MEMORANDUM

DATE: March 27, 2023

TO: Derek Bays, PG
Engineering Geologist
Governor's Office of Emergency Service
3650 Schriever Ave.
Mather, CA 95655

SUBJECT: Cal OES Mission Task No. 2023-SOC-97887 - March 2023 Storms - Engineering Geologic Reconnaissance of Landslides at Wofford Heights, Kern County, CA

Introduction and Background

On March 1, 2023, Governor Newsom proclaimed a State of Emergency (SOE) for 13 counties in California, including Kern County, due to impacts from historic precipitation and the forecast for additional storms. On March 9 Governor Newsom requested federal assistance, and on March 10, 2023, President Biden declared a federal SOE for 34 California counties, including Kern County (FEMA-3592-EM). Kern County requested assistance through the California Office of Emergency Services (Cal OES) to assess future potential life-safety risks from two landslides reportedly generated by storms on March 10 and 11 in the Wofford Heights area northwest of Lake Isabella (see Figure 1). The California Geological Survey (CGS) was mission tasked by Cal OES on March 15 to conduct a rapid emergency assessment of potential impacts to life-safety and property posed by these two landslides during future storms. A team of two Certified Engineering Geologists mobilized from CGS on March 16 to conduct an emergency site assessment as requested.

Scope of Work

The purpose of this memo is to provide Cal OES, Kern County, and other responsible agencies with descriptions of site conditions, on-going hazard risk potential, and preliminary mitigation measures to assist in emergency planning and mitigation efforts relative to the two observed landslides. One landslide is located on the southwestern flank of Cane Peak about 300 ft above Cane Peak Court and the second is located along Sierra Vista Drive. CGS geologists conducted the following specific tasks:

- Coordination with Joshua Stinnett of the Kern County Fire Department (KCFD) and other staff from KCFD to define the scope and goals of the emergency landslide assessment.
- Field observation and rapid documentation of geologic and geomorphic conditions at both landslide sites and rapid reconnaissance of conditions at a residential development ("Pala Ranches") southwest of State Route (SR) 155, off Pala Road on the east margin of the French Fire.

- Rapid field assessment of hazard potential and preliminary emergency mitigation measures, and review with Kern County field personnel on March 15.
- Preparation and delivery of an email brief summarizing the observed conditions and preliminary mitigation measures to representatives of Kern County and Cal OES on March 16.
- Research into the timing and intensity of the triggering rainfall event(s)
- Review of previous post-fire hazard assessments by CGS for the 2014 Way Fire and 2021 French Fire.
- Preparation of maps illustrating the observed landslides at Cane Peak using lidar and photographic drone imagery base maps provided by the UC San Diego AlertCalifornia drone team.
- Preparation of this memorandum summarizing CGS's reconnaissance observations, preliminary conclusions regarding future hazards from the two subject landslides, and preliminary emergency mitigation measures to reduce future potential adverse impacts to life and property at Wofford Heights.

The conclusions and recommendations provided in this memorandum should be considered preliminary in nature and are intended to be the starting point for more detailed evaluations. A summary of the landslides reviewed and CGS observations and recommendations is provided below.

Rainfall Data

The Wofford Heights area has been impacted by multiple atmospheric river and Pacific frontal storms this winter. Rain gage WFHC1, located 0.6 miles west of Cane Peak Court (See Figure 1), recorded 27.6 inches of rain between October 1, 2022, and March 12, 2023, which is more than double the average annual rainfall of 13 inches recorded in the Lake Isabella area. Of this total, 3.96 inches occurred on March 10 and an additional 1.98 inches occurred on March 11 leading up to the landslide failures that were first observed by KCFD on March 12. Peak 60-minute rainfall intensity during these last two days was 0.39 inch/hour (see Figure 2), which is expected to have a 50- to 100- percent annual chance, or a recurrence interval of about 1.5 years per NOAA Atlas 14 climate data (see Table 1). However, the 3.96 inches of rainfall recorded over a 24-hour period on March 10 is only expected to occur about once every 12 years, and the 5.94 inches of cumulative rainfall recorded over a 48-hour period on March 10 and 11 is only expected to occur about once every 22 years, which are much more uncommon events (see Table 1). The exact timing of movement is not known for either landslide, but the Cane Peak landslide was photographed by Kern County Staff on March 12.

Rain Gage	3-10&11-23 60-min (in.)	Atlas 14 ARI (years)	3-10-23 24-hr (in.)	Atlas 14 ARI (years)	3-10&11-23 48-hr (in.)	Atlas 14 ARI (years)
WFHC1	0.39	1.5	3.96	12.3	5.94	21.8

Table 1. Peak depths for 60-minute, 24-hour, and 48-hour duration rainfall totals on March 10 and 11, 2023, recorded at the NWS WFHC1 rain gage (located 0.6 miles west of Cane

Peak landslide), and corresponding annual recurrence intervals (ARI's) interpolated linearly between the nearest ARI for each recorded depth based on NOAA Atlas 14 climate data (https://toolkit.climate.gov/dashboard-noaa-atlas-14-precipitation-frequency-data-server). Rainfall data for WFHC1 gage extracted and processed by Francis Rengers (USGS).

