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

Station Fire, Angeles N.F.

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Abstract

Three USFS BAER Team geologists assessed increased risks from geologic hazards within the 161,000 acre Station Fire. Watershed response to moderate and high severity burned areas will depend on storm intensity and duration, but is likely to be threatening to life, property and natural resources, and costly. Even small storms have a high to severe relative hazard rating for dangerous debris flows across most of the burned area. Most treatments to reduce debris flow risk were deemed not feasible, not effective, and cost prohibitive. Rockfall, debris slides and dry ravel will add additional hazard and sediment bulk to flood flows. Debris basins will fill quickly, and could overtop and damage downstream communities and infrastructure. Debris storage sites are lacking. Abandoned mines are exposed and add additional hazards. Treatment options are few, and warning systems and public education are critical.

Introduction

The Station Fire started on August 26, 2009, on the Los Angeles River RD of the Angeles N.F., Los Angeles County, California, and was scheduled to be contained on September 23, 2009, at a total of over 161,000 acres. An initial geologic hazards assessment and report were completed on September 24, 2009. This report describes and assesses the increase in risk from geologic hazards within the Station Fire.

I. Resource Condition Assessment

A. Objectives of Resource Assessment

- Assess pre- and post-fire geologic and watershed conditions that contribute to understanding risks;
- Identify values at risk within and downstream of the Station Fire area;
- Determine areas where the potential of increased risk from geologic hazards may cause an emergency for the values at risk, including to human life, property and resources, and recommend treatments.

B. Methodology

The findings of the geologic hazards assessment for the Station Fire are based on helicopter survey, selected ground survey and local knowledge. Due to the large area and limited access to some areas within the fire perimeter, there was a reduced ability to conduct a complete ground assessment of the burned area. Evaluation of the effects of different geomorphic processes and the response of different rock types on the values at risk (VAR), slope stability, and erosion potential within each watershed were based on observation of pre-fire slope instability and geomorphic features within different rock types and terrains, analysis of burn severity maps, topographical and geological maps and aerial photography, discussion with other scientists and local land owners, and field observations.

C. Resource Setting - Geology and Geomorphology of the San Gabriel Mountains

The San Gabriel Mountains form a major part of the east-west trending, central Transverse Ranges of Southern California. According to Dibblee (1982), these mountains consist of a variety of plutonic and metamorphic rocks ranging in age from Precambrian to Miocene. They include some of the oldest crystalline rocks in California. The Precambrian metamorphic rocks, mostly gneisses and schists, were intruded by the Mesozoic crystalline basement rocks which include quartz and hornblende diorite, anorthosite, gabbro, amphibolite, granodiorite and undifferentiated granitic rocks. Quartz/feldspar sills and dikes cut through all of the above mentioned rock types. Major fault zones bound the elevated basement rocks, and lesser faults traverse the area, giving strong influence to some of the linear deeply incised canyon trends and discrete eroding ridges of varying rock types. These east-west trends disrupt much of the normal southward drainage from the main divide of this range. Canyon bottoms and mountain fronts frequently display Quaternary older and Recent alluvial deposits forming elevated, dissected terraces.

The San Gabriel Mountains are some of the most tectonically active and rapidly uplifting mountains in the United Status. The forces lifting the mountains to great heights are being countered by opposing forces tearing them down. Forces such as gravity, moving water, wind, earthquakes and human activities interact and combine to bring down small particles to whole hillsides at a time. The fluvial geomorphic processes which have shaped, and are currently shaping these ever-changing mountains include landsliding of various types, rockfall, dry ravel, sheet and rill erosion by water and wind, flooding, debris flows, and excavations and material disposal by humans.

We concluded that various characteristics of the geology of the area have definite influences on the "watershed response" to the fire, as observed by different degrees of roundedness, dissection, and rock cover of slopes. Time did not permit, however, for a close correlation between the numerous rock types and structural geologic features with the specific effects of the various geomorphic processes acting on them.

D. Findings / Observations

The Station Fire burned approximately 161,000 acres in the northeastern extent of Los Angeles Basin and adjoining basins (Figure 1). Assessment found the overall soil burn severity to be 11% unburned and very low, 16% low, 62% moderate, and 11% high.

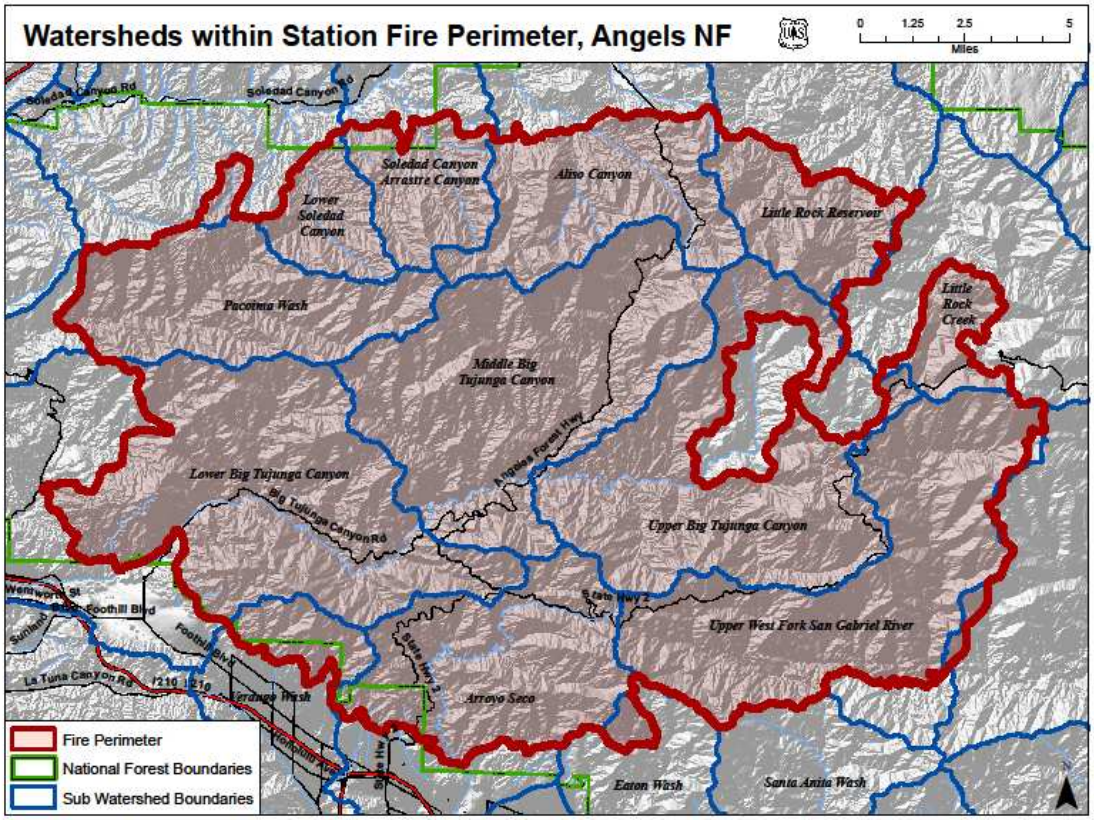


Figure 1: Shaded relief map of the Station Fire, Angels N.F.

Dry Ravel - When the Station Fire removed vegetative cover and burned surface soil structure, slopes became even more unstable than normal. Dry ravel has already increased dramatically across the entire burned area, and is adding large volumes of loose sediment to roads and trails, ephemeral channels and creek bottoms. Some of the granitic rock-types weather deeply and produce smooth, rounded slopes with little surface rock. Those slopes are especially subject to dry ravel.

