Continued evaluation of post-fire recovery and treatment effectiveness for validation of the ERMiT erosion model (combined proposals P07-2-2-10 and P07-2-3-06) Final Report

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Joint Fire Science Program

Project Title: Continued evaluation of post-fire recovery and treatment effectiveness for validation of the ERMiT erosion mode (Combined P07-2-2-10 and P07-2-3-06)
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I. Abstract

The use and cost of post-fire emergency stabilization treatments continues to grow. To help maximize the impact of these treatments, many assessment teams use the Erosion Risk Management Tool (ERMiT) erosion model to predict postfire erosion and mitigation effects. However, despite several completed JFSP projects, the long-term effects of these treatments remain unknown, and the ERMiT model has not been validated. Long-term post-fire erosion and runoff data on a variety of mulches and erosion barriers were collected using 12 existing sites throughout the Western U.S. The agricultural straw and wood strand mulch treatments were very effective at reducing erosion and runoff. The contour-felled log treatment was effective at reducing runoff and erosion for small storms, but was not effective for larger events. The hydromulch formulations tested in this study were not effective at reducing runoff or sediment yields. Numerous presentations, field trips, and Burned Area Emergency Response (BAER) trainings were conducted. These activities provided much-needed information about the effectiveness of stabilization treatments.

II. Background and Purpose

Wildfire is often an agent of large landscape changes within and downstream of the burned area. Increases in post-fire runoff and erosion, and subsequent increases in flooding, debris flows, and sedimentation are well documented (Kunze and Stednick 2006; Lane et al. 2006; Moody et al. 2008a, b; Moody and Martin 2009; Shakesby and Doerr 2006; Silins et al. 2009). In areas where drought, changes to snow accumulation and melt processes, and other effects of climate change are aggravating wildfire conditions, such as in the western US, the number and severity of wildfires is likely to increase (Brown et al. 2004; Flannigan et al. 2000; Miller et al. 2009; Westerling et al. 2006). In addition, the number of people living in and around wildland urban interface areas continues to increase putting human life and safety, property, and infrastructure as well as drinking water quality, aquatic habitat, and valued natural and cultural resources at risk from wildfire and the secondary effects of wildfire (Robichaud 2005;

Robichaud 2009; Stewart et al. 2003). Consequently, post-fire management efforts may include use of hillslope stabilizing treatments to protect public health and safety and to reduce potential damage to resources from increased flooding, erosion, and sedimentation (Robichaud et al., 2010).

Given this increased use and high cost of post-fire stabilization treatments, the effectiveness of these treatments is of great concern. Two recent Government Accounting Office reports—Wildland Fires: Better Information Needed on Effectiveness of Emergency Stabilization and Rehabilitation Treatments, GAO-03-430; and Wildland Fire Rehabilitation Forest Service and BLM Could Benefit from Improved Information on Status of Needed Work GAO 06-670—were critical of the lack of documented evidence of post-fire treatment effectiveness while spending on treatments continued to escalate.

Early results of post-fire effects research suggested that post-fire erosion rates decrease by an order of magnitude with each post-fire year and that erosion rates returned to pre-fire levels by the third post-fire year (Robichaud and Brown 2000). This early perception, along with forest service policy limiting BAER program funding to three years, influenced the planned 3 year duration of our post-fire stabilization treatment effectiveness studies. However, our sites experienced rainfall and erosion events after the third post-fire year, and these events indicated that post-fire erosion recovery rates may be less tied to the number of years of recovery and more dependent on rainfall intensity and other site characteristics (Robichaud et al. 2008).

Early observations from these watersheds and complementary graduate research were used to develop the framework for the Erosion Risk Management Tool (ERMiT) interface. The ERMiT model provides realistic expectations of erosion mitigation treatment performance with probability-based output specifically designed for risk analysis by BAER/ESR teams (Robichaud et al. 2007a and b). ERMiT is currently available (http://forest.moscowfsl.wsu.edu/FSWEPP) and being widely used for post-fire assessment and treatment decisions. The prediction engine in ERMiT is the Water Erosion Prediction Project (WEPP) model, which is used to produce a probabilistic output of burned area sediment yields. The development and initial calibration and testing of the ERMiT model was completed under JFSP 98-1-4-12 and JFSP 01-3-02-08.

The goal of this project is to collect additional long-term post-fire recovery and treatment effectiveness data for various ecosystems and to use this data to validate the ERMiT model.