Fire History and Past Post-Fire Hazard Assessments

Areas northwest of Wofford Heights have been burned by three wildfires since 2014 (see Figure 3). The Cane Peak landslide is located just inside of the perimeters of both the 2016 Cedar Fire and the 2021 French Fire, and is just southwest of the perimeter of the 2014 Way Fire. Review of post-fire hazard assessments for the Way Fire (CGS, 2014) and French Fire (CALFIRE and CGS, 2021) and pre-fire Google Earth imagery indicates that the vegetation at the location of the Cane Peak landslide was a patchy mix of small shrubs and grasses, which burned at low soil burn severity (SBS map in CALFIRE and CGS, 2021). Compared with adjacent areas outside the fire perimeters, the vegetation currently appears to be in the process of returning to pre-wildfire conditions, with abundant grasses and shrubs being reestablished and generally smaller than those on nearby hillslopes outside of the listed historic fire perimeters. No rills were observed in the Cane Peak area and the style of failure for the Cane Peak landslide indicates that it was driven by infiltration of rain water rather than by post-fire runoff, which is consistent with the relatively low, short-duration rainfall intensities recorded at the WFHC1 gage and the low combined hazard for post-fire debris flows identified by USGS debris flow modeling at the Cane Peak slide drainage (CALFIRE and CGS, 2021). The observed peak rainfall intensity of 0.39 inch/hour is approximately one-half of the fire-wide threshold of 0.78 inch/hour for triggering debris flows recommended for year-one, post-fire conditions at the French Fire. The Sierra Vista Drive landslide was not located within any known historic fire perimeter.

Geologic Overview

The subject sites are located in the southern portion of the north-northwest-trending Sierra Nevada geomorphic province of California (CGS, 2002). The Sierra Nevada is underlain primarily by Jurassic- and Cretaceous-age granitic rocks that intrude older metamorphic rocks and are locally capped by younger Tertiary sedimentary and volcanic strata. The eastern escarpment of the Sierra Nevada is bounded by a large normal fault and the southern portion of the range is cut by the range-parallel Kern Canyon Fault, which is located east of Wofford Heights where it is concealed below Lake Isabella. The Kern Canyon Fault is considered Holocene active and may produce future damaging earthquakes in the Wofford Heights area (Jennings and Bryant, 2010).

The occurrence of geologically young uplift and subsequent erosion has produced steep mountainous terrain that is subject to landslide occurrence as a result of heavy seasonal and/or storm driven rainfall, or strong ground motions from nearby earthquakes. Bedrock underlying the subject landslides consists of metasedimentary quartzite, schist and local metavolcanic rocks of the Cretaceous Fairview Formation (Ross, 1995). At Cane Peak, geomorphic conditions, including scarps and benches, and irregularities in metamorphic foliation orientation indicate that (using the classification system of Cruden and Varnes,

1996) a large dormant old rockslide (Qols) and a nested, younger, dormant young debris slide (Qyls) underlie the smaller landslide (debris slide and debris flows) that occurred in March 2023 (see slide annotations on Figure 4 and Photo A). Movement associated with the older slides has likely reduced the strength of the material, making slopes within the larger slides more susceptible to additional landslide movement. The landslide at Sierra Vista Drive consists of soil and colluvium weathered from the underlying Fairview Formation. Additional details regarding each subject landslide are provided below.

Site Observations: March 16, 2023

Cane Peak Landslide: The CGS team met with Matt Henry and Andrew Duitsman from the Kern County Fire Department (KCFD) at Cane Peak Court. CGS also spoke with Eric Lo and other members of a team from UC San Diego who were in the process of flying lidar and photographic imagery of the landslide area with a drone (see Photo B). CGS staff then hiked up the slope to the location of the March landslide and documented the geologic and geomorphic conditions (see Figure 5). The landslide initiated as a debris slide (definition at: https://www.conservation.ca.gov/cgs/landslides#debrisslides) with a maximum width of about 110 feet and a downslope length of about 130 feet. A five-foot-high scarp is present at the head of the slide, which exposes older disrupted landslide debris (see Photos C and D). The lower face of the debris slide displaced the scarp of a previous, possibly historic, shallow debris slide. Ground water was observed actively seeping from the face of the slide (see Figure 5). In addition, debris flows originated from the lower face of the debris slide mass and flowed down two parallel channels for distances of about 100 and 135 feet, respectively, with gradients of about 30 degrees (see Photo E).

Sierra Vista Drive Landslide: The landslide along Sierra Vista Drive occurred in an old ascending cut slope on the west side of the road (Photo I). Residents have reported that slope failures have occurred here at times over at least the past 15 years. The landslide is composed of soil and colluvium (slope deposits) derived from weathering of the underlying metamorphic bedrock and the type classifies as an earth slide/flow (see definition at: https://www.conservation.ca.gov/cgs/landslides#earthflows). The landslide is about 50 feet wide, and the scarp of the slide varies in elevation from 15 to 25 feet above the road grade. The March landslide moved up to six feet laterally into the road alignment based on a resident's report, but no evidence of slide movement was observed on the downslope side of the road.

Pala Ranches: Kern County staff noted that no evidence of recent landslide occurrence was observed at the Pala Ranches residential area southwest of SR 155, but they requested CGS to make a reconnaissance review of the area. No new landslides were observed by CGS and no evidence of post-fire debris flows were observed in canyons sourced in the French Fire burned area to the west. Grassy vegetation recovery was observed in the burned area between granitic outcrops.

Conclusions and Recommendations

Cane Peak Landslide: Observations indicate that the landslide was generated by infiltration of water from the unusually heavy rainfall over the preceding 24 to 48 hours overprinted onto high antecedent moisture conditions derived from the exceptionally high seasonal rainfall (>200% of average) beginning in late December 2022. Water infiltration was likely sourced from within the slide area and from the adjacent bench areas associated with the older landslides (see Figure 4). Water infiltration rates likely exceeded seepage rates, as evidenced by continued seepage from the toe of the landslide, and buildup of water and hydrostatic pore pressures within the old slide debris destabilized the landslide mass. Debris flows were then generated along the lower face of the debris slide due to excess seepage resulting in shallow failures that mobilized into flows.

