Geology

Rough Fire BAER
(Sierra NF Portion)
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Executive Summary
Debris flows and rock falls are eminent in the Rough Fire Area. Values at risk were evaluated for debris flow hazards with the aid of USGS debris flow modeling, and for rockfall hazards with the aid of ArcGIS. A **HIGH TO VERY HIGH RISK** for debris flows was determined for Garnet Dike Road, and segments of the PG&E Road off Black Rock Road, Rodgers Ridge Roads, and hiking trails (Rodgers Ridge Trail, Bear Wallow Trail, and Kings River Trail) in the burned area. Areas susceptible to rock falls occur in areas that have a low burn severity, but risks to Values at Risk will benefit by including rockfall hazard in general hazard signs posted for the burned area. Treatments for debris flows include notification of the public of these hazards through warning signs and seasonal road closures of Garnet Dike Road.

I. Potential Values at Risk

Debris flows and rock falls are the primary geologic hazards associated with burned watersheds (Santi et al., 2013; Parise and Cannon, 2012). Debris flows are of particular concern due to their destructive force and the distance from their source they can travel. Commonly, debris flows from burned area are runoff-generated rather than triggered from small discrete landslides mobilizing downslope into channels (Parise and Cannon, 2012). Most of the debris flow volume results from mobilization and scour of material deposited within the channel where the debris flow is passing. On average, an additional 23% of a debris flows volume comes from material issuing from side channels. Only an average of 3% (max. 10.5%) of a debris flows volume comes from rills formed on adjacent slopes (Santi et al., 2008).

Limited debris flow activity is common within the area affected by the Rough Fire. Examples of areas where precipitation-induced debris flows have occurred include south-facing slopes of Rodgers Ridge, the slopes above Garnet Dike Road (FS Road 12S01). Previous debris flow deposits have impacted Garnet Dike Road and other roads/trails with similar geology and slope steepness.

Rock falls in the form of individual rocks or small groups of rocks have rolled onto roads and trails within the Rough Fire area. It is recognized that rock fall activity often takes place during and immediately after a wildfire. The potential threat to life of people on Garnet Dike Road, Blackrock Road, and Rodgers Ridge Road to wildfire-induced rock fall was identified and measures are recommended to reduce the risk to life. Rocks in motion or large rocks (1-foot diameter or larger) can damage pavement, cause accidents, damage vehicles, and cause injury or death.

Therefore, roads and trails within the Rough Fire area all constitute potential values at risk for both debris flows and rockfall. Table 1 contains a complete list of the potential values-at-risk.

Table 1 – Geologic Hazard Value-at-Risk Summary Description. See Figure 1 and Figure 2 for specific locations.

Value-at-Risk	Objective	Description	Cost
Garnet Dike Road	Protect life and property	debris flow	Recommend closing the road starting at Rodgers Crossing for the first winter season (November-March), and post a debris flow warning sign at the beginning of the road.
PG&E road off Black Rock Road	Protect life and property	debris flow	**No Cost to Govt:** Send notification letter to PG&E concerning debris flow potential and their existing debris flow barricade. Barricade would be more effective if replaced with K-rails.
Garlic Road (11S045,45A,45B)	Protect life and property	debris flow	Post a debris flow warning sign at the beginning of Forest Road 11S045, just off Rodgers Ridge Road.
Rodgers Ridge, Bear Wallow, and Kings River Hiking Trails	Protect life	debris flow	Post 4 debris flow warning signs at the respective trailheads (see Figure 1). A sign is not needed at the Kings River Trail if the access road (Garnet Dike Road) is seasonally closed.
Rodgers Ridge Road	Protect life and property	rockfall	Recommended that rockfall hazard be included in general hazard signs posted for the burned area.
Rodgers Crossing	Protect life and property	rockfall	Recommended that rockfall hazard be included in general hazard signs posted for the burned area.

II. Resource Condition Assessment

A. Resource Setting

The Rough Fire burned 133,244 acres within the Kings River drainage in the Southern Sierra Nevada and is 31 percent contained as of September 9, 2015. The fire is currently the largest active fire in California. Due to the size and status of the fire we split the BAER analysis into a north and south zone. The north zone is primarily within the Sierra National Forest, and the south zone is primarily within the Sequoia National Forest. This report is for the north zone.

Kings Canyon is a wide glacial valley with precipitous canyon walls within the park. Below the park and within the Rough Fire area, the canyon deepens and steepens becoming what is the deepest canyon in the Sierra Nevada and is arguably as the deepest canyon in North America. The confluence of the South Fork and Middle Forks of the Kings River lies at 2,260 feet, while Spanish Peak on the north side is 10,051 feet tall.

