STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station July 2008

Erosion Risk Managament Tool (ERMiT)

by Peter R. Robichaud

Federal land management agencies have spent tens of millions of dollars on post-fire emergency watershed stabilization measures intended to minimize flood runoff, peakflows, onsite erosion, offsite sedimentation, and other hydrologic damage to natural habitats, roads, bridges, reservoirs, and irrigation systems (General Accounting Office 2003). The decision to apply post-fire treatments to reduce runoff and erosion is based on a risk analysis—assessing the probability that damaging floods, erosion, and sedimentation will occur; the values that are at risk for damage; the need for reducing the risk of damage; and the magnitude of risk reduction that can reasonably be expected from mitigation treatments. Potentially damaged resources can be identified and the costs of post-fire erosion mitigation treatment can be determined; however, the risk of damaging runoff, erosion, and sedimentation occurring and the effectiveness of mitigation treatments are not well established. Consequently, managers often must assign these probabilities and estimate treatment effectiveness based on past experience and consensus of opinion.

The Erosion Risk Management Tool (ERMiT) (Robichaud and others 2006, 2007) was developed to provide land managers with a tool to determine post-fire erosion hazard probabilities and balance the costs and potential benefits of post-fire mitigation treatments. ERMiT's "event sediment delivery exceedance probability" output can help managers decide where, when, and how to apply treatments to mitigate the impacts of post-wildfire runoff and erosion on life, property, and natural resources. Using ERMiT, managers can establish a maximum acceptable event sediment yield and determine the probability of "higher than acceptable" sediment yields occurring. For example, a short-term decline in water quality may be more acceptable than damage to a cultural heritage site, and modeling the hillslopes above these two resources would likely have different user-designated exceedance probabilities and treatment criteria. By modeling various hillslopes within a burned area, managers can determine the probabilities of erosion-producing runoff events occurring, the expected event sediment deliveries, and rates of recovery for the post-fire conditions that exist.

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Using the ERMiT Model

ERMiT is a web-based application that uses Water Erosion Prediction Project (WEPP) technology to predict erosion in probabilistic terms on burned and recovering forest, range, and chaparral lands, with and without the application of mitigation treatments. ERMiT combines weather variability with spatial and temporal variabilities of soil properties to model the range of post-fire erosion rates that are likely to occur. Based on a single 100-year WEPP run and 20, 30, or 40 10-year WEPP runs, ERMiT produces a distribution of runoff event sediment delivery rates with corresponding exceedance probabilities for each of five post-fire years. In addition, sediment delivery rate distributions are generated for hillslopes that have been treated with seeding, straw mulch, straw wattles, and contour-felled log erosion barriers.

Input Data

User inputs for ERMiT are: 1) climate, 2) soil texture, 3) soil rock content, 4) vegetation type (forest, range, chaparral), 5) hillslope, 6) gradient and horizontal length, 7) soil burn severity class, and 8) range/chaparral pre-fire plant community descriptions. The interactive browser screen in ERMiT provides brief hints to the user for inputting data and links to obtain more extensive explanations related to the input parameters.

Process

ERMiT uses WEPP as its erosion calculation engine. WEPP models the processes of interrill and rill erosion, evapotranspiration, infiltration, runoff, soil detachment, sediment transport, and sediment deposition to predict runoff and erosion at the hillslope scale (Flanagan and Livingston 1995). In addition, spatial and temporal variability in weather, soil parameter values, and soil burn severity are incorporated into ERMiT. Three general steps were used to incorporate parameter variability into the model:

1. Establish a range of measured parameter values from field experiments.
2. Select five representative values from within the range.
3. Assign an “occurrence probability” to each selected value.

Temporal variation, the change in soil parameter values over time due to recovery, is modeled by changes in the occurrence probabilities assigned to the selected values for each year of recovery.

Initially, ERMiT runs WEPP for the user-specified climate, vegetation, and topography using the “most erodible” soil parameters and soil burn severity spatial pattern with the 100-year weather file. ERMiT selects the single event with the largest runoff value in each of the 100 years. From the 100 selected runoff events, the 5th, 10th, 20th, 50th, and 75th largest runoff events (and the year those events occurred) are chosen for further analysis. Each selected event year and its preceding year is run through WEPP multiple times using all combinations of the 10 soil parameter sets and four, six, or eight soil burn severity spatial arrangements. The three sources of variation (climate, soil burn severity, and soil parameters) are each assigned an independent occurrence probability. These independent occurrence probabilities are combined to determine the occurrence probability associated with each of the 100, 150, or 200 sediment delivery predictions.

