Emergency Burn Rehabilitation: Cost, Risk, and Effectiveness[1]

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Abstract: The fires of 1987 had a heavy impact on the Hayfork Ranger District. Over 50,000 acres were burned within the South Fork Trinity River watershed, which contains an important anadromous fishery. Major problems within the burned area were found to be: (1) slopes having highly erodible soils where intense wildfire resulted in a total loss of ground cover, and (2) burnout of the natural woody sediment barriers in stream channels. Emergency watershed treatments included aerial seeding of selected slopes with species selected for their ability to germinate quickly and re-establish ground cover. Success was mixed depending on aspect and elevation. Mulching and contour felling were also used. Of the slope treatments, aerial seeding was the most cost effective, while mulching gave best results with least risk. Contour felling was costly and not effective. Channel treatments included straw bale check dams, which were effective in trapping sediment and stabilizing ephemeral stream channels. Log and rock check dams were installed in larger intermittent and small perennial channels, where large woody debris had burned, resulting in the release of large quantities of transportable sediment. This treatment was very successful in trapping sediment and stabilizing channels. Both channel treatments had acceptable costs and risks.

On August 30, 1987, a dry lightning storm caused over 100 fires on the Shasta-Trinity National Forests. Impact was greatest on the Hayfork Ranger District, with three individual fire complexes, including over 20 separate fires, covering 50,000 acres. All these fires burned within drainages tributary to the South Fork Trinity River. The lower reaches of these tributaries contain important spawning and rearing habitat for anadromous fish.

Following containment of the individual fire complexes, interdisciplinary teams were assembled to survey watershed and facilities damage and to recommend and prescribe Emergency Burn Area Rehabilitation (EBAR) measures. These teams concentrated on specific areas of high burn intensity, highly erodible soils, domestic water sources, destabilized channels, and large capital investments. These teams recommended EBAR measures to maintain soil productivity, and to protect water quality and the endangered structures.

Implementation of the prescribed EBAR treatments began in late October using California Conservation Corps and Forest Service personnel. The goal was to perform the prescribed measures quickly so that they would be in place before the onset of fall and winter storms. All treatments were implemented by late November.

The purpose of this paper is to evaluate five of the more widespread treatments in terms of relative risk, cost, and effectiveness. Treatments prescribed to maintain soil productivity and water quality can be divided into two groups: slope treatments and channel treatments. Slope treatments analyzed include aerial seeding, mulching, and contour felling. Channel treatments include straw bale check dams and log and rock check dams. The analyses we have used for the different treatments are somewhat subjective, and are not statistically valid. This evaluation was not a research or administrative project, but simply the result of relatively rapid, representative sampling of five treatments. Cost data include equipment, labor, room and board, materials, and overhead.

PHYSICAL SETTING

The fire complexes were located within portions of the large upland area which lies within the central portion of the South Fork Trinity watershed. Elevations range from approximately 2,000 ft (600 m) along the South Fork Trinity River to 5,000 ft (1524 m) within the uplands. Average annual precipitation ranges from approximately 45 to 60 in (114 to 152 cm), and generally occurs between October and April. Stream channels within the upland area are for the most part alluvial and have relatively low channel gradients. Many of the streams are highly unstable because of the unconsolidated nature of the alluvial material in which they are incised. Lateral cutting is common in these stream channels. In contrast, channels along the margins of the upland area, especially the lower reaches,

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are steep in gradient, bedrock controlled, and relatively stable.

Nearly all the burned areas lie within the western portion of the Klamath Mountain physiographic province. Bedrock lithologies that are prominent include diorite, metabasalt, phyllite, and peridotite. The soils in the burned areas vary greatly in their erosion hazard potential. Highly erodible soils are locally present within the burned area, especially in areas underlain by diorite bedrock. Hydrophobicity was only present in a few areas within the burned complexes, and was not a significant factor in contributing to surface erosion hazards.

The burn intensity was highly diverse, with areas of low, moderate, and high intensity burn distributed in a mosaic pattern throughout each of the complexes. Approximately 20 percent of the fire complexes burned hot; 40 percent were considered moderate, and 40 percent were low intensity.

