Emergency Watershed Protection Measures in Highly Unstable Terrain on the Blake Fire, Six Rivers National Forest, 1987[1]

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Abstract: The Blake Fire burned about 730 ha of mature timber on the west slope of South Fork Mountain in northwestern California. Many steep innergorge and landslide headwall areas burned very hot, killing most large trees and consuming much of the large organic debris in unstable drainages. This created a potential for adverse effects on downstream fisheries from landsliding and the release of sediment formerly retained behind large organic debris. Emergency rehabilitation focused on enhancing channel conditions by falling and bucking downed logs and dead trees and by salvaging dead "high-risk"-trees that could displace soil directly into these drainages by toppling or sliding. Straw bales were wedged behind "replacement" logs to promote retention of landslide debris and other sediment. Current field observations indicate that some of these emergency measures have been effective in the short term. Further data collection and analysis will be needed to evaluate long-term effectiveness.

The Blake fire was started on August 30, 1987 by a lightning strike on the west slope of South Fork Mountain in northwestern California (Fig. 1). It burned approximately 730 ha of National Forest land between 1000 and 1700 m elevation, and killed about 250,000 m^3 (60 MMBF) of timber worth an estimated 6 million dollars. Although small compared to other California fires, the Blake fire burned hot and in very unstable terrain. Approximately 160 ha burned at high intensity, killing all vegetation and consuming virtually all protective litter. Another 285 ha burned at moderate intensity, killing the trees but leaving a protective ground cover of unburned duff and subsequent needle fall. The remaining 285 ha burned at low intensity, with scattered trees dying during the first year. Some of the hottest fire burned in unstable drainages where much of the large organic debris was consumed. Sediment production from these tributary drainages can adversely affect anadromous fish habitat in Pilot Creek and the Mad River.

Purpose & Scope

Once the fire was controlled and preliminary rehabilitation (such as straw mulching of tractor firelines) was accomplished, the primary management goal was expeditious salvage of burned timber. Field inventories of the burned area revealed that postfire conditions in many of the drainages and on adjacent slopes, combined with the geologic instability of the area, could seriously affect water quality and fisheries downstream. Poor access to unstable drainages limited what could be done realistically within the remaining 1 to 2 months before winter. Therefore, the Forest decided to concentrate emergency rehabilitation efforts on the most critically impacted drainages. This paper will focus on various measures employed in an attempt to improve the stability of these drainages. The apparent merits and difficulties of these emergency actions will also be discussed.

Geomorphic Setting

The burned area is underlain by rocks of the Franciscan Complex, including South Fork Mountain schist exposed along the ridge crest, and other metasedimentary rocks on the steep, benched slopes to the west. The Franciscan terrane has been extensively sheared and faulted, and these locally weak parent materials have experienced widespread landsliding over the past several thousand years. The colluvial mantle in the burned area is derived principally from South Fork Mountain schist and has a gravelly silt loam to clay loam texture with low plasticity.

Landslide deposits cover about half of the burned area (fig. 1). These older slides appear to be dormant, but subsidiary landslide processes have been active within and adjacent to drainages that occupy many of the lateral slide margins. These channels are recent geologic features resembling very large gullies and having unstable sideslopes like an innergorge. Nearby private logging in the late 1960's created similar gullies 5 to 10 meters deep where skid trails and roads concentrated water. Gradients of the innergorge/gullies vary from 20 to 50 percent, and sideslopes are commonly in excess of 80 percent. Fresh scarps and wet hummocky ground are widespread,

