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

Fork Complex, Shasta-Trinity N.F.

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Abstract

The Fork Complex started on July 30, 2015, on the Hayfork RD of the Shasta-Trinity N.F., Trinity County, California, and burned a total of 36,498 acres. This report describes and assesses the increase in risk from geologic hazards within the Fork Complex 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 Fork Complex burned area, a high degree of mass wasting as shallow slope failures, ravel, translational-debris slides and rotational-translational slide activity has occurred in the past and will increase during future storms. In addition, some dormant landslides are located in the burnt area which might be re-activated during future storms as a result of the fire.

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 many 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

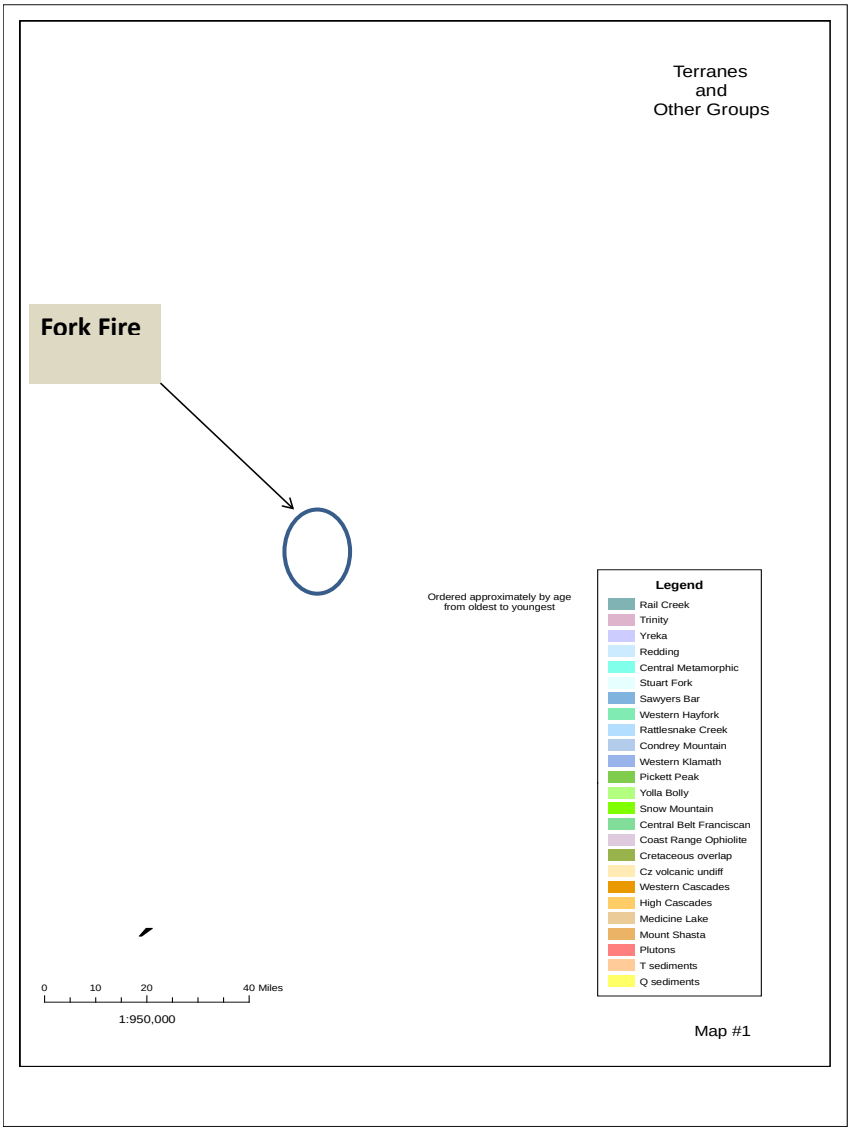
flows and rock falls are the primary geologic hazards associated with burned watersheds (Santi et al., 2013; Parise and Cannon, 2012). Watersheds with steep slopes and significant amounts of moderate to high soil burn severity are especially likely to generate debris flows. The majority of debris flows exacerbated by wildfires usually occur 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 Fork Complex lies within the Klamath Mountains Physiographic Province, and is underlain predominantly by Paleozoic and Mesozoic metavolcanic and metasedimentary rock, along with a minor amount of Cretaceous and Tertiary sediments. Tectonic processes accreted numerous terranes to the western margin of North America and three of these occur within the fire area; the Sawyers Bar, Western Hayfork, and Rattlesnake Creek Terranes (Table 1). These terranes were intruded by granitic plutons, the largest of which is the Wildwood Pluton, in the east central part of the Fork Complex, straddling Hayfork Creek. Small outcrops of sedimentary rock, the Great Valley Sequence and Weaverville formation occur in the center of the complex. Figure 1 displays regional distribution of terranes, with the location of the Fork Complex indicated.

Belt/Assemblage	Age	Terrane/Formation	Unit	Sequence	Rock type
Western Pz & Tr	Pz / Mz	Sawyers Bar	East Hayfork		ms, Chert, Argillite
Western Pz & Tr	Pz / Mz	Western Hayfork			mv plus ms Tuff/Breccia
Western Pz & Tr	Pz / Mz	Rattlesnake Creek			Ms, Diamictite, Serpentinite, Peridotite
Cretaceous Overlap	Cretaceous		Undefined	Great Valley	Sedimentary, Sandstone, Mudstone
Weaverville	Tertiary	Weaverville			Sedimentary, Alluvium/Lacustrine
Plutons	Jurassic				Intrusive ig., Diorite, Gabbro, Pyroxenite

Table1: Rock Units on the Fork Complex



<u>Figure 1</u>: Geologic Terranes and Plutons

The **Sawyers Bar Terrane** occupies the northeastern 2/3 of the fire complex, and consists primarily of metasedimentary rock, including some small limestone bodies with known caves. It contains a scattering of dormant landslide deposits, primarily slump and earthflow complexes, amounting to about 10% of the area. The Stafford fire of 2012 burned an area of Sawyers Bar Terrane in the center of the Fork Complex, (It did not re-burn in the Fork Fire of 2015) and provides a little insight into the post-fire response of this terrane. The Stafford Fire has experienced no debris flows since it occurred in 2012, but it is noteworthy that precipitation has been relatively mild in the years since the fire. One small post-fire debris flow has been documented within the Sawyer's Bar Terrane, and this was on the north side of Natural Bridge

Creek, a short distance north of Natural Bridge picnic area. The debris flow occurred around 2009, following a fire a few years before that.

The **Western Hayfork Terrane** is primarily metavolcanic, and occupies the center and SE corner of the fire complex. Along the west central of the fire complex, between Salt Creek and Brock Gulch to the west, a large area is mapped entirely as dormant landslide. This appears to be a mapping error (possibly polygon labeling). The topographic expression is not consistent with dormant landslide deposits, and the southern boundary runs exactly east-west in a straight line, again not typical of a landslide boundary. Aside from this location the density of dormant landslide in the Western Hayfork Terrane (within the fire complex) is lower than in the Sawyers Bar Terrane (<10%). The Western Hayfork Terrane contains small bodies of limestone which could have caves.

The **Rattlesnake Creek Terrane** occupies the SW Corner of the fire complex, and a large proportion consists of diamictite, a weak metasedimentary rock which is prone to deep seated landslides. It contains a high density of dormant landslides in the west central part of the fire complex (about 90% of the area of this Terrane within the fire perimeter). However in the SE corner of the fire, few dormant landslides are mapped in this terrane, and rather, two large active earthflows are identified within and adjacent to the fire perimeter. Small bodies of serpentinite and peridotite occur within this terrane, and could contain natural asbestos.

