SHANNON & WILSON

Preliminary Observations of the Sequim Fault for the Dungeness Off-Channel Reservoir Project

May 24, 2023

Sequim Fault

- Included as Class A fault in the U.S. Geological Survey Quaternary Fault and Fold Database
- Poorly studied and understood
- Database mapping consists of four strands ranging from approx. 1 to 2 km each, zone with a total length of approx. 4.5 km (7 km in text entry)
- Basis of inclusion in database from one map (Nelson and others, 2007) that covered lidar-based mapping of generally east-west-striking faults along the northern Olympic Peninsula.
- Not included in 1:24,000-scale geologic mapping of the Sequim (Schasse and Logan, 1998) or Carlsborg (Schasse and others, 2000) quadrangles

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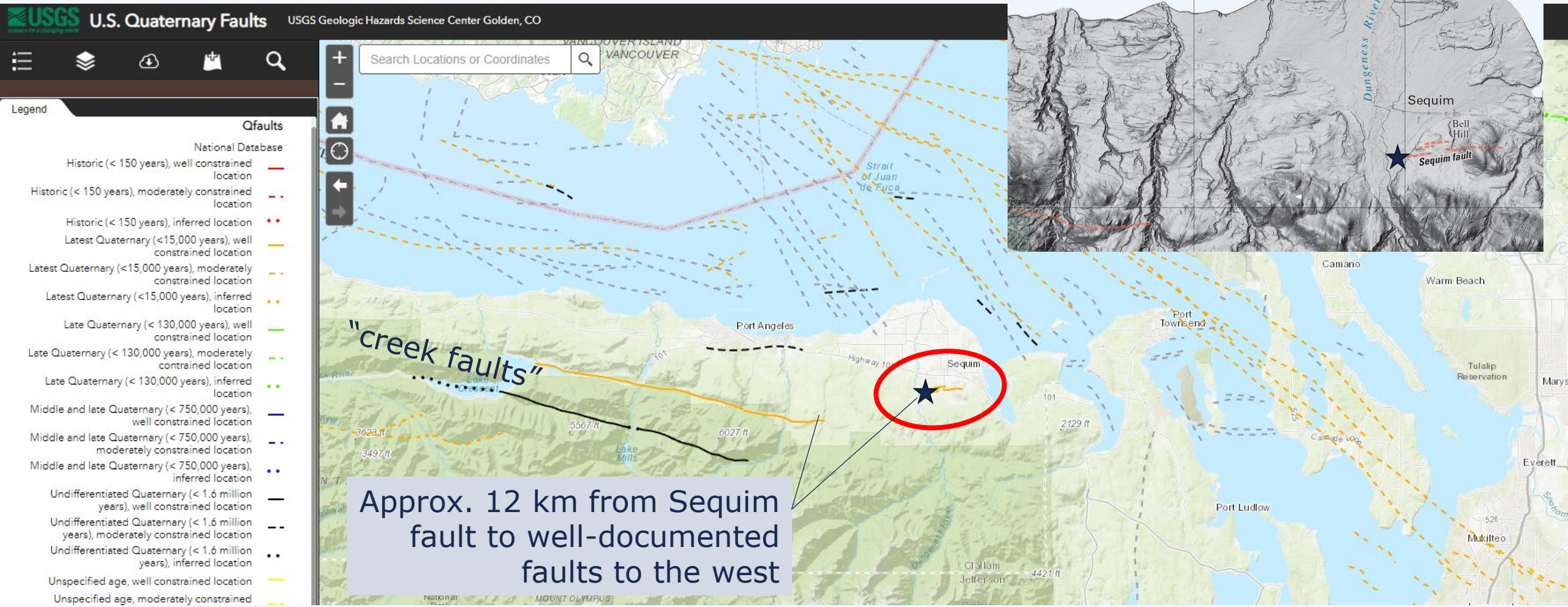

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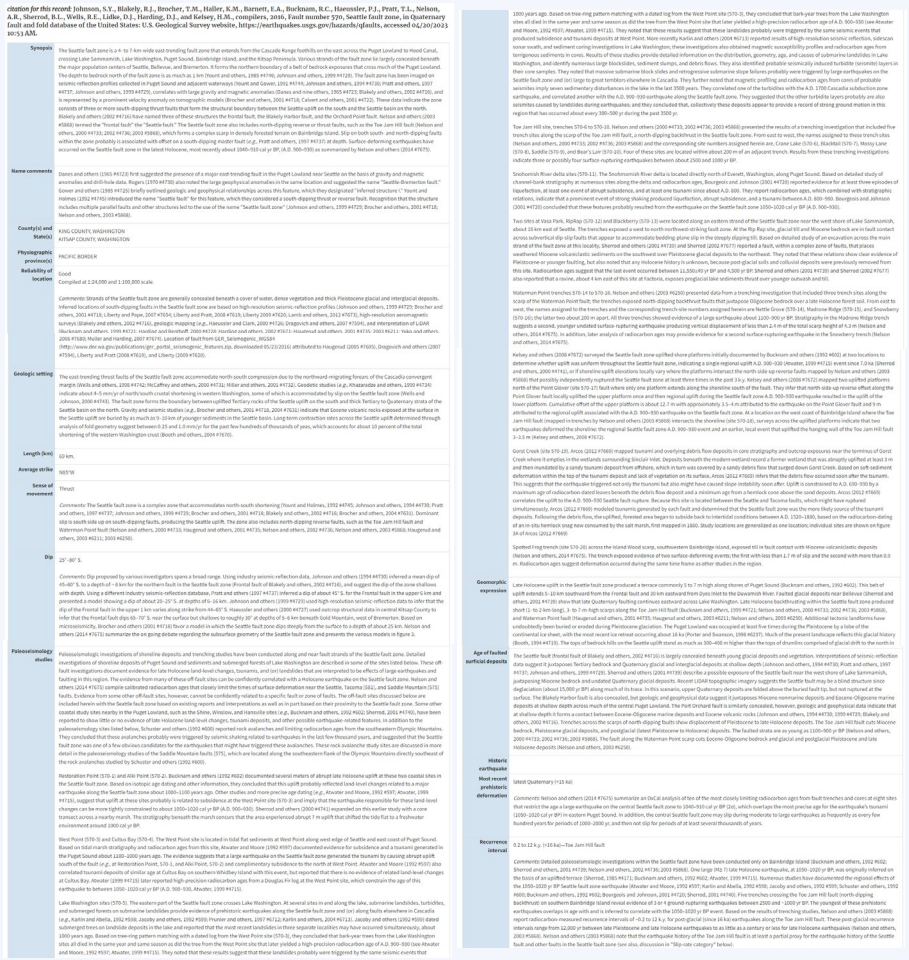
citation for this record: , compiler, 2017, Fault number 549, Sequim fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 04/20/2023 11:04 AM.

Synopsis	
Name comments	
County(s) and State(s)	CLALLAM COUNTY, WASHINGTON
Physiographic province(s)	PACIFIC BORDER
Reliability of location	Compiled at 1:unspecified scale. *Comments:* WA attributed to Nelson and others (2007) mapped at unspecified scale.
Geologic setting	
Length (km)	7 km.
Average strike	
Sense of movement	Unspecified
Dip	
Paleoseismology studies	
Geomorphic expression	
Age of faulted surficial deposits	
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:*
Recurrence interval	
Slip-rate category	Unspecified
Date and Compiler(s)	2017
References	#6916 Nelson, A.R., Personius, S.F., Buck, J., Bradley, L-A., Wells, R.E., Schermer, E.R., 2007, Field and laboratory data from an earthquake history study of scarps of the Lake Creek-Boundary Creek fault between the Elwha River and Siebert Creek, Clallam County, Washington: U.S. Geological Survey Scientific Investigations Map 2961, 2 sheets.

Sum of all knowledge of the Sequim fault



…plus 60 references covering pages

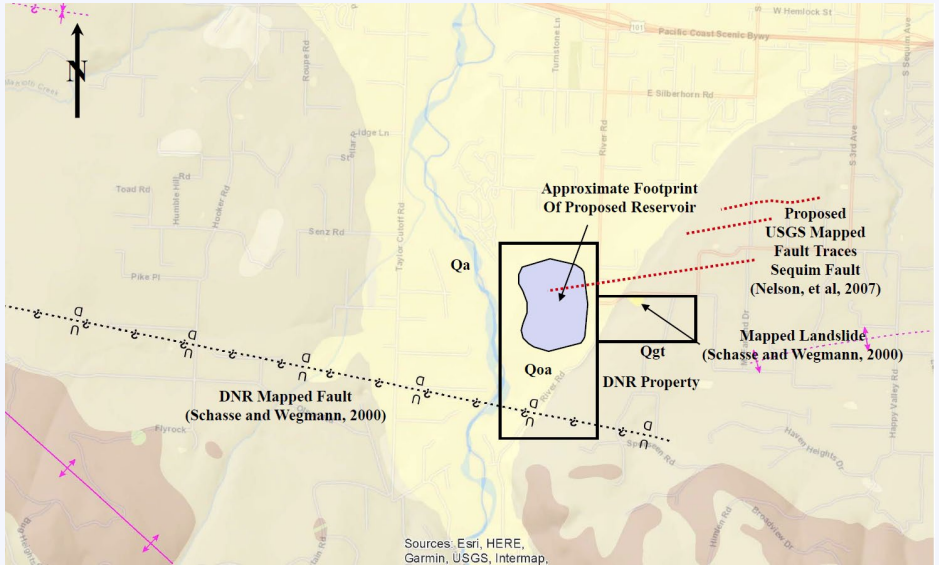
- Database entry for the Sequim fault (left) is sparce compared with the database entry for the Seattle fault (right)

- Prior communication between S&W and the USGS suggests the survey was in favor of reclassifying the Sequim fault from a Class A to Class B fault:
  - Class A: "Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed for mapping or inferred from liquefaction or other deformational features."
  - Class B: "Geologic evidence demonstrates the existence of a fault **or** suggests Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.

