Burned Area Emergency Response (BAER) Assessment
FINAL Specialist Report – GEOLOGIC HAZARDS

Rough Fire – South Zone, Sequoia N.F.

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Introduction

The Rough Fire started on July 31, 2015, on the High Sierra RD of the Sierra N.F., Fresno County, California, and burned a total of 151,102 acres, out of which 6,031 acres were high soil burn severity, 41,943 acres were moderate soil burn severity, 66,497 acres were low soil burn severity and 36,631 were very low/unburn soil burn severity. This report describes and assesses the increase in risk from geologic hazards within the south zone of the Rough Fire burned area.

When evaluating Geologic Hazards, the focus of the "Geology" function on a BAER Team is on identifying the geologic conditions and geomorphic processes that have helped shape the watersheds and landscapes, and assessing the impacts from the fire on those conditions and processes that affect values at risk. Using that understanding of rock types and characteristics, geomorphic processes, and distribution of geologic hazards helps predict how the fire changed the watersheds that will be impacted during upcoming storm seasons. Within the Rough Fire burned area, a high degree of slope failures as rock fall, rock slides and dry ravel activities have occurred in the past and will increase during future storms.

Fast moving, highly destructive debris flows triggered by intense rainfall are one of the most dangerous post-fire hazards. Protective vegetation is gone or altered and will not return to the same levels of protection for years. Soil is exposed and has become weakened, and surface rock on slopes has lost its supporting vegetation. Roads and trails are at risk from rolling rock and drainage flow out of control. Slopes will experience greatly increased erosion. Stream channels and mountainside ephemeral channels will be flushed of the sediment that in some places is loose and deep, in other places shallow. That sediment will deposit in some channels, choking flow, raising flood levels and covering roads with deep sediments. Risk to human life, infrastructure and natural resources are high in some areas.

Wildfire can significantly alter the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous debris flows, rock falls and debris slides. Debris flows and rock falls are the primary geologic hazards associated with burned watersheds (Santi et

al., 2013; Parise and Cannon, 2012). Watersheds with steep slopes and significant amounts of moderate to high soil burn severity are especially likely to generate debris flows. The majority of debris flows exacerbated by wildfires usually occurs within 1-3 years after the watersheds are burned. Destructive debris flows bring side-slope materials and channel deposits racing down channel bottoms in a slurry similar to the consistency of concrete, in masses from a few hundred cubic yards to hundreds of thousands of cubic yards of saturated material.

I. Resource Setting

Geology and Geomorphology: The Rough Fire occurred on the west slope of the Central Sierra Nevada within the Kings River drainage. The phisiography of the region is dominated by the extremely rugged canyons of the Middle and South Forks of the Kings River, which form one of the deepest canyons in the United States.

Bedrock within the boundaries of the Rough Fire consists of two primary rocks types: Paleozoic meta-sedimentary and meta-igneous rocks and Cretaceous granitics of the Sierra Nevada batholith. Small areas are covered by younger Tertiary volcanics that cap ridges (Fig.1 Geologic Map). Surficial geologic units include glacial deposits covering various bedrock units, alluvial gravel and sand of varying ages and surficial scars and deposits from various types of instability features.

Metasedimentary (and meta-granitic and meta-volcanic) rocks cover about one third of the burned area. Rock types include metamorphosed sandstone and shale (quartzite, schist and phyllite), marble and slightly metamorphosed limestone, and meta-volcanic rocks and gneiss. The phyllite is generally erosive and subject to debris slides, and often erodes to very smooth, light to dark brown slopes with little rock exposed on the surface. The schist, metavolcanics and meta-granitics are more resistant to erosion, but still subject to rockfall and debris sliding. Roads passing through metamorphic rocks are generally not as subject to erosion as are roads within granitic terraine, and tend to have more rockfall of sharp angular rocks.

The Boyden Cave roof pendant is a dominant metamorphic exposure that crosses both forks of the Kings River. The spectacular marble/limestone white outcrop that crosses the South Fork and dominates the landscape (Photo 1) includes Boyden Cave and reportedly other caves, and is the primary feature of the Windy Gulch Geologic Area. The prominent marble spires, mostly devoid of vegetation, are bordered to the west by quartzite, phyllite and schist, and to the east by meta-volcanics and meta-granitics.

Granitic units are light colored granite or granodiorite, and mafic, dark colored gabbro and diorite. These units are predominately stable, except in portions that are heavily-chemically

weathered or physically fractured. Decomposed granite (dg) can be deep and highly erosive. On steep slopes, granitic rocks usually weather out as rounded boulders and cobbles which can roll downslope, or fractured blocks which can fall off of steep slopes, when soil or vegetative support is removed by fire or erosion.

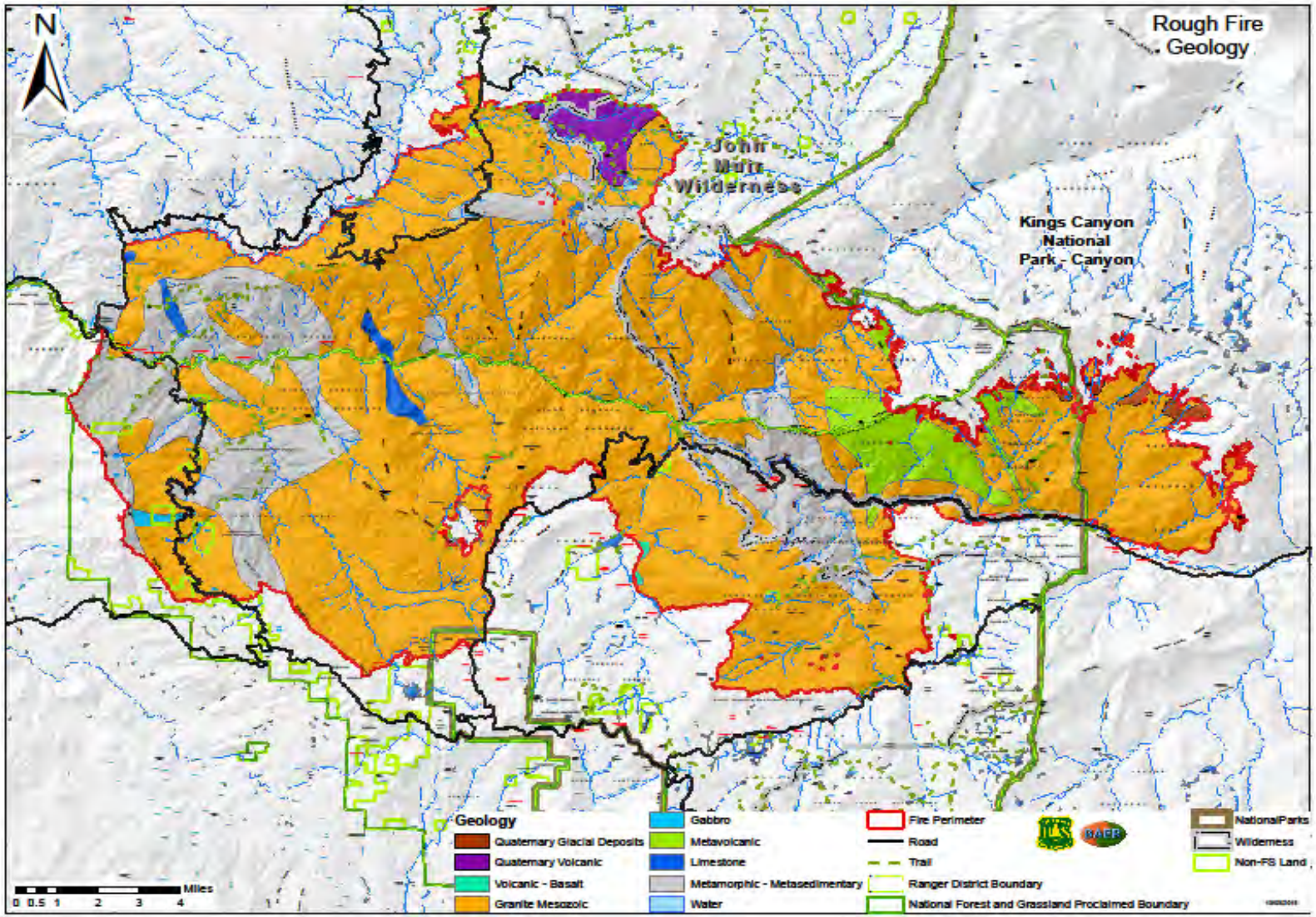
Minor remnants of once widespread **Tertiary volcanic rocks** include basalt which can be highly resistant to erosion, and has been used elsewhere as a source of good quality rock for road surfacing, but also can weather to deep soil and dust on roadways, such as on the 13S05 Road.

Quaternary Alluvium: These are recent deposits of alluvial and stream gravel, forming creek and river bottoms and floodplains, and sometimes seen as terraces representing past flood flow levels or previous geomorphic terranes (Photo 2). These unconsolidated sediments are available for transport during flood flows, and can add tremendous bulk and erosive power to moving water. The **Glacial** rock formations are Pleistocene and Holocene age glacial deposits, remaining from past stages of glacial activity.

