

Landslides and Related Mass Wasting Features in the Yakima River Corridor Field Trip

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Field Trip Overview

Field Trip Description:

Central Washington includes a variety of landslides and related “mass wasting” features. Why? What causes these? How active are they? What have they impacted? On this trip, we will explore the evidence of various types of mass wasting along the Yakima River corridor from east of Cle Elum to south of Union Gap. Examples will include landslides, debris flows, rockfall, dry ravel, and creep. Along the way, we will develop a sense of what indicates past mass wasting, what caused it, what are its implications on the surroundings, and where it might occur again in the future. Our stops will range from ancient landslides to recent debris flows to the currently active Rattlesnake slide.

Tentative Schedule:

10:00am	Depart CWU
10:30	Stop 1— Lambert Road, East of Cle Elum
11:15pm	Depart
11:45	Stop 2—Near MP 101, WA 10, North of Thorp
12:45	Depart
1:30	Stop 3—MP 20, WA 821, Yakima River Canyon
2:30	Depart
3:00	Stop 4—Between MP 3 and 4, WA 821, Yakima River Canyon
3:45	Depart
4:15	Stop 5—North of MP 74, US 97, South of Union Gap
5:00	Depart
6:00	Arrive at CWU

Our Route & Stops



Figure 1. General route map of field trip. Source: Google Maps.

Ellensburg to Lambert Road

Route. From Ellensburg, head west on I-90 toward Cle Elum. Take Exit 85 (the first Cle Elum exit when westbound). At the yield sign on the off ramp, turn right onto WA 970 toward Wenatchee. Follow this approximately 3 miles east just past the junction of WA 970 and WA 10. Turn right (east) onto Lambert Road and follow this to its crossing of the Teanaway River. East of the bridge, pull off to the right side of Lambert Road and park. **Please do not park on the bridge!** This is Stop 1.

Kittitas Basin geology. Our drive from Ellensburg begins on the floor of the Kittitas Basin *syncline* with downfolded Columbia River Basalts ~4000 feet below us (Figures 2, 3, & 4). Mantling the Columbia River Basalts are volcanic *lahar* sediments of the Ellensburg Formation, *alluvial fan* sediments from streams exiting the surrounding mountains, and windblown *loess* (Waite, 1979; Tabor and others, 1982).

Mass wasting at 70 mph. Just west of Thorp, look north and see a steep escarpment in the Ellensburg Formation and overlying alluvial Thorp Gravels. At the toe of this escarpment, you will a “hummocky” surface. This escarpment and the hummocky deposits represent huge, mostly ancient landslides. We will discuss these landslides enroute to Stop 2.

Past glaciers. West of Thorp, we ascend from the Kittitas Basin onto Elk Heights (or “Thorp Prairie”). This surface consists of Columbia River Basalts overlain by older glacial *end moraine* and more recent loess. The end moraine mantling Thorp Prairie represents the farthest downvalley extent of the Upper Yakima River Watershed glaciers during the Kittitas-Swauk Prairie glaciation (Porter, 1976; Waite, 1979) (Figure 5). These are also apparently the farthest downvalley extents of any glaciers in the Upper Yakima River Watershed. Thorp Prairie moraines are thought to be the same age as those of Swauk Prairie to the north (Figures 5 & 7). Therefore, the Kittitas-age glacier that deposited these features had split into two lobes near its terminus because of prominent Lookout Mountain. The glacier that deposited these moraines formed from coalescence of the Cle Elum, Kachess, and Keechelus valley glaciers (Figure 8). At its maximum extent, >500,000 years before present, this glacier was >40 miles long (Swanson and Porter, 1997).

Kittitas Basin climate. The wind towers of the Kittitas Valley Wind Farm remind us of the regularity and strength of winds in the Kittitas Basin. The thick, fine textured deposits of loess that blanket the Thorp Prairie area are a reminder of the importance of wind over time as well.

Ellensburg to Lambert Road

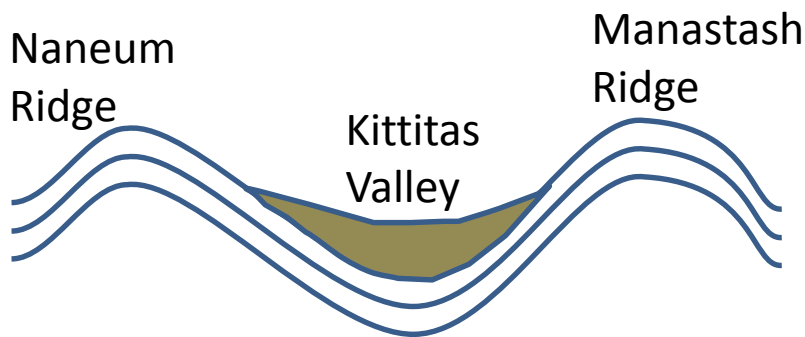


Figure 2. Location of Kittitas Basin syncline between Naneum Ridge and Manastash Ridge anticlines. Source: Jack Powell.

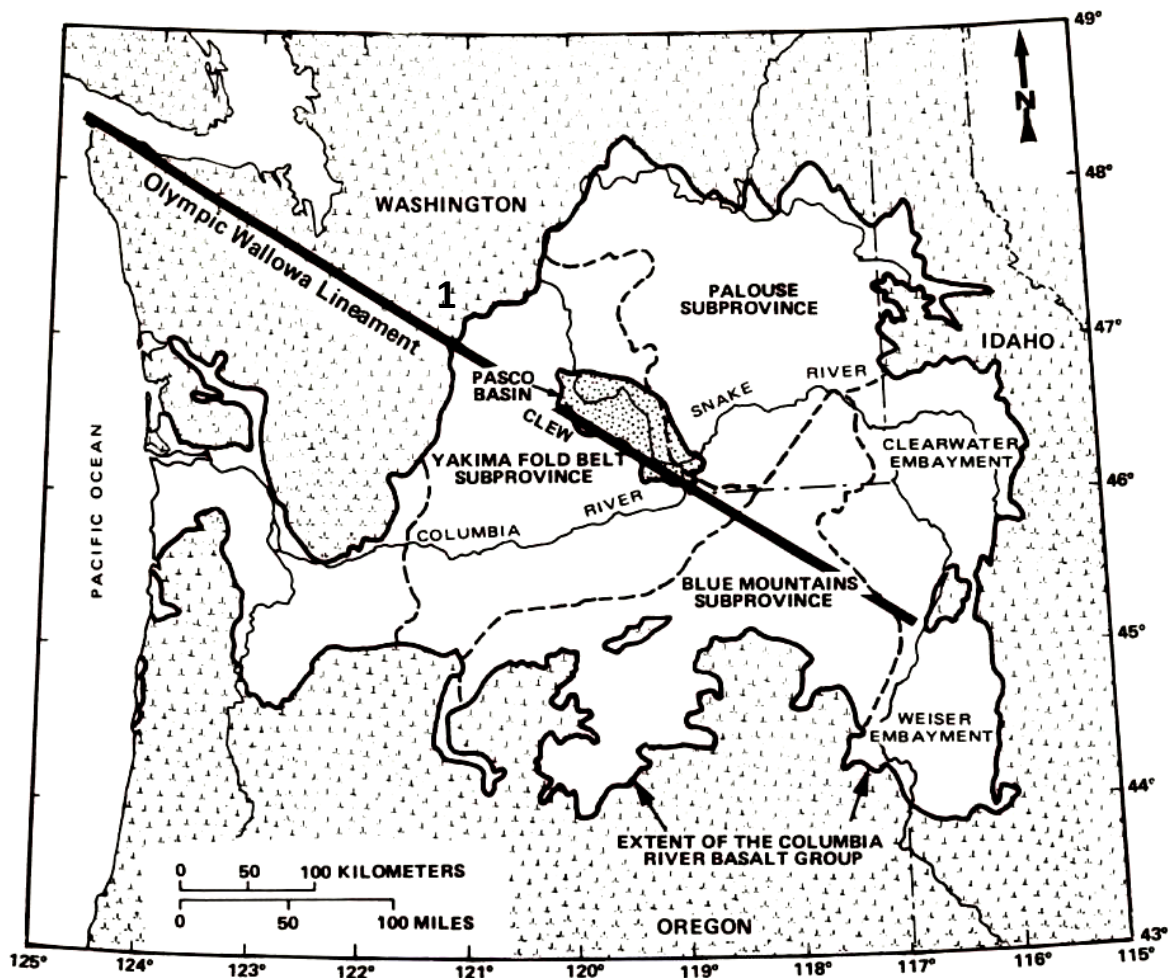


Figure 3. The Columbia Plateau and the spatial extent of the Columbia River Basalt Group, the four major structural-tectonic subprovinces (the Yakima Fold Belt, Palouse, Blue Mountains, and Clearwater-Weiser embayments), the Pasco Basin, the Olympic-Wallowa lineament. Number 1 indicates approximate location of Stop 1. Source: Reidel & Campbell (1989, p. 281).

Ellensburg to Lambert Road

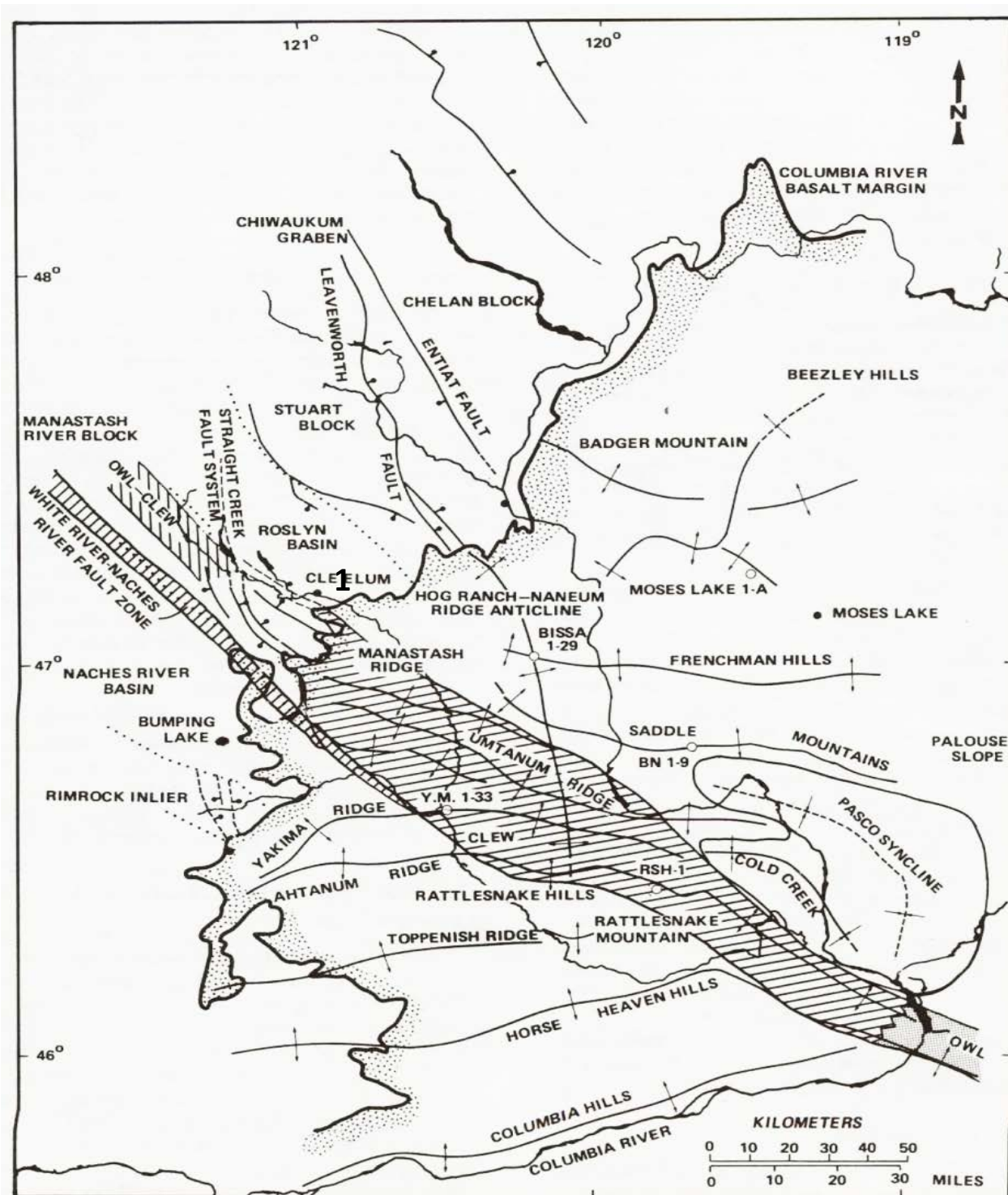


Figure 4. Generalized map of major faults and folds along the western margin of the Columbia Plateau and Yakima Fold Belt. Bold number 1 indicates approximate location of Stop 1. Source: Reidel & Campbell (1989, p. 281).