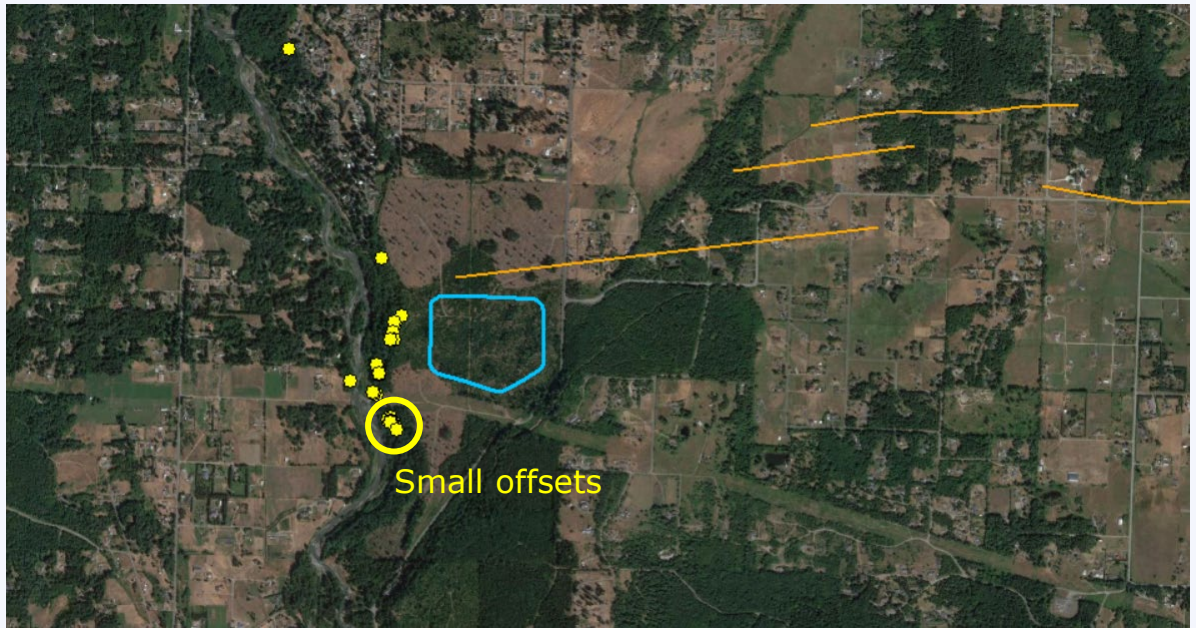
Source: https://www.usgs.gov/programs/earthquake-hazards/faults

Investigation of the Sequim Fault for the DOCR

- PanGEO Report (2020)
  - Nelson (2007) is basis for fault
  - Faults in previous geologic maps are questionable
  - B. Sherrod and S. Angster of USGS performed field recon with PanGEO
  - Recon revealed 'No certain evidence of past faulting/Holocene movement'



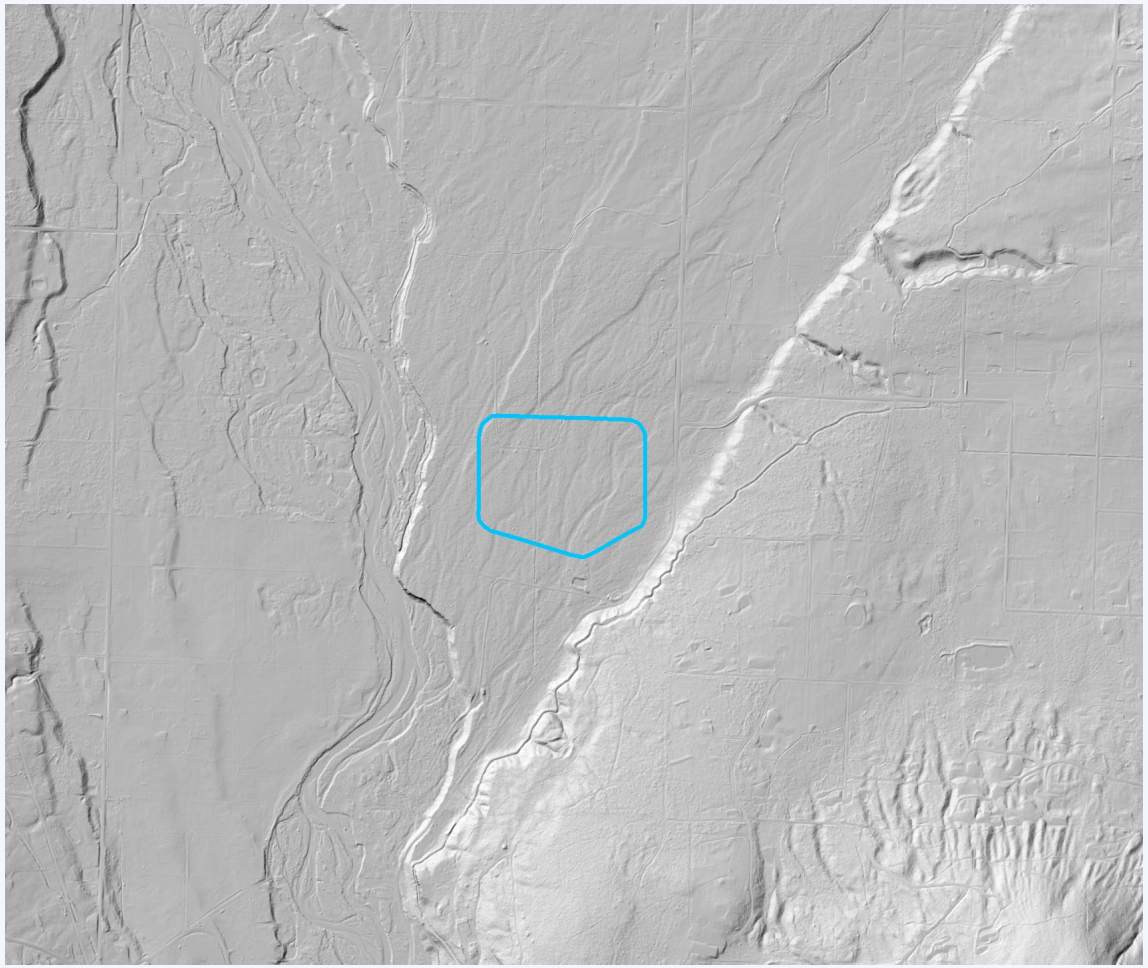
- Shannon & Wilson recon (2021)
  - D. O'Malley and W. Pollock
  - Observed several small-offset fractures in bluff southeast of the site



