



Final Report for Project FRJF1C

Post-fire Hillslope Treatment Effectiveness— Synthesizing 10 years of Knowledge

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I. Abstract

This synthesis of post-fire treatment effectiveness describes our current knowledge of the factors that impact hillslope treatment effectiveness and reviews post-fire hillslope emergency stabilization treatment research and monitoring with an emphasis on the past decade. Since 2000, erosion barrier treatments (contour-felled logs, straw wattles), which were a mainstay of post-fire management prior to 2000, have declined in use for hillslope stabilization. At the same time, mulching treatments are increasingly being applied when values-at-risk warrant protection. This change has been motivated by research that shows the proportion of exposed mineral soil (or conversely, the proportion of ground cover) to be the primary factor in the amount of post-fire hillslope erosion. Erosion barrier treatments provide little ground cover and have been shown to be less effective than mulch, especially during short-duration high-intensity rainfall events that often result in the largest erosion responses.

Innovative options for producing and applying mulch materials have made it possible to apply ground cover over large burned areas that are inaccessible by road. Although longer-term studies on mulch treatment effectiveness are still on-going, early results and short-term studies have shown dry mulches (agricultural straw, wood strands, wood shreds, etc.) to be highly effective post-fire hillslope stabilization treatments. Consequently, it has become more common to apply post-fire mulch treatments to protect high values-at-risk. Hydromulches, and to a lesser degree, soil binding chemical treatments have been used after some fires but these treatments have been less effective than dry mulches in stabilizing burned hillslopes and generally decompose or degrade within a year.

II. Background and purpose

It has been nearly a decade since the research for *Evaluating the Effectiveness of Postfire Rehabilitation Treatments* (Robichaud and others 2000) was completed. Given the increased use and high cost of post-fire hillslope stabilization treatments, the effectiveness of these treatments continues to be a great concern. Land and resource managers need reliable information on treatment effectiveness if they are to protect values-at-risk from potential post-fire damage from flooding and erosion. Two recent Government Accounting Office reports were critical of the lack of documented evidence of post-fire treatment effectiveness while spending on treatments continues to escalate (GAO 2003, 2006).

Research and monitoring results from the past decade are beginning to provide the data needed to predict hillslope treatment effectiveness in a range of post-fire environments. However, this up-to-date treatment effectiveness information generally is found in various professional journals and agency reports that are not easily accessed by Emergency Stabilization and Restoration (ES & R) and Burned Area Emergency Response (BAER) Teams. The need to summarize and provide post-fire hillslope treatment effectiveness information in readily available, easy-to-use formats motivated the JFSP to include this synthesis in the “Summaries of Knowledge for Managers” section of their webpage.

Prior to writing this proposal, we contacted five land managers from five public land agencies and asked them what format(s) would be most useful for this type of information. The land

managers who are most involved in post-fire assessment and treatment decisions wanted the authors to glean the salient conclusions from research studies and present that information along with implications for post-fire stabilization and rehabilitation treatment decisions. Respondents intimated that they would likely use this information on an “as needed” basis when actively involved on a BAER or ES & R team or in post-fire assessment team trainings. Based on those responses and past experience, this synthesis is being published as a USDA-Forest Service General Technical Report, which will be available as a printed document and electronically in pdf format. An abridged version of the report has been developed and posted on our website (<http://forest.moscowfsl.wsu.edu/BAERTOOLS/HillslopeTrt/>).

III. Study description

Significant factors that impact post-fire treatment effectiveness were described. The environmental factors (such as rainfall characteristics, soil burn severity, and ground cover remaining) were summarized in the **Introduction**. In addition, treatment performance characteristics (such as longevity, resistance to wind displacement, and sediment trapping ability) have been described for each treatment type.

A review of quantitative results, both from technical reports and peer-reviewed publications, was done to determine the proven effectiveness of various hillslope treatments. Many issues of comparison and normalization became apparent among studies where 1) measurements were made at different scales and with different methodologies; 2) there were significant differences in research sites (including lab and field studies), rainfall, length of studies, etc.; and 3) there were many data sets with minimal or no statistical analyses to support conclusions. In addition, there were too few studies available to report hillslope treatment effectiveness by ecoregions. These issues were resolved to provide BAER teams and managers with as much information as possible and caveats where needed. The results from research and monitoring studies were tabulated, put into a common table format, and a common metric of treatment effectiveness (percent reduction in sediment yield) was applied. These tables were published in the appendices by treatment type. The study conclusions were summarized by treatment type in both the text and the appendices of the document.