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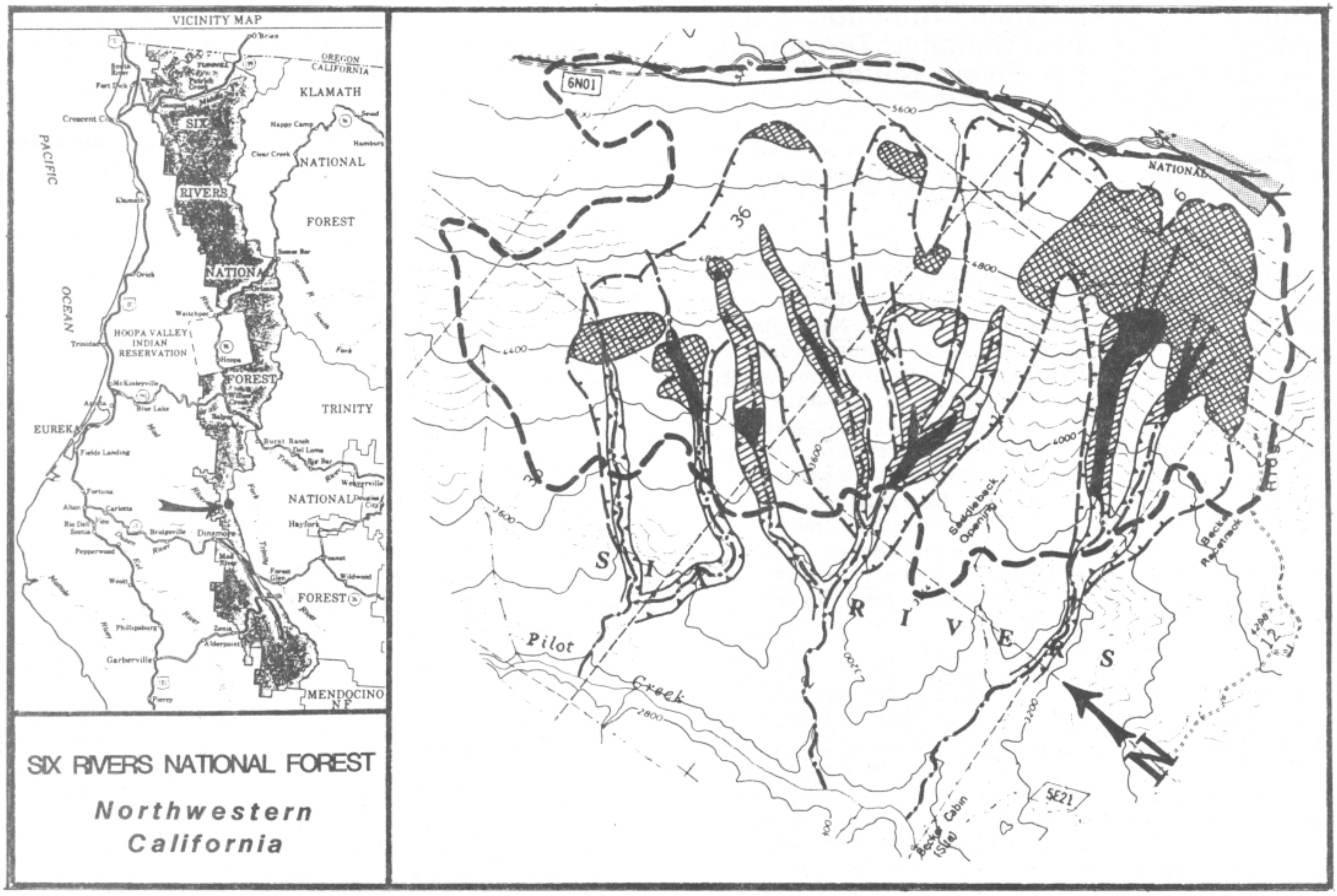

Figure 1--Location map of Blake Fire, showing burn intensity areas and landslide activity. <u>Heavy dashed line</u> - perimeter of fire; <u>solid line with sawteeth</u> - active landslide areas; <u>dashed line with hachures</u> - dormant landslide features and deposits; <u>dash-dot line</u> - stream channels; <u>solid black</u> - high burn intensity in active slide areas; <u>crosshatched</u> - high burn intensity in dormant slide areas; hatched - moderate burn intensity in active slide areas.

indicating a high susceptibility to debris sliding and rotational-translational slumping. A large amount of landslide debris has accumulated behind natural barriers of logs and boulders that occur along most sections of channel. The resulting profiles are very irregular with short cascades alternating with aggraded sections.