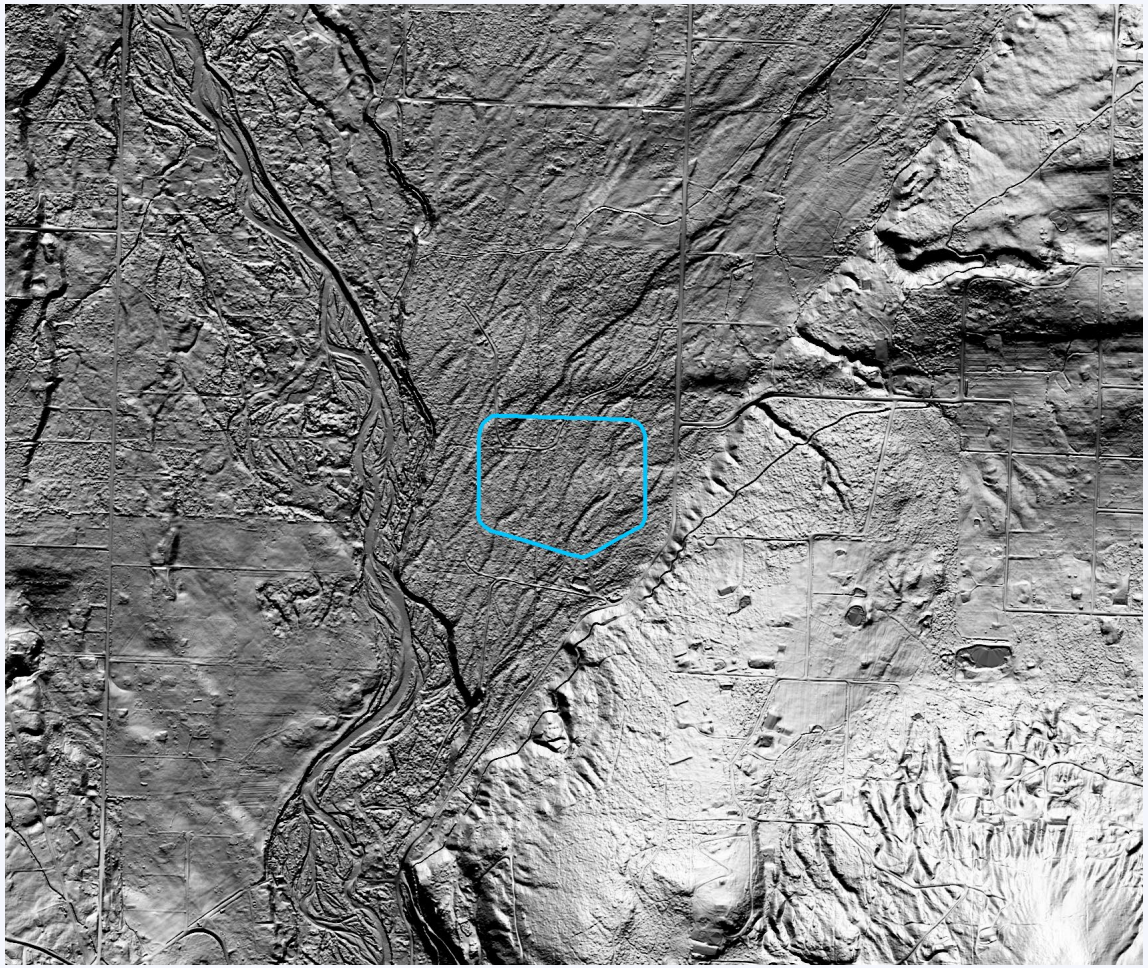
S&W Reevaluation of the Sequim Fault

- Downloaded digital terrain model (DTM) for the 2019 Olympic Peninsula Washington 3DEP Project administered by the USGS
- 3 ft x 3 ft grid resolution with average ground classification (non-vegetation, -structure, -vehicle, etc.) of 1.84 points/m^2; vertical accuracy on the order of 10 to 20 cm.
- The DTM was used to develop several derivative topographic products:
  - **Hillshades** with various sun azimuth, angle and vertical exaggeration
  - **Slope** (visually manipulated to highlight shallow slope angles)
  - **Local relief** (moving window to calculate high and low elevation within window)
  - **Low pass filter** (nine-pixel moving window, assigns average value – removes speckling and sharpness, typically not related to natural topography)

