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Geologic Assessment of Slope Stability
Proposed Babu Vineyard Block C
3300 White Sulphur Springs Road
Saint Helena, CA 94574

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Introduction

This geologic assessment considers the potential effect on slope stability of proposed vineyard development on the above referenced property (APN 027-010-033) as described in the Babu Vineyards: Block C Erosion Control Plan (ECP), including the inherent stability of earth materials at the site. It has been prepared according to County of Napa guidelines for Landslide Hazard Evaluation. O'Connor Environmental, Inc. (OEI) was engaged by the property owner, Arvin Babu, to conduct this geologic assessment as a component of the Erosion Control Plan Application.

OEI has conducted several similar slope stability assessments in Napa County and Sonoma County. In addition, OEI has several years of experience mapping landslides and evaluating slope stability in forested upland regions of western Washington and northern California. The landslide hazard evaluation was prepared by Michael Sherwood, a Professional Geologist in California with support from Dr. Matthew O'Connor, a Professional Geologist and Certified Engineering Geologist in California and a Licensed Engineering Geologist in Washington. Dr. O'Connor prepared a similar report related to the ECP for vineyard blocks A and B located on the subject parcel in 2017. In October 2020 the Glass Fire burned intensely through the project area destroying much vegetation and ground cover. Since then, salvage logging of dead trees has been conducted further altering ground cover conditions. Although ground cover is currently very sparse due to the recent fire and subsequent cleanup activities, impacts of the proposed project upon slope stability under current conditions have been considered with respect to post development conditions when substantial recovery of vegetation is expected to have occurred.

Project Description

The 67.8 acre parcel presently contains approximately 2.05 acres of vineyard (Blocks A and B, Figure 1) and has a completed well with a yield of 50 gallons per minute. The proposed project would develop 0.41 gross acres (0.24 acres net) of vineyard on a small ridgetop south of existing Block B (Figure 1). A detailed site plan for the project is summarized in the vineyard Erosion Control Plan that shows the proposed conditions on the parcel.

Methods

To evaluate existing and potential slope stability hazards at the project site, the following tasks were undertaken: review of available geologic maps and previous slope stability assessments, review of available historic aerial photographs, review of soil survey data, field reconnaissance (multiple site visits), and synthesis of available information regarding existing and likely future stability of the site.

Regional & Site Geology

The project is located within the California Coast Ranges geomorphic province. Numerous faults oriented northwest-southeast occur in this region, and extensive tectonic activity has created a landscape of northwest-southeast trending ridges and valleys. The tectonic activity is associated with the collision between the Farallon and North American plates occurring particularly in the late Mesozic (about 100 million years before present), and with movement along the San Andreas Fault which formed in the mid-Cenozoic (about 30 million years before present) at the boundary between the Pacific and North American plates.

The project site lies about one mile east of the ridge separating the Sulphur Canyon/Napa River watershed and the headwaters of the Santa Rosa Creek watershed to the west. No faults considered to be active are located at the site. The nearest active faults (Holocene age or younger) are the Rogers Creek about ten miles to the west and the West Napa about 10 miles to the southeast. A Quaternary age thrust fault of uncertain age[1] oriented northwest-southeast extends about six miles from a point about one-half mile west of the project site to a point in the upper Mark West Creek watershed. This unnamed fault is not considered active.

The bedrock unit underlying the project site is a member of the Franciscan Complex described as graywacke and mélange of Early Cretaceous and Late Jurassic age (map unit KJfs; Graymer et al. 2007). The KJfs unit consists of massive to distinctly bedded, lithic wacke and dark-gray or black siltstone, shale, and slate, grading into mélange consisting of sheared argillite and graywacke matrix enclosing blocks and lenses of sedimentary, metamorphic, and volcanic rocks. These rocks have been significantly deformed and altered by tectonic activity and large, deep and complex landslides are commonly found in the Franciscan Complex. A landslide deposit covering about 22 acres is mapped through the central portion of the parcel (Wagner & Gutierrez, 2010) which was classified in the field in 2017 by Dr. Matt O'Connor as a dormant rockslide[2] (Figure 1) as part of the Landslide Hazard Evaluation (LHE) associated with the ECP for Babu Vineyards Blocks A and B.