EFFECTS OF THE FIRE ON SLOPE STABILITY AND SEDIMENT PRODUCTION

<u>Direct Effects</u>

The fire had several direct effects that could influence future slope stability in the burned area. A large number of conifers were either killed immediately or have died in the past year. In some places where fire intensity was high, root systems were consumed to depths of 70 to 100 cm. The most important effect was the almost total

Figure 2--Typical condition of burned out innergorge/gully area. Note 100 percent tree mortality and bare, unstable sideslopes.

Figure 3--Detail of postfire channel condition showing burned out organic debris and unstable sediment deposits.

mortality of trees within and adjacent to innergorge/gully areas where the channel acted as a chimney and concentrated the heat of the fire (fig. 2). Much of the large organic debris also was consumed in these channels because of the extremely dry fuel conditions (fig. 3). Material that was not consumed tended to be large and often was suspended above the channel bottom. Many hardwoods were burned, but most of their root systems have survived and are sprouting.

Potential Indirect Effects

There are several indirect effects that could occur in the burned out innergorge/gully areas. These effects vary in terms of severity of impact and likelihood of occurrence in a roughly inverse manner. We have attempted to evaluate severity and risk qualitatively, based on relevant literature and our own experience.

Short-Term Effects

We estimated that a large amount of sediment (400-500 m^3) resulting from past landsliding was stored in the drainages affected by the fire. It appeared likely that the first winter storms would mobilize much of this sediment and scour the channel because the large organic debris that had formerly retained it had been consumed by the fire. Of lower risk but greater concern to water quality was the possibility that severe winter storms (having a 15 to 30-year recurrence interval) could produce widespread landsliding along these channels, as has occurred in the recent past. Much of this newly delivered sediment could also be scoured by streamflow and transported downstream. Finally, the possibility of debris flows being initiated by a saturated debris slide near the head of an innergorge/gully was also considered (Johnson 1984; Benda and Dunne 1987; Bovis and Dagg 1987). Once mobilized, this type of mass movement could readily entrain large amounts of sediment in storage because much of the reinforcement of large organic debris in the channel had been lost. Such a debris flow would produce adverse effects extending far downstream of the area directly affected by the fire. In our judgment, this was a relatively low risk, but one that could not be ignored because of the severe potential impact.

Long-Term Effects

Sediment yield would probably increase over the longer term as well, due to the progressive loss of root strength from tree mortality, which would occur throughout the drainages in a common timeframe. This could increase the frequency of debris slides and shallow slumps compared to pre-fire conditions. The load imposed by very large (1.2 to 1.8 m DBH), dead trees on unstable slopes could trigger small slides as their root systems decayed. For typical slides observed in these drainages (15 to 25 m^3), tree weight can be as much as 20 percent of the driving force. Toppling or windthrow of dead trees could displace additional sediment where actual slope failure did not occur. In addition, potential sediment production from scour of landslide debris and possible debris flows could increase over the long term. Because of the longer timeframe (10 to 15 years), the cumulative risk of these effects would be somewhat greater than in the short-term case.

According to currently accepted principles on tree root decay and soil strength (Burroughs and Thomas 1977; Ziemer 1981), net soil strength would be lowest and potential for mass wasting would be highest from 5 to 13 years after the fire. Because of the high percentage of true fir which decomposes rapidly, a significant loss of root support is expected within three years. Since most of the timber in these unstable drainages was already dead and would cease to provide root strength in the near future, the risk of removing dead trees was evaluated differently from the way it would be done in a conventional timber sale, where logging operations are generally avoided in this terrain.

EMERGENCY REHABILITATION

There have been differences in professional opinion regarding the value of organic debris in stream channels. Currently, the prevailing view is that large organic debris is a beneficial component of natural channels because it provides stability by dissipating energy and temporarily retaining sediment (Megahan 1982; Swanson and Lienkaemper 1978; Keller and Swanson 1979). The storage of sediment and organic matter behind large organic debris in first and second order channels significantly delays its downstream transport. Large organic debris also can prevent sudden deposition of fine sediment in downstream spawning areas (Megahan 1982), and can store considerable amounts of sediment at the base of unstable hillslopes (Wilford 1984). We attempted to apply these principles in a practical way to promote stabilization of affected channels, with the objective of reducing the amount of sediment that might be transported during the slower, natural healing process.