Ellensburg to Lambert Road



Figure 5. Glacial-geologic map of the Upper Yakima River drainage basin. Bold number 1 indicates approximate location of Stop 1. Source: Porter (1976, p. 62).

Stop 1—Lambert Road

Location. We are located on the floodplain of the Teanaway River near its junction with the Yakima River. Lookout Mountain to our east represents the westernmost extent of Columbia River Basalts in the area.

Mass wasting. Mass wasting includes all types of gravity-driven slope movements including:

- slide
- flow
- creep
- fall
- dry ravel

Often these movements may occur together in the same area. Central Washington's Yakima River corridor is characterized by all of these forms of mass wasting. Our focus at Stop 1 is on slides and falls.

Landslides & their evidence. Landslides are just that—sliding masses of land that may also include surficial features such as trees and various human structures. Evidence for landslides includes:

- tilted features—land, trees, fences, etc.
- escarpments (often arcuate & vegetation free)
- tension cracks
- displaced blocks (often as steps on slope)
- hummocky terrain
- ponds/wetlands
- sharp bends in roads & streams
- fan-shaped deposits
- pressure ridges
- deranged drainage patterns

Which of those pieces of evidence do you see here?

Types of landslides. Two varieties of landslides exist—*translational* (like a sled on hill) and *rotational* (like sliding or slumping down in a chair or couch). For this reason, rotational slides are also referred to as *slumps*. The recent Oso Landslide that resulted in the deaths of 44 Stillaguamish River residents was a rotational slide with a flow at the toe. Translational and rotational slides occur on steep slopes. Translational slides typically follow geological structures such as layers of bedrock or sediment. Rotational slides typically cut across bedding. The easiest way to differentiate the two is based on the presence or absence of of backtilted blocks in the upper portions of the slide—i.e, if present, the feature is a rotational slide (Figure 6).

Stop 1—Lambert Road

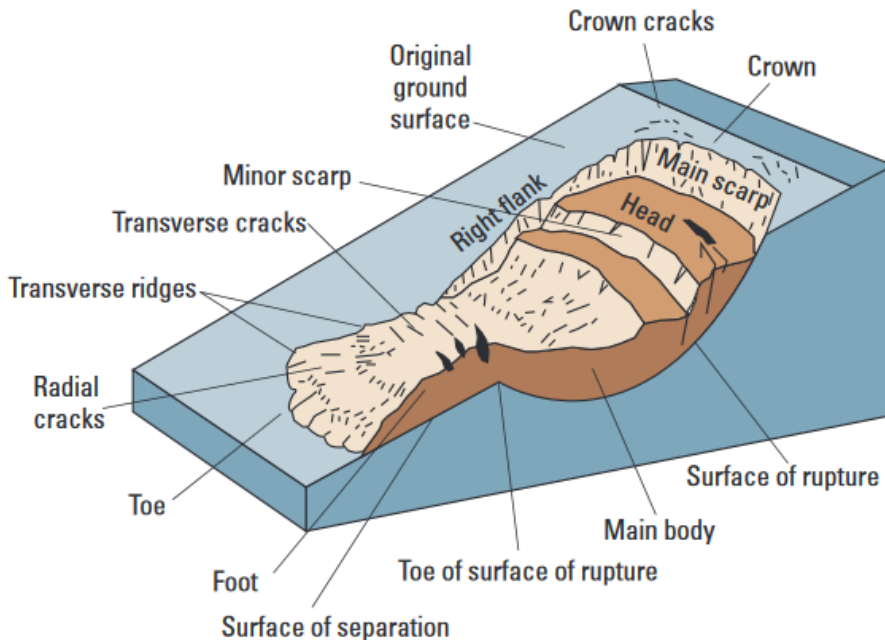


Figure 6. Model of a rotational slide. Source: Highland and Bobrowsky, 2008, p. 5)

Lookout Mountain rotational landslide and rockfall. The Lookout Mountain landslide was first recognized by Russell (1900) and Smith (1904). It is a large, rotational landslide that occurred in prehistoric times. Evidence for this rotational slide includes: 1) the prominent escarpment (i.e., main scarp) high on Lookout Mountain; 2) the large, backtilted blocks and associated minor scarps and ponds just downslope of the escarpment; and 3) the hummocky toe that extends to the Teanaway River near here (Figures 8, 9, & 10). At least four ponds are impounded within the large slide blocks. Subsequent rockfall occurred from the near vertical, bare, basalt face of the main scarp.

Age. How old is the feature? First, we don't know if the slide occurred all at once or piecemeal over time. Second, we can only address its age in a relative sense. Smith (1904) recognized a river terrace atop the middle portion of the slide. Waitt (in Tabor and others, 1982) attributes that terrace to the Swauk Prairie-age glacial outwash deposits. Recall that Swanson and Porter (1997) estimate that Swauk Prairie deposits are >500,000 years old so this slide is potentially more than one-half million years old! This is hard to believe given that the feature is so well-preserved. Perhaps this preservation is due to the semiarid climate and the hard basalts so little degradation has occurred over time.

Stop 1—Lambert Road

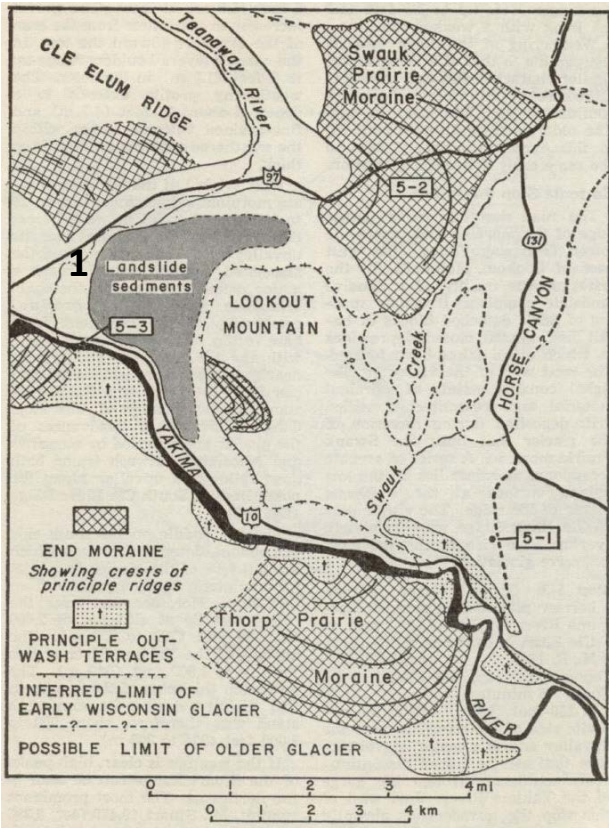


Figure 7. Middle Pleistocene glacial features in the vicinity of Lookout Mountain, Upper Yakima River Watershed. Bold number 1 indicates field trip stop. Source: Porter (1965, p. 37).

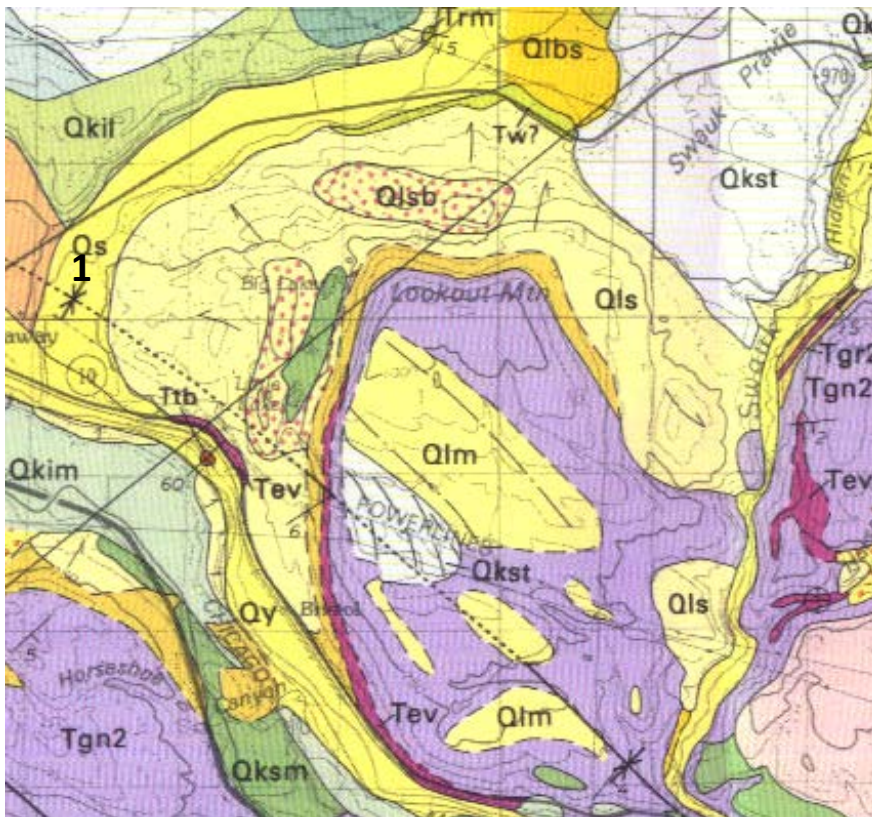


Figure 8. Geologic map of Stop 1 and vicinity. Bold number 1 indicates field trip stop location. Purple = Columbia River Basalt, pale yellow with arrows = alluvium, and bright yellow = landslides. From Tabor & others (1982)