[1] Fault Activity Map of California (2010) California Geological Survey (maps.conservation.ca.gove/cgs/fam)
[2] The surface of rupture of the slide body occurred at substantial depth (10's of feet) below ground surface in bedrock material (Cruden and Varnes, 1996; Keaton and DeGraff, 1996).

Proposed vineyard Block C is located on the ridge on the southern flank of this rockslide; Block C is not on the rockslide body and is believed to be perched above its remnant lateral scarp.

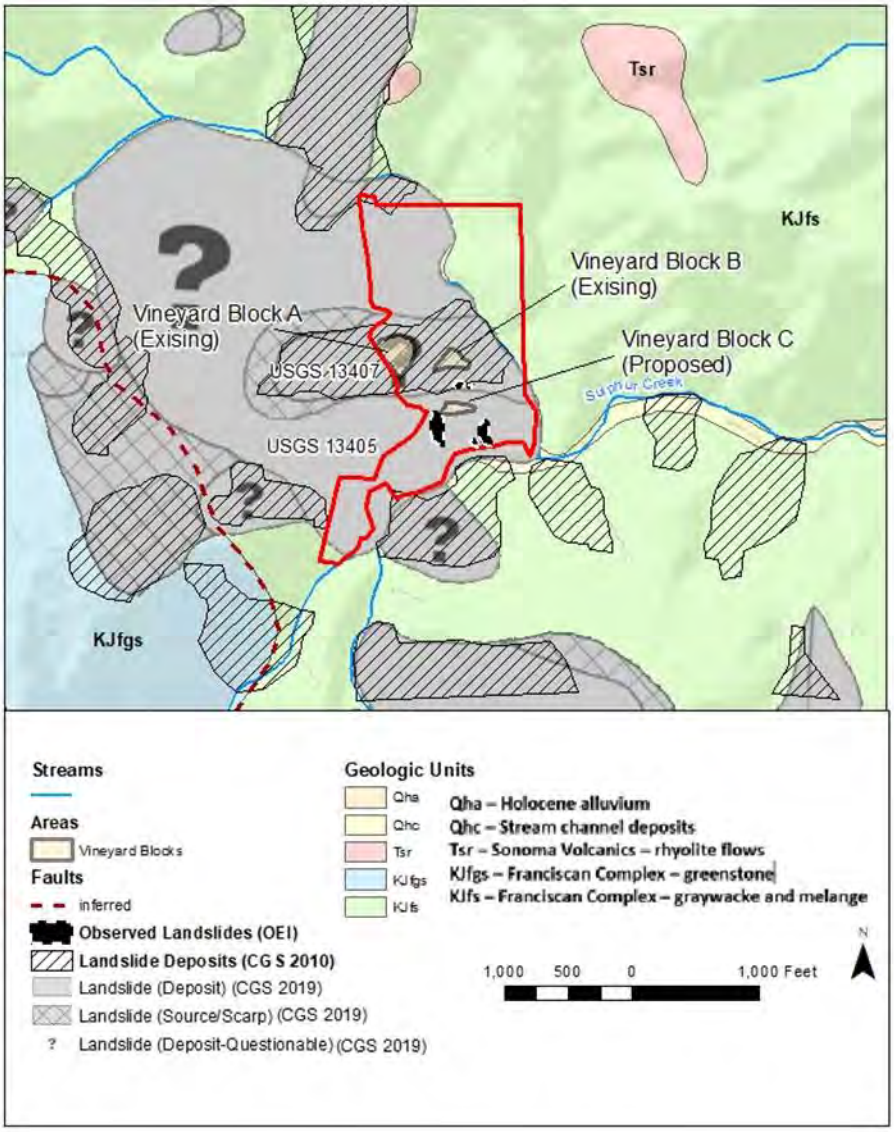

Figure 1. Local area geology (Graymer et al. USGS , 2007), landslide deposits (Wagner and Gutierez CGS 2010, CGS Landslide Inventory 2019, and OEI field observations 2021) and subject parcel outlined in red.

The map of Graymer et al. (2007) indicates bedding planes dipping 35 degrees to the north with a strike oriented west-east at a location along the site access road near the eastern edge of subject property near the stream channel of Sulphur Canyon. Indications of structural features of the bedrock (e.g. strike and dip of bedding planes) may vary significantly over short distances in sedimentary rocks of the Franciscan Complex, so this isolated data point may or may not be representative of conditions on the subject property.

