

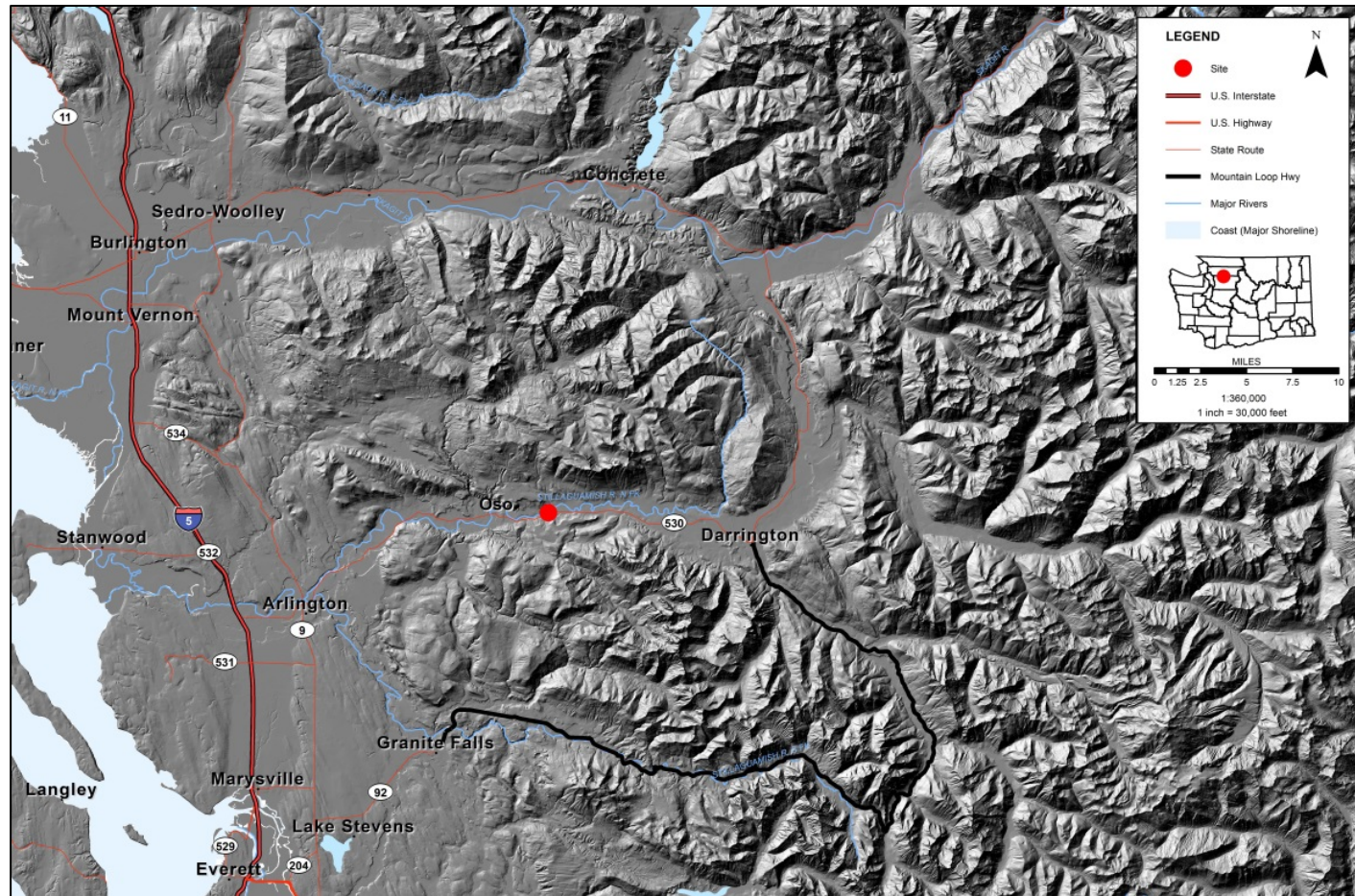
Washington State Mudslide

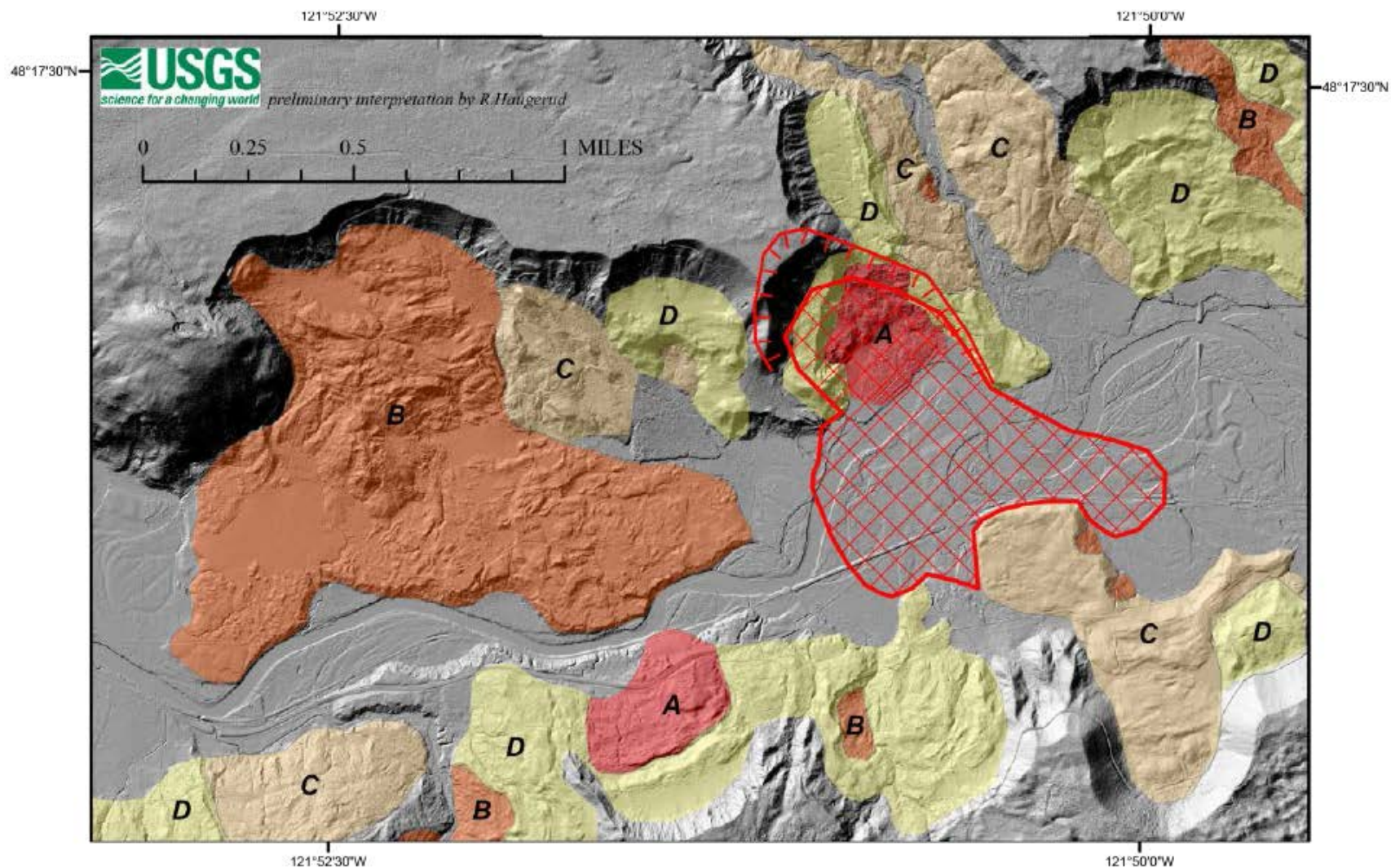


Casey Kramer, PE
WSDOT State Hydraulics Engineer

2014 National Hydraulic Engineering Conference
Iowa City, IA
August 22nd, 2014

Vicinity Map





Haugerud, R. Report 2014-1065

Pre-Landslide Topography



Image courtesy of S. Schilling



Post-Landslide Topography

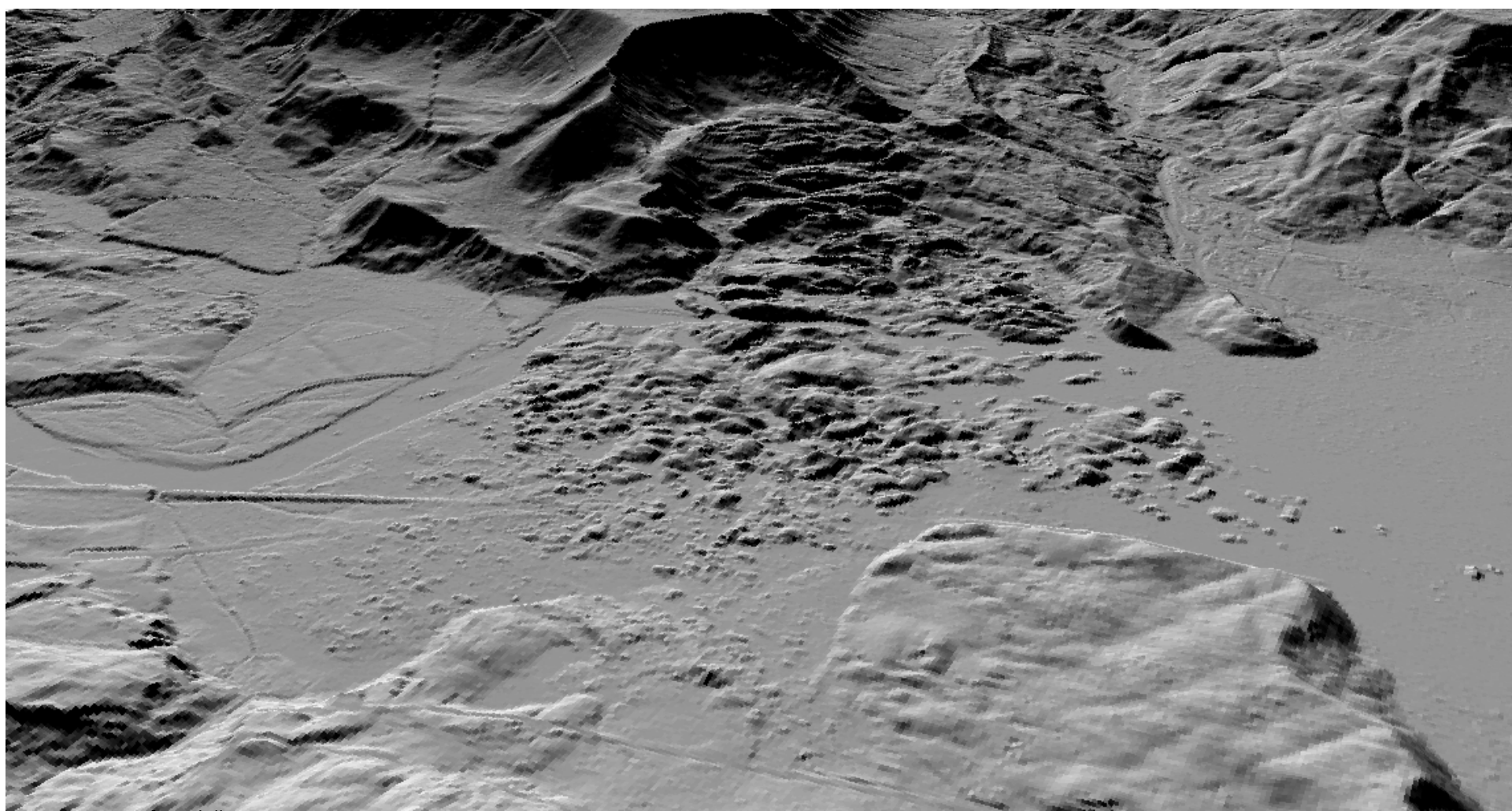


Image courtesy of S. Schilling



Washington State
Department of Transportation

2013



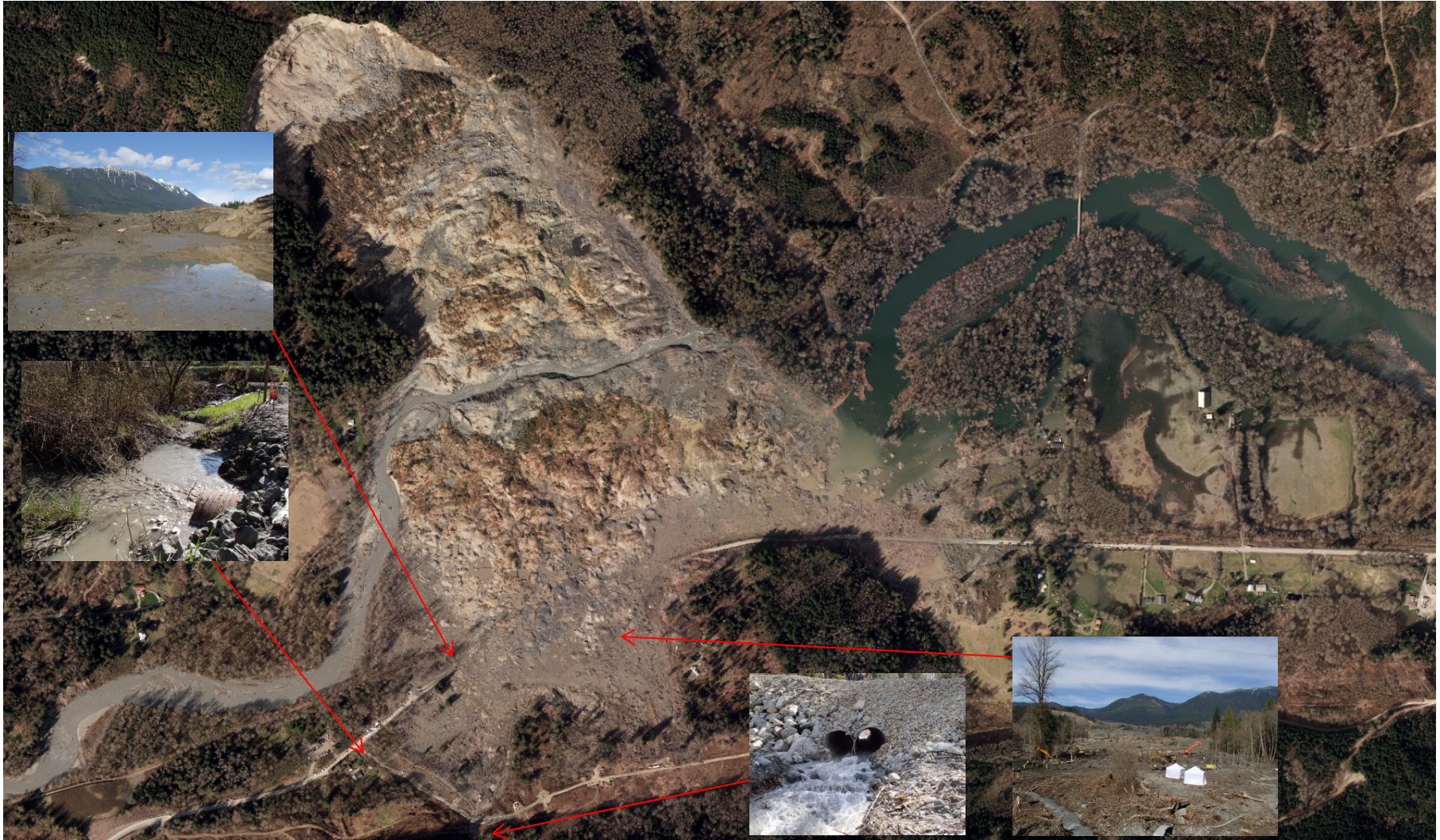
Washington State
Department of Transportation