Infiltration from future rainfall could again generate excessive pore water pressures and result in additional landslide movement. Modest rainfall would likely generate localized movement of the debris slide. However, unusually heavy or prolonged rainfall could cause more extensive debris flows that could continue down channel into the developed area (see photos F and G for perspectives). The small catchment area that exists on the upstream side of the drainage where it crosses Cane Peak Court is significantly smaller than the volume of the March debris slide and therefore would not likely have the capacity to contain the volume of a significant debris flow mobilizing from the debris slide. Flows that reach the road will clog the small diameter culvert and because of the inclination of the road down to the southwest where it crosses the channel, flows will preferentially diverge southwestward, either toward the residence at 110 Cane Peak Court or down the roadway (see Figure 4 and Photo H). Flows that continue down Cane Peak Court could make the road impassable but would not likely reach the homes because the homes are elevated relative to the road grades. Flows that do continue southward within the natural channel could reach and impact Anchorage Avenue and beyond.

Several emergency measures could be implemented to reduce the potential for adverse impacts to residents down gradient of the Cane Peak landslide.

- K-rail could be positioned at Cane Peak Court to divert flows either down Cane Peak Court and/or down the existing natural channel east of the residential structures. The K-rail should be anchored to help resist impact forces from the debris flow. It may also be beneficial to place a second row of K-rails considering that the potential volume of the flow is uncertain, and debris flows commonly exhibit an elevated, high-energy surge front, that may overtop the K-rails.
- Evacuation of the residents at 110 Cane Peak Court if a major storm is forecast or there is indication of imminent landslide failure.
- Placement of K-rails at the south end of Cane Peak Court to divert flows away from a home down gradient of the road end.
- Sandbags or K-rail could also be placed to direct flows away from homes adjacent to Anchorage Avenue and down the natural channel.

- Placement of anchored visqueen over the area of the March landslide (debris slide) scarp and landslide mass to limit water infiltration.
- Emergency planning such as ensuring culverts and roadside ditches and drains are cleared prior to forecast storms, and monitoring road conditions during forecast storms and stationing of equipment to clear debris and provide emergency access to residents along Cane Peak Road if needed.
- Educating residents regarding the potential hazards for situational awareness and emergency preparedness.

It should be noted that additional rainfall could generate new landslides within the existing older Cane Peak slide complex. A licensed professional geologist and geotechnical engineering consultant with experience evaluating slope instability could be hired to provide a more detailed assessment and more specific mitigation measures relative to the stability and potential hazards associated with the Cane Peak slide complex.

Sierra Vista Drive Landslide: The Sierra Vista landslide area was restricted to the road area, and additional movement appears likely to be localized to the area upslope and on the uphill side of the road prism. The slide is not expected to catastrophically affect residences downslope of the road. Potential emergency mitigation includes continued maintenance of the road to clear debris as needed following future storm events to provide access for the residents. A permanent solution to mitigate future slope failures would be construction of a retaining structure. It should be noted that removal of the slide debris with no other mitigation may create more slope instability.

Pala Ranches: No evidence of landslides or post-fire debris flows was observed. However, future storms with higher intensity rainfall could still produce debris flows in susceptible areas, as identified in the Watershed Emergency Response Team (WERT) report addressing post-fire hazards from the 2021 French Fire CALFIRE and CGS (2021). See Figure 6 for map of USGS debris flow hazard modeling and Values-at-Risk identified by the WERT in the Pala Ranches area.

Summary

CGS staff prepared this memorandum to assist Kern County, Cal OES, and responsible agencies in their emergency planning for potential life-safety and property hazards identified at two landslide sites at Wofford Heights. Responsible agencies should consider both short-term emergency mitigation and repairs along with more robust permanent mitigation where appropriate. Future storms this winter and in the coming years may exacerbate the observed issues and lead to additional impacts. If Kern County, Cal OES, or any responsible agencies have questions regarding the findings and preliminary emergency mitigation options provided in this memorandum, please feel free to contact the undersigned staff at CGS.

It should be noted that the observations and recommendations included in this memo are not intended to be fully comprehensive and/or conclusive, but rather to serve as a preliminary tool to assist local and emergency responding agencies (e.g., Kern County, affected towns, Governor's Office of Emergency Services, utility companies, and other responsible agencies) in the development of more detailed emergency protective measures and response plans. ***It is intended that the emergency responding agencies will use the information presented in this report as a preliminary guide to complete detailed evaluations and attendant emergency response plans, activities, and mitigations.***

March 27, 2023

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March 27, 2023

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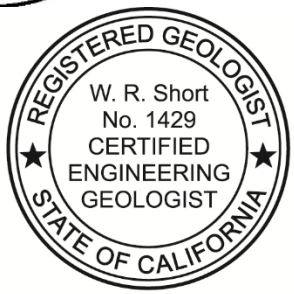

March 27, 2023

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Concur

References: page 8

Appendix A: Figures 1 through 6

Appendix B: Field Photographs A through I

References

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Appendix A:

Figures

Figure 1: Index map showing locations of Cane Peak and Sierra Vista Drive landslides in the Wofford Heights area, Kern County, CA.