Potential Slope Instability

Napa County GIS Parcel Reports indicate that landslides are present on the project parcel. Landslides deposits were mapped by Wagner and Gutierrez (2010) and were overlain on the map (shown as polygons with cross hatching, Figure 1) of Graymer et al. (2007) using GIS techniques. The landslides deposits (Qls) are described as "Landslides (Pleistocene to Holocene-Includes debris flow and block slump landslides". The landslide subject to evaluation for our previous LHE was identified independently by OEI and was subsequently found to correlate with the interpretation of Wagner and Gutierrez (2010).

In addition, a recent regional landslide mapping effort by the California Geological Survey (the California Landslide Inventory, CGS 2019) has compiled several landslide mapping efforts across the state. One of these prior landslide mapping projects in the vicinity of the subject parcel identified landslides on the Kenwood 7.5 Minute Quadrangle using aerial photos (Dwyer, Noguchi and O'Rourke, USGS 1976) show several large landslides near and on the project parcel (Figure 1, Table 1). Two questionable large landslide deposits are mapped intersecting the project parcel (questionable is defined as "50% confident it is a landslide" by the USGS study). The larger of the two, Landslide Number 13405, covers approximately 170 acres and the second, Landslide Number 13407, is located within the first covering about 23 acres and is the same landslide evaluated in our previous LHE. This landslide was described by Dr. Matt O'Connor, CEG, as a relatively stable dormant translational/rotational rockslide that did not pose a threat to Babu Vineyard Blocks A and B. Proposed vineyard Block C is located within the larger of the two landslides (13405) near its southern boundary (Figure 2).

A strong indicator of potential slope instability is slope gradient. Observations of slope gradient in the field did not suggest significant potential slope instability in proposed Block C. Slope gradient on the proposed vineyard site is generally less than 30% with some small inclusions of > 30% slope. In most non-cohesive earth materials, potential instability is generally very low on slopes less than about 50% and may typically be found to be significant on slopes greater than 65%. On some landslide deposits and in some clay-rich materials under certain conditions, there may be higher potential instability on slopes in the 50% to 65% range.

Table 1. Landslides mapped by Dwyer, Noguchi and O'Rourke (USGS 1976) and observed by OEI (2017) intersecting the project parcel and located near proposed Vineyard Block C.

Project Parcel (APN **027-010-033**)			
Source	Landslide Number	Landslide Type (per USGS)	Review Notes
USGS 1976	13405	Questionable Undefined Landslide	Probable dormant deep seated rockslide complex. Large area covered, contains several smaller previously mapped and unmapped features. USGS Landslide 13407 and OEI landslides 1-6 are relevant features located within this mapped area and discussed separately as they relate to Vineyard Block C.
USGS 1976	13407	Questionable Undefined Landslide	Previously evaluated in LHE for Babu Blocks A and B. Defined as a Dormant Translational/Rotational Rockslide. Determined to be relatively stable and not a threat to development of Blocks A and B.

Due to the proximity of proposed vineyard Block C to mapped landslides and the proximity of slopes greater than 65% downslope a site-specific assessment of slope stability was conducted. Several smaller landslides were identified within the vicinity of proposed Block C during site visits conducted in the autumn 2021. The main elements of the project and features of the observed landslides near the project site are portrayed in Figure 2. A discussion of the observations made during the site visit is provided later in this document.

Soils and Slopes

Soil types at the proposed vineyard sites were queried using the NRCS Web Soil Survey (USDA). The review of soils data is not particularly germane to site-specific determination of evidence of slope stability or instability but is sometimes helpful in identifying evidence of susceptibility to slope instability.

The soils mapped on the project parcels are listed in Table 2. Web Soil Survey data for the project site indicate Boomer-Forward-Felta complex 5 to 30% slopes (111) in the western portion and Felton gravelly loam 30 to 50% slopes (136) in the eastern portion of the Project area (Figure 3). The Boomer-Forward-Felta complex soils are said to be derived from weathered volcanic and metavolcanic rocks most likely associated with the Sonoma Volcanics[MO1]; however, this bedrock is not generally present in this portion of the Sulfur Creek watershed. As mentioned above the project area is underlain predominantly by meta sedimentary and metavolcanic rocks (KJfs and KJfgs) of the Franciscan Complex which likely indicates that descriptions of parent materials by the Web Soil survey are somewhat generalized for soils found across Napa County. Erosion hazard is reported to range from slight to moderate for this complex (USDA, 1978). The Boomer-Forward-Felta complex soils are classified in Hydrologic Soil Group B which has a moderately low runoff potential when thoroughly wet and water transmission through the soil is unimpeded. The Felton gravelly loam soils are derived from weathered sandstones and shales of the Franciscan Complex and the hazard of erosion is moderate to high (USDA, 1978). These soils are classified in Hydrologic Soil Group C which have a slow infiltration rate when thoroughly wet and have a slow rate of water transmission.

