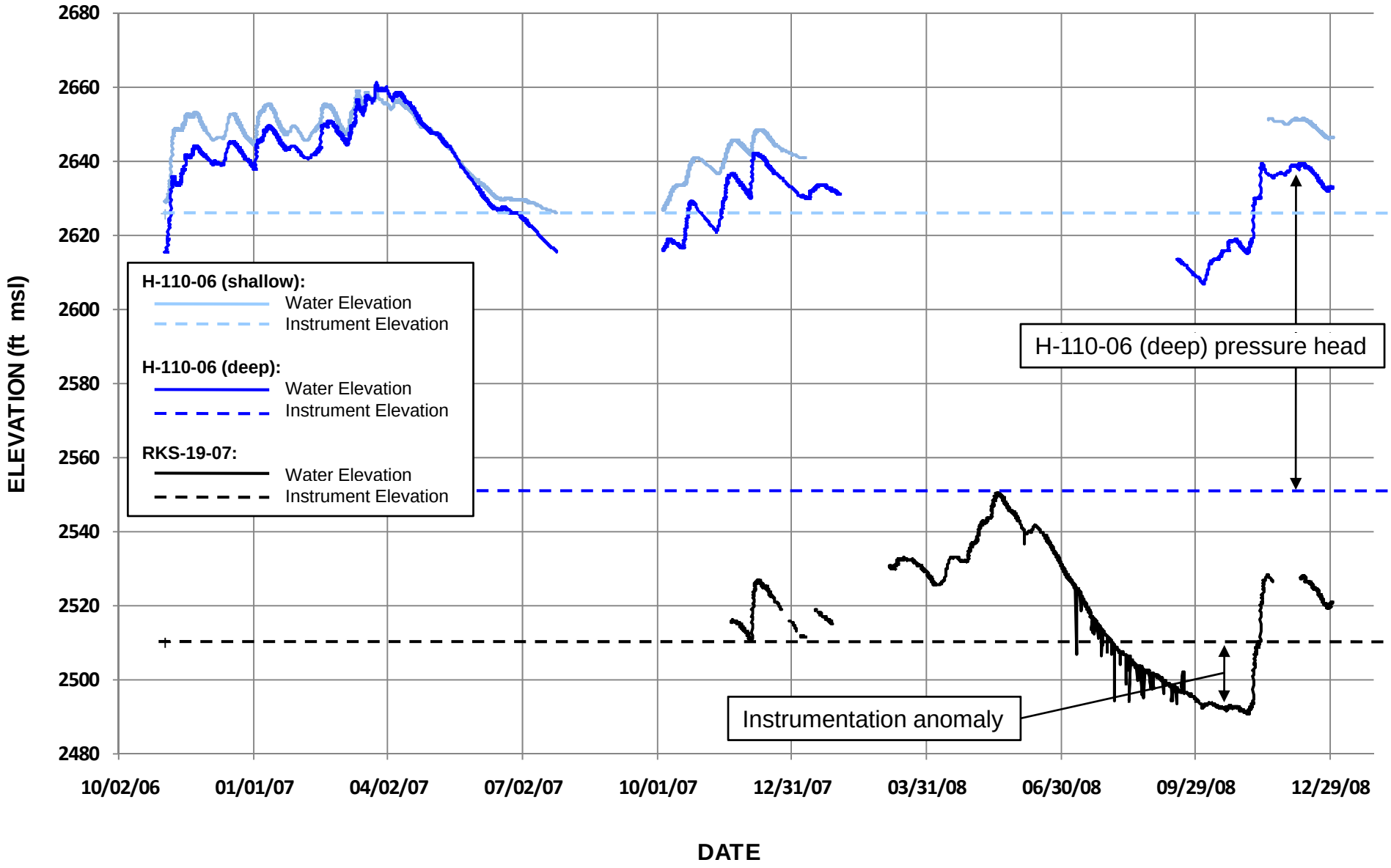


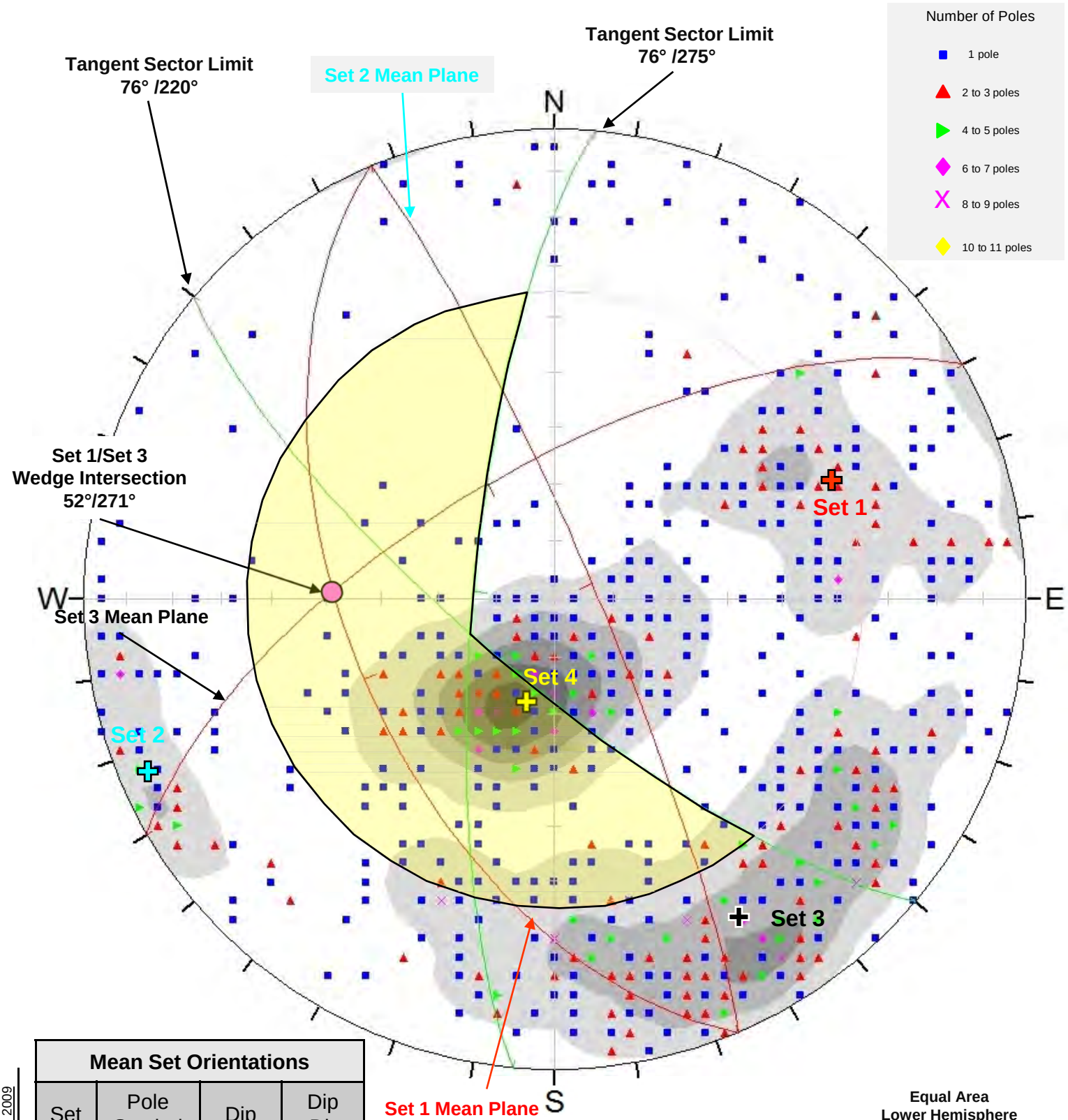
Figure 33

Piezometeric Data for Design Sector XII (Eastern)

Piezometric data provided by WSDOT

Project No. 062-2002 Date: January 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Equal Area
Lower Hemisphere
777 Poles

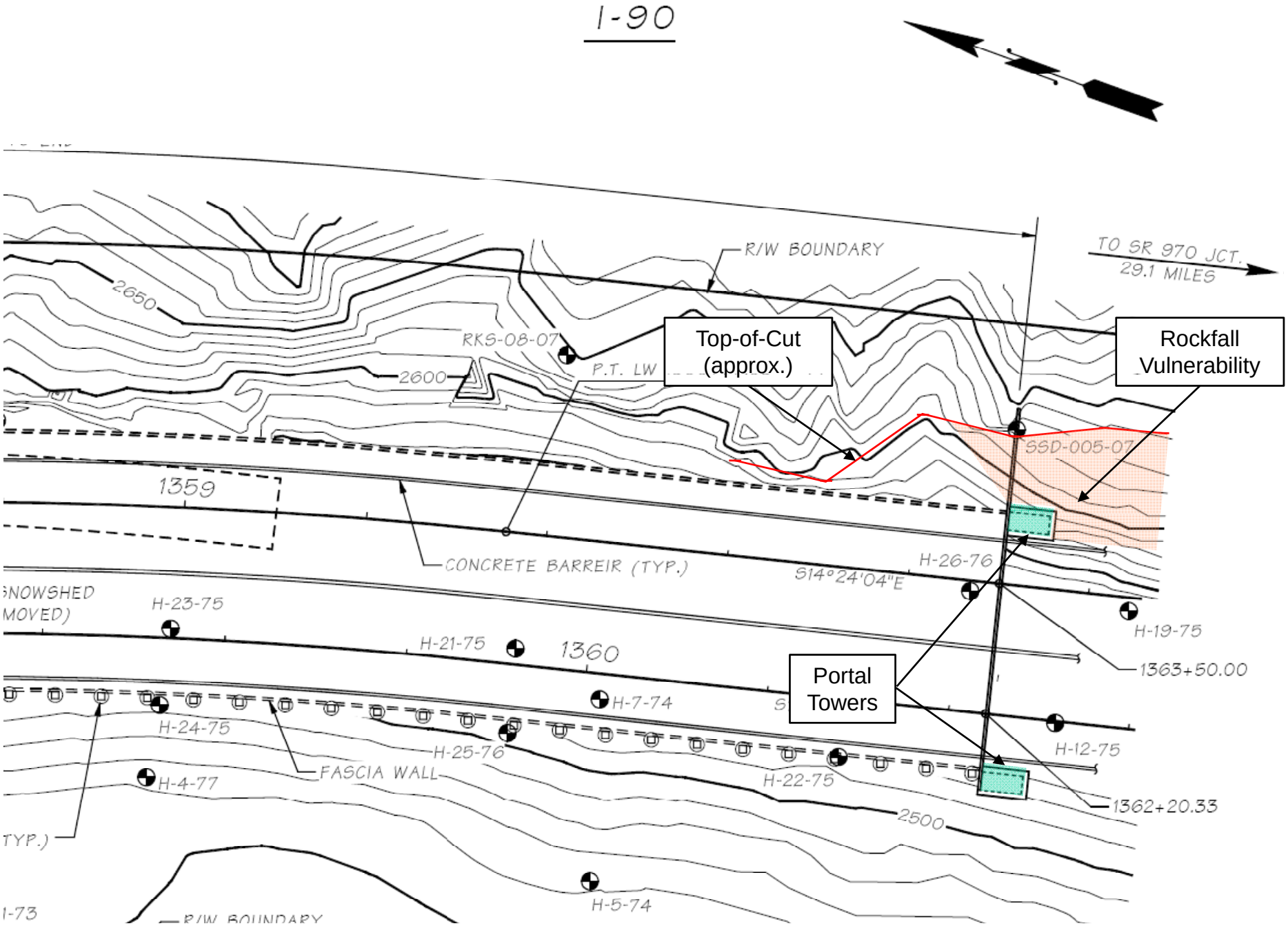
Mean Set Orientations			
Set	Pole Symbol	Dip	Dip Dir
1	✚	54°	247°
2	✚	83°	067°
3	✚	67°	330°
4	✚	18°	014°

Project No. 062-2002 Date: February , 2009

Figure 34

Design Sector VIII (Snowshed) – Detailed Kinematic Analysis

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Reference Drawing: from WSDOT

Figure 35

Snowshed East Portal Plan

Project No. 062-2002 **Date:** February 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