Project Objectives:

1) Measure runoff and erosion on 6 paired watershed sites (14 watersheds) and 5 hillslope-plot sites to evaluate post-fire mitigation treatment effectiveness.
2) Document post-fire recovery in forested burned areas beyond the first 3 years.
3) Incorporate new information on post-fire recovery and treatment effectiveness into databases, articles, and reports.
4) Statistically validate ERMiT erosion predictions in forested areas for up to five post-fire

years with existing and newly acquired erosion data collected from existing paired watershed and hillslope-plot sites.
5) Incorporate new information on recovery and treatment effectiveness into training opportunities for post-fire assessment teams, including the use of the ERMiT model's probabilistic output in risk-based decision making, treatment selection, and the design of treatment performance monitoring efforts.
6) Assemble and post a web-based database of regional post-fire erosion rates and the effectiveness of erosion mitigation treatment.

III. Study Description and Location

Study Site

To quantify the effectiveness of some post-fire mitigation practices, small paired watersheds (4 to 20 ac [2 to 10 ha]) were installed between 1998 and 2003 in various ecosystems throughout the western U.S. after eight major wildfires (Figure 1). Each site contained one burned, untreated watershed as a control and at least one watershed treated with one of the following post-fire mitigation treatments: contour-felled log erosion barriers; straw mulch; or hydromulch. Three of the oldest sites (Mixing, North 25, and Valley Complex, and Fridley) were removed after 4-6 years of monitoring but treatment effectiveness has been continuously measured in the remaining sites. Hillslope scale silt fence plots (⅛ to 1 ac [0.05 to 0.4 ha]) were also installed at eight sites to measure the impact on sediment yields of one or more of the following treatments: straw mulch; hydromulch; wood strands; native seeding; and needle cast. All sites were characterized by moderate or high burn severity and the soil type, topography, and vegetation type were documented. Rigorous data quality standards were used for all measurements including precipitation, runoff, peak flow, sediment yield, ground cover, and soil water repellency.

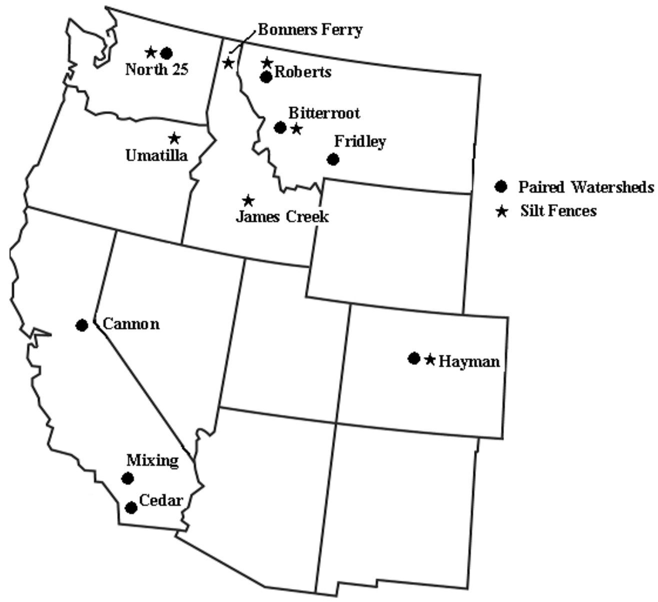

Figure 1. Burned area emergency stabilization monitoring sites in the Western U.S. The Hayman site in Colorado has two paired watershed sites.

BAER Treatment Effectiveness Studies-Watershed Monitoring Sites (Figure 1):

- 1998 North 25, Wenatchee NF, WA (contour-felled log erosion barriers)
- 1999 Mixing, San Bernadino NF, CA (contour-felled log erosion barriers)
- 2000 Valley Complex, Bitterroot NF (contour-felled log erosion barriers)
- 2001 Fridley Fire, Gallatin NF, MT (contour-felled log erosion barriers);
- 2002 Hayman Fire, Pike and San Isabel NF, CO (contour-felled log erosion barriers);
- 2002 Hayman Fire, Pike and San Isabel NF, CO (straw mulch and hydromulch);
- 2002 Cannon Fire, Humbolt-Toiyabe NF, CA (contour-felled log erosion barriers);
- 2003 Cedar Fire, Viejas Reservation, Cleveland NF, CA (50 % and 100 % hydromulch);
- 2003 Robert Fire, Flathead NF, Montana (straw mulch)

BAER Treatment Effectiveness Studies—Hillslope Plots Monitoring Sites (Figure 1):

- 2002 Hayman Fire, Pike and San Isabel NF, CO (wood strands, straw mulch); 24 plots
- 2003 Myrtle Creek Fire, Idaho Panhandle NF, ID (hydromulch, straw mulch, needle cast); 24 plots
- 2003 Hot Creek Fire, Boise NF, ID (straw mulch); 12 plots
- 2005 School Fire, Umatilla NF, WA (wood strands, straw mulch, hydromulch with native seed, and native seed); 35 plots