Table 2. Soils located near the project site, properties from USDA Web Soil Survey.

Soil Type	Soil Description	Depth to Bedrock (inches)	Hydrologic Soil Group
111	Boomer-Forward-Felta complex, 5 to 30% slopes	20 - 80	B
136	Felton gravelly loam, 30 to 50 % slopes	30	C

Aerial Photo Review

Historical aerial photography available on Google Earth was reviewed for evidence of active landslides at or near the project parcel. The available imagery was abundant for the period 2002 to present; the oldest image from this source was 1985. The one feature visible in the aerial images is landslide OEI 1 which shows up as a blurry but high contrast area in the 1985 image.

The extent of OEI 1 does not appear to change throughout time however year to year vegetation cover changes may indicate some movement of landslide materials within the body of the landslide. Further discussion of existing slope conditions, hazard levels and recommended actions for this landslide is presented in the following sections.

Observed Landslides and Slope Conditions

I conducted field reconnaissance of the proposed vineyard site on September 1 and 22, 2021 over a total of six-hours. Site photos are compiled in Appendix B. I measured the slope gradient of the ground surface at various locations in the proposed vineyard site using a clinometer. I found slopes consistent with those documented in the ECP and the LiDAR-derived topographic data. In addition, I inspected the ground surface around the perimeter of the proposed vineyard block where slopes are > 30%, where natural swales are found and where evidence of slope instability and landslide activity would likely exist if present.

Landslides observed during the site visit were mapped as shown in Figures 1 and 2; Table 2 provides brief descriptions of each landslide along with recommended actions to minimize slope stability hazards. Photographs of the landslides are shown in Figures 3 -8.

Landslide type and activity states are described using methods outlined by Cruden and Varnes (1996) and Keaton and DeGraff (1996). All landslides observed in the field are displayed on the maps as polygons with black and white outlines. The majority of the landslides mapped in the project area can be described as small landslides located within a portion of a much larger dormant deep-seated rockslide that was mapped previously as shown in Figure 1. The most common type of landslide that occurs on dormant rockslides are debris slides (shallow, rapid slope failures; CDC 2013) originating on steep terrain associated with morphologic features of large, deep landslides: the landslide foot, the slopes of deeply incised stream channels draining landslide bodies, and at steep scarps formed above the head and along the flanks main body. Some evidence of small shallow landslides (debris slides) associated with cut slopes and fill slopes of the gravel-surfaced “truck road” just to the north of Blocks A and B has been observed in the field. In addition, aerial photo images show evidence of two or three debris slides that appear to have occurred after 1993 on the main scarp and associated with cut slopes and fill slopes of a road.

For purposes of this evaluation, we used the following nomenclature and criteria (see references above for sources):

<u>Landslide Activity</u>

- ***Active*** features displayed evidence of movement within the previous wet season, this included exposed soils, sharp unvegetated scarps and lateral flanks.
- ***Historically active*** features showed evidence of movement within (approximately) the past 100 years with no movement within the previous wet season.
- ***Dormant*** landslides are assumed to have moved sometime in the last 100 to 5,000 years.

<u>Landslide Type</u>

- Rockslide – A rockslide is a landslide involving bedrock in which the rock that remains largely intact for at least a portion of the movement. The sliding occurs at the base of the rock mass along one to several relatively thin zones of weakness.

- Earthflow- An earthflow is a landslide resulting from slow to rapid flowage of saturated soil and debris in a semi-viscous, highly plastic state. After initial failure, the earthflow may move, or creep, seasonally in response to destabilizing forces.
- Debris slide - A debris slide is characterized by unconsolidated rock, colluvium, and soil that has moved rapidly downslope along a relatively shallow translational failure plane. Debris slides form steep, unvegetated scars in the head region and irregular, hummocky deposits (when present) in the toe region.
- Debris slide slope- Debris slide amphitheaters and slopes are geomorphic features in which slopes have been sculpted by numerous debris slide events. The amphitheaters and slopes are characterized by an aggregate of debris slide scars left by the movement of predominantly unconsolidated rock, colluvium, and soil along relatively shallow failure planes.