WEPP is not re-run to model mitigation treatment effectiveness. Instead, treatment effects are modeled by increasing the occurrence probabilities of the less erodible soil parameters sets, decreasing the occurrence probabilities of the more erodible soil parameter sets, and/or adjusting treatment performance as compared to measured effectiveness.

Output

Output from the ERMiT analysis includes a plot of hillslope sediment delivery exceedence probabilities versus the predicted event sediment delivery amounts for each of the first five post-fire years. The mitigation treatment comparisons calculator within ERMiT allows the user to select an exceedance probability to assess the corresponding event sediment delivery predictions by different mitigation treatments for each of the first five post-fire years. The interactive probability exceedance function allows the user to define different levels of risk (exceedance probability) for potential erosion and then compare the relative effectiveness of various treatments to non-treatment as well as to one another.

Figure 1. The effects of the 2000 Valley Complex Fires on the Rye Creek drainage, Bitterroot National Forest, Montana (photo courtesy of USDA Forest Service 2000).

ERMiT Application Example

An example of an ERMiT application is presented to illustrate the user interface and model output formats and to describe the sediment delivery prediction analyses. The context for this example is the 2000 Valley Complex Fires that burned in the Bitterroot National Forest of Montana (fig 1). These large wildfires burned many steep hillslopes at high severity. The water quality of the streams and rivers within the burned area are highly valued resources that were at risk from large increases in sedimentation. This example is for a 900 ft slope adjacent to Rye Creek. The hillslope has a sandy loam soil with 25 percent rock and gradients of 15 percent at the top, 45 percent at mid-slope, and 25 percent at the toe (fig. 2). For this example, a custom climate for the site was generated in Rock:Clime (Elliot and others 1999) and the relevant climatic data needed to run the model are summarized in figure 3.

The post-fire assessment team needed to determine the risk of post-fire erosion that exceeded a tolerable limit for event sediment delivery at the base of the hillslope. To use the Mitigation Treatment Comparisons Calculator, the post-fire assessment team established the following decision criteria: 1) 3.0 ton/ac was the maximum tolerable single event sediment delivery in post-fire Year 1; and 2) straw mulch treatment will be applied if the Year 1 risk of exceeding the event sediment delivery limit (3.0 ton/ac) is greater than 10 percent and straw mulch application will reduce that risk to 10 percent or less.

By setting the output table to 10 percent exceedance probability, the post-fire assessment team was able to compare the effects of mulching at different rates (fig. 4). On the untreated hillslope, sediment delivery estimates with 10 percent exceedance probability are nearly 12.2 ton/ac, which is well above the 3.0 ton/ac tolerable limit set by the assessment team. Mulching at a rate of 0.5 ton/ac lowers the sediment delivery prediction with a 10 percent exceedance probability to 3.2 ton ac^{-1}, which is still above the tolerable limit set by the postfire assessment team. However, mulching at a rate of 1.0 ton/ac lowers the predicted sediment delivery with a 10 percent exceedance probability to 1.2 ton/ac, which is within the acceptable limits set by the team. Mulching at 1.5 ton/ac does not lower the predicted event sediment delivery enough to justify the additional mulch (fig. 4). These ERMiT predictions support the assessment team's recommendation to apply straw mulch at a 1.0 ton/ac rate on the burned hillslope.

Summary

Application of post-fire erosion mitigation treatments does not eliminate erosion, but treatments can reduce the hillslope response to many rain events. After wildfires, managers can

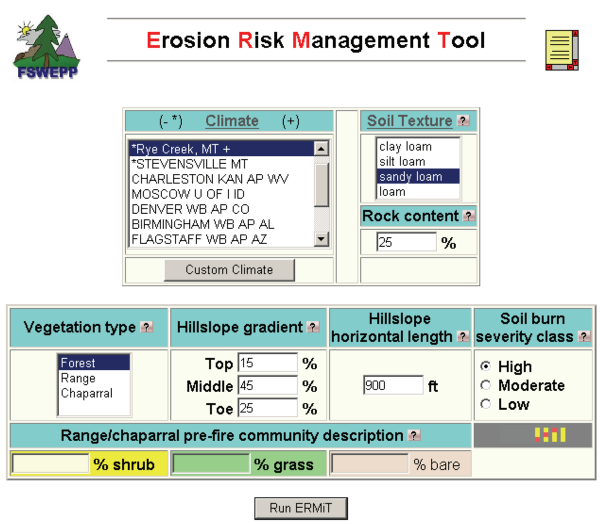

Figure 2. Input screen in ERMiT for a hillslope in the Rye Creek drainage (2000 Valley Complex Fires, Bitterroot National Forest, Montana).

use ERMiT to estimate the probabilities of erosion-producing rain events occurring, expected hillslope event sediment deliveries, and predicted rates of recovery for the burned area. In addition, realistic estimations of treatment effectiveness will allow managers to make more cost-effective choices of where, when, and how to treat burned landscapes.