Data Collection and Sampling

Paired watershed studies consist of two adjacent catchments (4 to 20 ac [2 to 10 ha]) that were closely matched in size, slope, aspect, elevation, soil characteristics, and burn severity. One catchment had a post-fire rehabilitation treatment applied and one was left untreated as a control. Hillslope plots, using silt fences to capture mobilized sediment, were generally installed in treated sets across hillslopes with a nearby untreated control area. These existing sites were maintained and monitored to measure post-fire treatment effectiveness and post-fire recovery for up to eight years.

To compare data from different sites, past data collection methods were continued (Robichaud and Brown 2002, 2003; Robichaud 2005). Precipitation data (amount and duration) were measured and associated with the resultant runoff, peak flow, and sediment yield measurements for the paired watersheds, and sediment yield measurements for the hillslope plots. The paired watersheds had continuous recording stage and depth measuring devices in the sediment traps (Figure 3). These devices, in conjunction with a v-notch weir, allowed runoff to be accurately measured for each storm. Accumulated sediment was removed from sediment traps at least semi-annually and more often when large events occurred. Sediment was removed from the sediment trap or silt fence area, weighed, sampled, and discarded down slope. Static site characteristics, such as soil properties, topography, and burn severity, were recorded and dynamic characteristics, such as ground cover and water repellency, were measured annually.

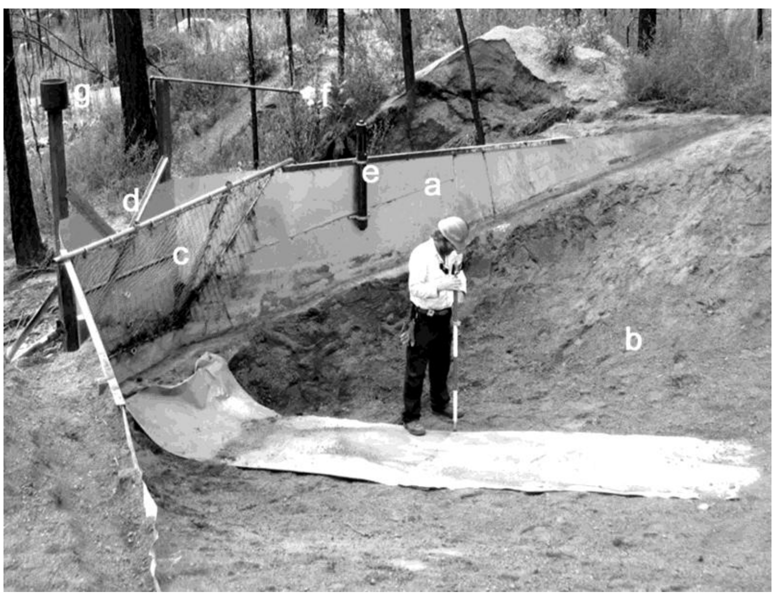

Figure 3. A typical sediment trap and instrumentation: a) sheet metal head wall; b) sediment deposition area; c) trash rack; d) V-notch weir; e) stage gauge; f) ultrasonic gauge to measure depth of accumulation; and g) tipping bucket rain gauge.

ERMiT model runs were conducted for each site. Inputs included: climatic conditions, soil type, burn severity, and hillslope length and angles. Output results were statistically compared to field measurements to derive a measure of fit. The data garnered from the extended monitoring period of existing sites were included in the validation.

Statistical Analysis

Ground Cover The ground cover was averaged by cover category for each plot (1 to 3 measurements per plot). Each plot was then treated as an independent observation of cover for each site. Repeated-measures analyses were conducted for each site using each plot as the subject and the post-fire day as the period of repetition. Least significant differences were used to compare differences in least-squares means (Littell et al., 2006; SAS Institute Inc., 2008).

Hillslope Plots The sediment yield and 10-min maximum rainfall intensity (I_{10}) data were normalized to compare data from across sites. Sediment yields were divided by the mean sediment yield from that site's control plots in the first post-fire year. I_{10}'s were divided by the intensity of that site's 2-yr, 10-min return interval rain storm. The sediment yield and I_{10} data were then log-transformed to homogenize the variance of the residuals (Helsel and Hirsch 2002). To log-transform data with zero values, 0.005 Mg ha^{-1} was added to all sediment yield values.