Plutons in the Klamath Mountains typically form sandy soils and can be particularly prone to shallow debris slides and debris flows in steeper watersheds after wildfire. Granitic lands on the Klamath Forest about 100 miles to the north of the Fork Complex (near Seiad Valley, CA) experienced extensive debris flows in July of 2015 after having been burned in 2014. The Wildwood pluton in the SE edge of the fire complex area contains a large body of pyroxeninte which could possibly contain natural asbestos.

Geomorphology:

Most of the geologic terranes of the Klamath Mountains are weak and prone to landslides. Rapid uplift, high precipitation, and seismic activity to the west have created a landscape with abundant deep seated landslides, many of which occupy several square miles. Most of these larger complexes are dormant under present climatic and seismic conditions though some from 10’s to 100’s of acres in size are known to be active. Both the dormant and active landslides are very important parts of the landscape because they are often the source of debris slides during wet winters, and the debris slides in turn generate debris flows. Post-fire summer debris flows triggered by the rapid influx of sediment from rills and gullies typical of places like southern California and the Rockies are less common, possibly because intense summer storms occur less frequently. The geomorphic map (Figure 3) is a derivative map produced by overlaying the geomorphic coverage with slope and bedrock.

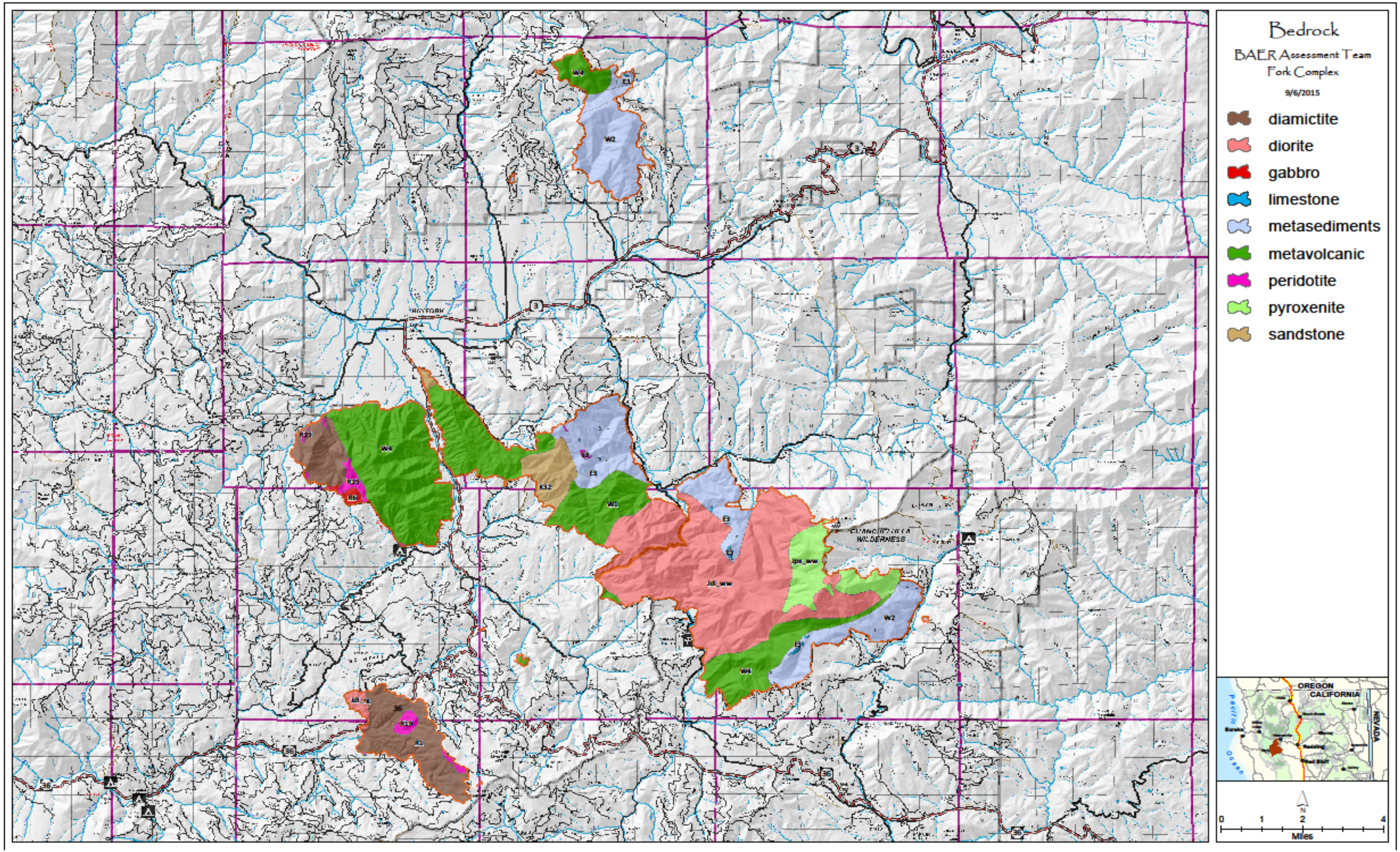


Figure 2: **Bedrock map of the Fork Complex area**

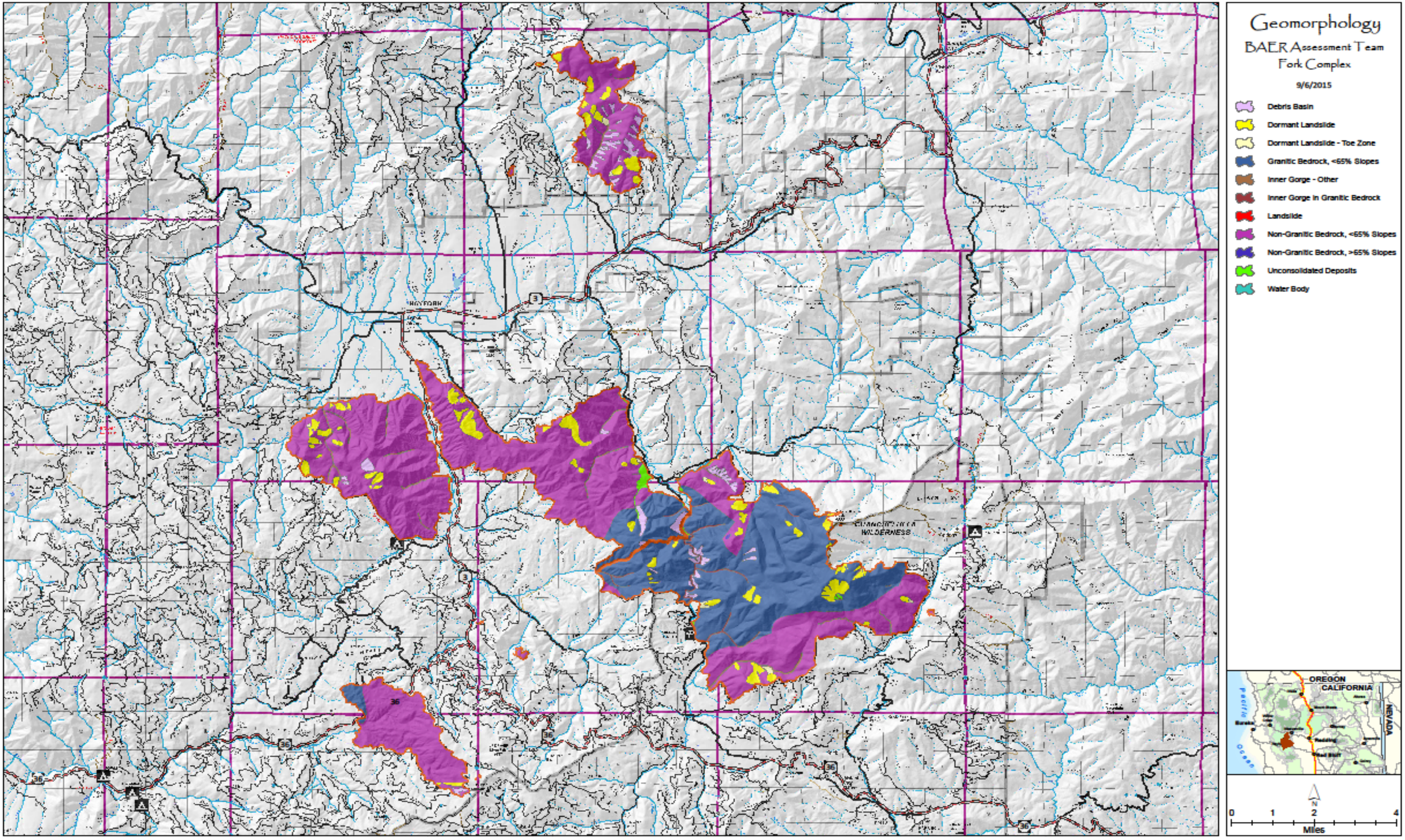


Figure 3: Geomorphology map of the Fork Complex area

Faults:
A large number of faults traverse the fire complex, including numerous thrust faults separating geologic terranes. However, these faults have not exhibited recent movement. The nearest Quaternary faults lie about 20 miles to the west and are associated with the Coast Ranges.

Landscape characteristics: The area is characterized by dissected ridge lines in a southeast – northwest direction and slopes ranging from gentle (0-15%) to steep (>60%) slopes (see Figure 4). The major creeks draining the fire area include the Hayfork Creek, the Salt Creek, the Little Barker Creek and the Rattlesnake Creek all tributes of the South Fork of the Trinity River which is a tribute of the Trinity River, which is in turn a tribute of the Klamath River.