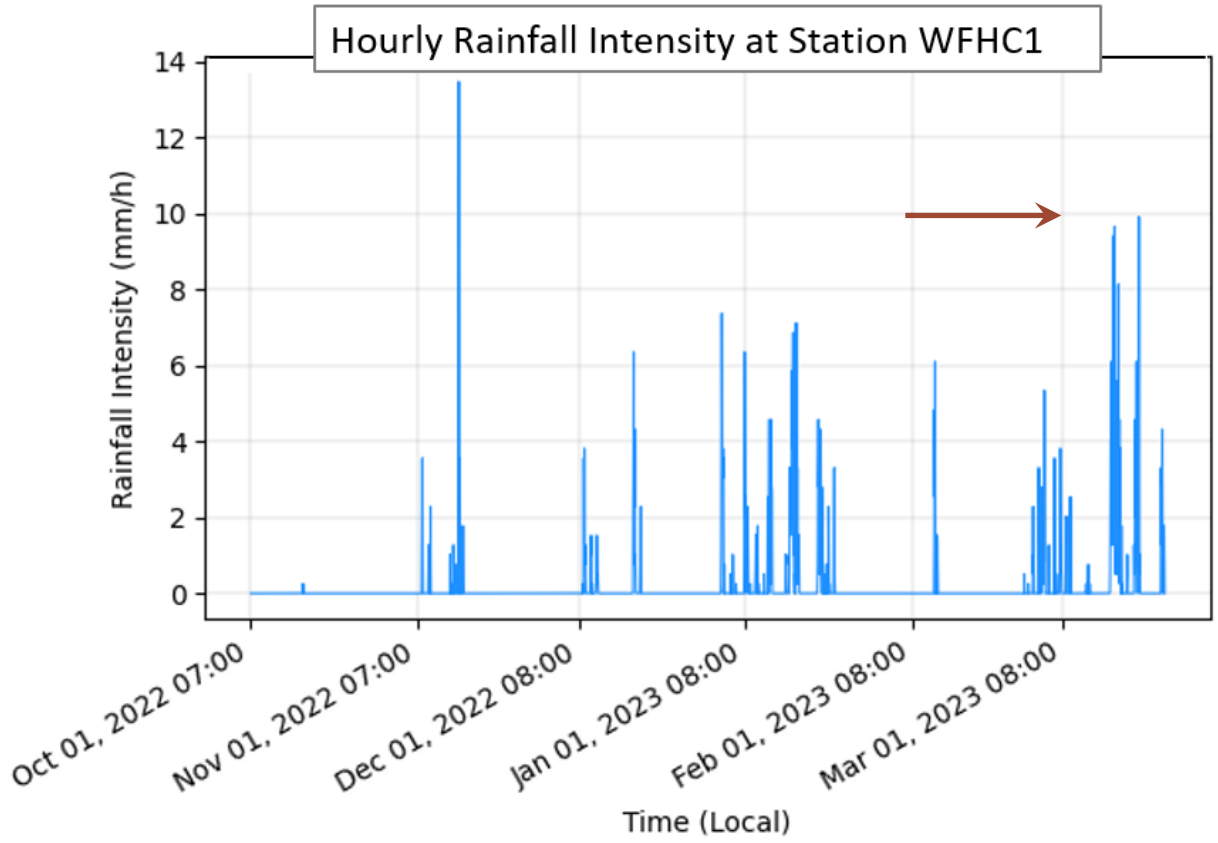

Figure 2: Rainfall intensity plot at 60-minute duration recorded at WFHC1 rain gage for period of October 1, 2022, through March 19, 2023 (see Figure 1 for gage location). Data extracted and processed by Francis Rengers (USGS). Note peak intensity of about 10 mm (0.39 inch)/hour for March 10-11. Total rainfall from October 1, 2022, through March 19, 2023, is 31.5 inches.