Watershed Data The runoff, peak flow rates, and sediment yields were expressed as per unit area (mm, m^3 s^{-1} km^{-2}, and Mg ha^{-1}, respectively) by dividing by the watershed area. The runoff ratio was the event runoff divided by the event rainfall. Runoff (and peak flow) consisted of water and transported sediment. The event runoff was the sum of residual volume of water and sediment in the sediment trap and the total flow through the weir during each event. The peak flow rate for each watershed and event was the maximum of either the peak flow rate through the weir or the maximum change in sediment trap volume per unit time. The runoff, peak flow, and sediment yield data were square-root transformed to homogenize the variance of the residuals (Helsel and Hirsch 2002).

We assumed that, before treatments were applied, each of the treated watersheds was equal to its respective control watershed with respect to per-unit-area runoff rates, per-unit-area peak flow rates, and per-unit-area sediment yields. This assumption allowed us to test whether the slopes in the statistical models differed from one. When the values were different, the difference in slope was attributed to a post-fire treatment effect.

For the hillslope plots and watersheds, repeated measures analyses were used to test for significant relationships in transformed runoff, peak flows, and sediment yields between the treated and control watersheds (hillslope plots) for each event with complete data. A serial correlation among measurements was included in the repeated measures models by assuming a spatial power function of the number of days after burning for each event at each site (Littell *et al.* 2006). The years since burning, rainfall total, I_{10}, and I_{30} were also tested as covariates (Helsel and Hirsch, 2002).

ERMiT Validation Since ERMiT is a probabilistic model, traditional measures of model efficiency, such as the Nash-Sutcliffe model efficiency, or Root Mean Square Error (RMSE), were inappropriate. Instead, we used an analysis of overlapping ranges of predicted and observed sediment yields to determine model performance as well as a comparison of median and mean values for each location.

IV. Key Findings

1) Objective: Measure runoff and erosion on the nine remaining paired watershed sites and five hillslope-plot sites to evaluate post-fire mitigation treatment effectiveness.

- The paired watershed study from the contour-felled log erosion barriers watersheds indicated that this treatment can reduce sediment yields, runoff, and peak flows for small storms—less than a 2 year return period—but have little effect for larger storms (Robichaud et al. 2008).
- Contour-felled log erosion barriers can have several defects – both from improper installation and from degradation over time – that reduce their effectiveness. The most commonly observed defect in the present study was logs that had being installed or later moved off-contour, which often resulted in scouring and rill formation (Robichaud et al. 2008).
- The peak flows and sediment yields were smaller in the straw mulch watershed than control watershed at the Hayman site for all years. There was less runoff from the straw mulch treated watershed than the control watershed for post-fire years 2 and greater.
- There was no difference in runoff rates, peak flows, or sediment yields between the hydromulch treated watershed and the control at the Hayman site. Measured watershed responses at the Cedar site were attributed to differences in the watersheds and not to hydromulch treatment effects as essentially no hydromulch remained on the site just four months after burning.
- On the hillslope plots, the control and treated sediment yields decreased significantly over time, with the greatest sediment yields measured in the first post-fire year and the smallest in post-fire year 4.
- At the Myrtle Creek site, both the straw mulch and needle cast treated hillslopes produced smaller sediment yields than the control hillslopes. The sediment yields in the hydromulch treatment were no different than the sediment yields in the controls and were greater than the sediment yields in the needle cast and straw mulch sites.
- At the School Fire site, straw mulch, wood strands, and seeding all reduced sediment yields compared to the control plots. Hydromulch did not reduce sediment yields compared to the controls, and the hydromulch sediment yields were significantly greater than those in the straw mulch, wood strand, and seed treatments. At the Hayman site, wood strand mulch was also effective at reducing sediment yields.

2) Objective: Document post-fire recovery in forested burned areas beyond the first 3 years.

- The North 25, Mixing, Hayman and Cannon site data show that given a storm with a large enough intensity, considerable erosion rates can occur in post-fire years 4 or greater. The recovery period required for post-fire runoff, peak flows, and sediment yields may be longer than previously reported for selected regions (e.g., Colorado Front Range).
- The time since burning was a significant factor in explaining variation in sediment yields for the Hayman and Cedar sites; however, the impact on later post-fire sediment yields was not consistent across all watersheds. There was no sediment produced in the straw watershed after post-fire year 2. In contrast, the Hayman hydromulch and both the Cedar

hydromulch watersheds produced sediment in each post-fire year. The sediment yields in the later years continued to decrease at these sites as time progressed.
- Vegetative recovery rates varied between sites which reflected differences in climatic conditions and site characteristics. Ground cover of at least 60% is necessary to significantly reduce sediment, and indicate that ground cover closer to 70-80% may be necessary to reduce sediment yields to background values or negligible levels.