HILLSHADE

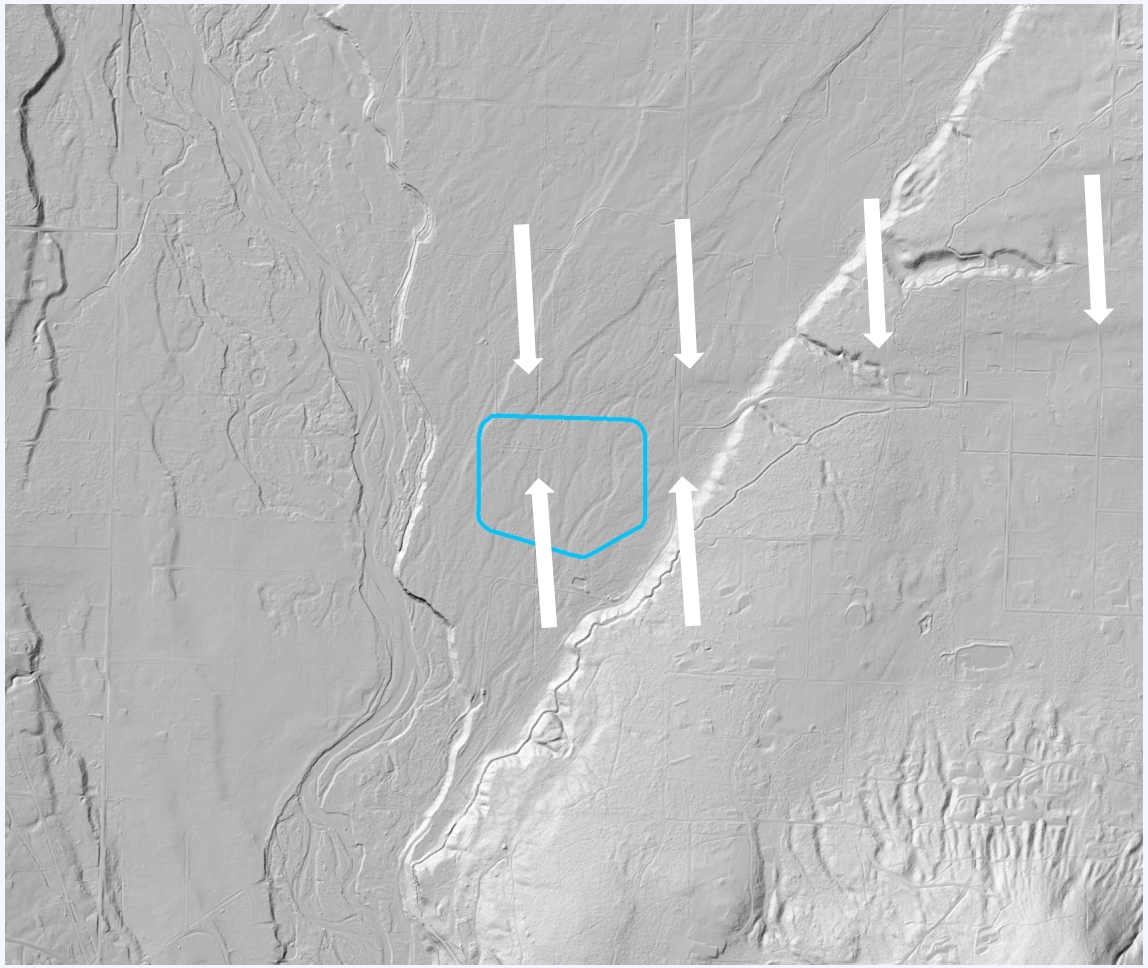


Sun azimuth: 315°
Sun angle: 45°
Vertical exaggeration: 1x



Sun azimuth: 0°
Sun angle: 20°
Vertical exaggeration: 10x

HILLSHADE



Sun azimuth: 315°
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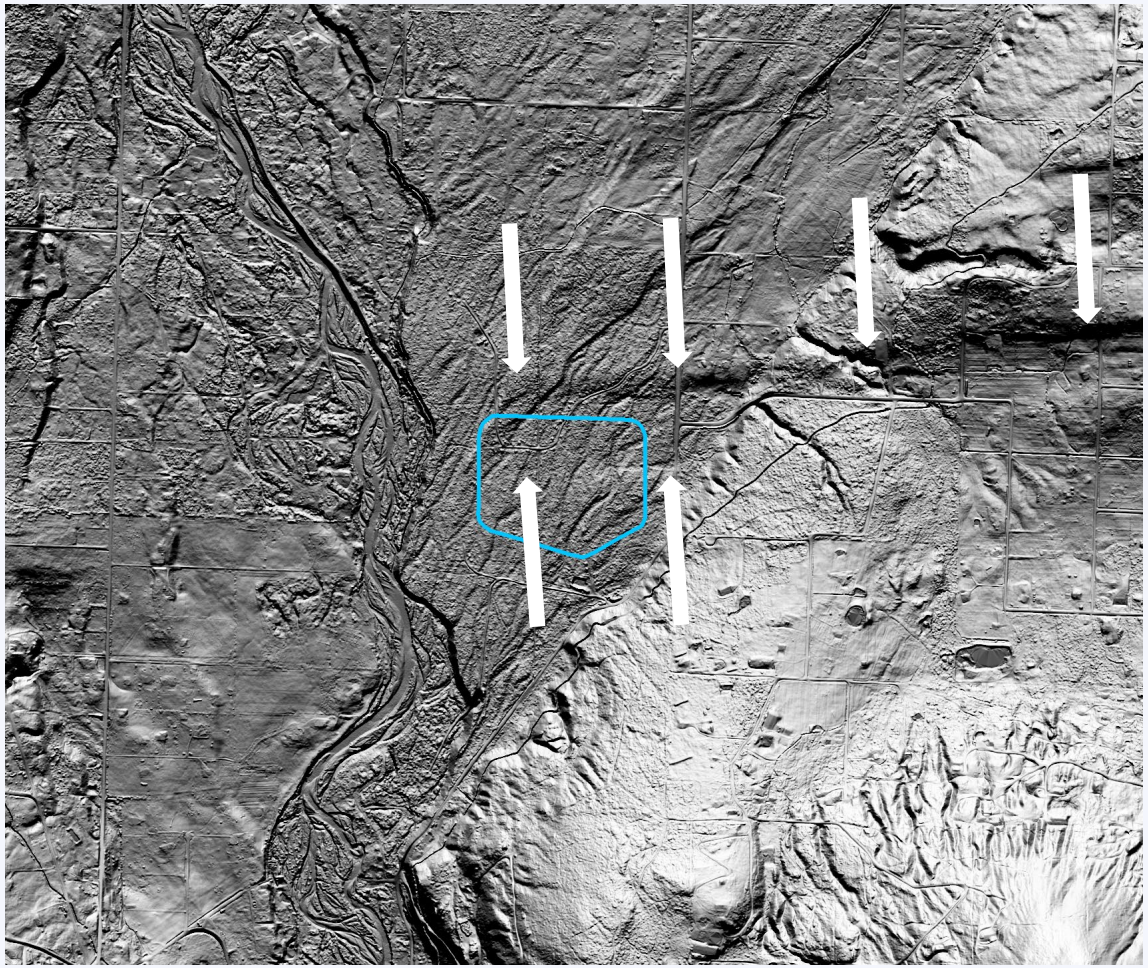
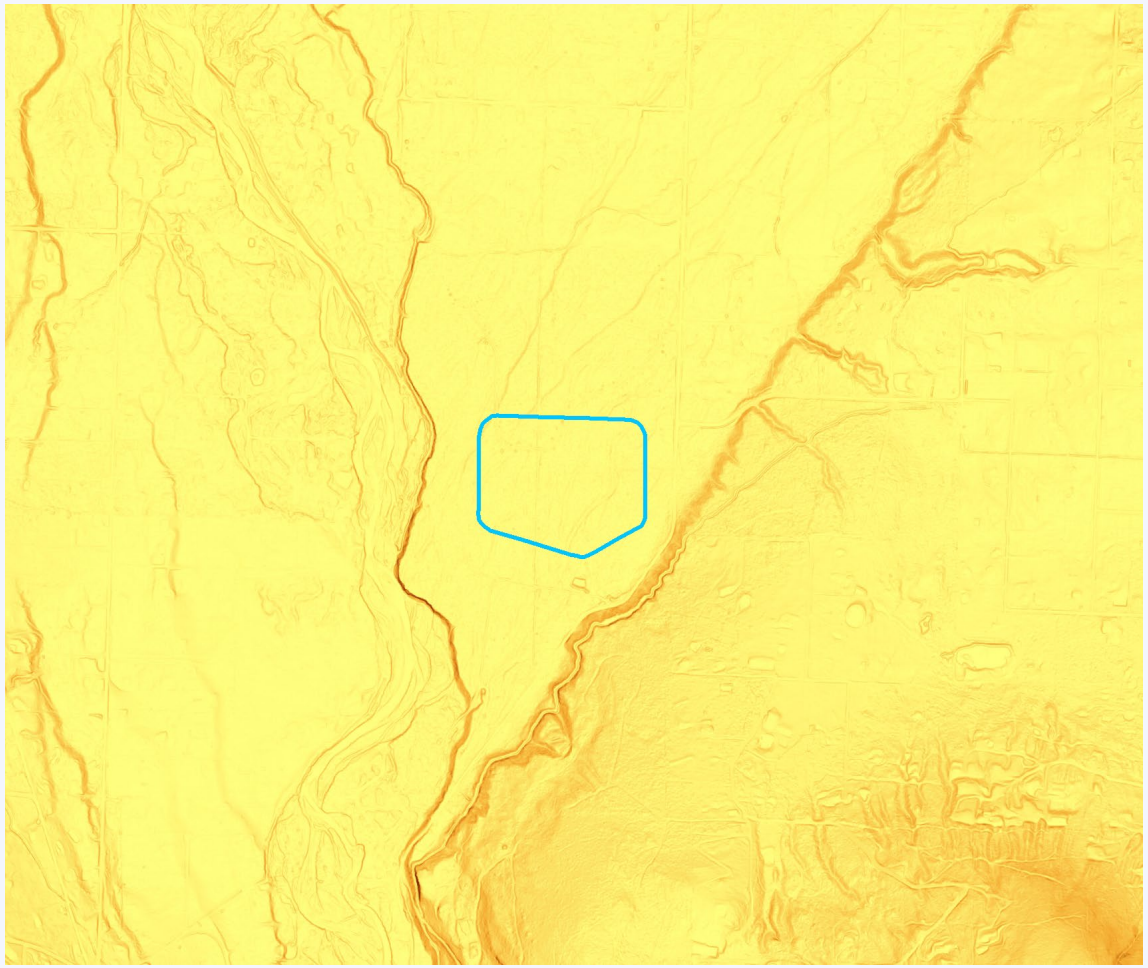
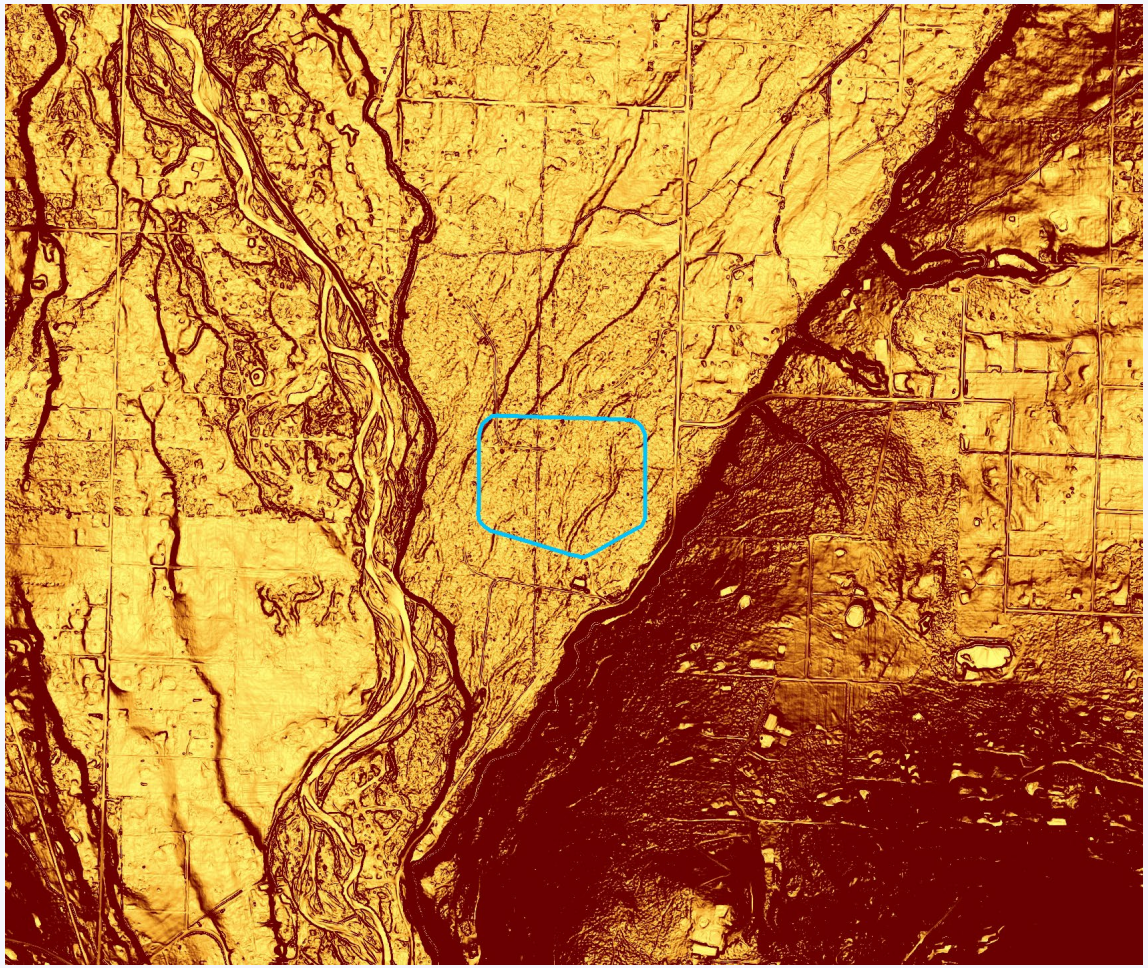