Additional Information

ERMiT was released in 2006 (Robichaud and others 2006) and can be run from the Internet on the USDA Forest Service WEPP web page (http://forest.moscowfsl.wsu.edu/fswepp/). The user manual, ***Erosion Risk Management Tool (ERMiT) User Manual (version 2006.01.18),*** provides a detailed discussion of input parameters, input interface, model processing, output files, and assumptions for the model. For additional information and references, please refer to the following publication: Robichaud, P.R.; Elliot, W.J.; Pierson, F.B.; Hall, D.E.; Moffet, C.A.; Ashmun, L.E. 2007. Erosion Risk Management Tool (ERMiT) user manual (version 2006.01.18). RMRS-GTR-188. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 24 p. Copies are available online at http://www.fs.fed.us/rm/pubs/rmrs_gtr188.pdf.

Climate parameters for Rye Creek, MT +
46.36°N 113.94°E; 6986 feet elevation
81 years of record

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	32.6	14.6	4.58	9.3
February	39.4	19.1	3.54	7.1
March	48.2	24.4	3.75	7.4
April	59.3	30.5	2.86	7.3
May	67.7	37.2	3.54	8.9
June	75.0	43.8	2.88	9.6
July	84.5	46.9	1.26	5.7
August	83.1	45.0	1.91	6.0
September	71.7	38.0	1.80	6.4
October	58.9	30.4	2.00	6.4
November	43.2	23.0	3.03	8.2
December	34.4	16.9	3.67	8.7
Annual			34.81	91.0

Figure 3. Output screen of custom climate data generated for a hillslope in the Rye Creek drainage, Bitterroot National Forest, Montana. Climate data from the Stevensville, Montana climate station were used to customize the climate data for the site based on its location and elevation.

Mitigation Treatment Comparisons

Probability that sediment yield will be exceeded 10 % go	Event sediment delivery (ton ac^{-1}) Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	12.21	5.52	1.35	0.98	0.26
Seeding	12.21	3.83	1.12	0.75	0.26
Mulch (0.5 ton ac^{-1})	3.23	3.11	1.35	0.98	0.26
Mulch (1 ton ac^{-1})	1.16	1.87	1.35	0.98	0.26
Mulch (1.5 ton ac^{-1})	1.08	1.64	1.35	0.98	0.26
Mulch (2 ton ac^{-1})	0.4	1.49	1.35	0.98	0.26
Erosion Barriers: Diameter 0 ft Spacing 50 ft go ?					
Logs & Wattles	12.21	5.52	1.35	0.98	0.26

Return to input screen

Figure 4. The mitigation treatment comparisons calculator generated by ERMiT for a hillslope in the Rye Creek drainage (2000 Valley Complex Fires, Bitterroot National Forest, Montana).

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Saving West Coast Salmon

by Robert T. Lackey

Wild salmon in California, Oregon, Washington, Idaho, and southern British Columbia are in serious trouble. South of the Canadian/United States border, most runs are less than 10 percent of their pre-1850 levels and over two dozen are listed as threatened or endangered under the U.S. Endangered Species Act. Similarly, several runs in British Columbia are listed under the Canadian Species at Risk Act. Worse, from California to British Columbia, many runs have disappeared, and more will follow unless there is a reversal of the long-term downward trajectory (Lackey 2003).

The decline in west coast wild salmon numbers started with the California gold rush in 1848; the causes include water pollution, habitat loss, over-fishing, dam construction, irrigation projects, predation, competition with hatchery-produced salmon and non-native fish species, and many others (Lackey 2004). In political terms, the aspiration to restore decimated wild salmon abundance enjoys broad support; yet wild salmon numbers continue to dwindle. The social dynamics surrounding salmon restoration create what political scientists explain as a wicked, messy policy problem. It is characterized by competing societal priorities, a large and expanding human population (and the resulting pressure on natural resources), the expectation that "experts" can solve the problem with technology, and confusion caused by the unwillingness of salmon scientists and other technical experts to remain neutral in policy debates (Lackey 2007).