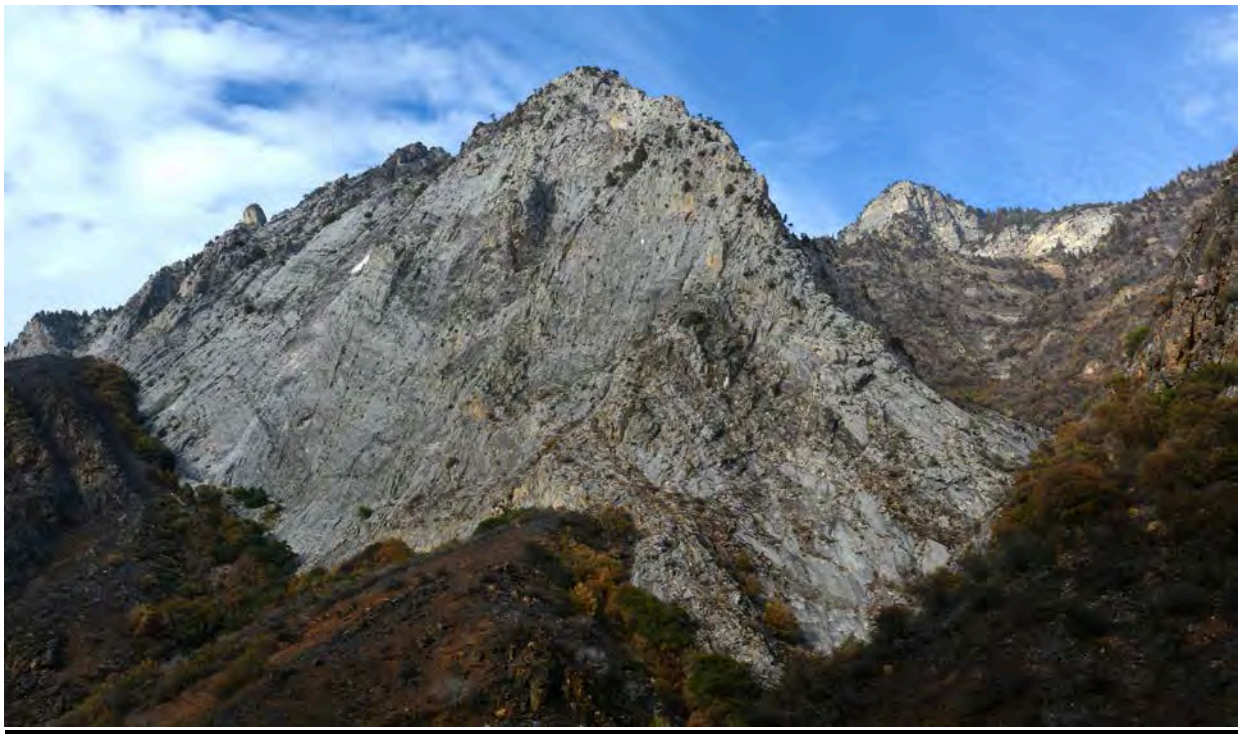
Faulting: The study area does not contain any significant faults according to the California Geologic Survey Fault Activity Map. Although there is no faulting the granitic rocks are highly fractured from Cenozoic uplift (westward tilting) of the mountain range and from isostatic rebound from un-roofing of the mountain range (erosion of the volcanic deposits). These fractures can increase physical and chemical weathering, and increase soil development and slope instability.

Landscape characteristics: The area of the south zone Rough Fire is characterized by dissected ridge lines and drainages flowing in a general direction from south to north into the Kings River. Elevations in the burned area range from about 1,000 feet above sea level (just above Pine Flat Reservoir) to over 10,000 feet above sea level (in the Monarch Wilderness area) with slopes ranging from gentle (0-15%) to steep (>60%) slopes (Figure 2). The major drainages in the south zone Rough Fire area include: Mill Flat Creek, Verplank Creek, Converse Creek, Ten-mile Creek, Big Meadow Creek and Boulder Creek; all flowing into the Kings River.

Slope in-stability features such as recent pre-fire debris slides, rock-falls frequent the steep inner gorge slopes above the kings Canyon east of Yucca Point, while fluvial erosion processes have shaped the gentler valleys and ridges. Some areas show a great deal of slope dissection and slope instability, while other areas are amazingly smooth, un-dissected and devoid of instability features. Some channels were choked with rocks and sediment, once again mostly above the Kings Canyon, east of Yucca Point while other channels, especially on the west end of the burned area, were devoid of pre-fire sediment and rocks, but now are subject to filling with post-fire colluvial debris and rolling rock.

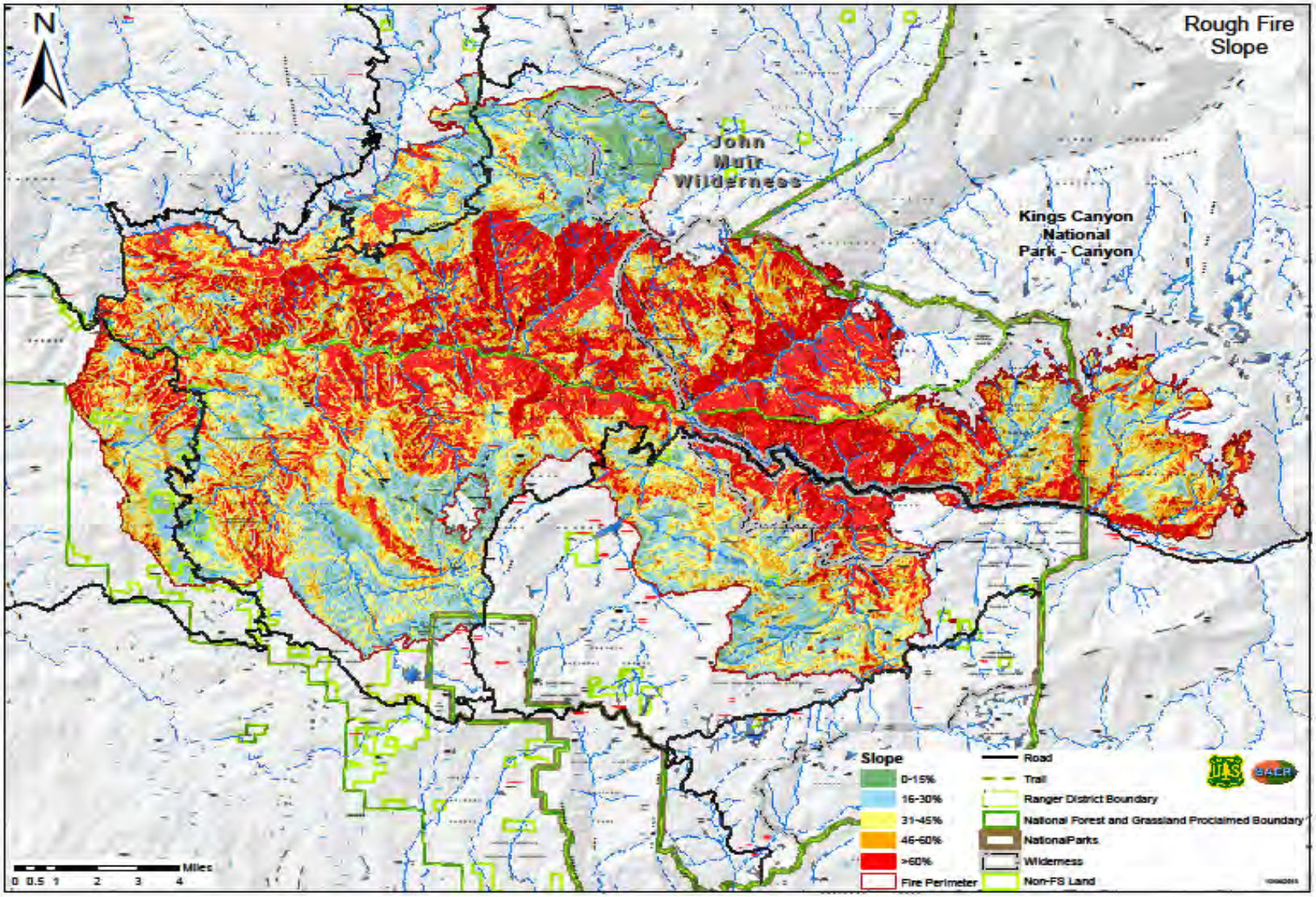


<u>Figure 1</u>: Geological map of the Rough Fire area



<u>Photo 1</u>: Marble/limestone outcrop dominating the landscape - South Fork Kings River

<u>Photo 2</u>: Quaternary Alluvium Deposits at the confluence of Deer Cove Creek and South Fork Kings River