METHODS

The analysis evaluated the effectiveness of the selected treatments in terms of soil or sediment stabilized. To help measure the effectiveness of the aerial seeding and mulching treatments in retarding soil erosion, the universal soil loss equation (USLE) (Dissmeyer and Foster 1984) was used. The authors understand the difficulty of using USLE on steep forest land; however, the method seems to offer the best source of information available on potential erosion rates for a variety of factors such as soil erodibility, slope, slope length, and cover.

For our purpose, USLE was calculated for a 30 and 50 percent slope using a conservative slope length of 25 ft (7.6 m) and three different k factors representative of a low, moderate, and high soil erodibility. Each k factor was then calculated using a 0, 20, and 75 percent cover factor. The relationship between cover classes for a given k factor or erodibility class is given in figure 1. The figure also indicates the estimate of soil that was held on site for a given set of site factors and level of cover established by the treatments.

Soil trapped behind logs in the contour felling prescription was measured in representative tenth-acre (.04 ha) plots. Sediment caught behind check dams was measured by digging trenches or auguring the deposits, and measuring the width and length of the wedge.

SLOPE MEASURES

Slope treatments were intended to replace lost ground cover in order to prevent surface erosion, to disperse overland flow and prevent water concentration, and to provide local sediment storage sites. Slope treatments selected for analysis include aerial seeding, mulching, and contour felling.

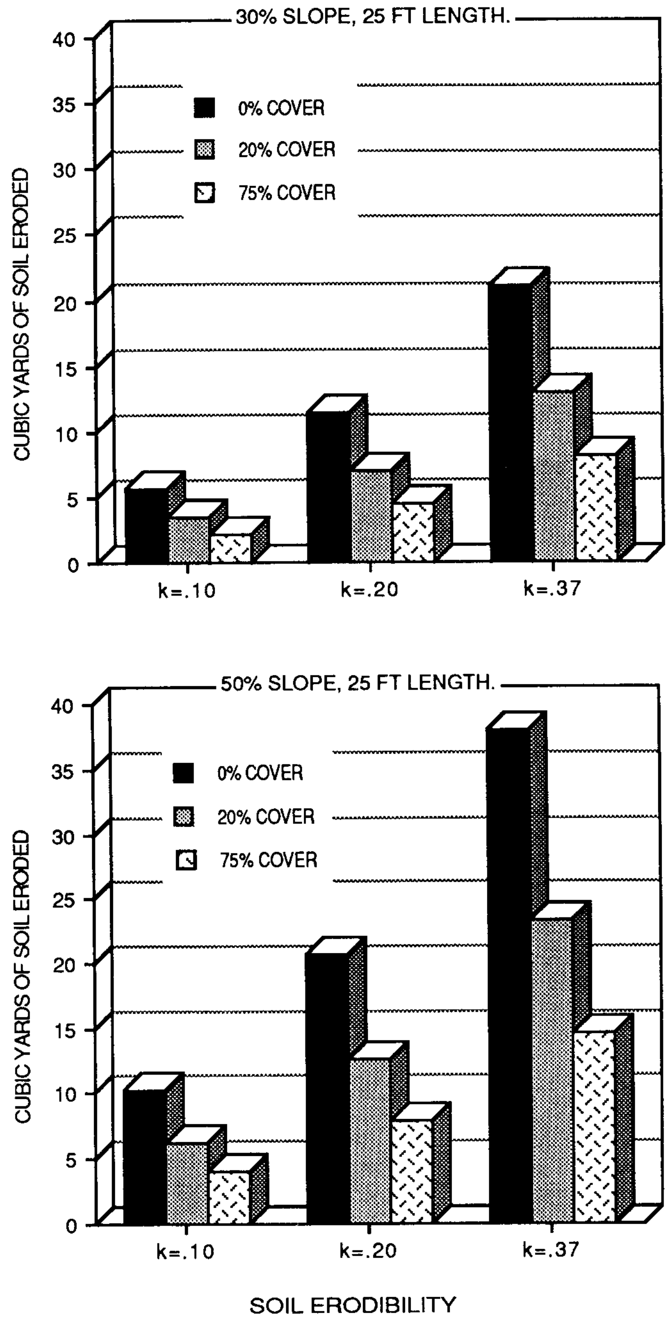

Figure 1--Effect of ground cover on soil erosion.