Slope in-stability features such as recent pre-fire debris slides, rock-falls, channels and gullies frequent the steep inner gorge slopes, while fluvial erosion processes have shaped the gentler valleys and ridges. Areas of active mass wasting are typically void of vegetation (see photo 1). 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 sediment that will mobilize during flood events and add significant bulk to flowing water. Other channels, especially on steep hillsides, were relatively devoid of pre-fire sediment, but now are subject to filling with post-fire colluvial debris and rolling rock.

Photo 1: Active mass wasting – Slump Earth Flow, Rail fire

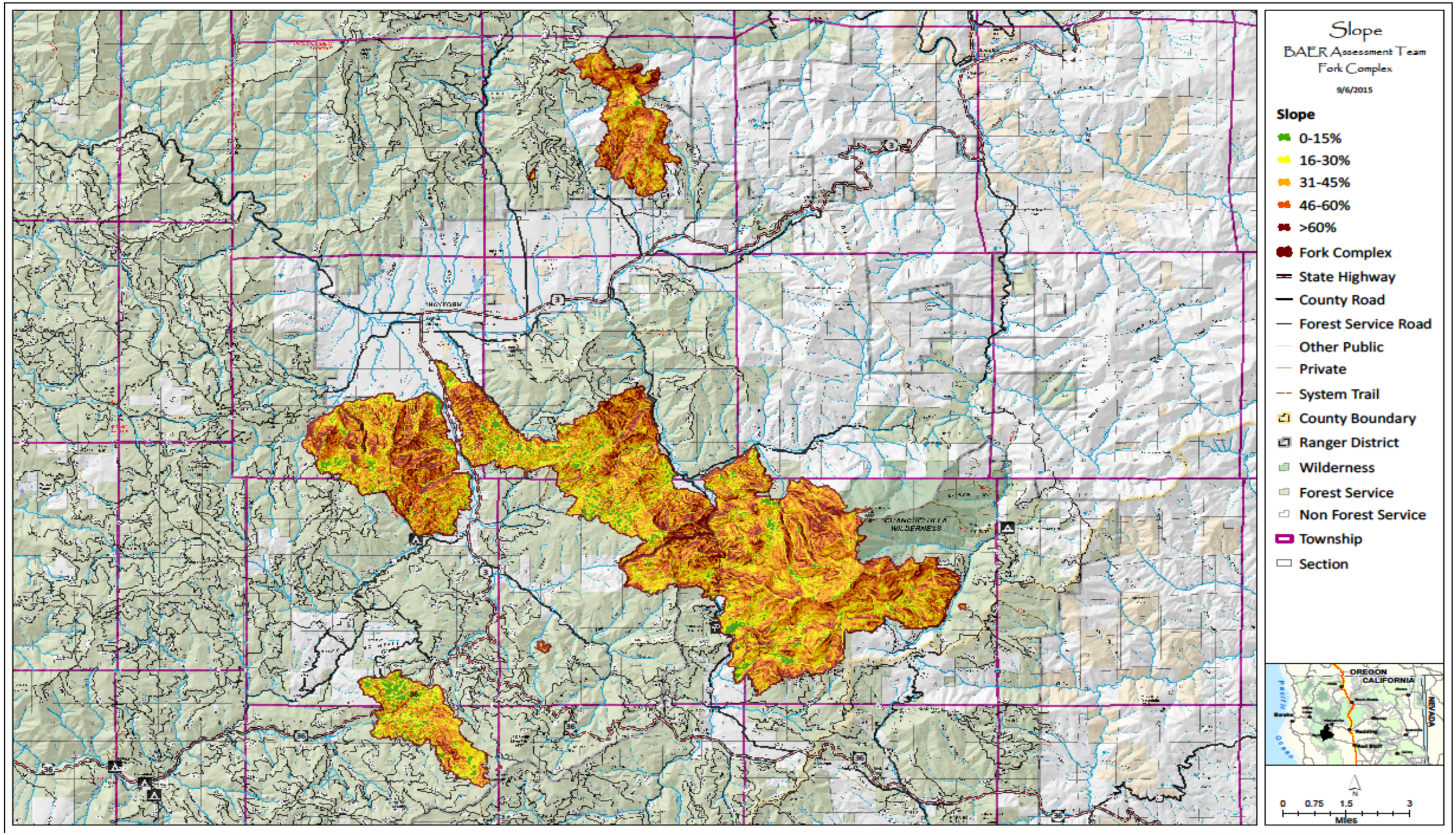


Figure 4: Slope Map – Fork Compelx

Findings / Observations

Through ground surveys, flight recons and study of geomorphic maps evidence of past mass wasting was observed throughout much of the Fork Complex burnt area. From on-the-ground observations it is clear that some of the headwaters of the Little Barker creek, the Wilson creek and others are loaded with unsorted, unconsolidated materials available to be transported.

Barker Fire:

The Barker fire area includes the headwaters of three major watersheds: The Barker Creek-Hayfork Creek, the Carr Creek and the Conner Creek-Trinity River. Out of these three watersheds the Conner Creek-Trinity River watershed was least affected by the fire (very low or unburned soil burn severity). The headwaters of an un-named creek flowing into the Carr Creek exhibit some high soil burn severity. The watershed that was most affected by the Barker fire (large area of high soil burn severity) was the Little Barker Creek watershed which is a sub-basin within the Barker Creek – Hayfork Creek watershed (see photo 2). With a lithology of an-unstable meta-sedimentary bedrock and slopes of over 60%, the headwaters of the Little Barker Creek are extremely steep and loaded with lots of unconsolidated materials available to be transported. Beyond some level 1 & 2 FS roads that might experience some excessive rock falls and erosion, the major concern/Value At Risk (VAR) in this area is the crossing of Little Barker Creek under County road 331. In an event of a 10-year storm, the Little Barker watershed is predicted to produce debris flows ranging from 10K to 100K cubic meters with a probability of 60-80% and with a high debris flow hazard rating.