<u>Figure 2</u>: Slope Map – Rough Fire

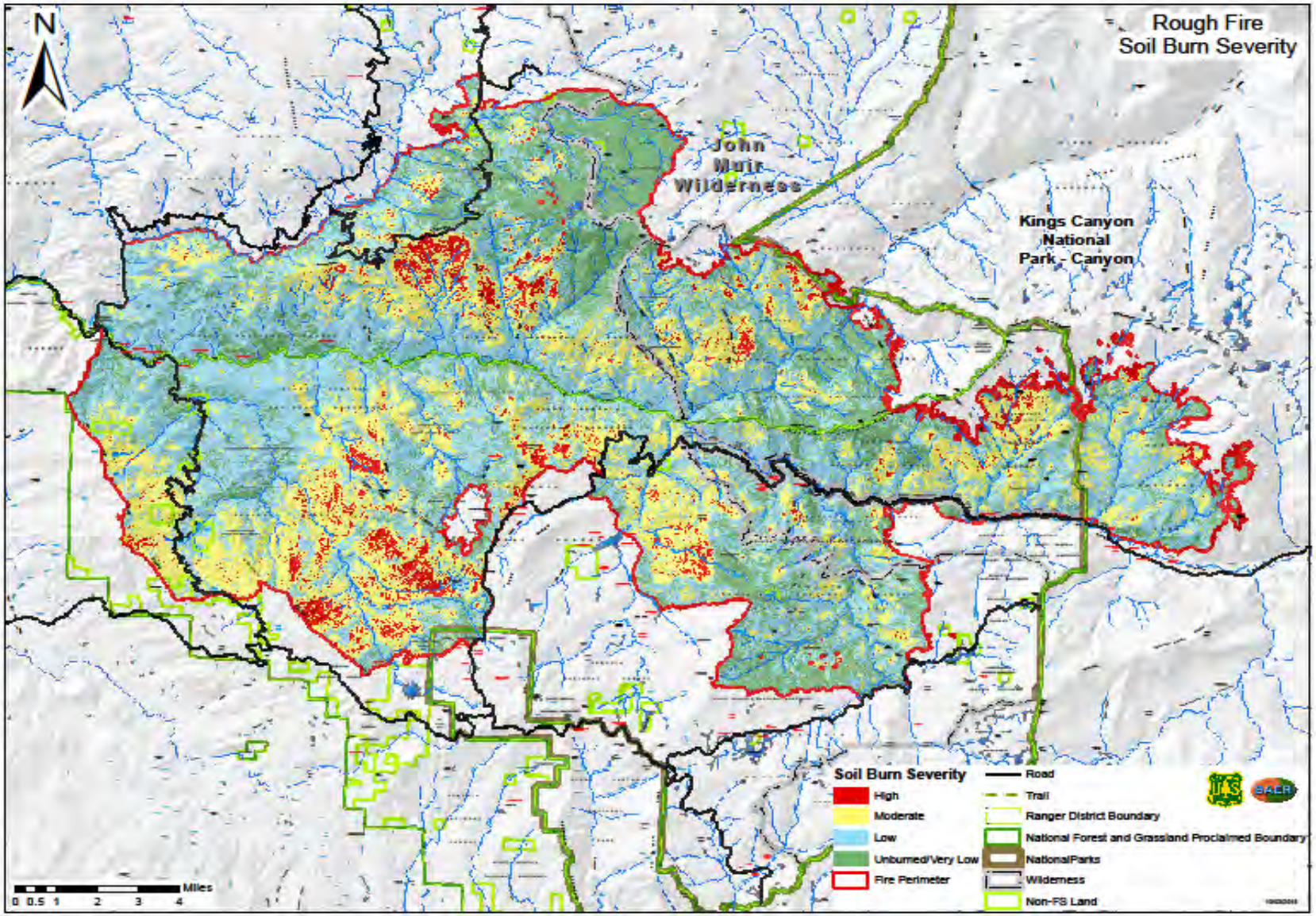
Findings / Observations

During ground surveys, a flight recon, and study of aerial photography, evidence of some past mass wasting was observed throughout the burned area. From on-the-ground observations it is clear that some of the slopes and drainages above Highway 180 in the Kings River corridor are loaded with unsorted, unconsolidated materials available to be transported. In contrast to this area (Hwy 180 corridor in the Kings River Canyon), the majority of the large drainages / creeks in the western portion of the fire are flushed to the bed-rock, void of any unconsolidated materials with the exception of a few channels and slopes along Forest Road 12S01 in the Davis Creek/Sampson Creek drainages which are loaded with unsorted, unconsolidated materials.

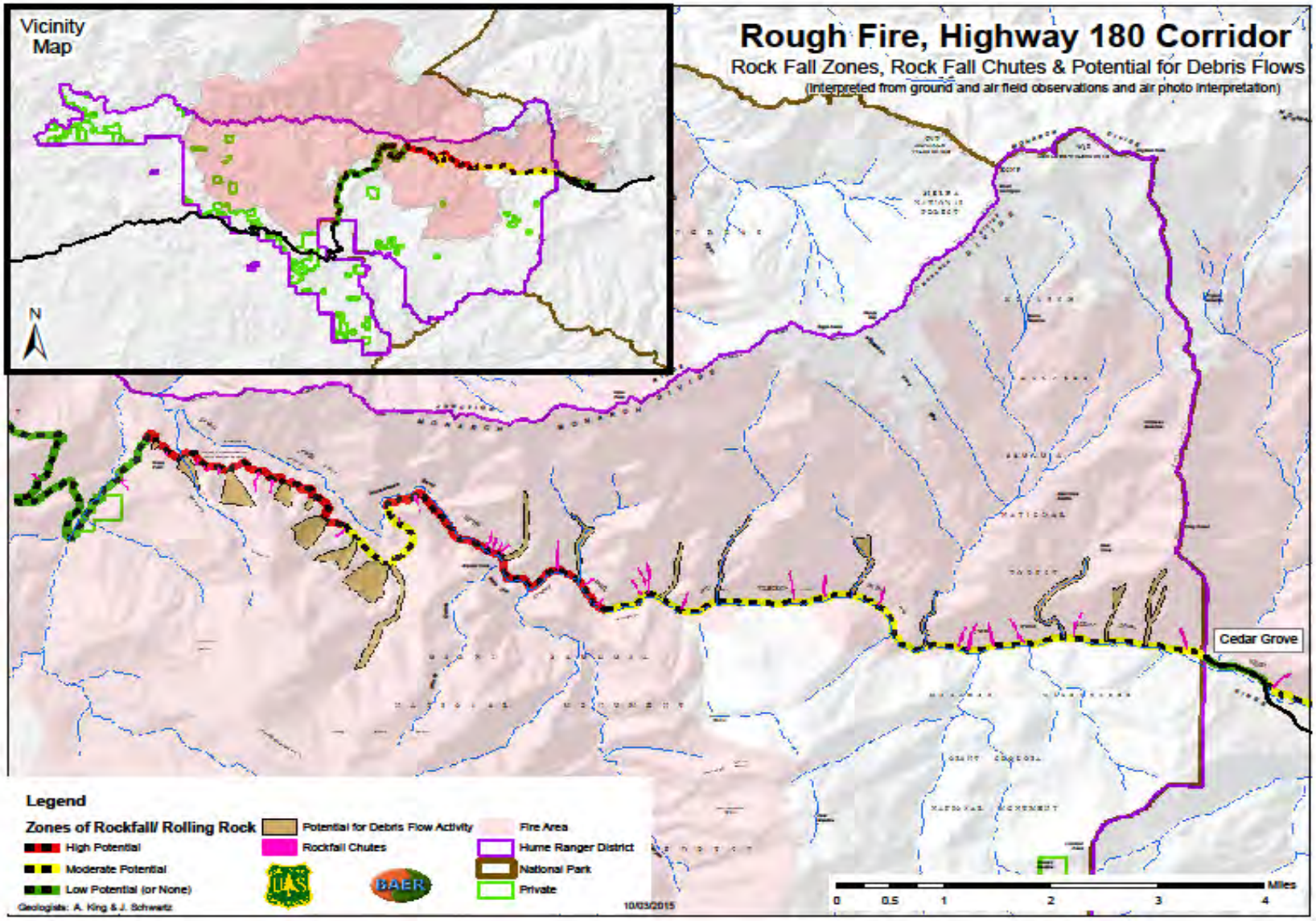
Kings River Watershed/Highway 180

The Kings River is an important source of water for down-steam users. Slopes on both sides of the River experienced mostly low and unburned soil burn severity (Figure 3). Granitic and metamorphic rocks line the inner canyon. Rockfall, debris flows and occasional debris slides dominate the active slope processes and will be very active during high intensity storm events. Based on USGS debris flow modeling, the majority of the drainages along this portion of the canyon have a low (0-20%) probability of debris flow activity initiated by a 10 year storm event. The majority of the sub-basins within the burned portion of this watershed are rated with a low debris flow hazard class rating, however field observations showed many debris flow channels and deposits causing question about the accuracy of modeling. Past rockfall talus and slope coverings are widespread and assured to be exacerbated by future storms. Old and recent debris slides are present, but not common. Between Yucca Point and Cedar Grove, as many as 18 channels crossing Highway 180 were mapped (Figure 4) as channels subject to past and future debris flow damage. Fortunately, a number of those channels have quite large and deep catchment basins behind the road fill that can help mitigate the effects of debris flows.

Rock and debris-fall (Photo 3) and cutlsope failures will likely occur frequently during storm events and will require frequent cleanout (which could pose threat to maintenance crews) if the road is to be kept open. Zones of expected potential rockfall, rolling rock, and defined chutes (Photo 4) where rockfall will be concentrated were also mapped (Figure 4) and defined below.



<u>Figure 3:</u> Rough Fire - Soil Burn Severity map



<u>Figure 4</u>: Potential for Rolling/Falling Rock, Rock Chutes and Debris Flows along Hwy 180

Potential for Rolling/Falling Rock, Rock Chutes and Debris Flows

1. Road Segments mapped for **Potential for Rock Fall and Rolling Rock** onto Hwy 180

Definitions of Low, Moderate and High Potential: Some, but not all of the descriptors may apply under each designation.