3) Objective: Incorporate new information on post-fire recovery and treatment effectiveness into databases, articles, and reports.

- A synthesis of treatment effectiveness was written and published as a General Technical Report. This publication combined results from JSFP project 08-2-1-10 and this project. Other publications listed below include data from these sites used in the current project. Additionally, there have been several presentations and seminars to inform land managers, BAER teams, the public, and other research and academic institutions about the findings from these study sites.
  - Robichaud, P.R., L.E. Ashmun, B.D. Sims. 2010. Post-fire treatment effectiveness for hillslope stabilization. GTR-RMRS-240. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 62 p.
  - Riechers, G.H.; Beyers, J.L.; Robichaud, P.R.; Jennings, K.; Kreutz, E.; Moll, J. 2008. Effects of three mulch treatments on initial postfire erosion in North-Central Arizona. Session C. USDA Forest Service Gen. Tech. Rep. PSW-GTR-189. 107-113.
  - Robichaud, P.R.; Pierson, F.B.; Brown, R.E.; Wagenbrenner, J.W. 2008. Measuring effectiveness of three postfire hillslope erosion barrier treatments, western Montana, USA. Hydrological Processes 22:159-170.
  - Robichaud, P.R.; Wagenbrenner, J.W.; Brown, R.E.; Wohlgemuth, P.M.; Beyers, J.L. 2008. Evaluating the effectiveness of contour-felled log erosion barriers as a post-fire runoff and erosion mitigation treatment in the western United States. International Journal of Wildland Fire 17:255-273.
  - Cerdà, Artemi; Robichaud, Peter R., eds. 2009. Fire effects on soils and restoration strategies. Enfield, NH: Science Publishers (USA). 605 pages. ISBN 978-1-57808-526-2. (PI Robichaud also coauthored six chapters)

4) Objective: Statistically validate ERMiT erosion predictions in forested areas for up to five post-fire years with existing and newly acquired erosion data collected from existing paired watershed and hillslope-plot sites.

- ERMiT validation runs were completed for 6 watersheds with contour-felled log erosion barrier treatment (North 25, Fridley, Valley, Mixing, Hayman and Cannon); and 3 watersheds with straw mulch and hydromulch treatments (Cedar, Hayman, Robert).
- The climate generator within the WEPP model (CLIGEN) generated reasonable 10-minute rainfall intensities for each site as compared to the published NOAA 10-minute rainfall intensities as well as the observed maximum 10-minute rainfall intensities for each location.

- The ERMiT Model under predicted sediment yields for the Colorado site (Hayman) and over predicted sediment yields for the California (Mixing, Cedar, and Cannon) and Northern Rockies (Valley, Fridley and Robert) sites. The observed sediment yields fell within the predicted range of sediment yields for 97 of 122 site-years. The mean predicted sediment yield across all sites was 2.9 Mg ha^{-1} as compared to a mean observed sediment yield of 2.0 Mg ha^{-1}. The range of values predicted by ERMiT where similar to the observed range of values 77 percent of the time. The median of the ERMiT predictions was greater than the mean, typical of a skewed distribution dominated by a few very large events.
- The vegetation recovery rates used in the ERMiT model affect predicted post-fire sediment yields. The sediment yield validation data from post-fire years 3 through 7 indicate that the recovery curves are appropriate for the California and Northern Rockies sites, but the recovery for the Colorado site (Hayman) occurs too quickly.
- Possible improvements to the ERMiT model include modifying the rainfall duration, shortening the time to the peak intensity, or decreasing the soil water content before the storm, reducing the effects of snowmelt.

5) Objective: Incorporate new information on recovery and treatment effectiveness into training opportunities for post-fire assessment teams, including the use of the ERMiT model's probabilistic output in risk-based decision making, treatment selection, and the design of treatment performance monitoring efforts.

- PI Robichaud presented treatment effectiveness results, models and model performance information to national BAER Training conferences during the past 8 years
- In 2008, eight presentations were made to BAER teams and land managers at trainings, conferences and workshops.
- In 2009, 10 presentations by PI Robichaud and Co-PI Elliot were made including a FSWEPP workshop, professional meetings and an international meeting.
- In 2010, 4 presentations by PI Robichaud were made for national and regional meetings and trainings.
- The ERMiT model is now being used for postfire assessments in Australia, Canada, Greece, Turkey, Portugal and Spain even though challenges exist on building climate files for these locations.
- The ERMiT model has become the post-fire erosion model most often selected by assessment teams.

6) Objective: Assemble and post a web-based database of regional post-fire erosion rates and the effectiveness of erosion mitigation treatments.