Stop 1—Lambert Road

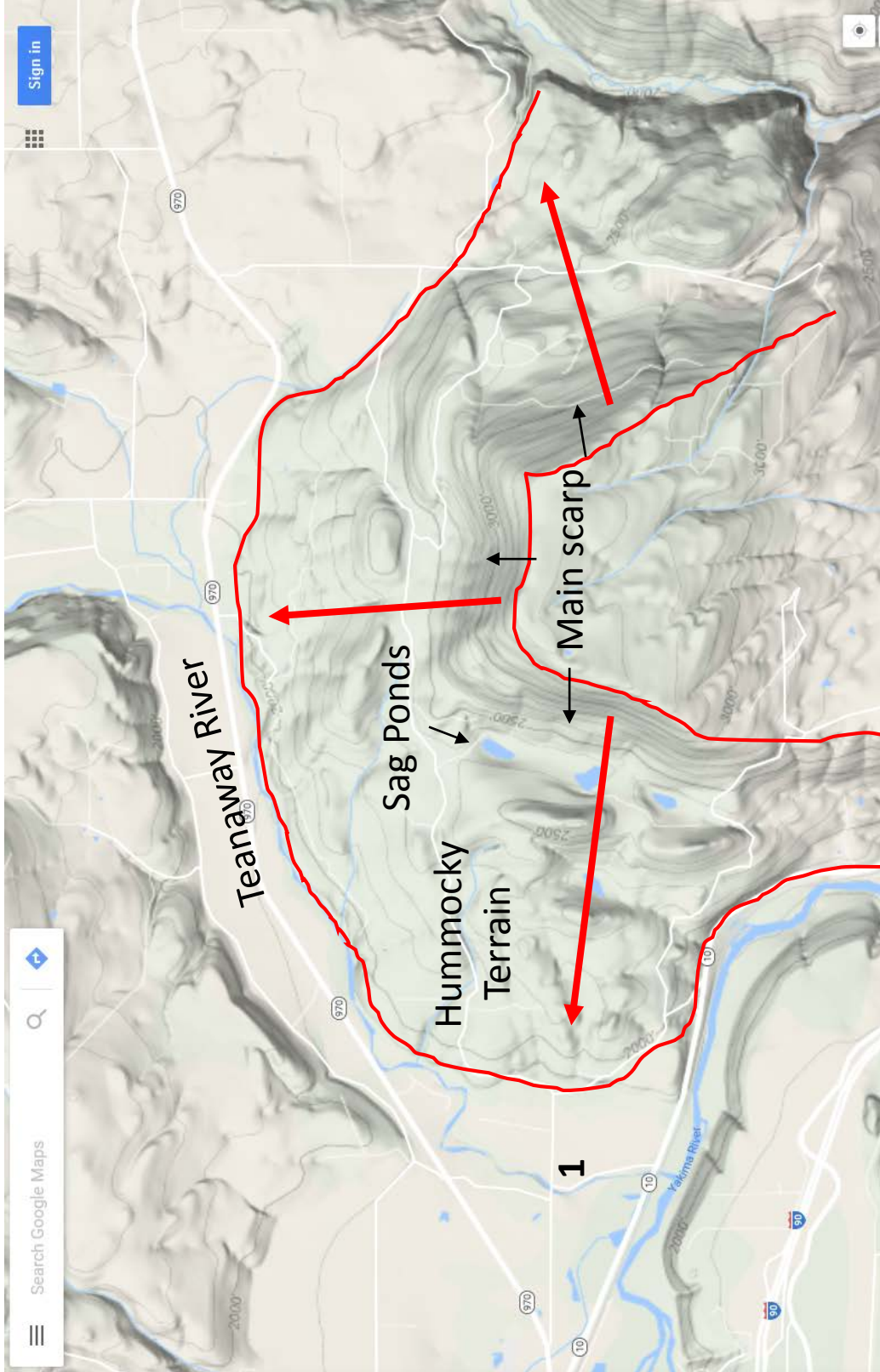


Figure 9. Lookout Mountain rotational landslide enclosed within red lines. Large arrows indicate landslide movement direction. Number indicates field trip stop. Source: Google Maps.

Stop 1—Lambert Road

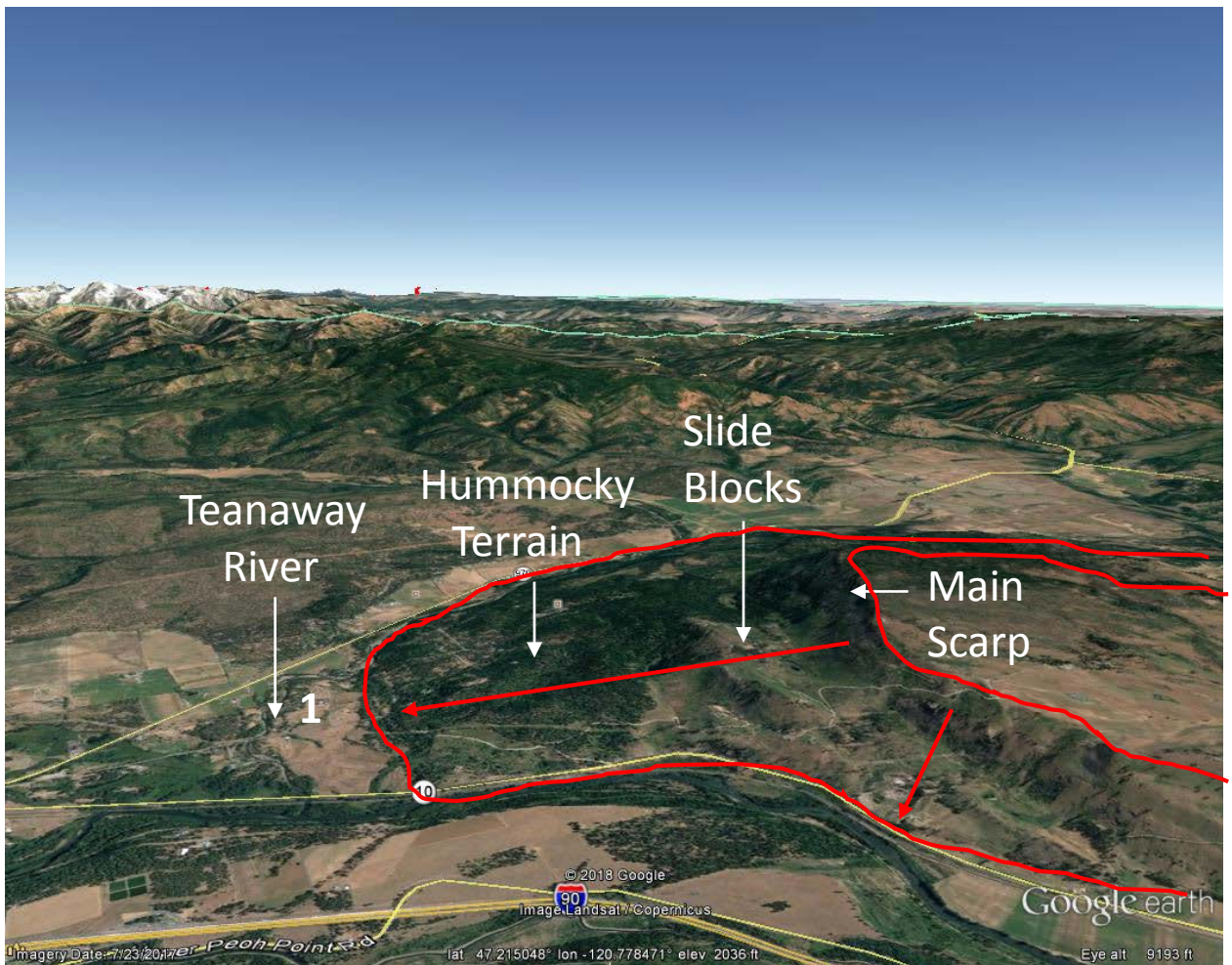


Figure 10. Oblique view of Lookout Mountain landslide. Red lines outline extent of landslide. Heavy red arrows indicates rotational nature of slide and direction of movement. Bold number 1 is field trip stop. View toward north. Source: Google Earth.

Causes. What caused this rotational slide? Weak interbeds between the Columbia River Basalts likely played a role as did a wetter climate. Perhaps a large earthquake triggered such a large slide. Waitt (in Tabor and others, 1982) speculates that a large lake impounded in the lower Teanaway River Valley by glaciers or moraines may have saturated substrates causing the failure of this slope. Given the size of the feature, it is unlikely that undercutting by the Teanaway River caused the slide.

Implications. The proximity of the Lookout Mountain slide and the Teanaway River suggests that the slide pushed the river to the west. Such slide-river interactions are relatively common results of mass wasting. We will explore this issue further at Stop 2.

Lambert Road to Near Milepost 101, WA 10

Route. From Stop 1, we will continue east on Lambert Road to its junction with Taylor Road. Turn right (south) onto Taylor road and follow it around to its junction with WA 10. Turn left (east) onto 10 and follow it approximately 10.5 miles to a large pullout on the right (south) just before milepost 101. **Carefully** walk across WA 10 and up a short but steep trail onto the 1970 and 1971 landslide surface. Please respect this private property! This is Stop 2.

A canyon created by the Yakima River. We are travelling through a Yakima River-eroded canyon. Columbia River Basalt flows, their interbeds, and overlying alluvial basin fill are evident on the drive.

Canyon mass wasting. Mass wasting is evident in all forms on our drive through the steep-walled canyon. Steep slopes, unstable geology, undercut slopes, and leaky irrigation ditches have all likely played a role in mass wasting here. Add to these wet seasons and wet years and you have a great recipe for mass wasting.

At the Lambert Road-Taylor Road junction you are on the toe of the Lookout Mountain slide. Note the hummocky deposits of the slide as we follow the road to WA 10.

Numerous mass wasting events have occurred through this upper canyon in historical times. A quick look at past *Ellensburg Daily Record* articles identifies at least five significant mass wasting events since the 1950's that damaged the highway, railroad or irrigation canals through the area. There were likely many other mass wasting events here during that time—this would be a good undergraduate research topic! Perhaps the most notable of these occurred near the old Northern Pacific rail stop of Bristol in April 1995. Here, the Bristol Flats landslide took out a 200 foot section of the Kittitas Reclamation District canal leaving more than 59,000 acres of farmland without water for approximately two weeks (Johnston, 1995; 1996).

Outwash terraces. Immediately upon leaving the confines of the canyon just downstream of the confluence of Swauk Creek and the Yakima River, the road ascends over prominent *glacial outwash terraces* that Porter (1976) was able to trace back to moraines upvalley.

More landslides. Just downvalley of the prominent outcrop of whitish Ellensburg Formation deposits along WA 10, a large, agglomeration of slides extends nearly to Stop 2. From Ellensburg Ranches Road downvalley, this appears to be a rotational landslide in Ellensburg Formation. Indian Lake is a sag pond impounded behind one of the backtilted blocks in this slide. Back in 1997, CWU Geography undergraduate Kelly Peterson, with the assistance of Dr. Jim Chatters and I, cored this pond to try to determine its age. An age on the pond would give us a minimum age on the landslide that created the depression in which the pond occupies. The minimum age for this landslide is 1,450 years before present (Beta 105965). Based on the topography here I expect that the landslide is much older than this.

Stop 2—Near Milepost 101, WA 10

Location. We are located at the site of the 7 June 1970 and 28 August 1971 landslides. This is private property and access is graciously provided to us by landowners David and Louise Wright. Please ask permission before entering this land.

Geology. The geology of the escarpment to our north and extending from Swauk Creek to our west to Dry Creek to our east is mostly geologically recent Thorp Gravels (Waite, 1979; Tabor and others, 1982) (Figure 11). These were originally thought to be part of the Ellensburg Formation (Smith, 1904) and later mapped as glacial outwash (Porter, 1976). However, Waite (1979) argued that the Thorp Gravels were non-glacial, stream-deposited deposits based on: 1) very different rock types included in the Lookout Mountain and Swauk Prairie drifts compared to the Thorp Gravels; 2) Thorp “terrace” heights are very different than those of the Swauk Prairie drift; 3) highly-cemented nature of the Thorp Gravels compared to Lookout Mountain drift; and 4) problem of Thorp Gravel “till” post-dating Thorp Gravel “outwash” in the vicinity of Horse Canyon (to our north on US 97). The Thorp Gravels likely accumulated in the Kittitas Basin syncline because uplift of Manastash Ridge lowered the grade of the Yakima River and its tributaries causing deposition of sediments. This part of the Thorp Gravels is known as “mainstream” meaning that they derived from the Yakima River eroding underlying Ellensburg Formation and depositing it downstream. These gravels were laid down in the Pliocene approximately 3.3 to 4.4 million years ago.

Rotational Landslides. As noted in the driving segment from Lambert Road to here, mass wasting has been a relatively common phenomenon along the Upper Yakima River (Figure 12). It shouldn’t be a surprise then that two significant landslides occurred here over a 14 month period. What is surprising is that they occurred during the typically dry months of June and August when mass wasting is relatively rare in the Pacific Northwest. The first occurred on 7 June 1970. Following that the slope continued to move until a second large slide occurred on 28 August 1971. It is unclear what has happened since then other than plenty of rockfall off of the main scarp face.

Both of the slides were rotational in nature therefore similar to the Lookout Mountain slide. As supporting evidence for this, note the steep main scarp, the backtilted slide blocks, and the hummocky toe (Figures 13 & 14). Further, note the transverse cracks evident just downslope of the main blocks. Even 47-48 years after the events, the transverse cracks are still visible on the ground.