CDC (2013) provides guidance to Professional Geologists regarding mitigation of landslide hazards for timber harvest and forest management activities. This guidance is appropriate for this project, which involves converting about 0.4 acres of forest (locally destroyed in the Glass Fire) to vineyard use. With respect to debris slides, the guidance regarding management objectives is as follows:

> *Because debris slides are characterized by unconsolidated materials above a shallow slide plane, the main management objectives are to: retain root support, minimize water flow along the soil/rock interface, avoid the undercutting of materials to the slide plane, and minimize the weighting of unconsolidated materials on steep slopes*

Runoff and drainage patterns are modified by project infrastructure as necessary to conform to Napa County General Plan guidelines that require no increases in runoff or erosion from the site. Consequently, nearly all the runoff from Block C (0.41 acres total) is collected in cross field ditches, directed to rock lined ditches along the vineyard edges and then routed through a small flow attenuation basin to a level spreader on the eastern edge of the vineyard block. The flow spreader will be located on a divergent slope with a gradient of about 35% and will direct water down the most stable portion of the nearby hillside.

Field Observations and Interpretation

This section describes the observations made during the site visits and some general recommendations for development planning.

Potential geologic hazards observed in my site reconnaissance include six debris slides of varying scales located along the southern and northeast edges of proposed vineyard Block C. Within the area reviewed, one feature was observed to be active: Landslide OEI 1. The remaining landslide features (Landslides OEI 2-6) were observed to be historically active.

Landslide OEI 1 is an active debris slide located near the southwest corner of proposed vineyard Block C. This landslide has evidence of intermittent shallow erosion in the form of fresh soil exposures on portions of its scarp, margins and throughout the landslide body. Figure 3 shows photos of the scarp and a portion of the main body of the landslide. Review of aerial imagery available through Google Earth indicate that OEI 1 is greater than 30 years old. No tension cracks or evidence of recent significant movement was observed along the margins or within the body

of the landslide. Landslide OEI 1 is considered low hazard with respect to the proposed project as runoff from the vineyard will not flow to the landslide area. All runoff from the proposed vineyard area will be collected in a rock-lined ditch located along the southern vineyard block boundary and diverted to an attenuation basin at the eastern edge of the block (Figure 2 and ECP). This water will be released from the attenuation basin on to the divergent slope below via a level spreader.