Low Potential (to No Potential):

- Bedrock relatively stable and un-weathered on slopes
- Low burn severity
- Low amount of stored sediment, few available loose rocks on slopes
- Gentler slopes or steep slopes not adjacent to Highway
- Significant large vegetation
- Little evidence of past rockfall onto roadway

Moderate Potential:

- Bedrock fractured or weathered on slopes
- Low-moderate burn severity
- Slope surface has abundant loose rock, subject to gravity
- Slopes steeper than 50%
- Some vegetation has been removed or weakened, lessening support for slope materials
- Some evidence of past rockfall onto roadway

High Potential:

- Bedrock fractured or weathered on slopes
- Low-high burn severity
- Significant stored sediment/loose rock on slopes
- Slopes steeper than 70%
- Large vegetation is sparse or absent, soil structure may have been highly modified, support for slope materials has been compromised
- Some evidence of past rockfall onto roadway

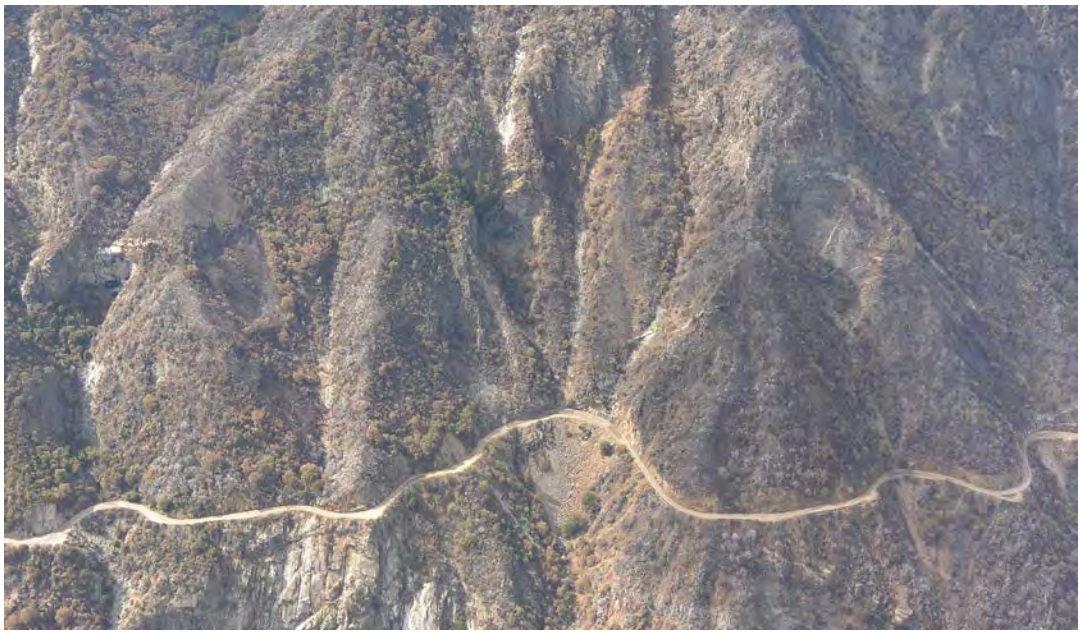
2. Rock Chutes

Deposits that occur on steep slopes in linear chutes, often below steeper cliff areas, were mapped to show areas which may produce high concentrated areas of rockfall, rolling rock and rock-slides (Photo 4). This mapped was done by observations from the road, helicopter recon and by air photo mapping.

3. Debris Flows

Areas which were observed to have stored material on slopes, a significant drainage area, a defined channel, and in some cases evidence of past debris flow activity were listed with a potential for debris flow activity. The field and photo interpretation were also compared to debris flow modeling by the USGS.

<u>Photo 3</u>: Rock-fall on Hwy 180 just past Horseshoe Bend



<u>Photo 4</u>: Rock Chutes - Channels crossing Highway 180 subject to past and future rock-fall, rolling rock and rock-slides

Treatments that might be considered by CalTrans to mitigate the risks include:

- Frequent cleaning of ditches, debris basins;
- Addition of risers and drop inlets, with protection, and up-size culverts where needed;
- Installation of trash racks where needed;
- Fillslopes armored where feasible; downdrains added to protect fillslopes;
- Locate and approve waste disposal sites for debris end-hauling;
- Road closure;

Davis Creek Road, 12S01, Sampson and Davis Creek Watersheds

This mostly unsurfaced road is the only road which traverses from the high country near Sequoia Lake down to the Kings River, just upstream from Pine Flat Reservoir. It crosses through both granitic and metamorphic rock types, which respond very differently to roads and trails. Much of the road crosses through gently sloping terrain.

Soil burn severity was moderate with patches of high in upper portions of both Sampson Creek and Davis Creek watersheds, but low to unburned in lower sections. Mill Flat watershed, with similar burn severity characteristics, influences the lowest portion of Davis Road. Bedrock underlying the upper two thirds of the road is mostly granitic, and meta-sedimentary with minor meta-volcanics in the lower third.

The road portions underlain by granitics tend to gully and rutt, and are highly eroded by water flow on the surface (Photo 5). Increased flows from the moderate-high severity burn will increase damage to the road unless drainage structures are improved before winter rains and snow. Outsloping of sections with a grade less than 6%, rolling dips, and properly sized and armored culverts could help winterize the road and improve drainage and drivability.

The road portions underlain by metavolcanics are not highly erosive, but through steep sideslopes can have significant rockfall. The road tread often is solid bedrock which can wear to somewhat rocky, uneven surfaces.

<u>Photo 5</u>: Gullies on Davis Creek Road (12S01) underlain by Granitic rocks

The prospect on private land in Section 1 was not accessed.

Metamorphic hillslopes above and below the road appear extremely smooth with no evidence of math wasting or gully features, but now that vegetation along these slopes is mostly burned some excessive sedimentation from the slopes down to the creeks bellow is expected. As a result of winter storms, sediments from these burned slopes ending in the creeks bellow will eventually make their way down to the Kings River and the Pine Flat Reservoir.

From air recon and ground observations it appears that the Sampson Creek channel is loaded with sediments and rocks available to be transported by debris flows. At the crossing of Davis Creek Road (12S01) and Sampson Creek a debris flow deposit was observed. Based on the USGS debris flow modeling it seems that segments of Sampson Creek right above the Davis Creek road crossing are predicted to produce debris flows with probabilities of 20-40% and 40-60% and with volumes of 1,000 – 10,000 cubic meters. Once again, based on USGS modeling, an un-named drainage located about ¼ mile south (higher) then the crossing of Sampson Creek

and Davis Creek road is predicted to produce debris flows with probabilities of 60-80% and with volumes of 1,000 – 10,000 cubic meters.

In contrast to Sampson Creek and some of the drainages above it, the main creeks / channels in the west portion of the south zone Rough Fire are completely flushed of sediments and un-consolidated rocks/materials. These scoured creeks include Mill Flat Creek, Verplank Creek and Converse Creek. The channels of these creeks are flushed to bed-rock and expose deep pools (Photo 6).

<u>Photo 6</u>: Mill Flat Creek channel flushed of sediments and un-consolidated rocks

FS Road 13S05

FS road 13S05 takes off from FS road 13S09 which is the main access road to Hume Lake from the south. It crosses through both volcanic and granitic rock types, which respond very differently to roads. The segment where the road is underlined by the volcanic rock, the rock has been weathered to deep soil and dust which accumulates on the road as a thick layer. The road portion underlain by the granitic rock type tends to gully and rutt, and is highly eroded by water

flow on the surface. From a ground recon of FS road 13S05 it is clear that some segments of the road are in poor shape and will continue to deteriorate as a result of the new fire conditions. Increased flows from the moderate-high severity burn will increase damage to the road unless drainage structures are improved before winter rains and snow. Out-sloping of sections with a grade less than 6%, rolling dips, and properly sized and armored culverts could help winterize the road and improve drainage and drivability. In addition, in these areas where the road is underlain by the granitic rock type, slopes above the road are abundant with unstable rocks of various sizes (up to boulder size rocks) and potentially could roll down to the road creating a hazard to drivers.

Windy Gulch Geological Area

The 3,500 acres of the Windy Gulch Geologic Area contains a number of outstanding formations, including caves and marble roof pendants. Mesozoic granitic rocks are the dominant rock type and consist of several plutons approximately 100 million years old. The metamorphic rocks are known as the Kings Terrain; the most extensive of these are the Lower Kings River, Kaweah River, and Tule River roof pendants. The Lower Kings River roof pendant includes the Boyden Cave roof pendant, whose marble contains several caves including Boyden Cave and Church Cave (The Giant Sequoia National Monument Management Plan (Monument Plan) – Sep. 2012).

As a result of the fire rock-fall will likely occur frequently during storm events on the trail leading to the Boyden Cave. Other direct impacts to the main entrance to Boyden Cave are not expected. Approximately 1/4 of a mile up Windy Gulch on the north-west slope of the gulch is a small (2 feet diameter) back entrance to Boyden Cave that is located at creek/channel level and as a result of the fire is expected to receive excessive flow, sedimentation and other debris. Up the gulch (approximately 1/8 of a mile) on the south-east slope of the gulch are a whole set of entrances which are all part of the Church Cave system. Beyond one entrance that is at creek/channel level, all other entrances are located well above the creek level and are not expected to be directly affected by the fire. The one entrance that is at creek/channel level (the Route entrance) is located right at the bottom of the channel, below a 10 foot waterfall. Once again, this entrance will receive excessive flow, sediments and debris as a result of the fire. In addition, the whole route up Windy Gulch is prone to rock-fall, particularly during storm events.

Due to fire hazards, lack of time and remoteness, ground assessment of other caves in the rough Fire area did not take place.

USGS Debris Flow Assessment:

In order to assess the probability and potential volumes of debris flows in the burned area the assistance of the US Geological Survey (USGS) - Landslide Hazards Program was obtained. Their ongoing research has developed empirical models for forecasting the probability and the likely volume of such debris flow events. To run their models, the USGS uses geospatial data related to basin morphometry, burn severity, soil properties, and rainfall characteristics to estimate the probability and volume of debris flows that may occur in response to a design storm (Staley, 2013). After receiving the final Rough Fire burn severity map, the USGS conducted a debris flow assessment of the fire area that presented debris flow hazard classes, probability of occurrence, and volumes of materials occurring for multiple precipitation events including 2, 5, 10, 25, 50 and 100 year storms. We selected the 10 year design storm which has a magnitude of 1.25" of rain in a 1-hour duration, referred to as a 10-year storm (a 10% chance of occurrence in any given year) to evaluate debris flow potential and volumes since this magnitude of storm seems likely to occur in any given year (Figures 5 - 10). Below is the magnitude of the recurrence interval rainstorm for the area of the Rough Fire associated with a 1-hour duration rainstorm.