Rockfall/Rolling Rock - Other granitic/plutonic rocks produce more rock on weathered slopes and are subject to rolling rock hazards. Some hillsides, especially those composed of schist (metamorphic) weather to angular, rock covered slopes. Their angularity makes them somewhat less subject to rolling rock than other rock-types which weather to more blocky shapes. Within the Angeles National Forest, State Highways, County roads, private parcels, and Forest Service facilities and infrastructure are threatened by an increase in rockfall hazard. The increased hazard is a result of the loss of stabilizing roots and soil structure and increased water affecting nearby slopes. Specific locations identified during BAER assessment work are more fully described in the treatment

section of this report and the engineering report. Rocks which have lost their supporting vegetation on steep slopes have already started to roll down to roadways or canyon bottoms, or to places where they are stopped by obstructions or gentler slopes (Figure 2). Groundwater which previously fed vegetation is now surfacing as seeps and springs on some slopes and in canyon bottoms, and may initiate slope movements in some areas, even before the arrival of winter rains.

Figure 2: Rockfall, Road 2N81.1

Debris Slides - There are many existing debris slides generally found along major roads, on steep upper slopes, and deep inner gorges, where additional movement can be expected due to saturation of slopes increasing instability within loosely consolidated material. Similarly, bedrock throughout the area is highly fractured. Increased water entering these fractures, combined with loss of vegetative cover, increases the likelihood of slope instability. This often destabilizes other rocks in the process increasing the size of the resulting rockfall or debris slide, or additional sliding to happen some time later, even days or weeks later. Most of this activity will take place on steeper slopes and bedrock exposures. However, it can potentially have an impact for a significant distance downslope from the point of initiation. Debris dams could form from landslides damming channels, or from mineral and organic debris clogging drainages, especially in narrow constrictions of channels. Specific sites were not identified.

Figure 3: Debris slide, Angeles Crest Highway.

Deep seated rotational landslides and earthflows are relatively few in these mountains, but could occur in deep saturated slopes, especially if shaken by an earthquake. Many earthquake faults crisscross and boarder these mountains, and quakes could significantly increase all types of slope movements when slopes are saturated. Thin surficial slides and deeper translational debris slides will increase due to the destruction of soil structure and loss of root support.

Debris Flows - The most dramatic geologic hazard response to the fire will be the increase in destructive debris flows which bring sideslope 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, destroying everything in their path until they finally lose their momentum or are caught in a debris catchment basin. Evidence abounds of past debris flows throughout much of the burned area. Much of the material deposited in alluvial fans that form aprons or remnants of old alluvial deposits was likely generated from debris flows, especially where deposits are composed of large quantities of angular rock which has only been transported short distances. Levees or berms from past debris flow deposits left along the sides of debris flow channels were seen in Big and Little Tujunga Canyons, and several front country canyons, and undoubtedly would be found in many other areas.

Figure 4: Debris Flow deposit (center of photo), west of La Paloma Flat.

USGS Debris Flow Assessment - The U.S. Geological Survey analysis (Appendix 1) used a suite of three statistical-empirical models specifically developed to evaluate post-fire debris flow processes for the Station Fire. It is documented in an administrative report with accompanying maps (hereafter referenced as USGS, Written Comm., September 21, 2009). It included calculating a combined hazard rating for both a 3-hour long storm with a 1-year recurrence, representing a thunderstorm cell, and a 12-hour duration storm with a 2-year recurrence, representing a large frontal storm.

The Combined Relative Hazard Ranking, based on both the probability of debris flow occurrence and expected volume, was calculated for all 678 sub-watersheds within the fire area. The Combined Relative Hazard Rankings, calculated in response to the 3-hour-duration storm, were either "high" or "severe" for all but 18 sub-watersheds in the burned area, with a "severe" ranking for 72 of the sub-watersheds. These include Haines, Cooks, Dunsmore, Pickens, and Hall Beckley Canyons and the four sub-watersheds immediately east of Arroyo Seco. The 12-hour-duration storm resulted in either "moderately high", "high", or "severe" rankings for all but 25 of the sub-watersheds. The "severe" ranking was calculated for 47 sub-watersheds, including Haines, Dunsmore, and Pickens Canyons and the three sub-watersheds immediately east of Arroyo Seco (USGS, Written Comm., September 21, 2009). While high-intensity, short duration thunderstorms increase the chance of larger debris flows occurring, any given storm will affect only a few sub-

watersheds. Large frontal storms with lower-intensity and longer duration will affect a greater number of sub-watersheds at the same time, but any given storm will trigger fewer large debris flows.

The large number of sub-watersheds with "high" or "severe" Combined Relative Hazard Rankings that drain into Big Tujunga Canyon, Pacoima Canyon, Arroyo Seco, West Fork of the San Gabriel River, and Devils Canyon indicates the potential for significant debris-flow impact, both in these drainages and well downstream from the burned area. Along the southern front country, calculations for Haines, Cooks, Dunsmore, Pickens and Hall Beckley Canyons and four small watersheds immediately east of Arroyo Seco consistently yielded both high probabilities of occurrence and expected volumes greater than 100,000 m3 under short, high intensity storms making these locations of particular concern (USGS, Written Comm., September 21, 2009).

The model describes debris-flow probability as a combined function of areal burned extent, soil properties, basin gradients, and storm rainfall. Fast-moving debris flows generated from recently burned areas are particularly dangerous because they can occur in places where flooding or debris flows have not been observed in the past and can be generated in response to very little rainfall. With normal rainfall conditions, most debris-flow activity occurs within about 2 years following the fire. In addition to the potential dangers within the basins evaluated, areas downstream from the defined basin outlets are at risk. The main channels can have a large impact further downstream, not only from the effects of multiple debris flows, but also from the cumulative impact with flooding. The final product of the USGS study predicted the minimum and maximum run-out zones that could be expected from best case and worst case scenarios for the same 1 and 2 year storms. Some drainages could produce debris flow runout as far as 4 kilometers below the base of the catchment basins they would overtop.

The USGS report concludes that "when compared with similar evaluations for past fires, this is the greatest number of basins we have seen with such high [debris flow} probabilities."

Selected Findings:

Front-Country: Verdugo Wash - The fire burned with low to moderate intensity close to many miles of residential areas where the mountains meet the communities. Fortunately, since these communities have been dealing with the watershed response from these steep slopes and numerous drainages for decades, most areas have hardened drainage channels and protective catchment basins, however some of those basins are likely to be overtopped by debris flows and flooding, causing inundation within downstream communities. See **Appendix 1** for details. Large grade-stabilizing check dams were installed in the mid-1900's in many of drainages. Those observed appear to have been successful in reducing downcutting of channels, however they are all full of sediment and will not be able to stop additional sediment from flowing into downstream catchment basins. Most front-country sub-watersheds have a high or severe Combined Relative Debris-flow Hazard Rating. A number of sites were found to have concerns as to their

ability to handle increased flood flows, unstable slopes, sediment discharges and potential debris flows. Some of those areas include, but are not limited to:

- End of Big Briar Road, La Cañada – no existing drainage system to handle expected flooding and sediment. K-Rails appear insufficient.
- Hall Beckley Canyon, La Cañada – residence and outbuildings in canyon bottom at risk from debris flows and flooding.
- Ocean View Blvd/ Mullally Canyon, La Cañada – rockfall potential behind several homes/potential debris flow damage to community.
- Starfall Drive, La Crescenta – slope failure potential and rockfall directly behind 2 houses.
- Ananda Ashrama retreat center, Glendale – debris flow potential in Ward Canyon, and sediment/flooding internally through conference center.
- Boston Avenue, Glendale – rolling rock hazards behind homes.
- Blanchard Canyon, Tujunga - narrow canyon with many residences, bridges and road at high risk from debris flows and flooding
- Rowley Canyon, Tujunga/Los Angeles – 3 road drainage crossings at risk from flooding and debris flows.