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Within the burned area, the bedrock is comprised of late Cretaceous and older granitic rocks and assorted metamorphic rocks intruded by them. Granitic rock types include granite, diorite, and monzonite, and metasedimentary rocks include: volcanic rocks, schist, quartzite, phyllite, and marble. Marble formations locally contain numerous caves.

B. Findings of the On-The-Ground Survey

Debris Flow Assessment - assessing the probability and volume of debris flows draws upon empirical models developed from research in southern California and the Intermountain Western United States (De Graff et al., 2007; Cannon et al., 2010; DeGraff and Gallegos, 2012). The assistance of Dennis Staley at the US Geological Survey (USGS) was obtained for assessing the debris flow hazard. Their ongoing research has developed empirical models for forecasting the probability of their occurrence and the likely volume of such an event. These are tied to a storm size consistent with the type of precipitation event which may occur within the first few years after the wildfire. The storm size used for this analysis is consistent with an El Niño year, as is predicted by most (25 year storm event). I provided the USGS scientists geospatial information on the fire perimeter and the soil burn severity caused by the fire. USGS conducted a debris flow assessment and provided their data. The results of the debris flow assessment were analyzed for values at risk within the Rough Fire Area.

Several channel crossings on Garnet Dike Road, PG&E road off Black Rock Road, the Rodgers Ridge area, and hiking trails (Rodgers Ridge Trail, Bear Wallow Trail, and Kings River Trail) were evaluated for debris flow potential. Garnet Dike Road is used by the public for camping, hiking, and rafting access. The PG&E private road is used exclusively by PG&E to access their reservoir. Rodgers Ridge is used for camping and hunting.

Rock Fall Assessment - The assessment of rockfall was guided by experience to methodically and consistently evaluate this geologic hazard within the knowledge currently available on this phenomenon (Santi et al., 2013; De Graff and Gallegos, 2012). A map was prepared showing the road and trail segments which were downslope from areas affected by moderate or higher soil burn severity on slopes inclined more than 39% (see Figure 3). Field survey consisted traveling many of these roads and observing the size and number of rocks which had rolled onto the road during or since the fire. This information was used to establish the rockfall hazard. While all the designated roads and hiking trails could not be traveled due to the need to avoid active fire operations, blockage by trees (or rocks) or general safety considerations, the primary travel routes were surveyed.

Rockfall hazards occur at Rodgers Crossing and a segment on Rodgers Ridge Road. However, the burn severity is mostly low and therefore will not significantly increase as a result of the fire. However, I recommend that rockfall hazard be included in general hazard signs posted at primary access points to the burned area.

2. Consequences of the fire on Values At Risk (VAR) – Geologic Values-at-Risk (VARs) all involve either a threat of causing injury or fatalities to people and/or substantial to moderate property damage. Debris flow threat to VARs was evident from the modeled results (Table 2), and rockfall threat to VARs was evident from hill slopes (≥40%). However, steep hill slopes above roads and trails were mostly burned at a low severity, making rockfall an existing condition that will receive little affect from the fire.

The USGS estimates of debris flow probability and volume is a low-moderate concern for the channel crossing on Garnet Dike Road, PG&E road off Black Rock Road, and the Rodgers Ridge area Roads. The probability of a debris flow occurring within the burned area will diminish over time, but should be planned for at least 2 to 3 years. In the event of a debris flow on Garnet Dike Road the primary stream crossings have low water crossings to accommodate debris flows; however, the low water crossings will be blocking by debris. These crossings contain evidence of historic debris flows and excavation of the road after seasonal storm events. The channel crossing on the PG&E road off Black Rock Road contains a recently constructed mounded barricade to stop the advance of debris flows onto the road. The roads on Rodgers Ridge and hiking trails are susceptible to debris flows.

Table 2 – Risk Assessment of Values at Risk from Debris Flows. See Figure 1 for locations.