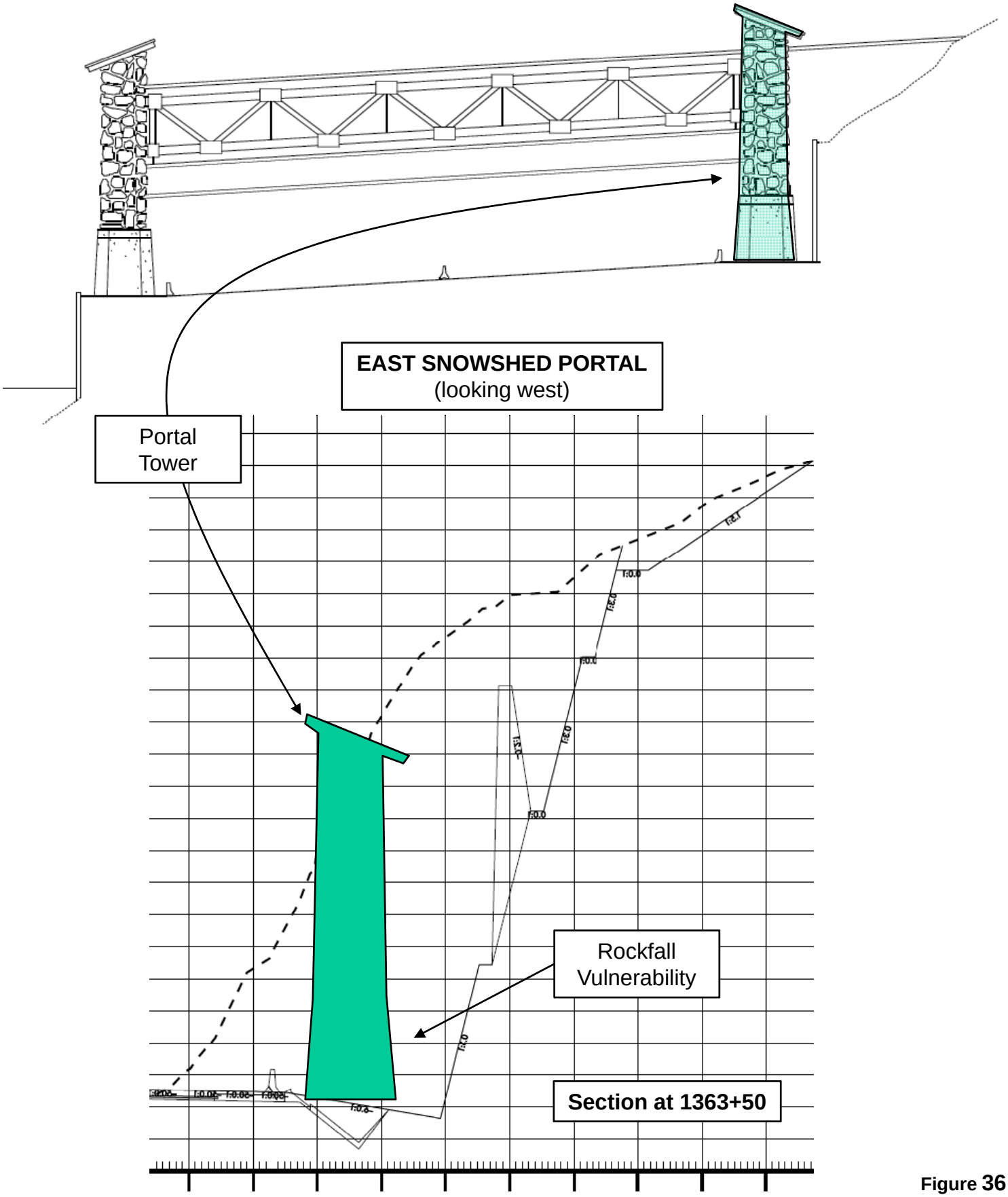


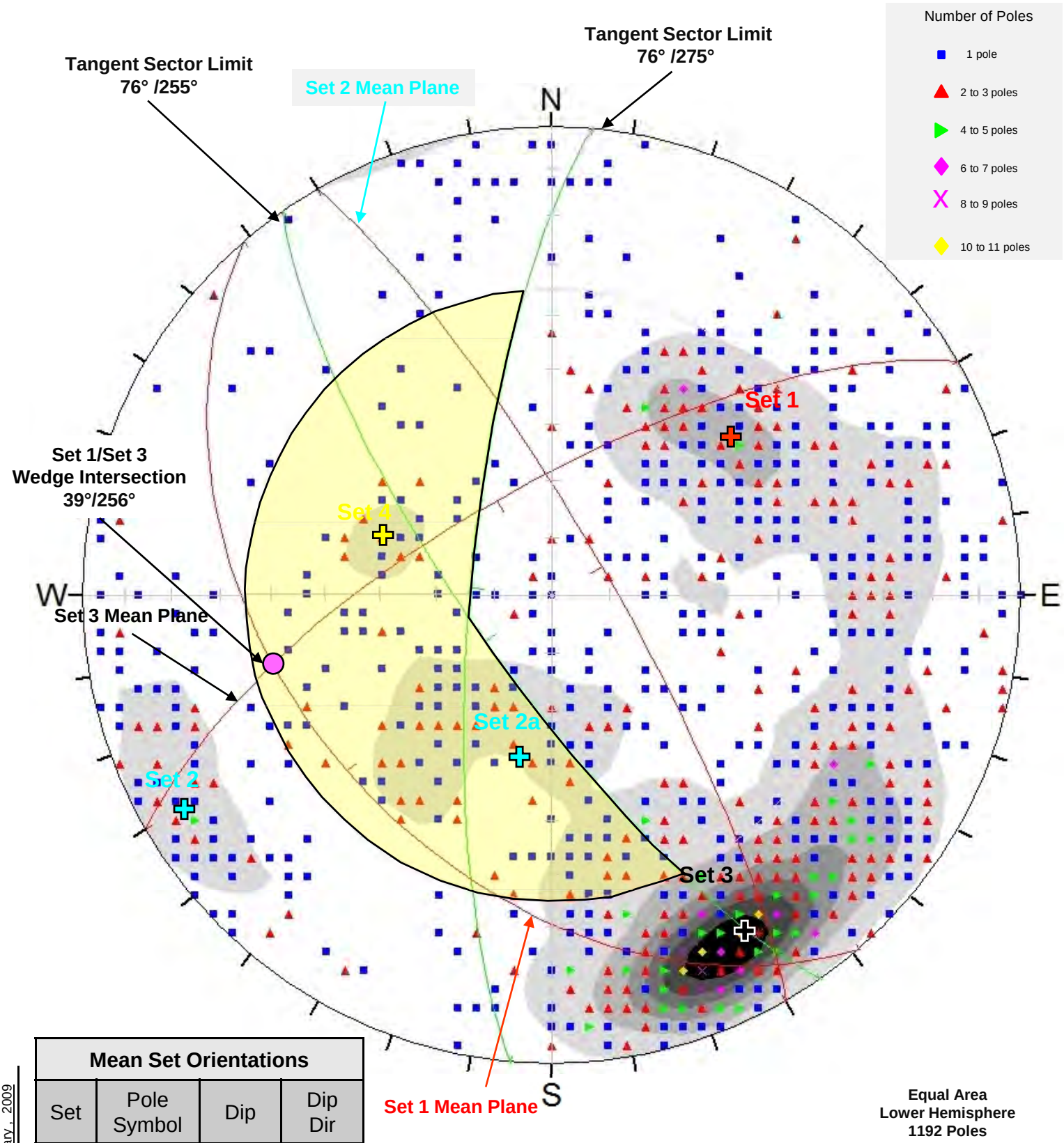
Figure 36

Snowshed East Portal

Reference Drawings: from WSDOT

Project No. 062-2002 **Date:** February , 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



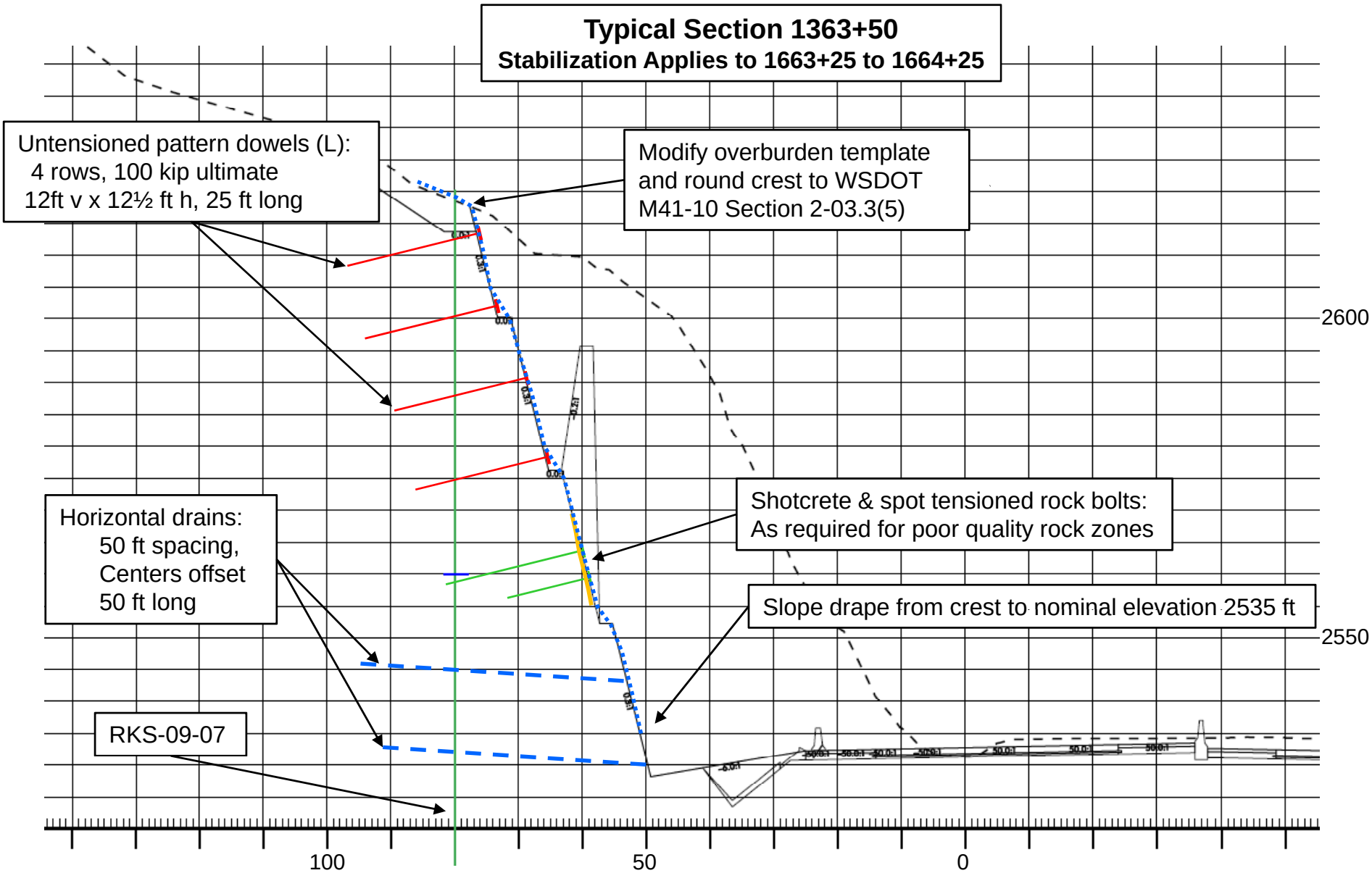
Mean Set Orientations			
Set	Pole Symbol	Dip	Dip Dir
1	✚	42°	229°
2	✚	80°	060°
2a	✚	29°	011°
3	✚	71°	330°
4	✚	31°	110°

Project No. 062-2002 Date: February , 2009

Figure 37

Design Sector IX – Detailed Kinematic Analysis

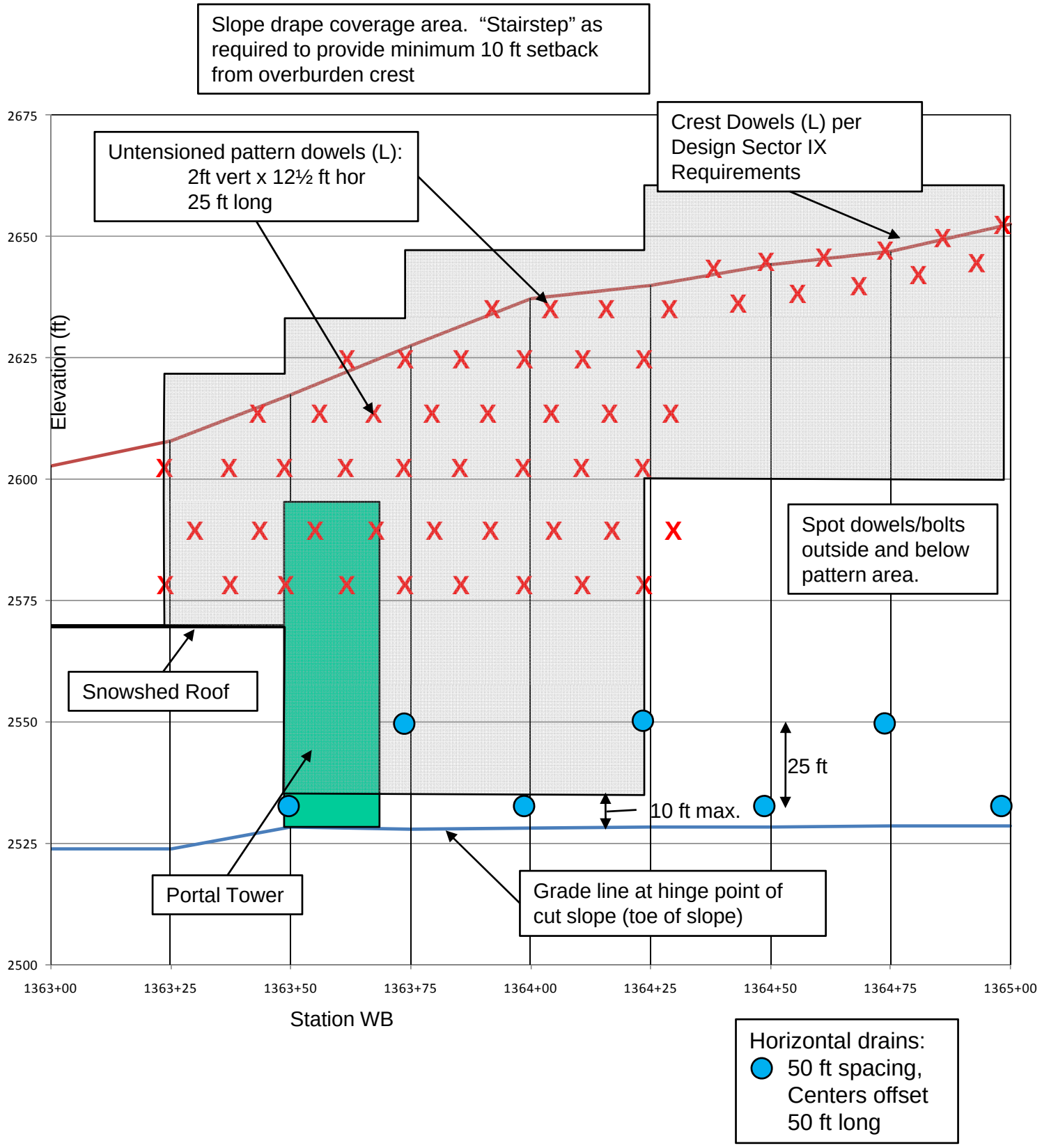
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Project No. 062-2002 Date: February 2009

Figure 38

Design Sector IX Portal Area– Stabilization Detail



Note: *Uppermost dowels for each row closest to cut slope line to be installed prior to first lift of rock excavation.*