The **Management Implications** section and the *Summary Chart of Hillslope Treatment Effectiveness and Performance Characteristics* describe a collective (authors and reviewers) sense of treatment effectiveness, which cautiously speculates beyond conclusive science. However, as stated above, our goal is to provide post-fire assessment teams with as much guidance as possible given the current state of our knowledge.

IV. Key findings

Key findings have been summarized on webpages that are available at <http://forest.moscowfsl.wsu.edu/BAERTOOLS/HillslopeTrt/>

The *Summary Chart* is included here:

Hillslope Treatment Effectiveness and Performance Characteristics Summary Chart

Ratings of post-fire hillslope stabilization treatment effectiveness for three rainfall regimes (high intensity, low intensity, and high total amount; see fig. 4 and Table 1 in main text) are presented in the table below. Treatment effectiveness codes: 1=more effective; 2=somewhat effective; 3=not effective.

Treatments are also rated as more likely (more) or less likely (less) to exhibit performance characteristics that impact treatment effectiveness, post-fire recovery, and/or the environment. Other phrases are used to describe the performance characteristics of treatments that are dependent on circumstances or are not effectively rated as more or less likely. Details of treatment performance characteristics can be found in the individual treatment sections of the main text.

[Chart on following page]

		Post-fire hillslope stabilization treatments					
		Straw mulches	Wood mulches	Hydro-mulches	Soil binders (PAM)	Contour-felled logs (LEBs)	Straw wattles
Overall effectiveness (rating: 1, 2, 3)	High intensity rainfall (>2 yr return interval)	1	1	3	3	3	3
	Low intensity rainfall	1	1	1	2	1	1
	High rainfall amount (>2 in [50 mm] in 6 hrs)	1	1	2	3	2	2
Performance characteristics that impact effectiveness	Resistant to wind displacement	less ^a	more ^a	more	more	more	more
	Remains functional for more than 1 yr	more	more	less	less	more	more
	Provides ground cover	more	more	more	less	less	less
	Increases infiltration	more	more	not known	depends on conditions	less	less
	Increases soil moisture retention	more	more	more	less	less	less
	Shortens flow paths	more	more	less	less	more	more
	Traps sediment	more	more	less	less	more	more
Other considerations	Slows development of concentrated flow	more	more	more	more	less	less
	Contains noxious weed seeds	possible	less	less	less	less	possible
	Delays re-vegetation	depends on mulch thickness	depends on mulch thickness	less	less	less	less
	Harmful to the environment	less	less	depends on components	depends on type and concentration	less	less

^aIn wind tunnel tests, agricultural straw resisted movement in wind speeds of 15 mi h⁻¹ (6.5 m s⁻¹) and wood straw resisted movement in wind speeds of 40 mi h⁻¹ (18 m s⁻¹) (Copeland and others 2006).

V. Management implications

Post-fire emergency hillslope stabilization treatments cannot prevent erosion, but they can reduce overland flow, erosion, and sedimentation, thereby reducing the risk to public safety and of damage to structures, roads, water quality, and critical habitat. However, the effectiveness of any hillslope stabilization treatment will depend on the actual rainfall amounts and intensities, especially in the first years after the fire (Robichaud and others 2000; Robichaud 2005). The need to protect the valued resources in and around burned areas has motivated efforts to refine post-fire erosion prediction models, improve the effectiveness of post-fire treatments, and evaluate new treatment technologies.

Longer-term Treatment Effectiveness

The BAER treatments are, by definition, emergency protection of public safety and short-term stabilization of burned landscapes. When the BAER program was established it was generally assumed that most burned sites were well-stabilized within three years of burning. Subsequent research has shown that this is not always the case (Robichaud and others 2008b). Some sites, especially in arid or semi-arid regions where naturally sparse ground vegetation leaves exposed bare soil, may need erosion protection for more than three years after a fire. Thus, the length of time a treatment remains effective has become more of concern as we gain a better understanding of the recovery process for various ecosystems.