Aerial Seeding

Aerial seeding was prescribed as a means of reducing surface erosion. The areas considered for this treatment were (1) highly erodible soils that burned very hot and had lost all ground cover, (2) areas adjacent to drainages which had burned hot, and (3) all equipment constructed fire lines. The seeding was done to provide ground cover that would protect the soil from raindrop impact and to provide a stabilizing root mass to bind the surface soil particles together. Two seed mixes (table 1) were selected to accomplish these objectives.

The perennial mix was prescribed for noncommercial brush fields, for fire lines, and for areas adjacent to perennial streams where a more permanent ground cover was needed. Orchard grass was the only perennial species in the perennial mix. The annual mix was seeded on forest land that was intended for restocking with timber species.

The barley was selected for its ability to (1) germinate rapidly and provide the ground cover needed before the winter rains, (2) die off after the first year (seed is retained in the seed head, thus preventing germination), and (3) provide a mulch for the second year. Some species in the mixes, such as blando brome, may not die out after several years, but these were considered nonaggressive as competitors for conifer seedlings. In addition to their value for erosion control, the inoculated subterranean clover and birdsfoot trefoil have the ability to add nitrogen to the soil, and provide benefits to wildlife.

The majority of the 2,155 acres (872 ha) were seeded by helicopter at an average cost of $55 per acre. Over 100,000 lb (45360 kg) of seed were applied to the burn areas.

During the seeding operations, seed cards were placed to monitor seed distribution. It was determined that a seed density of 50/ft^2 (538/m^2) was achieved. After the first winter, germination was monitored. Results ranged from 3 to 21/ft^2 (32 to 226/m^2), or 6 to 42 percent germination success. This resulted in a range of 10 to 90 percent ground cover, measured in the spring.

Table 1--Seed tables

Seed Species	Annual Mix	
	Lb/Acre	Seeds/ft^2
Cereal barley	44	15
Blando brome	2	13
Birdsfoot trefoil	2	21
Subterranean clover	2	3
Total	50	52
	Perennial Mix	
Cereal barley	40	13
Zorro fescue	2	30
Blando brome	2	13
Orchard grass	2	8
Birdsfoot trefoil	2	21
Subterranean clover	2	3
Total	50	88

The USLE analysis (figure 1) indicates that for the least erodible sites (30 percent slope, k=0.10, and 20 percent cover), seeding potentially reduced soil erosion by approximately 2 yd^3 /acre (4 m^3/ha). For highly erodible sites (50 percent slope, k=0.37 and 75 percent cover), seeding potentially reduced soil erosion by 24 yd^3/acre (45 m^3/ha). Using USLE as the method of evaluation and given the acres in each group of erodibility and cover class, the authors estimated that grass seeding Stabilized soil at an average of 7 yd^3/acre (13 m^3/ha) during the first year.

Using the cost of $55/ac to seed an acre aerially, and assuming the treatment stabilized 7 yd^3/acre (13m^3/ha), seeding cost less than $8/yd^3/acre to stabilize. Even if the USLE derived values are halved, to be conservative, the cost per cubic yard of soil stabilized is less than $16, which is still cost effective erosion control.

As for all treatments, there are risks associated with seeding. One problem encountered in this project was the difficulty in applying the seed to the ground before rain and before the weather turned too cool to germinate the seed. There was a small but effective rain during the first week of the seeding, but no rain for the following 3-week period. The first areas seeded had southerly aspects and were at a low elevation. The seed germinated quickly following the rain and put on much more growth than higher elevation sites which were seeded last. Even though the seeding was completed at the higher elevation sites while the weather was still fairly warm, there was no moisture to germinate the seed until after the weather turned cold. The barley germinated after the late rains and grew about 2 inches (5 cm) high before going dormant for the winter. In this state, the barley probably provided a minimum amount of erosion control. The other species were not noticeably present during the winter. They either had not germinated or were too small to perform any effective erosion control.