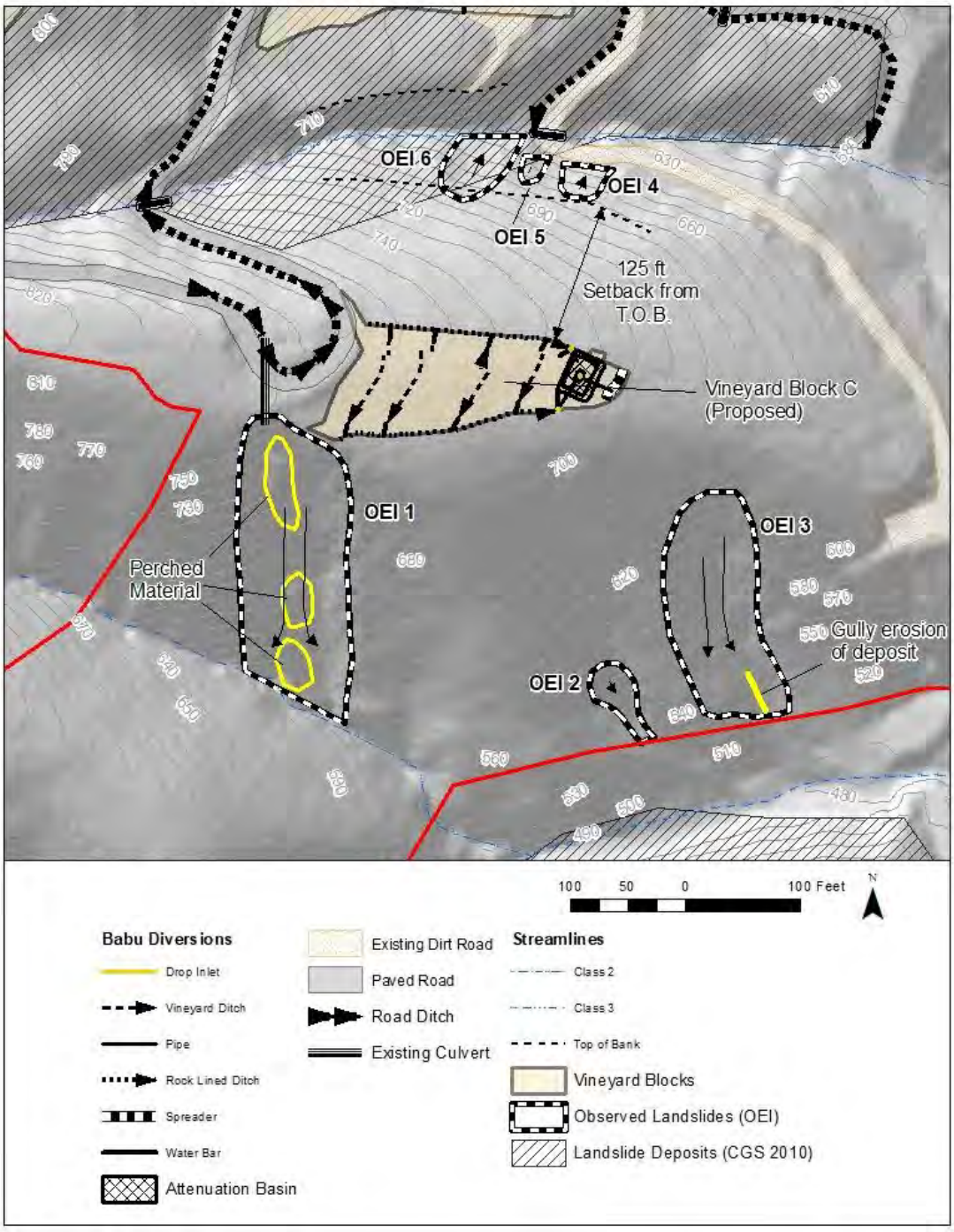

Figure 2. Observed landslides in the vicinity of proposed vineyard Block C. Topographic contours and hillshade derived from 2018 USGS Lidar.

Within the landslide body of OEI 1 there are three distinct lobes of perched, potentially unstable material (shown as yellow polygons in Figure 2). Although runoff from the proposed project will not arrive to these areas concentrated runoff from a road cross drain culvert does drain to the top of OEI 1. Damage to the culvert during the Glass Fire required this culvert to be replaced. Presently the culvert does not have a downspout to direct flows downslope away from the upper lobes of sediment. To avoid future destabilization of the landslide body from water diverted through the cross drain a downspout of an appropriate length should be installed. The specific length of this downspout has not been determined however it is expected to be between 100 and 200 feet. As stated in the ECP, coordination in the field is required between the contractor and a representative of OEI to determine the length and specific layout of the downspout.

Landslide OEI 2 is an historically active debris slide located approximately 200 feet east of OEI 1 and 240 feet south of Block C near the base of the slope (Figure 2). OEI 2 appears to be at least five years old as evidenced by a small maple growing in the body of the landslide. Landslide OEI 3 is also an historic debris slide located 50 feet east of OEI 2 and 108 feet southeast of the Block C boundary (Figure 2 and Figure 4). This landslide appears to be older than OEI 2 (possibly greater than 40 years) as larger diameter fir stumps were observed in the landslide body. Topographic features across OEI 2 and 3 are mildly to greatly subdued and no evidence of recent movement (within the last year) was observed; however, some gully erosion of the main deposit of OEI 3 was observed

Landslides OEI 2 and OEI 3 have been determined to be low hazard with respect to project effects owing to the relatively large distance from the proposed vineyard boundary and fact that runoff from the project will be collected in the proposed rock-lined ditch and diverted to an attenuation basin at the eastern edge of the block. All collected runoff will be released from the attenuation basin onto the divergent slope below via a level spreader and no concentrated flows are expected to arrive to either landslide.

Landslides OEI 4, OEI 5 and OEI 6 are all relatively shallow debris slides located to the north of proposed vineyard Block C along the flank of USGS Landslide 13407 the larger previously mapped Dormant translational/Rotational Rockslide (Figures 1 and 2, Table 1). These landslides vary in age between 5 and 8 years.