Choosing Treatments

Since 2000, we have seen spending on post-fire treatments increase along with fire suppression costs, and like suppression spending, BAER costs have come under scrutiny and cost containment protocols are being explored. Treatment justification has been reframed from “reducing a threat” to “protecting values-at-risk” so that the values-at-risk for damage or loss are clearly identified before an area is designated for treatment (Calkins and others 2007). The cost of repairing or replacing those identified values-at-risk is weighed against the cost of treatment and the potential treatment success. In some burned areas the “no treatment” option may be the most appropriate response. This is particularly true for areas burned at low or moderate severity where adequate ground cover is provided by remaining forest floor material and natural mulch, such as scorched conifer needles, and areas where rapid natural recovery is expected. In addition, the “no treatment” option may also be appropriate in areas burned at high severity that do not pose a high risk to identified values.

There is no single best approach to post-fire hillslope stabilization. The *Summary Chart* generally rates treatments based on known effectiveness. However, each BAER team will have to match their treatment recommendations to the specific environmental and climate factors as well as the burn conditions and predicted hydrological responses of the area. The Summary Chart also includes performance characteristics that impact treatment effectiveness for currently available hillslope treatments and some positive and negative aspects pertinent to their use. These factors may guide the development and selection of new materials and methods for post-fire hillslope stabilization.

The selection of “best available” treatment can be challenging for BAER teams. This synthesis of post-fire hillslope treatment effectiveness is a direct response to the need for evaluating and

sharing treatment effectiveness information. However, a printed document is, by its nature, static—a picture of the current state-of-the-art. We have provided information on environmental factors and treatment performance characteristics that impact treatment effectiveness that can be applied to future choices even if they are not directly referenced in this report. In addition, a hillslope treatment effectiveness web-page has been added to our BAERTOOLS web page (<http://forest.moscowfsl.wsu.edu/BAERTOOLS/>) where information from this synthesis can be accessed.

VI. Relationship to other recent findings and ongoing work

This synthesis focuses on post-fire hillslope emergency stabilization treatments, including erosion barriers, mulching, chemical soil treatments, and combinations of these treatments. This is a narrow focus given the range of post-fire emergency responses typically implemented by BAER teams (see Napper 2006 for a comprehensive review of post-fire treatments). However, these hillslope treatments are usually the most expensive post-fire treatments used, which makes cost effectiveness an important issue in their selection. In addition, recently completed reports synthesize the current information for other post-fire emergency treatments. For example, a synthesis of broadcast seeding, one of the first and most extensively used post-fire hillslope treatments (Robichaud and others 2000), is thoroughly discussed in the deliverables from the concurrent, but separate, JFSP Project 08-2-1-11, *Post-wildfire Seeding in Forests of the West: Trends, Costs, Effectiveness, and Use of Native Seed*.

Post-fire stabilization treatments for roads are frequently implemented to facilitate the passage of potentially larger post-fire water flows that may damage roadway, culverts, bridges, etc. These post-fire road treatments and their known effectiveness are the focus of a General Technical Report, *A Synthesis of Post-Fire Road Treatments for BAER Teams* (Foltz and others 2009). This GTR is a deliverable from the JFSP 06-3-4-03 and part of the JFSP **Black Series**.

Post-fire treatments to stabilize channels or deflect large channel flows are occasionally recommended after wildfires, but there are few quantified data on treatment performance and these treatments are not discussed in this document. However some hillslope treatment effectiveness studies have been done on swales, hillslope plots that contain two convergent hillslopes forming a zero-order channel, and on small catchments that contain one or more low-order channels with a clearly defined outlet. In these studies the measured eroded sediment is trapped at the base of the hillslope swale or at the outlet of the low-order catchment channel system and includes the eroded sediment from the hillslopes and channels within the contributing area. They are included in this synthesis because hillslope stabilization treatments (as opposed to channel treatments) were evaluated.

We have synthesized the available post-fire hillslope treatment effectiveness research and monitoring data that applies to the United States. However, with few exceptions the data are from studies done in the western U.S. There are some post-fire hillslope treatment studies from Europe, particularly Spain and Portugal, but the majority of the relevant research is from the western U.S. where hillslope treatments have been implemented after large wildfires. Wildfires do occur in the central and eastern U.S., but post-fire hillslope stabilization treatments are rarely implemented and there are little or no available data on treatment effectiveness. Generally post-fire recovery occurs more rapidly in these wetter climates than in the drier western forest. However, with climate change, the risk of larger and more severe wildfires is becoming

increasing important in areas like the southeastern piedmont forests (Crumbly and others 2007). The treatment effectiveness information that has been generated in the western U.S. will likely apply to other areas if post-fire treatments are warranted.