Project No. 062-2002 **Date:** February , 2009

Figure 39

Design Sector IX Portal Area – Stabilization Layout

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

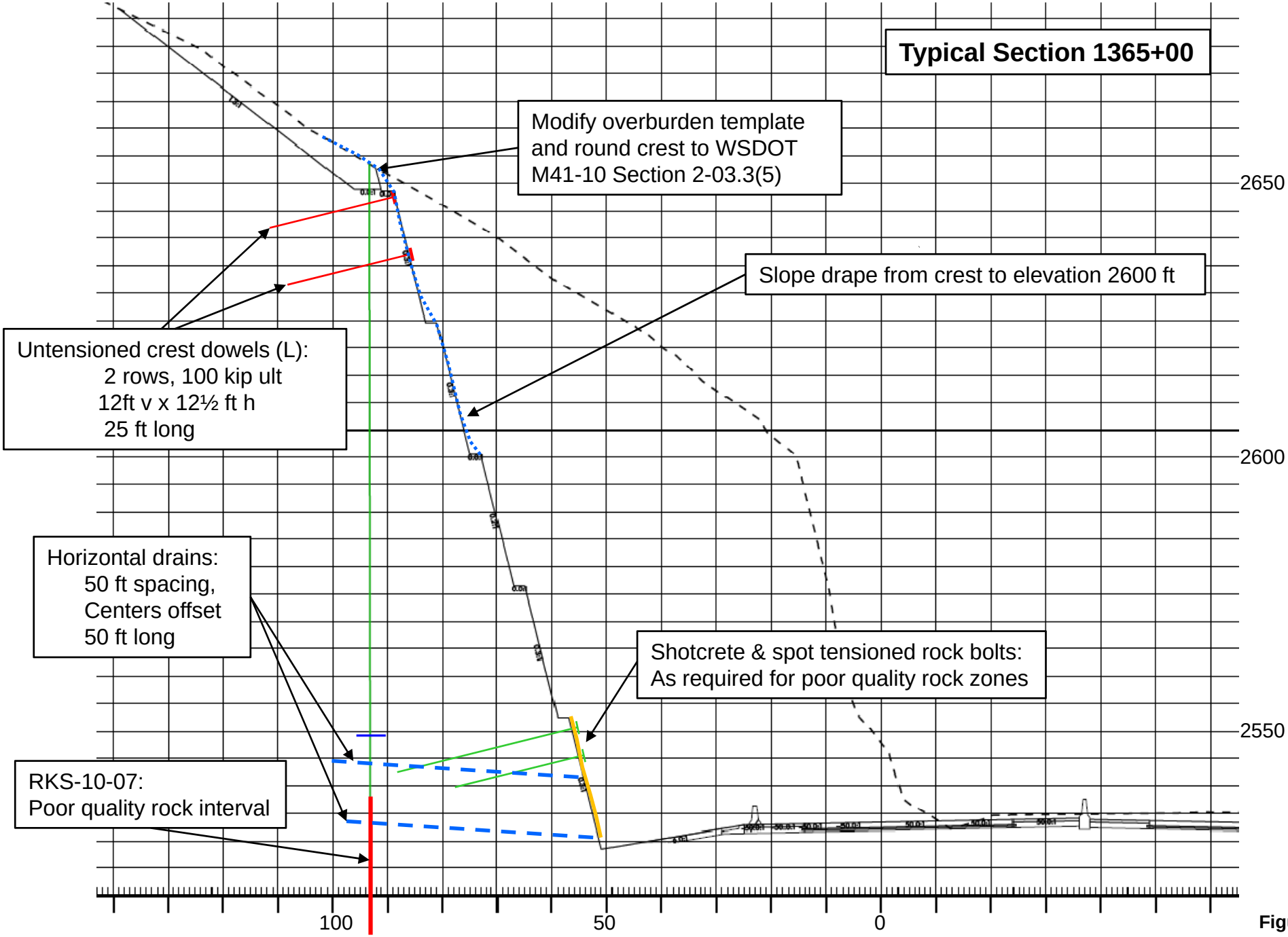


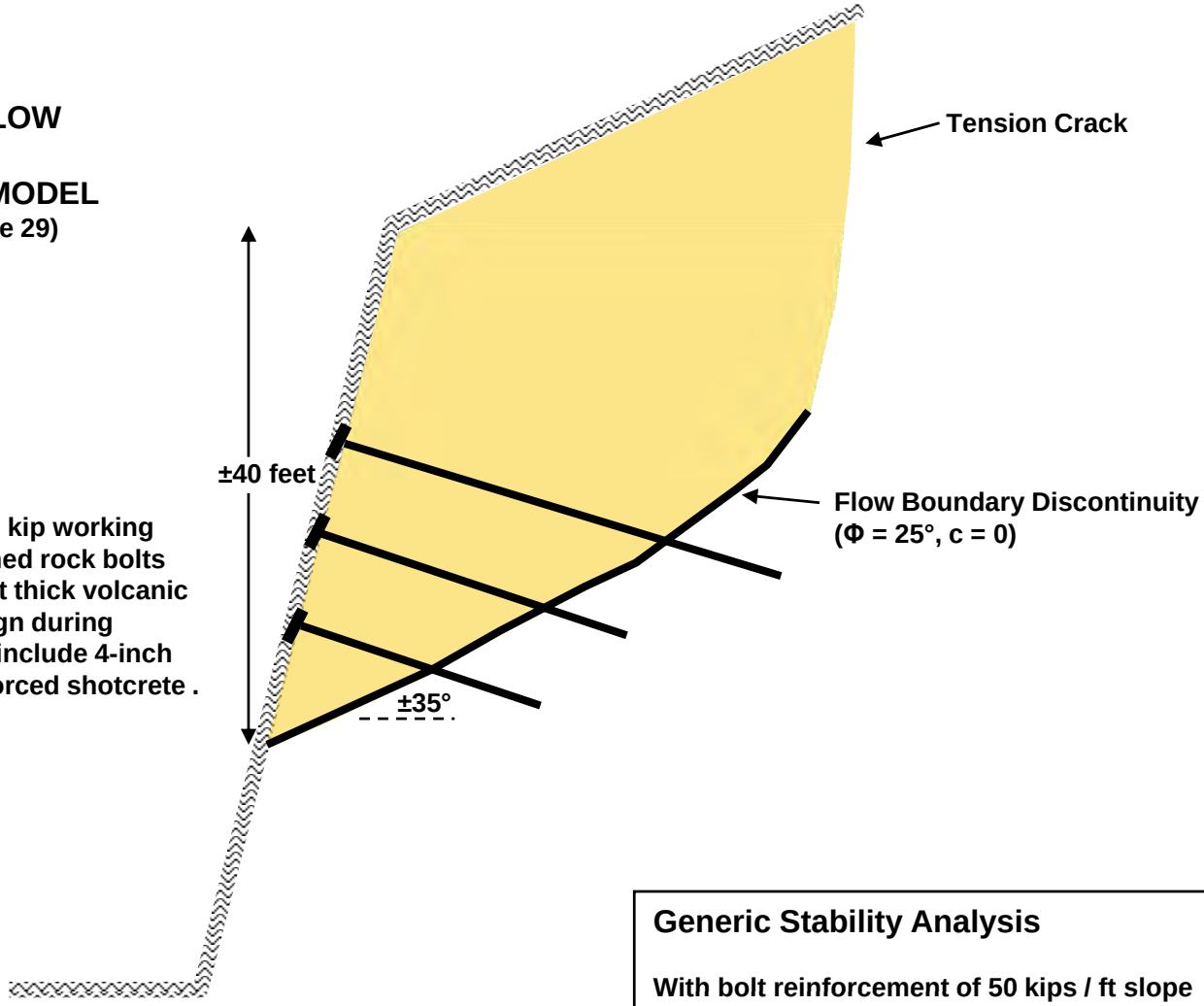
Figure 40

Design Sector IX – Stabilization Detail

Project No. 062-2002 Date: February 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

GENERIC FLOW BOUNDARY STABILITY MODEL
(see Figure 29)

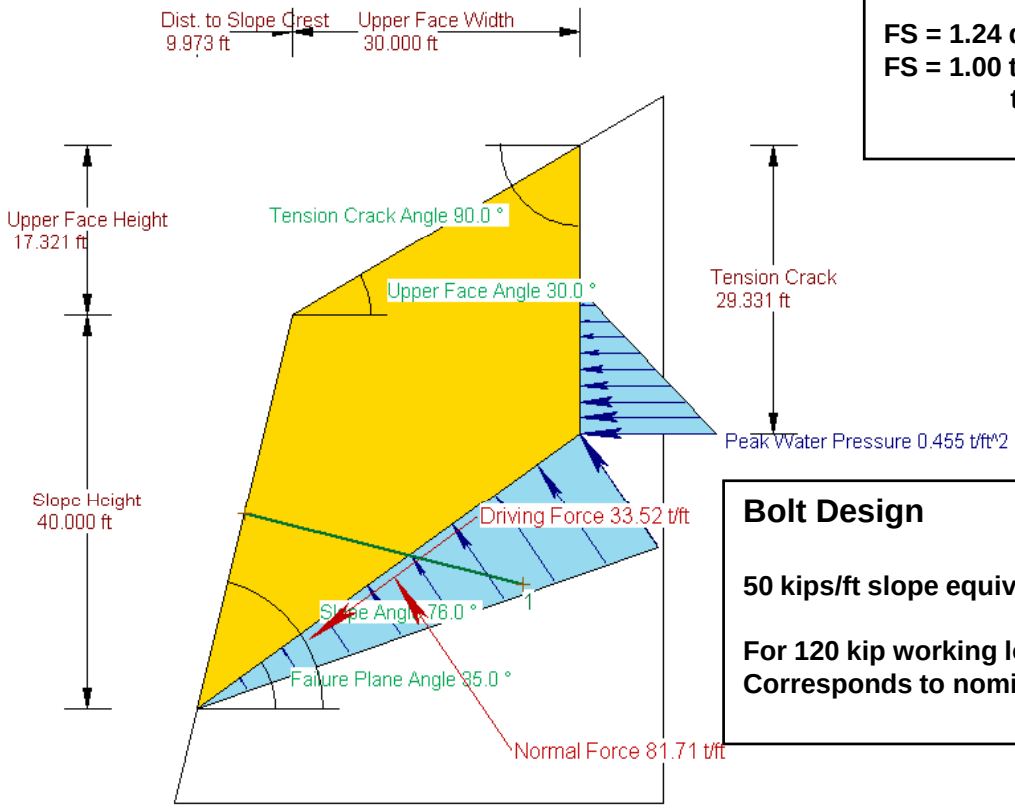


As required, 120 kip working capacity tensioned rock bolts based on 40-foot thick volcanic flow. Final design during construction to include 4-inch thick fiber-reinforced shotcrete .

Generic Stability Analysis

With bolt reinforcement of 50 kips / ft slope

FS = 1.24 drained slope
FS = 1.00 transient groundwater ≡ 50% tension crack fill & base plane



Bolt Design

50 kips/ft slope equivalent to 1.21 kips / sf

For 120 kip working load bolts, face area per bolt = 100 sf
Corresponds to nominal 10 ft x 10 ft pattern

Project No. 062-2002 **Date:** November 21, 2006

Figure 41

FLOW BOUNDARY STABILITY MODEL

wyllie & norrish ROCK ENGINEERS

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

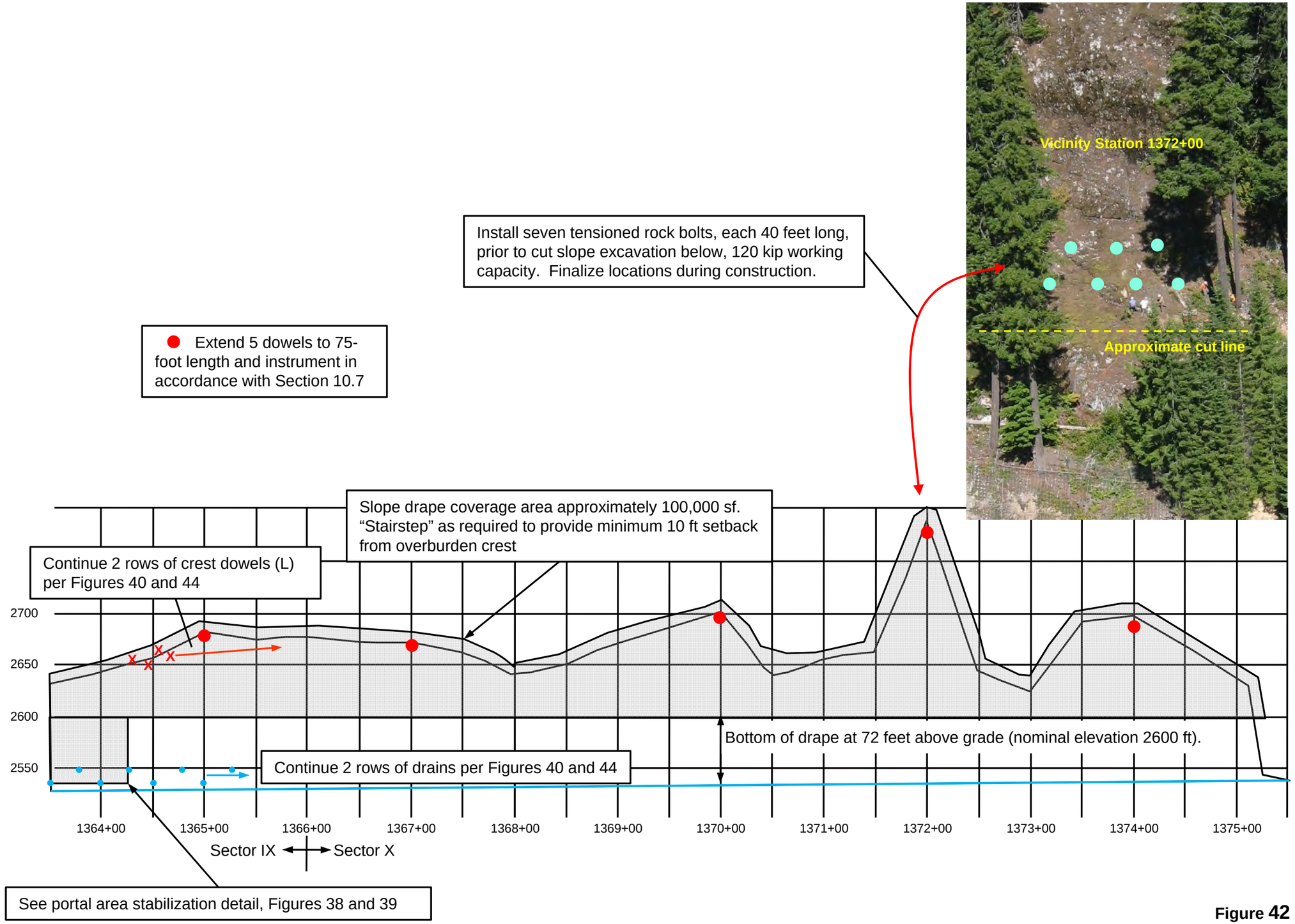
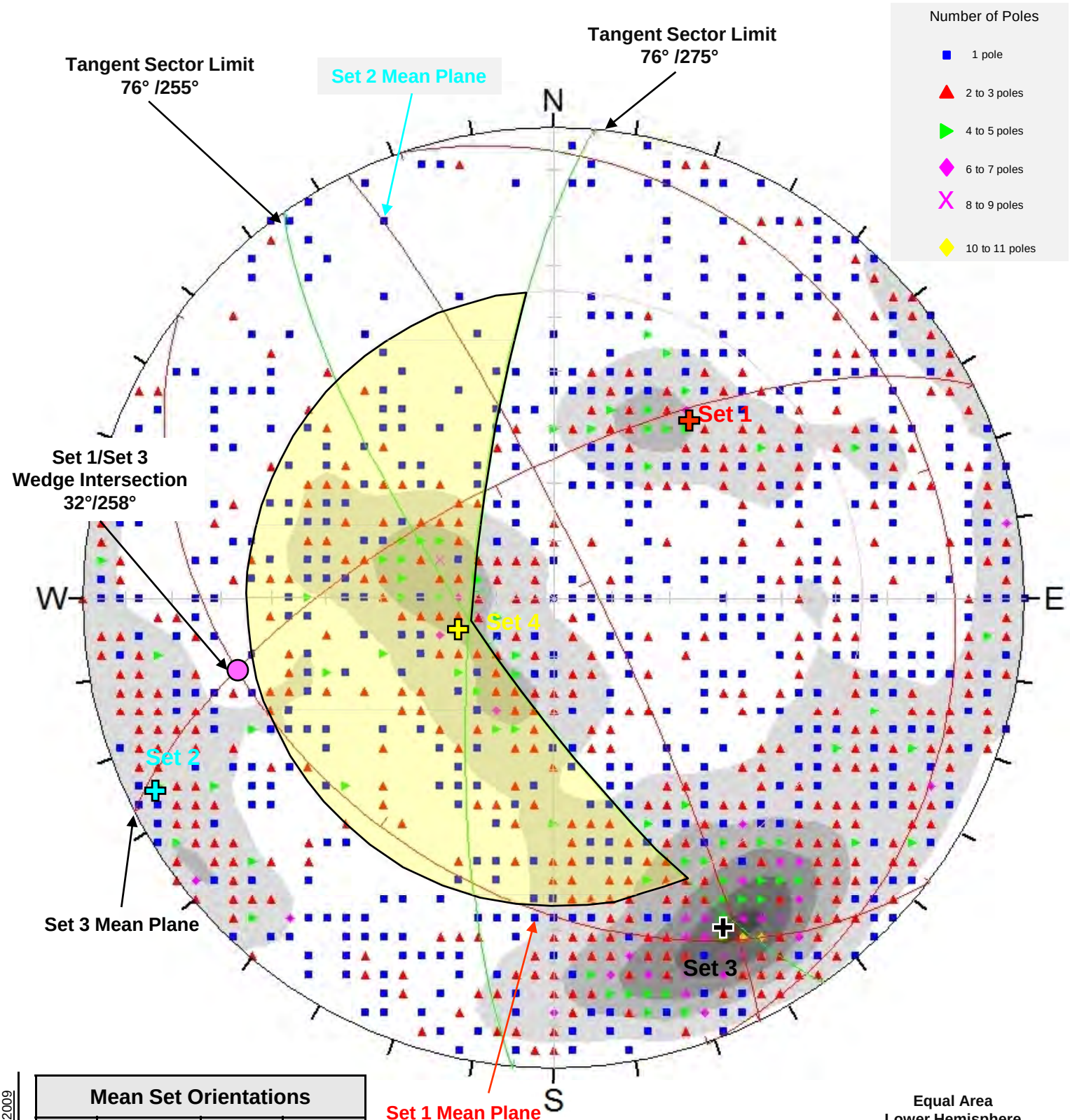