Stop 2—Near Milepost 101, WA 10

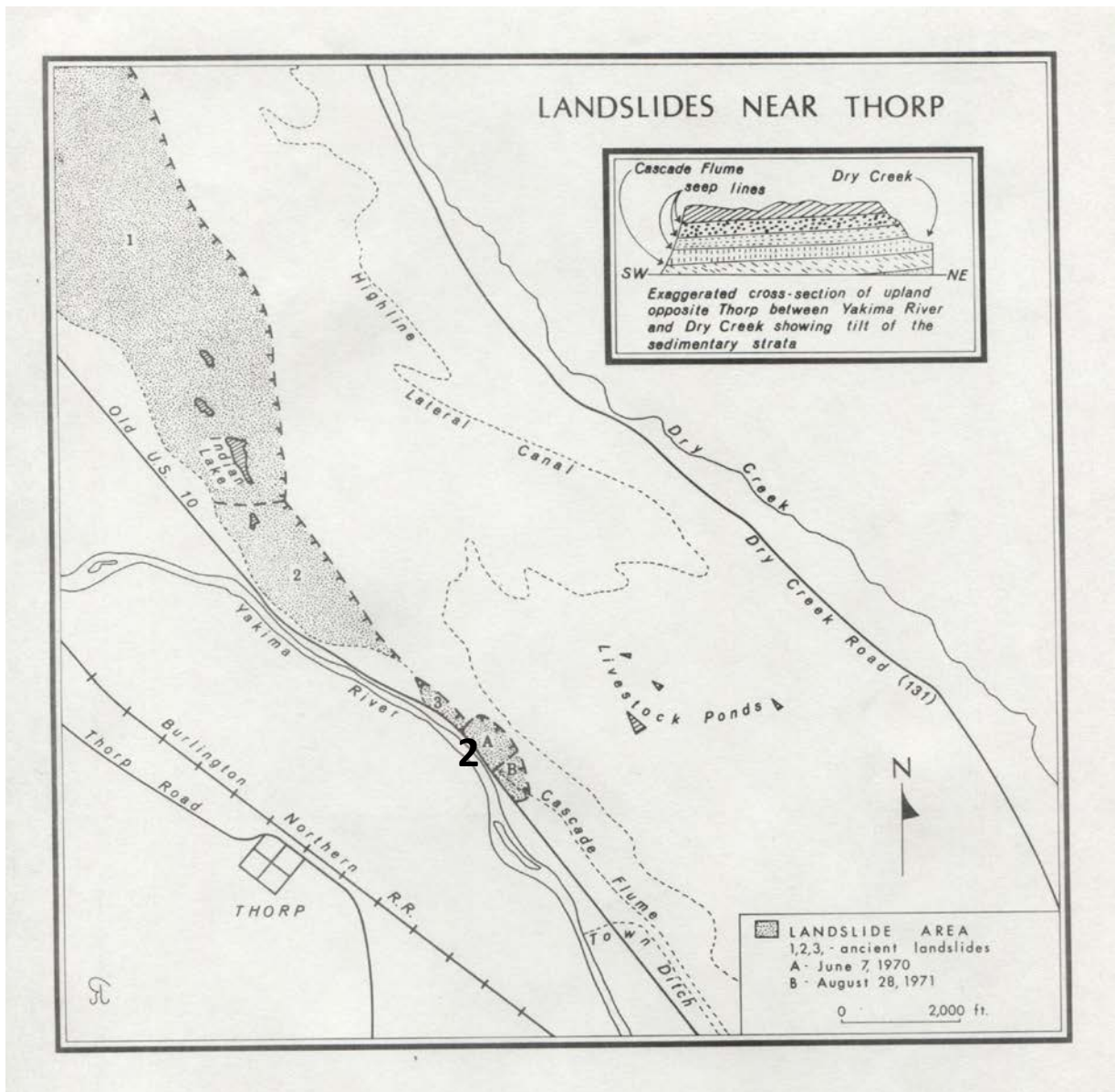


Figure 12. Landslides of the Milepost 101 area, WA 10, north of Thorp. Note the differentiated 1970 and 1971 slides. Bold number 2 represents field trip stop. Source: Roger Jacob, CWSC Geography student & Martin Kaatz files, CWU Archives.

Potential causes. What caused these events, especially during the typically dry summer months? The slides were sufficiently deep-seated that it is unlikely that one or even a series of wet months caused them—i.e., it would take too long for water to reach the depth of the sliding plane. No significant earthquakes occurred at the time of either slide. Over time, the Yakima River has undercut slopes along the floodplain. However, these slides started well

Stop 2—Near Milepost 101, WA 10

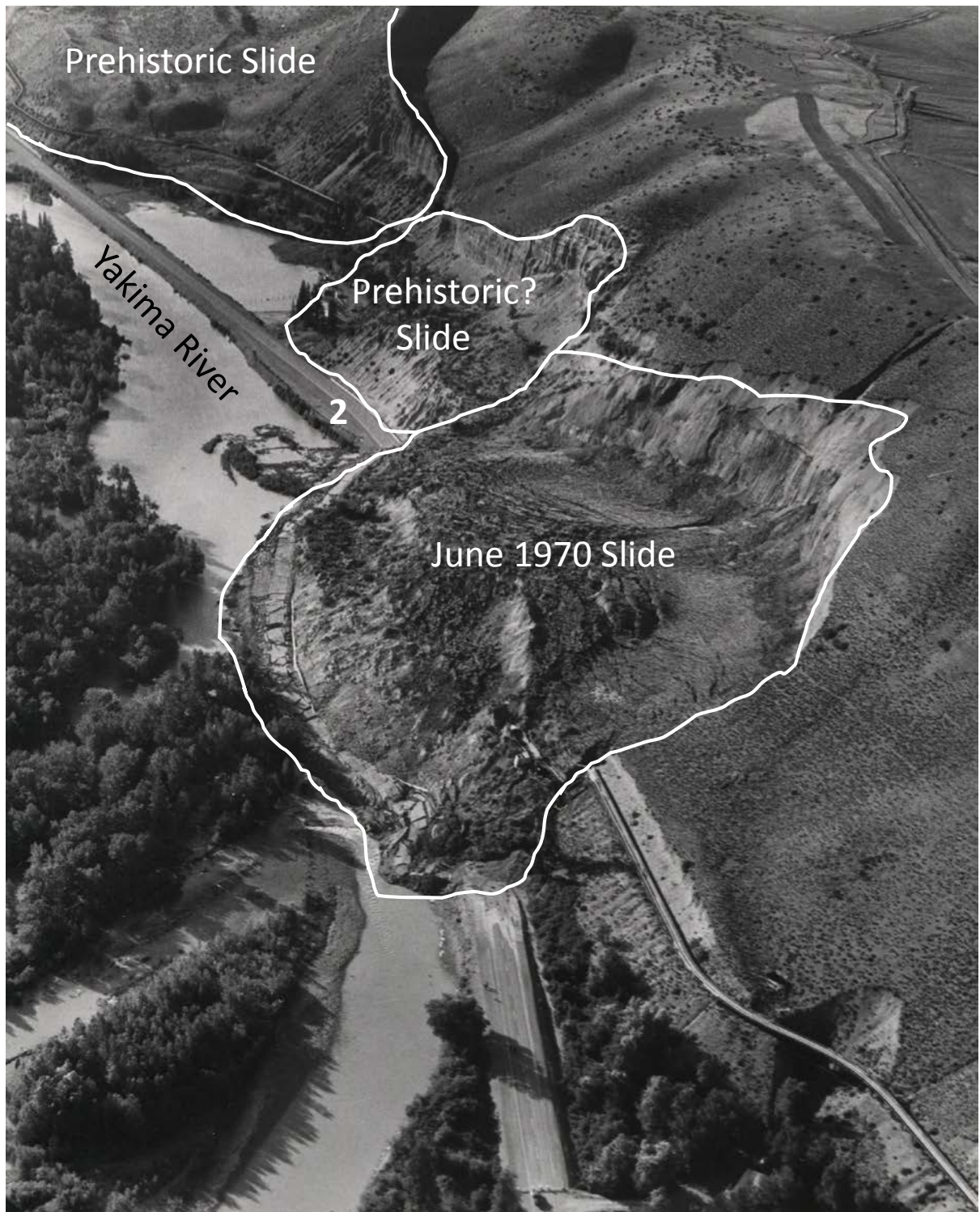


Figure 13. Oblique view upriver (west) at the June 1970 landslide near Milepost 101, WA 10. Note the destroyed highway and the shifted Yakima River. Unknown photographer. 8 June 1970. Cars are parked at bold 2. Source: Martin Kaatz files, CWU Archives.

Stop 2—Near Milepost 101, WA 10



Figure 14. Annotated oblique view upriver (west) at the June 1970 landslide near Milepost 101, WA 10. Cars are parked at bold 2. Source: Kaatz (1971).

Potential causes (continued)...above the level of the river. Martin Kaatz, longtime Geography Professor at CWU, thought it more likely here that geology combined with groundwater may have been the cause (Kaatz, 1971). We can see the evidence of groundwater in the slopes above us. Seeps and springs are often visible on this face as is the vegetation resulting from these seeps. Landslides occur where the water does not exit the slope as a seep or spring; instead, it builds up and increases pore water pressure until it ultimately weakens the bonds between sediments in sedimentary layers. Think of this increase in pore water pressure as lubricating the slide. So what was the source of the groundwater? One possibility was the Highline Lateral Canal (Figure 12). Another potential cause was several livestock ponds near the canal. Perhaps a leaky Cascade flume running through the slide area was another cause. The reasoning with each of these is that water migrating downward from leaky canals/flumes and unlined ponds could become the groundwater that helped trigger these slides.