Value-at-Risk	Storm Event	Debris Flow Probability	Debris Flow Volume Estimate (m^3)	USGS Combined Hazard	Probability of Damage or Loss	Magnitude of Consequences	Risk
Rodgers Ridge Trail							
#1	25 Yr	15%	23,000	MOD	Possible	Major	High
#3	25 Yr	35%	1,000	MOD	Possible	Major	High
PG&E Road							
#2	25 Yr	16%	11,500	MOD	Possible	Major	High
Bear Wallow Trail							
#4	25 Yr	23%	3,000	MOD	Possible	Major	High
Rodgers Ridge Area Roads							
#5	25 Yr	59%	1,000	MOD	Likely	Major	Very High
#6	25 Yr	29%	1,500	MOD	Possible	Major	High
Garnet Dike Road							
#7	25 Yr	2%	19,500	MOD	Unlikely	Major	Intermediate
#8	25 Yr	3%	35,000	MOD	Unlikely	Major	Intermediate
#9	25 Yr	5%	18,500	MOD	Unlikely	Major	Intermediate
#10	25 Yr	11%	42,500	MOD	Possible	Major	High
#11	25 Yr	20%	62,500	MOD	Possible	Major	High
Kings River Trail							
#12	25 Yr	16%	81,000	MOD	Possible	Major	High
#13	25 Yr	51%	410,000	HIGH	Likely	Major	Very High
#14	25 Yr	17%	23,000	MOD	Possible	Major	High

III. Emergency Determination – An emergency exists for threat of life or injury to individuals using Garnet Dike Road, and segments of PG&E's road off Black Rock Road, Rodgers Ridge, and the three hiking trails within the Rough Fire (see VAR table and Figure 1 for details). This threat stems from debris flow activity attributable to the changed conditions created by the wildfire. There is also a threat from rockfall (Figure 2) at Rodgers crossing and segments of Rodgers Ridge Road, but this threat is existing and is not significantly affected by the wildfire.

IV. Treatments to Mitigate the Emergency

1. **Treatment Type and description**:
    a. Notification and Warning Signs
    b. Seasonal closures of Garnet Dike Road
2. **Treatment Objective** – See Table 1
3. **Treatment Cost** – See Table 3

Table 3 – Treatment Costs

ID	Line Item	Units	Unit Cost	Quantity	BAER Cost
Rodgers Ridge Trail	Debris Flow Warning Sign	EA	REDACT	2	REDACT
Bear Wallow Trail	Debris Flow Warning Sign	EA		1	
Kings River Trail	Debris Flow Warning Sign	EA		1	
Garnet Dike Road	Debris Flow Warning Sign	EA		1	
Rodgers Ridge Roads	Debris Flow Warning Sign	EA		1	

4. **Probability of Completing Treatment in First Year Prior to Damaging Storms**: The treatments for the emergencies identified for debris flows and rock falls are summarized and described in Table 1. The probability of completing the mitigating treatments prior to the damaging storm or event is 100%.
5. **Probability of Treatment Success**: It is expected that the treatment will be 100% successful in the first year. For the second and third years, treatment may drop slightly to 95 to 90% depending on adjustments to closure timing or affected road length.

V. Discussion/Summary/Recommendations –
Debris flows and rock falls are eminent in the Rough Fire Area. Debris flow hazard areas have been identified with the aid of USGS Debris Flow Modeling. The debris flow modeling data was used to identify values at risk that have some potential of threats from debris flows. Rock fall hazard areas have been identified and reviewed in the field. Treatments for debris flow and rock fall hazards include notification of the public of these hazards through warning signs and seasonal road closures of Garnet Dike Road.

VI. References

Cannon, S.H., Gartner, J.E., Rupert, M.G., Michael, J.A., Rea, A.H. and Parrett, C. (2010) Predicting the probability and volume of postwildfire debris flows in the intermountain western United States. GSA Bulletin 122:127-144.

De Graff, J.V. (1994) The geomorphology of some debris flows in the southern Sierra Nevada, California: Geomorphology 10:231-252.

De Graff, J. V. (2001) Sourgrass debris flow: a landslide triggered in the Sierra Nevada by the January 1997 New Year Storm, In Ferriz, H. and Anderson, R. (eds.), Engineering Geology Practice in Northern California, California Div. of Mines and Geology Bulletin 210, p. 69-76.

De Graff, J.V., Cannon, S.H., Gartner, J.E. and Gallegos, A.J. (2007) Reducing post-wildfire debris flow risk through the burned area emergency response (BAER) process. In Schaefer, V.R., Schuster, R.L. and Turner, A.K. (eds.), Conference Presentations, 1st North American Landslide Conference, Vail, CO, AEG Special Publication No. 23, p. 1440-1447.

De Graff, J. V. and Gallegos, A. J. (2012) The Challenge of Improving Identification of Rockfall Hazard after Wildfires: Environmental and Engineering Geoscience 18(4):389-397

Lockwood, J. P., Bateman, P. C., (1976): Geologic map of the Shaver Lake Quadrangle, Central Sierra Nevada, California, Geologic Quadrangle Map Shaver Lake Quadrangle, California, GQ-1271.