Design storm (x" of rain / 1-hour duration):

Recurrence interval rainstorm	2- years	5- years	10- years	25- years	50- years	100- years
60 min duration	0.793"	1.04"	1.25"	1.57"	1.83"	2.12"

Debris flow probability and volume were estimated for each basin in the burned area as well as along the upstream drainage networks, where the contributing area is greater than or equal to 0.02 km^2.

The **probability model** was designed to predict the probability of debris-flow occurrence at a point along the drainage network in response to a given storm. Probabilities predicted by the model potentially range from 0 (least likely) to 100 percent (most likely). The predicted probabilities are assigned to 1 of 5 equal (20 percent) interval classes for cartographic display.

The **volume model** was designed to estimate the volume (in m^3) of material that could issue from a point along the drainage network in response to a storm of a given rainfall magnitude and

intensity. Volume estimates were classified in order of magnitude scale ranges 0–1,000 m^3; 1,000–10,000 m^3; 10,000–100,000 m^3; and greater than 100,000 m^3 for cartographic display.

Debris-flow hazards from a given basin can be considered as the combination of both probability and volume. For example, in a given setting, the most hazardous basins will show both a high probability of occurrence and a large estimated volume of material. Slightly less hazardous would be basins that show a combination of either relatively low probabilities and larger volume estimates or high probabilities and smaller volume estimates. The lowest relative hazard would be for basins that show both low probabilities and the smallest volumes.

Kean et al. (2013) and Staley et al. (2013) have identified that rainfall intensities measured over durations of 60 minutes or less are best correlated with debris-flow initiation. It is important to emphasize that local data (such as debris supply) influence both the probability and volume of debris flows. Unfortunately, locally specific data are not presently available at the spatial scale of the post-fire debris-flow hazard assessment done by the USGS. As such, local conditions that are not constrained by the model may serve to dramatically increase or decrease the probability and (or) volume of a debris flow at a basin outlet.

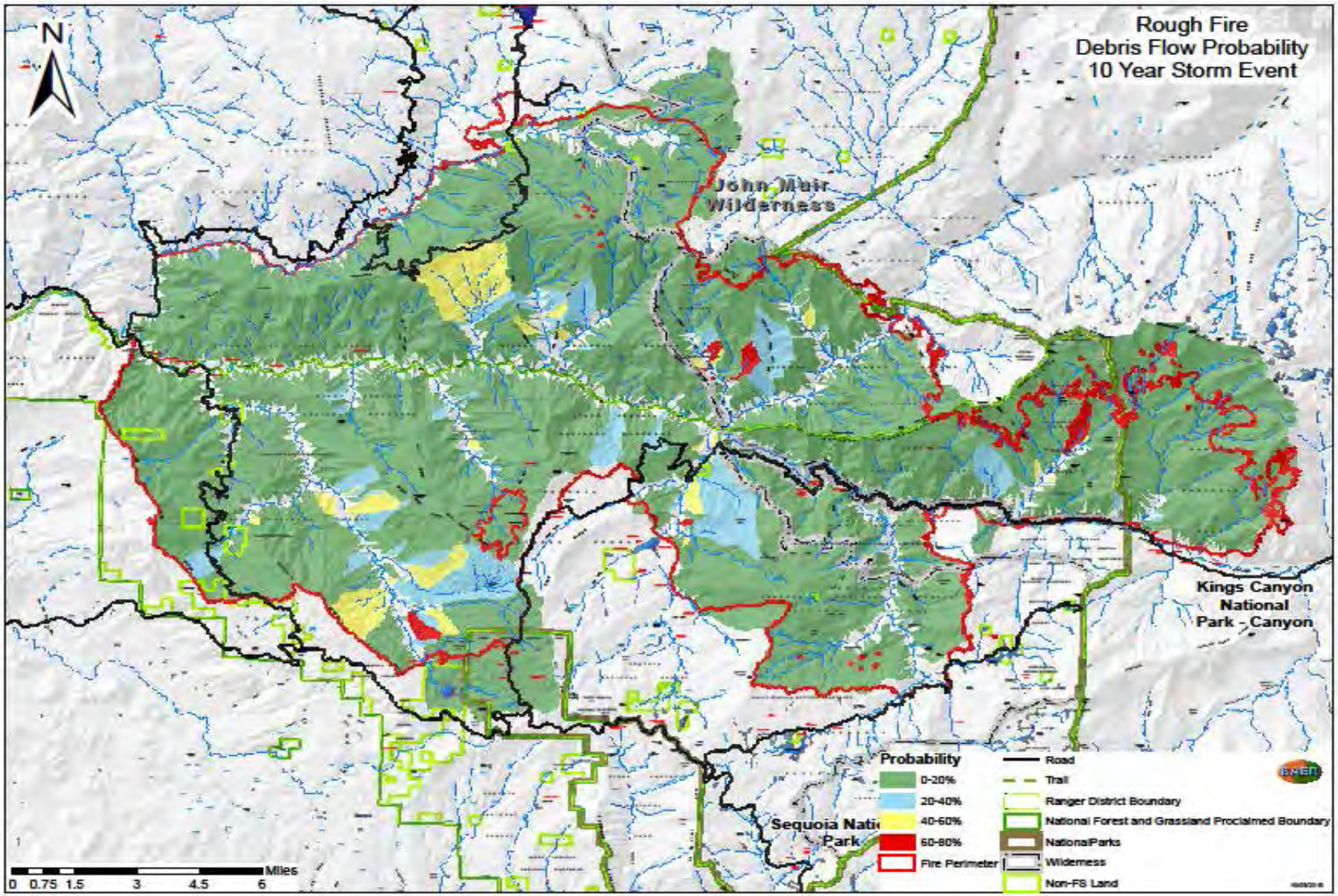


Figure 5: Predicted debris flow PROBABILITY basin map for the Rough Fire – 10 year storm

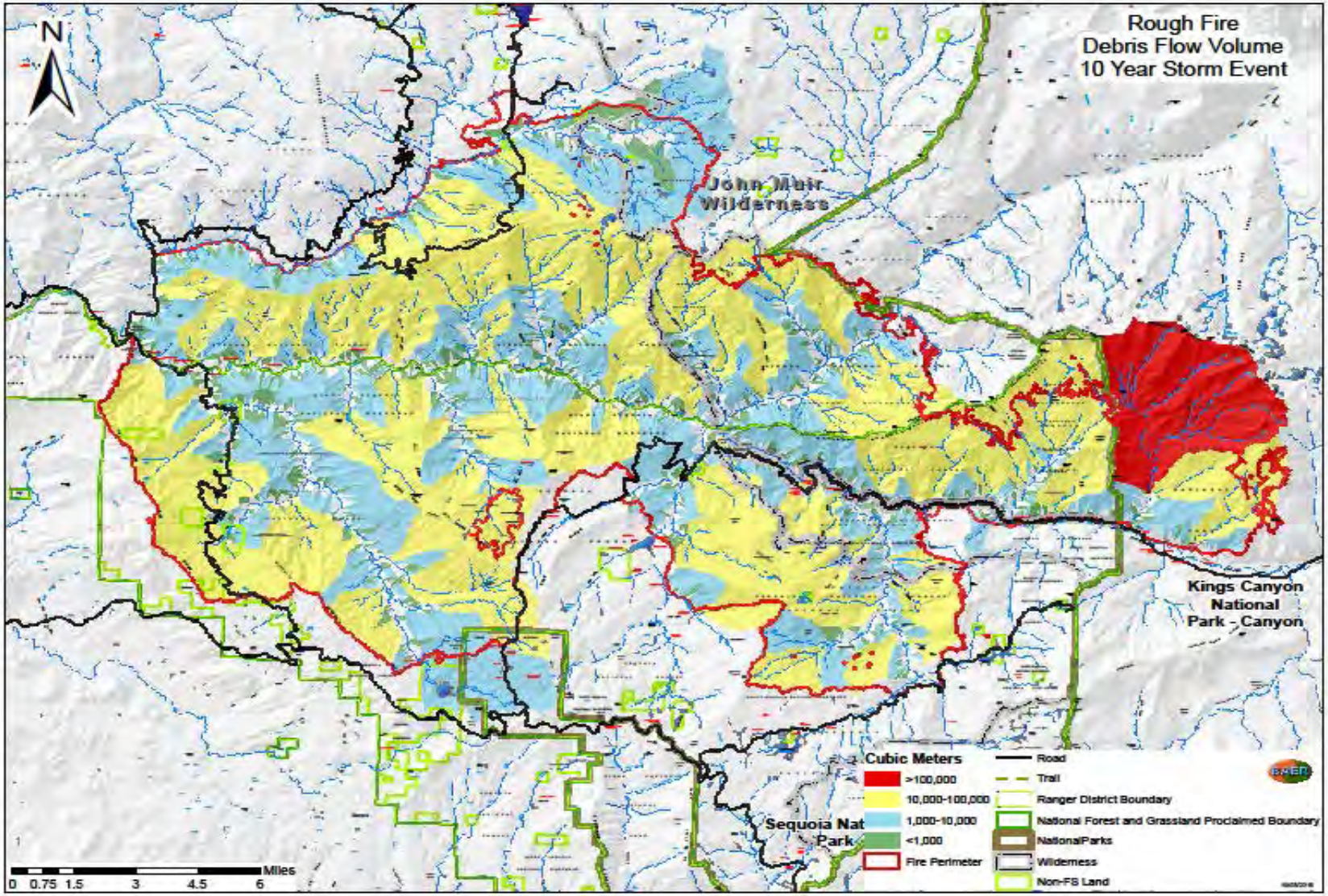


Figure 6: Predicted debris flow VOLUME basin map for the Rough Fire – 10 year storm