March 24th, 2014



April 1st, 2014

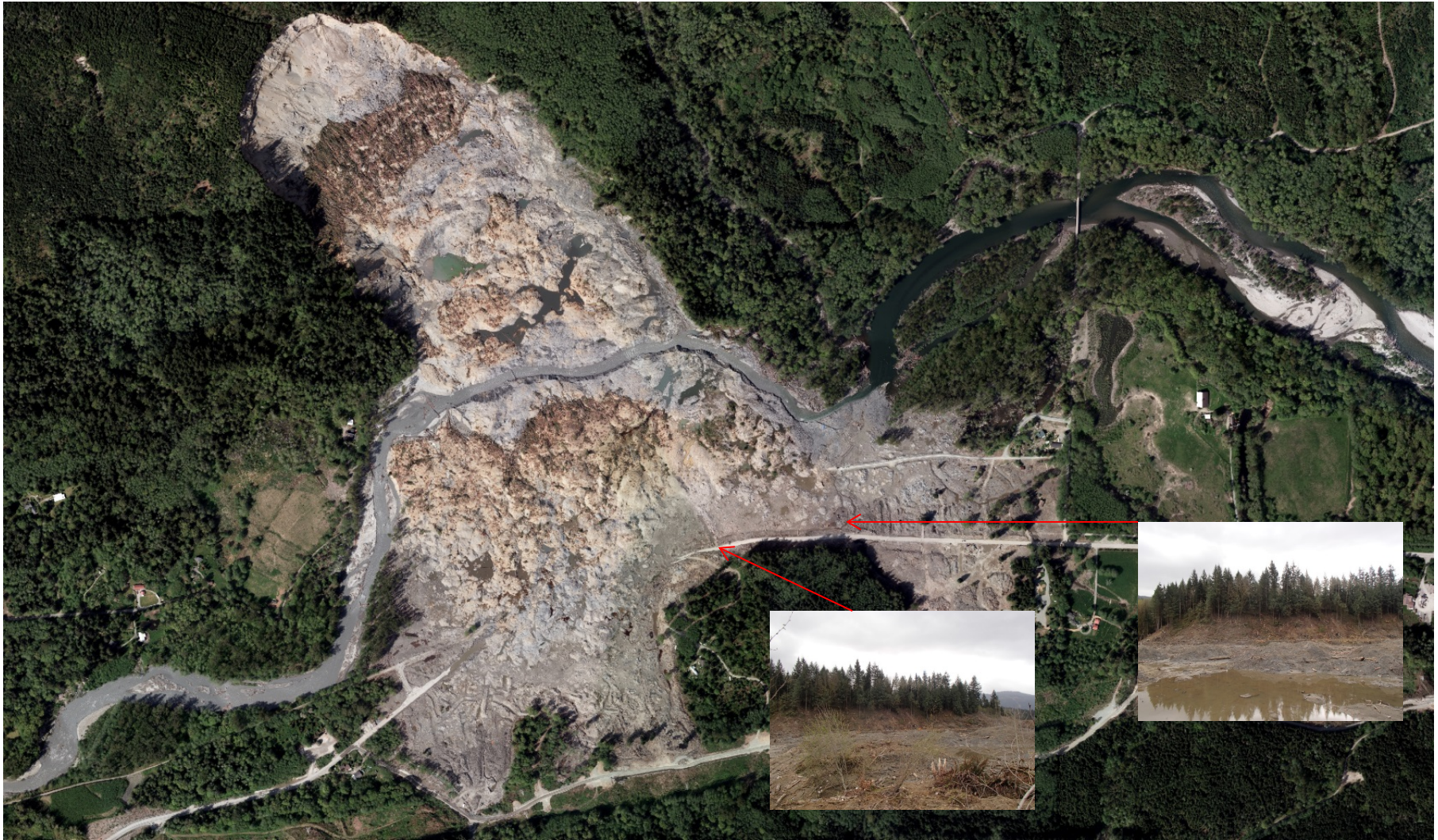




April 14th, 2014



May 1st, 2014

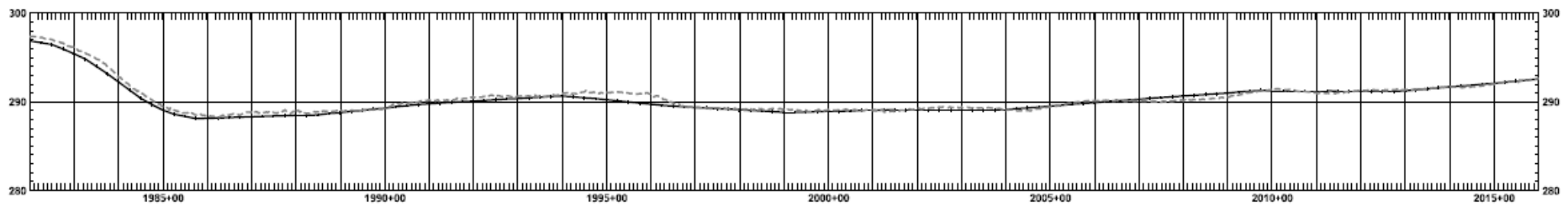
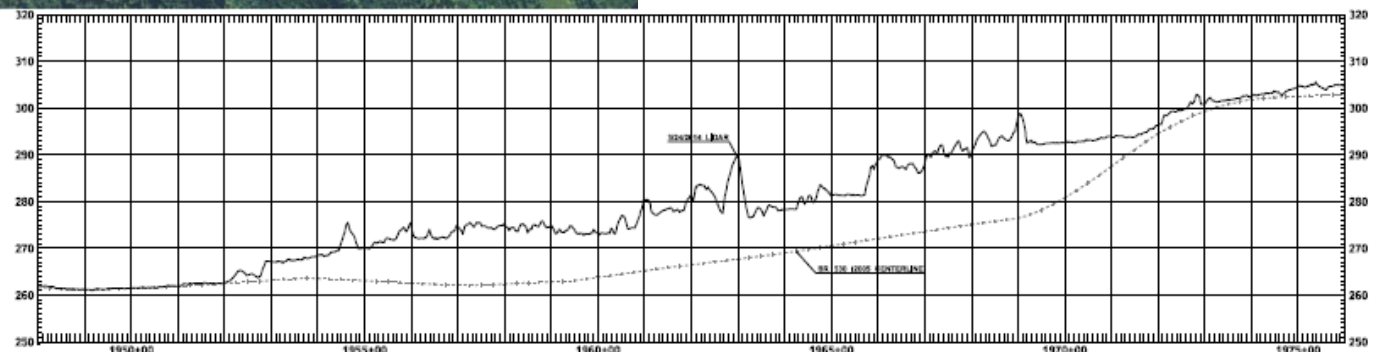
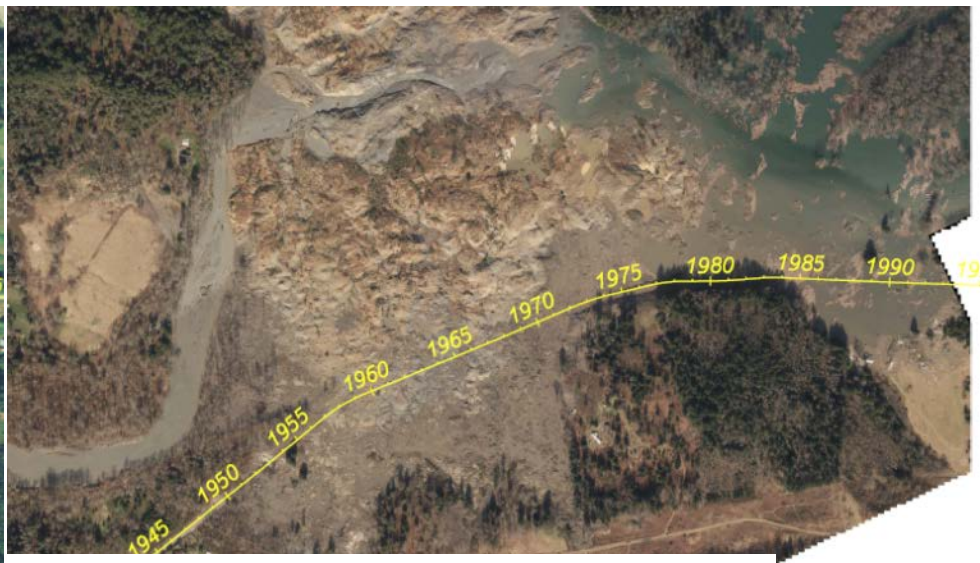


July 1st, 2014

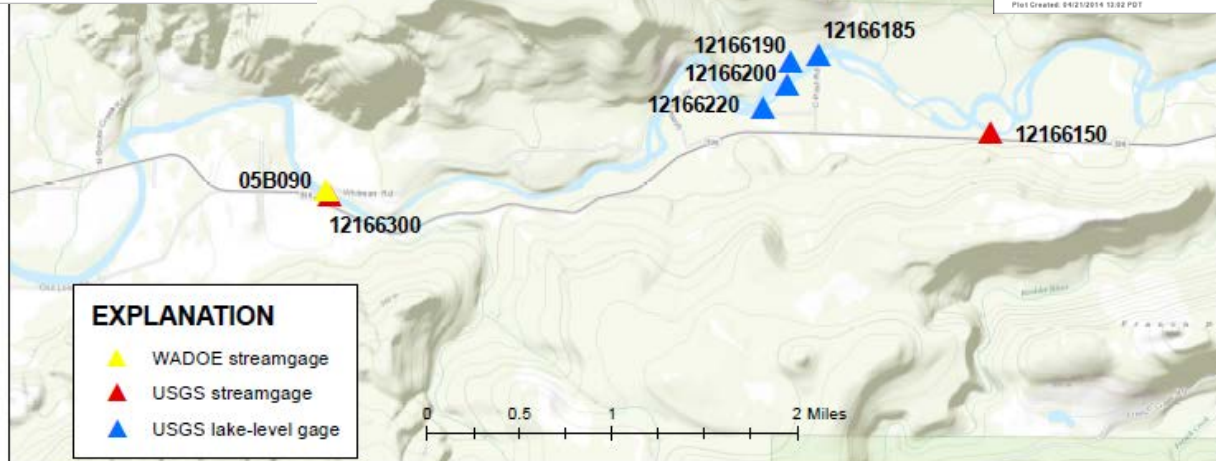
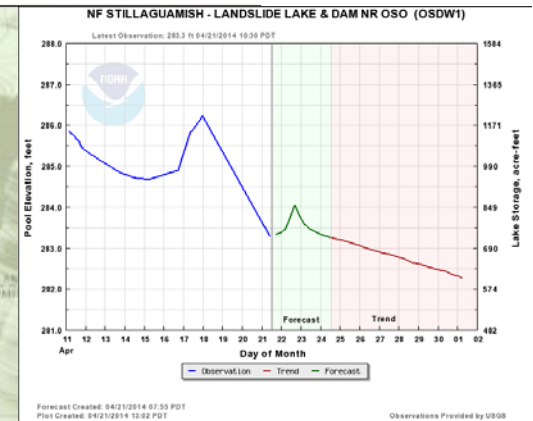
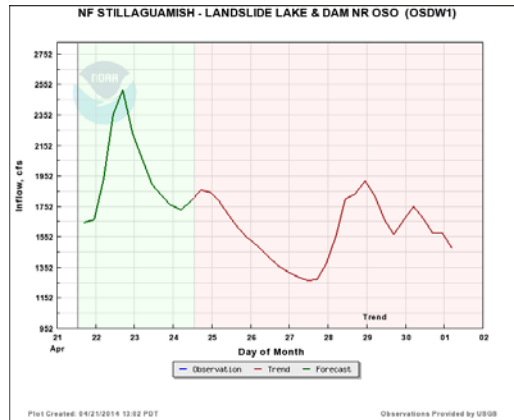