Given the widespread support, is there a politically viable solution to reversing the decline of wild salmon in California, Oregon, Washington, Idaho, and southern British Columbia? The Salmon 2100 Project was launched around a restaurant table in downtown Seattle, Washington in 2002, where a group of veteran fisheries scientists mulled over the conference we had attended that day. We had been assembled to discuss policy and management options for restoring wild salmon along the west coast. The atmosphere at the conference was the usual mixture of policy complexity and scientific uncertainty, overlaid with a public veneer of optimism. As always, the unspoken premise seemed to be: "if the experts could just solve the *scientific* challenges, or if we could just get sufficient *money* for fixing this or that obstacle to migrating salmon, runs could be brought back to sustainable levels."

In contrast to the *public* conference, however, the tone around the table that evening was markedly gloomy. Everyone agreed that salmon recovery was technically complex and scientifically uncertain, but the challenges were not primarily scientific. Rather, dramatic and far-reaching public policy changes were needed to reverse the decline of wild salmon in the Pacific Northwest. Everyone sitting around the table was skeptical that such dramatic changes were likely to occur.

Many of the conference participants were the same people now sitting around the table, yet the tenor of the two discussions was as different as night and day. It was as if two parallel worlds existed: the public one, with a fairly optimistic perspective, and a private one, with a highly skeptical assessment of the recovery strategies under consideration.

Why the dichotomy? Are fisheries biologists and salmon advocates creating a "conspiracy of optimism"? If the technical experts are truly pessimistic, it is not being communicated to decision-makers responsible for developing and implementing salmon policy nor to the public. To confuse matters further, the fact that most salmon caught in the region are *hatchery* fish renders the status of *wild* salmon essentially invisible to the public. As if to erase any remaining public concern about the sorry state of *wild* salmon, *farm-raised* salmon are abundant in grocery stores, available year-round, and relatively inexpensive.

The Salmon 2100 Project

The goal of the Salmon 2100 Project was to develop a variety of policy options that could, if adopted, protect and restore wild salmon runs from southern British Columbia southward. My co-project leaders and I enlisted 33 salmon scientists, salmon policy analysts, and salmon advocates; participants who often disagreed, to put it mildly, and several who only grudgingly conceded each others' right to an opinion. Nonetheless, all their views enrich the policy debate and all were invited to participate in the project.

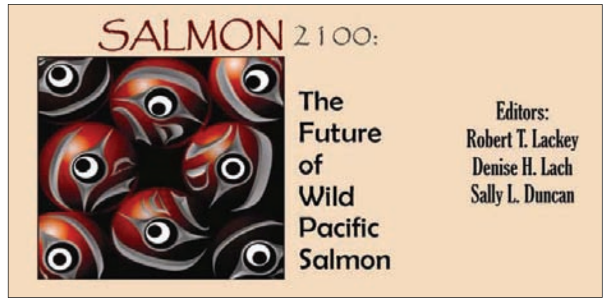
Each Salmon 2100 Project participant was asked the same question: *What specific policies must be implemented in order to have a high probability of sustaining significant runs of wild salmon through 2100 in California, Oregon, Washington, Idaho, and southern British Columbia?* Surprisingly, while nearly all participants concluded that current recovery efforts are largely ineffectual, none of them considered salmon recovery hopeless. Each author formulated at least one recovery strategy or policy prescription that could successfully restore wild salmon runs to significant levels.

What did they think would work? The policy prescriptions tended to fall into several broad approaches (Lackey and others 2006): 1) Employ Technological Intervention, 2) Apply Ecological Triage, 3) Change Bureaucracy, and 4) Domesticate the Policy Issue.

Employ Technological Intervention

Some authors openly accepted the reality that there would be a quadrupling of the human population along the west coast by 2100 and that most people will not drastically alter their life style to save wild salmon. Accepting such facts, prescriptions focused on technological intervention solutions such as habitat improvement, including creation of new "engineered" streams to replace lost salmon habitat. Society could also reverse some causes of habitat loss by removing dams, restoring vegetation, and reducing logging and road building.