Stop 2—Milepost XX, WA 10

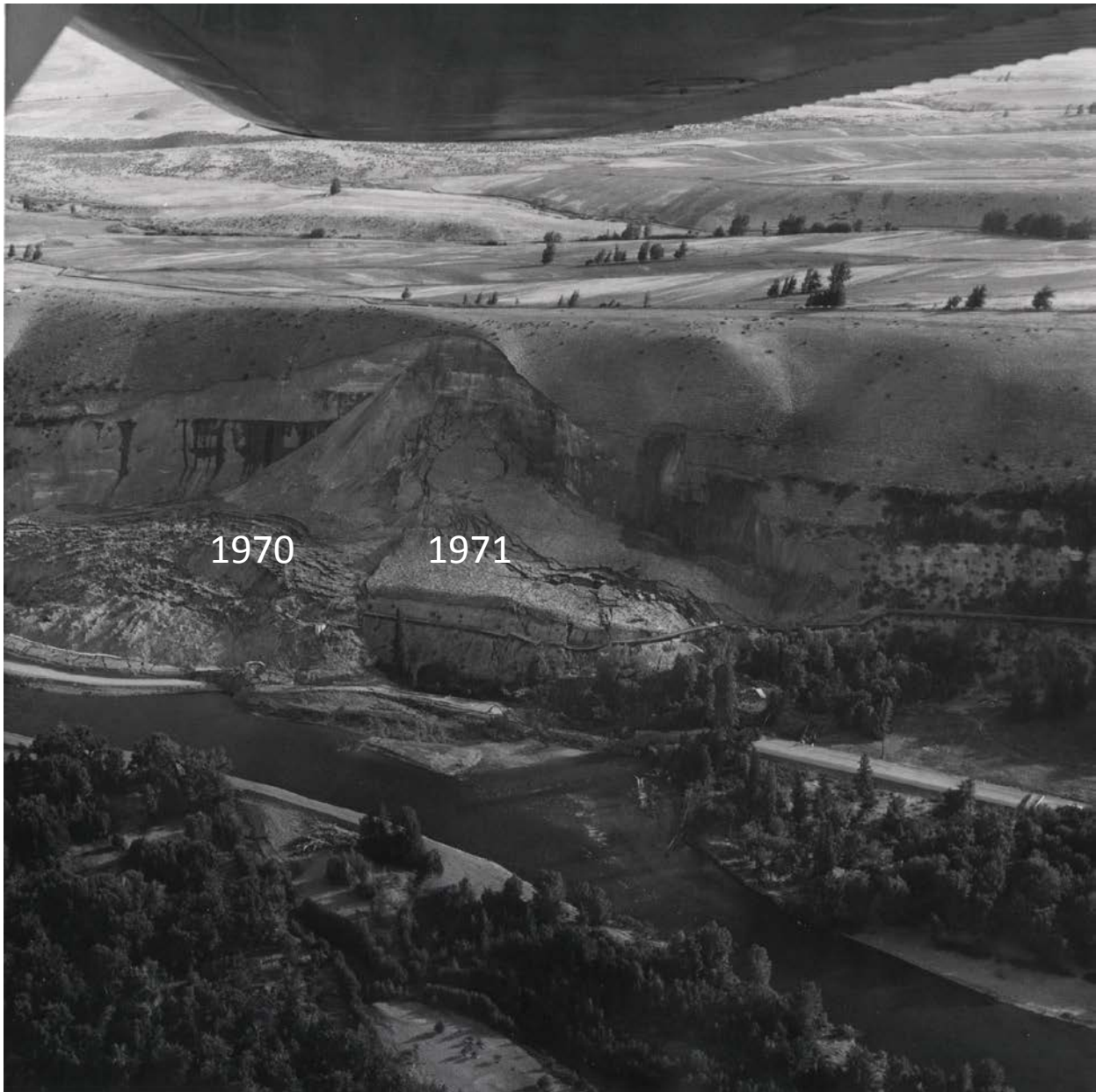


Figure 15. View of 1970 slide and slope that slid in 1971 near Milepost 101, WA 10, north of Thorp. Unknown photographer and date. Source: Martin Kaatz files, CWU Archives.

Potential causes (continued). A human source of landslide-triggering water is something that has been noted in other agricultural places (e.g., Schuster and Hays, 1984). In fact, of 17 historic landslides identified in the canyon extending back toward Stop 1, 11 were adjacent to the KRD Canal suggesting a causal relationship between leaky canal and mass wasting (Lillquist, 1999).

Stop 2—Milepost xx, WA 10

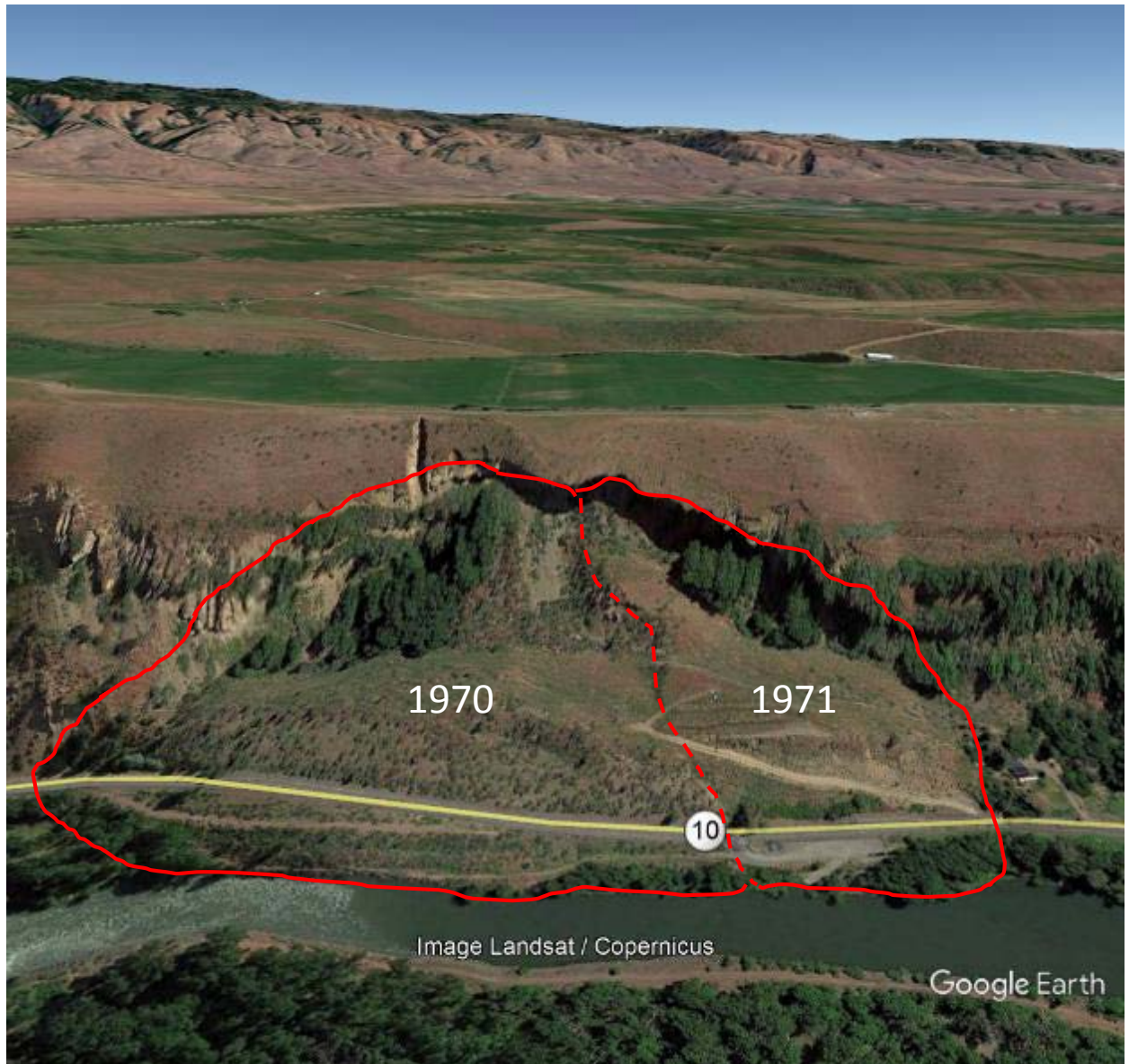


Figure 16. 1970 and 1971 rotational slides near Milepost 101, WA 10 north of Thorp. Solid red line outlines landslides. Dashed red line is in the approximate boundary between the two events. Source: Google Earth, 2017.

Implications. No one was injured in either of the slides here. About 2,500 feet of WA Hwy 10 (formerly US 10) was destroyed (Figure 13). Approximately 1,000 feet of that went into the Yakima River. Further, roughly 2,600 feet of Cascade Irrigation Company tunnel and flume was also destroyed (Ludtka, 1970). This left approximately 20-25 farms cumulatively farming ~2,500 acres without water. Finally, the 1970 slide temporarily blocked and diverted the Yakima River to the south.

Near Milepost 101, WA 10 to Milepost 20, WA 821

Route. From Stop 2, we continue east on WA 10 to its junction with US 97. We follow US 97 then WA 10 into Ellensburg where it becomes University Way. At the junction of University Way and Main Street, turn right (south) and head toward the South Interchange. **I encourage you to stop and use a restroom at one of the many businesses in Ellensburg on University Way or Main Street.** From the south extension of Main Street continue south on Canyon Road which becomes WA 821 at Thrall. We will follow this to Milepost 20 in the Beavertail portion of the Yakima River Canyon. This is Stop 3

Yakima River. The Yakima River is an “exotic river” originating in the humid Cascade Range and flowing through semiarid Central Washington. It is a highly managed system with three large reservoirs upstream storing water for diversion to farms. In addition to agriculture, it is very important to salmonids and recreation.

Columbia River Basalts, Yakima Fold and Thrust Belt & Yakima River. As we approach the mouth of the Yakima River Canyon, note the escarpments (or “scarps”) on either side of the canyon entrance. The taller eastern scarp is estimated to be approximately 100,000 years old while the shorter, western scarp is likely closer to 50,000 year old (Kelsey and others, 2017). The Yakima River Canyon is one of the key geologic and geomorphic gems of Central Washington. Once in the canyon, numerous basalt flows are evident in the canyon walls. Erosion by the Yakima River created the “entrenched meanders” of the Yakima River Canyon. These meanders are indicators of tremendous incision & lateral erosion!

What makes the entrenched meanders more interesting is that they run generally perpendicular to the structures of the Yakima Fold and Thrust Belt (Figure 18). Because of this, we refer to the Yakima River as a “structure-transverse” drainage. Such drainages form in one of four ways (Baker & others, 1987): 1) *superposition* —river incised through a debris cover exposing underlying structures; 2) *headward erosion* into weaker strata that is exposed by folding and faulting to form a *subsequent stream*; 3) *antecedence*—river was here before structures and subsequent incision kept up with uplift; and 4) streams travel in structural lows (e.g., synclines) therefore are *consequent streams*. Over time, antecedence has been the favored theory. However, Schmincke (1964) and Waitt & Swanson (in Baker & others, 1987) argue that the course of the Yakima River roughly corresponds to the structurally lowest route across the anticlines—i.e., a place where the *plunging anticlines* from the west and the plunging anticlines from the east meet. Such a route likely originated early in the development of the Yakima Fold Belt when the topography was much lower. This folding, hence the incision that made the steep, landslide-prone canyon walls, began sometime between 7-12 million years before present (Kelsey & others, 2017).

Near Milepost 101, WA 10 to Milepost 20, WA 821

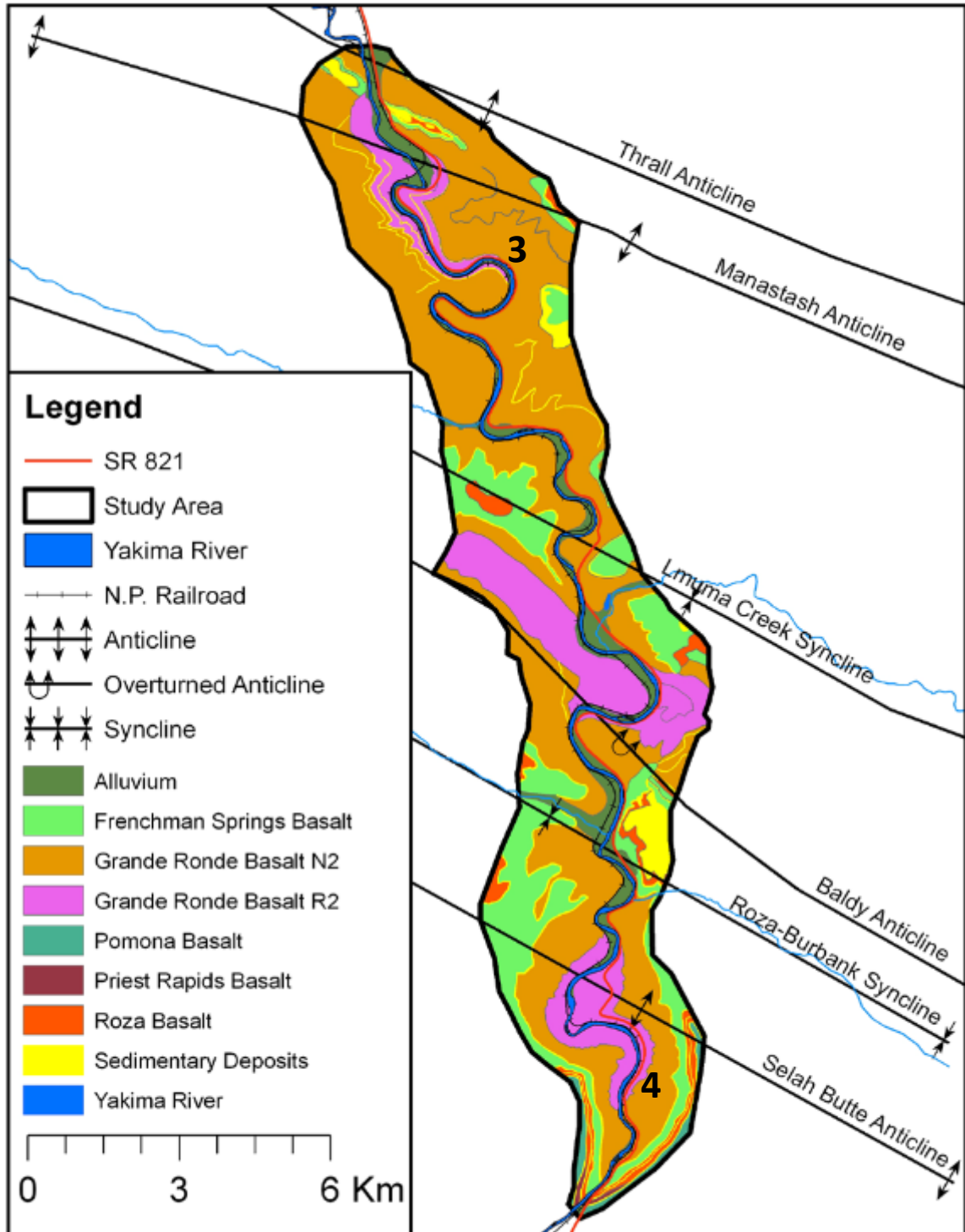


Figure 17. Simplified geologic map of Yakima River Canyon. Bold numbers represent field trip stops. Source: Winter (2012, p. 34).