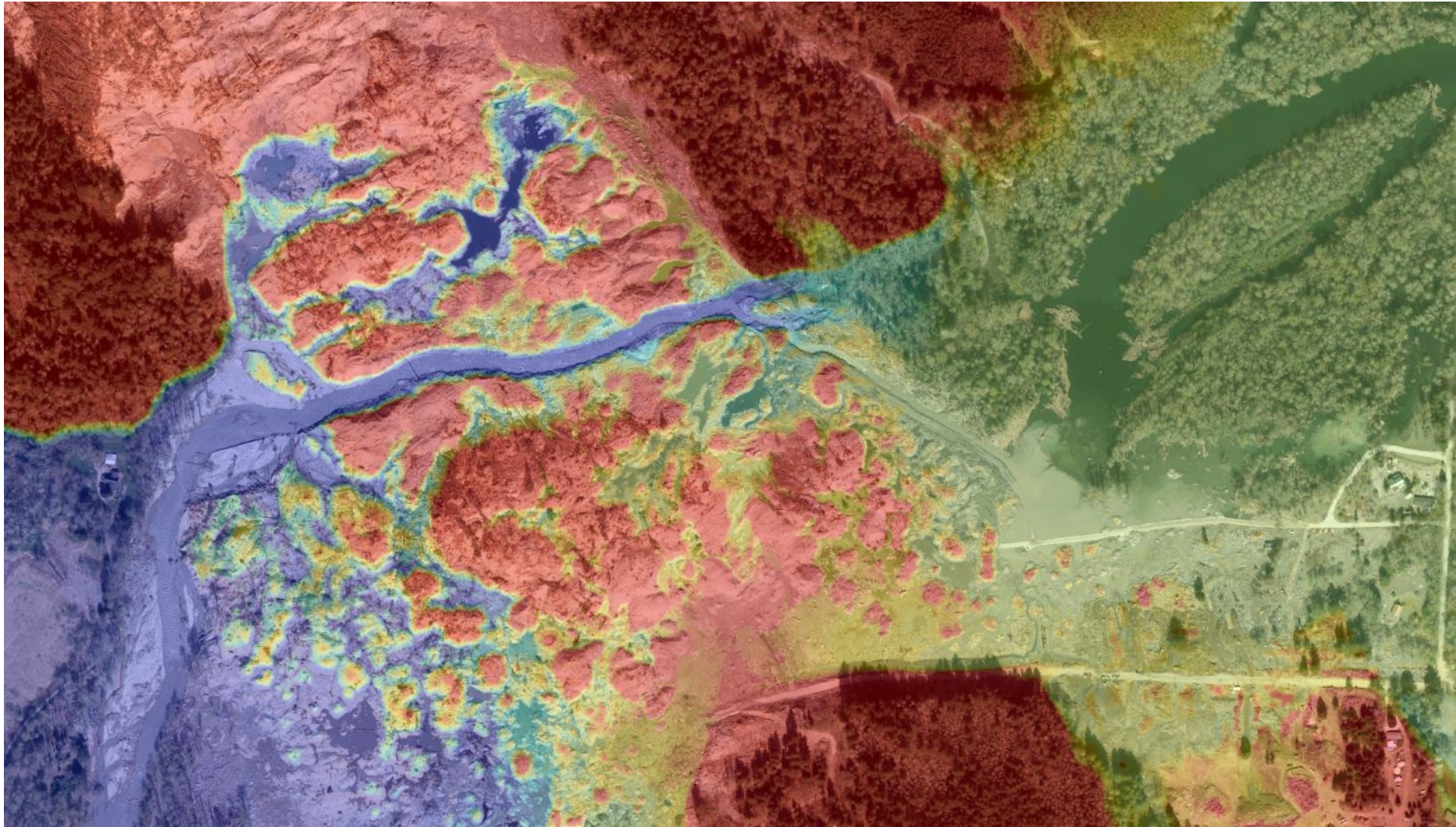




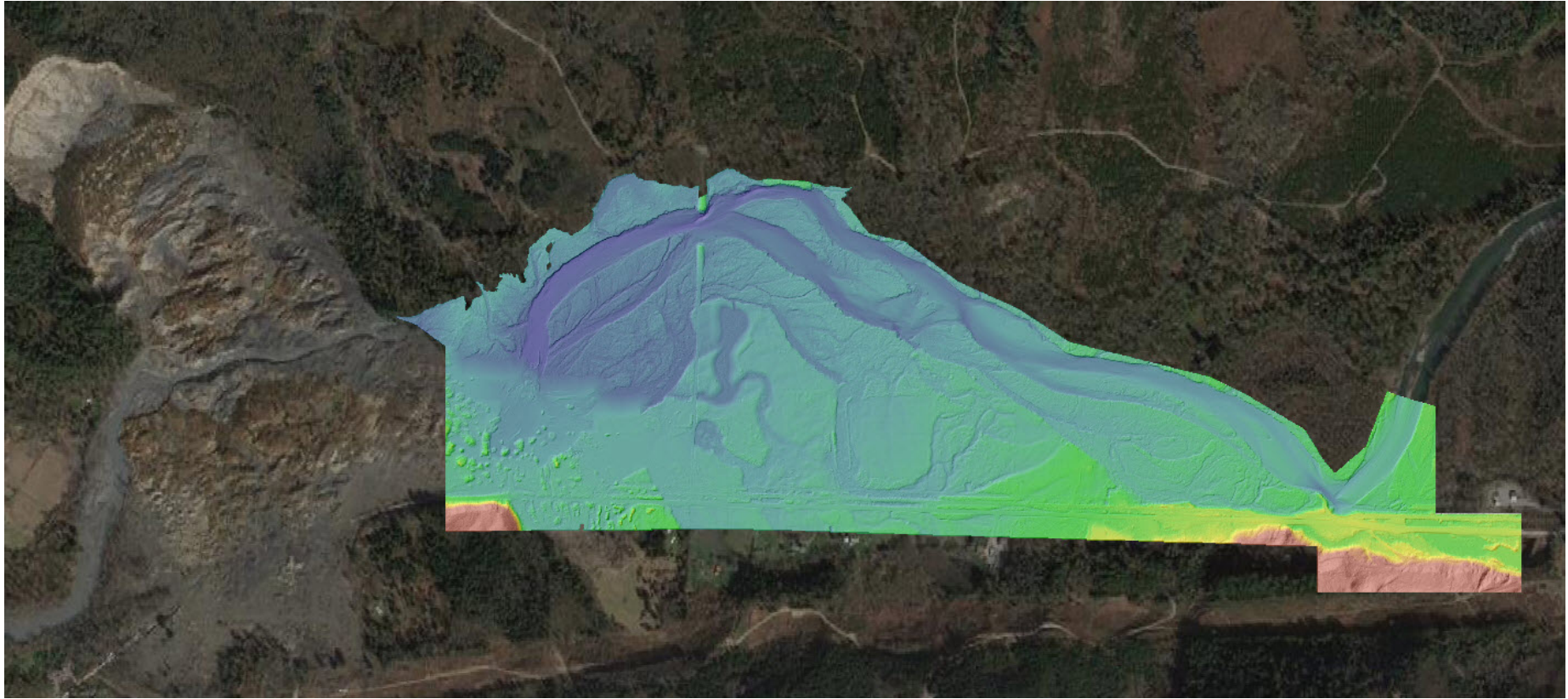
USGS Real-time and NWRFC Forecast Data



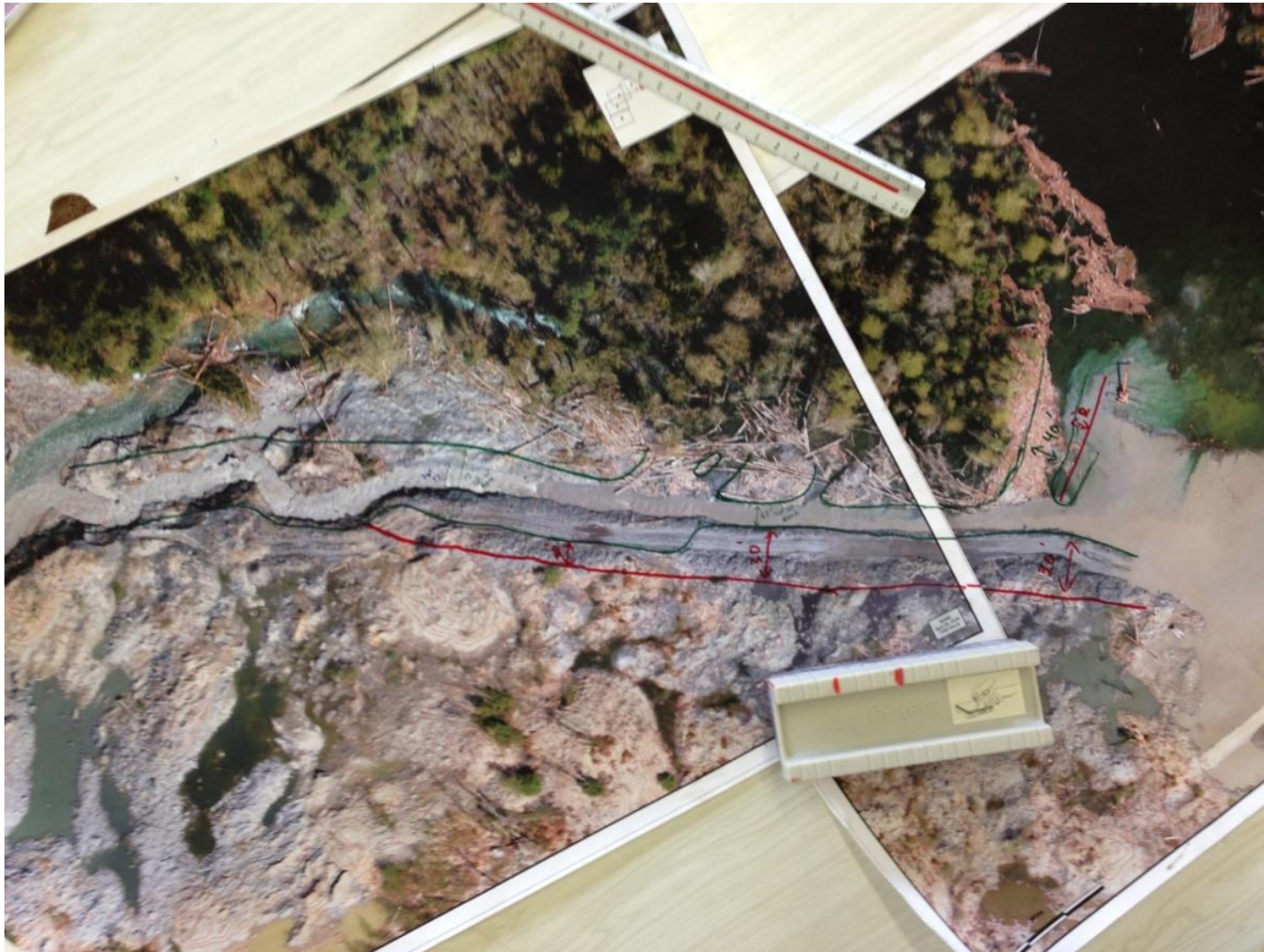
LiDAR 4/6/2014



Current Merged Bathymetry and LiDAR



BCI Markup of excavation plan

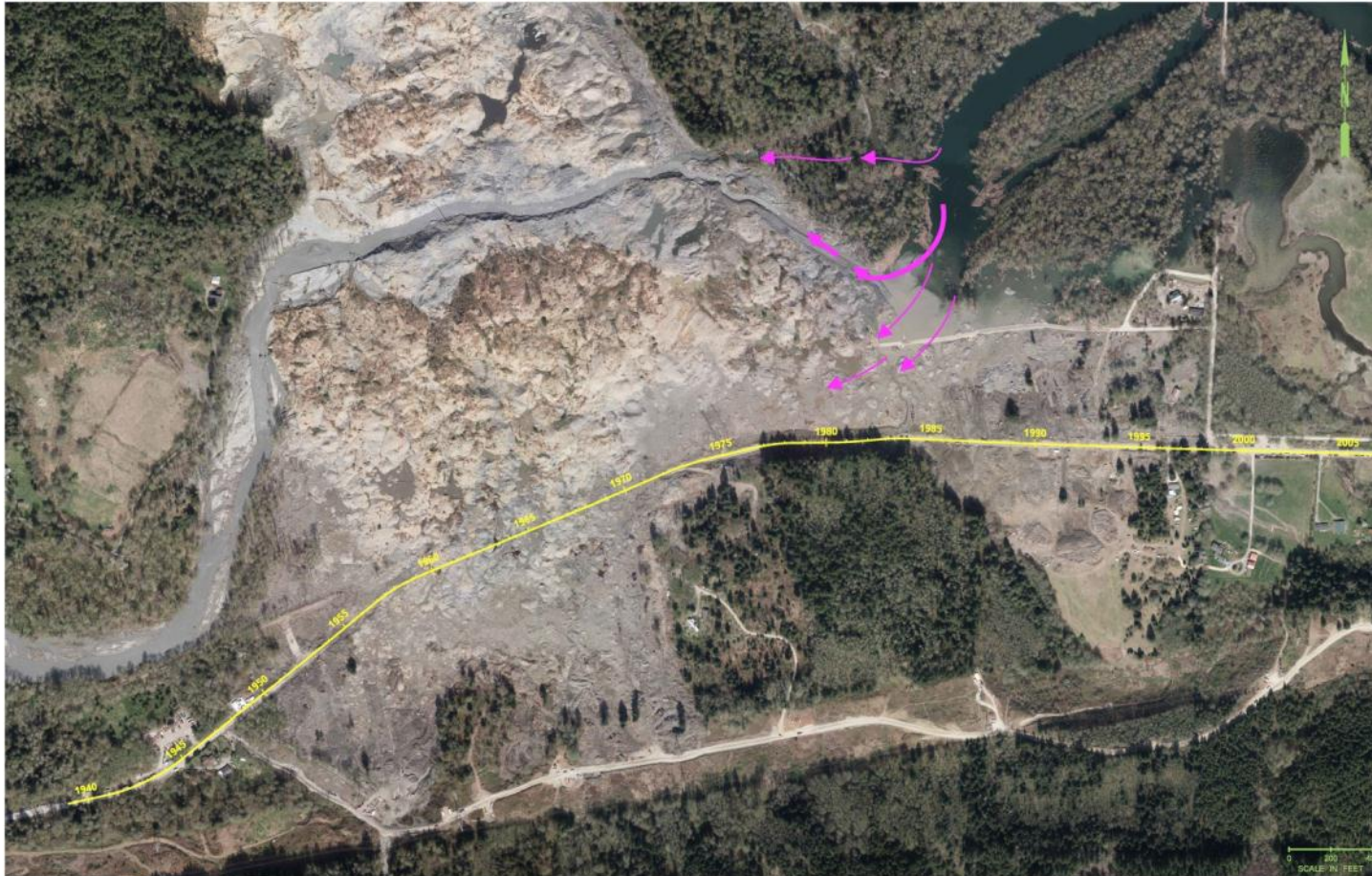


NFStillaguamish	Plan:	1) DEM2013XSs	4/19/2014	2) New Topo_ck	4/19/2014
		NFStillaguamish	NFStillaguamish		

