# Assessing Risk in a Postfire Landscape: Are Currently Available Tools Good for the Local Land Owner?

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## ABSTRACT

Wildfires and events that follow such as flooding and erosion are natural disturbances in many ecosystems. However, when these types of postfire events threaten life, property, and resources they become a concern for resource managers, communities, and private landowners. A procedure for rapid assessment that uses different tools exists for federally owned lands, however after wildfire many non-federal landowners wonder how to manage and reduce risk on their lands. For this reason it is important to understand whether tools used by federal teams are accessible and approachable for non-federal users. We critically assessed tools for evaluating postfire landscapes that are used by federal teams through a scoring system for practicality of use by private or community land managers. Each tool was scored based on three criteria: required inputs, required equipment, and available guidance. Tools were further characterized by scope, scale, use of Curve Numbers, and capacity to incorporate treatments. Results show that the Soil Burn Severity Datasheet, the Burned Area Reports Database, the Rule of Thumb by Kuyumjian, and USGS Regression Equations are most accessible for non-federal audiences. FERGI and HEC-HMS are the least transferable. Currently available postfire assessment tools are usable by non-federal audiences, with some more approachable than others. As new tools are developed, opportunities exist to build tools that are more accessible to more diverse user groups.

*Index terms:* debris flows; erosion; flooding; postfire evaluation tools; risk assessment

## INTRODUCTION

Wildfires are important natural disturbances that shape physical, chemical, and biological characteristics of watersheds (DeBano et al. 1998; Ice et al. 2004; Neary et al. 2005). Loss of vegetation and litter, as well as changes in the water repellency and stability of soils (Neary et al. 1999; Shakesby and Doerr 2006), reduces the capacity of catchments to absorb and store water, leading to enhanced hydrologic and geomorphologic activity (Tiedemann et al. 1979; Loáiciga et al. 2001; Neary et al. 2005). The likelihood of postfire flooding or erosion is strongly influenced by burn severity patterns and precipitation regimes including the timing, magnitude, and duration of storm events within burned areas (Garfin et al. 2016). When recently denuded slopes with transformed soil properties are subjected to precipitation, the result is often increased runoff, debris flows, or sedimentation in downstream rivers, lakes, and reservoirs (Rinne and Neary 1996; Bixby et al. 2015). After fire, surface runoff can increase by more than 70% and erosion can increase by up to three orders of magnitude (DeBano et al. 1998; Robichaud 2005; Foltz et al. 2009). These disturbances are natural, however in some cases events negatively impact water quality (Earl and Blinn 2003; Dahm et al. 2015), ecology (Bixby et al. 2015), wildlife (Gresswell 1999; Minshall 2003; Bixby et al. 2015), and infrastructure (Foltz et al. 2009; Moody and Martin 2009).

To reduce impacts and loss, communities, resource managers, and private landowners must be able to respond rapidly to threats from postfire events (Neary et al. 2000; Kuyumjian 2004; Robichaud et al. 2009). The first critical step is assessment because not all watersheds are equally at risk and not all postfire treatments will be equally effective or appropriate for reducing that risk (Kuyumjian 2004; Robichaud et al. 2009; LeQuire 2011). On federally owned lands this process is carried out by Burned Area Emergency Response (BAER) teams that work efficiently to reduce threats to life, property, and natural and cultural resources following wildfire (Neary et al. 2000; Robichaud et al. 2009). BAER crews are typically composed of specialists such as hydrologists, soil scientists, biologists, foresters, range conservationists, and archeologists (Kuyumjian 2004; Robichaud et al. 2009). They use a series of historically successful approaches to rapidly assess watershed condition and identify where management actions are warranted, apply treatments, and monitor their effectiveness for up to 3 y (Neary et al. 2000; Kuyumjian 2004; Robichaud et al. 2009; LeQuire 2011). Other federal programs, such as the Natural Resource Conservation Service Emergency Watershed Protection Program (EWP) help non-federal landowners address threats in burned landscapes provided the stakeholder meets certain requirements including sponsorship by local subdivisions of government (NRCS 2010).

Both BAER and EWP use several tools to collect field measurements, estimate erosion and flooding, and evaluate effectiveness of potential restoration treatments (Kuyumjian 2004; NRCS 2010; LeQuire 2011). These tools are generally well vetted, cover a range of potential applications, and can use a variety of data types (LeQuire 2011). However, many were designed for specific user groups and, as a result, can be difficult to access, require sophisticated or expensive inputs, or assume a team of specialists for implementation (LeQuire 2011). Additionally, federal land management agencies do not have the jurisdiction to complete postfire assessment or apply restoration treatments on neighboring non-federal lands (Kuyumjian 2004).