Stop 3—Milepost 20, WA 821

Location. We are located in the heart of the Yakima River Canyon, one of Central Washington's geomorphic gems, at what is locally known as "Beavertail Bend".

Yakima River Canyon Mass Wasting. Mass wasting is a common phenomenon in the Yakima River Canyon. Like the canyon between Stops 1 & 2, steep slopes (aided by highway and railroad) here promote mass wasting and lots of it. CWU Resource Management graduate student Tom Winter (2012) identified nearly 250 discrete mass wasting features in the Yakima River Canyon (Figure 18). Collectively, these features cover about 22% of the canyon walls! Mass wasting here occurred in prehistoric and historic times in a variety of types. The most common mass wasting are shallow, rapid events including debris and earth flows, translational slides, and rockfall. Most of the mass wasting (~70%) is active or recently active. Using old newspaper articles and historical aerial photographs, Winter (2012) mapped mass wasting dating from 1942 to 2006 in the Yakima River Canyon (Figure 19).

Debris flows. Debris flows are just like their name implies...flows of debris. These often originate on steep slopes with heavy precipitation or snowmelt combining with ample debris. The result is a viscous (think milkshake consistency) flow that is capable of rapid travel and transport of large debris picked up enroute. Debris flows are mostly confined to channels in their upper reaches but often spread out as a fan at their toes.

July 1998 Debris Flows. We are standing above the remnants of several debris flow fans. These debris flows originated soon after an intense thunderstorm stalled on Manastash Ridge, depositing locally heavy rain and hail on the mid-afternoon of 3 July 1998. According to Kaatz (2001), more than three inches of rain fell atop Manastash Ridge in less than one hour. An orchard on the Kittitas Basin side of the ridge received five inches of hail in this same event. When I visited the Yakima River Canyon the next day, hail was still present in roadside ditches. Reflecting the often spotty nature of thunderstorm precipitation, other nearby areas received little or no precipitation.

Numerous debris flows formed in the impacted area (Figures 20 & 21). In the Beavertail Bend area alone, I identified 13 debris fans on both sides of the river. These flows mostly shared the following characteristics: 1) originated high in their respective watersheds; 2) followed existing channels; 3) were mostly composed of coarse basalt fragments picked up from steep slopes; 4) in places, scoured channel walls; 5) in others, deposited within channels; and 6) all deposited fans at or near the Yakima River (Figures 22, 23 & 24). It was (and is) these fans that are of most significance in the river. In addition to serving as a course of coarse debris, they also add complexity to the planimetric (i.e., overhead) and cross-sectional shape of the river.

Stop 3—Milepost 20, WA 821

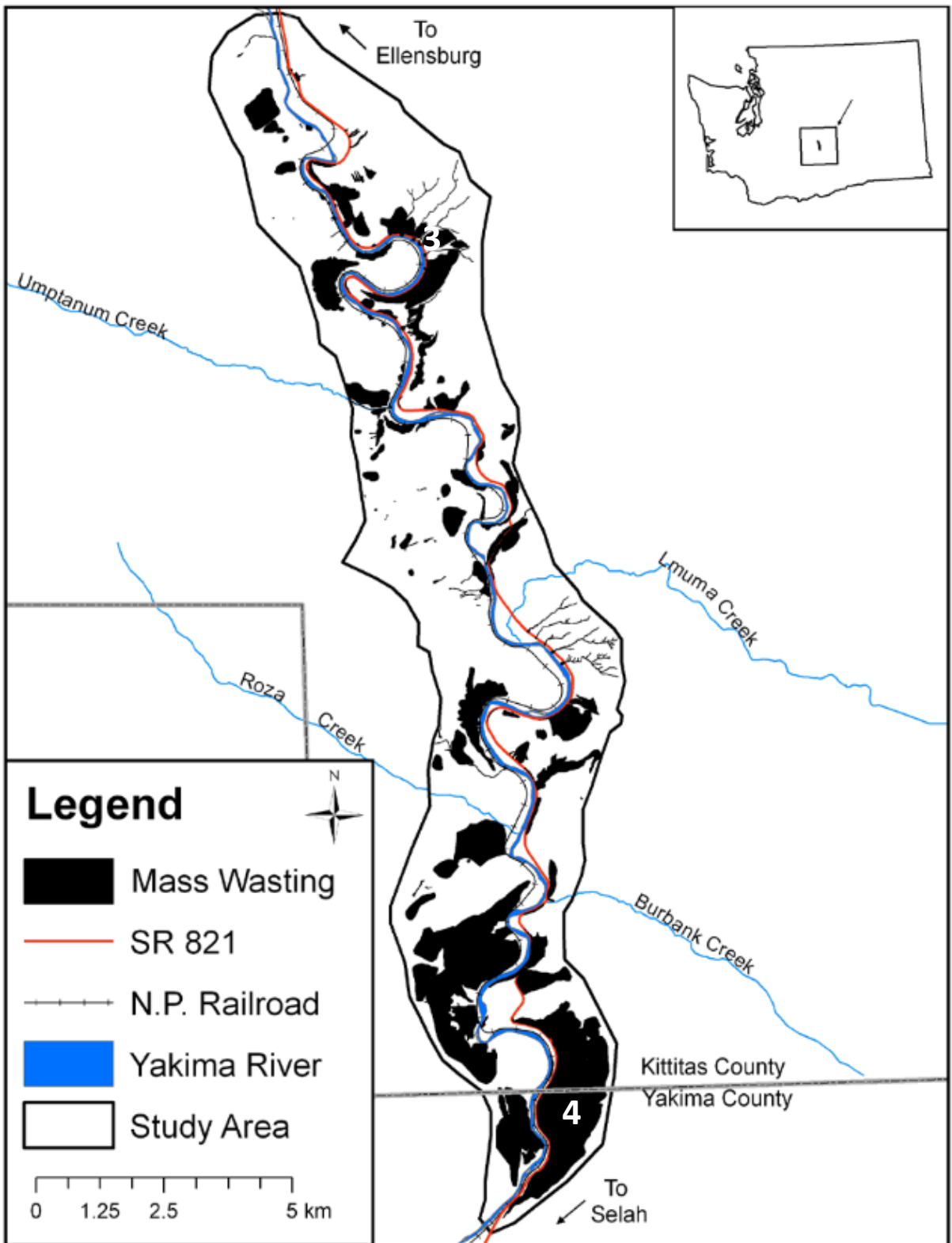


Figure 18. Overall mass wasting in Yakima River Canyon. Bold numbers represent field trip stops. Source: Winter (2012, p. 60).

Stop 3--Milepost 20, WA 821

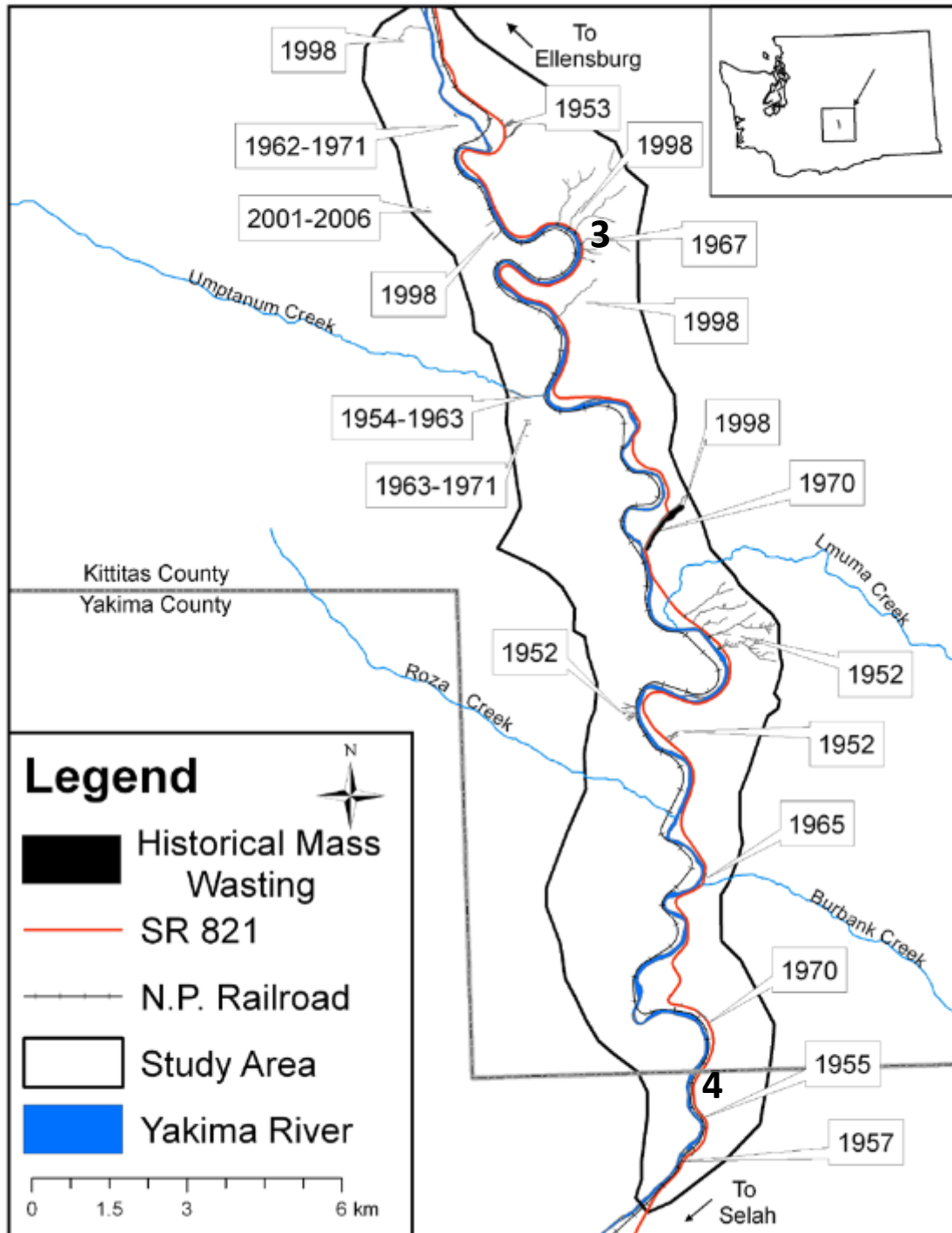


Figure 19. Historic (i.e., 1942-2006) mass wasting events in the Yakima River Canyon. Events showing a range were mapped solely from aerial photographs while discrete dates were determined from aerial photographs and newspaper articles. Bold numbers represent field trip stops. Source: Winter (2012).