Figure 42

Design Sectors IX and X – Slope Drape Conceptual Layout

Project No. 062-2002 **Date:** February 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Equal Area
Lower Hemisphere
2115 Poles

Mean Set Orientations			
Set	Pole Symbol	Dip	Dip Dir
1	✚	39°	217°
2	✚	83°	064°
3	✚	68°	333°
4	✚	17°	071°

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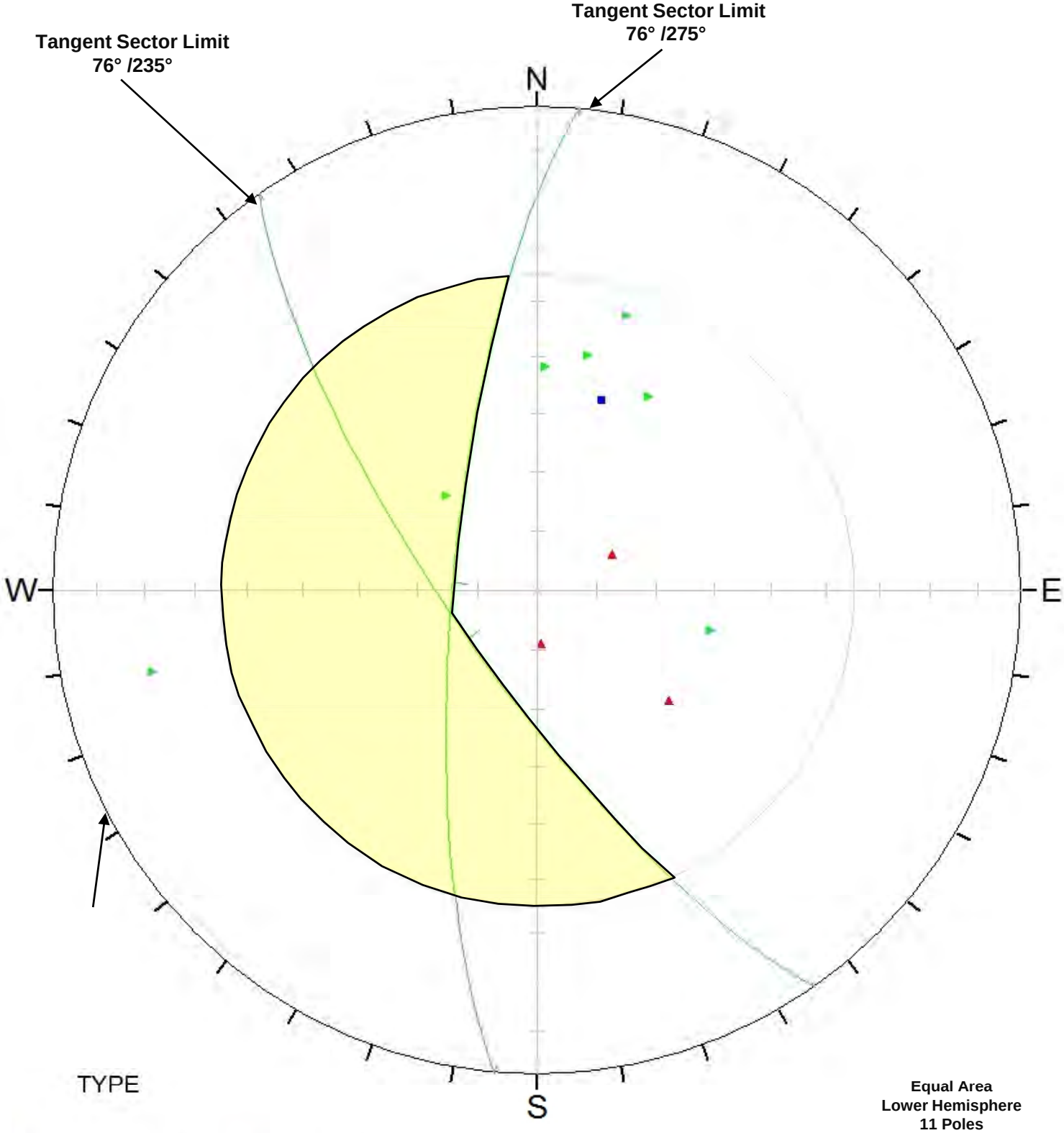
Figure 43

Design Sector X – Detailed Kinematic Analysis

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



TYPE

- Flow [1]
- Possible Fault [3]
- Possible Flow [7]

Equal Area
Lower Hemisphere
11 Poles

Most faults and flow boundaries do not represent kinematically viable planar failure surfaces for Design Sectors IX and X.

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Figure 44

Design Sector IX & X – Kinematic Analysis Faults & Flow Boundaries

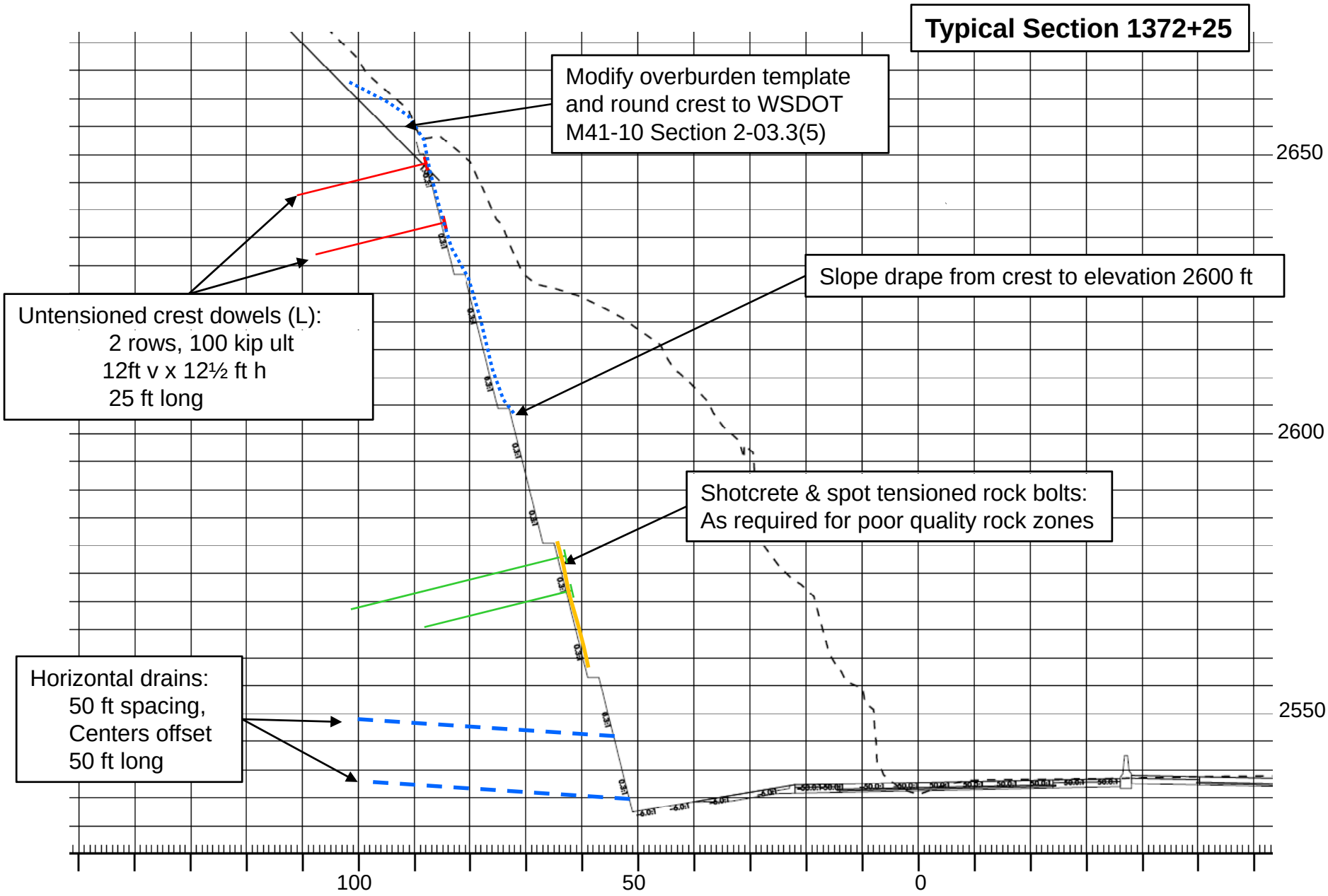
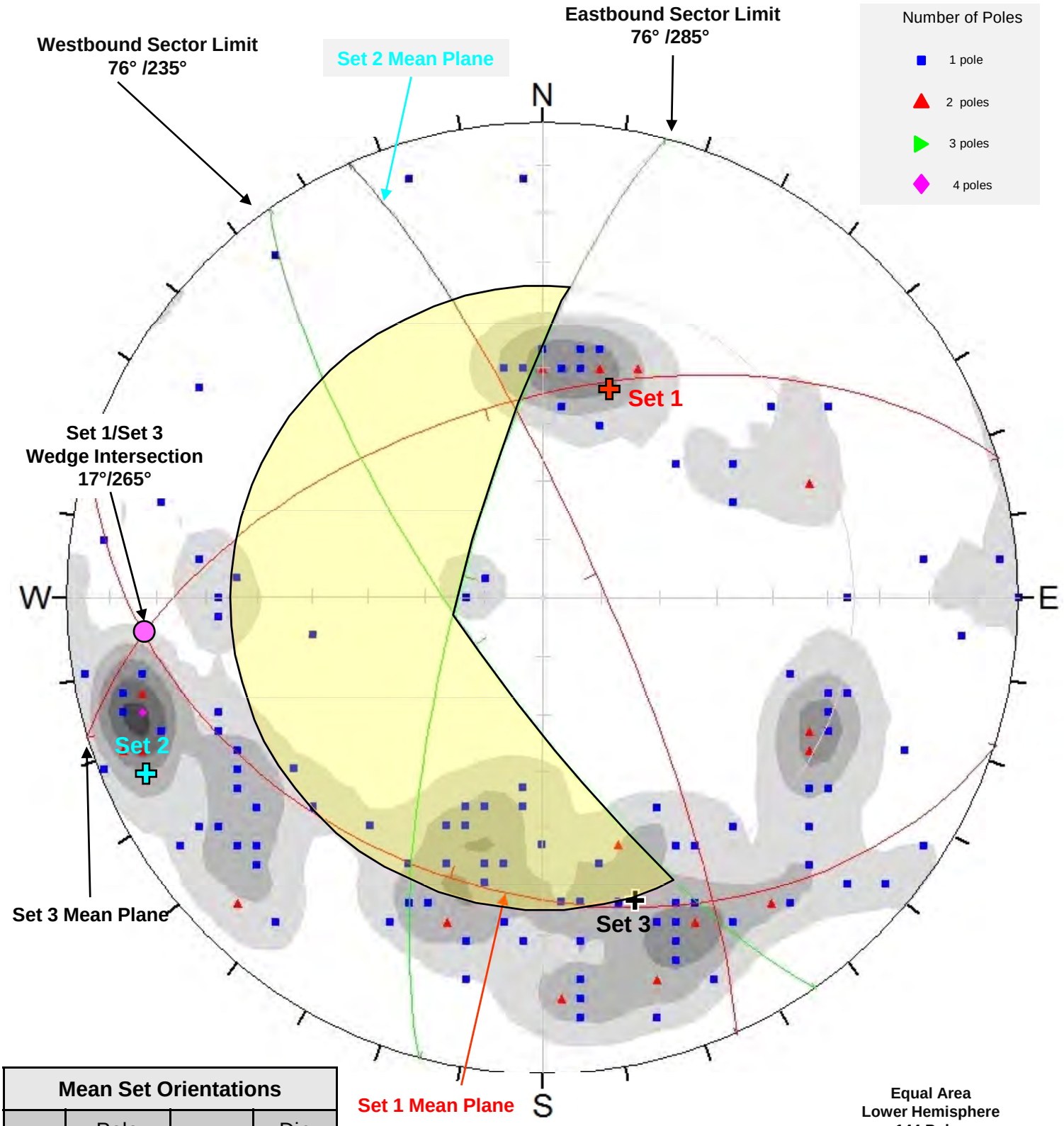


Figure 45

Design Sector X – Stabilization Detail

Project No. 062-2002 Date: February 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Equal Area
Lower Hemisphere
144 Poles

Mean Set Orientations			
Set	Pole Symbol	Dip	Dip Dir
1	✚	38°	198°
2	✚	80°	066°
3	✚	56°	343°
4			