By combining results from a previous project JFSP # 08-2-1-10 and this project, we synthesized all available information on treatment effectiveness in a single easy to use document (Robichaud et al. 2010). While building that synthesis, we surveyed the intended audience on the format for this type of information. The survey results indicated that they prefer simple tables of ratings of all treatments for various factors. We completed that rating and made it available on our BAERTOOLS web page (http://forest.moscowfsl.wsu.edu/BAERTOOLS).

V. Management Implications

- The goal of post-fire mulch treatments is to immediately increase effective ground cover to protect soil from water-driven erosion. All three mulch treatments evaluated (wheat straw, wood strands, and hydromulch) met this requirement and increased cover to at least 60% in the first year after the fire. However, the effectiveness of these treatments varied by fire and by year.

- Wood strands were the most effective treatment in these studies. However due to its higher costs it is prudent to only consider its use when values at risk are high and treatment area size reasonable. Wood straw may be a better solution for areas that don't recover quickly or for areas that need more confidence in the treatment (i.e. extreme values at risk, such as life).

- Straw mulch significantly reduced erosion in the first post-fire year; results were mixed in subsequent years at the hillsope scale and were effective at the watershed scale for subsequent years. Straw mulch is an economically feasible treatment, and appears to be most successful where recovery is likely to occur within a year or two after the fire because of rapid natural vegetation recovery. There is an issue of potential weed contamination of straw mulch; users need to be cognizant of the impact of undesirable species and the likelihood of persistence. Straw mulch many also be susceptible to redistribution by wind in unprotected areas.

- The hydromulch treatments were not effective in the hillslope plots, yet this treatment reduces runoff, peakflow and sediment yields at the small watershed scale in Southern California (Cedar). However other site factors may have contributed to its performance.

- Southern California presents a unique situation after a fire; slopes are highly erodible and highly exposed and are often interspersed with wildland-urban areas, and wind and water conditions can be severe (e.g. Santa Ana winds). Vegetation often recovers quickly in these ecosystems, fire return intervals are historically close together, and shrubs and other vegetation are fire resistant. Thus, the need for an immediate, short-lasting, and wind-resistant treatment is apparent. The tackifier nature of hydromulch may be appropriate for these conditions because of the wind-resistance properties, and the short-term need for protection.

- Regional climate conditions combined with local geographic settings greatly influence vegetation recovery. Our data clearly indicate that recovery may be longer than previously understood for selected ecoregions and climatic regimes (e.g. Colorado Front Range).

- Variation in sediment yields in the postfire years depends on treatment longevity, vegetation recovery and when "large" events occur. Our data indicated the even when "large" events occurs in postfire years 5 to 7 when the site may "appear" recovered, large sediment yields are still possible. Thus the effects of the fire may be greater than three years.

- The ERMiT validation efforts indicated that our modeling approach, a probabilistic model is the appropriate technique to model postfire erosion. The large variability in our observed sediment yields is best represented by the probabilistic output that we designed into ERMiT. The model overestimated erosion from California and Northern Rockies sites but under estimated erosion for the Colorado Front Range.

VI. Relationship to other findings and ongoing work on this topic

This JFSP project has very strong support and interest from local and regional Forest Service managers, Department of Interior Emergency Stabilization Leadership, and BAER Teams throughout the United States. Many National Forests, BLM Districts and Native American Tribes provided financial and logistical support to help expand this project.

- Salvage logging is still a common management option after fire. We are studying runoff and erosion effects of ground based logging activities after several fires. This work is being funded JFSP # 08-2-1-10.
- Channel treatment effectiveness in postfire environment is currently being studied. One PhD student and one MS student are beginning to look at channel treatment effectiveness. J. Wagenbrenner is collecting data using a laboratory flume to determine the effectiveness of strawbale check dams as a postfire channel treatment. He modeled the sediment loading and flow characteristics from a channel on the Hayman Fire.
- Several study sites are still producing sediment from 5 to 8 year postfire. For example, the Hayman Fire and the Cedar Fire study continue to have significant runoff and erosion event. Efforts are under way to find funding to continue monitoring these sites.
- Alternative wood mulch products for post-fire erosion control are being evaluated in pilot phase studies. This includes simulated rainfall in a laboratory setting, hillslope plots and small paired watersheds of wood shred mulch areas and controls. This work is funded under JFSP # 07-1-1-01.
- Postfire road treatments are often prescribed after fires. The fire does not affect the road itself but the increased runoff and sediment from the burn area can impact the road infrastructure. We have completed a current knowledge assessment of road treatments in an easy to use GTR reference (Fotlz et al 2009) funded by JFSP # 06-3-4-03. Since published, three fires have been selected to monitor road improvement treatments with short-term funding (3 years) by regional funds.
- Improvement to the watershed scale modeling for fuel and fire effects and the subsequent impacts on fisheries habitat are be developed using various WEPP model interfaces that we have developed including the ERMiT interface . The project PI is G. Reeves under JFSP # 09-1-08-26 in collaboration with W. Elliot.