<u>Photo 2</u>: High soil burn severity at the headwaters of the Little Barker Creek watershed

Shield Fire:

The Shield fire burnt area includes three major watersheds: The Hayfork Creek watershed, the East Fork of the Hayfork Creek watershed and the Upper Browns Creek watershed. Out of these three watersheds the one that was least affected and has the least Values At Risk (VAR's) is the East Fork of the Hayfork Creek watershed. Some of the headwaters of the Brown Creek exhibit moderate – high soil burn severity which in turn will impact water qualities of the Brown Creek in addition to some of the level 1 & 2 FS roads up in that south-east corner of the Shield fire. The largest watershed in the Shield fire is the Hayfork Creek watershed which exhibits major – large areas of moderate soil burn severity and some smaller areas of high soil burn severity, mostly at the headwaters of Wilson Creek (see photo 3) and some at the headwaters of Chanchelulla Gulch which in turn will affect water qualities in these creeks. In addition to the effects on water quality, some of the level 2 FS roads up in that south and south-west corner of the Shield fire will experience excessive rock falls and erosion. Along these roads, it is recommended to keep the basins at the creek crossings as clear as possible and have storm patrols after every major rain storm. It is also recommended to install rises on some of the culverts crossing these roads, as well as installation of rolling dips to channel plugged culverts off the roadway. Along County road 302 / Wildwood road it is likely that some segments of the road (with steep burnt slopes above the road) will experience some rock fall which should be addressed via warning signs and storm patrols.

<u>Photo 3</u>: High burn severity at the headwaters of Wilson Creek – Shield fire

Rail Fire:

The Rail fire can be divided into two major watersheds which include to the east and north-east the Hayfork Creek watershed and to the west and south-west the Salt Creek watershed. The fire area ranges between very low or unburned to moderate soil burn severity with a majority of the fire area ranging between low to moderate soil burned severity. On this fire as a result of burnt vegetation/lack of vegetation and unstable meta-volcanic and sedimentary bedrock many of the level 1 & 2 FS roads might experience rock falls and excessive erosion issues (see photos 4 & 5).

Photo 4: FS system level 1 & 2 roads in the Rail fire - FS 31N42

Photo 5: Active mass wasting above and below FS road 31N19

Peak Fire:

The Peak fire can be divided into two watersheds which include: the Salt Creek watershed to the east and the Tule Creek watershed to the west. The Peak fire area ranged between very low or unburned to moderate soil burn severity. In this fire the most prominent feature is the lookout tower and cell site tower at the top of Plummer Peak. Very few VAR's were identified in the fire area. To the east and below the fire area (along Hwy 3) some private properties my experience some excessive sedimentation deposits from the burned slopes above.

Blue Fire:

For the most case, the majority of the Blue fire is within the Rattlesnake Creek watershed. The bulk of this fire is defined as moderate soil burn severity, which in conjunction with some steep slopes (over 60%) and a volcanic broken formation will affect water qualities in the Rattlesnake creek. In addition, level 3 FS road 30N29 will most likely experience rock fall and dry ravel from burnt slopes above (see photos 6 & 7). Some of the culverts under this road might plug as a result of excessive flows, sedimentation and debris. It is recommended to keep the basins at the creek crossings (under this road) as clear as possible and have storm patrols after every major rain storm. In addition, installation of some rises on the culverts located at these drainage crossings is recommended as well as installation of rolling dips to channel plugged culverts off the roadway. In the community of Trinity Pines, County road 351 might experience some deposition of sediments in addition to potential plugging (see photo 8) and failure of 3 coverts crossing this road.

<u>Photo 6</u>: Dry ravel and erosion on cut-slope above FS road 30N29

<u>Photo 7</u>: Mass wasting and loaded channel above FS road 30N29

<u>Photo 8</u>: Plugged culvert under County road 351 – Trinity Pines

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) 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 Fork Complex fire burn severity map (Figure 5), 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 0.773" 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 very likely to occur in any given year (Figures 6 - 11). Below is the magnitude of the recurrence interval rainstorm for the area of the Fork Complex 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	0.458"	0.631"	0.773"	1.967"	1.12"	1.27"

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.