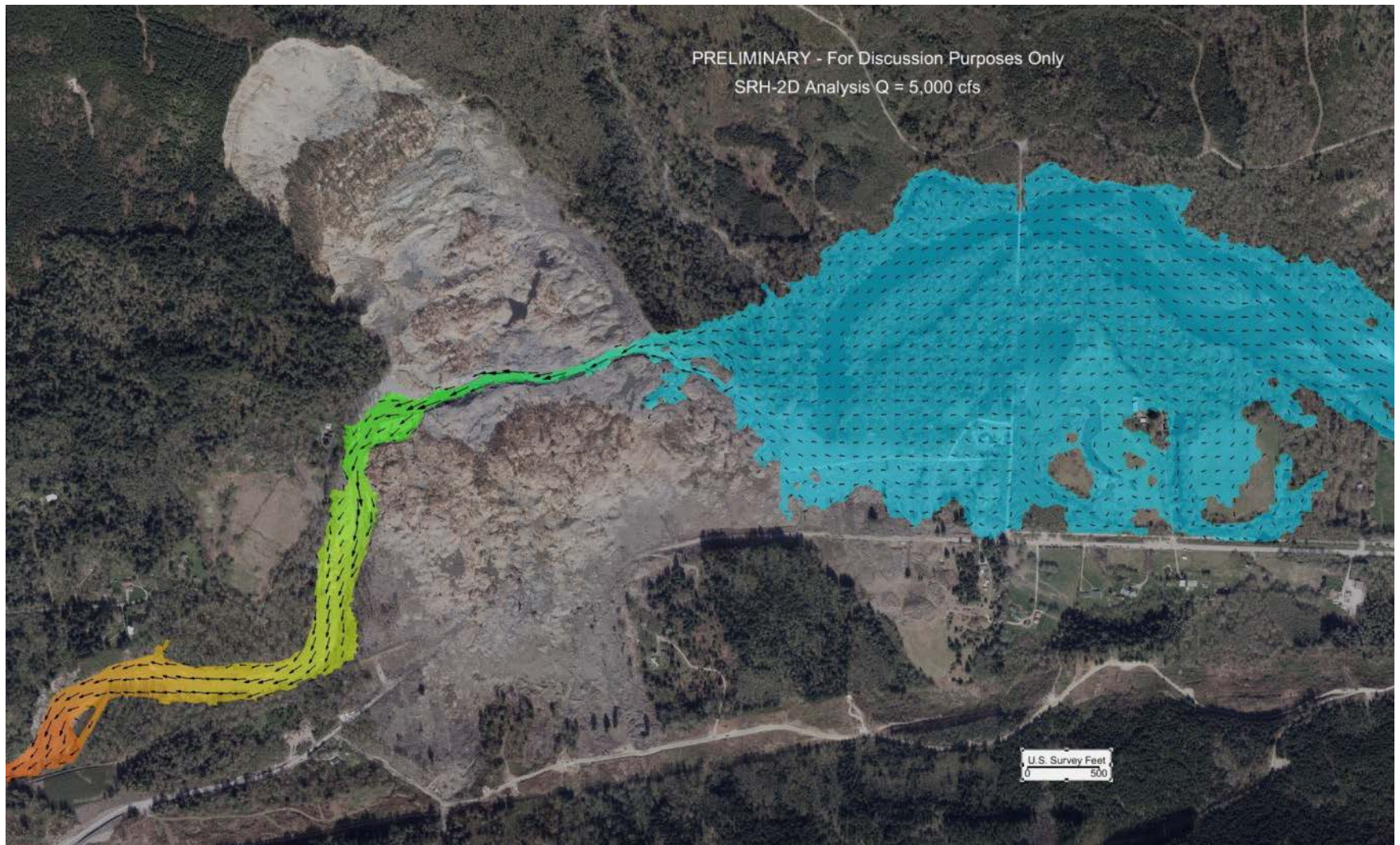




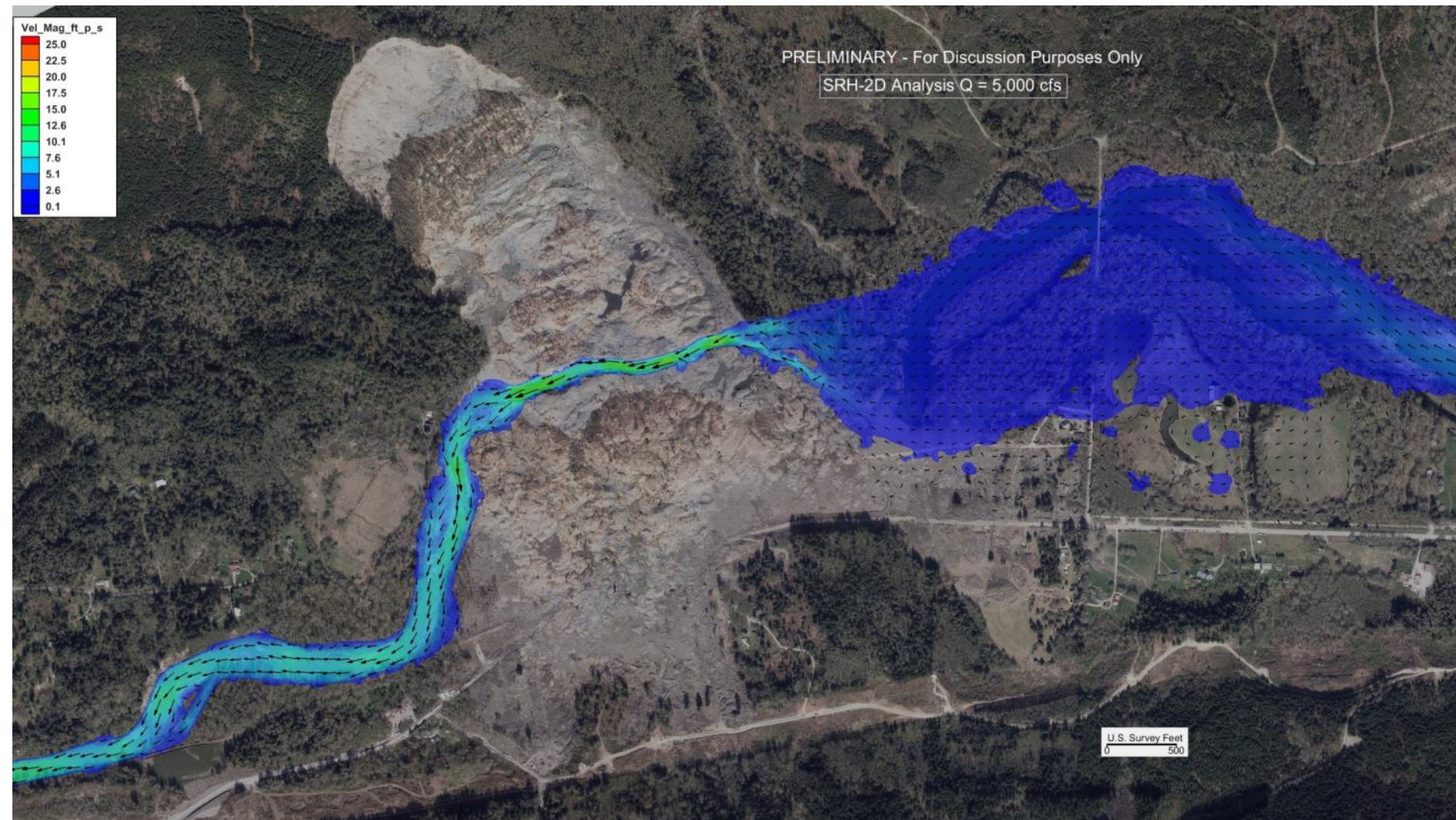
Existing Potential Flow Paths



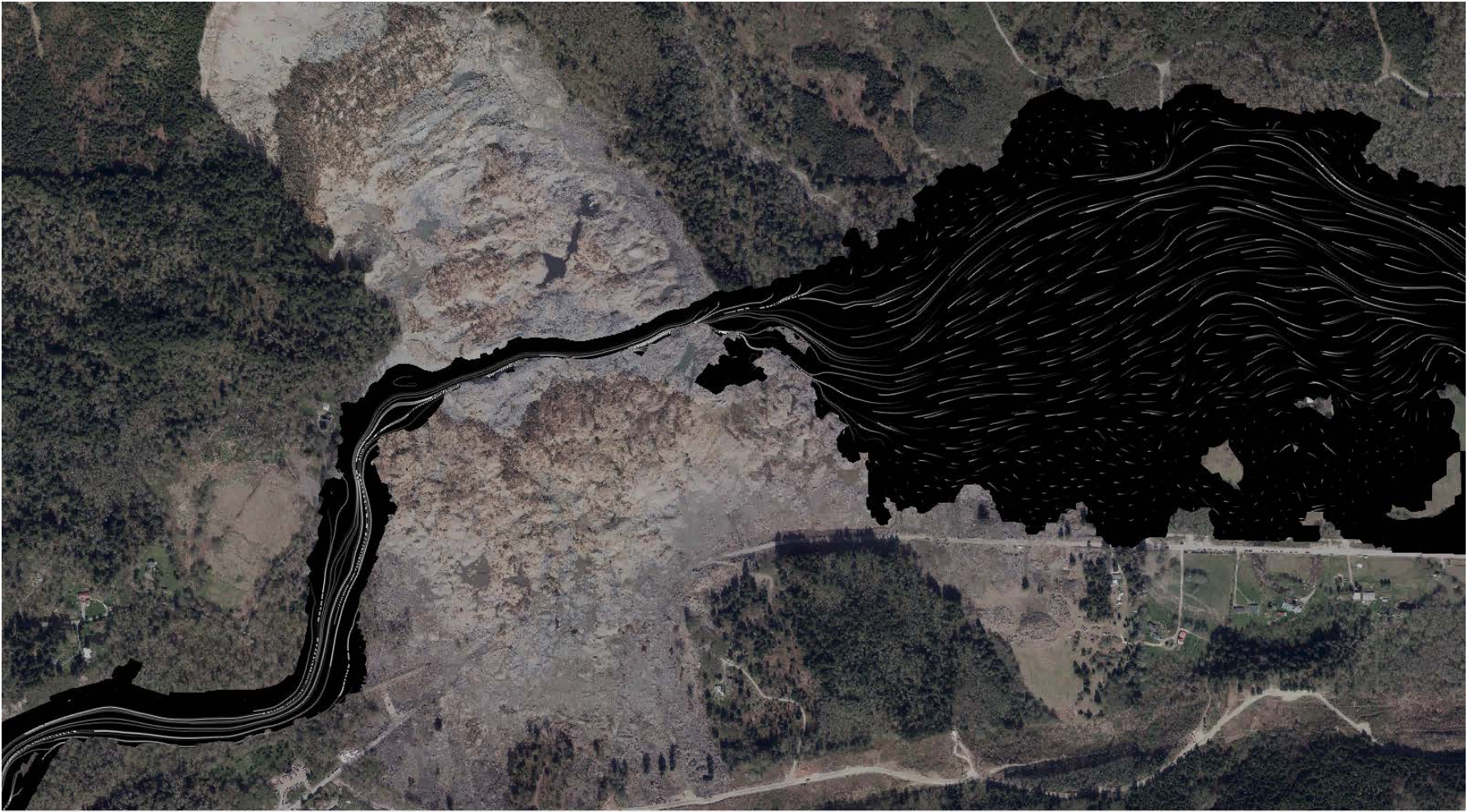
Q = 5000 cfs – Water Surface Elevation



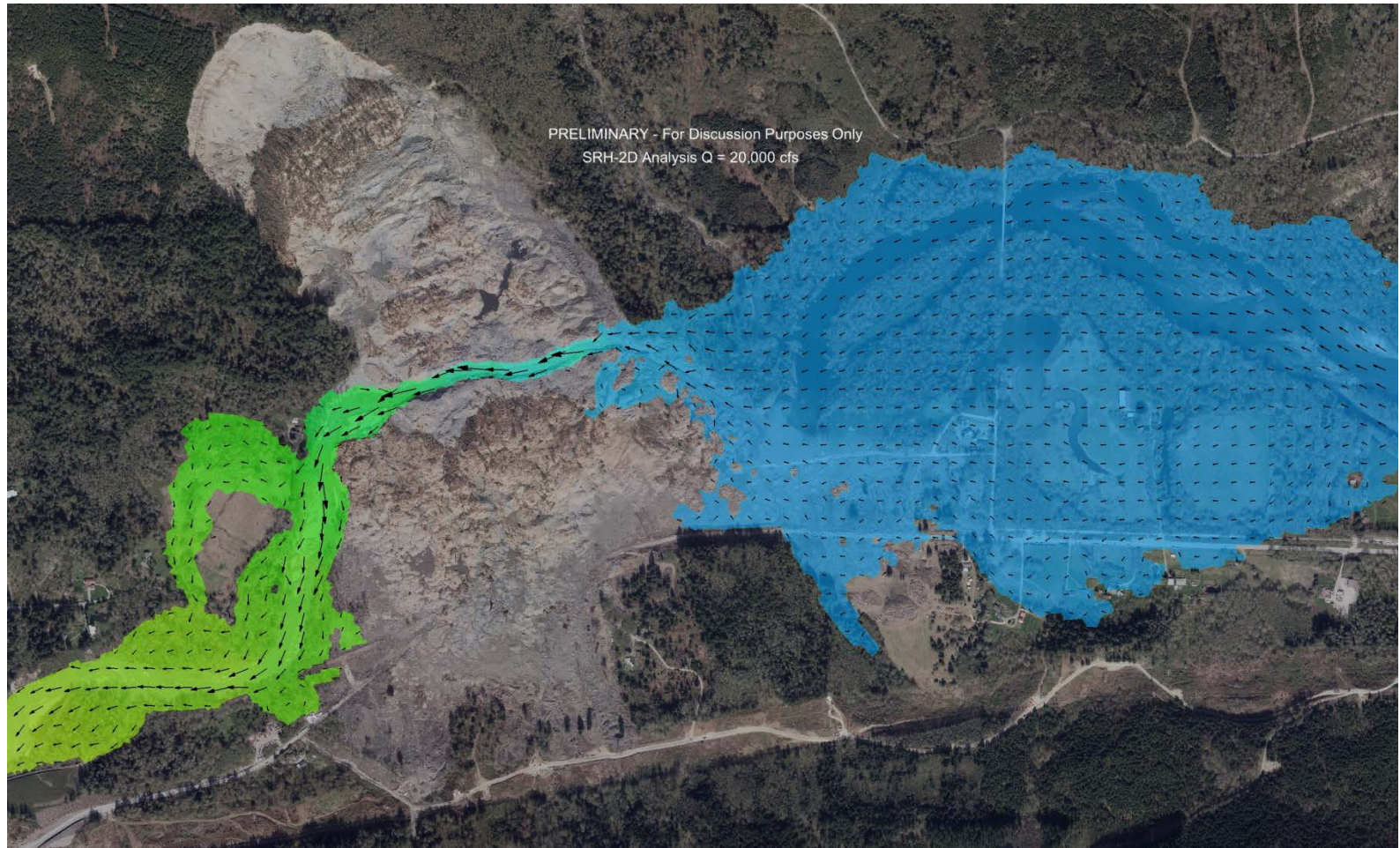
Q = 5000 cfs - Velocity



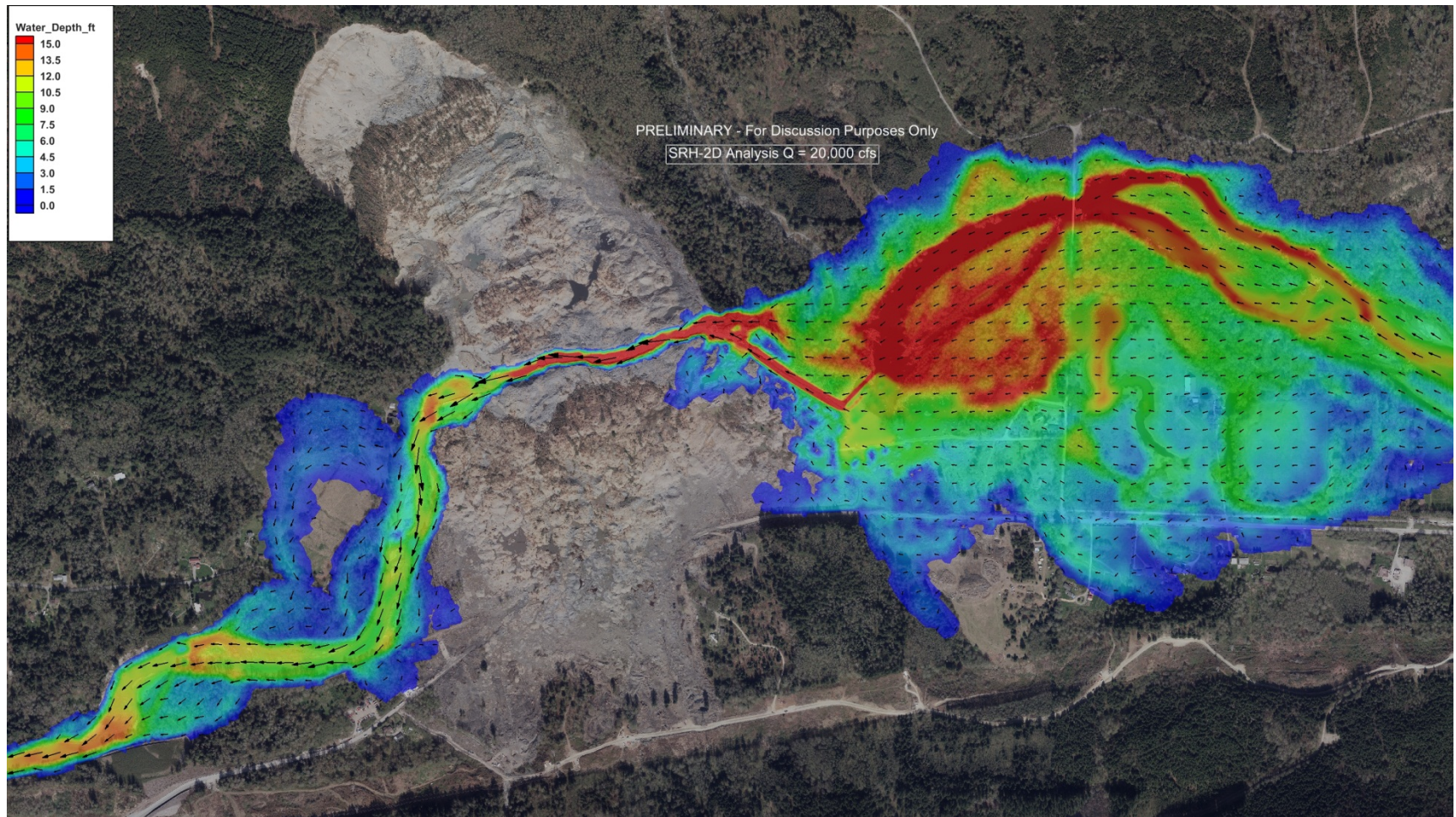
$Q = 5000 \text{ cfs}$ - Velocity



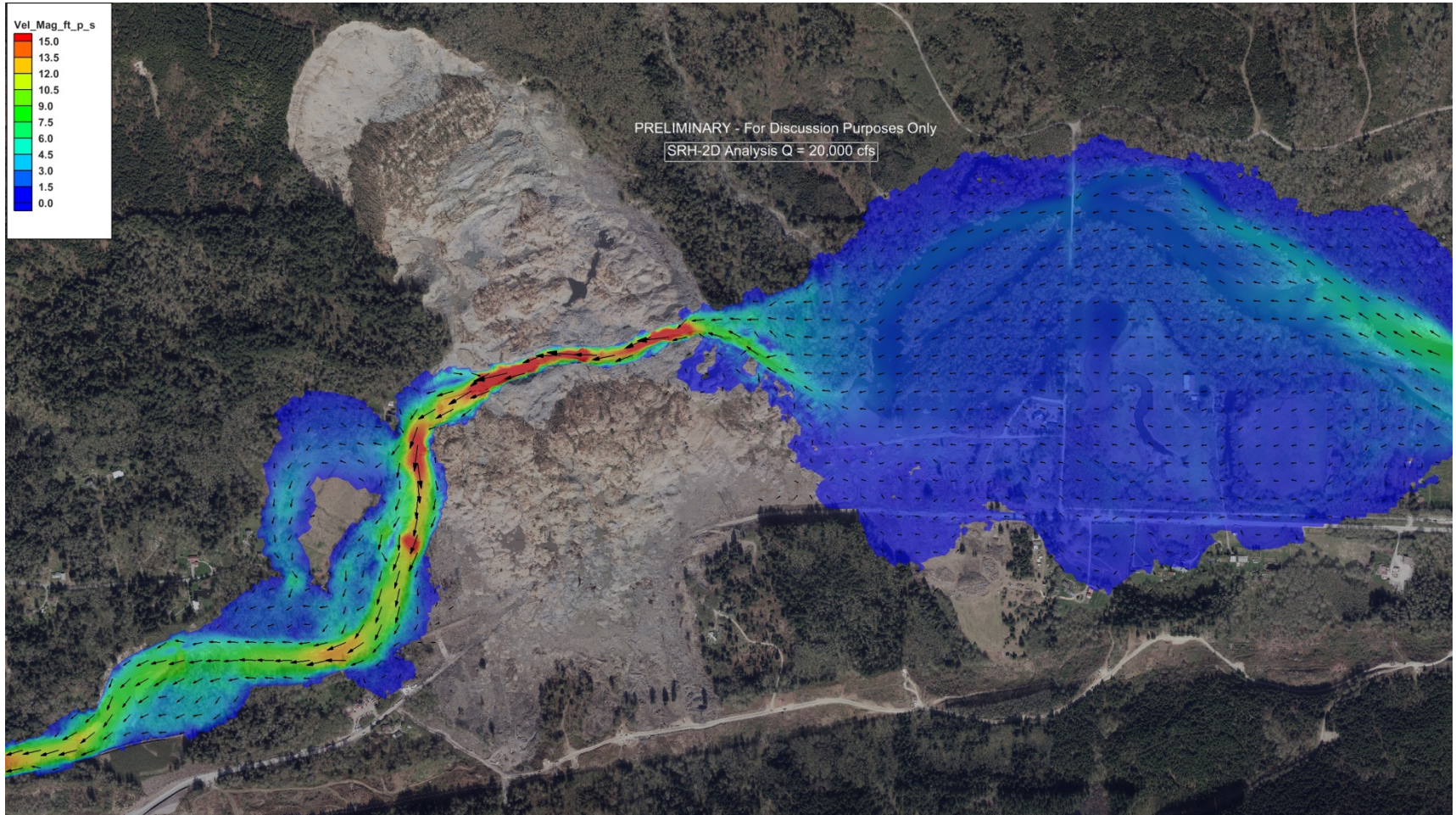
$Q = 20,000$ cfs (~ 2 -YR)– Water Surface Elevation