Big Tujunga, Little Tujunga and other interior Forest canyons and ridges, San Gabriel Wilderness – Slopes are extremely steep in much of the interior fire area. Most of the interior sub-watersheds have a high or severe Combined Relative Debris-flow Hazard Rating. Many drainages contain large amounts of stored sediment, both in channels and in denuded raveling slopes. The highest severity burn areas were mostly on north-facing, steep upper slopes. Big Tujunga Dam is undergoing seismic retrofit, and water flow cannot currently be controlled. The parking area for construction equipment is at risk. There is currently lots of water and sediment storage, which can help reduce impacts further downstream. Debris flows, rock fall and debris slides will impact roads in many areas. Debris storage/disposal sites have not been identified for the expected massive volumes of sediment and rock which will be cleared from catchment basins and roadways. If side-casting of waste material continues, material will only add to the sedimentation and debris bulking issues, and can do additional damage to other resources.

Arroyo Seco Canyon - has a long history of major floods and debris flows, associated with large storms and fires. Most of the Arroyo Seco sub-watersheds have a high or severe Combined Relative Debris-flow Hazard Rating. Large grade stabilizing check dams were installed in 60's in the channel above Switzer Campground. Gabrielino National Recreational Trail has been heavily damaged due to rolling rock and dry ravel, plus damage to structures supporting the trail tread. Angeles Crest Station structures could be at risk from debris flows/flooding, and the road to Mt. Lukins is likely to be damaged during storms. Highway 2 is at risk from ongoing rockfall and debris sliding, exacerbated by the fire.

Figure 5: Dry ravel, rockfall and damaged structures on Gabrielino Trail.

North-Side/Desert-Facing Watersheds - Most of the north-facing sub-watersheds have a high or moderately-high Combined Relative Debris-flow Hazard Rating. Past watershed response from recent fires was very moderate, but the topography shows evidence of past storms and slope instability. Alluvial fans suggest that debris flows and flooding are a significant part of the geomorphic development of that area. Flooding of '69 and '82 is remembered by locals, but they recalled no significant damage in 2004-05. Structures built after past flooding may have helped stabilize channels and reduce flood impacts. Reconnaissance of the area showed little evidence of slope instability in the foothills, but the aerial reconnaissance showed some debris sliding and a great deal of dry ravel in the steeper uplands, much of which burned with high burn severity.

Forest Service Stations and Residences - Several Fire stations were visited, and emphasis was put on impacts to slopes above and channels passing through or near to the facilities. Chileo Fire Station is on a flat, in an unburned island, with low potential for problems in that area. Monte Cristo Fire Station is built on and alluvial fan, and has a large watershed behind it with a high probability of debris flow activity. A deflection wall is being proposed to protect structures. Current drainage structures may be sufficient for water flows, but may not contain a debris flow, and the unburned residence is at risk. Big Tujunga fire Station at Vogel flats is located fairly high on the alluvial river bottom, and appears to be a low risk from flood flows or debris flows.

Recreation Residences, FS and Private - Vogel Flat: One of the burned Forest Service residences, #12, and an unburned residence, #11, were flagged as having a debris slide/rockfall/sedimentation issue. Our brief assessment determined that due to the slope configuration and highway drainage system immediately above them, some rockfall, additional debris sliding and some sedimentation will come off the slope above, but the source area is very small, and additional protective structures are not recommended. Cleanout of existing sediment behind rock walls and concrete drainage channels behind both Residence 11 and 12 is recommended. A nearby well is at risk from high water flows and sediment load from Vogel Creek. It is recommended to widen and deepen the Vogel Creek channel near the well and pile excess material as a deflection device around the wellhead. Installation of K-rails to protect other rec residences was recommended by others, but not evaluated by the geologists.

La Paloma F.S. Rec. Residences - The sub-watershed above has a severe Combined Relative Debris-flow Hazard Rating. Two residences, # 36 and 37, were unburned. Both are at risk from slope instability above, and rolling rock retaining/deflection walls are recommended. Residence #36 is also at risk from debris flows. Widening and deepening of the channel just east of #36 to slow and channelize where a debris flow could travel is recommended. If a future debris flow is relatively small, this treatment could help. If it is as large as one in the drainage about ½ mile to the west, no treatment will help.

Abandoned Mines - Thirty four known abandoned mines are located within the fire boundary (see Appendix 2). Now that vegetation has burned and left many of those mines exposed and visible, they pose new safety concerns for Forest visitors who may try to explore those areas. Chemical and physical hazards could exist at some or all of those mines. It is recommended that all mines within ½ mile of a road, which allows easier access, be closed and fenced until detailed surveys are completed to determine if risks to the public are present. Two abandoned mine adits, previously undocumented on the Forest Inventory, were discovered above La Paloma Flat in Big Tujunga Canyon. See Appendix 2 for further details.

Figure 6: Previously undocumented abandoned mine adit, Big Tujunga Canyon.

Roads and Trails: FS, State and County - All roads and trails within the burned area, except for segments in gently sloped terrain, are already experiencing some dry ravel and rockfall, and occasionally, debris slides. Some of the specific problem areas for roads have been documented by the BAER Engineering Team. Loss of control of water has already affected some locations on both roads and trails. Maintenance crews have kept main roads cleared, but much of the excess soil and rock debris has been side-cast, or used to augment or create berms (see Appendix 5), and will contribute to already high levels of down-slope erosion and sedimentation.

Disposal Sites: Watershed response to the Station Fire has already produced large amounts of dry ravel and rock-fall off of steep, burned slopes. Loaders and graders have been hard at work cleaning roadways. Some of the material has been hauled to debris disposal sites, but much of it has been pushed over the sides of roads. Often that material adds extra sediment to already eroding slopes. Material dumped on steep burned slopes can create debris slides that carry far down-slope, in some cases into creek channels. There are insufficient approved disposal sites to handle the upcoming need. See Appendix 4 for further details.

E. Values At Risk

The following "values at risk" (VARs) are threatened by debris slides, debris 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 – Lost of life or Injury could take place as a result of debris slides and flows, rockfall, or flooding. In addition lost of life or injury could take place as a result of physical or chemical hazards in abandoned mines.

Property:

- Forest Service Stations and Recreation Residences.
- Private property, including homes, farms, ranch land, and facilities, both within and outside the Forest boundary, downstream and downslope from the burned area.
- Cal Trans. and Los Angeles County roads.
- Forest roads and trails.

As a result of the fire, excessive runoff and channel flows, unstable slopes causing debris flows, debris slides, rockfall and dry ravel will most likely compromise and adversely affect the properties above.

Natural Resources:

- Water quality for wildlife, riparian sustainability and downstream uses – As a result of the fire, excessive sedimentation will adversely affect water quality in many of the creeks which are considered critical habitat for Mountain Yellow Legged Frog, sensitive fish species, and other amphibians.