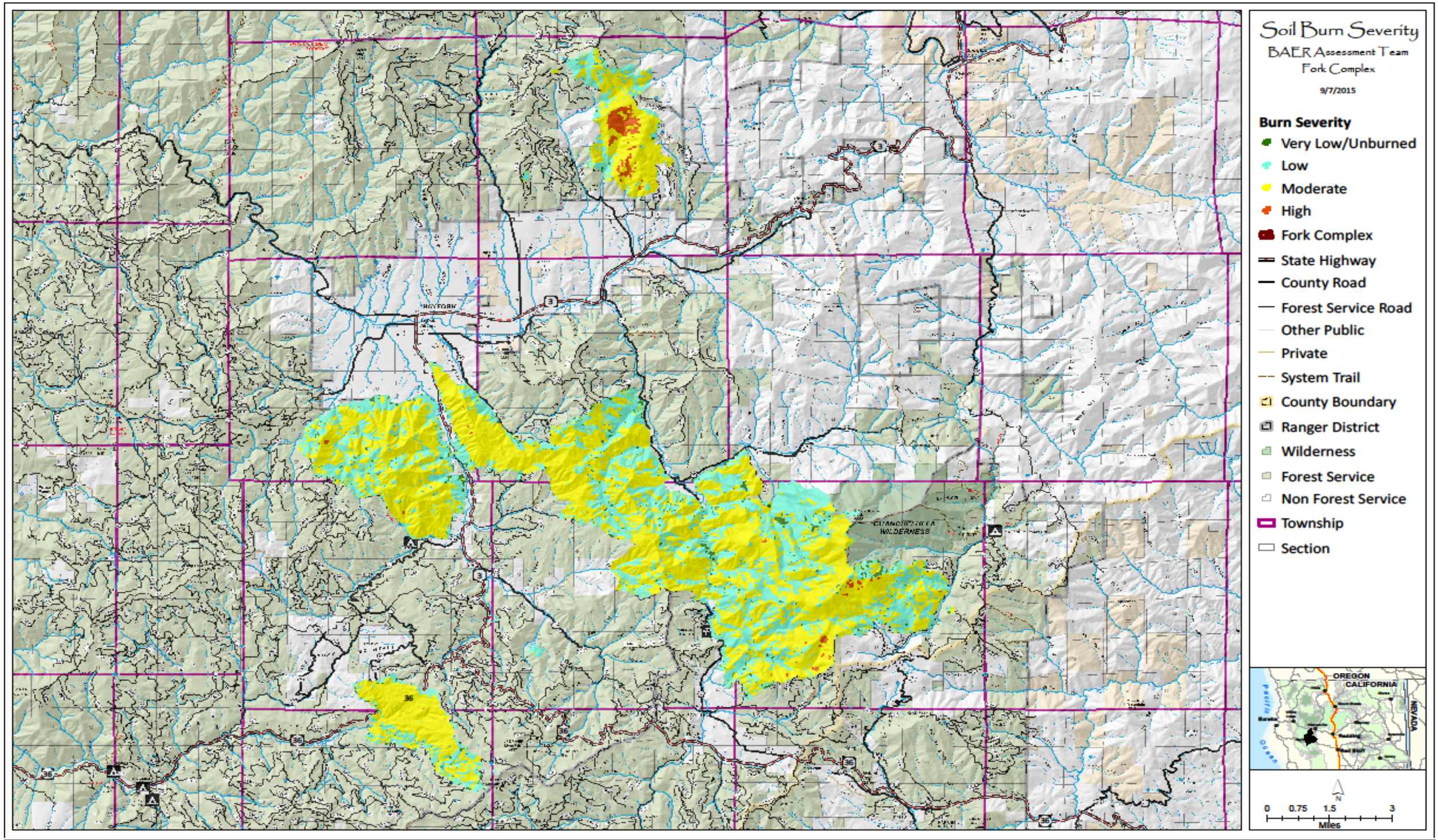


Figure 5: Soil Burn Severity map – Fork Complex

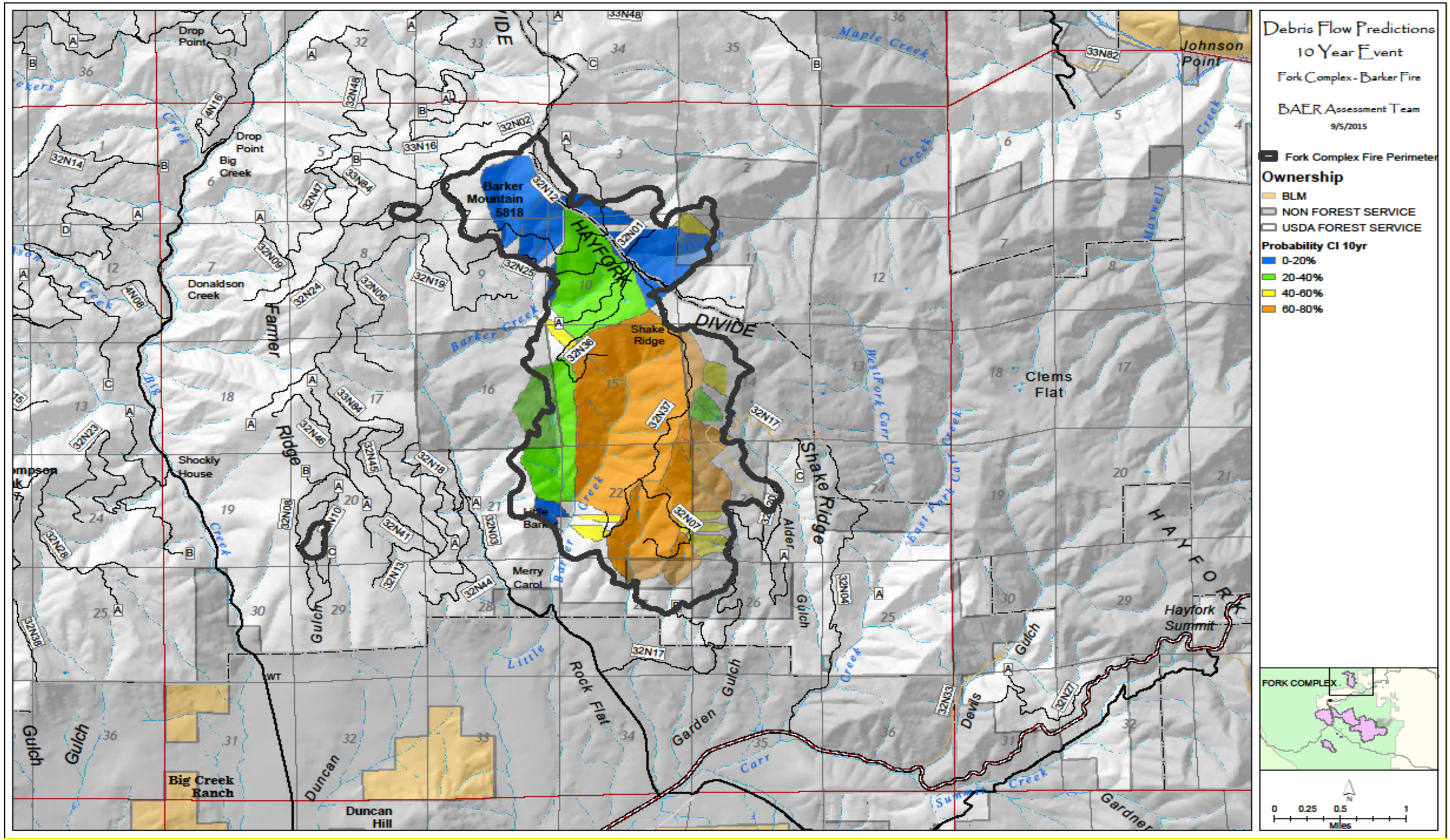


Figure 6: Predicted debris flow PROBABILITY map for the Barker Fire – 10 year storm

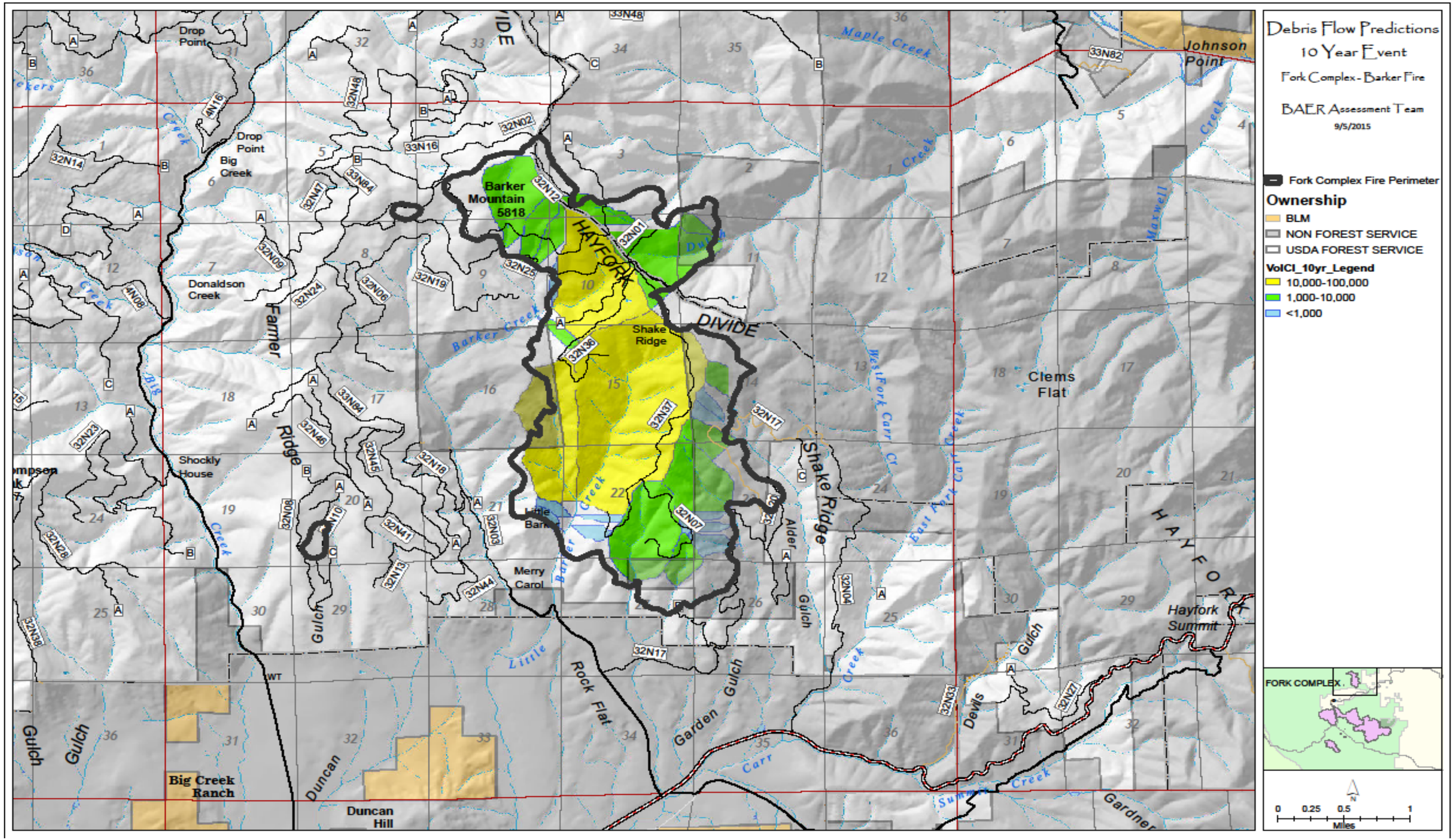


Figure 7: **Predicted debris flow VOLUME map for the Barker Fire – 10 year storm**