Sun azimuth: 0°
Sun angle: 20°
Vertical exaggeration: 10x

SLOPE

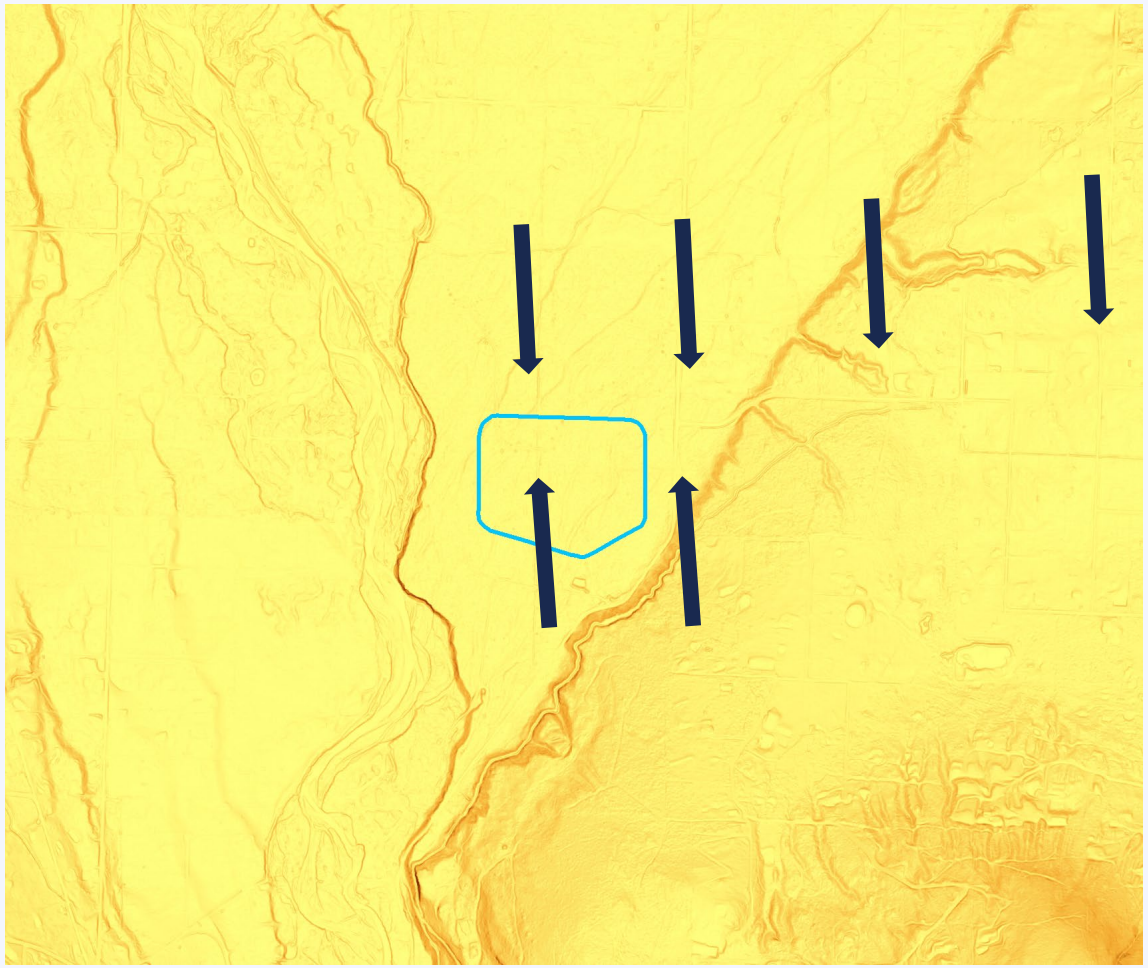


Ramped 0° to 80° (max)