Specific identified Values At Risk and their conditions are presented in the tables below listed in five different categories.

Table 1: Forest Service Stations and Recreation Residences at Risk from Debris Flows and Rockfall

Value at Risk	Map Code	Threat Description
Vogel Flat (NFS Land) (Lower Big Tujunga)	GEO6-LBT	Debris flow down Big Tujunga Canyon could kill and/or injure people, damage/destroy residences; require reconstruction, and cause cost of clearing Big Tujunga Fire Station access road of debris.
La Paloma Flat (Lower Big Tujunga)	GEO7-LBT	Unburned recreation residence near the apex of fan with debris flow channel displaying activity within last 20 years; burned condition and dry ravel suggest that this tributary to Big Tujunga Canyon could yield debris flow potentially impacting structure. Rockfall & slope instability hazard above 2 residences.
Unburned Residence at Monte Cristo Fire Station (Middle Big Tujunga)	GEO4-MBT	Significant watershed directs flow onto alluvial area where fire station is located. Existing drainage has protected upper residence, but expected debris flow from severely burned watershed would easily overwhelm drainage and impact residence.

Table 2: Survey results for site-specific debris flow and rockfall threats to private land near and within the Angeles National Forest.

Value at Risk	**Map Code**	**Threat Description**
Street access and private property, Big Briar Way La Canada – (Arroyo Seco)	GEO1-AS (H11)	Debris flow; Storm will bring water and sediment onto street and possibly into yards/homes. No culvert or other drainage system exists where basin drains on to Big Briar Way.
Life and Safety, private home & outbuildings, loss of access on dirt road - Hall Beckley Canyon – La Canada (Arroyo Seco)	GEO2-AS (H7)	Flood or debris flow could impact private residence property and roadway access.
Life and Safety, access road to Ebey Canyon – Sunland – Tujunga (Lower Big Tujunga)	GEO2-LBT	Expected debris flow will impact the road. Blockage/impairment of low-water crossing of Big Tujunga. This is the only road access for residents.
Private property in Ybarra Ranch (Church Camp)	GEO5-LBT	Potential debris flow passing down Big Tujunga exceeding channel capacity near flat could impact buildings.

Value at Risk	Map Code	Threat Description
Private property in Vogel Flat (Private Land) (Lower Big Tujunga)	GEO6-LBT	Debris flow down Big Tujunga could kill and/or injure people, damage/destroy residences.
Equipment and facility just bellow Big Tujunga Dam (Lower Big Tujunga)	GEO9-LBT	Debris flow from upper watershed could cause maximum bypass flow with significant sediment preventing work and possibly damaging equipment to equipment parked near bypass.
Big Tujunga Reservoir	GEO5-MBT	Debris flow reducing reservoir storage capacity
Private house at xxxx Ocean View Blvd. La Crescenta (Verdugo Wash)	GEO3-VW	Steep, rocky slope behind house. Surface erosion and dislodging of rocks and possible debris slide caused by small (or larger) rainfall events.
Three private homes 2701, 2702, 2703 Starfell Dr. La Crescenta (Verdugo Wash)	GEO4-VW	Potential rock fall and / or debris slide from steep, unstable slopes behind houses. Less likely damage to 2702 Starfell Drive as it farther from slope.
Residence and infrastructure at the Ananda Ashram Retreat Center, La Crescenta (Verdugo Wash)	GEO5-VW	Small or larger rainfall event could cause debris flow, slide/sedimentation/loss of water control.
Three private homes at 5171, 5161, 5155 Boston Ave., La Crescenta (Verdugo Wash)	GEO6-VW	Small or larger rainfall event could cause rockfall and sedimentation into backyards and homes on uphill side of Boston Ave.
Fourteen homes in Blanchard Canyon, Tujunga, CA (Verdugo Wash)	GEO7-VW, H20	Blanchard Canyon area, small or larger rainfall event could trigger debris flows and/or rockfall impacting private residences.

Table 3: Debris Flow, Rockfall and Related Hazards Identified for State and County Roads

Value at Risk	Map Code	Threat Description
State Route 2 between CHP post (La Canada) to Red Box Station	GEO4-AS	Rockfall resulting in individual and clusters of rocks from 3" to several feet in diameter falling on road surface & steep slopes adjacent to hwy

Woodwardia Cyn Road	GEO5-AS	Rockfall / landslide activity of moderate severity, steep slopes with existing large debris slide - will increase in size/height
Big Tujunga Canyon Rd between the bridge (Delta Flat) and mouth of Ybarra Canyon (Lower Big Tujunga)	GEO3-LBT	Continuing accumulation of dry ravel and sporadic rockfall creating hazard to driving or road use.
Big Tujunga Canyon Rd at Ybarra Canyon (Lower Big Tujunga)	GEO4-LBT	Flood and debris flow caused by minor and larger storms could damage the 8' culvert and portion of roadway
Big Tujunga Road (near mouth, at the boundary of L.A. City) (Lower Big Tujunga)	GEO11-LBT	Large rockfall area near the mouth of Big Tujunga Canyon, at the boundary of L.A. City (two adjacent areas, one with burned wood retaining barrier).
Maple Canyon debris disposal area (Lower Big Tujunga)	GEO12-LBT	Ravel and slope washed material blocking intake of drainage structure on Tujunga disposal bellow Angeles Forest Highway might plug resulting erosion / failure in disposal material
State Highway 59 at Clear Creek Fire Station (Lower Big Tujunga)	GEO14-LBT	Sedimentation and debris could plug 8 ' culvert under State Highway 59 (at Clear Creek Fire Station) resulting in damage to road fill and roadway.
Big Tujunga Road (between ANF Hwy and Falls Creek Campground Road junction) (Middle Big Tujunga)	GEO1-MBT	Increased rockfall hazard on Big Tujunga Road from junction with ANF highway to Fall Creek campground road junction.
Angeles Forest Hwy (near junction with Big Tujunga Canyon Rd) (Middle Big Tujunga)	GEO2-MBT	Recent (within the last year) debris slide next to road has 20+ ft head scarp and some partially moved material above the road, below burned slope which could be mobilized en mass during storm. Could impact the Big Tujunga Canyon road where it passes under downslope.
Angeles Forest Highway by Lucas Creek (N 34.30155, W 118.15825) (Middle Big Tujunga)	GEO3-MBT	Burn severity will affect water in slope where existing fractures and their orientations making rockslides on road more likely to have rockfall activity.

Table 4: Forest Service Roads and Trails at Risk from Debris Flows and Rockfall

Value at Risk	Map Code	Threat Description
Stone Canyon Trail (Lower Big Tujunga)	GEO8-LBT	Trail impacted by extensive dry ravel and possible rockfall hazard to hikers.
Condor Peak Trail between Fusier Canyon and Stonyvale campground (Lower Big Tujunga)	GEO10-LBT	As a result of the fire and vegetation removal Condor Peak Trail between Fusier Canyon and Stonyvale campground will experience increased rockfall / mass movement onto trail tread posing hiking hazard.
Forest Service Road 2N86, Rowley Creek Road (Lower Big Tujunga)	GEO13-LBT	Road crossing (48" culvert) at Rowley Ck (Forest Service Road 2N86), and next 2 crossings to NW could be washed out if culverts or "big macs" are plugged or overwhelmed adversely affecting roadway. May need to replace big macs and enlarge culvert.
Gabrieleno National Trail (Arroyo Seco)	GEO3-AS (H9)	Mod-high severity steep slopes. Loss of water control will cause more damage to trail tread, and storms will cause more sedimentation, rockfall, debris sliding on trail.