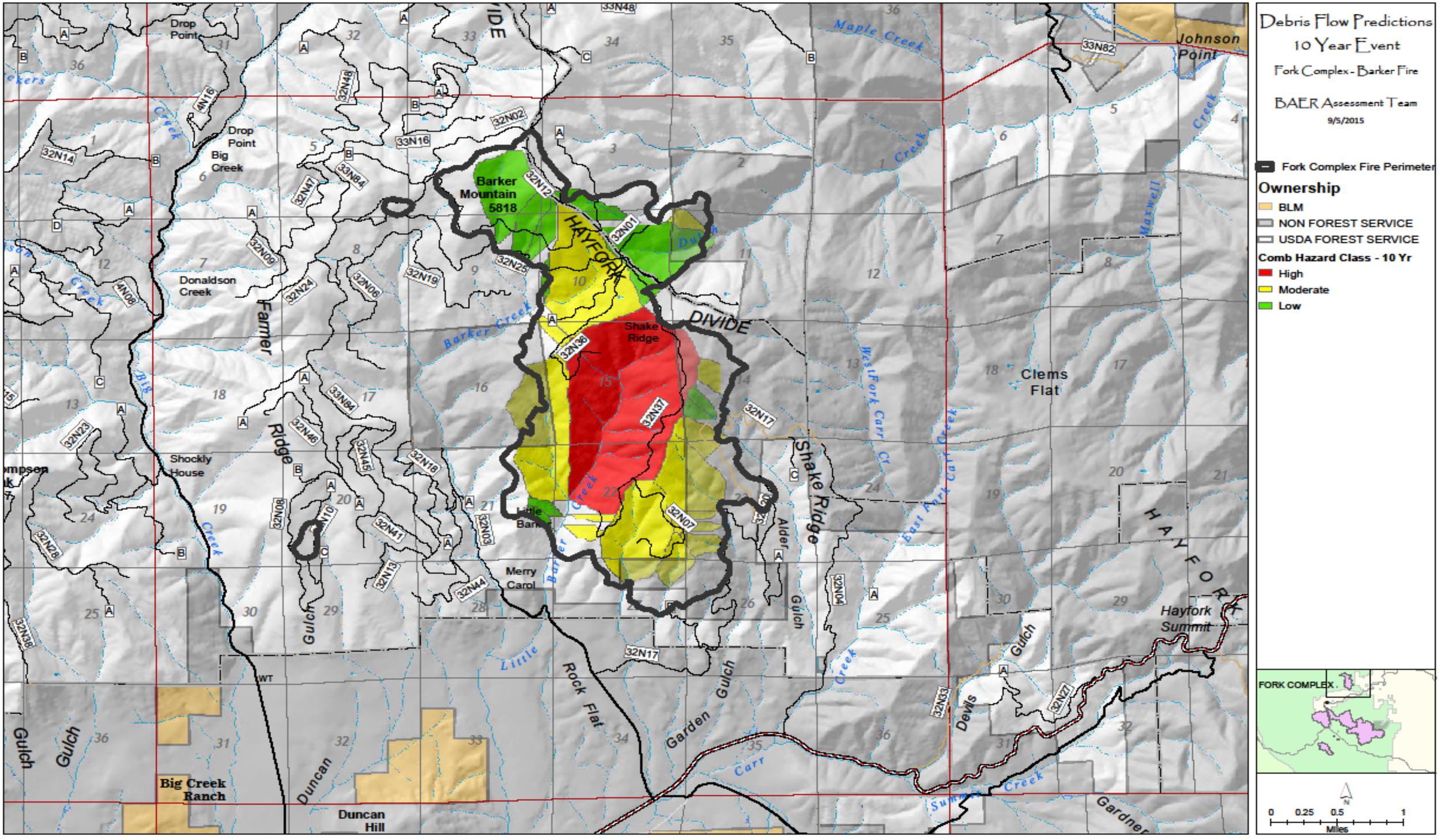


Figure 8: Predicted debris flow COMBINED HAZARD CLASS map for the Barker Fire – 10 year storm