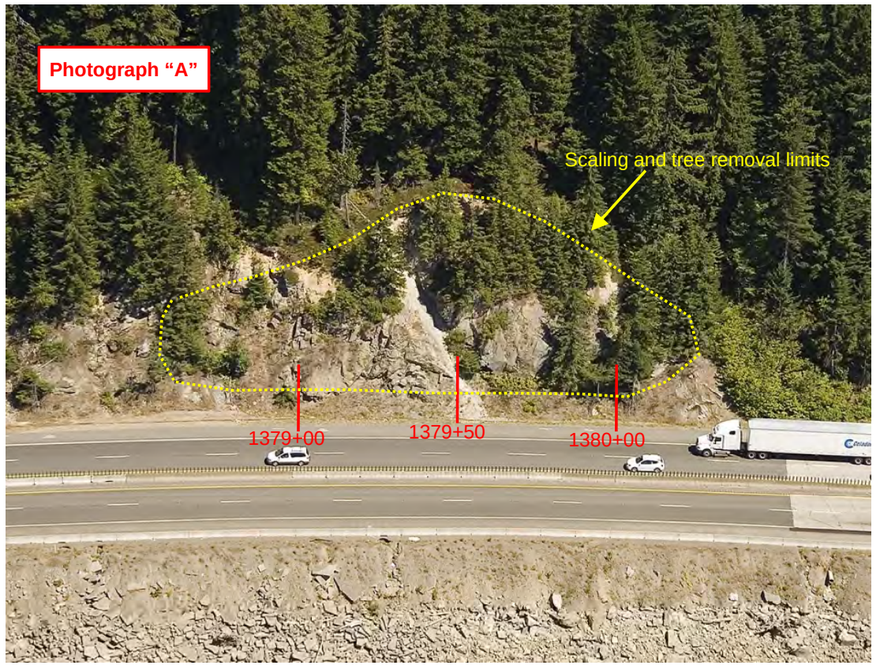
Project No. 062-2002 Date: February , 2009

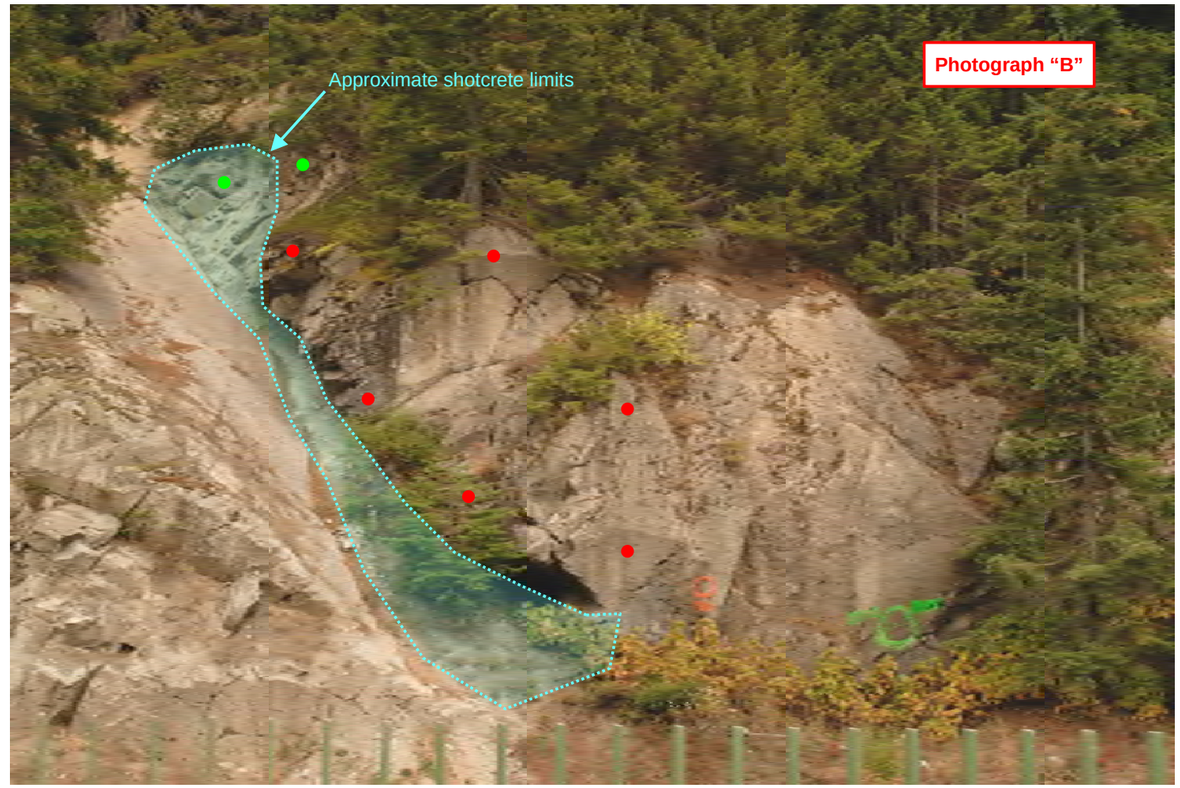
Figure 46

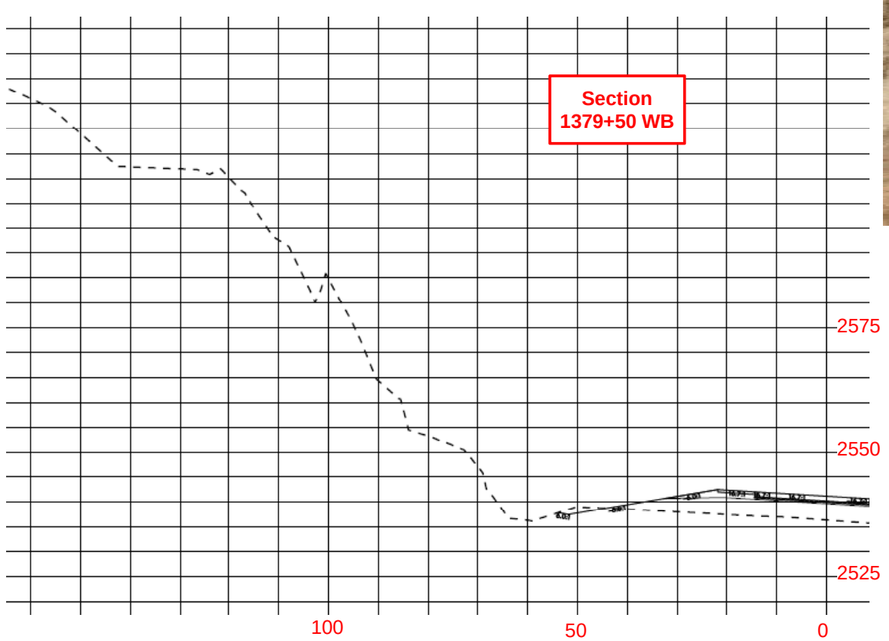
Design Sector XI – Detailed Kinematic Analysis

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

KEY	STABILIZATION ITEM	ESTIMATED QUANTITY
●	50 kip (working) tensioned rock bolt	8 x 25 ft = 200 ft (includes contingency)
●	50 kip (working) untensioned rock dowel	4 x 20 ft = 80 ft (includes contingency)
	Shotcrete	5 cy
	General scaling / tree removal	50 crew hr







Stabilization Sequence:

- ► Remove all coniferous trees greater than 4 inches at the butt from the rock face within scaling limit (Photograph "A").
- ► Perform general hand scaling to remove loose blocks from rock slope face to the scaling limits shown (Photograph "A").
- ► Install rock bolts or dowels from **top down** at specified locations and as directed by the Engineer. Dowels may be substituted for bolts at the discretion of the Engineer to suit rock conditions. (Photograph "B").
- ► Apply shotcrete (3 inch minimum thickness) to seal fault to nominal limits shown (Photograph "B")..

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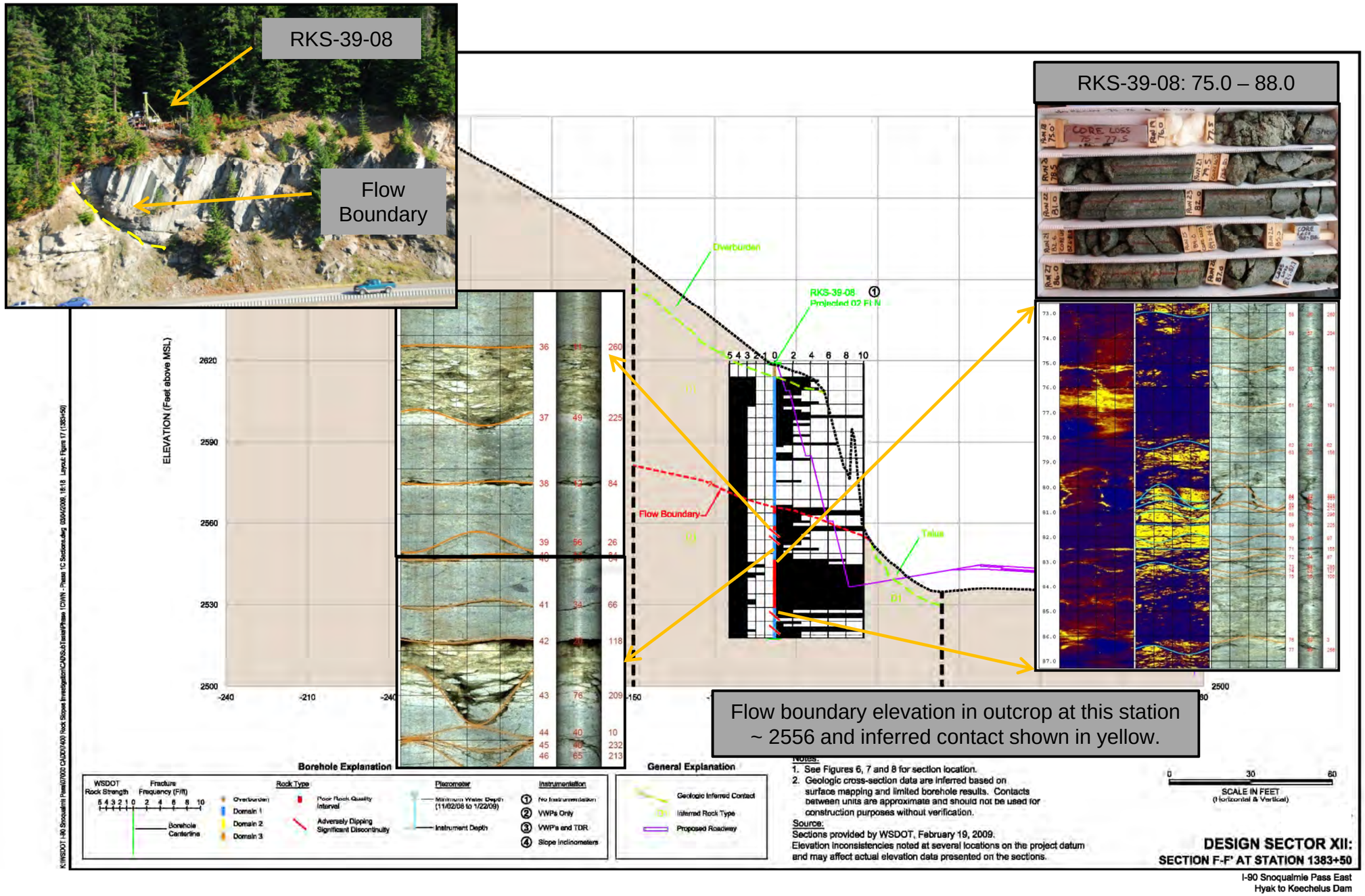
Figure 47

Design Sector XI – Stabilization Detail

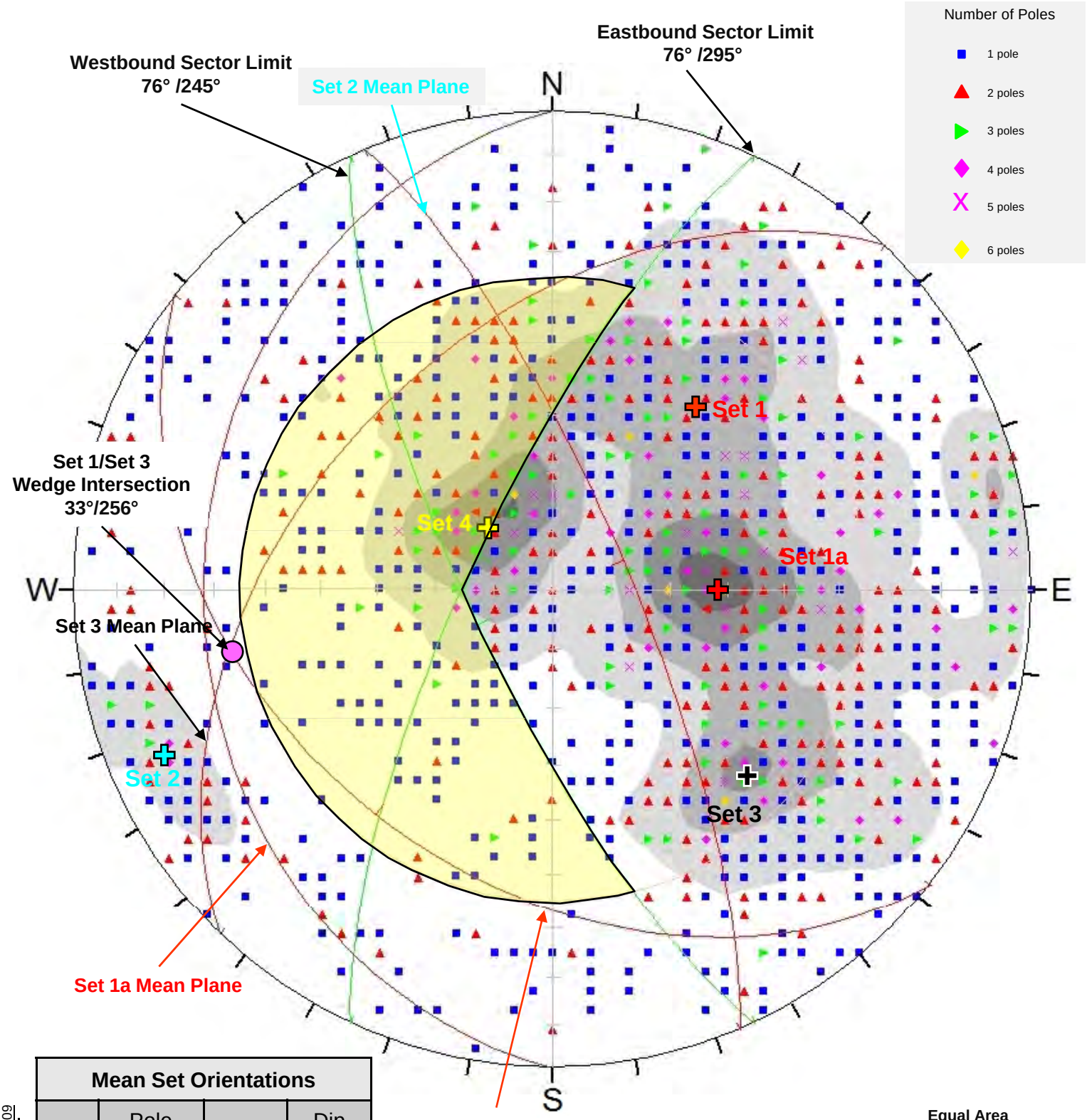
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Project No. 062-2002 Date: March 2009