Table 5: Abandoned Mine Lands identified for closure to mitigate threat to life and safety

Value at Risk	Map Code	Threat Description
Life and Safety associated with the following abandoned mines: Alexander, Boatwright Prospect, Dawn, Dewey Group, Eagle, Falcon Mine, Gold Bar Mine, Josephine/west, Kelly Bros., Limco Mine, Lodestone Mine, Markwell, Mt. Gleason Mine, Ore Hill Group, R. Vella, Thousand Word, Trail Canyon Deposit	All watersheds within the fire perimeter	The following abandoned mine lands have been chosen for closure based on distance from roads, visibility and the physical and chemical hazards associated with these sites. As a result of the removal of vegetation by the fire many of these mines are now more visible and exposed to the public. This exposure increases the accessibility of the public to these locations and therefore magnifies the issue of threat to life and safety.

II. Emergency Determination

The Station Fire has created an emergency situation by accelerating natural geologic processes through its effect on vegetative cover and soil condition. This results in a greater likelihood and larger size of potential debris flows during future rainfall events for at least two years, and increased slope instability, primarily rockfall. The debris flow hazard is widespread through much of the burned area due to the significant extent of moderate and high burn severity. Increased rockfall hazard occurs at more specific locations scattered throughout the affected area. Both geologic hazards impact values at risk (VAR) resulting in site-specific emergency situations. The risk to human lives and infrastructure posed by this emergency is very high due to the probability of damage or loss being likely and the magnitude of the consequences ranging from major to moderate. In addition to the risk to humans and property, there is also a very high risk due to the loss of water control and water quality. Assessments carried out by the geology group of the BAER team identified twenty eight (28) abandon mine sites within the fire parameter located within ½ mile of a road. The increased visibility and accessibility by the public to these sites as a result of the fire magnifies the probability of injury or fatality.

III. Treatments to Mitigate the Emergency

Most debris flow material comes from channel erosion and not hillslope erosion (Santi, et. al., 2006). Mitigating increased debris flow hazard by land treatments is not generally effective following wildfires, and especially on the Station Fire where a very small percent of the steep, burned land is suitable for land treatments. To be effective, treatment of the debris flow source (hill-slopes) and transport zone (channels) would require halting or slowing down-slope/down-channel movement of soil and rock particles over most of the 161,000 acres affected by the Station Fire. It would also have to prevent increased runoff during storms from saturating and mobilizing the sediment stored along the length of the many streams and ephemeral channels within the burned area.

Effective debris flow mitigation can be done in the transport zone (channel) or deposition zone of a debris flow if the physical conditions permit. Debris basins like those operated by Los Angeles County are excellent examples of a mitigation measure applied to the deposition zone. Most Angeles NF lands are located in the steep mountainous source and transport zones. Deposition zones are mostly located downslope and outside of the Forest boundary. Hence, the ANF has very few, if any, opportunities for effective debris flow mitigation. Most in-stream or on-slope treatments considered were deemed not feasible, ineffective, or cost prohibitive. The only known effective debris flow treatments available to the Forest Service involve early warning systems, warning signs, and various forms of public education.

Rockfall, debris slides, dry ravel and other slope instability hazards can sometimes be at least partially mitigated by constructing barriers, deflection devices or catchment structures. Warning signs, hazard removal operations and public education can also be effective.

Maintenance of drainage structures is critical to keeping roads and trails passable, and for controlling water flow so that roadways and water conveyance structures are not destroyed. To the degree that roads can be patrolled safely, "storm patrol" should be conducted during or soon after storm events to un-plug culverts, overside drains, ditches and snorkels. Extreme caution should be used to avoid falling rock, landslides, unstable fillslopes, and deep impassable deposits of ash and silt. It may not be feasible to repair and open some trails until after at least the first rainy season, possibly the second, so as to give slopes a chance to stabilize. Berms should be used where needed to channel water and provide a sense of security, but should be removed where not needed, and should not be used as a means to dispose of waste material. Side-casting of waste should not be allowed on Forest lands, by county, state or Forest Service maintenance crews. Material should be piled in appropriate temporary or permanent disposal sites, and moved after the emergency as needed (see Appendix 5). Disposal sites are lacking. Engineering and watershed specialists should work together to identify appropriate new disposal areas to receive the large amounts of debris that will be generated following this fire.

Specific treatment areas include the following:

Forest Service Stations/Residences and Personnel Safety Treatment

A. **Type**: Protection and Safety
B. **Objective**: To prevent potential harm to FS employees and visitors working and living at or near facilities or patrolling within the Station Fire during storm events.
C. **Description:** Develop an emergency response plan for personnel stationed, living or working within or adjacent to the Station Fire area (including, but not limited to: Angeles Crest Fire Station, Monte Cristo Fire Station, Big Tujunga Fire Station and Clear Creek Fire Stations). The plan should identify affected facilities including FS residences and roads, and specifically identify geologic hazards as well as flood and other hazards that could impact each facility. A key element will be communication through Dispatch and supplemented by a phone tree to ensure notification of affected sites. The plan would designate actions to be initiated based on NOAA special announcements of approaching weather. Additional actions would take place when NOAA institutes watches and storms. Response actions could range from increased vigilance while driving affected roads to re-scheduling travel within the area to evacuation to safer locations.

USFS Structures Requiring Debris Flow and Rockfall Mitigation Treatment

A. **Type**: Protection and Safety
B. **Objective**: To prevent potential harm to the Forest service employees and the public and protect investments in structures.
C. **Description:** Table 1 identifies three specific locations where debris flow hazards may threaten USFS structures or residences. Following is a description of mitigation measures and the cost for each specific location:

1. Vogal Flats picnic area: Remove and store picnic tables prior to rainy season; place two (2) course-high berm of sandbags around the toilet and remove debris to restore road/parking lot.
2a. La Paloma Flat (2 Unburned recreation residences): Excavation of debris to enlarge channel at mouth through to point even with downslope end of unburned residence. Length/X-sections roughly estimated volume of 1,850 yd3 of which ¾ will be removed; remainder used to increase height of natural levee barrier.
2b. La Paloma Flat (2 Unburned recreation residences): Construct 70 ft long gabion structure behind Res. #36, and 100 ft long gabion structure behind Res. #37, both 4'W x 4'H, above existing rock walls, to catch or slow rolling rock and debris.
3. Unburned Residence at Monte Cristo Fire Station**:** Install a 400 ft deflection barrier to force a debris flow to the west side of the unburned residence using k-rails/sandbags. Cause flow material to pass/deposit in the area of burned residence and beyond.

Off-Forest/Private In-holdings Debris Flow and Rockfall Threat Treatment

A. **Type**: Protection and Safety
B. **Objective**: To prevent potential harm/property loss to private landowners and public entities
C. **Description:** Coordinate with appropriate agencies and public entities (NRCS, Los Angeles County, City of Los Angeles, Cal. Trans etc.) to ensure timely notification about potential threats from Station Wildfire where on-Forest treatments are infeasible (Table 2). This notification should also include the particular debris flow hazard identified in the USGS Administrative Report concerning Haines, Cooks, Dunsmore, Pickens, Hall Beckley and four other small canyons (immediately east of Arroyo Seco). The inundation maps in the USGS Administrative Report will also be useful for a comprehensive understanding of the emergency management situation that might occur during the next year (USGS, Written Comm., September. 21, 2009).
D. **Cost:** Use existing interagency coordination (NIMO, Forest) to provide the information to the appropriate entities. Consider including the U.S. Geological Survey administrative report on debris flow hazard in addition to the BAER Geology Report. Information transfer should be documented through letters or other means to ensure communication is complete, timely and understood.