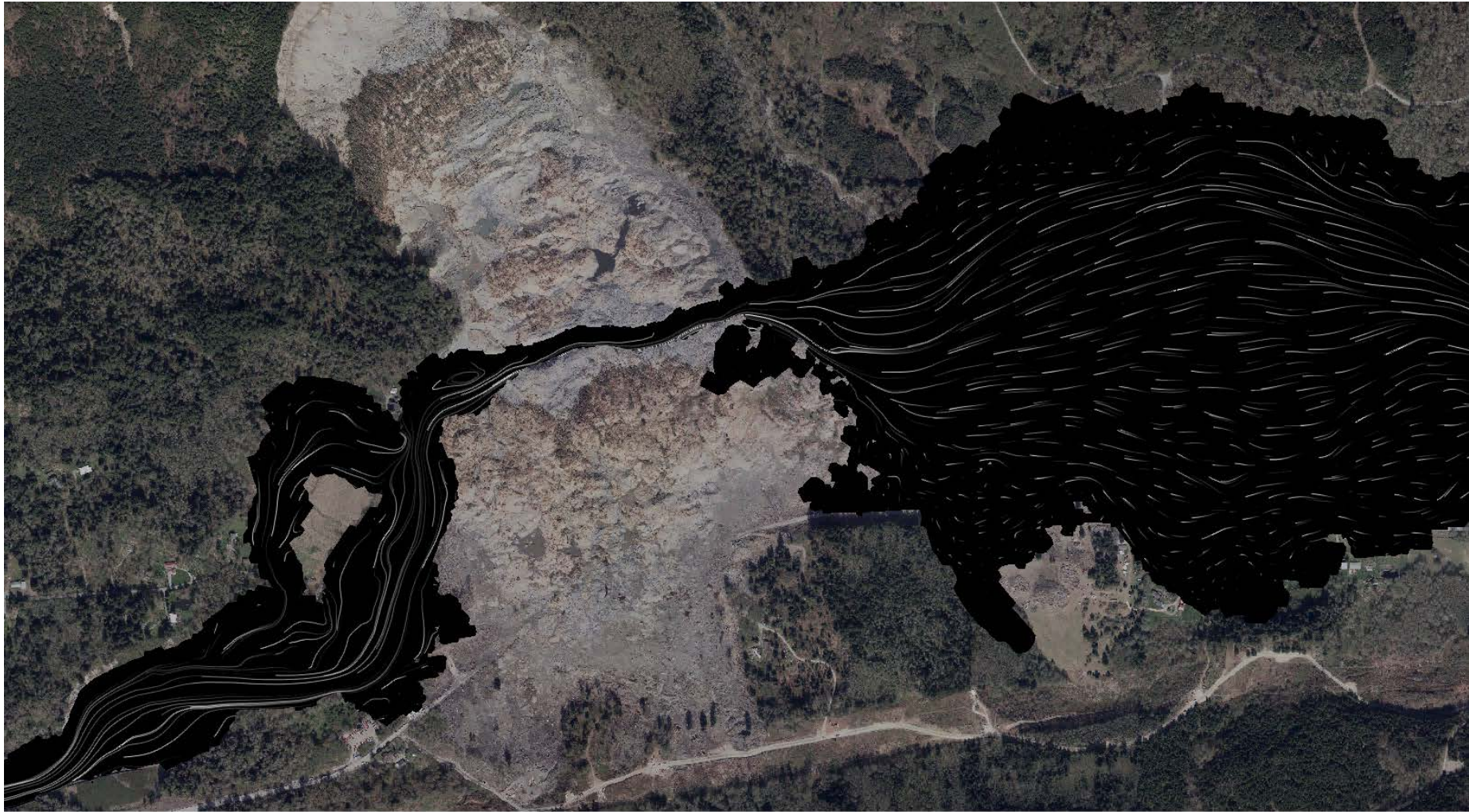
Q = 20,000 cfs (~2-YR)– Depth



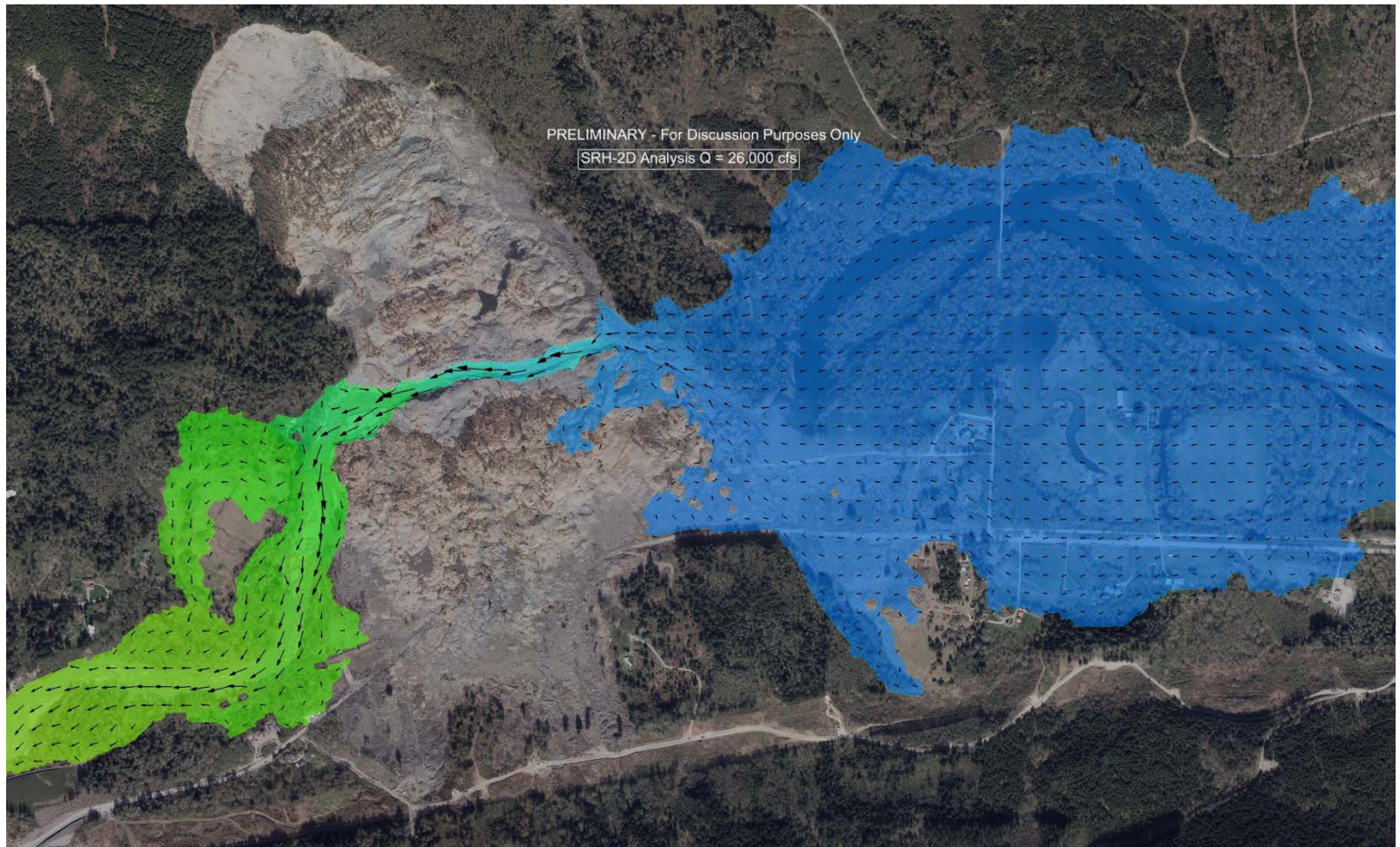
Q = 20,000 cfs (~2-YR) - Velocity



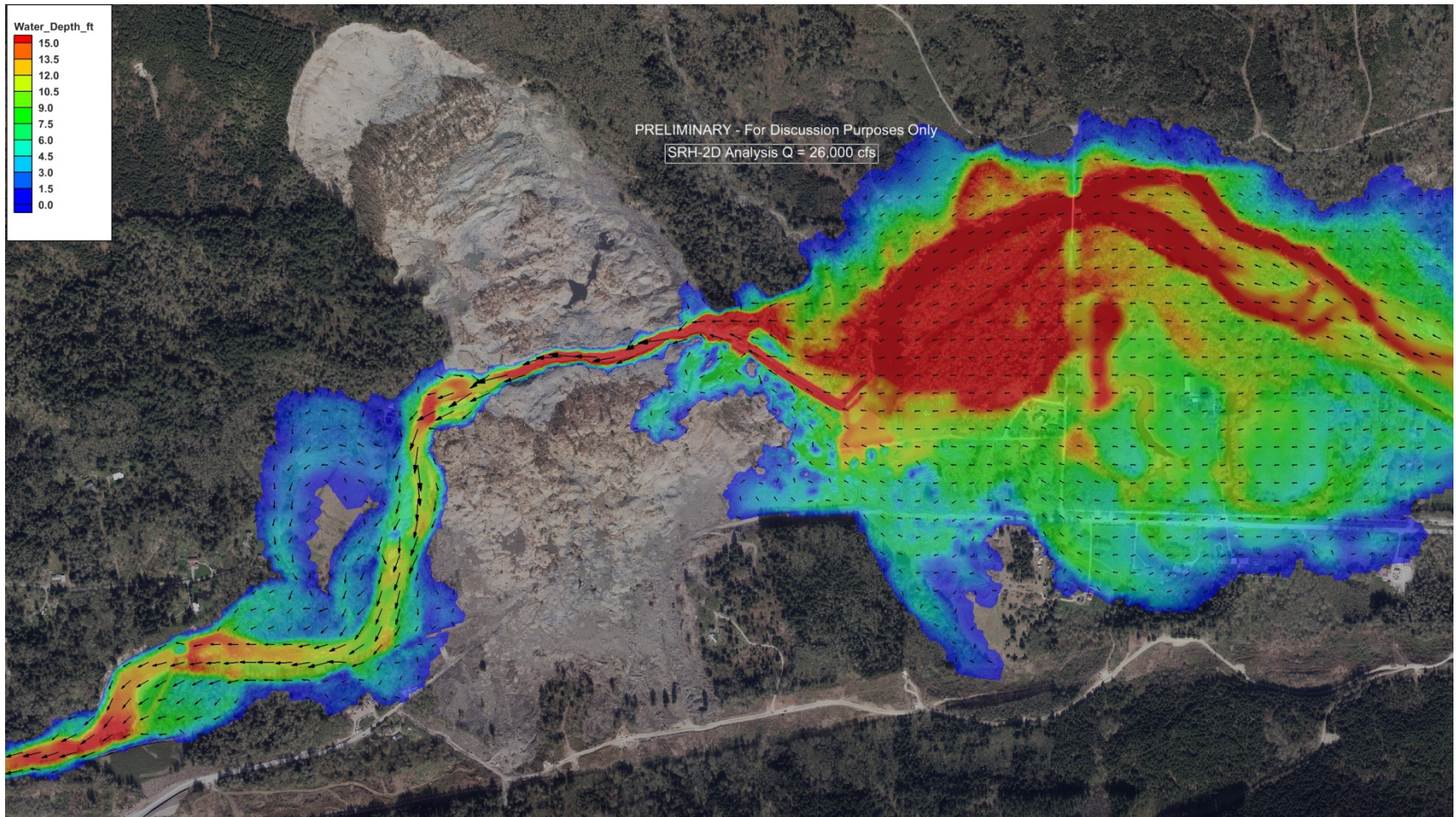
$Q = 20,000$ cfs (~ 2 -YR) - Velocity



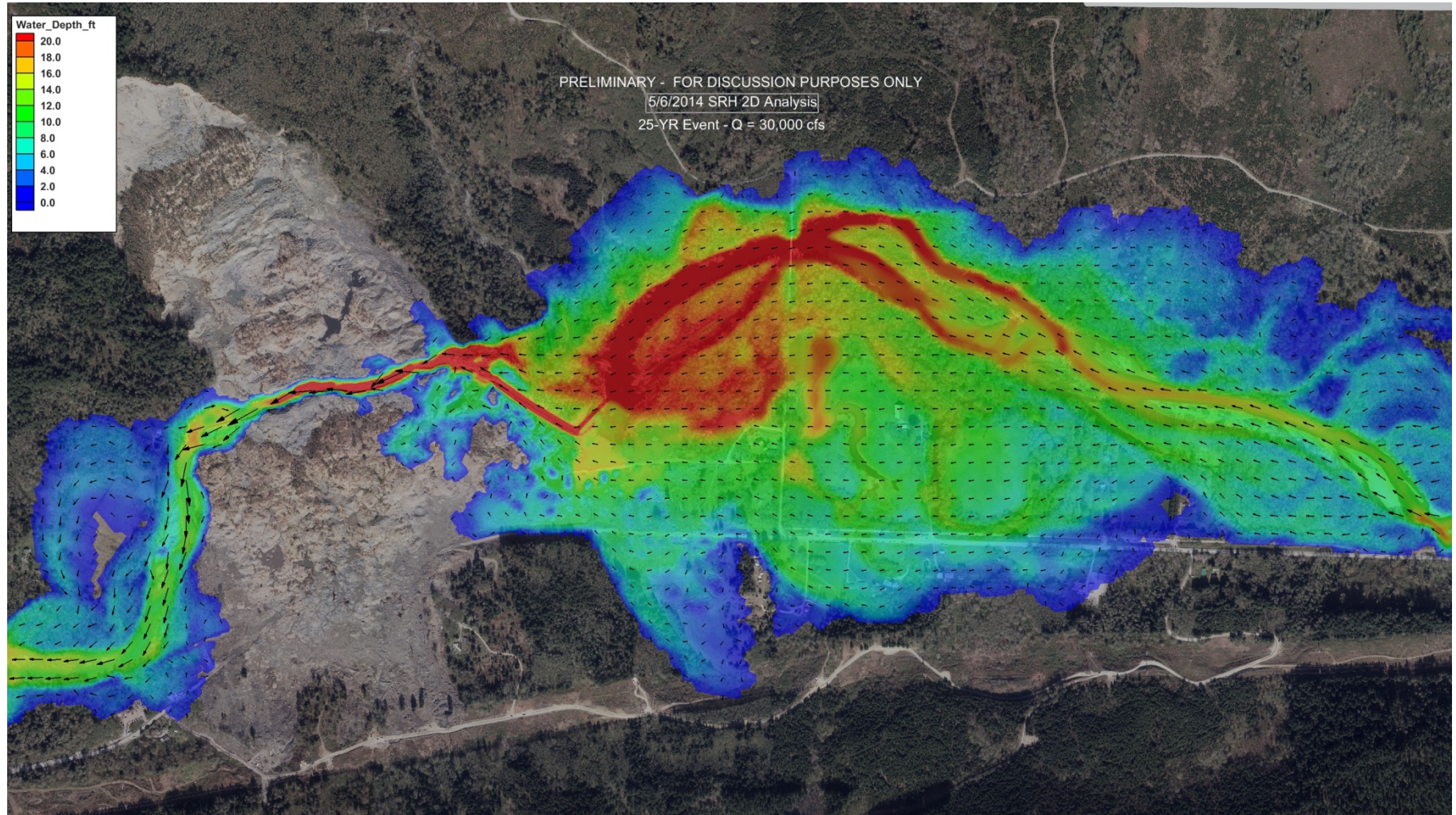
Q = 26,000 cfs (~10-YR) – Water Surface Elevation