Mulching

Burned areas considered for mulching were (1) road fill slopes adjacent to perennial streams, (2) fire lines in highly erodible soils, (3) areas where fire lines crossed drainages, and (4) areas with extreme erosion hazards. The objective of mulching was to minimize erosion by providing a suitable ground cover to help reduce raindrop impact and to disperse overland flow.

Approximately 35 acres (14 ha) were treated within the burned areas.

Wheat straw was applied by hand at a rate of 2 t/acre (4483 kg/ha) on areas that did not have access for straw blowers. On large fire lines and road fill slopes where straw blowers could be used, the straw was applied at 1 t/acre (2242 kg/ha). Both methods achieved nearly 100% percent ground cover at the time of application. In the spring, analysis indicated that the hand spread mulch at 2 t/acre (4483 kg/ha) still provided nearly 100 percent ground cover but the 1 t/acre (2242 kg/ha) machine blown straw had decreased to about 60 percent ground cover, due to wind and settling from the rain.

Following the same method used to evaluate erosion control for seeding and assuming a 75 percent ground cover from the straw mulch on a moderately erodible soil (k=0.20), the practice as seduced erosion by 8 and 13 yd^3/acre (15 and 25 m^3/ha) on a 30 and 50 percent slope respectively. This averages about 10 yd^3/acre (19 m^3/ha) of soil stabilized.

The average cost of straw mulching by both methods was $350 per acre. Assuming that the treatment trapped 10 yd^3/acre (19 m^3/ha), the cost per cubic yard of soil stabilized was $35.

The risks associated with straw mulching are small; it is a simple task to perform either by hand or straw blower. However, large crews are required for reasonable progress. Strong winds can blow the straw off site but these effects can be minimized by applying it at 2 t/acre (4483 kg/ha), by punching it into the soil with equipment, or by falling submerchantable trees on top of it to hold it down. Logistics of getting straw to remote areas can be expensive, but helicopters using cargo nets are very effective.

Contour Felling

Contour felling was another measure prescribed to limit surface erosion from highly erodible slopes which burned intensively. The objective of contour felling was to provide sediment storage sites on the hillslope and to disperse overland flow. Contour felling was performed by felling submerchantable trees (less than 10 in [25 cm] DBH) which were bucked and limbed so they would rest on the ground surface. They were then placed on the contour and braced, where possible, against stumps. Slash and soil was placed on the uphill side of the log in order to plug minor bridging with the underlying ground surface. The logs were spaced approximately 15 to 20 ft (4 to 6 m) apart on the slope in order to minimize exposed slope length. Typically, 80 to 100 trees/acre (200 to 250 trees/ha) were felled.

Contour felling was performed on approximately 80 acres (32 ha) at an average cost of $500 per acre, making it the most expensive of the slope treatments. In evaluating the effectiveness of the treatment, it was apparent that for the most part, the specifications were not met. Bridging of the ground surface was relatively common, and many logs were not placed properly on the contour.

Measurements indicated that a range of 0 to 2.4 ft^3 (0 to .068 m^3) of soil was stored at each site and a total of 2 to 9 yd^3 stored per acre (4 to 17m^3/ha). If we use an average value of 4 yd^3 per acre (7.5 m^3/ha) of soil stabilized, which we believe to be somewhat optimistic, the cost is $125/$yd^3$.

There are many risks in this treatment. The task is relatively difficult to perform. The logs need to be placed as close as possible to the contour to be effective and all areas bridged by the log need to be plugged. If this is not done, water is concentrated, leading to rilling and accelerated erosion. The effectiveness of the treatment also depends on the stand composition. The treatment does not work well in old-growth stands where small trees are not abundant. The task is very slow; few acres can be treated in a day, even by a large labor force. In addition, the storage area offered by these submerchantable logs is not tremendous; however, if larger logs are used, their size makes proper placement more difficult. Our experience indicates that a more effective practice would be to simply fall all submerchantable and nonmerchantable trees and then limb, buck, and scatter them. The cost would be less and the practice may be more effective.