Non-USFS Roads Requiring Debris Flow and Rockfall Mitigation Treatment

A. **Type**: Roads and Trails
B. **Objective**: To prevent potential harm to travelers on non-USFS roads within the affected area and limit infrastructure damage/repair to public entities.
C. **Description:** Coordinate with appropriate agencies and public entities (Los Angeles County, Cal. Trans etc.) to ensure sufficient time for public agencies with road responsibilities to undertake appropriate actions to protect the public and maintain their existing system (Table 3).

D. **Cost:** Use existing interagency coordination (NIMO, Forest) to provide the information to the appropriate entities. Consider including the U.S. Geological Survey administrative report on debris flow hazard in addition to the BAER Geology Report. Information transfer should be documented through letters or other means to ensure communication is complete and document timeliness.

Selected USFS Trail Debris Flow and Rockfall Mitigation Treatment

A. **Type**: Roads and Trails
B. **Objective**: To reduce risk of injury to the public using Forest Service trails and roads
C. **Description:** This threat will be significantly mitigated by the closure of these trails through the first rainy season. Table 4 includes some roads where specific risks due to rockfall or accelerated erosion were recognized. This list is neither exhaustive nor comprehensive; it is illustrative of the threat from geologic hazards. It is expected that warning signs be placed to forestall use by those who might inadvertently try to use the trail despite their closure. Educational and informational efforts related to the closure of the trails should emphasize the dangers and the benefit to trail maintenance of this action.
D. **Cost:** The cost of the Rowley Creek Road drainage is included in the Engineering report. A total of four (4) warning signs increase the cost for the trails identified in Table 3. However, it is expected that this cost is only in addition to other trail closure costs which likely includes additional signs.

Physical Hazards associated with Abandoned Mines on F.S. Lands in the Burned Area Treatment

A. **Type:** Protection and Safety
B. **Objective:** To prevent potential harm to the public exploring the burned area from injuries or death in vertical shafts, collapsing adits, other unstable mine workings or from chemical hazards.
C. **Description:** This threat will be partially mitigated by the temporary closure of the burned area. But, since it is expected that some members of the public will inadvertently enter the burned area despite the closure and since the vegetation cover will take some years to recover, many of these abandoned mines will still be visible and accessible by the public after the closure is lifted. In order to mitigate this threat to the public, fencing and signing around some of the most visible and accessible abandoned mines will take place. In addition to visibility and accessibility by the public to these mines a third criteria determining which mines will be fenced and signed is the physical hazards potential of the mine. Table 6 presents the names of the specific mines which were chosen for fencing and signing. In order to carryout this temporary closure an archeologist will need to assess the historical significant of each site before any fencing or ground disturbance can take place.

BAER Treatment Item: ROADS: Remove or stabilize berms

A. Treatment Type and Proposed Location: On Forest roads or roads maintained by others which affect Forest resources, remove unnecessary/inappropriately located berms, and stabilize necessary berms, at numerous locations to be identified during BAER implementation.
B. Treatment Objective: To reduce resource damage, stabilize eroding berms, improve road drainage, and discourage future side-casting.
C. Treatment description: Remove berms unless side-slopes, design considerations or safety requires the berm. If required, build or repair existing berms according to engineering specs for each section of roadway. Vegetate (shape, seed and mulch) berms, where needed, to improve stabilization. Haul waste material/debris to approved disposal sites. If end-hauling is not an immediate option, stockpile excess materials in a nearby place where they will not erode down-slope and will be removed to approved disposal areas as soon as feasible. If necessary, modify road maintenance practices to meet these objectives. In general, where needed, all berms should be constructed 1½ to 3 ft high, with a 1½:1 or 2:1 (h:v) side-slopes, with a 6" to one foot flattened top, tamped, and shaped to contour the edge of the slope, but with a 6" to one foot bench outboard of the berm, where possible, to catch loose material from eroding down-slope. Following shaping, and where possible, seed with native grass seed, and mulch with approved straw mulch, hand placed.
D. Treatment Costs: Include in engineering package.
E. Monitoring Needs: Monitor removal, construction and stabilization of berms, and improvement in road drainage.

IV. Conclusion

The Station Fire was big. The impacts will also be big. Cleaning of Debris Catchment Basins before and between storm events, public education, and establishing warning systems are critically important to downstream communities and values at risk.

V. References

Cannon, S., 2009. Emergency Assessment of Postfire Debris-Flow Hazards for the 2009 Station fire, Southern California, USGS Administrative Report, 19 p.

Dibblee, T.W. Jr., 1982. Geology of the San Gabriel Mountains, Southern California, in Geology and Mineral Wealth of the California Transverse Ranges, Fife, D.L., and Minch, J.A., eds., p. 131-147.

King, A., and Keller, G., 2003. Stabilization and Removal of Roadside Berms on Forest Roads, in Geologic Hazards Report, Piru Fire BAER Specialists Report, Nov., 2003, 2 p.

Santi, P., Higgins, J., Cannon, S., and DeGraff, J., 2006. Evaluation of Post-Wildfire Debris Flow Mitigation Methods and Development of Decision-Support Tools, Joint Fire Science Program/U.S. Geological Survey, 50 p.

VI. Appendices

Appendix 1: USGS Administrative Report: Emergency Assessmant of Postfire Debris-Flow Hazards for the 2009 Station Fire, Southern California – (attached separately)

Appendix 2: Abandoned Mines

Approximately 29 people die each year in the U.S. due to accidents involving mine land features, many of them on abandoned mine lands (AML). A significant number of these fatalities occur on private and public lands in the Southwest (http://www.msha.gov/SOSA/SOSAhome.asp). At one time, these abandoned mine lands were considered remote, but due to urban sprawl and the increased ability of the public to access these sites, and post-fire increased visibility, accidents continue to occur (http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands.html).

Resource Condition Assessment

Of the 127 recorded abandoned mines on the Angeles National Forest (ANF), 34 mines are within the burned area of the Station Fire. As a result of the extensive moderate and high burn severity in this area, the removal of vegetation will most likely lead to the discovery of new abandoned mine lands (AML). Two previously undocumented adits were discovered during the BAER assessment above La Paloma Flat in Big Tujunga Canyon.

The abandoned mines within the fire area include: underground and surface mines, open cuts, adits, shafts and placer operations. Commodities mined in these locations include: Gold, Silver, Copper, Lead, Manganese, Titanium, Aluminum, Graphite, Talc, Gypsum, Feldspar, Asbestos and Barite.

Both physical and chemical hazards may be present in any given mine. In some cases, as a result of the fire, the potential for debris slides, rockfall and dry ravel have increased the physical hazard rating of some mines. In addition, as a result of the removal of vegetation by the fire many of these mines are now more visible and exposed to the public. This exposure increases the accessibility of the public to these locations and therefore magnifies the issue of threat to life and safety. Some of the physical hazards that exist in these locations include shafts that might have had timber blocking their entrance and now is burned, and dangerous adits that might collapse and trap or injure an individual. Chemical hazards associated with abandoned mines include acid mine drainage and other heavy metals, and toxic gases.