Stop 3--Milepost 20, WA 821



Figure 20. Debris fans of 3 July 1998 debris flows, in vicinity of Beavertail Bend in Yakima River Canyon. Arrows indicate debris flows that reached WA 821 or the Burlington Northern Santa Fe railroad. Bold number indicates field trip stop. Source: Washington Department of Transportation photo, 6 July 1998.

Stop 3—Milepost 20, WA 821



Figure 21. Vertical aerial photograph of the Stop 3 site. Note the large debris fans extending into the Yakima River. Bold number indicates field trip stop site. Source: Washington Department of Transportation, 6 July 1998.

Stop 3—MP 20, WA 821



Figure 22. View up canyon at Milepost 20. Source: Karl Lillquist, 4 July 1998



Figure 23. View down canyon near Milepost 20. Source: Karl Lillquist, 4 July 1998

Milepost 20 to near Milepost 4-3, WA 821

Route. Drive approximately 16-17 miles south of Stop 3 to a large pullout on the left (east) side of the highway between Milepost 4 and 3. From this pullout, we will walk south along the highway before ascending a short trail up to an abandoned segment of old US 97. This is Stop 4.

Creep, dry ravel, and headward recession. The steep, *colluvium*-covered slopes of the Yakima River Canyon are very conducive to slow mass wasting. Colluvium is the collective term for deposits of mass wasting. We have seen it in various forms throughout our day. In the Yakima River Canyon, much of this colluvium originates from rockfall from the basalt bedrock above. Once on the steep slopes, it may move downslope in several ways: 1) slow grain-by-grain (or boulder by boulder) via the process of *creep*; and 2) more rapid rolling, bouncing, and sliding known as *dry ravel* (Gabet, 2003). Dry ravel is especially common on steep slopes of arid and semi-arid environments. Creep and dry ravel, combined with rockfall, are the constant source of sediment that fills Yakima River Canyon roadside ditches. These ditches, combined with large concrete Jersey barriers, protect the highway. Where the slope above the highway or the railroad terminates abruptly in a roadcut, we often see headward recession in the colluvium. These areas of headward recession are common throughout the canyon (Figure 24). Watch for them throughout the canyon.

Terracettes. Other common features of the steep slopes of the Yakima River Canyon are small terrace-like features aptly named *terraces* (Figure 25). A variety of origins have been proposed for terraces including creep, solifluction (i.e., slow soil flow), gelifluction (slow soil flow over permafrost), cattle and other hooved animals trampling, and micro-rotational sliding. Substrate and vegetation may also play a role in their formation (Rahm, 1962; Vincent & Clarke, 1976).

Milepost 20 to near Milepost 4-3, WA 821



Figure 24. Dry ravel and headward recession of Yakima River Canyon slopes. Near Milepost 18. Source: Karl Lillquist, March 2018.



Figure 25. Terracettes of Yakima River Canyon slopes. Source: Karl Lillquist.

Stop 4—Between Milepost 4 & 3, WA 821

Location. We are located on a segment of the old US 97.

Old slide-flow or translational slide. Just north of where we parked is a large, old landslide that extends from the top of the Selah Butte anticline to the Yakima River (Figures 18 & 26). This feature is especially visible when approaching the canyon from the south. Winter (2012) maps this as a complex slide flow meaning it is a rotational slide in its upper portion and a flow near its toe. Given that the slide appears to follow Columbia River Basalt bedding, I would instead map it as a translational slide. Based on its surface characteristics, he mapped it as an “Inactive-Mature” feature meaning it is old but not the oldest of the mass wasting features in the Yakima River Canyon. I estimate that such a feature is thousands if not tens of thousands years old. I would expect that the slide-flow or translational slide was caused by an interaction between weak geologic units and a much wetter climate. Perhaps it was triggered by an earthquake? It is possible that this large feature blocked the Yakima River impounding water that may have extended back into the Kittitas Basin (Jack Powell, April 2018, personal communication). The bottom line here is that this is either the largest or one of the largest landslides in the Yakima River Canyon and we know little about it.

Talus. We have seen talus since our first stop today. In lowland Columbia River Basalt settings talus often accumulates as broad *aprons* paralleling the slope and as smaller *cones* at the mouths of chutes that funnel rocks from above. Cones may coalesce to form aprons over time much as alluvial fans coalesce to form *bajadas* in desert landscapes. Here we see talus accumulating on old US 97 as coalescing cones (Figure 27). Retired WA DOT engineer Tom Lyon estimates that this segment of the highway closed sometime after 1965 therefore the talus accumulation here likely represents about 50 years of rockfall. Its deposition is aided by chutes formed in weak zones between odd pillars of basalt.

Stone Stripes. *Stone stripes* have been visible through much of our drive down the Yakima River Canyon (Figure 28). Many of these are *sorted*—i.e., the stripe consists of coarse basalt cobbles and boulders while the adjacent materials are a mix of fine and coarse material. In the broader picture, stone stripes are common on slopes throughout the Columbia Plateau. Because they are common in cold climates, stone stripes have been linked to a suite of cold climate processes including frost cracking, freeze-thaw, frost sorting, mass displacement, and frost heaving (e.g., Washburn, 1980). However, they are also present in warm deserts (e.g., Hunt and Washburn, 1966) so other processes must also result in these features. These may include salt cracking, salt heaving, differential mass wasting, and stream processes (Washburn, 1980). In geomorphology, we refer to this phenomenon as *equifinality*—i.e., different processes may result in the same feature.

Stop 4—Between Milepost 4 & 3, WA 821

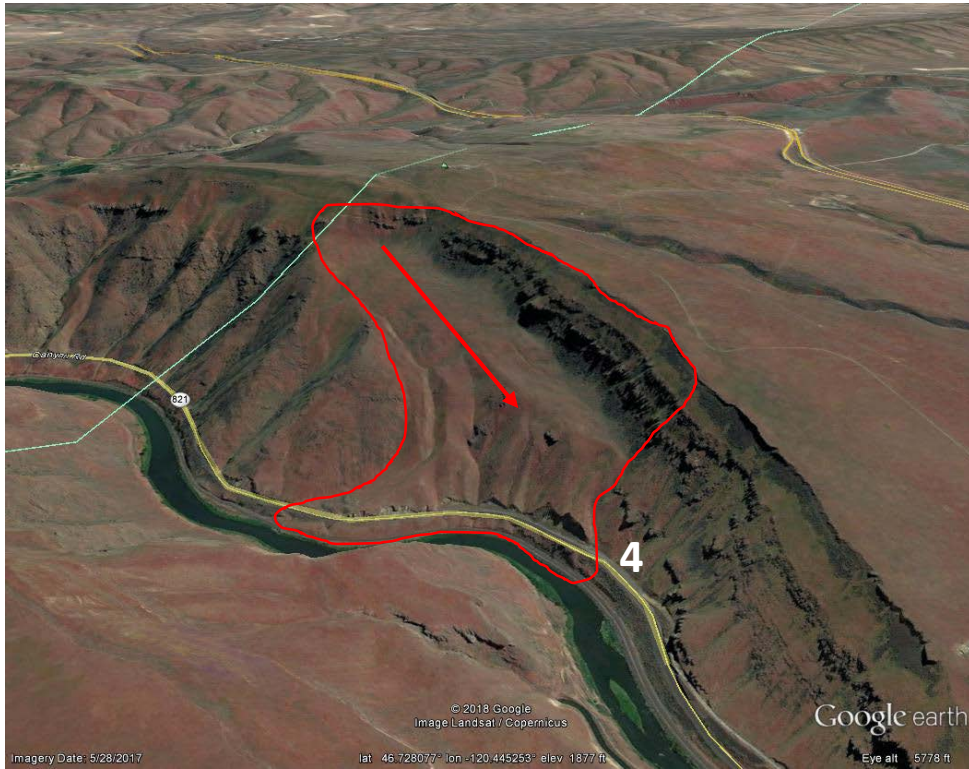


Figure 26. Complex slide-flow near the south end of the Yakima River Canyon. View toward the east. Bold number represents field trip stop. Source: Google Earth.



Figure 27. Talus accumulation on old US 97, south end Yakima River Canyon. Source: Karl Lillquist, March 2018.

Stop 4—Between Milepost 4 & 3, WA 821



Figure 28. Stone stripes across the Yakima River from Stop 4, southern Yakima River Canyon. Source: Karl Lillquist, March 2018.

Milepost 4-3, WA 821 To North of MP 74, US 97

Route. From Stop 4, continue south on WA 821 to its junction with Interstate 82. Head south of Interstate 82 through Yakima Gap to Union Gap. In Union Gap, exit Interstate 82 and head south on US 97. In Parker, turn left (east) off US 97 onto Second Avenue. Immediately upon joining Second Avenue turn left onto an unmarked road before crossing the railroad tracks and return to US 97 northbound. Head north for less than 1 mile and take an unmarked gravel road off to the right to follow the irrigation canal. We will stop near the dam on the canal.

Geology & geomorphology. Our route takes us out of the incised meanders of the Yakima River Canyon to the alluvial floodplain of the Yakima River in the vicinity of Selah. The river again cuts through the Yakima Ridge anticline to form a water gap. After again forming an alluvial plain around Yakima, the river again cuts through the Rattlesnake Ridge anticline forming Union Gap.

Stop 5—North of MP 74, US 97

Location. We are located along the Wapato Irrigation Canal north of Parker.

Rattlesnake Ridge Geology. Like other ridges seen today in the Yakima Fold and Thrust Belt, Rattlesnake Ridge is a generally east-west trending, asymmetrical anticline (Figures 29 & 30). Like the other anticlines, it is composed of Columbia River Basalt lava flows, occasionally separated by sedimentary interbeds. These interbeds formed between volcanic periods from direct weathering of the basalts as well as deposition of sediments atop the basalts. Subsequent folding inclined the basalt and interbed layers to 12 to 20° (Norrish, 2018) (Figure 31).

Rattlesnake Landslide. In October 2017, large tensional fissures were first observed in the hillslope above the Columbia Asphalt and Ready-Mix Anderson Quarry operation on Rattlesnake Ridge (also referred to as “Rattlesnake Hills”) (Norrish, 2018). Check out Youtube for some of the great video footage of the fissures on the upper slopes. If you look carefully from here you can also see these features. Monitoring of the slope revealed that a landslide was slowly moving south to southwest toward the quarry. Slide movement accelerated in mid- to late December suggesting that rapid failure could occur. The concern was that a rapid failure might inundate Thorp Road, nearby homes, and I-82, and potentially block the Yakima River.

As of January 2018, the slide was approximately 20 acres in area and about 12 feet deep, and was moving at a rate of 1.6 feet/week. This was an increase of approximately 0.5 feet/week since monitoring began. The total volume of the slide was estimated at 4 million cubic yards. As a precaution, Thorp Road was closed, homes located immediately south of the landslide were evacuated, and Washington DOT brought in large Conex containers (essentially large shipping containers filled with concrete) to stop the toe of the slide (if it reached them) and to catch potential rockfall coming off the sides of the slide.

Potential causes of the landslide. The Rattlesnake Ridge slide is a translational slide moving over a weak, tilted interbed between the Saddle Mountains Basalts of the Columbia River Basalt Group (Reidel and others, 2013) (Figure 31). Specifically, the sliding surface is the Selah interbed sandwiched between the Pomona basalt member (below) and overlying Umatilla basalt member (Reidel and Campbell, 2018 in Norrish, 2018). The tilt (or dip) of the Selah interbed is about 15° (Washington Department of Natural Resources, 2018). According to Norrish (2018) the most important factors affecting the stability of a translational slide are: 1) frictional shear strength along the sliding surface; 2) the dip of the sliding surface; and 3) groundwater pore pressure. The risk of the slide is diminished here as the strata lack significant pore water pressure.