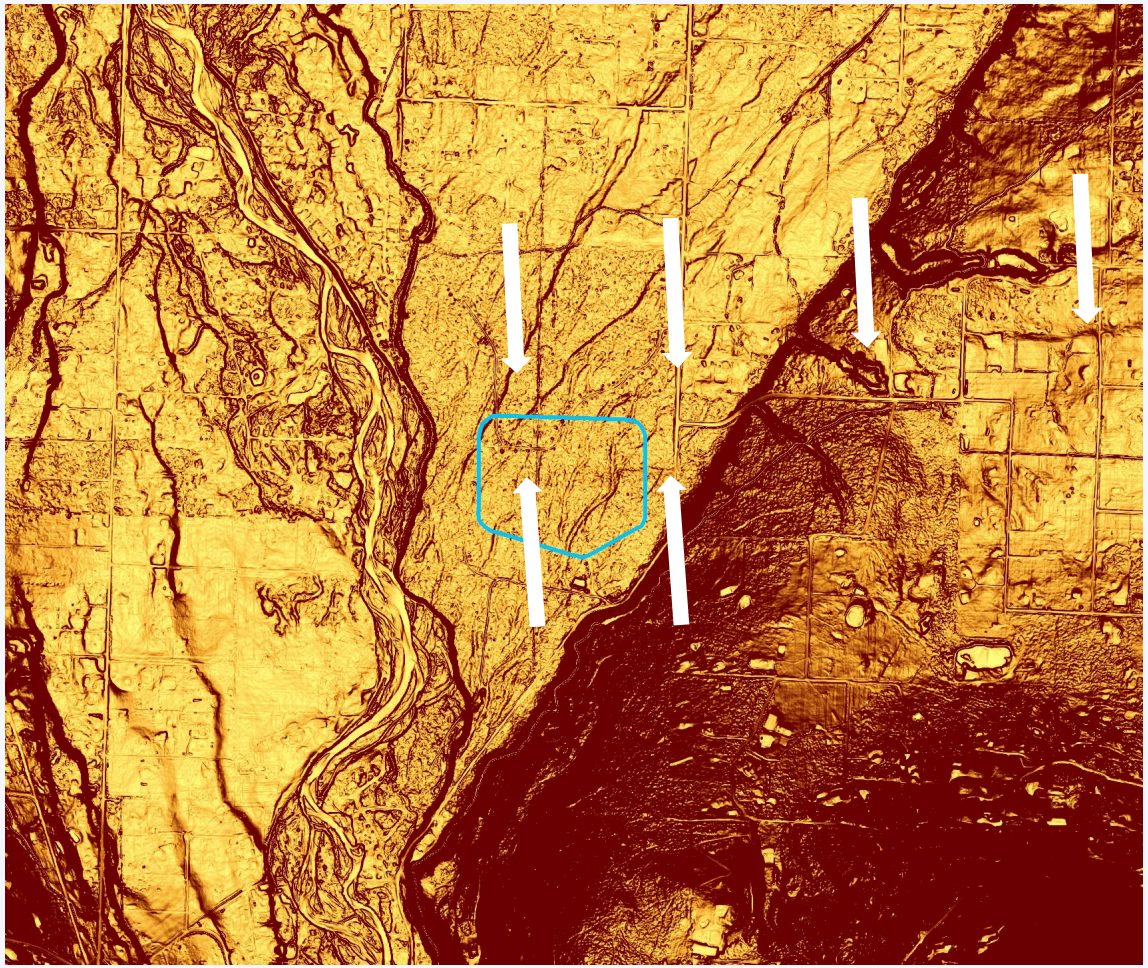


Ramped 0° to 6°

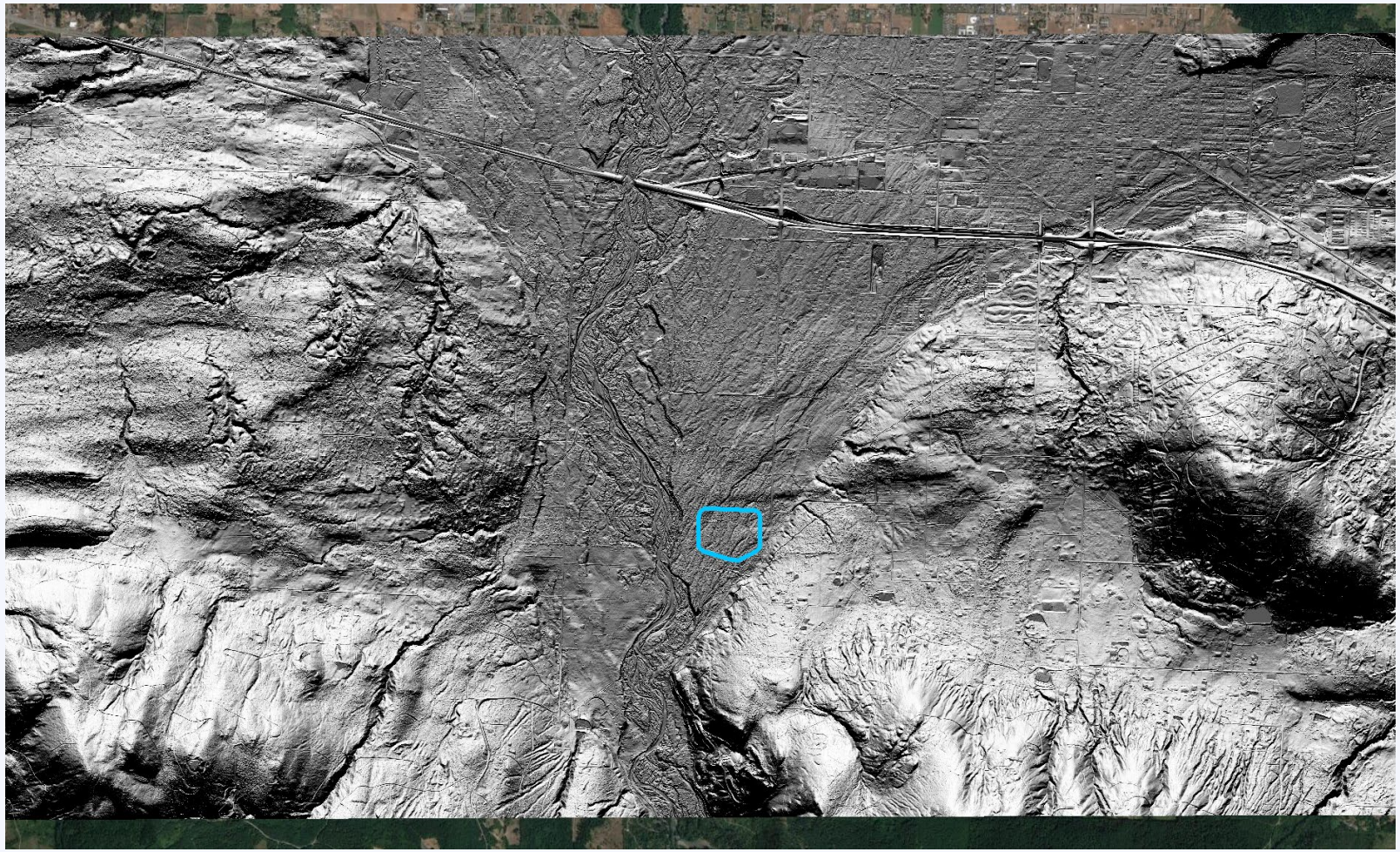
SLOPE

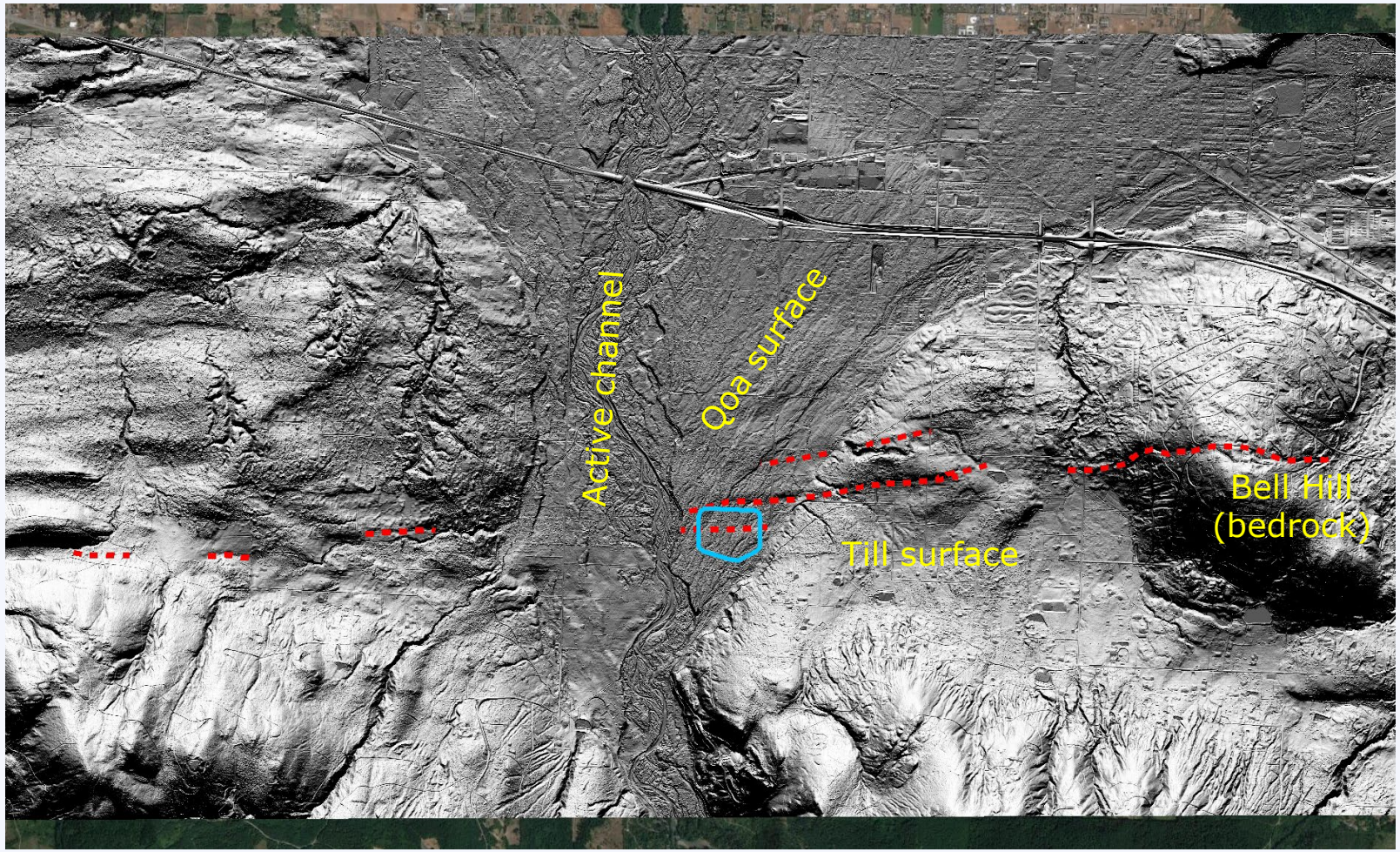


Ramped 0° to 80° (max)