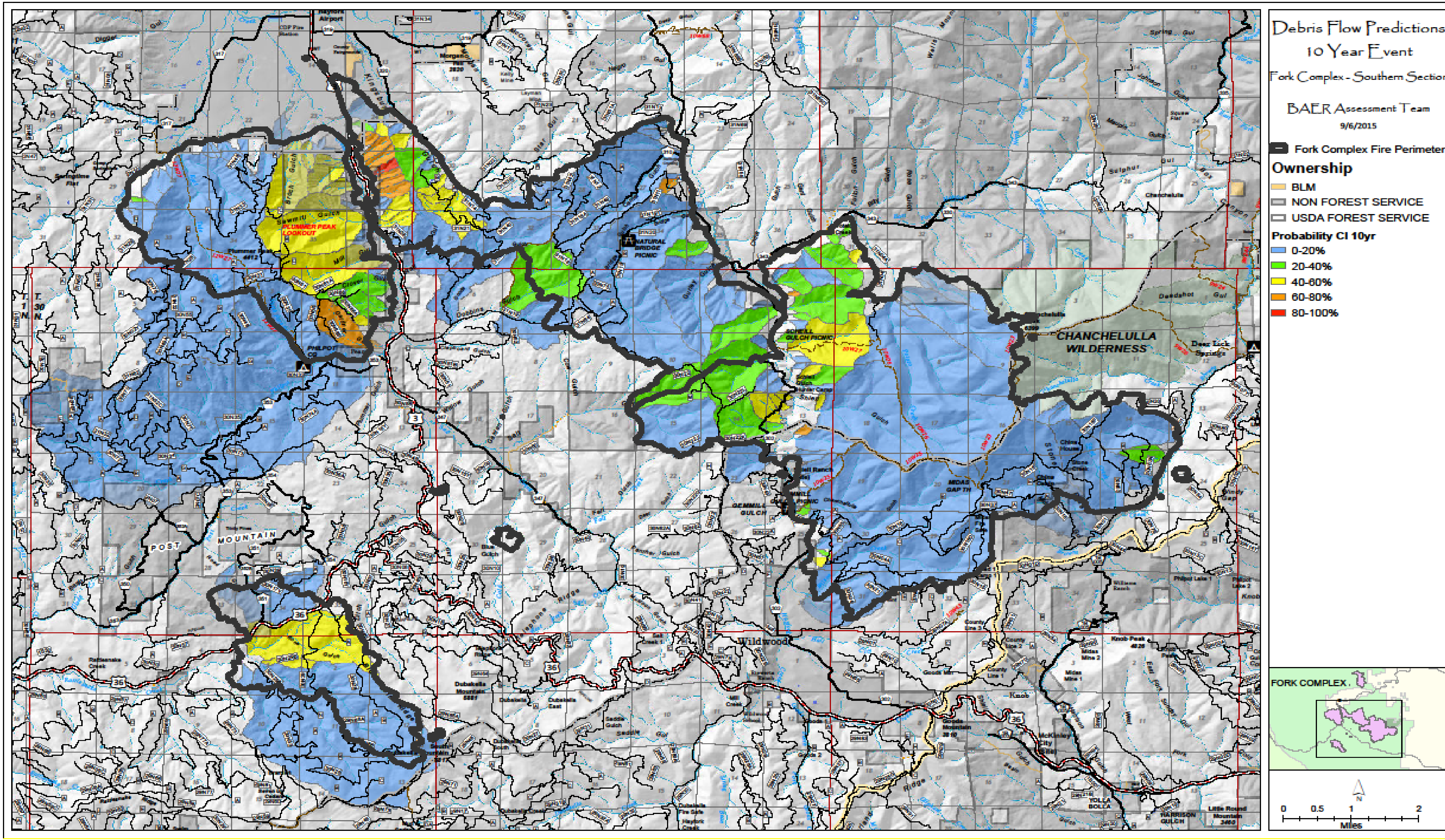
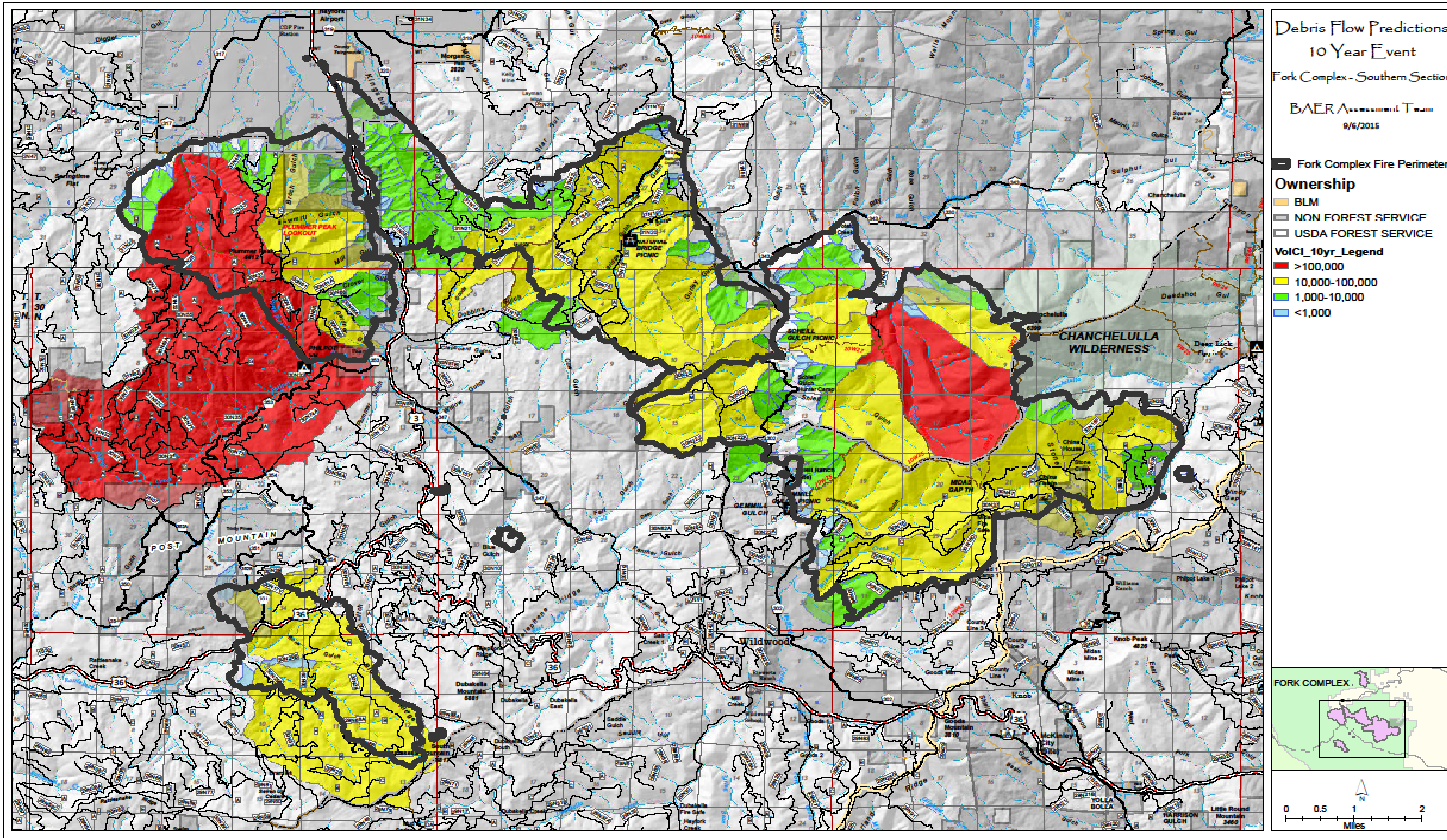


Figure 9: Predicted debris flow PROBABILITY map for the Fork Complex – Southern Section – 10 year storm



<u>Figure 10</u>: Predicted debris flow VOLUME map for the Fork Complex – Southern Section – 10 year storm

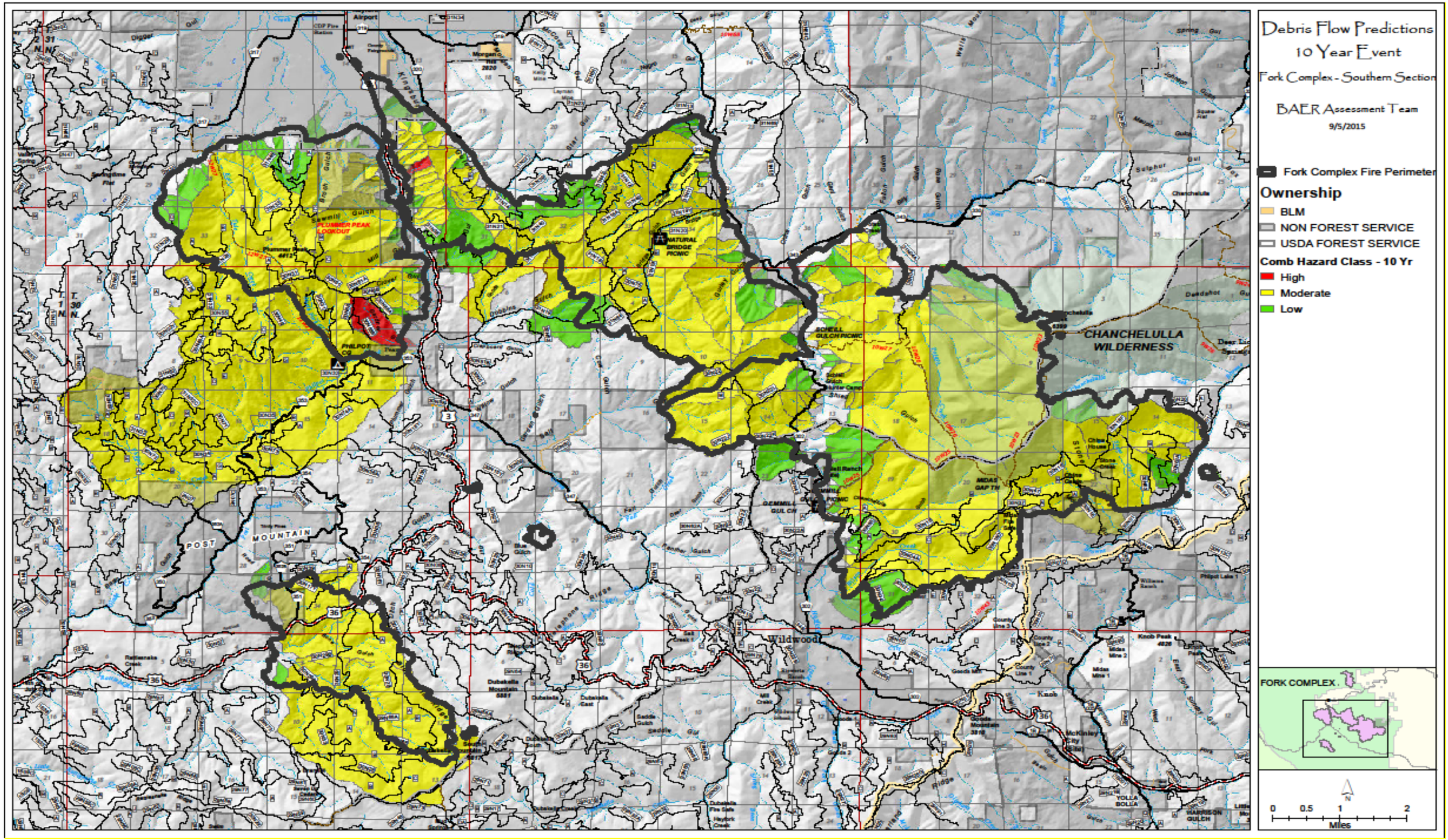


Figure 11: Predicted debris flow COMBINED HAZARD CLASS map for the Fork Complex – Southern Section – 10 year storm

Resource Conditions Resulting from the Fire

Assessment of the Fork Complex 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:

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

- Off-Forest roads and drainage-ways - As a result of the fire, excessive runoff and flows, sedimentation and debris will adversely affect some of the off-Forest roads and drainage-ways.
- Private property, including homes, roads and facilities, both within and outside the Forest boundary, downstream and downslope from the burned area, is at risk.