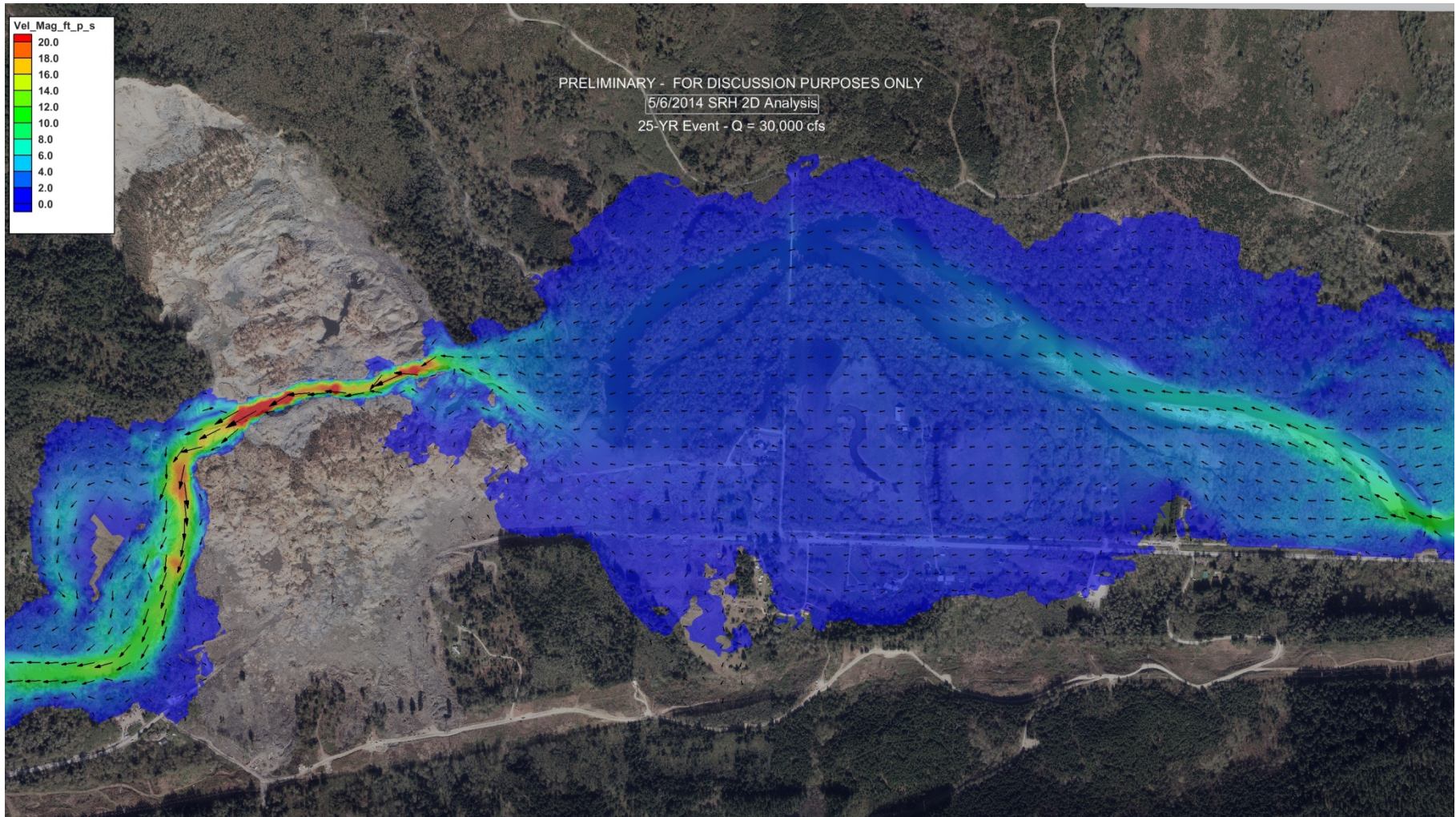
$Q = 26,000$ cfs (~ 10 -YR)– Depth



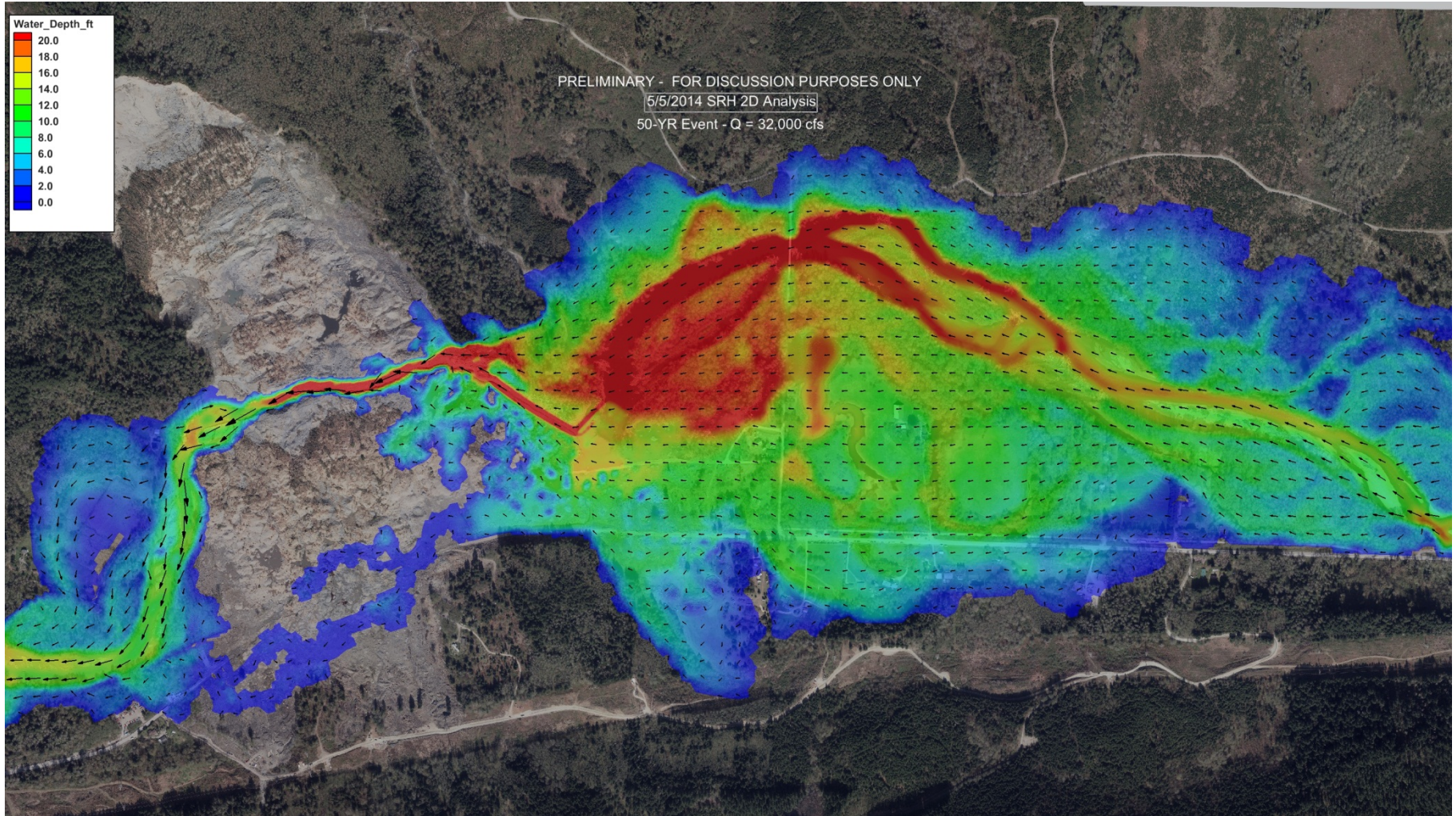
$Q = 30,000$ cfs (~ 25 -YR) – Depth



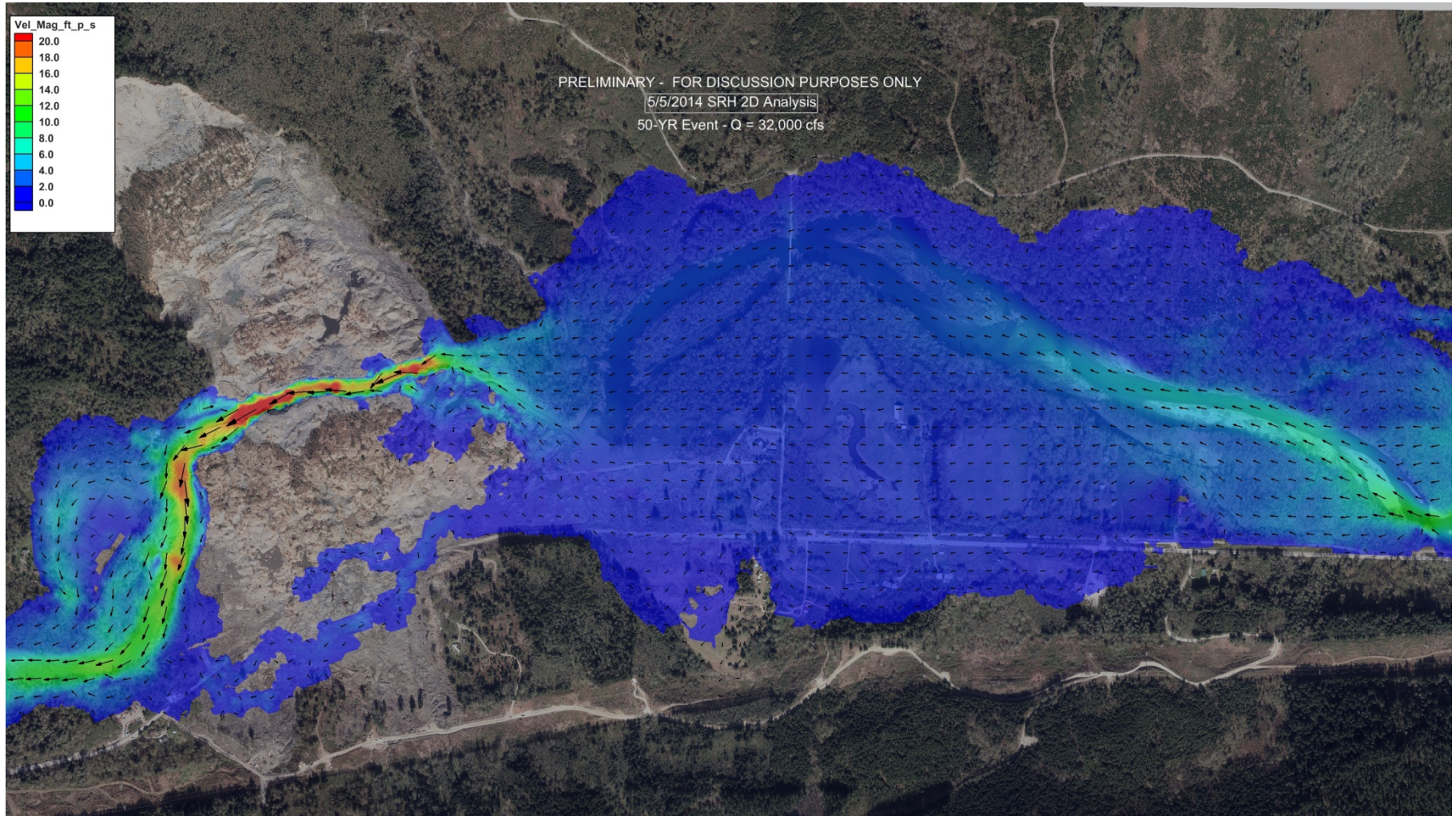
Q = 30,000 cfs (~25-YR) - Velocity



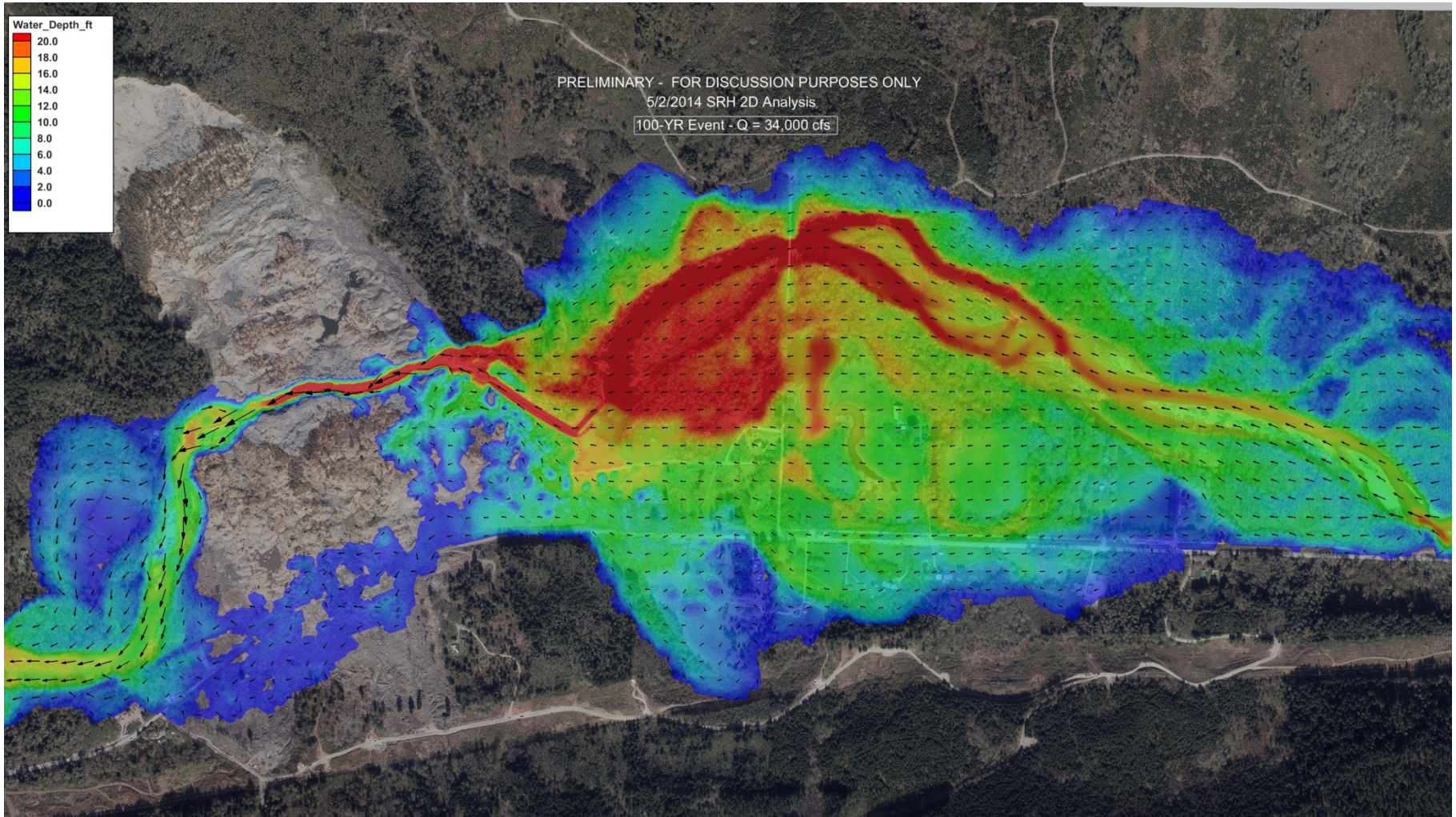
Q = 32,000 cfs (~50-YR) Existing Depth



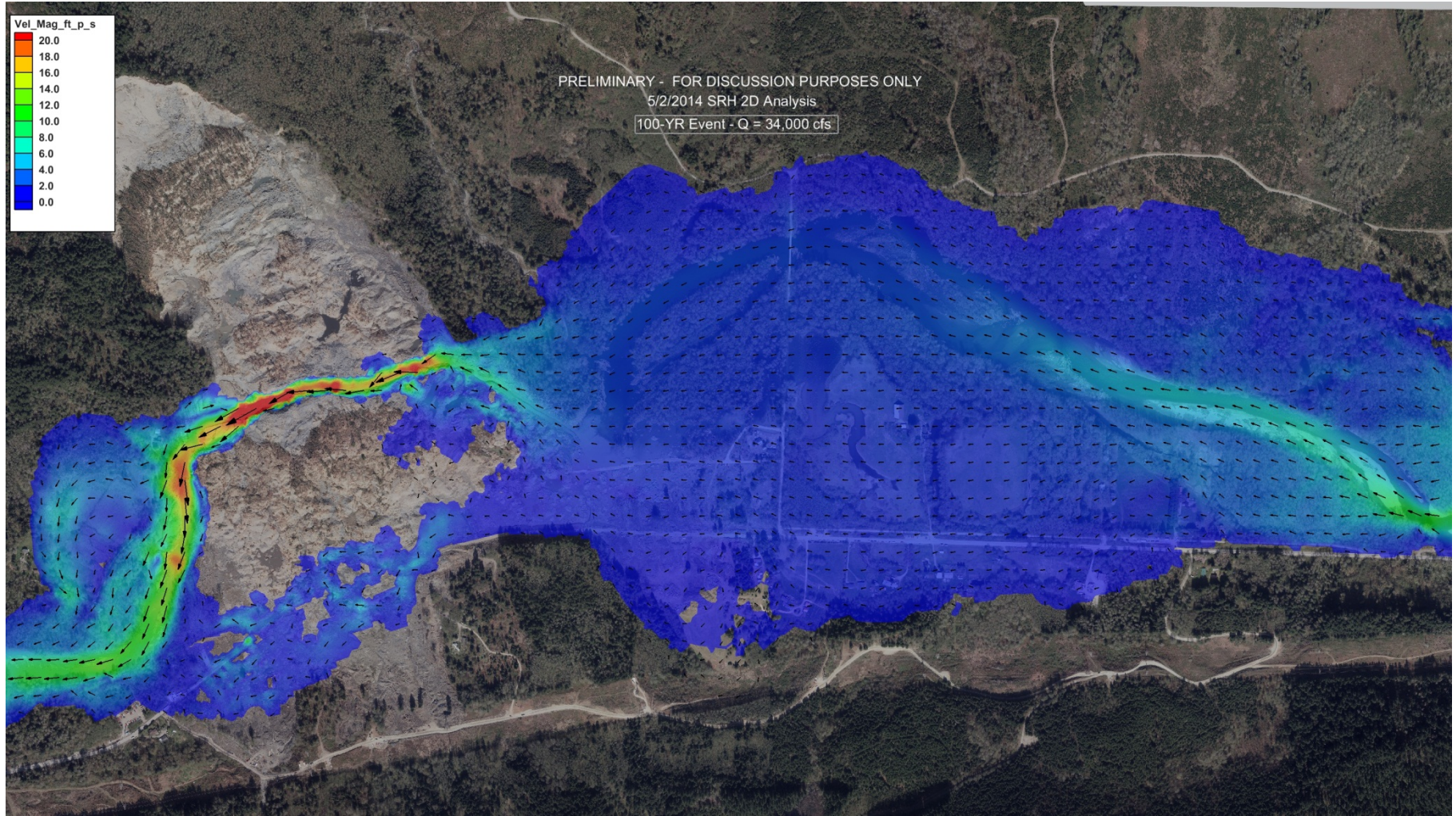
Q = 32,000 cfs (~50-YR) Existing Velocity



Q = 34,000 cfs (~100-YR) Existing Depth

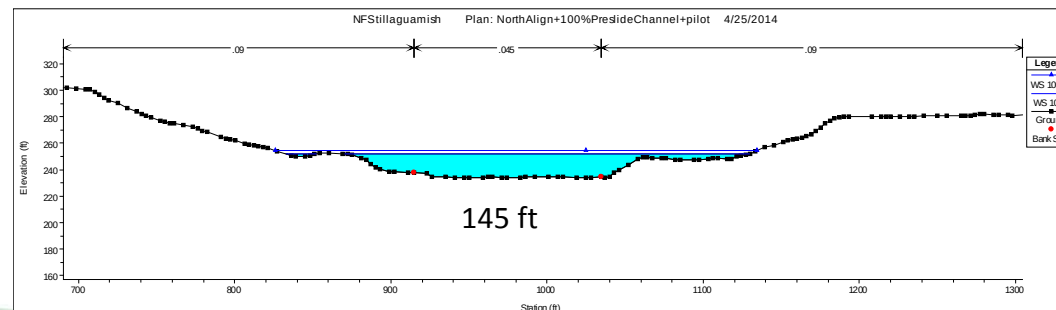
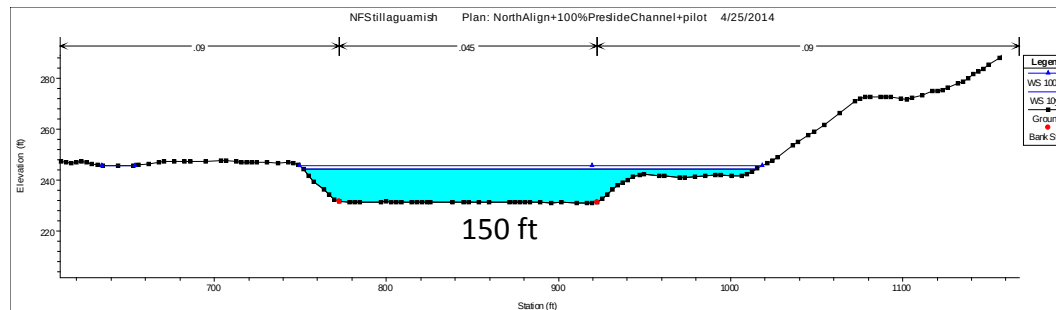


Q = 34,000 cfs (~100-YR) Existing Velocity





Use historic “Rowan” slide to inform what may happen through new slide



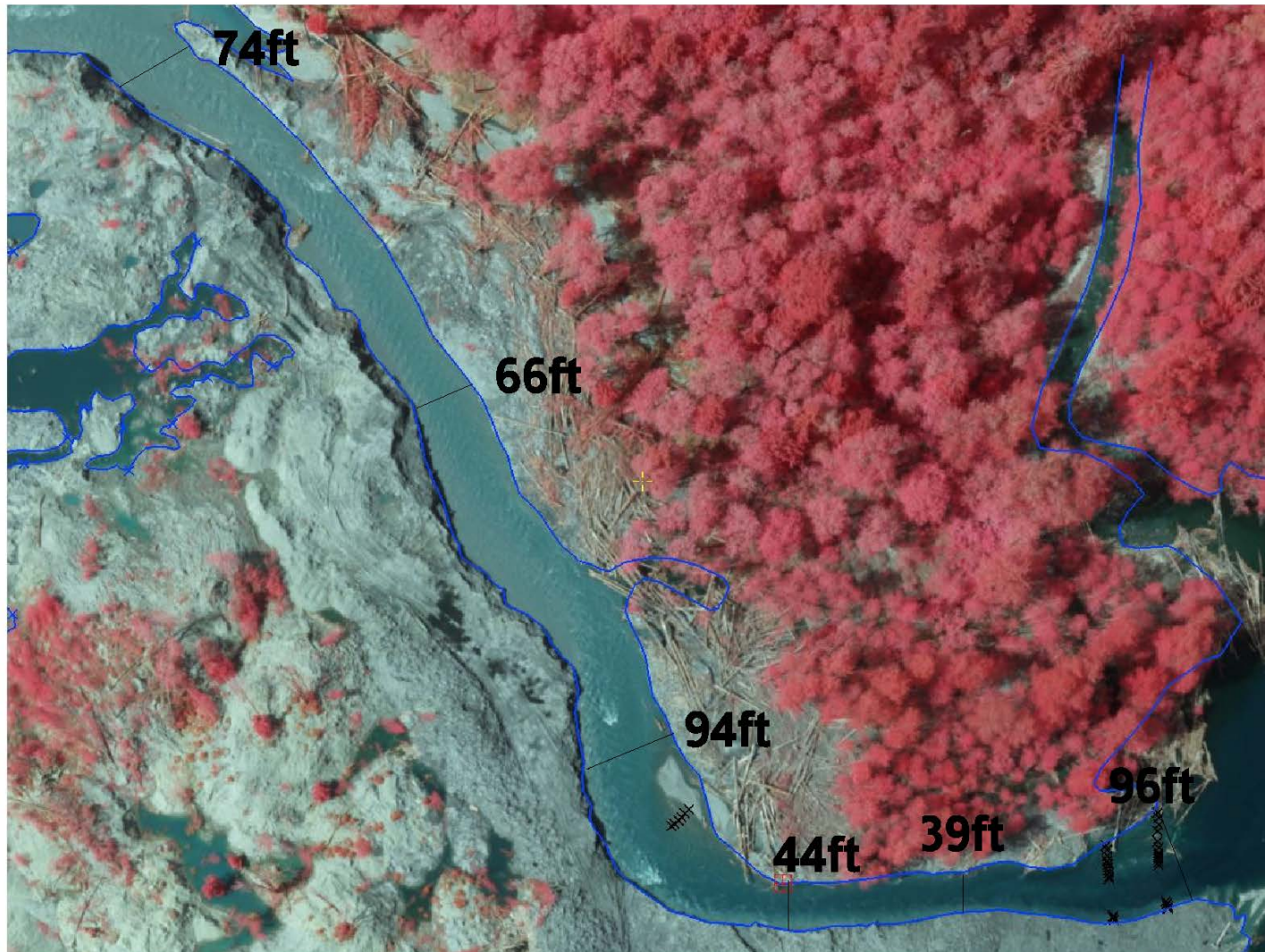


Potential Future Water Surface Elevation Sensitivity Analysis

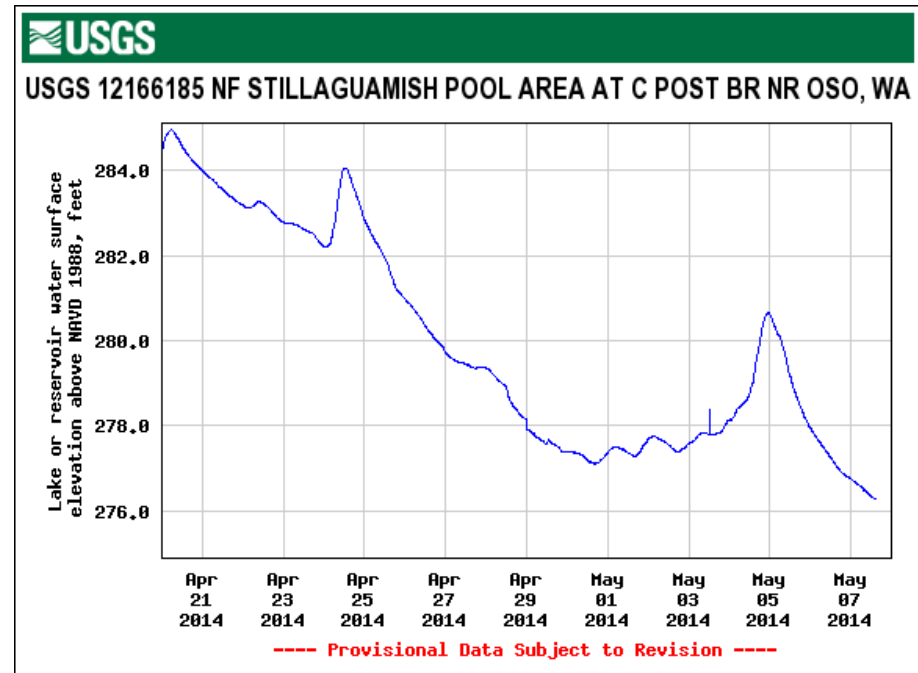
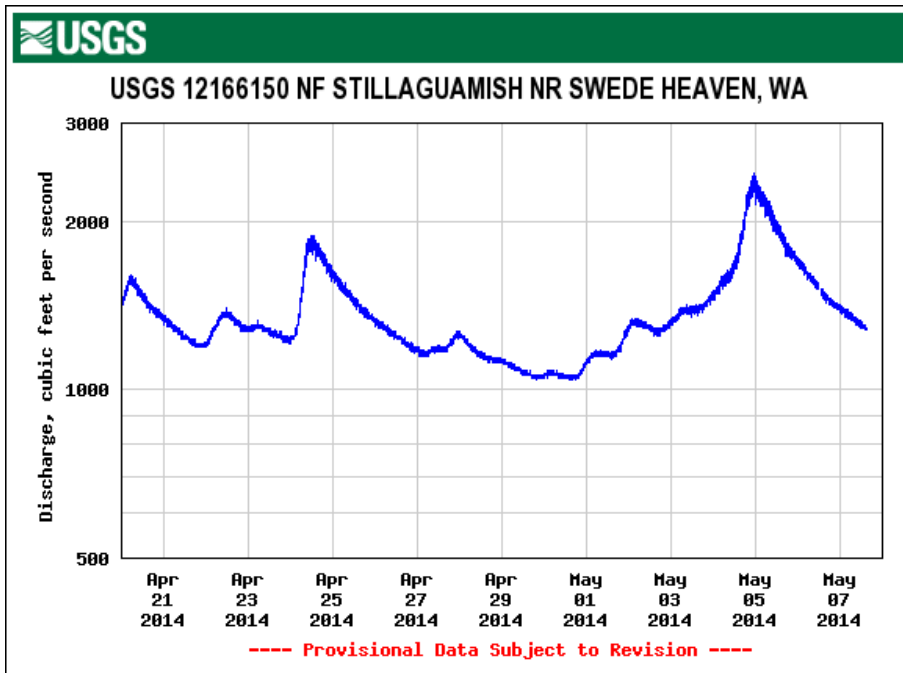
(Analysis Conducted by Corps, based on FEMA Preliminary Model)