Emergency Determination

Assessments carried out by the geology group of the BAER team identified twenty eight (28) abandon mine sites within the fire perimeter located within ½ mile of a road. Twelve (12) sites were identified within ¼ mile of a road. The increased visibility and accessibility by the public to these sites as a result of the fire magnifies the probability of injury or fatality in these sites.

Treatments

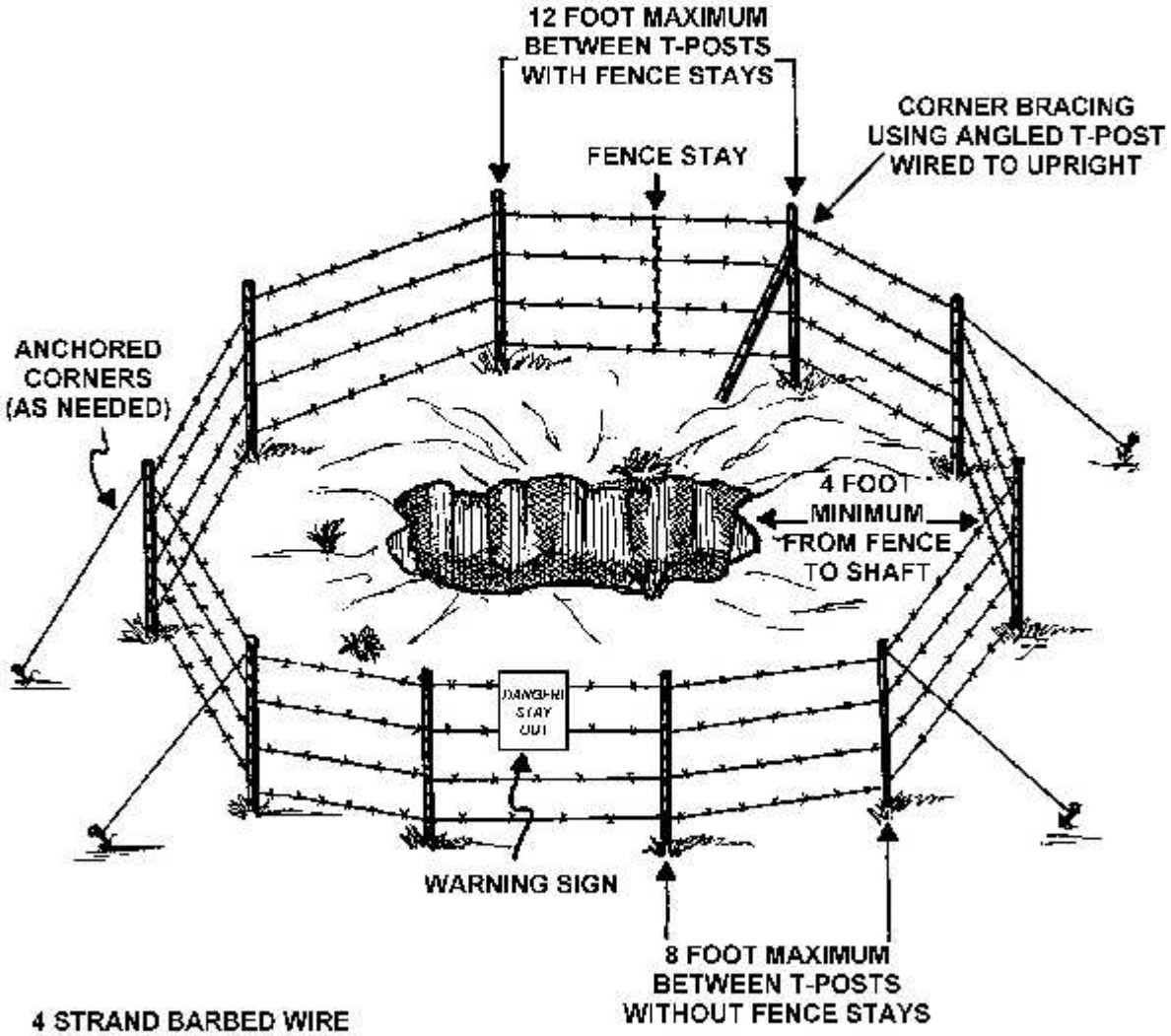
In order to mitigate physical and chemical hazards on AML within the fire parameter 17 sites will be temporarily fenced and signed to mitigate physical hazards. These sites were chosen by distance from roads, potential accessibility by the public and physical hazards in the sites. The method of fencing and signing the sites will follow the Minimum Standards for Nevada Division of Minerals (see Appendix 3). The only difference is that instead of using barbed wire, smooth wire fencing will be used.

Prior to the temporary closure of the mines, a archeologist assessment will take place to determine historical significance in and around the sites.

The temporary closure of the sites will be directed and managed by a mineral administrator. In addition to fencing and signing the sites, we recommend on-the-ground assessments to further identify AML sites which might have been exposed by the fire, and contain physical or chemical hazards which were not documented prior to the fire. These assessments will better identify the risk of environmental or safety hazards regarding abandoned mines within the fire perimeter.

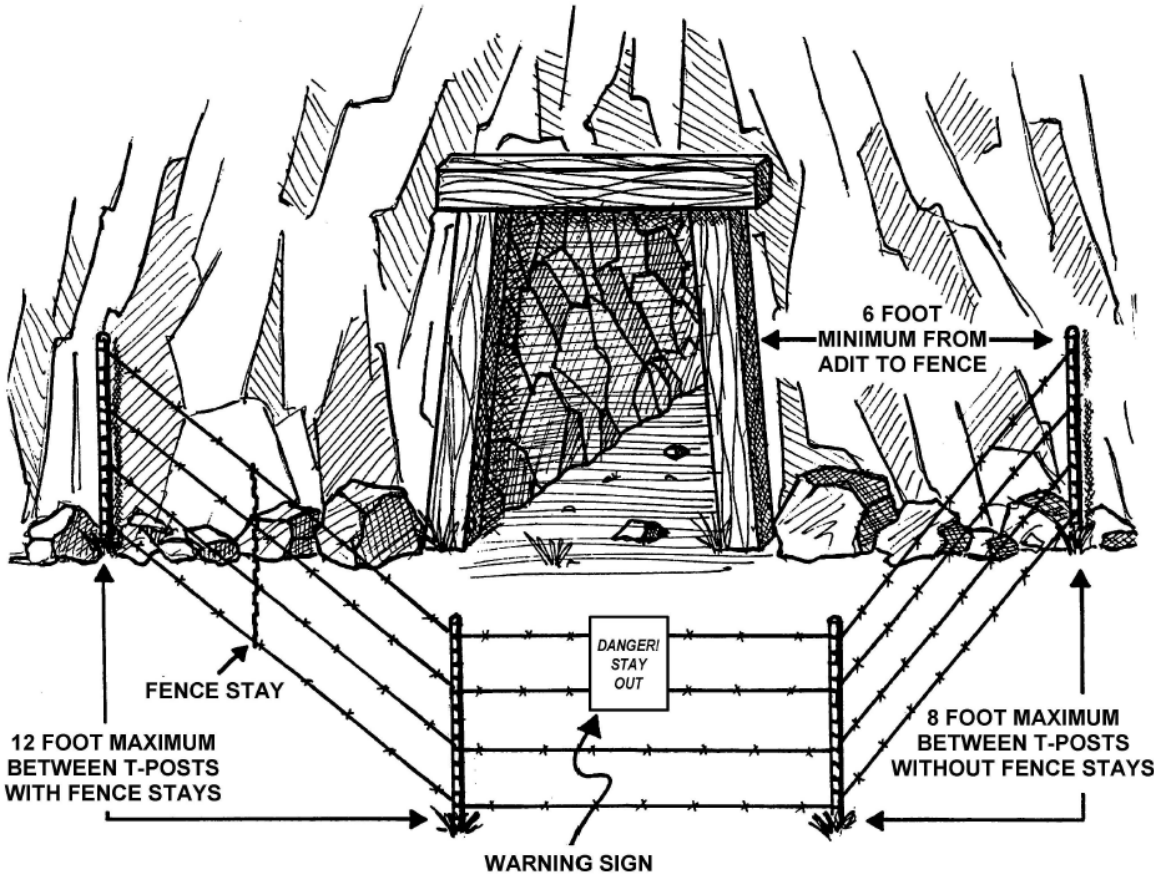
<u>Appendix 3</u>: Nevada Division of Mines