**Table 1.**—Criteria for evaluating postfire tools used by federal teams.

| Metric | 2 Score | 1 Score | 0 Score |
|---|---|---|---|
| Required Input | Inputs selected from lookup tables or database; estimations during field survey | Field survey with specific measurements | Output from another model; raster or shapefile data |
| Required Equipment | No required equipment | Commonly available equipment | Specialized equipment |
| Available Guidance | Publicly available step-by-step instructions; no guide necessary | Publicly available guide with examples | No publicly available guide; available guide that does not address modifications for use in burned landscapes |

Further, local communities and landowners are less likely to have an organized group or standardized process for evaluating postfire risk and may not be aware of the methods and tools available for assessment. Recognizing that wildfires and postfire effects cross landownership boundaries and that resources and expertise vary from federal agencies to local governments, communities, or non-governmental organizations, it is important to understand the transferability of tools and methods used by federal teams to non-federal audiences.

Here we assess the utility of currently available tools and resources for application on non-federal lands and by non-federal user groups including landowners or state and local governments. Our objective is to review the tools currently used and available for the assessment of postfire environments and characterize their usefulness for local or private land managers. To achieve this objective, we identify three critical factors that relate to tool accessibility, which we use to score each tool: required inputs, required equipment, and availability of guidance. In addition, we discuss the different types of applications produced by these tools and how they relate to various land management needs and questions.

## METHODS

### Data Collection

For this assessment, we identified federal tools through literature review, discussion with BAER team members, contact with experts in the field (see acknowledgements), and searches of websites dedicated to BAER and other postfire tools (e.g., afterwildfirenm.org). To locate literature and reports that used various tools to manage burned landscapes, we used the following search terms within Google Scholar: "postfire flooding," "postfire erosion," and "postfire debris flow." We used the same search terms to find websites dedicated to postfire response and identified recommended tools and approaches. We communicated with BAER specialists to identify the most commonly used tools and to ensure our list was exhaustive. Criteria for inclusion of a tool in this analysis included that the tool addressed some components of the postfire environment (e.g., soils, erosion), it could be used within the United States, and the tool had a demonstrated use in the field.

### Scoring System

We evaluated postfire assessment tools for usability with three metrics: (1) required input, (2) required equipment, and (3) available guidance (Table 1). These metrics relate directly to the accessibility of the tool for non-federal users and, because they are available for each tool, provide a set of common criteria for comparison. For each metric, each tool was given a score from 0 to 2, where 0 was associated with the least and 2 associated with the greatest ease of use. In this way, higher scores are associated with greater accessibility.

Required inputs consider the underlying data inputs needed to implement the tool. Tools that received the highest score, indicating greatest ease of use, rely on readily available inputs such as data selected from a database included with the tool or data easily estimated during a field survey. For example, the Soil Burn Severity Datasheet asks users to provide a rough estimate of ground cover (e.g., $<$20%, 20–50%, or $>$50%). These types of data do not require specialized knowledge to generate and most users should be able to provide the required input. We gave tools that required more specific field survey inputs, for example those that required exact measures of the area of high soil burn severity, soil rock content, or infiltration volumes, a score of 1. This type of input may require some background reading or study in order to understand data needs but, in general, is fairly simple for someone without expert or specific knowledge to generate. We assigned the lowest score of 0, indicating least ease of use, to tools that required inputs that are generated by other models or required raster or shapefile data (e.g., a differenced normalized burn ratio image). This last class of data inputs are likely to require some technical knowledge that may be more challenging for a layperson to generate on their own without additional training or by soliciting assistance.

Required equipment considers the type and availability of equipment needed to implement the tool. Specifically, we considered whether the tool required commonly available or specialized equipment. Differences in the required equipment were defined by cost, availability, and training demands, with the assumption that free or low-cost, widely available or familiar equipment with no need to undergo training are more approachable for nonexperts. We gave tools that needed only paper and pencil a score of 2; those that required basic equipment such as computers, internet, or Microsoft Excel a score of 1; and tools that needed specialized programs such as ArcGIS, modeling software (e.g., US Army Corps of Engineers' Hydrologic Modeling System), or field tools (e.g., infiltrometer) received a score of 0.

Available guidance considers the existence and accessibility of documents that provided instruction for implementing tools and interpreting results. We gave the highest score of 2, indicating greatest ease of use, to tools that either did not require directions or had a publicly available guidebook with step-by-step instructions. For example, the Emergency Assessment of Post-Fire Debris Flow Hazards does not require a guidebook, as the user simply sends materials to USGS for use in their model.