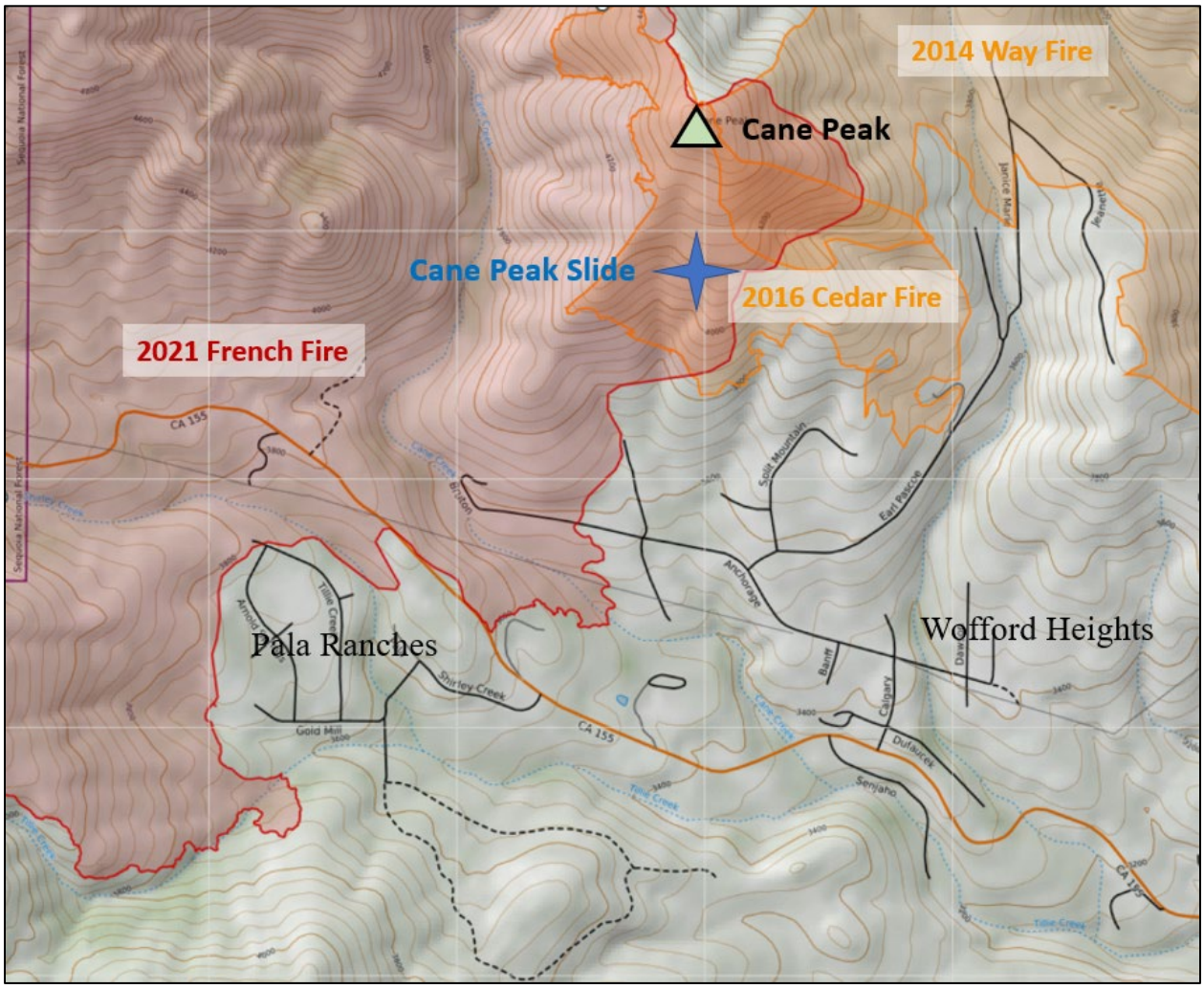

Figure 3: Fire History Map of Cane Peak area (obtained from CalTopo interactive website: https://caltopo.com/map.html#ll=35.71987,-118.48835&z=16&b=mbt&a=fire.

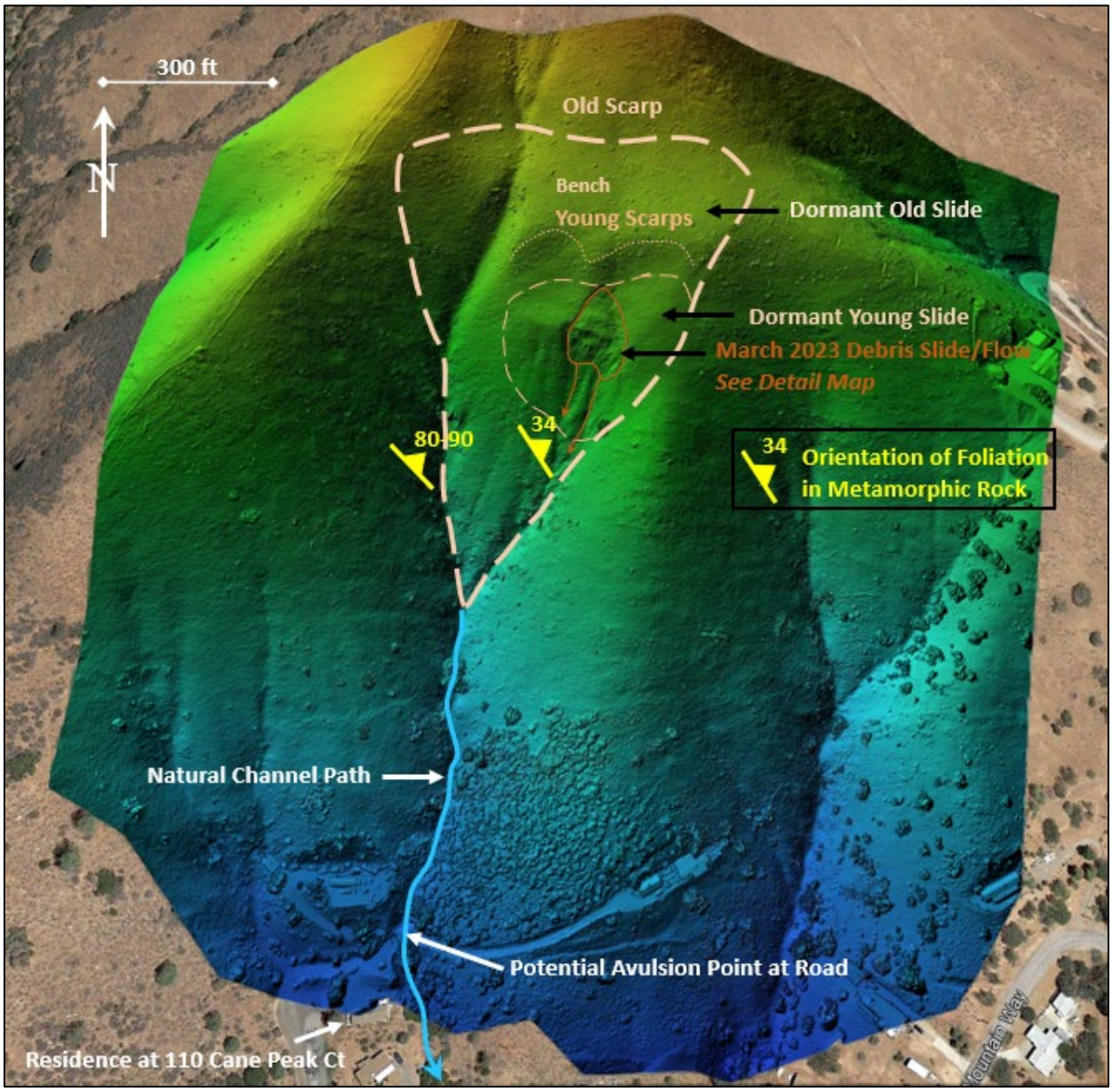

Figure 4: Overview map showing oblique perspective for March 2023 Cane Peak landslide nested within larger, older dormant old (Qols) and dormant young (Qyls) landslides; See Figure 5 for details of March 2023, landslide. Base map is comprised of a colored lidar hillshade topographic model provided by UC San Diego on March 16, 2023, draped onto Google Earth imagery.