VII. Future work needed

Several longer-term mulch studies are in progress within the western U.S. When these studies are complete and the data are analyzed, the information on post-fire mulching effectiveness will likely need to be refined to accommodate the new findings.

When BAER teams recommend hillslope treatments, they often adapt application rates, mulch formulations, and/or treatment combinations to improve the potential treatment effectiveness or to accommodate the climate or topography of the area being treated. Both private and public research and development groups are investigating new materials and methods for post-fire stabilization that are effective and have minimal negative impacts on site recovery. Efforts to make post-fire treatments cost effective will continue to motivate innovations. For all these reasons, post-fire hillslope treatments may have new facets to be evaluated. Monitoring the effectiveness of the specific treatment type and application rate for the climate (specifically the rainfall characteristics), topography, and burn severity of the area being treated is essential if treatment selection is to improve. Measurements of treatment effectiveness are most useful when they are directly related to the objective(s) of the treatment. For example, if a hillslope treatment is applied to reduce runoff and erosion, then the monitoring should measure rainfall characteristics, hillslope runoff, and erosion rates over several years. With data we can evaluate treatment effectiveness in terms of the characteristics that are known to limit effectiveness.

Research on the efficacy of post-fire channel treatments to stem post-fire floods and debris flows is also needed.

VIII. Deliverables crosswalk table

Deliverable	Description	Delivery Dates
General Technical Report	Synthesis of monitoring data and published literature on post-fire hillslope treatment effectiveness and management considerations. Document will be organized by eco-regions within the US and designed as a reference manual for post-fire assessment teams.	Completed Submitted to USDA-Forest Service, Rocky Mountain Research Station, Publication Services as a priority publication on 9 April 2010. Copies to be available in June 2010 for upcoming fire season.
Web-based database	A user-friendly synthesis of post-fire treatment performance monitoring results will be assembled and supported on our web page. Data will be accessible by eco-region and treatment type. Additional categories of organization and search may be	Basic website in place at http://forest.moscowfsl.wsu.edu/BAERTOOLS/HillslopeTrt/ Note: Eco-region information could not be developed for this synthesis as data were not available. Also, treatment effectiveness information is not

	added. Additional treatment effectiveness information from other funded JFSP projects will also be included.	being included from other JFSP synthesis projects as these projects are posted on the JFSP site and/or project webpages.
Workshops/ Training	Present post-fire hillslope treatment effectiveness synthesis information and products at national and regional BAER training meetings attended by BAER team members from Forest Service and Dept. of Interior agencies.	<ul style="list-style-type: none"> • USDA-Forest Service National and Regional BAER Coordinators Annual Meetings: <ul style="list-style-type: none"> ○ Feb 2008; Denver, CO ○ Jan 2009; Orlando, FL ○ Feb 2010; Albuquerque, NM • USDA-Forest Service, R1,4, and 6, BAER Training; April 2008; Spokane, WA • University of Idaho, Fire Ecology Course; November 2008; Moscow, ID • USDA-Forest Service Watershed Program Meeting, R1; March 2009; Missoula, MT • DOI, Pre-season BAER Training; April 2009; Boise, ID • Technical Fire Management Training-Fire Effects Strand; May 2009; Bothel, WA • USDA-Forest Service, R2 BAER Training; May 2009; Denver, CO • USDA Forest Service R5, Soils Meeting; October 2009; Redding, CA
Peer-reviewed article	An article based on the project synthesis will be submitted to <i>International J. of Wildland Fire</i> (although not request by the user agencies, acceptance by a peer-review journal validates published methodology and results)	<p>Two peer-reviewed works were published in 2009 that supersede the need to validate this synthesis in a journal article:</p> <p>Cerda, Artemi; Robichaud, Peter R. 2009. <i>Fire Effects on Soils and Restoration Strategies</i>, Volume 5 of Land Reconstruction and Management Series. Science Publishers, Enfield, NH. 579 p.</p> <p>Robichaud, P.R.; Lewis, S.A.; Brown, R.E.; Ashmun, L.E. 2009. Emergency post-fire rehabilitation and treatment effects on burned area ecology and long-term restoration. <i>Fire Ecology</i> 5(1): 115-128.</p>
Final Report	Project report on the current knowledge of post-fire hillslope treatment effectiveness and management implications.	Completed and submitted 29 April 2010

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