Implemented Measures

It was considered impractical to duplicate channel conditions that existed before the fire. Much of the large organic debris that burned was relatively stable, having been partially embedded in sediment and wedged into channel sideslopes. Replacement material was available, either suspended above the channel or in the dead and dying trees adjacent to the drainages. Although it would not be feasible to embed the logs as before because of poor equipment access, the natural recruitment of large organic debris could be accelerated by bucking suspended logs and falling additional dead and dying material into the channels.

All burned drainages were inventoried and suitable locations for sediment retention structures were flagged. These sites were selected on the basis of availability of unburned logs or standing dead trees, the likelihood of logs staying in place, and the expected amount of landsliding above the site that could be retained. In steeper channel sections, retention structures were flagged at closer intervals (5 to 8 m) where possible. We wanted to intercept landslide debris as close to its source as possible to lessen the chance of its becoming a debris flow that could probably sweep away any structures downstream. In other words, these measures were not expected to prevent debris flows, but rather to contain landslide debris near its source.

Contract fallers were hired to buck existing downed logs and to fell additional dead or dying trees as directed by an earth scientist on site. Approximately 50 logs were bucked and 80 trees were felled in eight drainages with a cumulative length of 4 kilometers. The faller made the final determination regarding safe and prudent operations. There was often a difference between what we had envisioned and what could actually be accomplished safely by a particular faller. Because of this limitation, some of our original plans had to be modified during the falling operations. Straw bales were flown in by helicopter and later wedged and staked around the log structures by crews under the guidance of an earth scientist.

The sediment retention structures were relatively low in cost and could be installed quickly. Approximately 80 log and straw bale structures were created in the draws for $24,100. The cost breakdown is as follows:

Helicopter and ground support	$9,600
Straw bales	1,800
Tree falling	1,700
CCC crew (12 persons, 6 days)	6,000
Project planning and supervision	5,000
Total (80 log structures)	$24,100

Tree values were not included but would add another $8000 to these costs. Transporting straw bales to the sites by helicopter was the major cost component. However, the ground crews and helicopter stood by for two weeks during adverse and unsafe weather conditions in November. Only two days of actual flight time were needed. Once the materials were on site, it took approximately 3 person-hours to build each structure. The drainages will be planted with deep-rooted species in the spring of 1989 to increase their stability. We avoided planting grass or other shallow-rooted species because they would compete with the more desirable deep-rooted trees. The estimated cost for this tree planting and contract administration is $40,000 or $155/ha.

Another rehabilitation measure applied during the commercial salvage operations was to harvest "high-risk" trees from unstable drainages. The purpose was to remove dead or dying trees which appeared likely to undercut potentially unstable areas by toppling or by loading a small slide. These trees were individually marked and were to be directionally felled away from the stream channel. However, many of the "high-risk" trees had to be felled along the channel because of hazardous felling conditions. These trees were lifted straight up and fully suspended over the unstable terrain. Approximately 40 percent of the dead trees within drainages were removed. The remainder were retained primarily for wildlife and secondarily for future debris recruitment.

Short-Term Results of Rehabilitation Measures

The emergency rehabilitation produced a mixed success. In larger drainages (8 to 12 m deep) where bigger logs were needed, satisfactory placement was difficult to achieve. Some logs were poorly emplaced because the green wood did not break into shorter sections as easily as expected. Bucking existing material usually produced a better result, but hazardous conditions prevented bucking some suspended logs or felled trees that would have created a more effective structure. A workable compromise was to criss-cross logs subparallel to the draw axis. Sometimes, a second tree effectively crushed and embedded another log or tree that could not be bucked safely. Wedging logs behind large boulders was another effective technique used in these drainages (fig. 4).

Figure 4--Logs crisscrossed behind 12-foot boulder in large innergorge/gully. Note person in upper center of photo for scale.

Figure 5--Typical log and straw bale retention structure in one of the smaller drainages. Note accumulation of sediment behind structure.