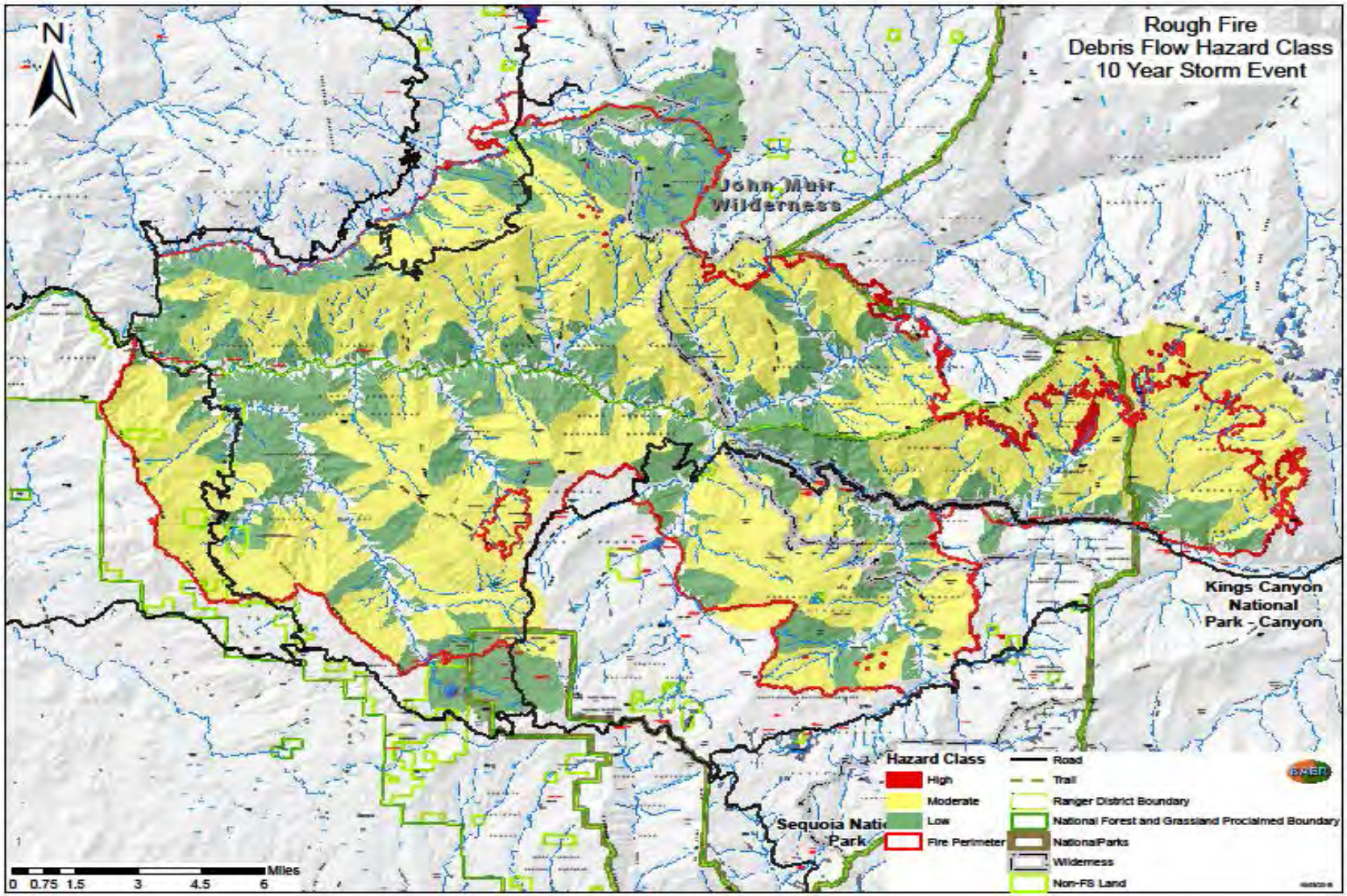


Figure 7: Predicted debris flow COMBINED HAZARD CLASS basin map for the Rough Fire – 10 year storm

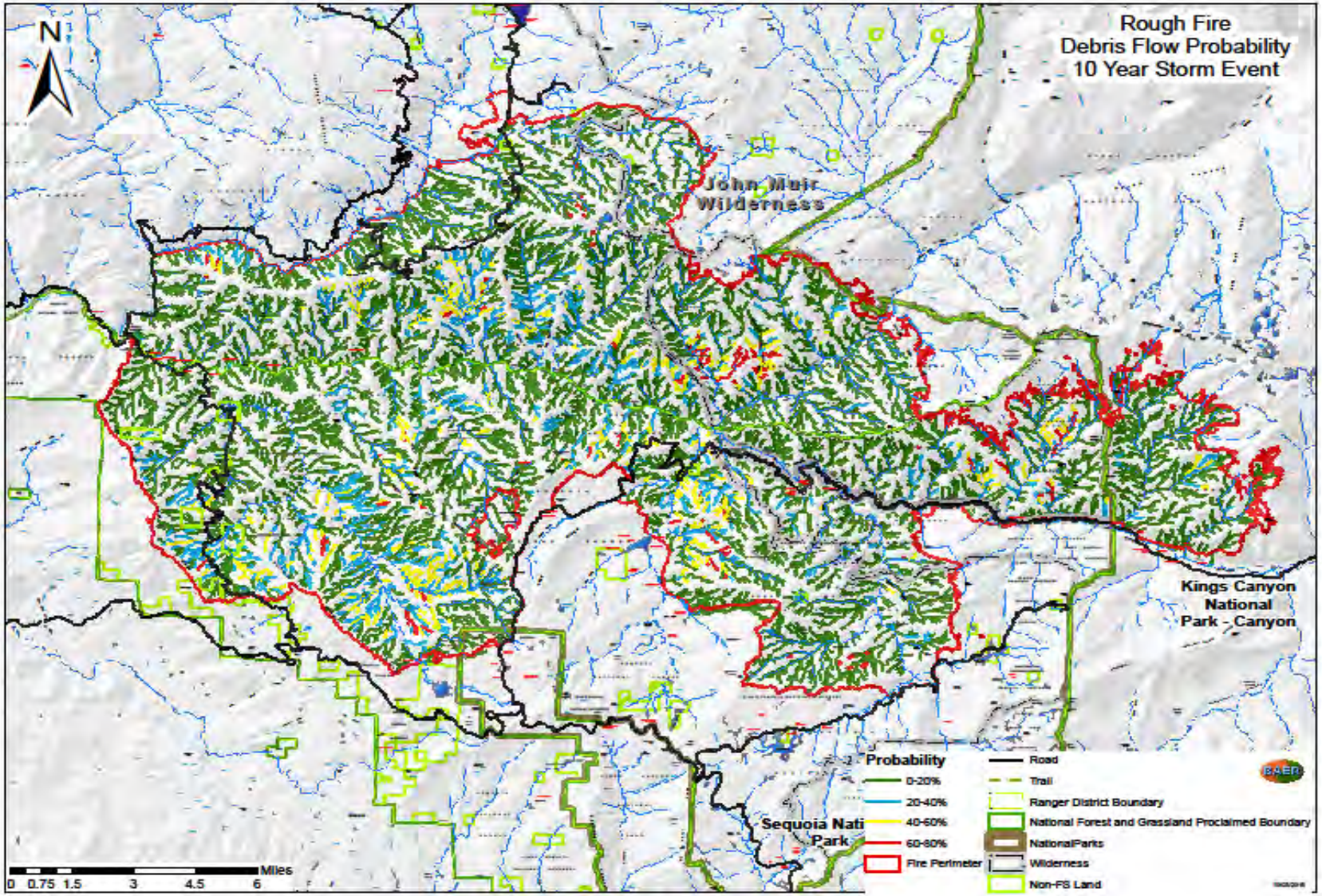


Figure 8: Predicted debris flow PROBABILITY segment map for the Rough Fire – 10 year storm