North Alignment - 1% Flood Event [^]									
#	Pre-Slide	Post-Slide	Short Term Measures Runs for Pilot Channel Excavation by 1 May			Long Term Measure Runs for Modifications to Existing (North Alignment) Channel			
1% Flood Event (100-year: 34,103 cfs)	FEMA Hydraulic Model with 2013 LiDAR and no Bathymetry	Baseline: Using Observed Data on/around 4/23/2014	Extend Excavation of 20' Base Width Pilot Channel U/S Through Debris Field	Extend Pilot and Increase Base Width to 40' Throughout	Extend Pilot, Increase Width to 40' and Invert to 270' Throughout*	Base Width of 150 Feet, 2:1 Side Slopes, and Elevation (variable) Equal to PreSlide Conditions**	Base Width of 125 Feet, 2:1 Side Slopes, and Elevation (variable) Equal to PreSlide Conditions	Base Width of 100 Feet, 2:1 Side Slopes, and Elevation (variable) Equal to PreSlide Conditions	Base Width of 75 Feet, 2:1 Side Slopes, and Elevation (variable) Equal to PreSlide Conditions
C-Post WSE	285.7	300.8	300.8	300.3	300.3	287.9	289.0	290.7	293.4
Upstream End of Slide Reach WSE (Pool /Pilot Transition Zone)	279.6	300.7	300.7	300.3	300.2	282.9	286.5	290.0	293.1
Midway Through Slide Reach WSE	269.3	285.1	285.1	285.1	285.1	273.5	275.6	278.0	280.7
Downstream End of Slide Reach WSE	265.5	266.5	266.5	266.5	266.5	265.3	265.5	265.8	266.0
Cut Volume to Match Existing Channel to Specified Geometry (Cu. Yd)						600000	463000	331000	210000

5/1/14 Channel Widths



Natural Channel Widening



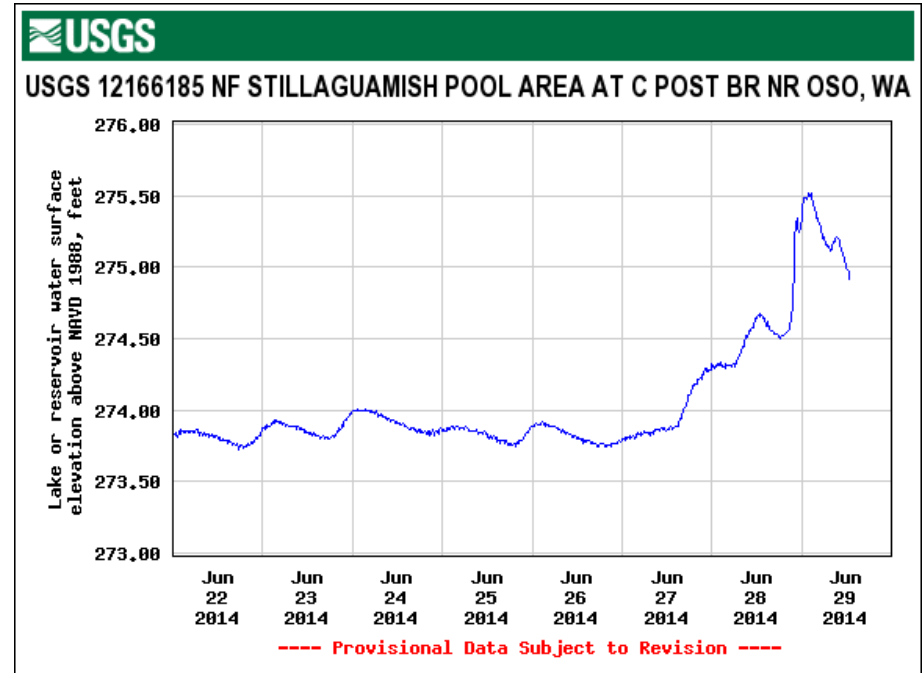
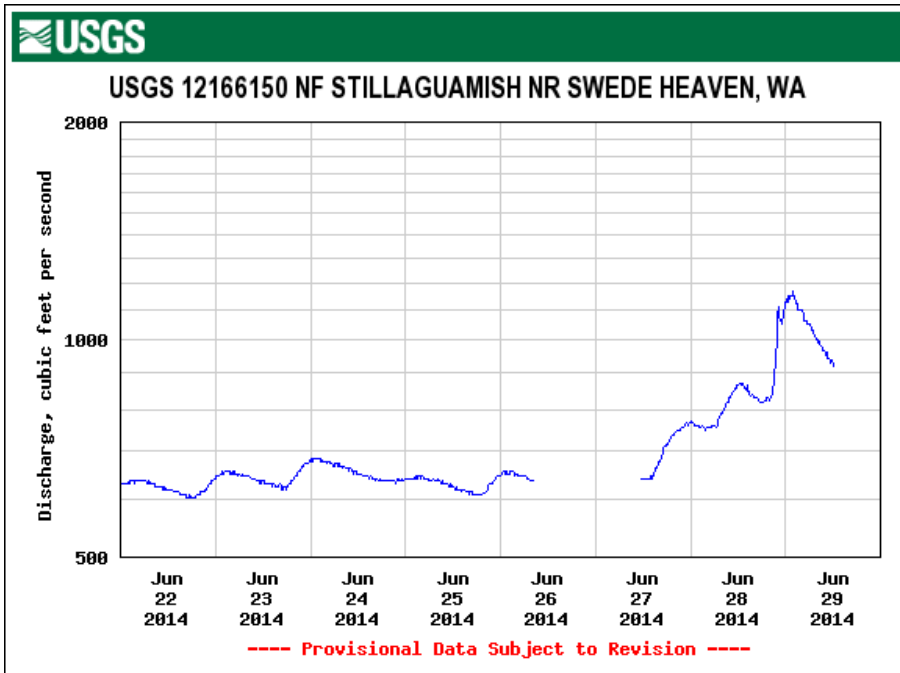
4/28/14 – Flow = ~1130 cfs WSE = ~ 278.4 ft

Excavation stopped on 4/30/14

5/1/14 - Flow = ~1100 cfs WSE = ~276.7 ft

5/7/14 - Flow = ~1400 cfs WSE = ~276.1 ft

Natural Channel Widening



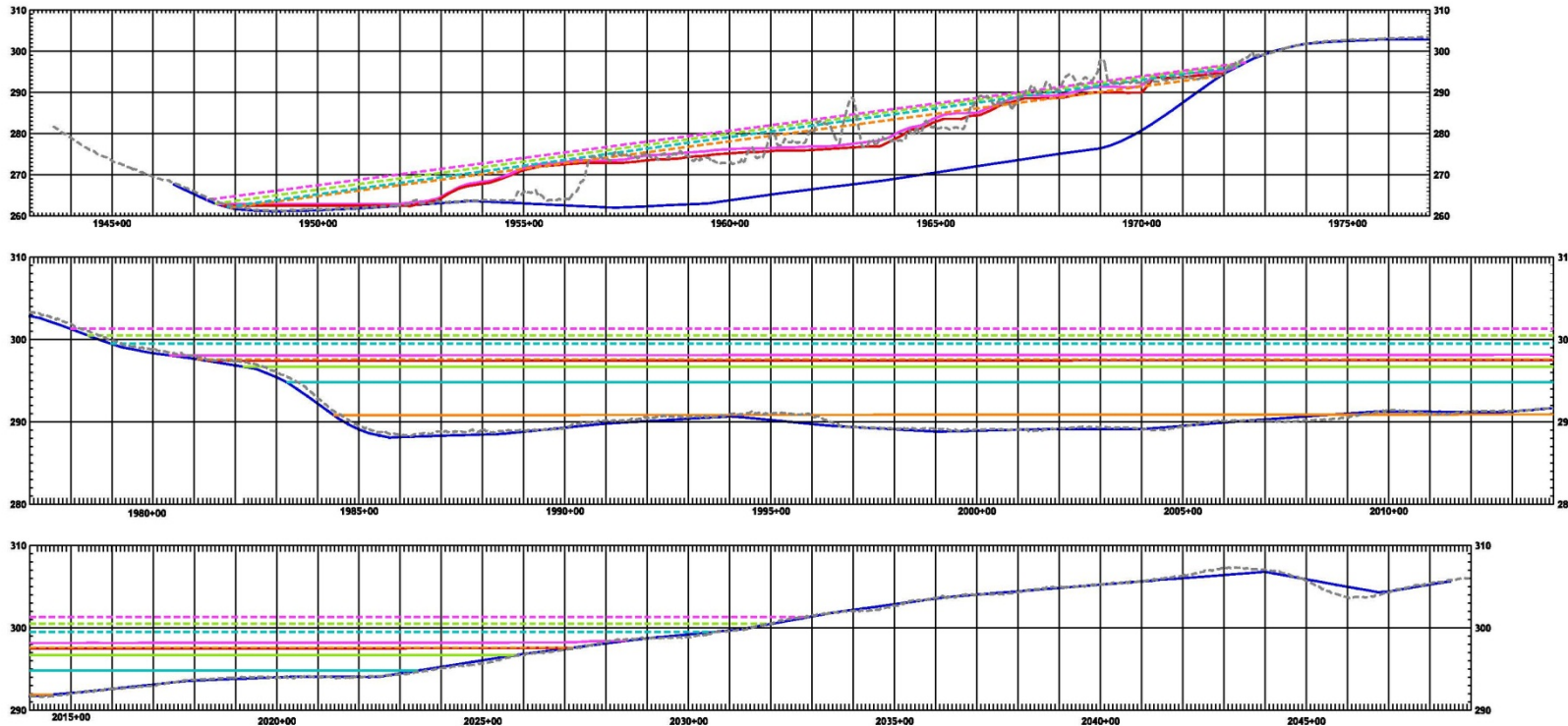
5/1/14 - Flow = ~1100 cfs WSE = ~276.7 ft

5/7/14 - Flow = ~1400 cfs WSE = ~276.1 ft

5/24/14 – Flow = ~1100 cfs WSE = ~275.3 ft

6/29/14 – Flow = ~1100 cfs WSE = ~275.4 ft

Water Surface Elevations and Potential Roadway Profiles



Legend 4-22-2014 Results

Flow Event	Line	West Side			East Side	
		Length	West Elev.	East Elev.	Length	Elev.
2-Year	-----	2405 ft	262.0 ft	294.0 ft	4614 ft	297.6 ft
10-Year	-----	2455 ft	262.2 ft	296.3 ft	5166 ft	299.5 ft
25-Year	-----	2496 ft	263.0 ft	297.0 ft	5362 ft	300.5 ft
100-Year	-----	2542 ft	263.9 ft	297.3 ft	5492 ft	301.3 ft

Legend 5-5-2014 Results

Flow Event	Line	West Side			East Side		
		Length	West Elev.	East Elev.	Length	West Elev.	East Elev.
2-Year	-----	N/A	N/A	N/A	3019 ft	291.8 ft	291.9 ft
10-Year	-----	N/A	N/A	N/A	4018 ft	294.7 ft	294.8 ft
25-Year	-----	N/A	N/A	N/A	4364 ft	296.7 ft	296.7 ft
50-Year	-----	2437 ft	262.5 ft	294.6 ft	4589 ft	297.4 ft	297.5 ft
100-Year	-----	2480 ft	262.9 ft	296.2 ft	4813 ft	298.1 ft	298.1 ft