In the smaller drainages, downed material was cut more easily into 6 to 10-foot lengths, forming an arc perpendicular to the draw axis. This generally produced satisfactory structures, but they have less capacity and may not be as permanent as the other more chaotic structures.

The 1987-88 winter produced no major storms. Only moderate amounts of sediment were mobilized in the burned area as a result of landsliding. Despite the mild winter, most of the structures in the smaller drainages filled to capacity, mainly with the sediment that was formerly retained behind burned out organic debris (fig. 5). The combination of wedged straw bales and logs appeared to work most effectively in the smaller drainages, judging by the amount of sediment that they retained. In some places, partial breaches developed beneath or around a log, suggesting that straw bales alone would have been considerably less durable in these steep gradient channels.

In the largest and most unstable drainages, only a few small slides occurred and less sediment was retained behind the larger structures. Straw bales were not effectively incorporated into these structures, primarily because of the size of openings beneath felled logs. Had more time been available, hand crews could have cut up additional small debris in the larger drainages which would have held the straw bales more effectively in place. It will probably require a major pulse of landslide debris to evaluate whether the larger structures effectively trap and retain sediment.

The harvest of "high-risk" trees was very successful in the skyline units because of cooperation between the sale administrators and loggers. Many "high-risk" trees were left in drainages adjacent to tractor units because yarding probably would have caused unacceptable damage to the innergorge. These trees will either be felled into the channels in the future, or left for comparison to other treated channel sections.

FUTURE EVALUATION OF REHABILITATION MEASURES

In the absence of a control watershed with baseline data on sediment production and landslide rates, monitoring the effects of these emergency rehabilitation measures on downstream sedimentation would be inconclusive. However, in place of studying sediment production, some useful insights can be gained by measuring and evaluating the direct effects of sediment-retention structures and the removal of "high-risk" trees in these sensitive drainages.

Our monitoring will address the following questions: (1) have the log structures effectively intercepted sediment and released it gradually, (2) have the structures trapped landslide debris and provided stable sites for revegetation, (3) have small landslides occurred less frequently in areas where "high-risk" trees were removed than in areas where they were left, and (4) has the removal of "high risk" trees adversely affected the amount of large organic debris in stream channels? These questions will be addressed both qualitatively and quantitatively where possible by means of systematic observation, photography from reference sites, and stream channel mapping throughout the burned area. Large scale (1:8,000) aerial photography was acquired as a baseline for monitoring purposes in August, 1988. Additional photo coverage will be obtained periodically for comparative analysis.

CONCLUSIONS

1. Appropriate strategies for emergency and long-term rehabilitation in unstable, landslide-dominated terrain are different from conventional practices that apply in more erosion-dominated terrain. Where the burn intensity is high, as it was in parts of the Blake fire, a prolonged series of mass-wasting events may be initiated. Rather than planting grass and cleaning drainages of debris, there appears to be a critical need to add essential large organic debris to regain some channel integrity and provide for future stability within the framework of natural landslide processes.

2. Similar reasoning applies to salvage or harvest of dead, "high-risk" trees in unstable streamside zones. It may seem improper to harvest trees from innergorge areas where fire effects are so severe. However, leaving these "high-risk" trees may have more impact than removing them because root strength will diminish rapidly and residual tree weight may be a significant component of the load on small slides in this terrain. On the other hand, the value of these trees for wildlife and as future sources of large organic debris in these channels should also be considered.

3. Preliminary observations suggest that the log and straw bale structures have captured sediment released by the burned-out organic debris and were effective in delaying the transport of this sediment to downstream spawning areas. Because last winter was relatively mild and because increased landsliding from the burn has not yet occurred, the effectiveness of these log structures in trapping and retaining slide debris, reducing channel scour, and reducing the risk of a large debris flow cannot be evaluated at this time. We expect that several years of careful observation and comparison with untreated drainages will be necessary for a full evaluation.

4. "High-risk" trees along these sensitive stream channels were successfully removed with minimal disturbance to the innergorge and channel banks. Long-term observations will be needed to evaluate the effectiveness of this treatment as well.

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