ERMiT includes a User Manual that gives instructions for accessing the model and input data and provides instructions with screenshots to walk the user through the process. The expectation is that most users will be able to generate information from the tool from these available guidebooks without additional training or technical assistance. We gave a lesser score of 1 to tools that had a publicly available guide but lacked step-by-step instructions. RUSLE2, for example, has a User's Reference Guide that provides extensive information, but does not explicitly walk the user through the process. Users may need to research additional training to use tools with this type of instruction. We assigned a score of 0, indicating least ease of use, to tools without a publicly available guide or, if available, the guide did not address how to use the tool in a burned landscape. In some cases, such as FERGI or WATBAL, the user must contact the tool manager for a guidebook. In other cases, such as HEC-HMS, the tool has many uses, one of them being postfire estimation, but no guidance exists for adapting the flexible tool for use in a burned landscape. For these tools, users will need to consult experts, the scientific literature, or take additional training in order to utilize the product correctly.

To estimate overall ease of use, we summed the scores for the three metrics for a total possible score of 6. Tools that scored higher were considered easier to use, whereas those with low scores were considered less accessible.

In addition to the scoring criteria, we collected information on four supplemental characteristics from the supporting documents for each tool: scope, scale, whether the tool uses curve numbers (CNs), and whether the tool is capable of estimating treatment effects. These characteristics do not necessarily influence accessibility, but are important information to be considered when selecting appropriate tools. Scope was characterized by the geographic location considered appropriate for tool application. Scale refers to the size of landscape at which the tool operates. Some tools can be applied at extremely local scales. In these cases, we identified the scale as "backyard." CNs are an important and influential parameter for some models that estimate runoff and peak flow. The user selects the CN based on landscape characteristics including rainfall, soils, cover type, treatment, hydrologic condition, and topography (SCS 1985). Tools that incorporate CNs require technical expertise due to the subjective nature of this particular data input. Lastly, in addition to predicting erosion, peak flow, or runoff some tools are able to further estimate how various postfire restoration treatments such as seeding, mulching, or contour-felled logs will alter postfire effects. We recorded tools with this capability as those that incorporate treatments.

## RESULTS

### Overview

We evaluated 22 tools used to assess potential risks after fire (Table 2). Of these, five are field measurement methods for collecting information on the condition of burned landscapes (Figure 1). Data collected through these techniques can in turn be used to parameterize hydrologic and geomorphologic models or to evaluate possible restoration treatments. Fifteen of the 22 tools model erosion, peak flow, runoff, or a combination of these outputs (Figure 1). One tool predicts debris flow hazard and one tool is a simple searchable database that provides users with information on previous postfire assessments (Figure 1).

### Scores

The postfire evaluation tools reviewed here varied in their ease of use with scores ranging from 6 to 0 (Table 3). The overall mean score for all tools was 3, as was the median. Tools with ease-of-use scores less than or equal to 2 fell below the 25th percentile and tools with ease-of-use scores greater than 3.75 were within the 75th percentile. Any tool with a score equal to or greater than 5 was in the top 10% of greatest ease-of-use tools. The following discussion details tool ranks by tool type, specifically, field measurement tools, models, or database type tools.

Field measurement techniques were generally the easiest to use of all tool types, with this group having an average score of 3.0 (range 2–6; Table 3). As a group, data collection procedures received low scores (less ease of use) for required inputs because they tend to rely on specific field measurements or input from other models. Field measurement tools tended to receive intermediate scores for required equipment due to the need for computers and common software (e.g., Microsoft Excel). Only the MDI Test Spreadsheet received the lowest score of 0 for required equipment due to its reliance on a specialized device, the infiltrometer. This group contained the only tool to receive a score of 6, the Soil Burn Severity Datasheet, which allows estimates in the field including selection from categories such as percent vegetative cover (<20%, 20–50%, >50%); only needs a printed copy of the datasheet and a pencil to implement, and it has a publicly available step-by-step instructional guide.

Of the 15 models that estimate erosion, runoff, and peak flow after fire events, those that estimate a single output (e.g., erosion *or* runoff) generally scored higher on the scale of usability than tools that estimate multiple outputs (e.g., erosion *and* runoff). One exception was FERGI, which received a total score of 1 and only predicts runoff. Most models received average scores below 3, indicating they are relatively difficult to use. Models that estimate peak flow had an average score of 2.8; models that predict erosion had an average score of 2.4; and models that estimate runoff had an average score of 1.8. Erosion and runoff models tend to require more sophisticated equipment, with all but one runoff model receiving scores of 0 (tool required specialized equipment) for this metric. Peak flow models received the lowest score for required inputs, with only one tool, WATBAL, receiving a score of 2.

Of the erosion-only models (Figure 1), ERMiT was the highest scoring model due to intermediate input and equipment requirements (Table 3) and publicly available step-by-step instructions. Disturbed WEPP and WEPP PEP were only slightly more difficult to use, both receiving total scores of 3, although for different reasons. Disturbed WEPP received intermediate scores for all three metrics, whereas WEPP PEP had better guidance documents but more difficult required inputs than Disturbed WEPP.