Parise, M. and Cannon, S.H. (2012) Wildfire impacts on the processes that generate debris flows in burned watersheds. Natural Hazards 61:217-227.

Santi, P.M., deWolfe, V.G., Higgins, J.D., Cannon, S.H. and Gartner, J.E. (2008) Sources of debris flow material in burned areas: Geomorphology 96:310-321.

Santi, P., Cannon, S., De Graff, J. (2013) Wildfire and landscape change, In Shroder, J. (Editor in Chief), James, L.A., Harden, C.P., Clague, J.J. (eds.), Treatise on Geomorphology. Academic Press, San Diego, CA, Vol. 13, Geomorphology of Human Disturbances, Climate Change, and Natural Hazards, pp. 262–287.

United States Geological Survey, 2015, Post-fire debris-flow hazard assessment for the 2015 Rough Fire, Fresno County, CA.

Appendix A – Figures:

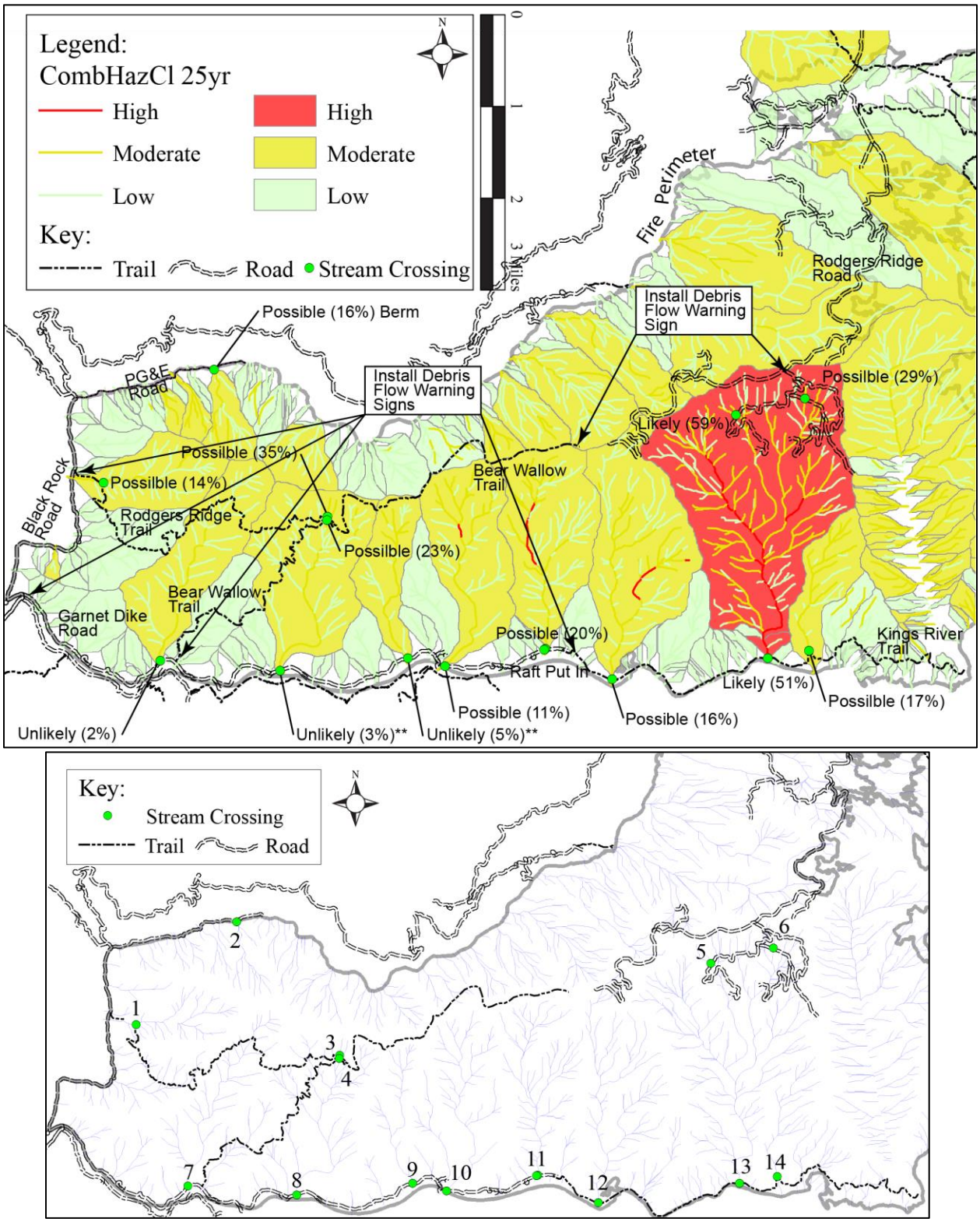

Figure 1–Debris Flow Hazard Map (***upper***) showing probability of debris flow hazard areas in the Rough Fire – North Zone for a 25 year storm event. Map (***lower***) shows unique identified for stream crossings.

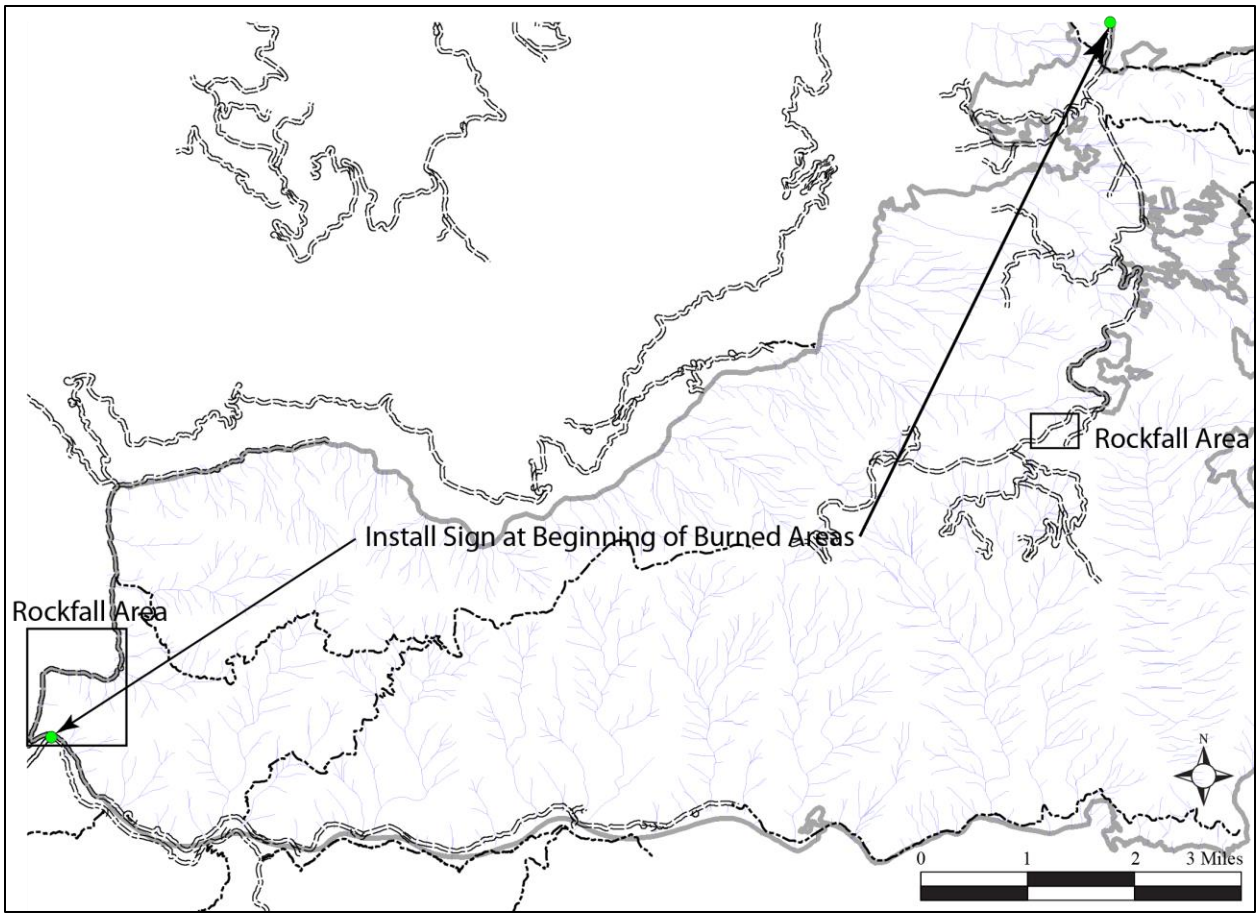

Figure 2–Rock Fall Hazard Map.