Potential Alternatives and Associated Benefits and Risks



Potential Channel Migration Risk



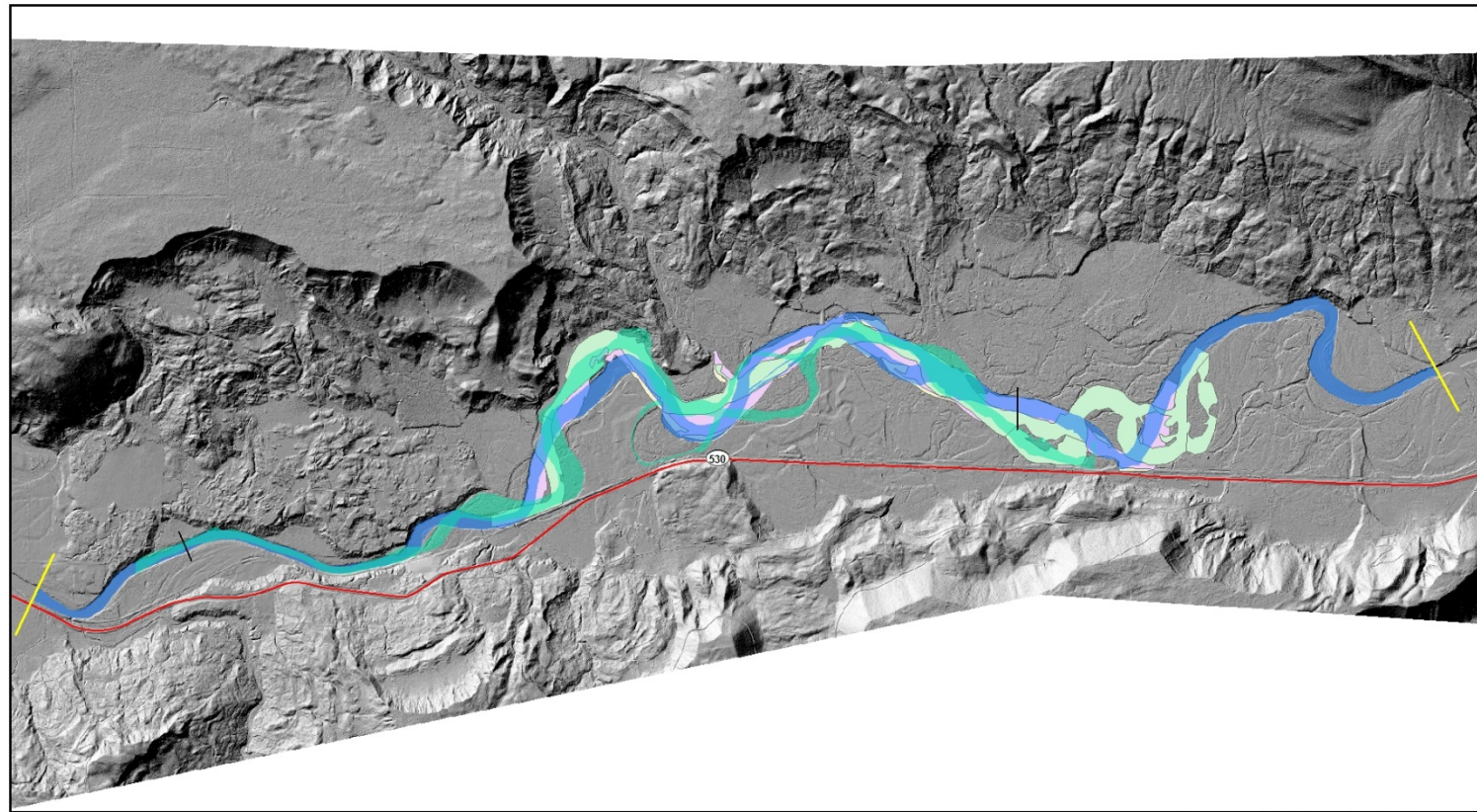
Historic Aerial



1933 Aerial



Historic Channel Migration



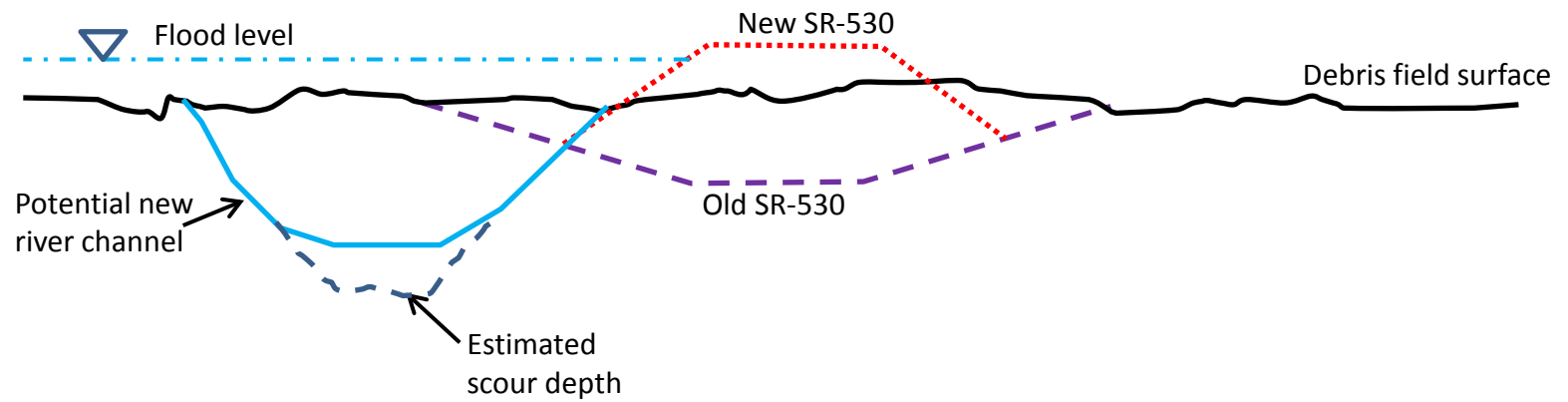
2013 Tulaip LiDAR

0 3,000 6,000
Feet

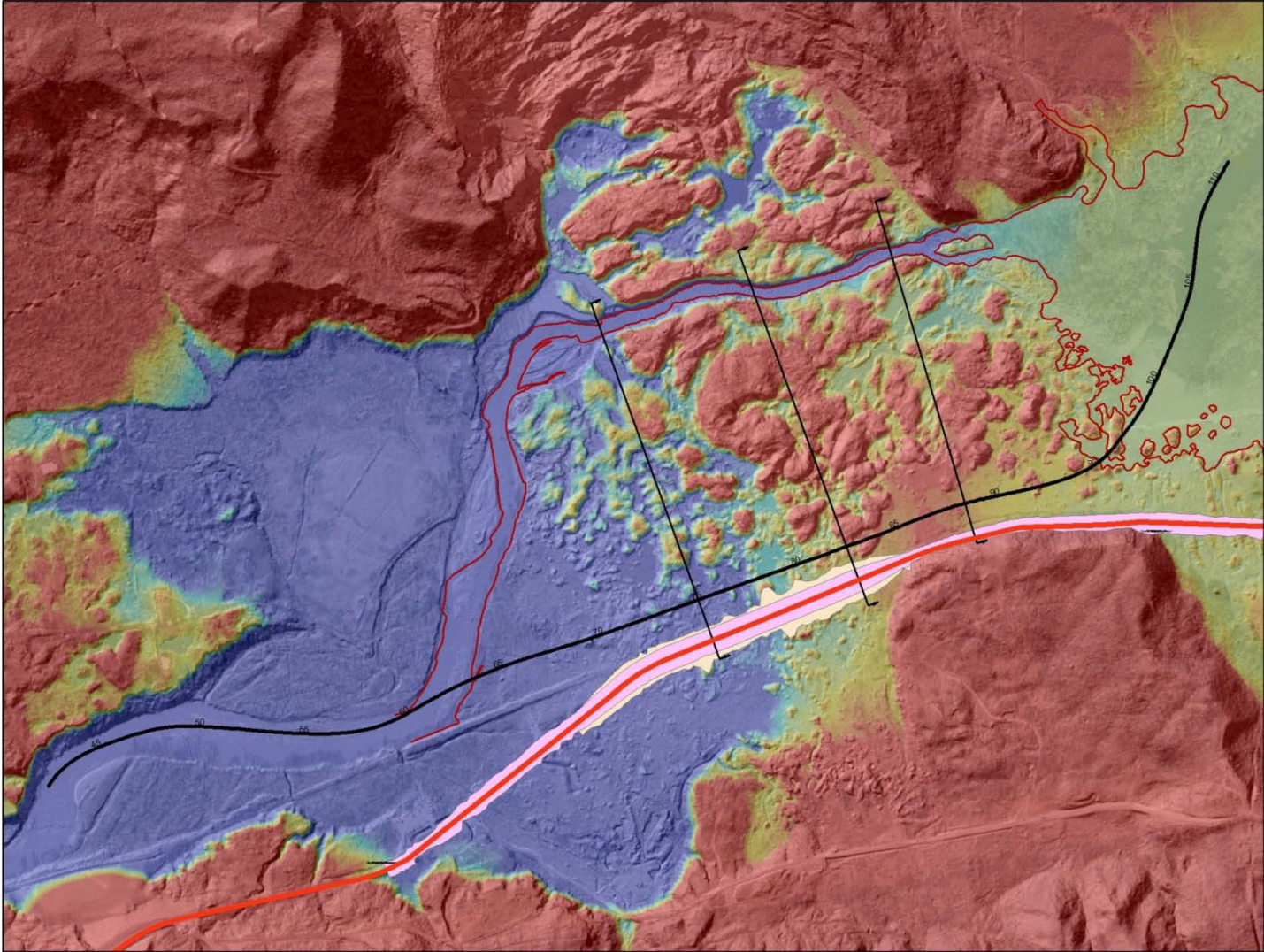


Channel Migration History
Oso Slide Area

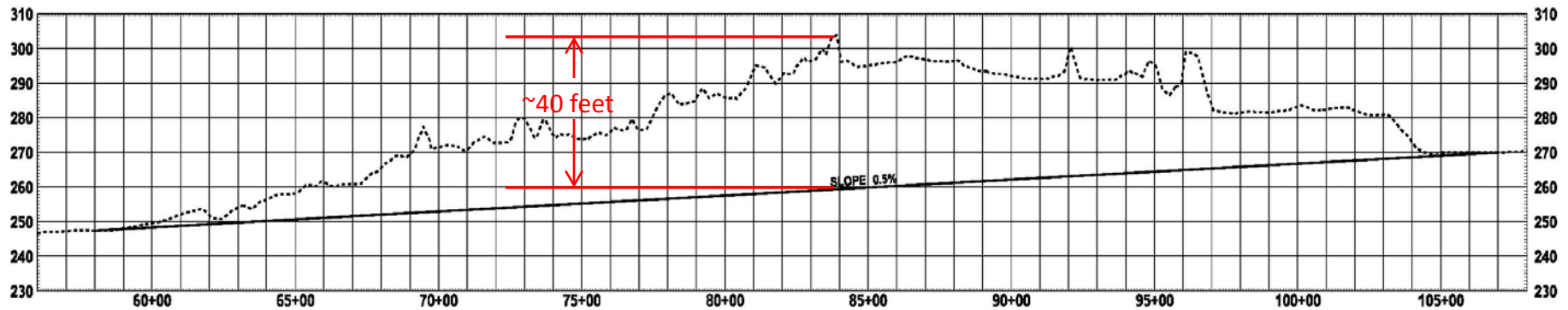
Potential Channel Migration or Remobilization Risk



Potential Channel Migration/Avulsion Risk

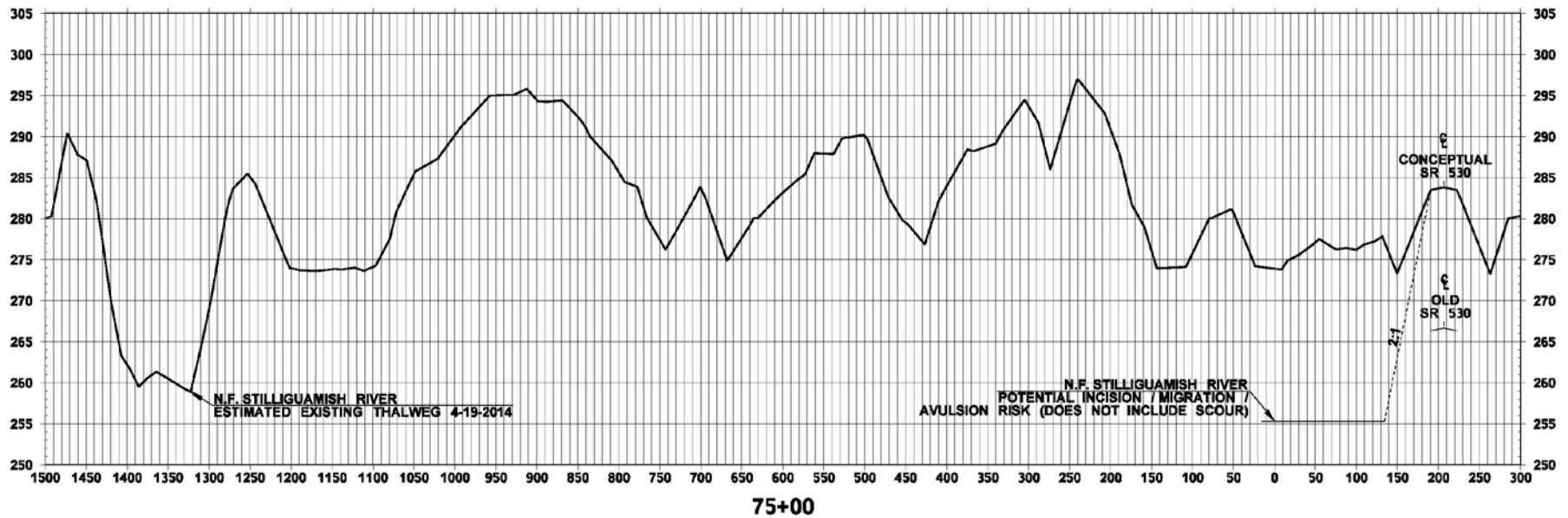


Potential Channel Migration/Avulsion Risk

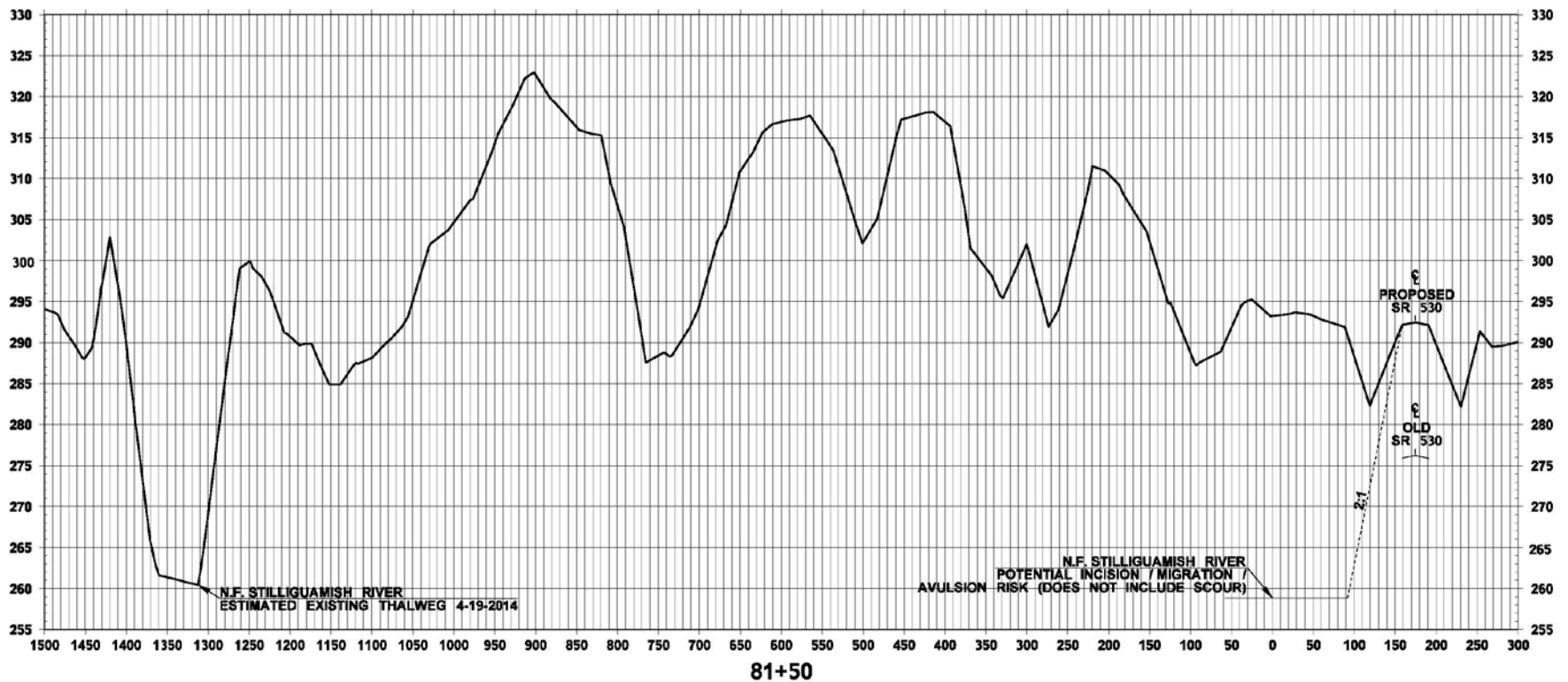


N.F. STILLIGUAMISH RIVER POTENTIAL INCISION / MIGRATION / AVULSION RISK

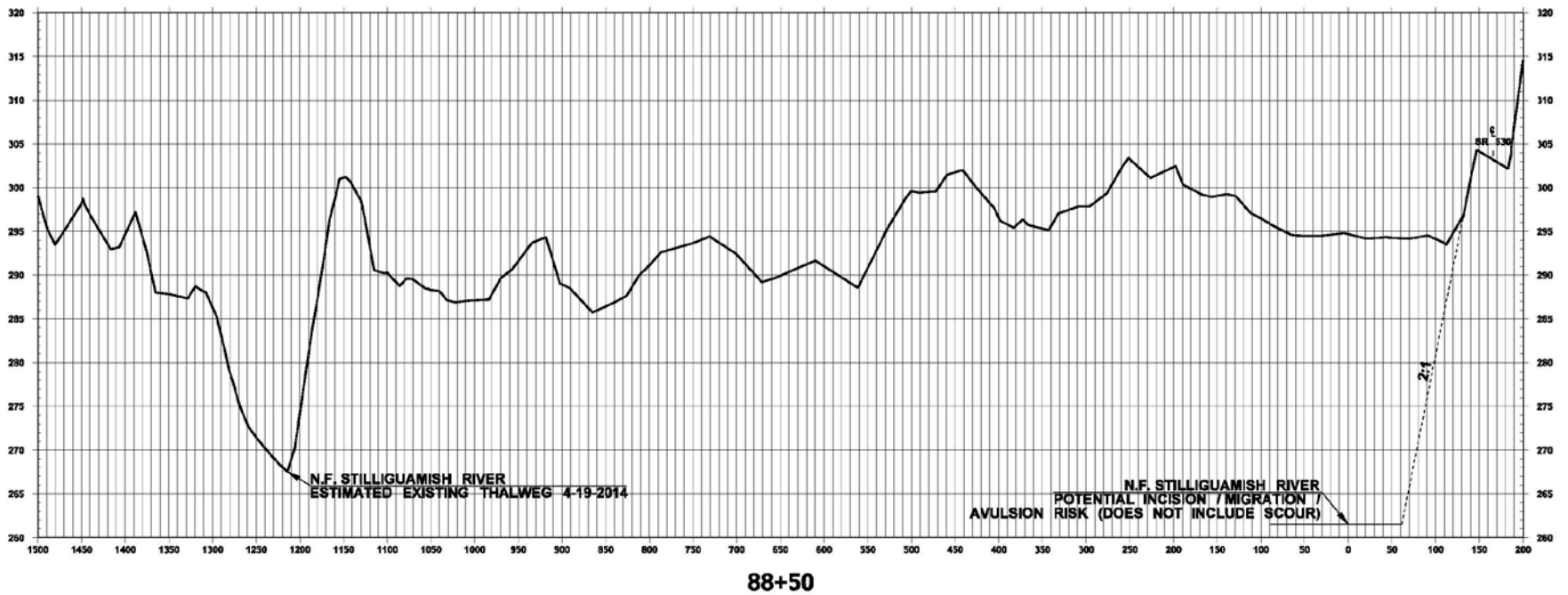
Potential Channel Migration/Avulsion Risk



Potential Channel Migration/Avulsion Risk

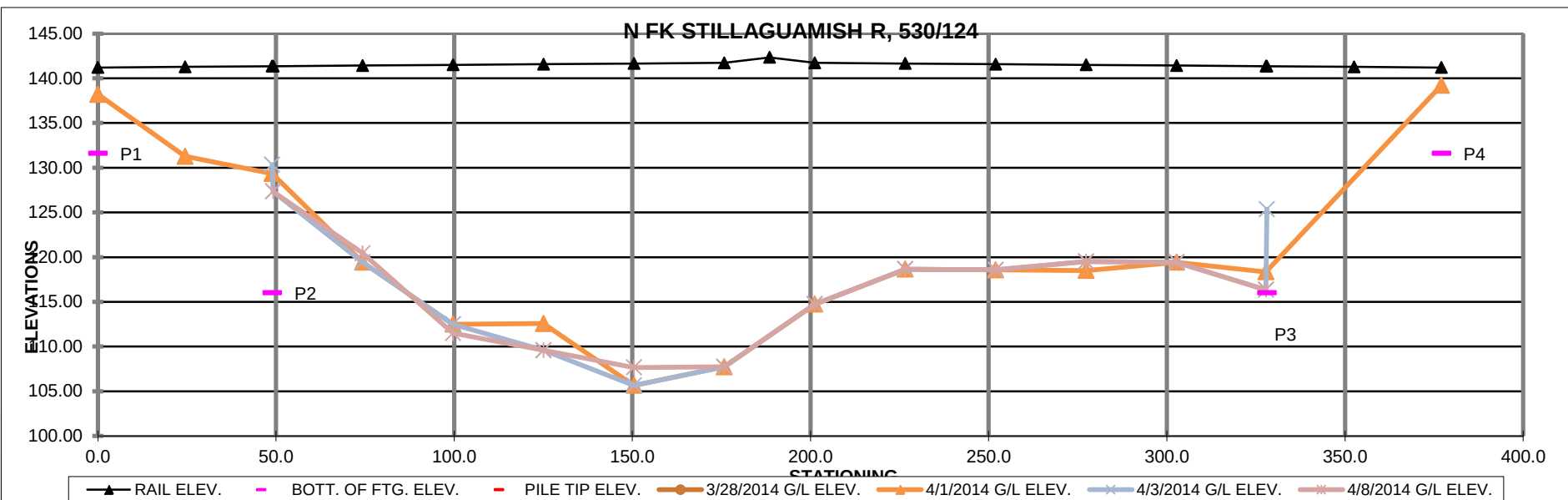
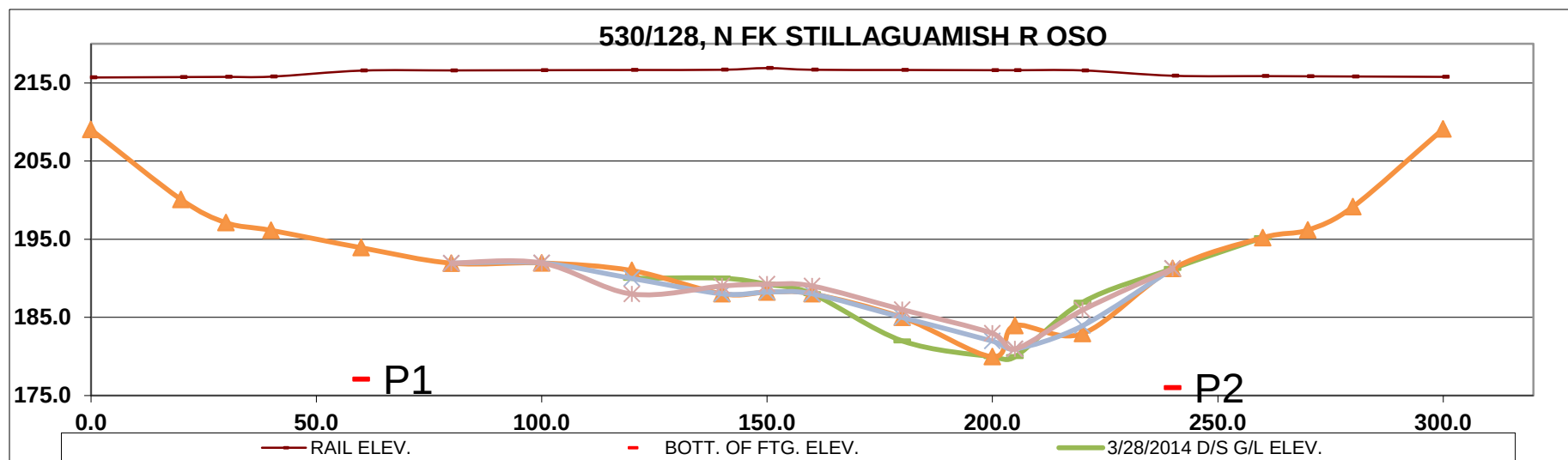


Potential Channel Migration/Avulsion Risk





Monitoring Downstream Bridges – Downstream Aggradation and Potential Effects on Downstream Infrastructure





Questions?

Casey Kramer

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WSDOT Development Division
(360) 705-7262

kramerc@wsdot.wa.gov

2014/04/01