Figure 48

Geologic Detail – Design Sector XII



Equal Area
Lower Hemisphere
1707 Poles

Mean Set Orientations			
Set	Pole Symbol	Dip	Dip Dir
1	✚	40°	218°
1a	✚	28°	270°
2	✚	77°	067°
3	✚	47°	314°
4	✚	15°	134°

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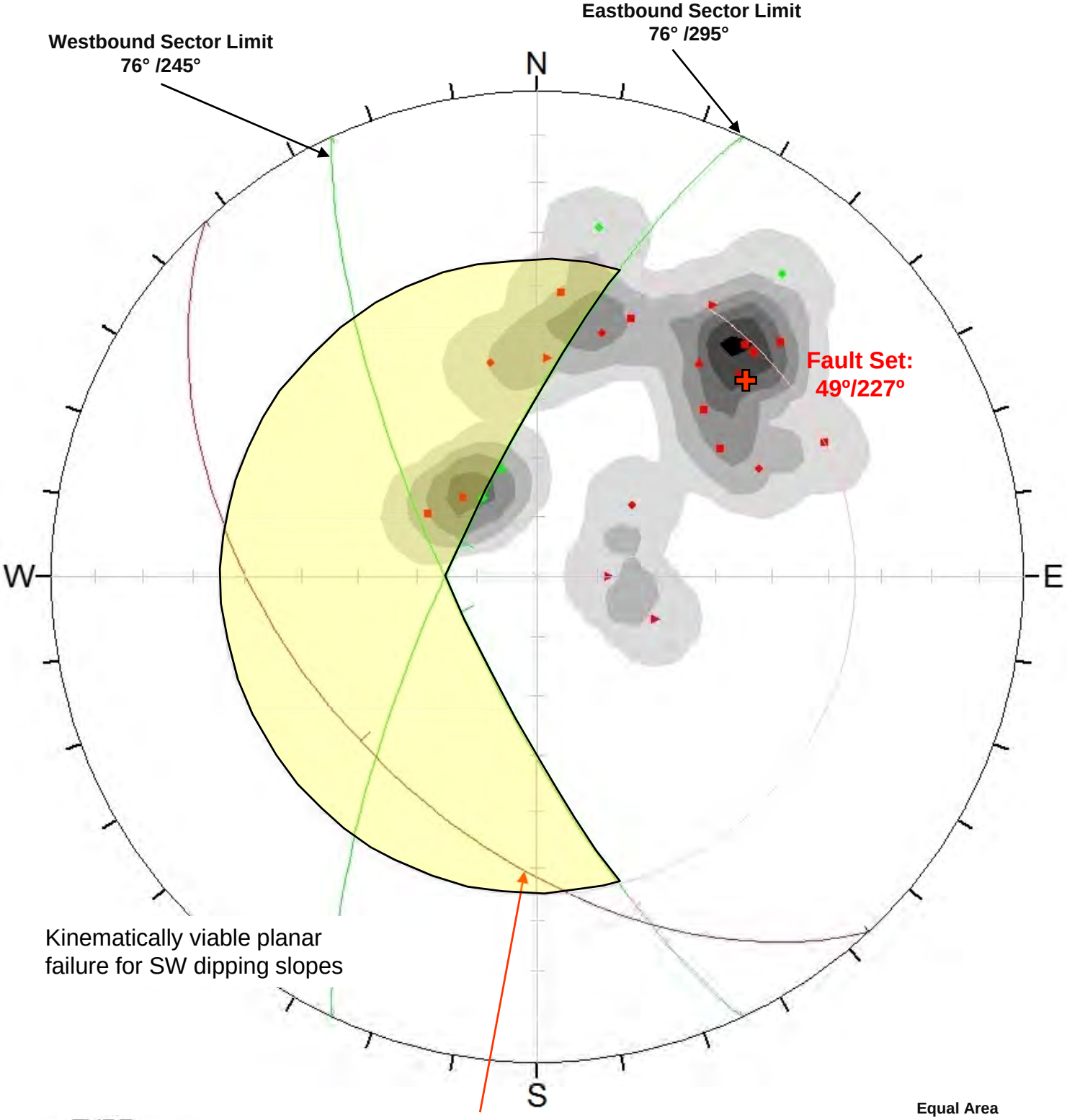
Figure 49

Design Sector XII – Detailed Kinematic Analysis

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Equal Area
Lower Hemisphere
24 Poles

TYPE

- Fault [10]
- Fault Zone [1]
- Possible Fault [4]
- Possible Flow [4]
- Probable Fault [5]

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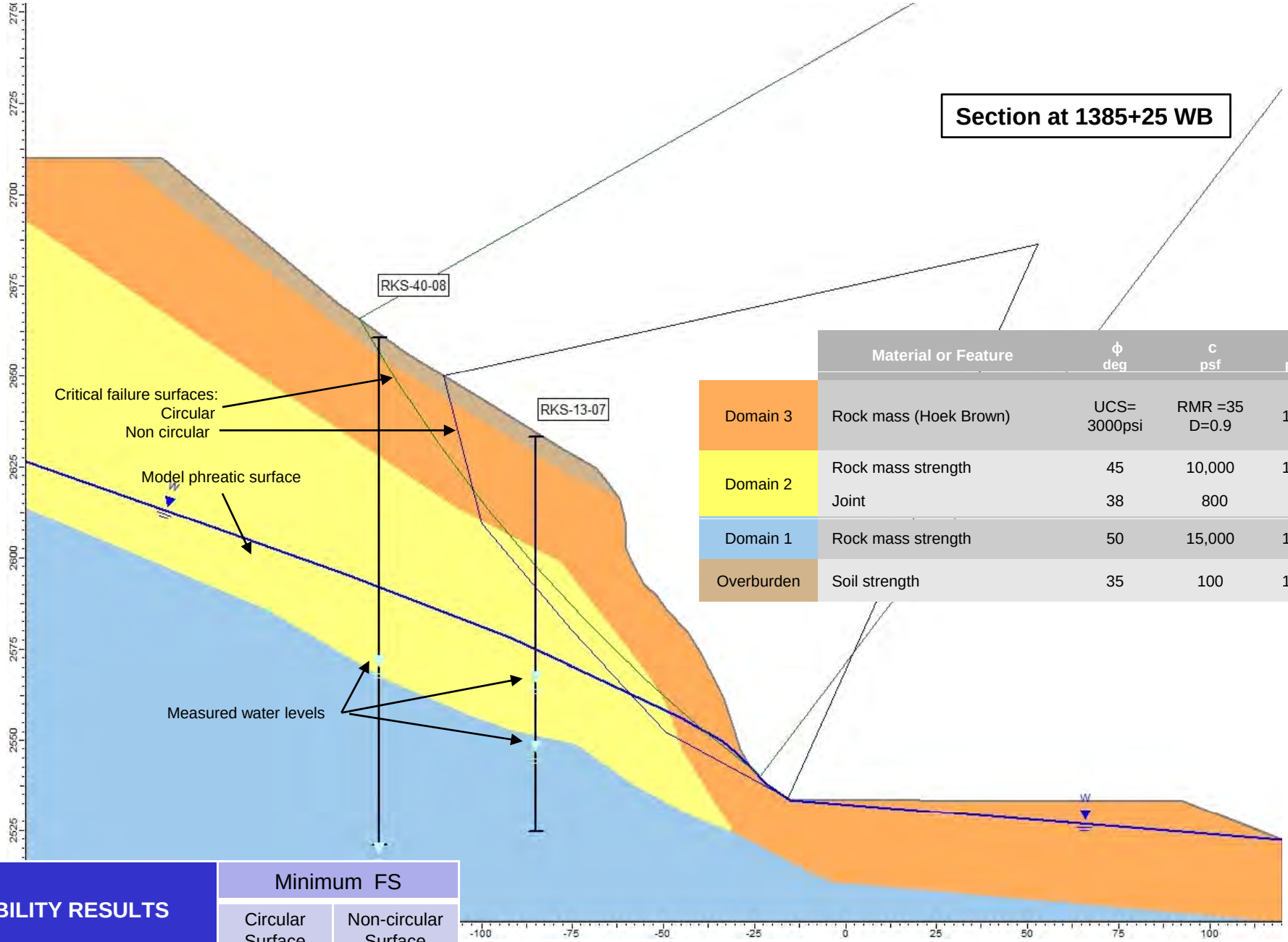
Figure 50

Design Sector XII – Kinematic Analysis for Faults

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



	Material or Feature	ϕ deg	c psf	γ pcf
Domain 3	Rock mass (Hoek Brown)	UCS= 3000psi	RMR =35 D=0.9	150
Domain 2	Rock mass strength	45	10,000	160
	Joint	38	800	
Domain 1	Rock mass strength	50	15,000	160
Overburden	Soil strength	35	100	120

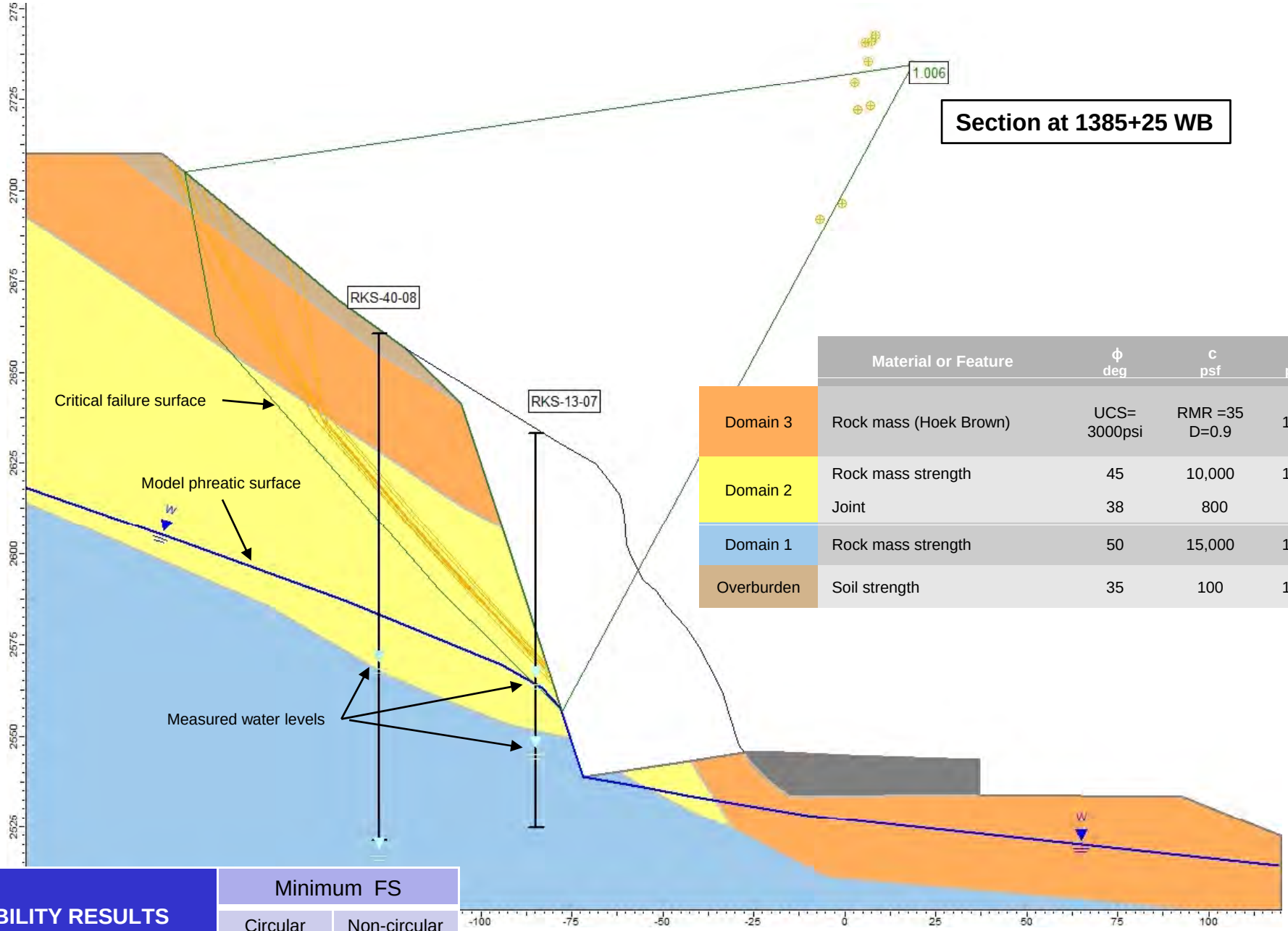
STABILITY RESULTS	Minimum FS	
	Circular Surface	Non-circular Surface
Overall: static	1.20	1.15
Overall: pseudo-static 0.07 g	1.05	1.02

Figure 51

Design Sector XII – Back Stability Analysis

Project No. 062-2002 Date: February 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



	Material or Feature	ϕ deg	c psf	γ pcf
Domain 3	Rock mass (Hoek Brown)	UCS= 3000psi	RMR =35 D=0.9	150
Domain 2	Rock mass strength	45	10,000	160
	Joint	38	800	
Domain 1	Rock mass strength	50	15,000	160
Overburden	Soil strength	35	100	120