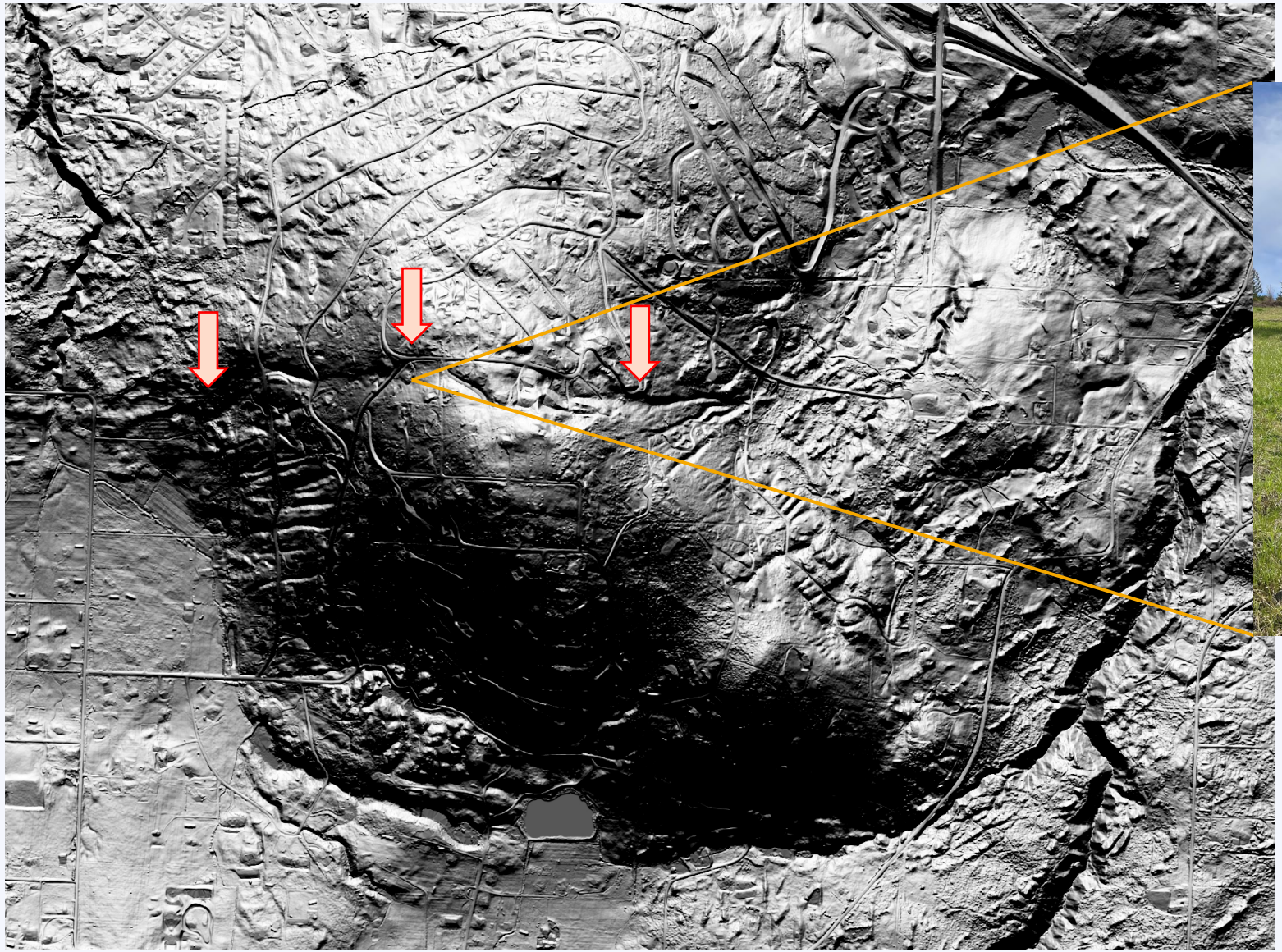


Ramped 0° to 6°



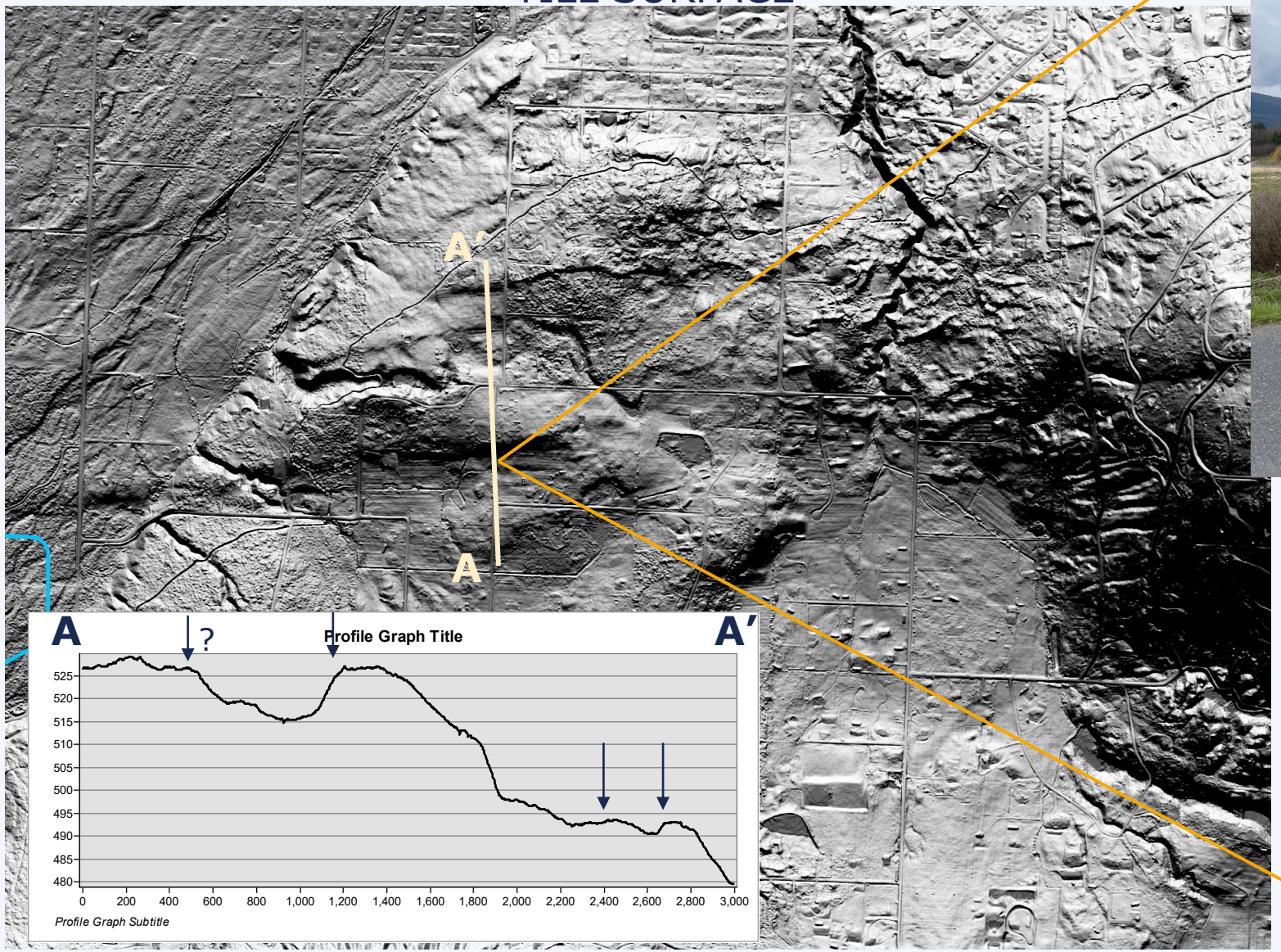

Active channel
Qoa surface
Till surface
Bell Hill
(bedrock)

BELL HILL

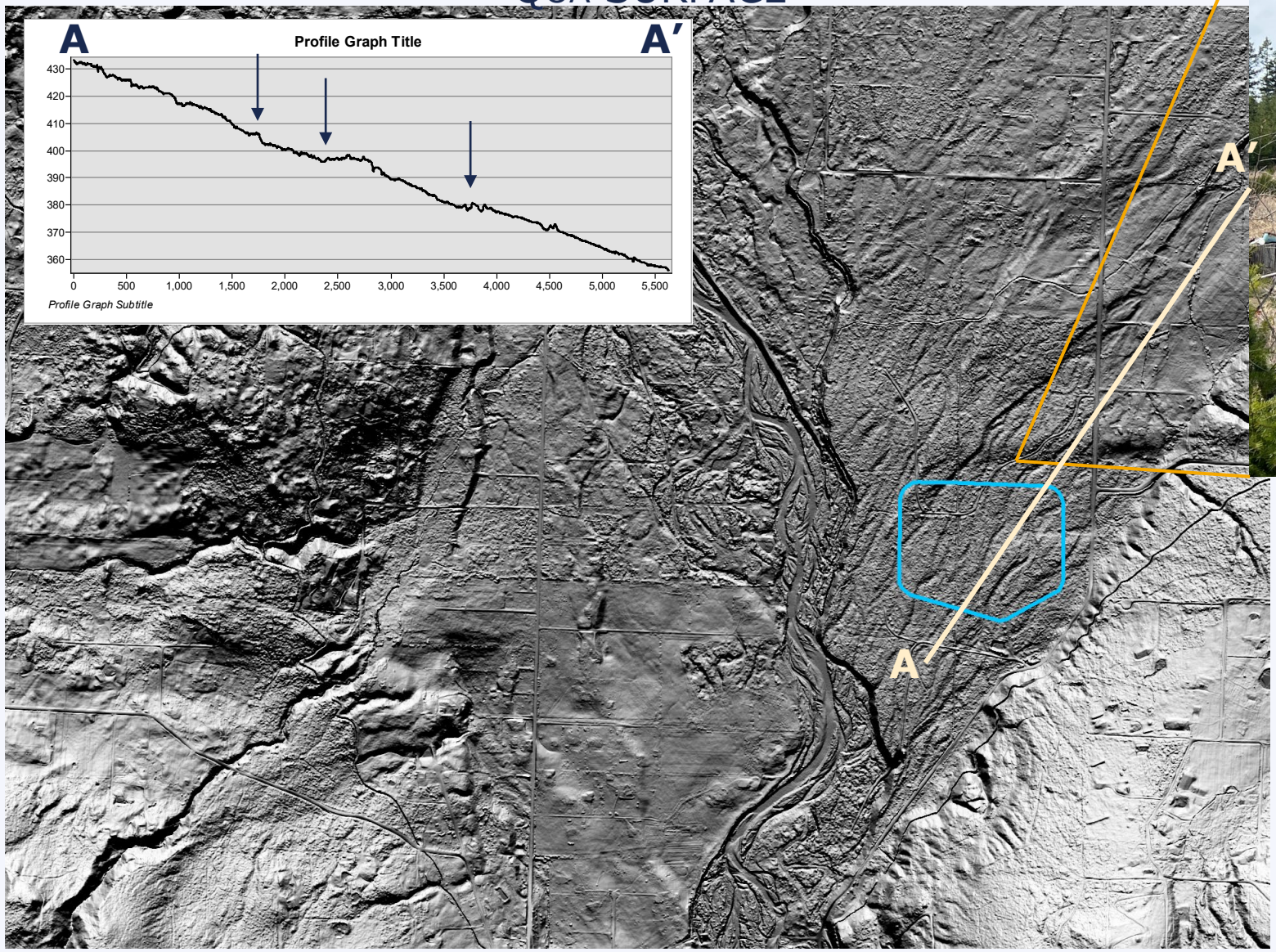


Subtle geomorphic features commonly associated with surface rupture noted along interpreted fault trace such as drainage capture and swales