The models that estimate only peak flow were often easy to use, with three of the five receiving a score of 4 or higher (75th percentile of scores). All but FIRE HYDRO have publicly

**Table 2.**—Twenty-two tools used by federal teams to assess burned landscapes, predict secondary fire events, and evaluate potential treatments. Tools are ordered from highest to lowest score (see Table 3).

| Tool | Description | Guidance document |
|---|---|---|
| Soil Burn Severity Data Sheet | Identifies indicators of soil conditions that differentiate soil burn severity classes in order to consistently interpret, field validate, and map soil burn severity. | Parsons et al. 2010 |
| Burned Area Reports Database | A database containing postfire assessment information from four decades of US Forest Service Burned Area Reports. | USFS BAER Burned Area Reports DB Guide |
| Rule of Thumb by Kuyumjian | An equation developed by an experienced BAER hydrologist that requires minimal input information and estimates peak flow. | USFS 2009a |
| USGS Regression Equations | Methods for estimating magnitude and frequency of floods of gaged and ungaged streams | USFS 2009b |
| ERMiT | An interface for predicting the probability of a given amount of soil erosion in each of 5 years postfire and estimating hillslope treatment efficacy. | Robichaud et al. 2007 |
| StreamStats | A web-based tool that estimates magnitude and frequency of floods at gaged and ungaged streams. | USGS 2017; USFS 2009b |
| Disturbed WEPP | An interface for estimating a given level of erosion from various disturbed forest and rangeland conditions. | Elliot and Hall 2000 |
| Forest Service Peak Flow Calculator | Makes use of curve number technology to estimate peak flow. | Elliot and Robichaud 2014 |
| MDI Test Data Analysis Spreadsheet | Used in postfire assessments to provide a practical and rapid evaluation of burned soil infiltration characteristics. | Robichaud et al. 2008 |
| RUSLE2 | Estimates soil loss, sediment yield, and sediment characteristics from rill and interrill erosion caused by rainfall and its associated overland flow. | USDA-ARS 2008 |
| WEPP Pep | An interface for estimating soil erosion postfire using soil burn severity maps. | Elliot 2017 |
| Wildcat5 | An Excel-based package for predicting peak flow and runoff volumes generated by single-event rainstorms for different soil and vegetation conditions within a watershed. | Hawkins & Barreto-Munoz 2016 |
| WinTR-55 | Calculates storm runoff volume, peak flow rate, hydrograph, and storage volume in small watersheds. | NRCS 2009 |
| AGWA | GIS-based watershed modeling tool that uses national available GIS data layers to estimate and display watershed runoff and erosion. | USDA-ARS et al. 2013 |
| Emergency Assessment of Post-Fire Debris Flow Hazards | Estimation of the likelihood and volume of debris flows produced by a storm in recently burned landscapes. Provided free to Federal, State, or Local Agencies and to any private organization. | USGS 2018 |
| VAR Tool LITE | An updated, simplified, and streamlined Excel-based framework to assess risk and economically evaluate possible treatments in a burned landscape. | Calkin et al. 2007; USFS 2018 |
| VAR Calculation Tool | Aids in the identification and valuation of values-at-risk and provides an economic assessment of postfire emergency treatments | Calkin et al. 2007; USFS 2018 |
| WATBAL | Simulates potential and likely effects on streamflow and sediment regimes of timber harvest, road development, and fire. | USFS 2009c |
| WDPT | Common field test for soil water repellency that only requires a water dropper and a stopwatch. | DeBano 1981 |
| FERGI | Estimates the likelihood of postfire rainfall excess, runoff, and positions of gully initiation on hillslopes with or without treatments. | Luce 2005 |
| FIRE HYDRO | An Excel-based spreadsheet to estimate peak flow from rainfall events in burned areas | NRCS 2005 |
| HEC-HMS | A rainfall-runoff model that describes physical watershed characteristics, precipitation, and the resulting runoff and streamflow. | Scharffenberg 2016 |

available step-by-step guidelines and none require inputs from other models or raster and shapefile data. Kuyumjian's Rule of Thumb and USGS Regression Equations are especially simple in terms of their equipment requirements. The FS Calculator was the only peak flow model to score a 0 for data inputs due to its reliance on output from ERMiT.

FERGI, which estimates only runoff and is not publicly available for download, received a low usability score because it does not have a publicly available guide and requires the program to be installed on the user's computer. FERGI has intermediate data requirements, however, because the program does provide guidance for all inputs.

RUSLE2, which predicts both erosion and runoff, has an intermediate ease-of-use score. While RUSLE2 allows selection of inputs from a database indicating higher ease of use it requires installation of a specialized software program on the user's computer resulting in a low score for required equipment. RUSLE2 has a publicly available guidebook but it does not have step-by-step instructions.