Stop 5—North of MP 74, US 97

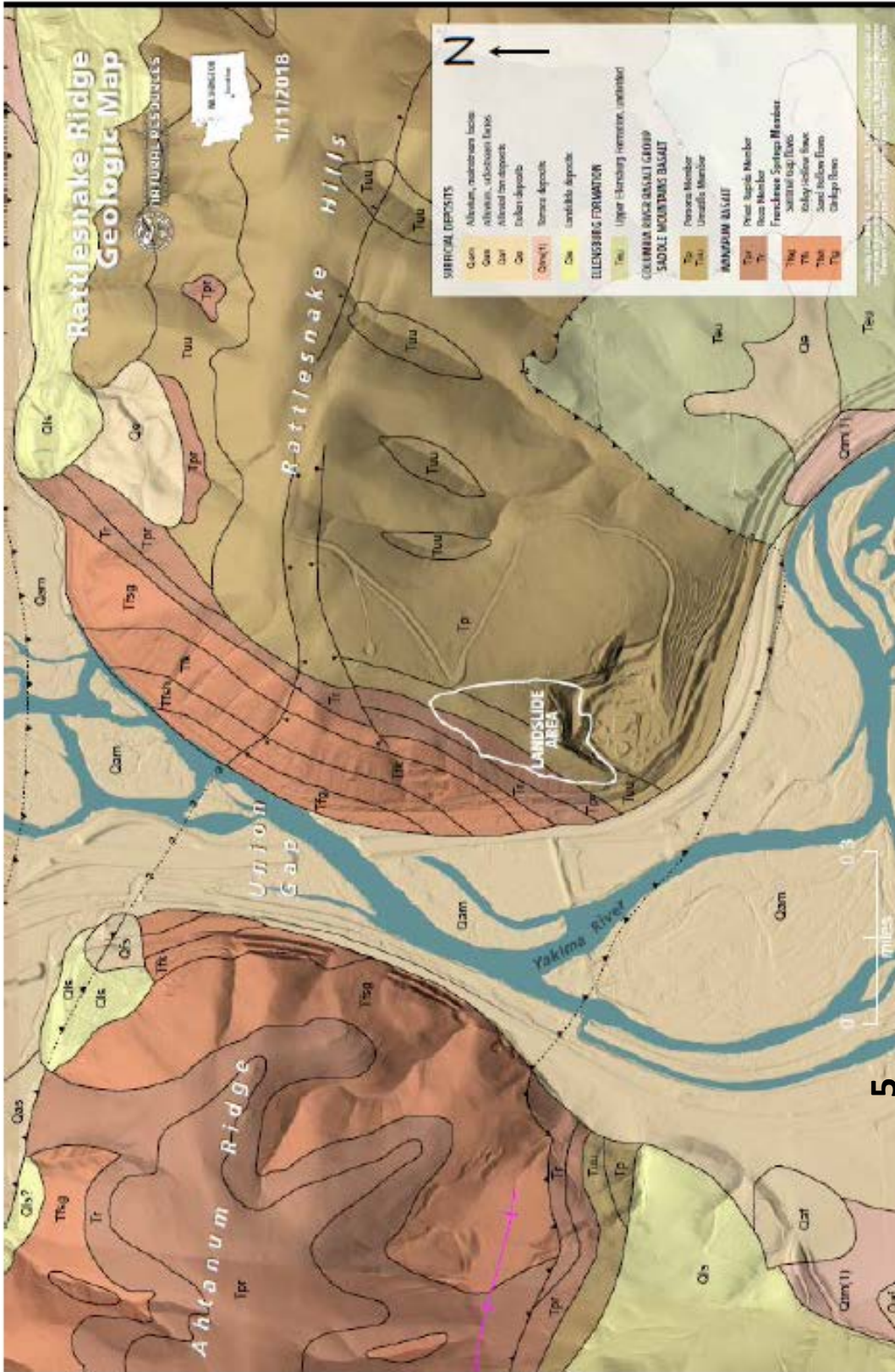


Figure 29. Rattlesnake Ridge landslide area geologic map. Bold number 5 indicates field trip stop. Source: Washington Department of Natural Resources in Norrish (2018).

Stop 5—North of MP 74, US 97

Rattlesnake Hills Anticline and Translational Landslides

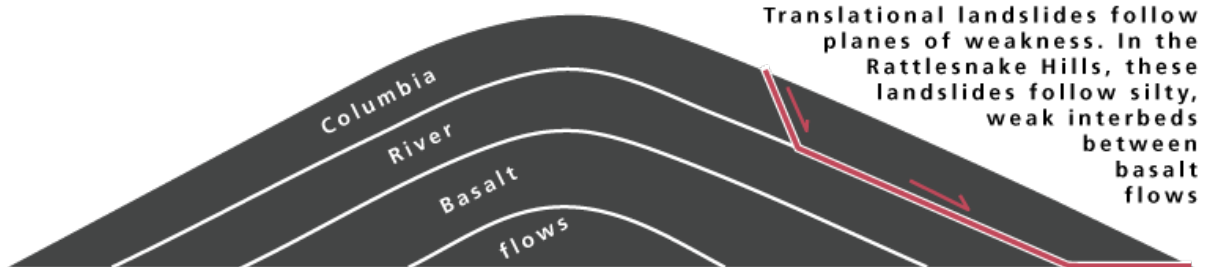


Figure 30. Rattlesnake Ridge anticline. Source: Washington State Department of Natural Resources Rattlesnake Hills Landslide website (<https://www.dnr.wa.gov/rattlesnake-hills-landslide>).

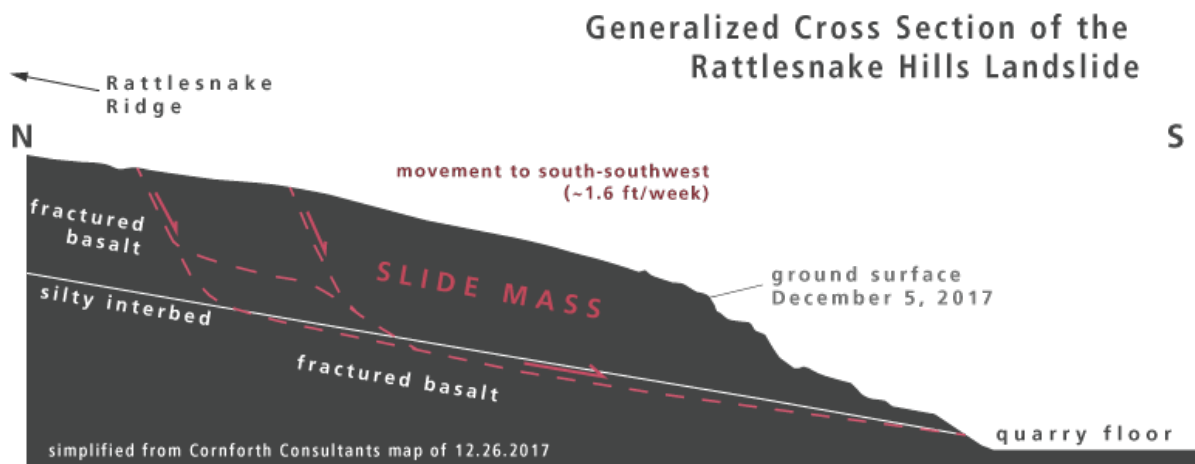


Figure 31. Rattlesnake Ridge landslide and associated geology. Source: Washington State Department of Natural Resources Rattlesnake Hills Landslide website (<https://www.dnr.wa.gov/rattlesnake-hills-landslide>).

Risk. The slide continues to move south toward the quarry (Figure 32). As of January 2018, Norrish (2018) estimated that the probability of a rapid failure (142 feet/day) was less than 5%. Further, there was an 85% probability that the slide would continue to “creep” at rates of 0.15 to .25 feet/day. How long might such slow movement continue? Norrish (2018) suggests that it could be years to decades. Ultimately, movement may stop as a natural talus buttress builds up at the slide toe. Stay tuned!

Stop 5—North of MP 74, US 97

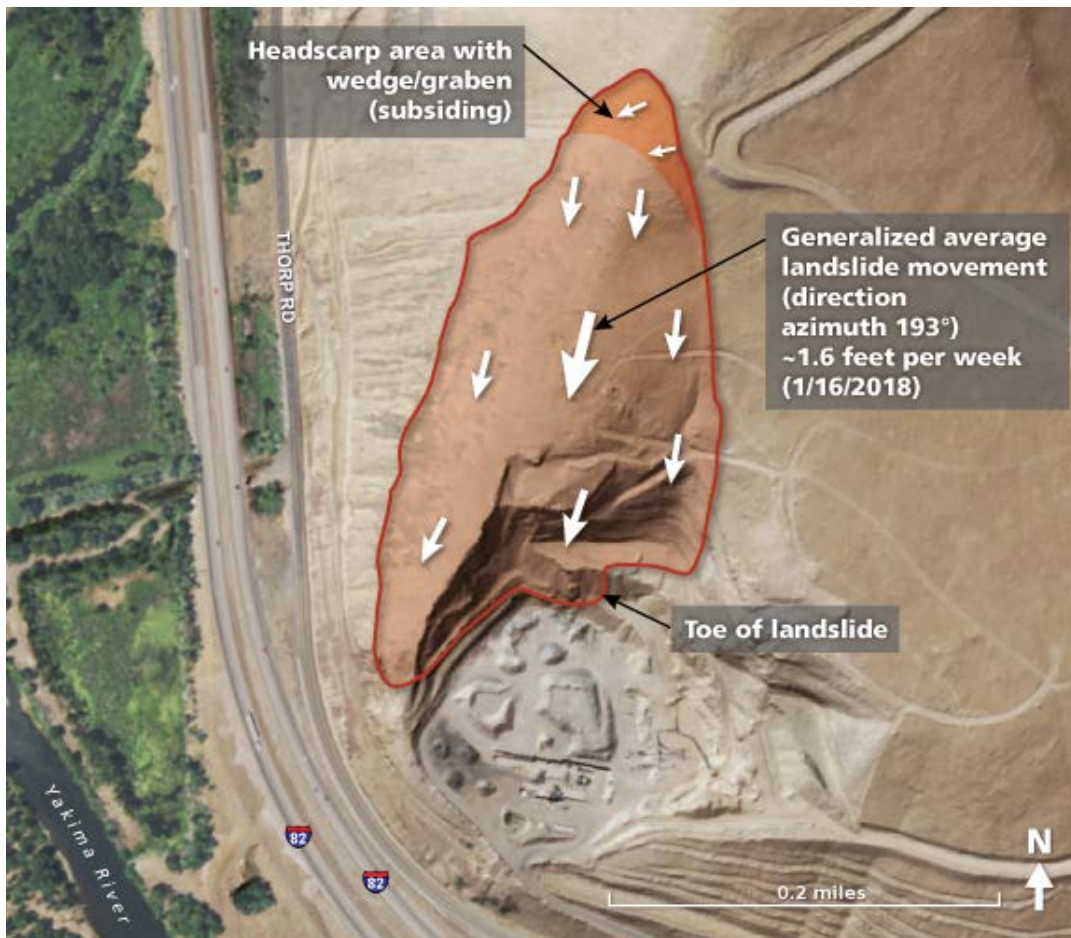


Figure 32. Rattlesnake Ridge translational slide movement direction. Source: Washington Department of Natural Resources (2018).

Wrap-up

Today, you have had the opportunity to see mass wasting, its potential causes, and its impacts on Central Washington's Yakima River corridor. Slides—rotational and translational, flows, fall, creep, and dry ravel have all shaped the slopes of Central Washington. Causes of these events may include weak geologic units, climate, weather, earthquakes, and humans. Mass wasting is a hazard to humans and has helped to dramatically shape landscapes and landforms, including those of the Yakima River corridor.

Thank you for your support of the Ice Age Floods Institute—Ellensburg Chapter, and Central Washington University. I hope this has been an educational and enjoyable field trip for you. Don't hesitate to contact me with questions or comments about this field trip or associated Ice Age floods issues.

Thanks for participating! Karl Karl.Lillquist@cwu.edu & (509) 963-1184

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