VII. Future work needed

- Additional knowledge on the longer term effects of mulch treatments on vegetation regrowth, seedling establishment and invasive species is needed to be sure that short term erosion control strategies are not creating longer ecological consequences. These mulch treatments include hydromulch, agricultural straw, wood straw and other wood-based products. These studies should be 7 to 10 years postfire when vegetation regrowth has established and is on a trajectory for its ecological succession.

- Hydromulches are continuing to be a popular treatment choice. However, various manufactures use widely different materials in their hydromulch mix thus success at one fire may not translate to success at another fire. Therefore there is a need to additional evaluation of hydromluch treatment to determine their usefulness. Additionally the chemical composition of the hydromluch mix may need additional evaluation as much of the ingredients are proprietary and therefore not known to land managers or BAER team since some manufactures chose not disclose the contents.
- From the ERMiT validation results, we have determined that ERMiT is over producing sediment in the out years for selected climates and rainfall regimes. Therefore it will be necessary to modify the ERMiT code or the WEPP code to better reflect erosion processes for these postfire conditions. Fortunately, we now have the data to understand what changes are needed. However, it will take additional funds and time to accomplish computer code modifications.
- Our users have indicated a need for an online watershed version of WEPP that uses the ERMiT template. After wildfires there are hundreds of hillslopes that need to be modeled to determine which areas pose the greatest risk. Currently time consuming hand methods are used. Thus an online watershed interface would be desired.
- Our validitation results suggested numerous erosion events occurred during the spring snowmelt period but our observations indicate that rarely do we have erosion after snowmelt. Thus improvements to the conditions and timing of snowmelt events are needed in the the WEPP technology.
- Develop and publish an easy to use web-base database of all past postfire evaluations for both the Department of Interior and Forest Service fires. This type of database would be very useful for active BAER teams who want to know what nearby Forests, BLM Districts or National Parks did for a local past fire. This past information tied with current local knowledge will make it easier for the current BAER Teams to complete their assessment and recommendations.

VIII. Deliverables

The information gained from this study has been integrated into usable models, databases, publications, and training activities. We have completed validation of the ERMiT erosion prediction model for post-fire assessment. The dissemination of newly obtained results and data are being published in peer-reviewed journals, while the impacts discovered in these studies have been disseminated via GTR publications, an online database of treatment effectiveness information, and presentations to post-fire assessment teams and land managers at workshops and conferences. All proposed products are complete, unless stated otherwise as ***in review*** at the end of the citation.

Proposed	**Delivered/status**
Annual progress reports	• Progress reports were completed for both 2008 and 2009.
Data Collection	

Collect data at post-fire treatment sites throughout the western US.	• We have actively and continuously collected sediment yield data, rainfall characteristics and ground cover for these sites through October 2010. That data is included in these analyses.
Web-based Database A user-friendly compilation of post-fire monitoring results will be assembled and supported on our web page. The data will be accessible by treatment, by recovery period, by region, or by a combination of the three.	• At the request of our user community we have published a simplified table of treatment effectiveness. The users did not want an expert system where the user selects a region, treatment, and expected recovery period, etc. Therefore, we choice a simple tabular format with simple rating system (1, 2, 3, etc.) and factorsthat influence treatment performance. This table is available at: http://forest.moscowfsl.wsu.edu/BAERTOOLS/HillslopeTrt/SummaryTable.pdf
National and Regional Meetings 1. We proposed to conduct workshops at national and regional BAER meetings for Forest Service and Dept. of Interior agencies on post-fire recovery treatment effectiveness and the use of ERMiT. 2. We also proposed to conduct two FSWEPP workshops each year that include training in the use of ERMiT.	**2008:** • Robichaud, P. (2008) BAER Treatment Effectiveness. Region 1, 4 and 6 BAER Team Leader Training, Spokane, WA, Sept 2008. • Robichaud, P. (2008) New Tools for Post-fire Assessment. Region 1, 4 and 6 BAER Team Leader Training, Spokane, WA, Sept 2008. • Robichaud, P. (2008) Update on New Tools and Treatment Effectiveness. Forest Service National BAER Coordinator's Annual Meeting, Denver, CO. May 2008 • Robichaud, P.R. (2008) Postfire assessment: models, treatments and effectiveness. US Army Corp. of Engineers, Assessment and Prediction of Wildfire Effects on Watershed Hydrology – Current Approaches and Needs, Las Vegas, NV. June 2008. • Robichaud, P.R., Lewis, S., Lentile, L., Morgan, P. (2008) Vegetation response to post-fire treatments. Fire in the Southwest – Integrating Fire into Management of Changing Ecosystems, Association for Fire Ecology Regional Conference, Tucson, AZ. January 2008. • Robichaud, P.R., Lewis, Brown, R., Wagenbrenner, J. (2008)