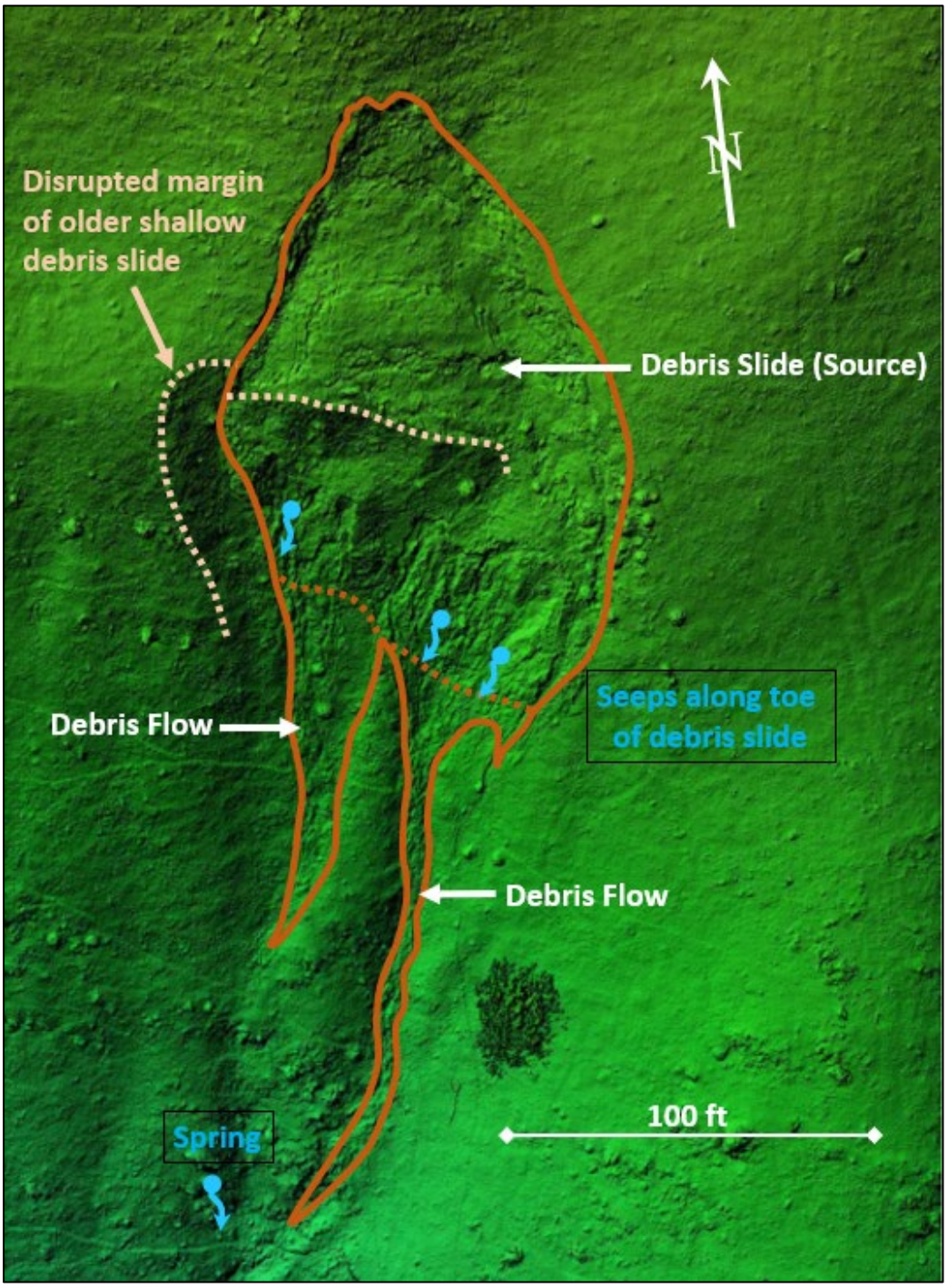

Figure 5: Detail map showing conditions at the March 2023, Cane Peak landslide. Base map is comprised of a colored lidar hillshade topographic model provided by UC San Diego on March 16, 2023, draped onto Google Earth imagery; note that image is rotated slightly relative to Figure 4.