Similarly, several argued that supplemental stocking from salmon hatcheries would be required to sustain salmon production at fishable levels. Some suggested that the controversy over *wild versus hatchery* salmon is misplaced, since the dispersal of hatchery fish to different streams over many decades has resulted in a massive mixing of the gene pool, making the goal of genetic purity impractical. Many authors felt that supplemental stocking could be a useful tool to assist in salmon recovery, and if society desires salmon in harvestable numbers, improvements in hatchery practices will be critical.



Apply Ecological Triage

Six of the policy prescriptions called for focusing resources and recovery efforts on the most pristine and productive watersheds. The rationale is that, despite spending billions of dollars, it is nearly impossible to restore runs once they are threatened or endangered. Some authors shared a common philosophy that at least some streams should be managed as refugia where no salmon harvest or other detrimental practices are allowed. One proposed the creation of a Wild Salmon National Park in the region, observing that one of the most successful methods for protecting endangered species is to create national parks where citizens can experience the species in its habitat. Another proposal would create salmon sanctuaries in designated watersheds where salmon will be protected and restored.

With nearly all the triage strategies, there was reluctance to bluntly identify the downside: no one wanted to "write off" (from a wild salmon perspective) the watersheds that show little promise for maintaining wild salmon runs through the balance of the century.

Change Bureaucracy

Several authors assigned responsibility for the failure of wild salmon recovery to various government agencies or specific organizations. These authors feel that successful salmon recovery would require major changes in "the bureaucracy". They observed that bureaucratic institutions are often built on practices and policies that do more to support the continued existence of the institution than to solve a particular problem. Authors identified other examples of "institutional incompetence" in salmon recovery, such as applying inflexible rules, and allowing elected officials or citizens to make decisions not based on the best available science.

Policy prescriptions included moving toward a more decentralized recovery effort, with rural residents playing key roles, and the appointment of officials who will solve problems using the best available science rather than personal preferences.

Domesticate the Policy Issue

Some prescriptions fell into a category that political scientists call "policy domestication", which is the political process of taking difficult, divisive issues off the table until a solution emerges, or the problem disappears on its own (e.g., the species is extirpated). The most common forms of domestication are funding more research, holding workshops and discussions, and tweaking current policies, to provide the illusion of action.

Clearly, offering policies that will domesticate the salmon decline issue is easier than developing policies to reverse the decline. Reversing the decline would require changing at least some of the following socio-economic realities: 1) most rules of commerce and economic growth are barriers to salmon recovery, 2) ecological options are limited by the increasing scarcity of key natural resources like water, 3) the current trajectory for the region's human population precludes many recovery goals, and 4) life-style preferences speak louder than words when it comes to support for salmon recovery.

Instead of proposing ways to change these socio-economic realities, most authors suggested variations on existing policy options: revise the Endangered Species Act or the Species at Risk Act, protect more salmon habitat, create new hatchery practices, offer K-12 education programs, and change public attitudes. The proposed domesticating strategies tacitly assume that at some future time we will formulate and agree on a viable solution. In reality, the public may not even be sure what the problem is, much less know what possible solutions exist.

Our Choices

We are currently in a holding pattern since the salmon recovery problem has been largely domesticated politically. As a society, we appear to be waiting for something to change, something that will shake us into a place where the problem becomes so apparent that the way forward is both clear and acceptable.

Society may eventually decide that the best we can do is create large-scale salmon parks, as has been done for the buffalo in Yellowstone National Park, for the enjoyment of our great-grandchildren. Historians of 2100 may wonder why we spent billions of dollars on salmon recovery when we had so many other pressing needs: poverty, defense, health care, drug abuse, crime, and disaster relief. Conversely, society may opt for making the difficult decisions to actually restore significant, sustainable runs of wild salmon.

Ultimately, of course, it is the general public that must become knowledgably engaged in salmon policy debates if effective decisions are to be made. The book, ***Salmon 2100: The Future of Wild Pacific Salmon,*** discusses what would have to change if wild salmon recovery efforts in California, Oregon, Washington, Idaho, and British Columbia are to have a chance of success.

Additional Information

Additional information and references on the Salmon 2100 project can be obtained online at http://oregonstate.edu/dept/fw/lackey/Salmon2100.htm. ***Salmon 2100: The Future of Wild Pacific Salmon*** is published by the American Fisheries Society and can be purchased for $55 online at http://afsbooks.org/x55050xm.html. The citation for the book is Lackey, R.T.; Lach, D.H.; Duncan, S.L. 2006. Editors. Salmon 2100: The Future of Wild Pacific Salmon. Bethesda, MD: American Fisheries Society. 629 p.

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STREAM NOTES

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