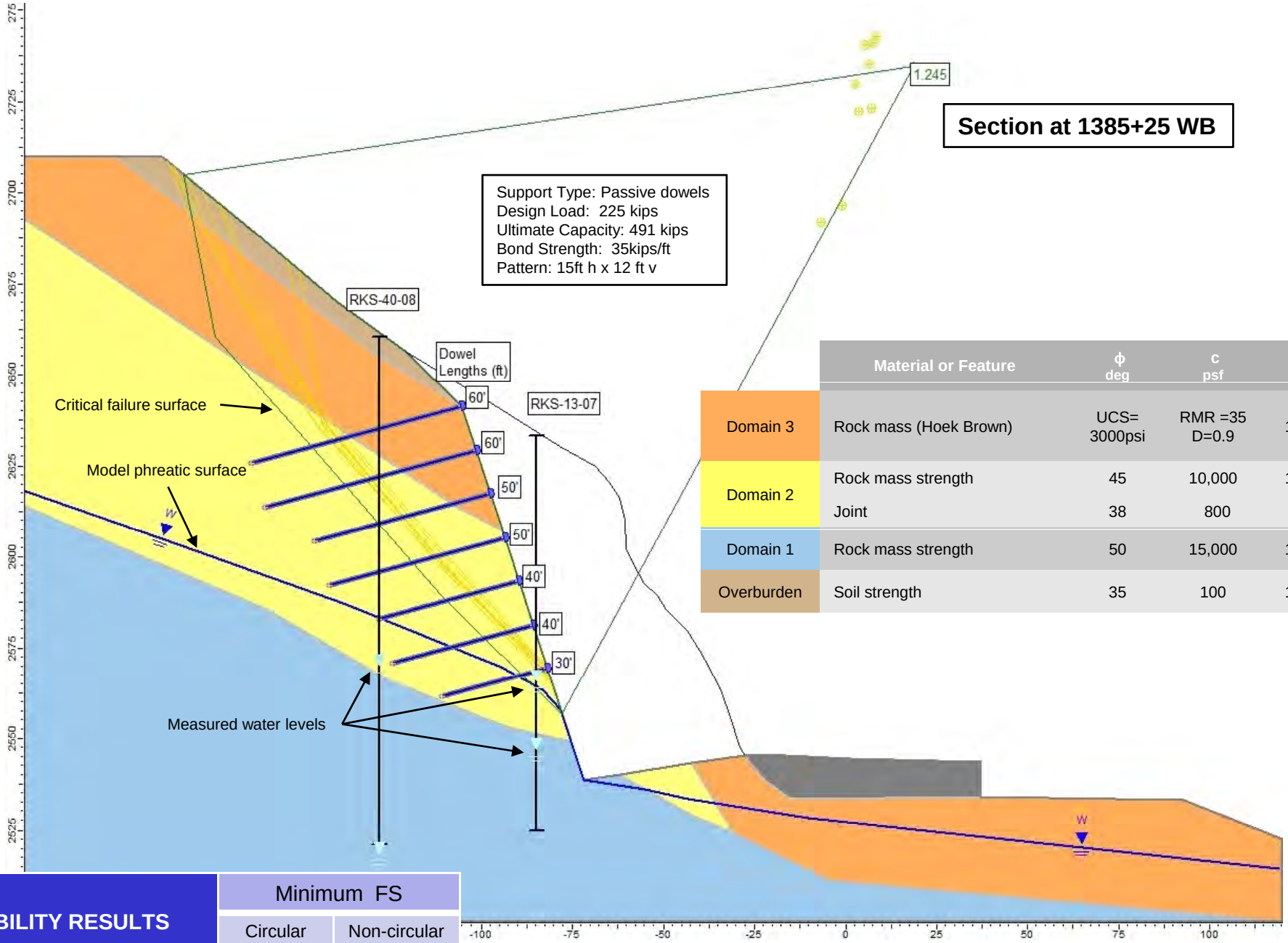
STABILITY RESULTS	Minimum FS	
	Circular Surface	Non-circular Surface
Overall: static	±1.8	1.01
Overall: pseudo-static 0.175 g	±1.4	0.74

Figure 52

Design Sector XII – Forward Stability Analysis No Reinforcement

Project No. 062-2002 Date: February 2009

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

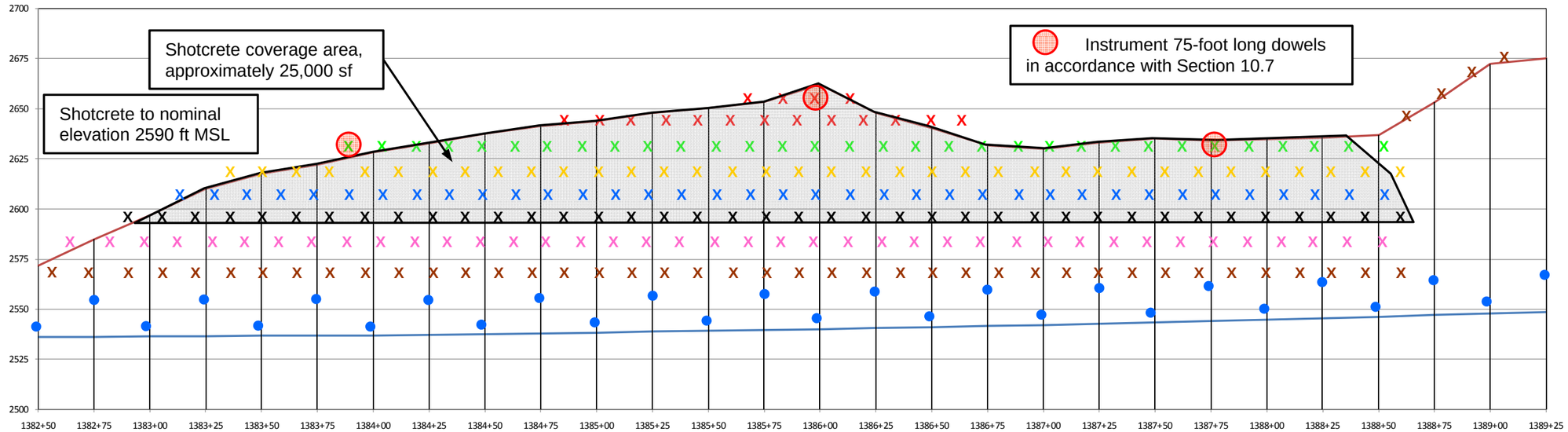


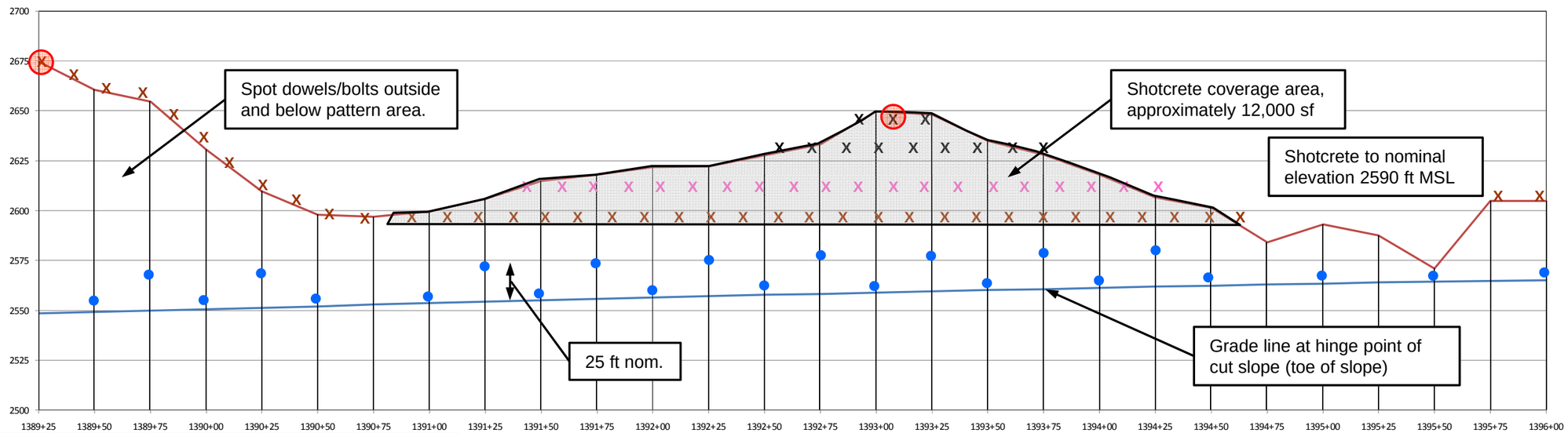
	Material or Feature	ϕ deg	c psf	γ pcf
Domain 3	Rock mass (Hoek Brown)	UCS= 3000psi	RMR =35 D=0.9	150
Domain 2	Rock mass strength	45	10,000	160
	Joint	38	800	
Domain 1	Rock mass strength	50	15,000	160
Overburden	Soil strength	35	100	120

STABILITY RESULTS	Minimum FS	
	Circular Surface	Non-circular Surface
Overall: static	±2.0	1.24
Overall: pseudo-static 0.175 g	±1.6	0.99

Figure 53

Design Sector XII – Forward Stability Analysis with Reinforcement





Row	Symbol	Length	No.	Cum.
1+	X	60	17	1020
2	X	60	32	1920
3	X	50	36	1800
4	X	50	37	1850
5	X	40	51	2040
6	X	40	60	2400
7	X	30	84	2520
		TOTAL	**251**	**13550 ft**

Notes: *All pattern and crest dowels type "H", 491 kip ultimate capacity, spot dowels/bolts as required.*
Uppermost dowels for each row closest to cut slope line to be installed prior to first lift of rock excavation.

Horizontal Drains:
- 51 @ 50 ft = 2550 ft. total

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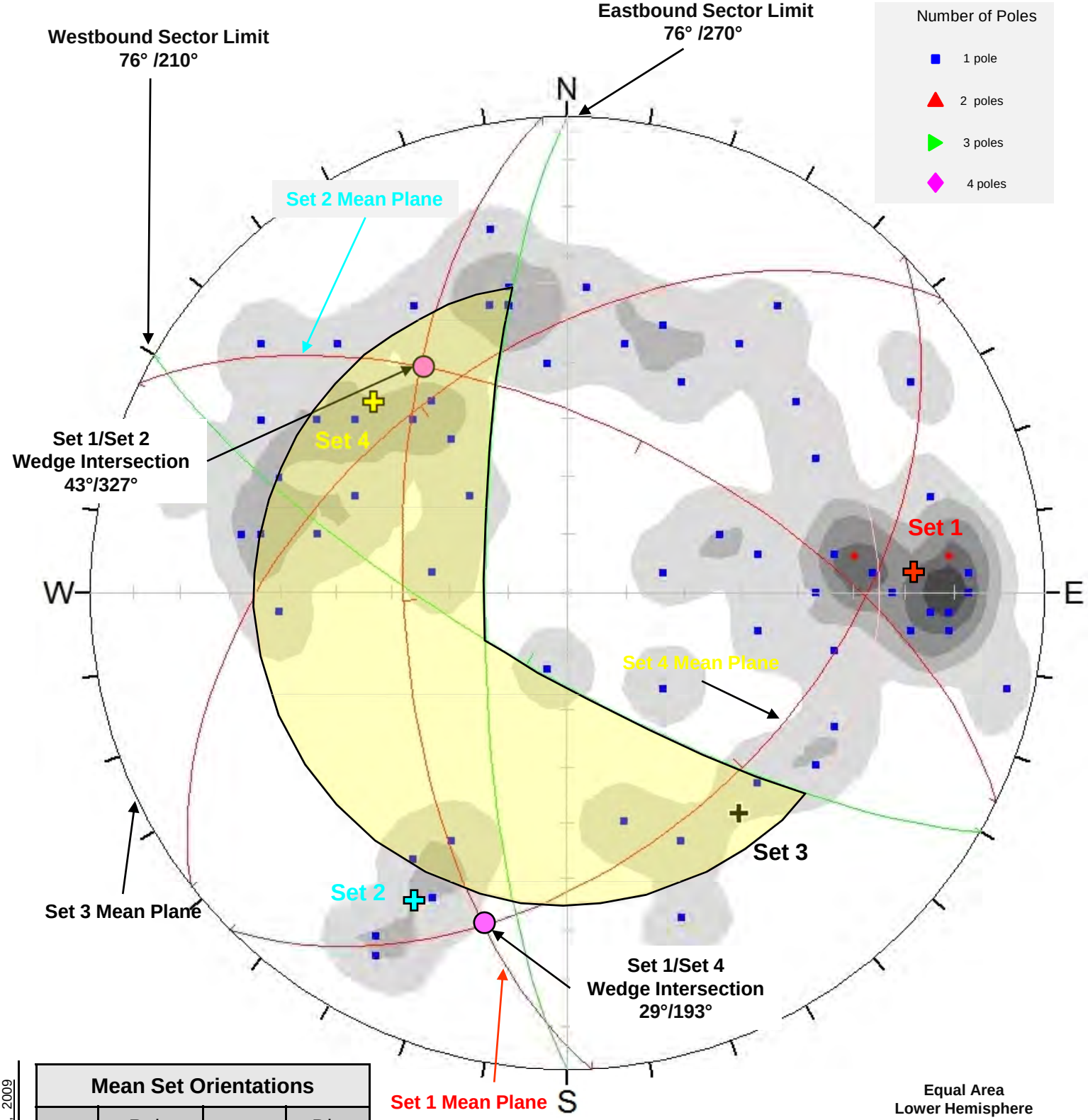
Figure 54

Design Sector XII – Conceptual Stabilization Design



Equal Area
Lower Hemisphere
66 Poles

Mean Set Orientations			
Set	Pole Symbol	Dip	Dip Dir
1	✚	62°	267°
2	✚	61°	026°
3	✚	49°	322°
4	✚	47°	135°

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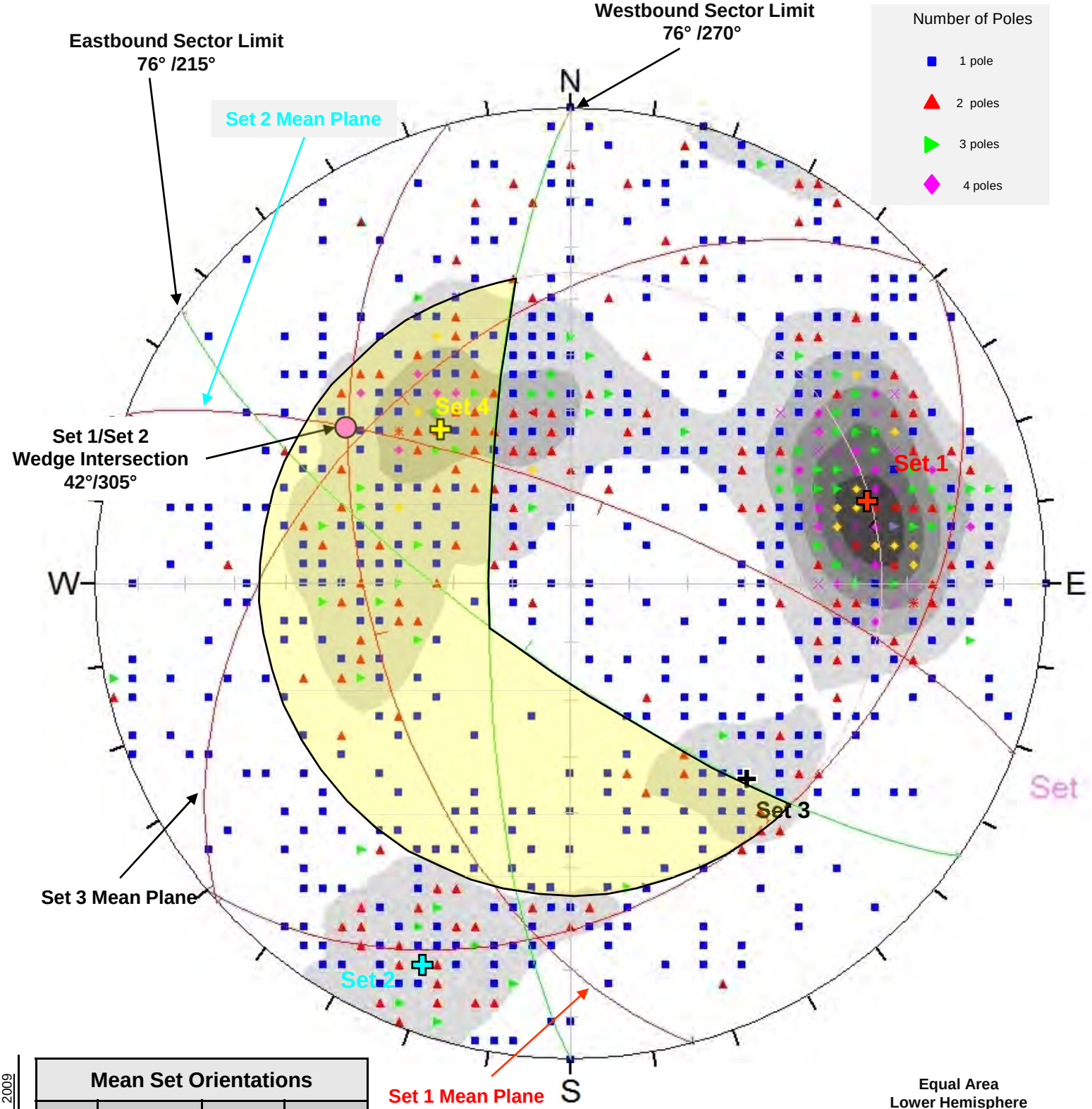
Figure 55