Wildcat5 and WinTR-55 are very similar models that predict both runoff and peak flow and have similar usability scores. WinTR-55 has better available guidance, but requires more equipment. Both models use curve numbers, are applicable throughout the United States, and work at the watershed scale, although WinTR-55 can be applied to sub-watershed areas. The major difference between the two was that Wildcat5 is capable of estimating restoration treatment effects.

The models capable of predicting erosion, runoff, and peak flow are generally more difficult to use than models with fewer output types (Table 3). HEC-HMS was the only tool assessed to

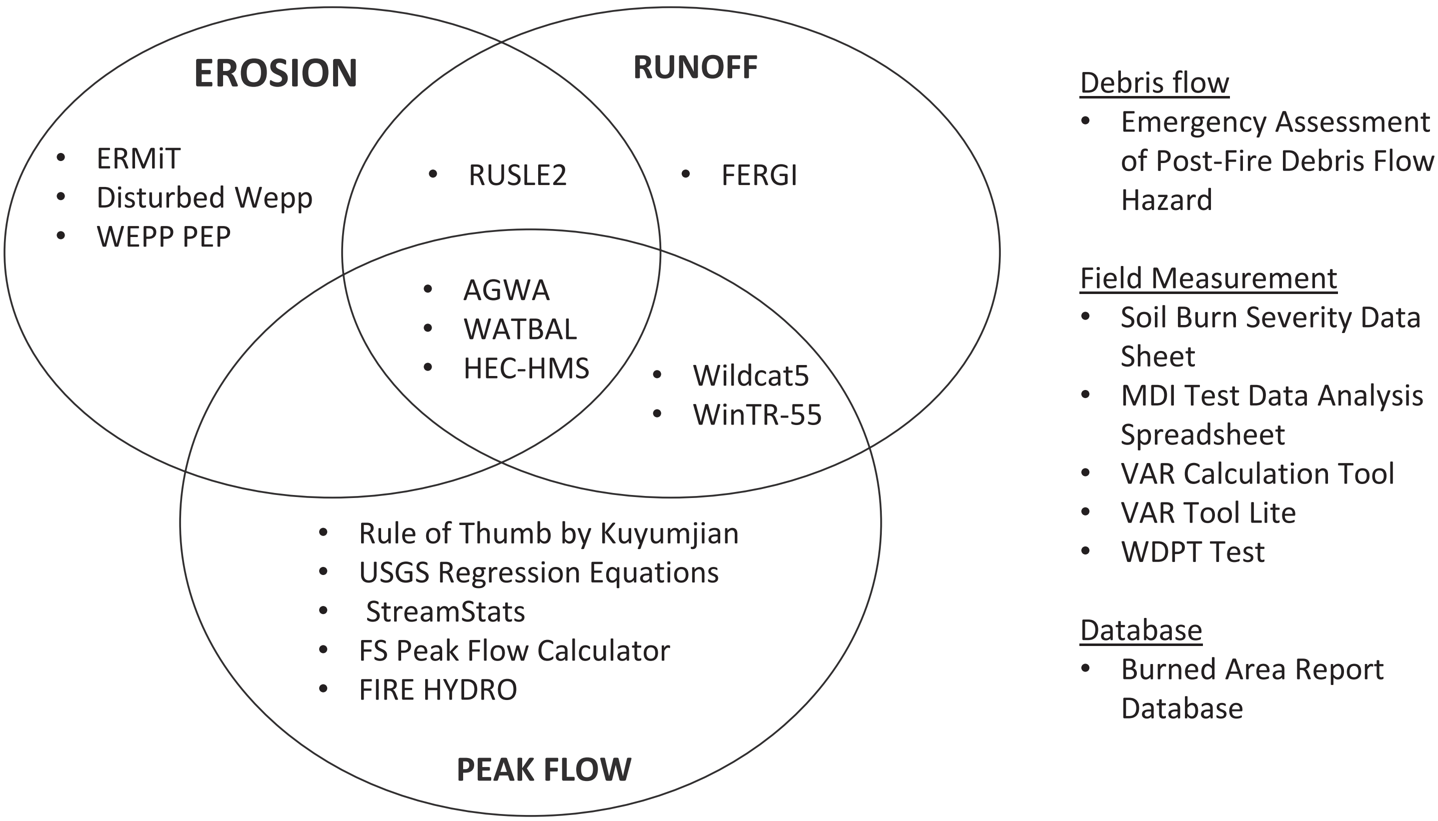


**Figure 1.**—Output types of 22 tools used by federal teams during burned area emergency response.

receive a score of 0, indicating lowest ease of use. While AGWA and WATBAL both received scores of 2, it was for different reasons. AGWA has better available guidance, but more complicated input and equipment requirements. WATBAL has more approachable inputs requirements but more complicated equipment needs and little guidance.