CHANNEL MEASURES

Channel treatments were prescribed to trap sediment and soil derived from adjacent slopes or within the channel and to replace burned large woody debris which provided sediment storage and local grade control. Several channel measures were used within the burned area. The most widespread of the practices were installation of straw bale check dams and larger log and rock check dams.

Straw Bale Check Dams

Straw bale check dams were prescribed to meet the objective of preventing sediment, eroded from hillslopes or destabilized within the channel after burnout of large woody material, from moving downstream through ephemeral and minor intermittent stream channels into the higher value perennial streams. The check dams would also serve the purpose of establishing a grade control that would reduce the potential for stream channel downcutting, a major source of accelerated erosion.

The check dams were designed to control rainfall-generated runoff and act as settling ponds to capture eroded soil and entrained sediment. Straw bales were chosen as the basic construction material because they were relatively inexpensive, easy to transport, were impermeable enough to capture water, and could be quickly constructed into the desired small-scale dam.

Site selection for the application of straw bale check dams was based on intensity of burn, channel condition, erodibility of the soils, and proximity to high-value beneficial uses of the water. Most commonly, a series of dams were constructed within the channels. Individual dam sites were selected to minimize the number of bales needed for construction while maximizing the area of storage upstream from the dam.

Efforts were made to prevent water from channeling under the bales by smoothing the ground surface. Three-foot lengths of rebar were spiked through each bale, with log or rock energy dissipators constructed below the spillway bales. Over 1300 straw bale check dams were constructed during the rehabilitation effort. The dams averaged five bales in width and cost an average of $110.

A representative sample of straw bale check dams were selected for analysis. A check dam failure was recorded if it was apparent that the structure had not worked as designed, allowing unknown quantities of sediment to pass downstream. In all, 13 percent of the structures were deemed to be failures. Failures occurred primarily from piping under or between the bales, or from undercutting of the central bale due to scour from the water flowing over the spillway bale.

Th9 average quantity of sediment trapped was 1.5 yd^3 (1.1 m^3) of sediment per check dam. Quantities varied primarily due to potential storage capacity. Stream gradient was the most influencing factor controlling storage capacity. Generally, ephemeral and minor intermittent stream channels have relatively high channel gradients. Channel gradient ranged from 5 to 35 percent, averaging 20 percent. Greater storage capacities could be achieved by locating the dams on lower gradient channels whenever possible, and placing the bales on their side.

Efficiency of the straw bale check dams can be expressed as $73/$yd^3$ of sediment. Success rates could be increased by including the use of filter fabric on the upstream side of the dam and on the spillway, with some additional armoring of the spillway. Over 200 of the dams were constructed in this manner. However, decreasing the failure rate to 5 percent increased the cost per structure by $50, which does not seem to be justified.

One of the limitations of the straw bale check dams is their life expectancy. The straw in the bales begins to decompose as soon as it is exposed to the elements. After 3 years the straw bales no longer provide any support for the captured sediment. Some of the sediment is stabilized by that time by means of natural vegetation and planted willow cuttings. Small logs and other woody debris placed downstream from the bales during their construction for spillway stabilization provide longer lasting storage for the sediment once the straw is gone. Even if the dams fail after several years, they still have accomplished their objective and continue to meter the sediment through the fluvial system in an acceptable manner.

Log and Rock Check Dams

Check dams constructed of logs or rocks were prescribed for some large intermittent and small perennial stream channels for the purpose of stream channel stabilization and sediment storage. In channels in areas severely burned, the large, stabilizing organic material had often been burned out. Log and rock check dams were prescribed to recapture the destabilized sediment and maintain the channel stability through grade control during the first winter following the fire. A potential extra benefit would be realized if the dams captured additional sediment generated from the burned slopes.

The dams were individually designed from standard check dam designs incorporating keyways, design flow spillways, and splash aprons. The log structures used logs 12 to 18 inches (30 to 40 cm) in diameter which were available at each site. Rock dams were constructed using a single fence design. Rocks were either hauled in or obtained at the site. Filter fabric was used in the lateral and bottom keyways, and on the banks adjacent to the dam in order to prevent undercutting and sidecutting, and on the face of the dam in order to make the dam more impermeable.