MINIMUM STANDARDS FOR NEVADA DIVISION OF MINERALS (NDOM) BUILT FENCES AROUND ORPHANED MINE SHAFTS



4 STRAND BARBED WIRE
4 FEET HIGH TO TOP WIRE
1 FOOT BETWEEN WIRES
5 TO 6 FOOT HIGH T-POSTS PLANTED SOLIDLY
AT LEAST ONE WARNING SIGN PER MINE OPENING OR 100' OF FENCE

MINIMUM STANDARDS FOR NEVADA DIVISION OF MINERALS (NDOM) BUILT FENCES AROUND ORPHANED ADITS



4 STRAND BARBED WIRE
4 FEET HIGH TO TOP WIRE
1 FOOT BETWEEN WIRES
5 TO 6 FOOT T-POSTS PLANTED SOLIDLY
FENCE MAY OR MAY NOT COMPLETELY CIRCLE ADIT, DEPENDING ON TOPOGRAPHY
AT LEAST ONE WARNING SIGN PER ADIT OR 100' OF FENCE

Appendix 4: Disposal Sites

Watershed response to the Station Fire has already produced large amounts of dry ravel and rock-fall off of steep, burned slopes. Loaders and graders have been hard at work cleaning roadways. Some of the material has been hauled to debris disposal sites, but much of it has been pushed over the sides of roads. Often that material adds extra sediment to already eroding slopes. Material dumped on steep burned slopes can create debris slides that carry far down-slope, in some cases into creek channels.

Much more material will erode and fall from slopes and flow down channels when winter storms arrive. Roads will need to be cleared, culverts will need to be unplugged, catchment basins will need to be excavated, and all that material will need disposal sites.

It is more practical, from a cost standpoint, to push material off of roads onto sideslopes, or push it to the sides of roads to create or enlarge berms. Those berms frequently erode and act as side-cast sources. It is more difficult and costly to end-haul material to approved disposal sites, but more appropriate from a watershed stability and water quality standpoint.

Currently Cal. Trans has 44 approved disposal sites along Hwy 2. Most of these disposal sites are very small (mostly at turnouts). Los Angeles County has 25 approved disposal sites along Big Tujunga Rd. and the Angeles Forest Hwy. Most of their sites are ½ - ¾ full. The Forest Service does not have any official disposal sites for maintenance of Forest Roads, and most material is disposed of by side-casting or placement in roadside berms. Approved disposal sites are needed. In order to better manage and protect watersheds and natural resources, it is recommended that the Angeles NF re-evaluate its practices of debris disposal and utilize official disposal sites. Regarding Cal Trans and L.A. County, it is obvious that many more sites with much more capacity will be needed post-fire than were being used pre-fire. Without clear direction and sufficient, approved disposal sites, side-casting practices will continue, and downslope/downstream impacts will occur.

In order to be approved, potential sites should be identified and then surveyed for potential impacts to watershed, biological, archaeological, or other impacts. They need to be evaluated for the volume of material that can safely be stored, whether storage can be long term or only short term, how sediment eroded from stored piles will be contained on-site, whether the site is geologically stable, and how material should be placed to assure maximum use and future access.

Appendix 5:

Stabilization and Removal of Roadside Berms on Forest Roads
(modified from A. King & G. Keller, 2003)

The objectives of this treatment item are to: 1) remove unnecessary berms in order to improve drainage, reduce erosion and improve watershed stability, 2) improve existing berms that are necessary, from an engineering perspective, such that they are much less susceptible to erosion, and 3) discourage future use of berms as a waste disposal mechanism, and change current side-casting practices.

Current Situation: On some portions of forest roads, berms have been used for safety devices, road drainage control, erosion control and material disposal. Safety concerns are real along many segments of the Station Fire roads, and berms are appropriate in some locations, but often are poorly constructed and maintained. Berms, and excess material dumped over them, also contribute large amounts of sediment into stream channels. In Southern California Forests, berms are more frequently constructed than in many other forest areas. Many berms may be convenient, but not necessary.

Berms help channel water to culverts, dips, or overside drains, which is necessary for road surface erosion and drainage control. They also prevent flow from sheeting off the road shoulder over erosive soils. A more subtle use of berms, however, is for roadside waste disposal. Excess soil and rock debris is generated when ditches are cleaned, slough material or landslides are removed from cutbanks, or rock is cleared from the roadway. In steep terrain, large quantities of this loose rock and soil debris drops on roads, especially after fires when vegetative cover on slopes burns away, freeing colluvial material to fall. It is much easier, and less costly, to dispose of this debris on-site, rather than bringing in extra equipment to load, haul and dispose of material off-site at approved or unapproved disposal sites.

Typically, loaders dump material, or graders push material to the edge of the roadway, where some of it stays as a part of a berm, and some of it is side-cast, depending on how much material is dumped and how much material needs to be disposed of. Over time, rainfall and wind erode the loosely consolidated sand, gravel and silt, and some of it rolls or washes down-slope, while some washes down the roadway until it is channeled off at a dip or culvert. Periodically, as the berms erode away, they are built back up with additional material from road maintenance or fire suppression/rehab activities. Berm erosion is not dramatic, such as can be easily recognized where gullying occurs, so it often goes unnoticed.

General criteria for selection of sites where berms ARE needed:

- steep sideslopes at or above the angle of repose;
- easily erodable side-slopes with little or no vegetation, and with a creek or ephemeral drainage directly below;
- where the road gradient is too steep for out-sloped drainage;
- where other safety factors dictate the need for a berm.

General criteria for selection of sites where berms ARE NOT needed:

- vegetated side-slopes, or burned slopes where vegetation will re-grow rapidly;
- on out-sloped of roads with rolling dips;
- where distance to a creek or ephemeral drainage is sufficient to allow eroded sediment to stabilize and not be carried into the stream;
- sites where berms were built just to get rid of post-fire debris, especially where no berms existed previously.

Whether to keep and improve, or remove berms should be reviewed in the field jointly by an engineer and a watershed specialist (geologist or hydrologist). Their decision and prescription for the disposition of berms should be documented. Material generated by berm removal should be end-hauled to approved disposal sites. Roads outside the burn area also should be assessed for berm treatment or removal, but are beyond the scope of BAER treatments.