The final two tools include assessments of debris flow hazard and a database of federal burned area reports. For the debris flow hazard assessment, the user simply sends data to the USGS and they produce a map of the likelihood and probable volume of debris flows. While the debris flow hazard assessments score high for available guidance, they score low for both data inputs and required equipment due to reliance on raster and shapefile data and ArcGIS programs. Lastly, the Burned Area Reports Database is one of the easiest tools to use in our assessment. It has a publicly available step-by-step guide, the inputs are selected from a list, but it requires a computer and internet connection.

## DISCUSSION

Of the tools reviewed in this assessment, we identified a wide range in usability for evaluating burned landscapes and estimating postfire effects on non-federal lands (Table 3). Approximately one-third of the tools were relatively easy to use with scores of 4 or greater; one-third had an intermediate level of usability with scores of 3; and one-third were considered difficult to use with scores of 2 or less. Of the six tools that received an ease-of-use score of 4 or greater, three predict peak flow, one estimates erosion, one is used for field measurement, and one is a searchable database.

We scored tools based on their ease of use, however other factors, specifically output type, application, and scope have relevance for how useful these tools may be for non-federal users (Table 3). Users of any background will get the best results by selecting the best tool for their particular situation and needs. For instance, users may select different tools depending on their location with respect to the burned area. Users in the immediate vicinity of a burned area may need to reference tools that specifically address the risk of postfire debris flows (e.g., RUSLE2), whereas users farther downhill might be better served by one of the tools that estimate peak flow and thereby flooding risk (e.g., USGS Regression Equations). Similarly, it is likely important for landowners interested in assessing burned landscapes to consider the scale at which the tool can be applied and the scale at which the outputs are produced. It is unlikely that most private land users will need basin-scale assessment methodologies. Rather, tools like the VAR Calculation Tool, which can be used in the backyard (Table 3), and ERMiT, focused on hillslopes, are likely to provide more appropriately scaled data.

The scope of the tools relates to the user's geographic location. Tools like RUSLE2 and WATBAL have extremely limited scopes, applicable only in the Southwest and the central and northern Rocky Mountains, respectively. These more focused tools are likely to provide more tailored information on geographically relevant events, such as erosion and runoff in monsoon driven climates in the case of RUSLE2. However, users need to select

**Table 3.**—Scores relating to the usability of postfire tools based on their required inputs, necessary equipment, and available guidance. The tools vary in the types of output, geographic scope, spatial scale, use of curve numbers, and whether they incorporate restoration treatment effects.

| Tool | Output type | Required input | Required equipment | Available guidance | Scope | Scale | CN | Treatments | Score |
|---|---|---|---|---|---|---|---|---|---|
| Soil Burn Severity Data Sheet | Field measurement | Field survey estimates | NA | Step-by-step instructions, publicly available | U.S. | Backyard | No | No | 6 |
| Burned Area Reports Database | Database | Selected from database | Computer, internet connection | Step-by-step instructions, publicly available | West U.S. | Watershed | No | Yes | 5 |
| Rule of Thumb by Kuyumjian | Peak flow | Soil burn severity map | NA | Step-by-step instructions, publicly available | U.S. | Watershed | No | No | 5 |
| USGS Regression Equations | Peak flow | Topographic & soil burn severity map | NA | Publicly available guide, website with step-by-step instructions for use in burned area | U.S. | Drainage basin | No | No | 5 |
| ERMiT | Erosion | Field survey, map | Computer, internet connection | Step-by-step instructions, publicly available | West U.S. | Hillslope | No | Yes | 4 |
| StreamStats | Peak flow | Selected from database, soil burn severity map | Computer, internet connection | Publicly available guide, website with step-by-step instructions for use in burned area | U.S. | Drainage basin | No | No | 4 |
| Disturbed WEPP | Erosion | Field survey, map | Computer, internet connection | Publicly available guide with examples | U.S. | Hillslope | No | No | 3 |
| FS Peak Flow Calculator | Peak flow | Input from ERMiT, field survey, map | Computer, internet connection | Step-by-step instructions, publicly available | U.S. | Watershed | Yes | Yes | 3 |
| MDI Test Spreadsheet | Field measurement | Field survey measurements | Computer, Excel, mini-disk infiltrometer | Step-by-step instructions, publicly available | West U.S. | Backyard | No | No | 3 |
| RUSLE2 | Erosion, runoff | Selected from database | Computer, installed program | Publicly available guide | SW U.S. | Hillslope | Yes | Yes | 3 |
| WEPP PEP | Erosion | Raster data, field survey | Computer, internet connection | Step-by-step instructions, publicly available | Conterminous U.S. | Watershed | No | Yes | 3 |
| Wildcat5 | Runoff, peak flow | Field survey, map | Computer, Excel | Publicly available guide with examples | U.S. | Watershed | Yes | Yes | 3 |
| WinTR-55 | Runoff, peak flow | Selected from database, map | Computer, installed program software | Step-by-step instructions, publicly available | U.S. | Sub-watershed | Yes | No | 3 |
| AGWA | Erosion, runoff, peak flow | Raster & shapefile data | Computer, ArcGIS, Spatial Analyst Extension | Step-by-step instructions, publicly available | U.S. | Watershed | Yes | No | 2 |
| Emergency Assessment of Post-Fire Debris Flow Hazards | Debris flow | Raster & shapefile data | Computer, ArcGIS, internet connection | No guide necessary | West U.S. | Drainage basin | No | No | 2 |
| FIRE HYDRO | Peak flow | Field survey, map | Computer, Excel | No publicly available guide | West U.S. | Watershed | Yes | No | 2 |
| VAR Calculation Tool | Field measurement | Input from ERMiT, field survey, map | Computer, Excel | Publicly available guide with examples | U.S. | Backyard | No | Yes | 2 |
| VAR Tool LITE | Field measurement | Input from ERMiT, field survey | Computer, Excel | Publicly available guide with examples | U.S. | Backyard | No | Yes | 2 |
| WATBAL | Erosion, runoff, peak flow | Field survey estimates | Computer, installed program | No publicly available guide | Central & Northern Rocky Mountains | Watershed | No | No | 2 |
| WDPT Test | Field measurement | Field survey measurements | Water dropper, stopwatch | No publicly available guide | U.S. | Backyard | No | No | 2 |
| FERGI | Runoff | Field survey, map | Computer, installed program | No publicly available guide | West U.S. | Hillslope | No | Yes | 1 |
| HEC-HMS | Erosion, runoff, peak flow | Raster & shapefile data | Computer, installed program software | Publicly available guide, but not for postfire | U.S. | Watershed | Yes | Yes | 0 |