TILL SURFACE

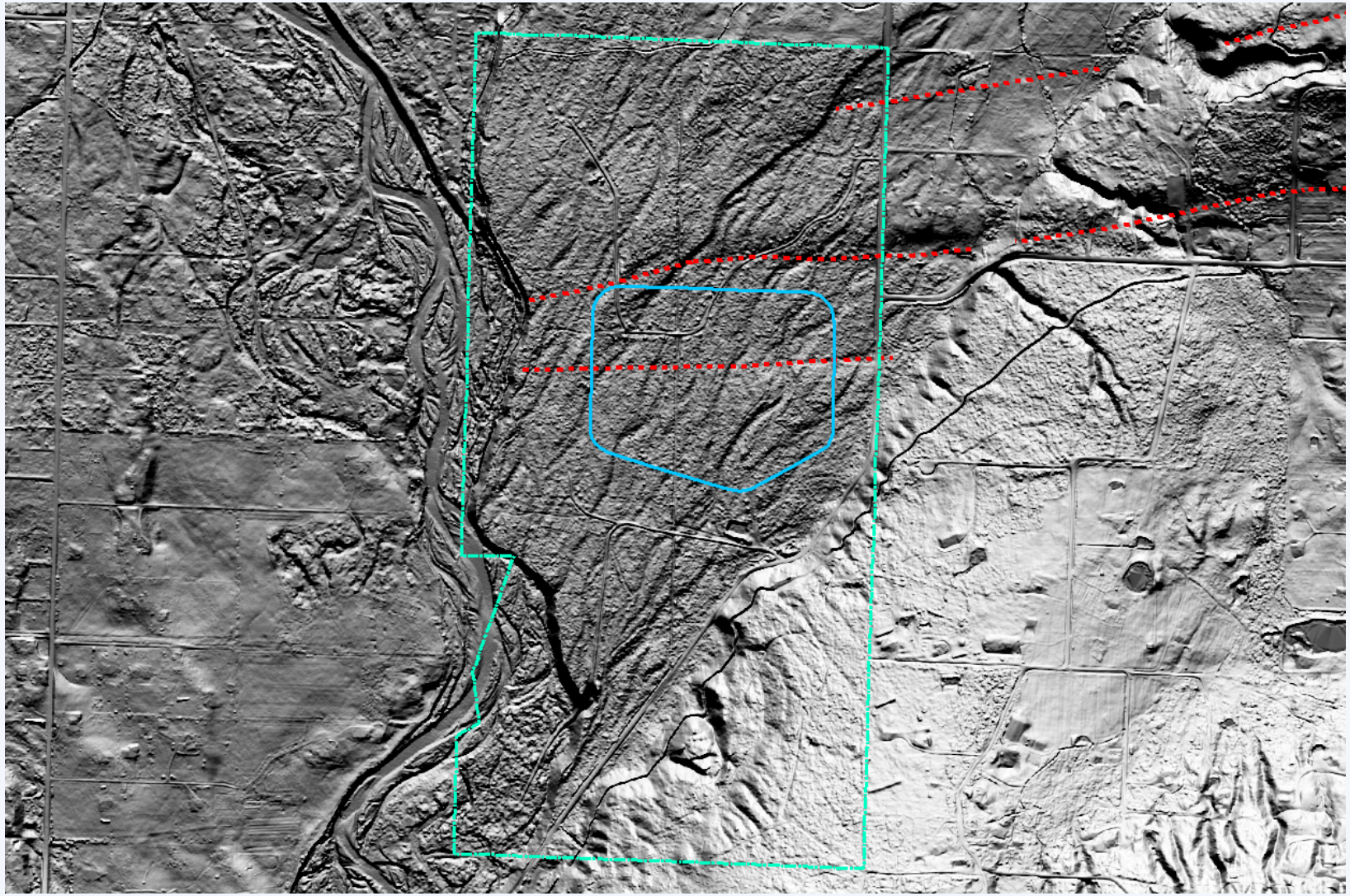


Qoa SURFACE



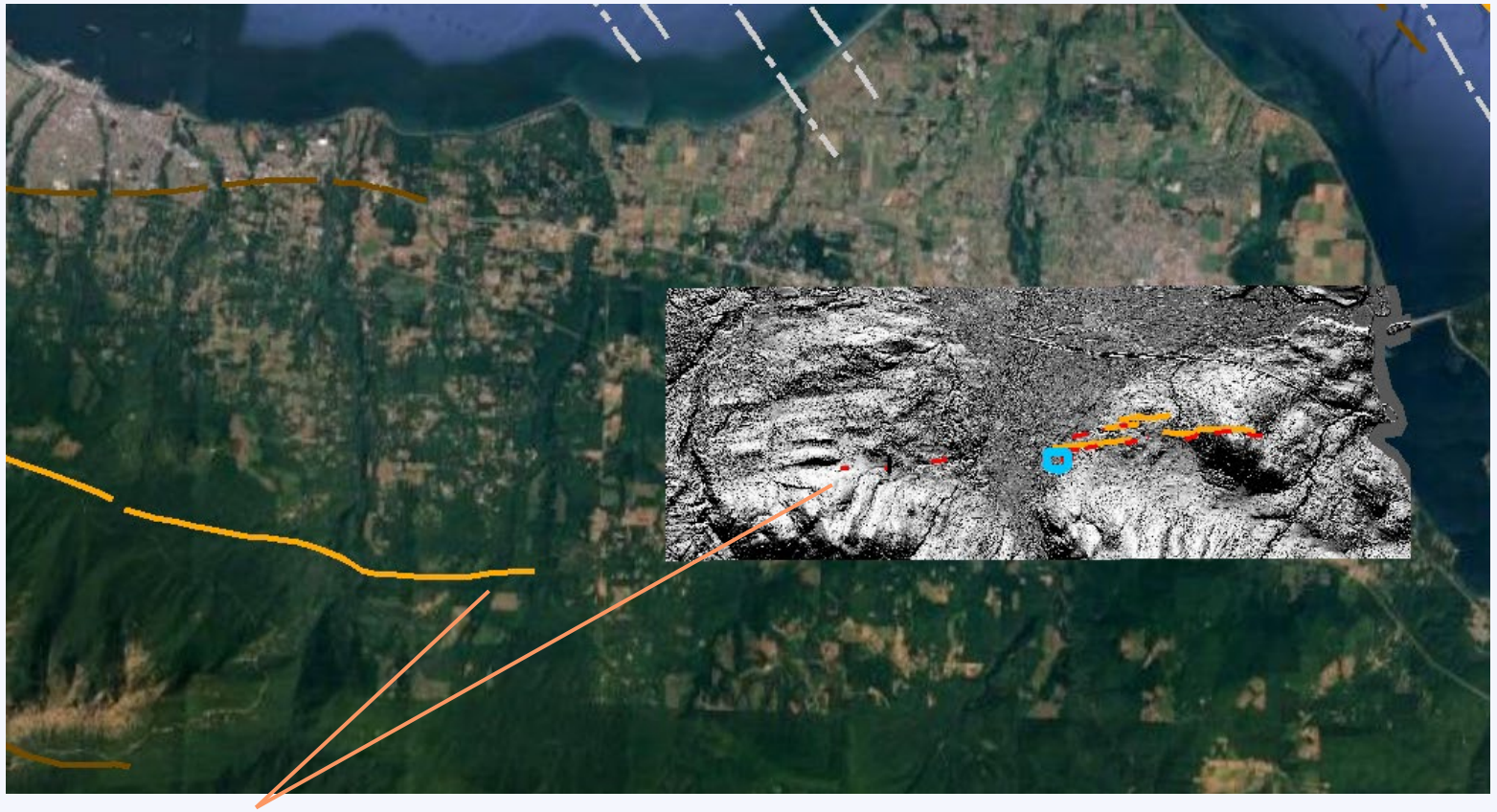
Subtle slope associated with scarp. Broad width and short height did not photograph well and were difficult to positively identify in the field. Abundant natural and artificial microtopography also obscured scarp.

Property Boundary



Qoa extends to near base of bluff north/downstream of scarps

Qoa over glacial (advance?) outwash in the vicinity of the project of the scarps. This is also approx. the most downstream exposure of glacial deposits, which have been covered by colluvium and/or vegetation. Note tilted bedding transitioning to horizontal bedding (many potential causes).



- Approx. 7 km to well documented faults to the west
- Little confidence in what has been mapped of the Sequim fault west of the Dungeness River valley

Alternative Hypotheses of Origin

Supporting	Opposing

• Tectonic fault
  • Linearity
  • Corresponding differences in scarp height in different age material (number of recorded events)
  • Uphill-facing
  • Generally similar orientation to known faults to the west
	• Very subtle, inconclusive in Qoa in field
	• Short, no obvious structural link to faults to the west
	• Inconsistent relationship with MASW till depth

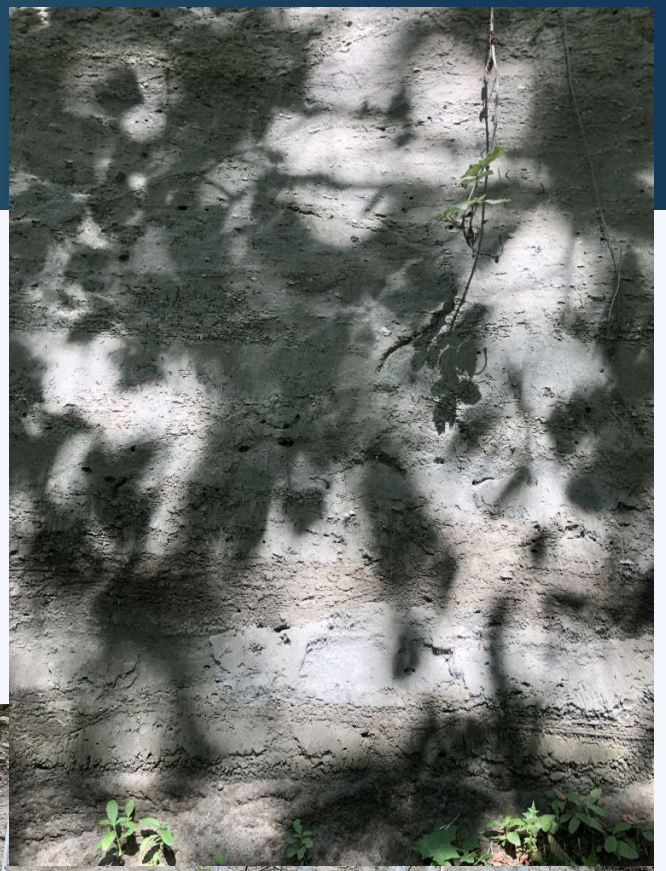
• Cracking/settlement/liquefaction
  • Diffuse scarps
  • Graben
	• Linearity (weak evidence)
	• Corresponding differences in scarp height in different age material would be unlikely

• Bedrock high
  • Scarps align with bedrock fabric to west
  • Differential settlement (low and high)
	• Corresponding differences in scarp height in different age material would be unlikely

• Anthropogenic
  • Active logging area
  • Noticed evidence of ground disturbance
	• Longer than would be expected

Additional Study

- Given the uncertainty in the origin of the observed topographic scarps, additional study may be warranted to understand whether they are fault-related, and if so, their age.
- Possible additional study methods / activities
  - Geomorphic mapping
    - Enhance lidar, additional assessments, profiles, etc.
  - Log Dungeness River east bluff
    - Clean selected areas with excavator or backhoe to facilitate observation
  - Trench excavation
    - Dozer or excavator trench across north and south scarps
    - Log exposures
    - Will likely require deep excavation
- Phased approach may be recommended



- Large exposure in river bluff south/upstream of site. Glacial stratigraphy ideal for identification of deformation. Observed several small offsets, interpreted as glaciotectonic.

Questions

1. Is there a fault? If there is a fault, is it active?
2. What level of confidence can be gained about the presence or absence of an active fault?
    a. Desktop work
    b. Field Work
3. If there is an active fault, what are the implications for the use of the site?
4. How can the presence of a fault be addressed in the reservoir design?

Questions from the County…