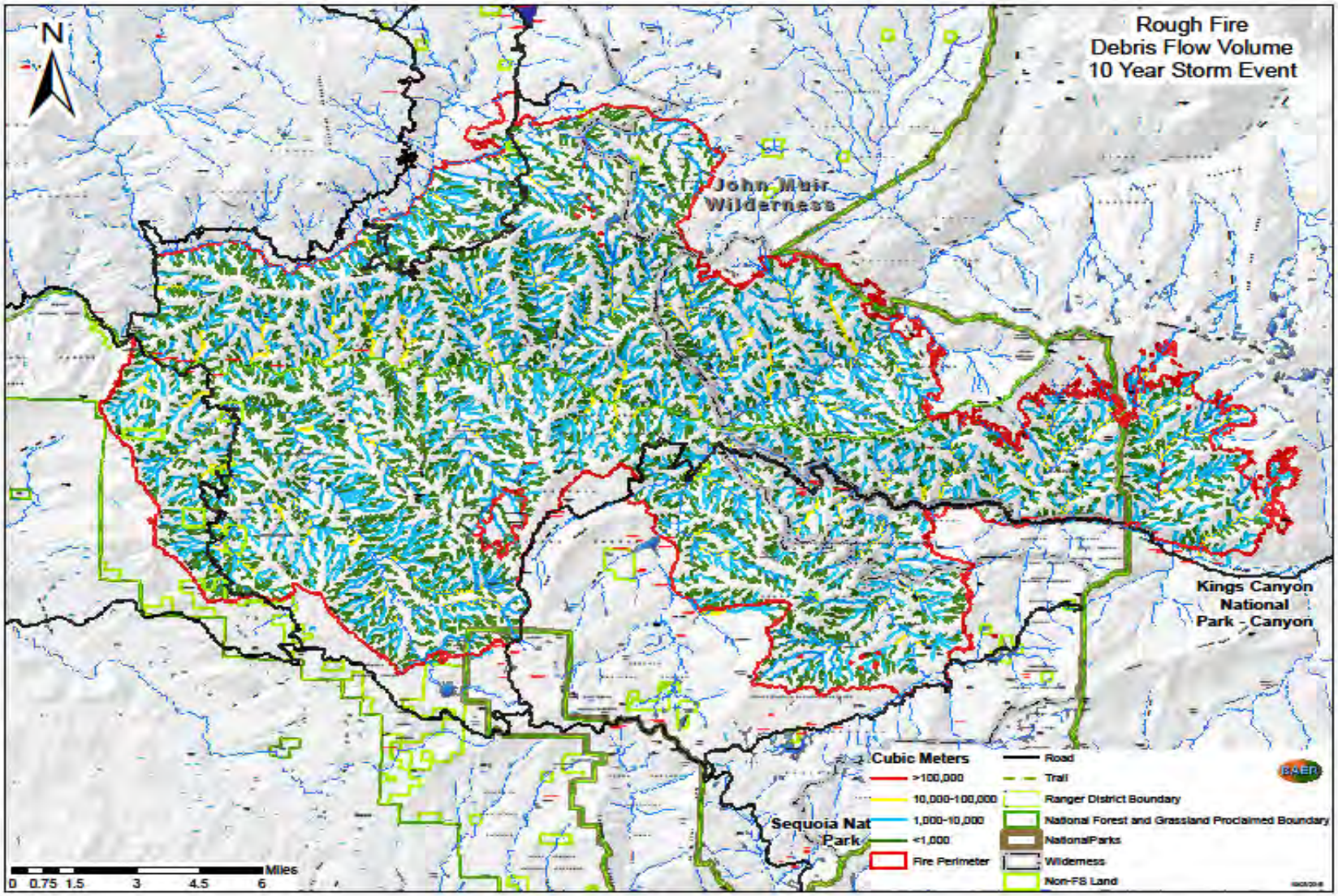


Figure 9: Predicted debris flow VOLUME segment map for the Rough Fire – 10 year storm

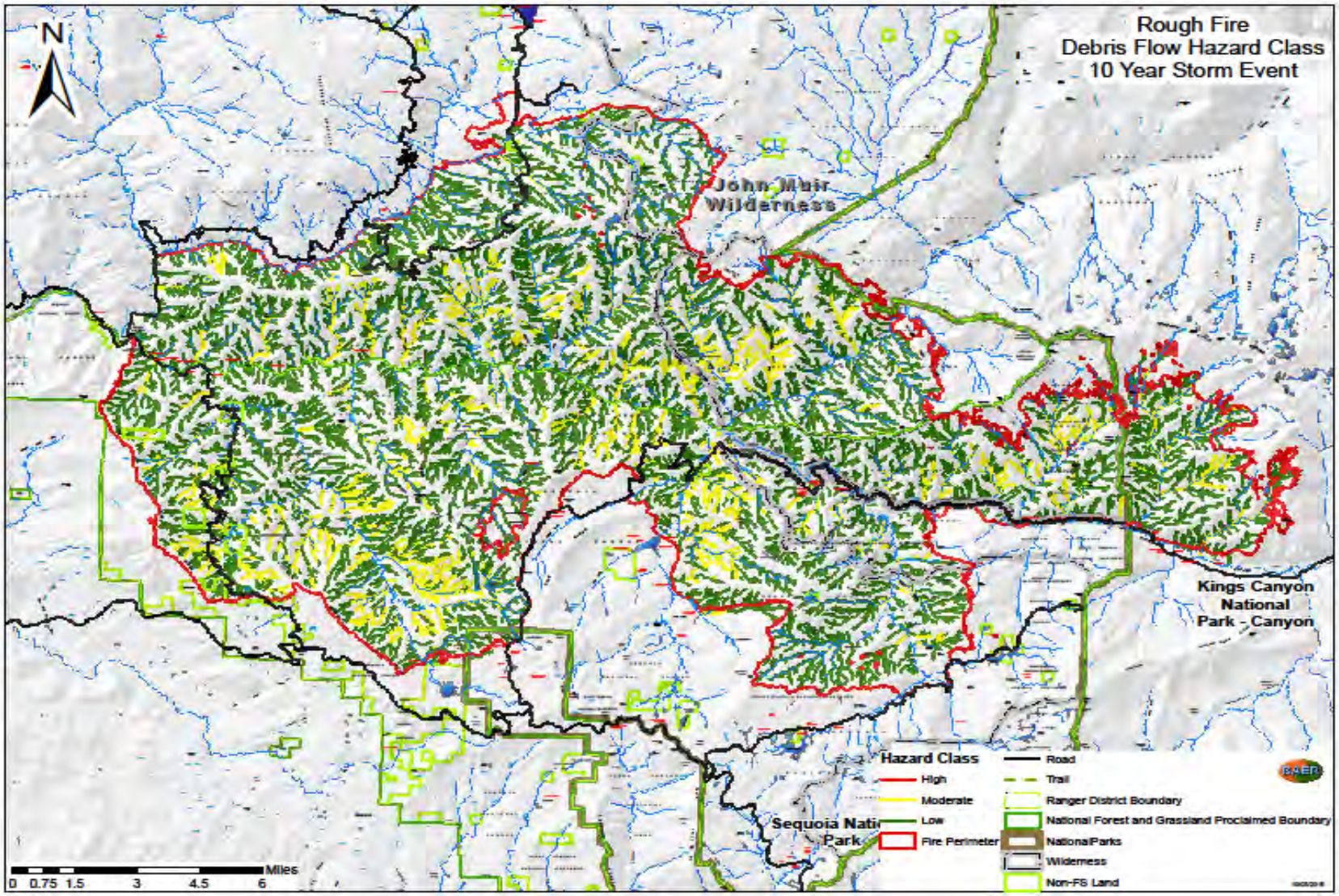


Figure 10: Predicted debris flow COMBINED HAZARD CLASS segment map for the Rough Fire – 10 year storm

Resource Conditions Resulting from the Fire

Assessment of the Rough Fire showed that susceptibility to slope instability will be associated with watersheds within the fire that have significant volumes of sediment in the channels or are likely to experience increases in sediment volume from fire-affected slopes. Sediment increases would be associated with significant areas of susceptible bedrock that were subjected to high or moderate burn severity. The basis for this assumption is recent research on wildfire-generated debris flows, which can be extrapolated to other types of slope movement. Rather than being the result of infiltration-induced slope movements into the channels, wildfire-generated debris flows are a result of progressive bulking of storm flow with sediment within the channel and washed from the adjacent slopes (Cannon, 2000, 2001). As Cannon and others (2003) state:

> **"Wildfire can have profound effects on a watershed. Consumption of the rainfall-intercepting canopy and of the soil-mantling litter and duff, intensive drying of the soil, combustion of soil-binding organic matter, and the enhancement or formation of water-repellent soils can result in decreased rainfall infiltration into the soil and subsequent significantly increased overland flow and runoff in channels. Removal of obstructions to flow (e.g. live and downed timber, plant stems, etc.) by wildfire can enhance the erosive power of overland flow, resulting in accelerated stripping of material from hillslopes. Increased runoff can also erode significant volumes of material from channels. The net result of rainfall on burned basins is often the transport and deposition of large volumes of sediment, both within and down-channel from the burned area."**

II. Potential Values at Risk

The following "values at risk" (VARs) are threatened by debris slides and flows, rockfall, or flooding augmented by the effects of the fire on steep, erosive and unstable slopes and water channels.

Human Life and Safety:

- People traveling through and below burned areas – Loss of life or injury could take place as a result of debris slides and flows, rockfall, or flooding.

Property:

- Highway 180, Forest roads, trails, and drainage systems – As a result of the fire, excessive runoff and flows, stability of slopes over Highway 180, Forest roads and trails will be compromised. Debris slides and flows, rockfall, and flooding will cause damage to these systems.

Natural Resources:

- Windy Gulch Geological Area – as a result of the fire, excessive flows, sedimentation and debris will impact some entrances / portions of the Boyden and Church Caves. In addition, rock-fall along the trail leading to these caves is expected during storm event.

- Water quality, riparian sustainability and downstream uses – As a result of the fire, excessive sedimentation will adversely affect water quality in some of the creeks flowing into Kings River which in turn might affect the Pine Flat Reservoir.

Specific Values At Risk (VAR's):

Specific VAR's that were identified and assessed by the geological team include highway 180, the Davis Creek Road (12S01), FS road 13S05 and the Boyden and Church caves.

III. Emergency Determination

The emergency to VARs from geologic hazards caused by the fire includes adverse effects to the health and safety of people, property, roads, trails and natural resources. Risk of loss of life and limb is of particular concern.

IV. Treatments to Mitigate the Emergency

The Geology Team was involved in numerous discussions with other team members about what treatments could be effective to mitigate potential impacts from the various watershed responses that endanger downstream values at risk. Most treatments are being proposed by other functions such as hydrology and engineering.

ROADS: Inside ditches, culverts, risers, rolling dips, downdrains, and outsloping

A. Treatment Type and Proposed Location: Inside ditches, etc. located along all roadways. Create outsloped road prisms and rolling dips to improve road drainage where berms are removed, gradients are gentle enough, and inside ditches are not needed, to reduce concentration of drainage and disperse overland flow.
B. Treatment Objective: To improve water flow along and below roadways to keep roads from being washed out where drainage becomes overwhelmed during peak flows, or is impacted by increased flows resulting from burn severity. To decrease resource damage.
C. Treatment Description: Fix ditch sloughing, sizing, install or repair culverts, many of which are undersized or damaged, enlarge, add risers and drop inlets as needed;

install or repair engineered dips and fords, install or repair downdrains, etc. Install outsloped road prisms with rolling dips and downdrains long enough to insure gullying does not create future threats to the road.