Fourteen structures were built at an average colt of 935 per structure. An average of 40 yd^3 (30 m^3) of sediment was captured per structure. None of the structures failed, although some needed maintenance to prevent future failure. Captured sediment ranged from 2 to 125 yd^3 (1.5 to 95 m^3). A more severe winter would have resulted in more sediment being captured, assuming no failures.

Efficiency of the log and rock check dams can be expressed as $23/$yd^3$ of sediment captured. The life expectancy of the log dams is 15 to 30 years. Rock structures are predicted to last until the next significant flood event.

DISCUSSION

The different slope treatments are compared in table 2. (Since slope treatments had different objectives than did channel treatments, we chose not to compare the two groups.) It is evident that aerial seeding had many advantages over mulching and contour felling. Both the cost per cubic yard of soil stabilized and the cost per acre treated were far superior to the other two

Table 2--Slope treatment summary

Treatment	Cost/yd^3	Cost/acre	Effectiveness	Production Rate	Risk
Aerial seeding	$16	$55	Moderate	Rapid	Moderate
Mulching	$35	$350	High	Slow	Low
Contour felling	$125	$500	Low	Slow	High

Table 3--Channel treatment summary

Treatment	Cost/yr^3	Cost/Structure	Effectiveness	Production Rate	Risk
Straw bale check dams	$73	$110	High	High	Low
Log and rock check dams	$23	$935	High	Slow	Moderate

treatments, because of material costs and mechanized rather than labor-intensive application. In addition, if many acres need treatment, aerial seeding can be performed rapidly, thus assuring that treatment of the land can be accomplished before onset of fall and winter storms. The disadvantage is that treatment success depends on the weather. The timing of storms, the risk of drying periods, the intensity of the first storm, and the onset of cooler temperatures can all affect germination and initial growth. In our example, the treatment was highly successful at the lower elevation sites that had rain shortly following application, but only moderately so at the higher elevation sites where temperatures were cooler and seeding was done after the initial storms.

Mulching also offers a reasonable solution to maintaining soil productivity and minimizing erosion with its relatively moderate price, high effectiveness, and low risk. The only drawback is the relatively slow production rate compared to seeding. If an area requires assurance of successful treatment, this is the appropriate treatment method. Considering available time, resources, site sensitivity and the downstream values, we would recommend a maximum amount of mulching feasible. The most sensitive areas should be mulched in order to minimize the risk of failure.

Contour felling is costly, of questionable effectiveness, has a low production rate and has high associated risks, because of variables such as stand type and distribution and the difficulty of meeting the specification. The risks of achieving success are considered unacceptable. We recommend mulching, which has a similar cost but greater production rate, or falling and limbing submerchantable trees. Either of these treatments would result in more effective soil stabilization, therefore more effectiveness in terms of the cost per cubic yard of soil stabilized.

The two channel treatments can be compared in a similar manner (table 3). The straw bale check dams-were more costly than the log and rock check dams, in terms of dollars per cubic yard, because of their lack of storage capacity. This difference is further reflected in the cost per structure and production rate. The typical straw bale check dam took approximately one hour to build. In contrast, the average log and rock check dam took 6 to 8 hours for a crew to build.

We consider both of these treatments appropriate for the individual site conditions. Numerous ephemeral stream channels required treatment. Using straw bales for structures was the most cost and time-effective measure available. In contrast, the larger channels had a tremendous volume of sediment available for transport and in conjunction with the relatively higher flows, demanded large, more sophisticated structures. This is reflected in the greater cost per structure but also in the relatively low cost per cubic yard of sediment stabilized.

Falling of large woody debris into stream channels can be an effective measure, but we believe that check dams offer a higher chance of success, in controlling flows and storing sediment. Falling and placing large organic material could be done in conjunction with check dams to achieve even greater success.

REFERENCE

Dissmeyer, G.E.; Foster, G.R. 1984. A guide for predicting sheet and rill erosion on forest land. Technical Publication R8-TP 6, Atlanta, GA: Southern Region; Forest Service, U.S. Department of Agriculture; 40 p.