Effectiveness of post-fire erosion control treatments. Fire in the Southwest – Integrating Fire into Management of Changing Ecosystems, Association for Fire Ecology Regional Conference, Tucson, AZ. January 2008.

- Robichaud, P. (2008) FSWEPP Models. Presented at the Technical Fire Management Fire Effects Module, Washington Institute, Bothel, Washington. May 2008.

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2009:

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Refereed Publications 1. ERMiT Validation: ERMiT outputs will be validated using recovery data for all five post-fire years.	• We completed the validation runs for our paired watershed sites throughout the western U.S. by comparing the predicted values to the observed values. • Elliot, W. J., P.R. Robichaud, J.W. Wagenbrenner. Verification of the Erosion Risk Management Tool, ERMiT model with postfire observations. *Catena*. In final preparation for submission.
2. General Technical Report: Synthesis of	• We met the need for this project and JFS Project 08-2-1-10 in a single GTR publication; it fulfills the same function and has provided an equivalent resource to the post-fire management community. This format

data, results, and recommendations from the paired watershed sites will be compiled as an "off the shelf" reference.	was at the request of the user community: • Robichaud P, Ashmun L, Sims B. (2010) Post-fire Treatment Effectiveness for Hillslope Stabilization. *Gen. Tech. Rep*. RMRS-GTR-240. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 62 p. • Because of the quality of this particular data, we decided to synthesize all of the contour-felled log data into a single peer-reviewed journal article: • Robichaud P, Wagenbrenner J, Brown R, Wohlgemuth P, Beyers J. (2008) Evaluating the effectiveness of contour-felled log erosion barriers as a post-fire runoff and erosion mitigation treatment in the western United States. *International Journal of Wildland Fire* 17, 255-273. • We had the opportunity to measure three treatments in a single location, thus we published those results separately: • Robichaud P, Pierson F, Brown R, Wagenbrenner J. (2007) Measuring effectiveness of three post-fire hillslope erosion barrier treatments, western Montana, USA. *Hydrological Processes* 22 (2), 159-170.
3. Peer-reviewed article: ERMiT's performance and limitations will be described in a peer reviewed article submitted to *Hydrological Processes*.	• Elliot, W. J., P.R. Robichaud, J.W. Wagenbrenner. Verification of the Erosion Risk Management Tool, ERMiT model with postfire observations. *Catena* In final preparation for submission. • Elliot W, Robichaud P. (2009) Risk based erosion modeling application to forest watershed management and planning. In Morgan, R.P.C., and M.A. Nearing (Eds.). Handbook of Erosion Modeling. Oxford, UK: Wiley-Blackwell. ***In press** at Wiley-Blackwell.* • Robichaud P, Elliot W, Pierson F, Hall D, Moffet C. (2009) A probabilistic approach to modeling post-fire erosion after the 2009 Australian bushfires. In: Anderssen R, Braddock R, Newham L (Eds.), 18th World IMACS Congress and MODSIM09 International Congress on Modeling and Simulation. Modeling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, July 2009, pp. 1893-1899. • Moffet C, Pierson F, Robichaud P, Spaeth K, Hardegree S. (2007) Modeling soil erosion on steep sagebrush rangeland before and after

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4. Peer-reviewed article: a paper on the effectiveness of mitigation treatments for out-years (4-8) will be submitted to *International Journal of Wildland Fire*.	We determined that a two part publication – *part I* hillslope scale plot results and *part II* watersheds scale results would better reflect the collected data with this project. • Robichaud, P.R., S.A. Lewis, J.W. Wagenbrenner, R.E. Brown, L.E. Ashmun. Post-fire mulching for runoff and erosion mitigation, Part I: Treatment effectiveness as measured on hillslopes. *Catena* In final preparation for submission. • Robichaud, P.R., J.W. Wagenbrenner, R.E. Brown, P.M. Wohlgemuth. Post-fire mulching for runoff and erosion mitigation, Part II: seven years of runoff and sediment yields from small paired watersheds. *Catena* In final preparation for submission.

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