## EXAMPLES

Many examples exist of non-federal groups making use of the tools evaluated in this assessment. One such example is the Damage Survey Report for the Lower North Fork Fire that burned in the Colorado Front Range in 2012 (NRCS 2012). About 70% of the Lower North Fork Fire burned private lands, 26% burned Denver Water Lands, and 4% burned Jefferson County Open Space (NRCS 2012). A survey team composed of local community members, the Natural Resource Conservation Service, Denver Water, Jefferson Conservation District, Jefferson County, and the Colorado Forest Service assessed postfire risks and threats to life, property, and infrastructure generated by the Lower North Fork Fire. The team used a Burn Area Reflectance Classification map of soil burn severity, which they ground-truthed using field methods like the Soil Burn Severity Datasheet. Erosion estimates for single storm events were generated using the ERMiT model (NRCS 2012). The analysis ultimately did not identify immediate or long-term postfire erosion or flooding concerns and determined that no mitigation from the Emergency Watershed Protection program was needed (NRCS 2012). This is one case study that provides an example of how postfire tools are used by private landowners in collaboration with state and local governments.

Additional examples of the use of some of the tools addressed in this assessment can be found on the Collaborative Conservation and Adaptation Strategy Toolbox (CCAST) web portal. This site inventories case studies on management actions including those meant to reduce postfire flooding and erosion. Examples on the CCAST portal include "Cuenca los Ojos: Three Decades of Restoring Water Flows on Private Land in the U.S. and Mexico," which provides links to papers and recorded presentations that discuss the use of restoration techniques for reducing flash flooding and erosion. Another case study, "Cienaga Watershed Erosion Management and Restoration Plan," describes the formation of the Cienaga Watershed Partnership to develop a watershed erosion management and restoration plan based on several methods including curve number approaches. Links to the case studies can be found at:

1. Damage Survey Report for the Lower North Fork Fire: http://www.jeffersonconservationdistrict.org/wp-content/uploads/2012/04/NRCS-Lower-North-Fork-Damage-Survey-Report.pdf
2. Cuenca los Ojos: Three Decades of Restoring Water Flows on Private Land in the U.S. and Mexico: https://usbr.maps.arcgis.com/apps/MapSeries/index.html?appid=8b3d8ade64b647d8847e1abbbfda738c
3. Cienaga Watershed Erosion Management and Restoration Plan: https://usbr.maps.arcgis.com/apps/MapSeries/index.html?appid=5387aa974a85425ea3e6f2c08a33dec8

tools appropriate for their specific location. Nearly one-third of the tools can be used within the western United States (MDI Test Data Analysis Spreadsheet, Emergency Assessment of Post-Fire Debris Flow Hazards, ERMiT, FERGI, Burned Area Reports Database, FIRE HYDRO). WEPP PEP is applicable within the conterminous United States and the remaining 13 tools can be used anywhere in the United States (Table 3).