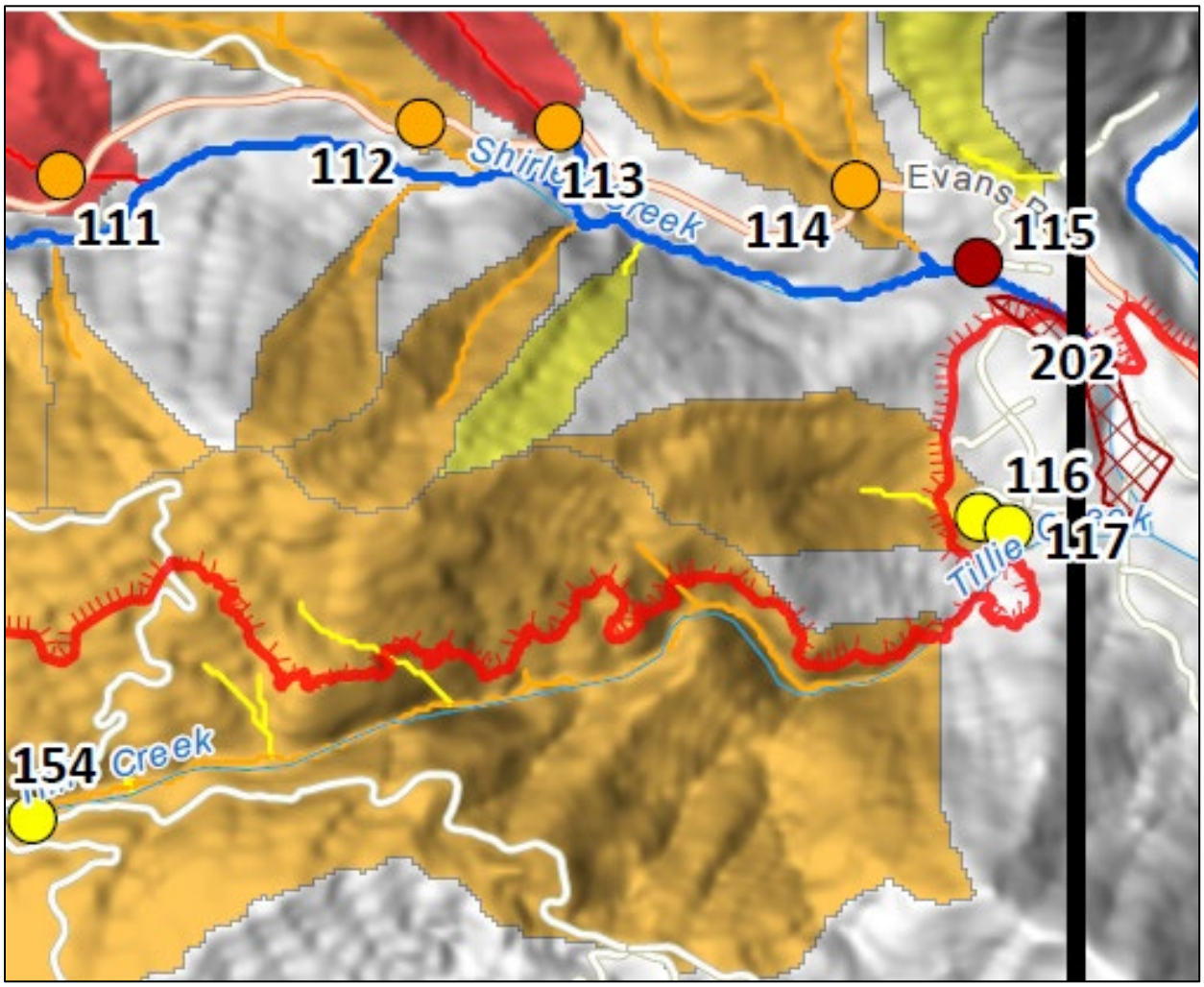

Figure 6: Clip of USGS debris flow hazard map for the French Fire showing source areas burned upstream of the Pala Ranches area. Note that the WERT identified two low hazard Values-at-Risk (VARs) in this area at VARs 116 and 117. No evidence of debris flows or hyper-concentrated flows were observed in this area as of March 16. Note that drainages are color coded based on the combined probability of a debris flow and estimated debris flow volume for a design 15-minute storm intensity of 1.1 inch/hour (28 mm/hour), which equates to 0.28 inches (7 mm) of rain in 15 minutes. The peak rainfall recorded at the WFHC1 gage was 0.39 inch/hour; note that 15-minute duration intensity was not recorded at this gage.

Appendix B:

Field Photographs

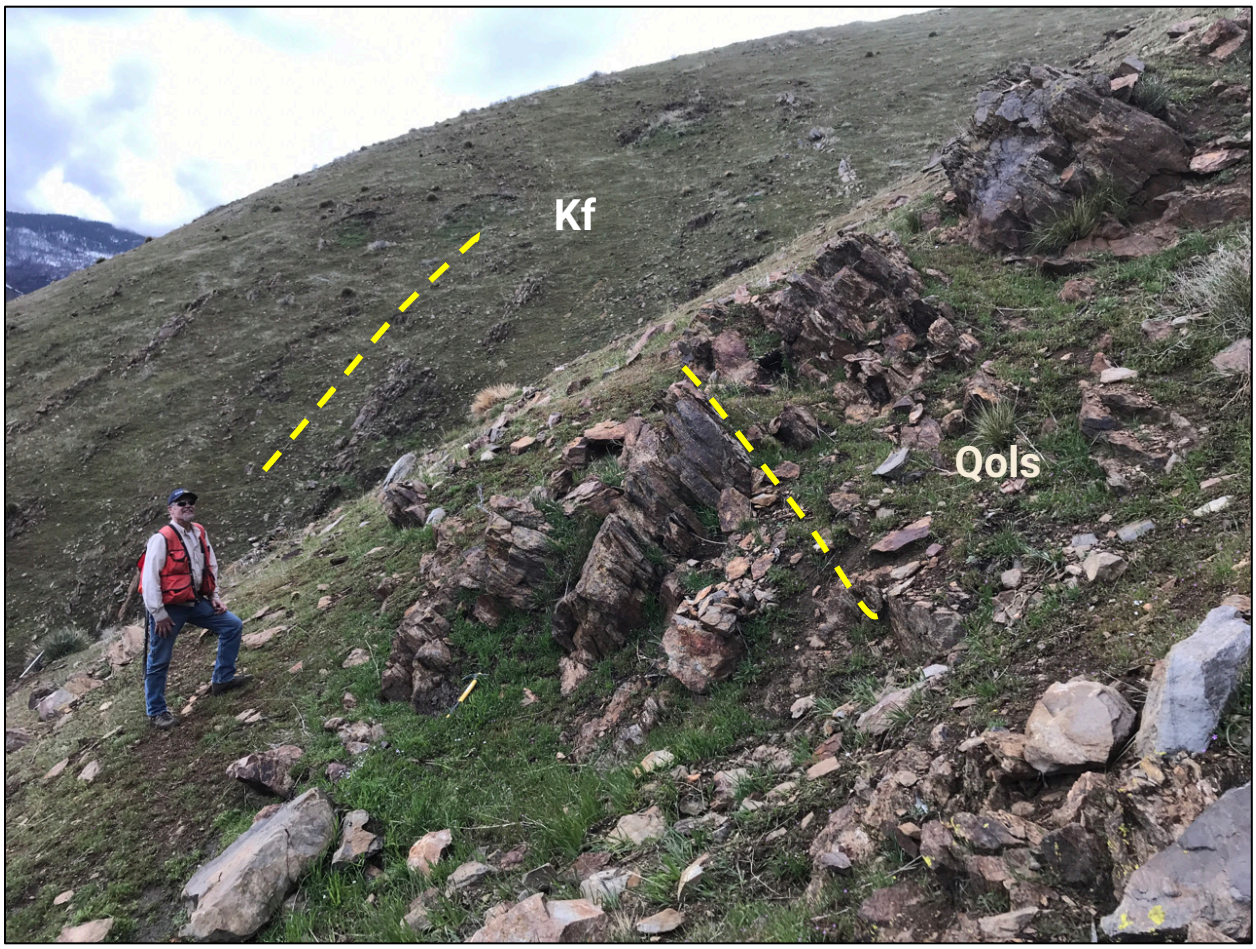

Photo A: View northwest of quartzite and schist outcrops of the Fairview metasedimentary formation (Kf) exposed downslope of March 2023 Cane Peak landslide. Note that the metamorphic foliation in exposures on the ridge in the background have a near-vertical inclination whereas the foliation in the foreground has a relatively oblique trend (as highlighted in yellow) and dips moderately to the north (see foliation orientations mapped in Figure 4). The discrepancy in orientations suggests the outcrops in the foreground may have been rotated by ancient slide movement (Qols).