D. Treatment Costs: See engineering contracts and specs.
E. Monitoring needs: If drainage devices plug or otherwise fail, severe damage can be done to roads, fills and drainage structures. Monitoring, especially during storm events is necessary.

ROADS: <u>Debris clearing, sidecasting and waste disposal sites</u>,

A. Treatment Type and Proposed Location: Debris clearing, where large deposits of debris threaten drainage systems, especially culverts; locations scattered throughout burned area. Include channel clearing to aid unobstructed flow. Work with both in-house and private contractors to stop sidecasting and improve ditch and dip maintenance practices, throughout the road system. Identify specific locations where changes in practices are most needed. Since the area has no approved disposal sites, and waste disposal is continually contributing to resource damage, and that damage will increase as a result of the fire, waste disposal sites that are on stable and otherwise approved land are an urgent need, to reduce resource damage.
B. Treatment Objective: To remove unconsolidated debris threatening drainage structures. To prevent slide and debris cleanout material from being sidecast or disposed of in inappropriate locations, especially once watersheds begin to recover.
C. Treatment Description: Use backhoe or excavator to remove loose material, end-haul, and dispose in approved disposal site. Document improvements and continuing problems. Locate and design and get all necessary approvals for disposal sites, strategically located so as to reduce haul costs and resource damage.
D. Treatment Costs: See engineering contracts and specs.
E. Monitoring needs: Continue identifying debris deposits, including new ones that may form during subsequent storms that threaten drainage structures. Monitor to assure sites are well drained and functioning properly.

ROADS: <u>Install warning signs</u>

A. Treatment Type and Proposed Location: Install approved warning signs regarding flood and landslide/rockfall potential during storm events, at major road intersections and as needed.
B. Treatment Objective: to improve safety from landslide/rockfall and flood events for workers and Forest visitors.
C. Treatment Description: Install approved signs at key access points.

D. Treatment Costs: See engineering prescriptions.
E. Monitoring Needs: Monitor continued existence of signs for next 3 years, and replace as needed.

<u>Natural Resources</u>: Caves system in the Windy Gulch Geological Area – In order to mitigate life and safety threats to visitors of caves in the Windy Gulch Geological Area, it is recommended to keep the area closed during storm events for the duration of three years after the fire. In addition, due to potential flows, sedimentation and debris entering the caves via creek level entrances, it is recommended during the next 3-years to monitor potential damage to the caves by local geologist via annual visitations after winter seasons.

<u>Photo 7</u>: Rock-fall on the trail leading to Boyden Cave

V. Discussion / Summary / Recommendations

Rock-fall and rolling rocks are eminent along some segments of highway (Hwy) 180 between Yucca Point and Cedar Grove. Along this same segment of the Hwy, debris flow hazard areas have been identified and reviewed in the field. In addition, with the aid of USGS Debris Flow Modeling, debris flow probabilities and potential volumes have been calculated.

The conclusion of our field observations is that whether the primary post-fire process is rockfall, debris slides, debris flows or sediment laden flooding, the cumulative risk of various types of slope instability, sediment bulking, and channel flushing is high along some segments of Hwy 180 between Yucca Point and Cedar Grove following the Rough Fire. Once again, even though the USGS modeling presents very low (0-20%) probability of debris flows in drainages flowing into the Kings River in the Hwy 180 corridor, based on ground and aerial observations (quantities of rocky materials and steepness of slopes, channels) we estimate that some drainages along the kings River, Hwy 180 corridor have moderate to high potential to produce debris flows.

Treatments for debris flow and rock fall hazards include notification of the public of these hazards through warning signs and road closure.

Following the Rough Fire, segments of the Davis Creek road (12S01) will experience excessive rock-fall, potential debris flows and erosion. In order to prevent as much as possible erosion and damage to the road surface it is recommended to take some actions (storm proofing) before the first winter-storms arrive. Specific recommendations/treatments are described in the engineering report. To mitigate life and safety issues to the public a road closure is recommended.

Due to new post-fire conditions rock-fall will likely occur frequently during storm events on the trail leading to Boyden and Church caves. In addition, as a result of excessive flows, sedimentation and debris during storm events in Windy Gulch some cave entrances that are located at creek/channel level will deliver sediment and debris into the caves, which in-turn might cause damage to geological resources. It is our recommendation to keep the caves close to public access during storm events for the duration of three years following the fire. In addition, monitoring of geological resources in the caves is recommended for this same duration following the fire.

Conclusions from the USGS Debris Flow Assessment:

Based on USGS debris flow modeling, the majority of the basins in the Rough Fire burn area have a very low to low (0-20% & 20-40%) probability to produce any debris flows. The few basins that have a moderate (40-60%) probability to produce debris flows are located in the

upper reaches of the Mill Flat watershed and are not expected to impact any VAR's directly. In addition, along the Tenmile Creek above Hwy 180 one other basin has a moderate (40-60%) probability to produce a debris flow. Beyond these basins, all other basins that have a 40-60% probability to produce debris flows are located either in the north zone of the Rough Fire or in a very remote area of the Monarch Wilderness (above the Middle Fork Kings River). In the head-waters of the Mill Flat Creek one basin has a high (60-80%) probability to produce a debris flow. However, based on air recon of the upper Mill Flat watershed it appears that beyond soils/sediments very little rocky materials are at the surface and are available to be transported. Once again the few other basins that are predicted to produce a debris flow with a 60-80% probability are either located in a remote area of the Monarch Wilderness or at the headwaters of Grizzly Creek, over 2-miles in distance from Hwy 180.

Final Thoughts:

When evaluating Geologic Hazards, the focus of the "Geology" function on a BAER Team is to identify the geologic conditions and geomorphic processes that have helped shape the watersheds and landscapes, and to identify where the effects of the fire resulted in adverse changes to geologic processes that then affect Values at Risk . Using that understanding of rock types and characteristics, geomorphic processes, and distribution of geologic hazards can help others understand the conditions and processes that affect their areas of concern and predict how the fire changed the watersheds that will be tested during upcoming storm seasons. Within the Fork Complex area, some sub-watersheds show a great deal of past debris slide, and rockfall activity that will be increased during future storms. Other areas have little evidence of recent past slope instability, but conditions have changed due to the fire.

Protective vegetation is gone and will not return to the same levels of protection for years. Soil is exposed and has become weakened, and rock on slopes has lost its supporting vegetation. Roads and trails are at risk from rolling rock and drainage flow out of control. Slopes will experience greatly increased erosion. Stream channels and mountainside ephemeral channels will be flushed of the sediment that in some places is loose and deep, in other places shallow. That sediment will deposit in some channels, completely choking flow and raising flood levels and covering roads with deep sediment.

Much discussion occurs during BAER assignments about how specialists seldom get to return to burn areas to evaluate how their estimates of watershed response and effectiveness of treatments actually turned out. Our final recommendation is to establish an annual requirement, just as is the fire refresher and walk/pack test, that in order to be a qualified for future BAER assignments, a specialist must attend a field monitoring and assessment session, minimum of 3 days, at least once (and preferably much more often) every two years. Without this kind of learning experience, we are likely to keep making the same mistakes over and over, and not truly understand the physical processes we are trying to manage.

We recommend that the Region and local Forests support and require BAER Team specialists, especially those evaluating and making costly treatment recommendations about watershed response issues, to return as an IDT with other experts in their field, to the same burned area they evaluated, one and/or two years later to monitor and analyze the effects of winter storms and of implemented treatments. We believe that more learning will occur from this experience than from weeks of office study and training sessions.

VI. References

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Appendix 1: Geology Inputs to 2500-8

Part II – Burned Area Description:

Geologic Types: Bedrock within the boundaries of the Rough Fire consists of two primary rocks types: Paleozoic meta-sedimentary and meta-igneous rocks and Cretaceous granitics of the Sierra Nevada batholith. Small areas are covered by younger Tertiary volcanics that cap ridges. Surficial geologic units include glacial deposits covering various bedrock units, alluvial gravel and sand of varying ages and surficial scars and deposits from various types of instability features.

Part III – Watershed Conditions

Within the burned area of the Rough Fire, some drainages along the Kings River – Hwy 180 corridor show a great deal of past mass wasting as debris slide/rockfall activity that will be increased during future storms. Other watersheds as the Mill Flat Creek, Verplank Creek and Converse Creek have little evidence of recent past slope instability, but as conditions have changed due to the fire, erosion and new mass wasting might be initiated.

In watersheds that experienced moderate to high soil burn serverity, as a result of the removal of vegetation by the fire, soils are exposed and have become weakened, and rocks on slopes have lost their supporting vegetation. Due to these post-fire new conditions, roads are at risk from rolling rock, plugged culverts, debris slides and in some cases, debris flows. Risks to human life, roads, trails and natural resources is moderate to high in some areas of the Rough Fire.

Eventhough the USGS debris flow modeling estimates that the mejority of drainages along the Kings River have a low probability to produce any debris flow, field and aerial observations confirm that some drainages along the Kings River – Hwy 180 corridor are loaded with large deposits of rock and soil, inceasing the threat to human life and safty.

Treatments for debris flow and rock fall hazards include notification of the public of these hazards through warning signs and road closures; clearing and improvement of catch basins and ditches along the road; maintenance and up-grade of drainage structures.

Due to new post-fire conditions rock-fall will likely occur frequently during storm events on the trail leading to Boyden and Church caves. In addition, as a result of excessive flows, sedimentation and debris during storm events some cave entrances that are located at creek/channel level will deliver sediment and debris into the caves, which in-turn might cause damage to geological resources. It is our recommendation to keep the caves close to public access during storm events for the duration of three years following the fire. In addition, monitoring of geological resources in the caves is recommended for this same duration following the fire.