Design Sector XVII – Detailed Kinematic Analysis

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Equal Area
Lower Hemisphere
1230 Poles

Mean Set Orientations			
Set	Pole Symbol	Dip	Dip Dir
1	✚	55°	255°
2	✚	75°	021°
3	✚	46°	318°
4	✚	35°	140°

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Figure 56

Design Sector XVIII – Detailed Kinematic Analysis

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

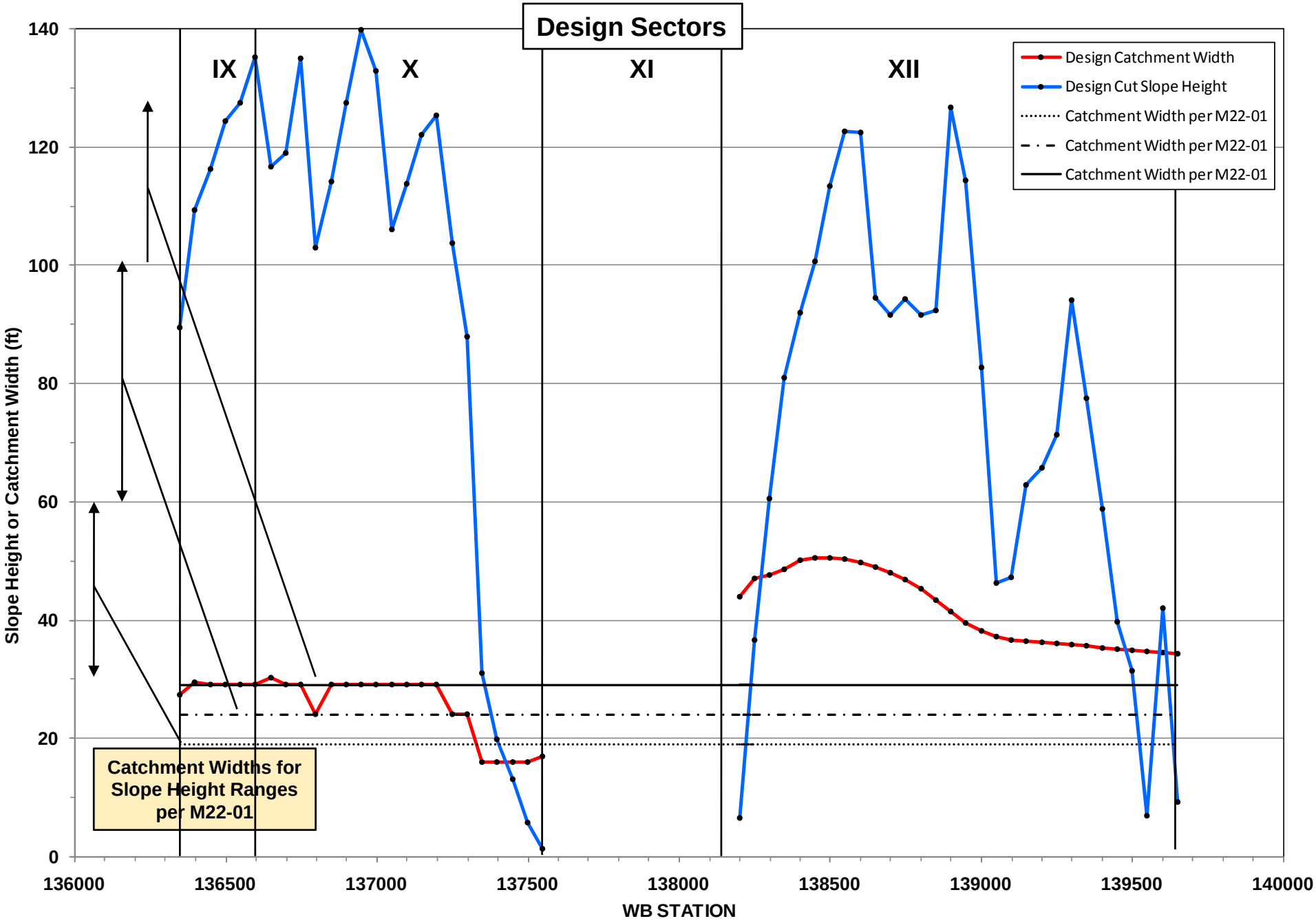

Figure 57

Design Sector IX to XII – Catchment Design

Slope height and catchment width data provided by WSDOT, January 22, 2009.

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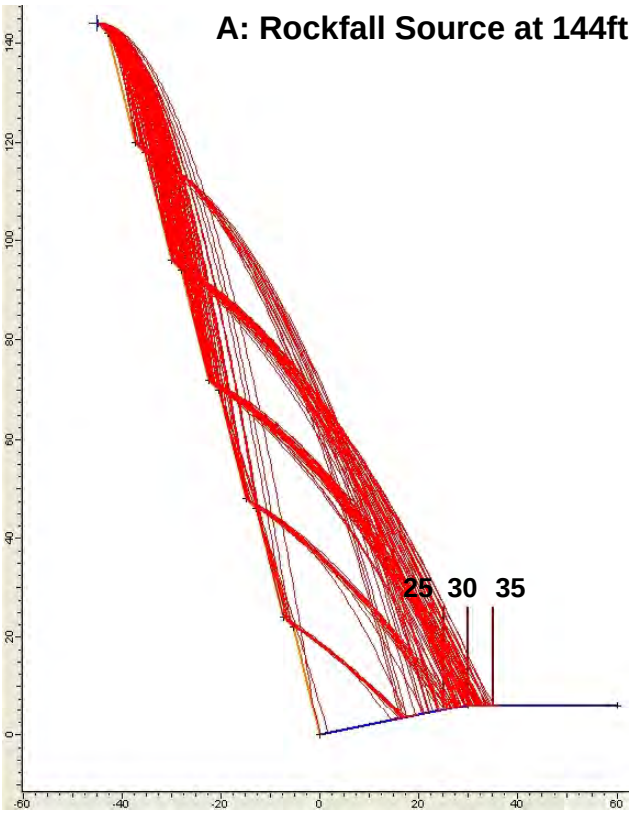
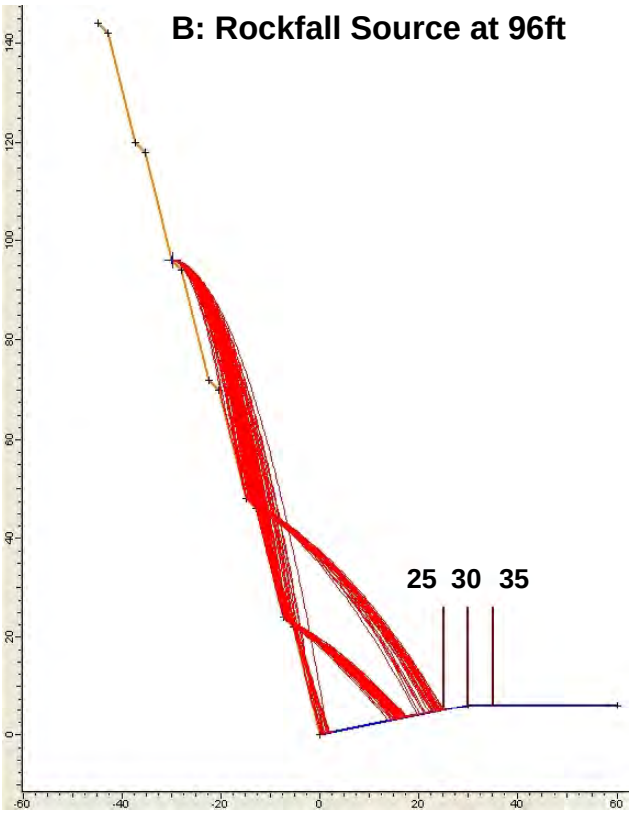
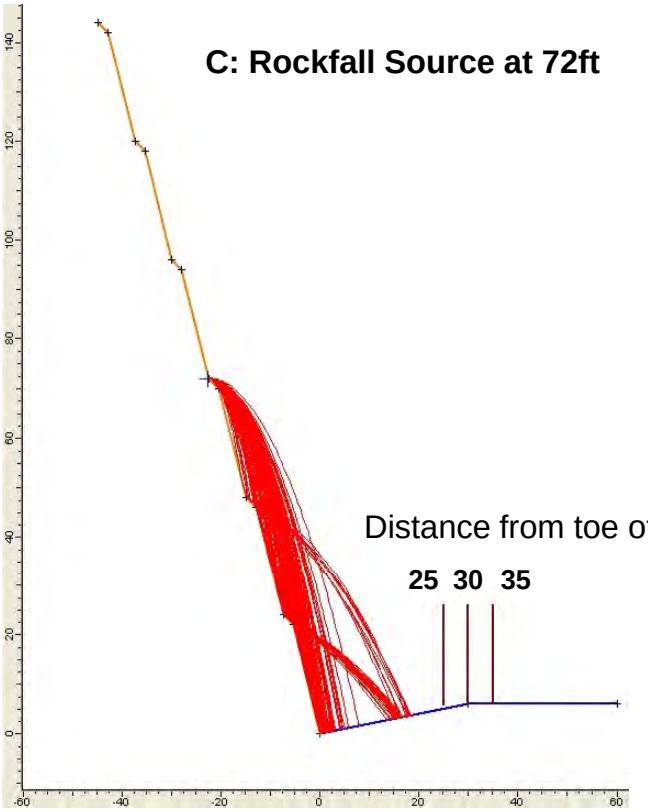
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam







Comparative Data:

1. Rock Island Rock Cut: 97-ft high slope at ¼H:1V: 20% of rock airborne at 25 ft, 8% airborne at 30 ft. (ref. Norrish and Findley, 2005)

2. ODOT Design Guide: 80-ft high slope at ¼H:1V: 99% probability first impact at 22 ft or less from toe. (ref: ODOT, 2001)

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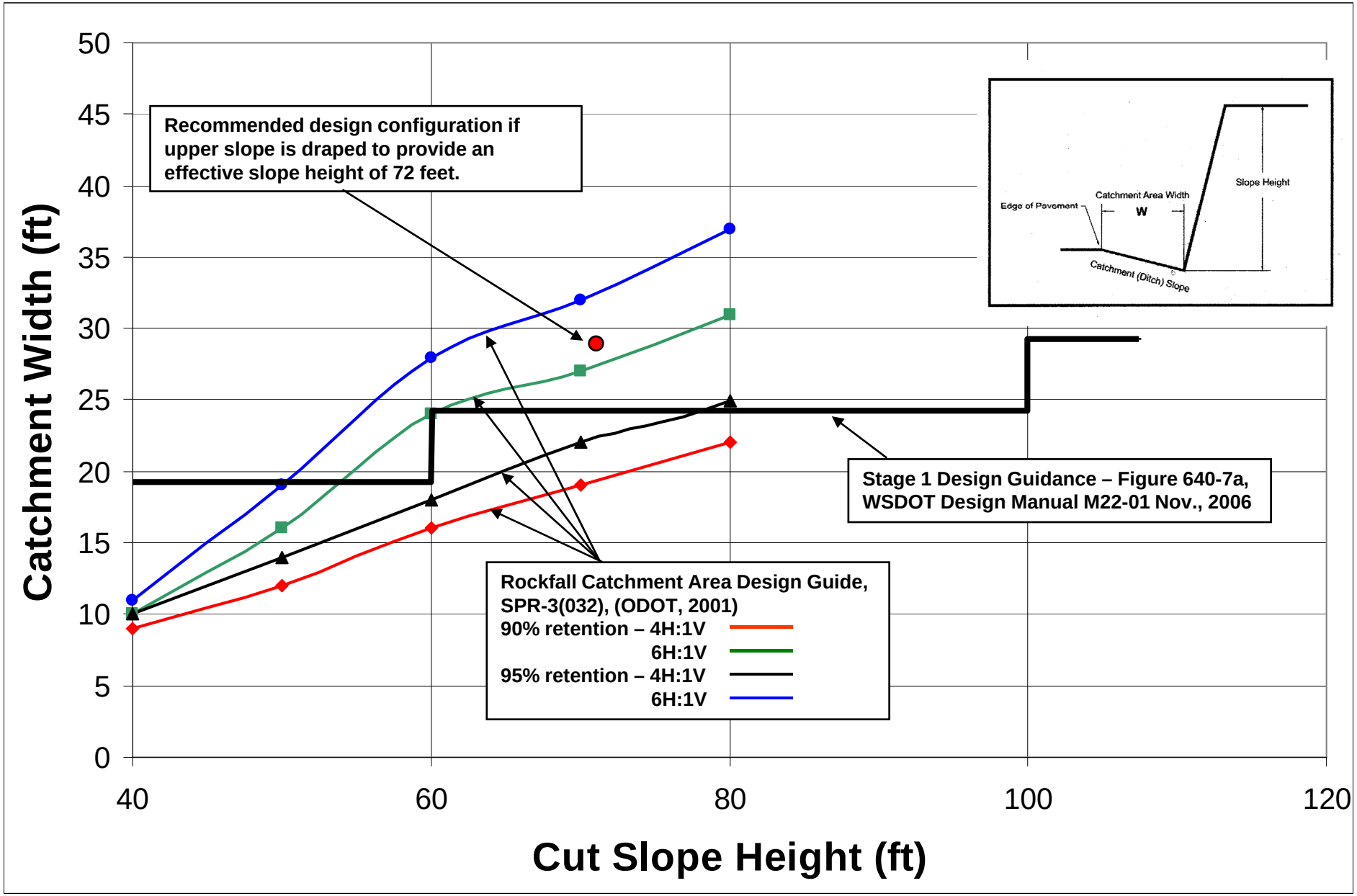
Figure 58

Design Sectors IX and X – Rockfall Analysis



Modified after Wyllie & Norrish, 2007b

Figure 59

CATCHMENT DESIGN GUIDE FOR 0.25H:1V ROCK SLOPES