The head scarps of these landslides align with the “top of bank” of the County-defined Class II stream which is located at the base of the hillslope. This top of bank line is the reference for the vineyard development setback of 125 feet as required for slopes above 65% by Napa County code as shown in the ECP. All runoff from the proposed vineyard area (of which a very small contributing area exists) will be collected in a rock-lined ditch located along the northern vineyard block boundary and diverted to the attenuation basin at the eastern edge of the block (Figure 2 and ECP). Water will be released from the attenuation basin via the level spreader will drain to the east and is will not reach Landslide OEI 4, OEI 5, or OEI 6. The proposed project is not expected to affect the stability of Landslides OEI 4, OEI 5, and OEI 6; there is low hazard with respect to project effects on stability of these existing landslides.

Table 2. Landslides mapped by OEI (2021)

ID	Activity	Description	Potential Hazard to Project	Recommended Actions
OEI 1	Active	Debris slide located in larger previously mapped large landslide area. Fresh soil exposed on portions of scarp, margins and in landslide body indicative of intermittent shallow unraveling. 30+ years old. 70-80% slopes along flanks. 225 ft long x 100 ft wide x 10 ft deep.	LOW-MED Hazard from proposed vineyard area and paved entrance road.	Avoid delivery of concentrated runoff down to this area from vineyard area. Ensure road cross drain culvert downspout is reinstalled
OEI 2	Historically Active	Debris slide located in larger previously mapped large landslide area. No visible exposed soils,~5 year-old maple observed in landslide evacuation area. 75 ft long x 35 ft wide x 5 ft deep.	LOW Hazard from proposed vineyard.	Avoid delivery of concentrated runoff down to this area.
OEI 3	Historically Active	Debris slide within previously mapped large landslide area. Subdued hummocky surface, two 24 in diameter fir stumps in body of slide indicates age is 40+ years old. 190 ft long x 80 ft wide x 5-8 ft deep. Gully 3ft wide x 4 ft deep formed in lower portion of deposit near property boundary.	LOW Hazard from proposed vineyard.	Avoid delivery of concentrated runoff down to this area.
OEI 4	Historically Active	Debris Slide cut slope failure. 5 to 8 year-old firs at base of landslide. 55% slope. 30 ft long x 40 ft wide x 1 ft deep.	LOW Hazard from proposed vineyard.	Avoid delivery of concentrated runoff down to this area.
OEI 5	Historically Active	Debris Slide cut slope failure located along margin of larger previously mapped Dormant translational/Rotational Rockslide. 80 % slope. 25 ft long x 20 ft wide x 2 ft deep.	LOW Hazard from proposed vineyard.	Avoid delivery of concentrated runoff down to this area.
OEI 6	Historically Active	Debris Slide. failure located along margin of larger previously mapped Dormant translational/Rotational Rockslide. 5 year-old bay in body of landslide. 75% slope. 60 ft long x 40 ft wide x 3 ft deep.	LOW Hazard from proposed vineyard.	Avoid delivery of concentrated runoff down to this area.

Figure 3. Landslide OEI 1 view upslope to the main scarp and downslope of the main body.

Figure 4. Landslide OEI 3 view from top of mapped area.

Conclusion

Development of the proposed vineyard, comprised of 0.41 acres of burned-over mixed forest vegetation that was cleared of trees killed by the Glass Fire, is not expected to reactivate or otherwise destabilize any landslides mapped near the proposed vineyard Block C including portions of the previously mapped large dormant rockslide (USGS 13405) underlying the project site. In addition, the project avoids areas with slopes greater than 35 to 40%, and as described above all project runoff that would otherwise flow to the active and historically active landslides (OEI 1-6) will be collected in cross field ditches, directed to rock lined ditches along the vineyard perimeter and then routed through a small flow attenuation basin to a level spreader on the eastern edge of the vineyard block. The depth of the surface of rupture of the previously mapped dormant rockslide is likely far below the rooting zone, so there is no direct stabilizing influence of vegetation as would be expected in relation to shallow landslide potential.

Limitations

This slope stability and erosion assessment has been prepared with generally accepted principles and practices of professional geology. The conclusions and recommendations presented are based on available data, site observations, and professional judgment.

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