Non-federal users also may want to consider whether a tool requires selection of a CN. We identified seven tools that include CNs as a parameter and these tend to be the tools capable of estimating multiple outputs. Of the six tools that predict a combination of erosion, peak flow, and runoff, WATBAL is the only one that does not require a CN. Tools that do rely on selection of a CN were relatively more difficult to use, with an average score of 2.3. Because outputs from these tools are extremely sensitive to the CN and selection of an appropriate CN requires some technical expertise (White 1988; Grove et al. 1998), users not familiar with this technology may want to select one of the tools that does not incorporate CNs. Those that do not use CNs cover all output types, giving users many viable options.

Private landowners, communities, and non-governmental organizations are likely particularly interested in whether postfire restoration treatments are warranted and economically feasible. Resources such as Napper (2006) and the VAR Calculation tools, as well as models that include a component to estimate treatment effects, are therefore especially relevant. We identified 10 tools that include a component for evaluating treatments, which can help facilitate postfire planning (Table 3). However, tools that incorporate treatments were slightly more difficult to use (scores ranging from 0 to 5, mean = 2.6) than tools that do not (range 2 to 6, mean = 3.2). Tools that address treatments cover a wide range of spatial extents: half can be used anywhere in the United States (FS Peak Flow Calculator, Wildcat5, VAR Calculation Tool, VAR Tool LITE); WEPP PEP can be used within the conterminous United States; three tools (Burned Area Report Database, ERMiT, FERGI) apply to the western United States; and one, RUSLE2, is extremely limited in scope. These 10 tools cover all output types, including field measurements, erosion, peak flow, runoff, and the searchable database.

After fires, infrastructure such as roads and bridges are exposed to increased runoff, sediment, and debris. In many cases these structures were not designed to accommodate the large stream flows and sediment loads from burned landscapes (Foltz et al. 2009). Tools that estimate increases in runoff and peak flow are frequently used by federal teams to judge whether road structures are capable of withstanding postfire hydrologic regimes. Additionally, tools that model treatment options help to reduce road and bridge failures by identifying locations where water bars or culverts can effectively move water around or through structures (Robichaud et al. 2000). Foltz et al. (2009) synthesized postfire procedures used by federal teams for rehabilitation of infrastructure and found that USGS Regression equations are by far the most common tool for estimating postfire peak flow, followed by curve number methods. Soil Burn Severity mapping was the most common method for estimating reduction in infiltration (Foltz et al. 2009). These tools, as well as the Foltz et al. (2009) review, are good resources for communities or local landowners concerned about threats to roads, bridges, or other structures following wildfire.

This analysis improves our understanding of the appropriateness and accessibility of currently available postfire assessment tools for non-federal audiences. In this study, we focused on tools used by federal teams to assess and evaluate burned landscapes, however many other resources for non-federal user groups exist. In a further effort to provide a wide range of information on postfire tools, we have collected numerous resources into an online toolkit that provides users with information on postfire concerns, management and science of postfire flooding and erosion, resources for federal and non-federal user groups, funding opportunities, and a publication library. Although After Fire: Toolkit for the Southwest (postfiresw.info) includes information specific to the south-western United States, most of the tools and resources are relevant throughout the country. This analysis, combined with the After Fire Toolkit, provide different users with information on the resources that are available, their usability, and identify ways to improve the accessibility of postfire assessment and evaluation tools to users with different skills and resources.

### Next Steps

While the results of this analysis show several tools currently used by federal teams to assess postfire conditions and risk have utility for non-federal groups, it appears that there is a need for more user-friendly tools, particularly field measurement techniques and runoff models. Field measurement approaches are highly relevant to non-federal users who want to assess the condition of their land following wildfire so they can identify areas at risk of debris flows or erosion and the most effective restoration actions. Additionally, while the tools we identified that incorporate treatments do cover all output types and generally have large scopes, most tend to have intermediate or low levels of usability. A major shortcoming in these tools was their complex data inputs, as demonstrated by the large number of 0 scores (Table 1) in this category. Future tools that incorporate treatments with simpler data inputs would be useful.

The Soil Burn Severity Datasheet provides an excellent example of a tool that is easy to use and able to provide useful information for planning in a relatively short period of time. Furthermore, it demonstrates several characteristics that would be advantageous in the development of new assessment tools: users choose among a selection of responses rather than generating specific measurements; it is in a format that can be easily printed and brought to the field; it relies on simple to collect and interpret inputs or observations of postfire environments; and it provides step-by-step instructions with photo examples. Models of erosion, debris flow, and flood risk tended to be less user friendly but some, such as ERMiT and USGS Regression Equations, appear approachable for most non-federal entities. New postfire erosion and flooding models will better address diverse user groups if they can be designed for broadly available software programs and data inputs. This would include using commonly available equipment like Microsoft Excel rather than specialized software or GIS programs that users may not be aware of or familiar with and minimizing data input requirements, allowing for estimation, or selecting from lookup tables.

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