Natural Resources:

- Water quality for Coho Salmon, riparian sustainability and downstream uses – As a result of the fire excessive sedimentation will adversely affect water quality in some of the creeks.

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, conveyance capacity of stream channels and other facilities within and downstream from the wildfire area. 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.

Specific VAR's in the Fork Complex include:

Rail Fire:

- 18" culverts along FS road 31N21 (level 1 road) might chock and fail – close road
- Rock fall and ravel will be an on-going issue along cut-slopes along FS roads 31N42, 31N19 (level 2 roads) and others – periodical storm patrol to clear rock/debris/ ravel from road prism
- Some private properties along highway 3 (west boundary of the fire) might receive excessive amounts of sediment/debris deposits to their properties coming down the west facing slopes of Kingsbury ridge. No structures were observed or evaluated.

Blue Fire:

- Some (24" – 36") culverts at creek crossings along FS road 30N29 (level 3 road) might chock and fail as a result of excessive debris/rocks/sediment coming down from 20% burnt slopes and channels above these crossings – frequent cleaning of ditches and debris basins; Install rises on culverts to prevent chocking; Installation of rolling dips to channel plugged culverts off roadway
- 3 culverts along county road 351, in the Trinity Pines community might plug and fail which in turn will cause mud and sediment on the road, creating a human safety issue – need to up-grade culverts and/or periodical storm patrol to keep the road clear

Peak Fire:

- Some private properties along highway 3 (east boundary of the fire) might receive excessive amounts of sediments/debris deposits to their properties coming down the east facing slopes of Plummer Peak. Of specific concern are the properties at the mouth of Gardner Gulch which is predicted to produce debris flows. No structures were observed or evaluated.

Shield Fire:

- Rock fall and ravel is expected along some segments of County road 302 (Wildwood road) which is a well-traveled road. These potential rock-falls create a human safety issue which will need to be addressed via Rock-fall warning signs along the road and periodical storm patrol to clear any rocks and debris on the road after major rain storms.

- Rock fall and ravel will be an on-going issue along cut-slopes along FS roads 30N04, 30N16 and other level 2 roads in that south area region of the Shield Fire. Periodical storm patrol to clear rock/debris and ravel from the road prism will be necessary to keep the road open.
- An un-named creek between Chanchelulla Gulch and Wilson Creek has a high fill (40'-50') at its crossing with 30N04. The culvert at this crossing is a 36" culvert which will most likely plug and fail due to a loaded V-shape channel with lots of sediment, rocks and woody debris right above the culvert. As a minimum, it is critical to pull all woody debris out of the channel, keep the channel as clear as possible from sediment, rocks and debris and install a riser on the culvert to prevent chocking / plugging. In addition, installation of some rolling dips on the road will channel any water off the roadway in case the culvert plugs.

<u>Barker Fire</u>:

- Rock fall and ravel will be an on-going issue along cut-slopes along FS roads 32N25, 32N37 and other level 1 roads in the Barker Fire perimeter. Periodical storm patrol to clear rock/ravel from road prism will be necessary to keep the road open.
- Little Barker creek crossing on county road 331 / FS road 32N03 is at the bottom of the Little Barker watershed basin which is predicted to produce debris flows of 10K – 100K cubic meters with a probability of 60-80%. The County should keep the channel above the road crossing as clear as possible and have storm patrols after every significant rain storm.

During the next 3-5 years all creeks in and downstream of these fires will experience excessive amounts of sediments, which in turn will affect their water qualities.

V. Discussion / Summary / Recommendations

Debris flows and rock falls are eminent in the Fork Complex Fire Area. Rock fall and 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 debris flows, rockfall, debris slides, rotational landslides, or sediment laden flooding, the cumulative risk of various types of slope instability, sediment bulking, and channel flushing and deposition is **high** following the Fork Complex Fire.

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; construction of rolling dips in critical locations along the road.

Conclusions from the USGS Debris Flow Assessment:

USGS debris flow modeling estimates that in the area of the Barker Fire, the Little Baker watershed basin is the only basin which has a combination hazard class of high. This high hazard class is a result of a combination of potential debris flows with volumes of 10K to 100K cubic meters with probability of 60-80% (see Figures 6, 7 & 8). The entire rest of the Fork Complex (Southern Section) has only two relatively small watershed basins that are estimated to have a high combination hazard class. One of these two basins is within the Gardner Gulch, located in the southeast corner of the Peak fire and is estimated to produce a debris flow of 10K-100K cubic meters with a probability of 60-80%. The second basin is a small basin on the west end of the Rail fire, just below the Kingsbury Range and above Hwy 3. This basin is estimated to produce a debris flow of 1K to 10K cubic meters with a probability of 80-100% (see Figures 9, 10 & 11). Based on field observations it seems that these two last basins do not have as much unconsolidated materials/rocks available to be transported as the Little Barker watershed basin, but both are located above private properties adjacent to the National Forest boundary.

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 Fork Complex is underlain predominantly by Paleozoic and Mesozoic metavolcanic and metasedimentary rock, along with a minor amount of Cretaceous and Tertiary sediments. The east central part of the Complex was intruded by granitic plutons, the largest of which is the Wildwood Pluton. Small outcrops of sedimentary rock occur in the center of the complex.

Part III – Watershed Conditions

Within the Fork Complex burned area, some watersheds show a great deal of past mass wasting as debris slide/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.

As a result of the removal of vegetation by the fire, excessive sediment and available transported material in channels and potential high runoff as a result of moderate to high rainstorms, debris-flow probabilities are high in some watershed basins. Soils are exposed and have become weakened, and rocks on slopes have lost their supporting vegetation. Roads are at risk from rolling rock, plugged culverts, debris slides and debris flows. 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, then covering roads or eroding road prisms. Risks to human life, roads, trails and natural resources are high.

Field and aerial observations in the Little Barker drainage showed numerous channels loaded with large deposits of rock and soil, and many slopes burned at moderate and high soil burn severity at risk for contributing large quantities of soil, rock and organic debris to the main channel. USGS debris flow modeling estimates that within the Little Barker watershed basin potential debris flows with volumes of 10K to 100K cubic meters with probability of 60-80% might occur. The entire rest of the Fork Complex (Southern Section) has only two relatively small watershed basins that are estimated to have a high combination hazard class of debris flows. One of these two basins is within the Gardner Gulch watershed basin, located in the southeast corner of the Peak fire and is estimated to produce a debris flow of 10K-100K cubic meters with a probability of 60-80%. The second basin is a small basin on the west end of the Rail fire, just below the Kingsbury Range and above Hwy 3. This basin is estimated to produce a debris flow of 1K to 10K cubic meters with a probability of 80-100%. Based on field observations it seems that these two last basins do not have as much unconsolidated materials/rocks available to be transported as the Little Barker watershed basin, but both are concidered as high concern since they are located above private properties adjacent to the National Forest boundary.

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; construction of rolling dips in critical locations along the road.