Photo B: View north of Cane Peak landslide; note CGS and Kern County staff for scale (denoted with green arrows). Note benches at and above head of March landslide, which likely formed due to past movement of older, larger landslides. Also note debris flow tracks down slope originating from main debris slide mass. Drone photo provided by UC San Diego.

Photo C: View northwest along main scarp and internal secondary scarps of the Cane Peak landslide.

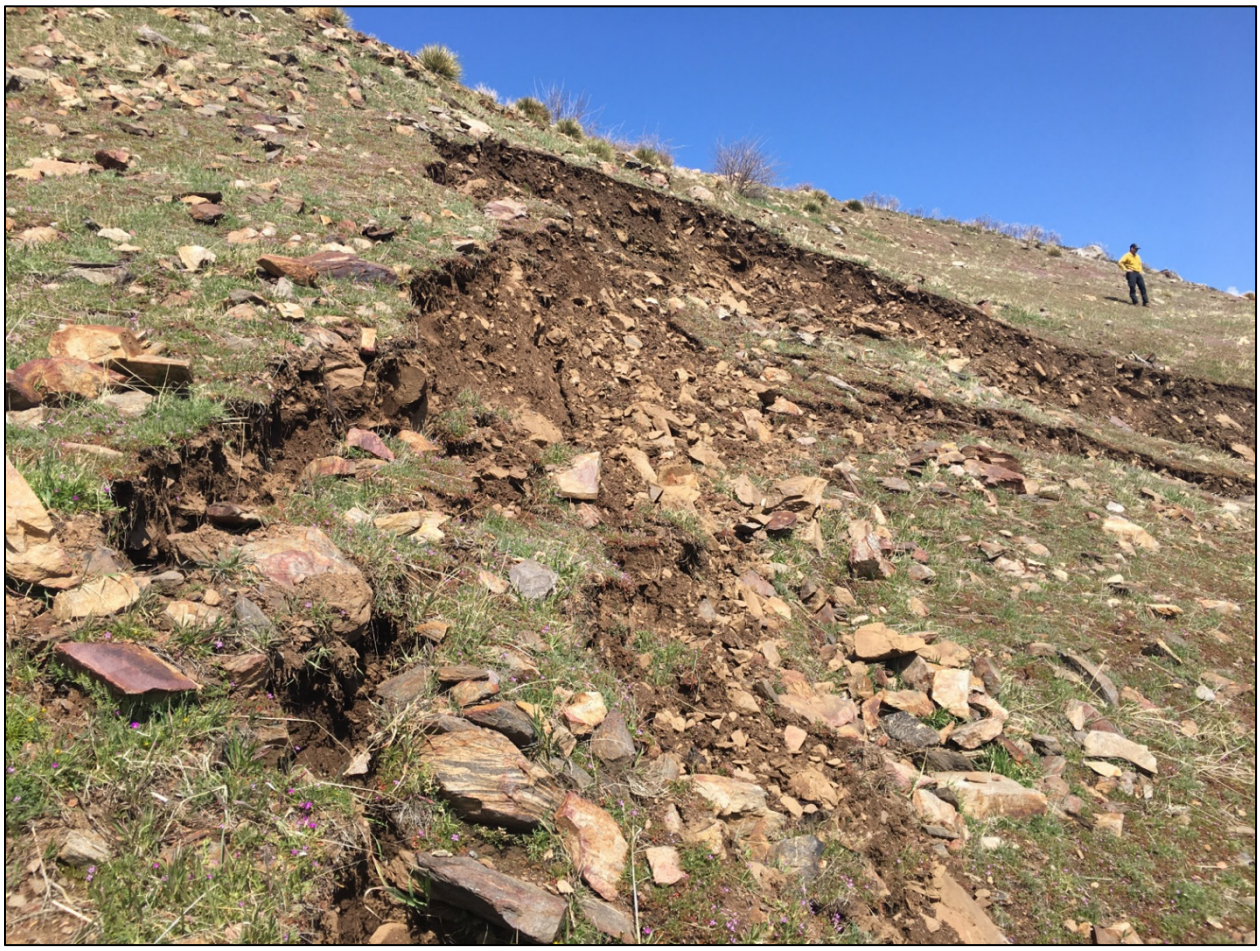

Photo D: View northeast of main head scarp showing disrupted fragments of Fairview metasedimentary rocks; scarp is five feet high. Note person in upper right background for scale.

Photo E: Debris flow deposits down gradient from main landslide mass. Note debris flow in foreground originating from main debris slide mass; note active water flow from seepage at source in debris slide face. The channel gradient is approximately 30 degrees.

Photo F: View down slope from west margin of slide mass toward developed area in vicinity of Cane Peak Court.

Photo G: View north up slope from Cane Peak Court toward landslide; note small catchment area in foreground.

Photo H: Residence at 110 Cane Peak Court on opposite side of road from channel that drains from landslide area.

Photo I: Landslide (earth slide/flow) sourced from soil and colluvium exposed in old cut slope along Sierra Vista Drive.

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