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Using WEPP Technology to Predict Erosion and Runoff Following Wildfire

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Abstract. *Erosion following wildfire can be as much as 1000 times the erosion from an undisturbed forest. In August, 2005, the largest fire in the lower 48 states occurred in the Umatilla National Forest in Southeast Washington. Researchers from the Rocky Mountain Research Station assisted the forest in estimating soil erosion using three different applications of the* ***WEPP*** *model.* ***GeoWEPP*** *was used to determine the onsite distribution of soil erosion.* ***WEPP Windows Watershed Version*** *was used to estimate peak runoff rates of each of the ten small watersheds analyzed. The* ***ERMiT*** *interface to* ***WEPP*** *was used to estimate the probability of erosion amounts on selected hillslopes, and the benefits of mulching those slopes. Within the three days available for analysis, about 38 percent of the burned area was analyzed. This paper summarizes the analytical methods, and the findings of the prediction runs.*

Keywords. Wildfire, Erosion control, Flooding, Forests, Hydrologic modeling.

Introduction

Soil erosion and peak runoff rates following wildfire can be as much as 1,000 times greater than those from an undisturbed forest. Following a significant forest fire on Forest Service lands, a Burned Area Emergency Rehabilitation (BAER) team is organized to evaluate potential values at risk in and around the wildfire, and to determine the need for mitigation activities. The safety of life is of primary importance to wildfire and rehabilitation managers, followed by any dangers imposed by the potential flooding. Also evaluated are risks to other assets such as buildings, camp sites, roads, and bridges.

In the past, peak runoff rates commonly were predicted using the SCS (Soil Conservation Service) Curve Number method, or USGS (U.S. Geological Survey) regional runoff curves. Soil erosion often was predicted by USLE-based technologies accompanied by an estimated delivery ratio from eroding hillslopes into the stream network. New, physically-based tools derived from the Water Erosion Prediction Project (**WEPP**) model have been developed to aid in BAER runoff and erosion analysis.

This paper describes the erosion and flood analyses that can support a BAER team during the rehabilitation planning phase following a major wildfire using **WEPP** technology. The School Fire that occurred in southeast Washington State, on the Umatilla National Forest is used as an example for these applications.

WEPP Erosion Technology

WEPP is a physically-based model to predict runoff, upland soil erosion, and hillslope sediment delivery (Flanagan and Livingston, 1995). It has both a hillslope and a watershed version. The watershed version links hillslope and channel segments and routes runoff and sediment through a channel network.

The climate file that drives WEPP is stochastically generated from weather station data by the **CLIGEN** weather generator (Flanagan and Livingston, 1995). Figure 1 shows the locations of these weather stations in the state of Washington. For situations in which the weather station does not reflect the weather at the point of interest, which is common in mountainous areas, there is an online interface to the **CLIGEN** weather generator (**Rock Clime**) that can alter the monthly precipitation values, number of wet days, and maximum and minimum temperatures to better represent the area of interest (Elliot et al., 1999; Elliot, 2004). Rock Clime also accesses the **PRISM** precipitation database, which has a database of monthly precipitation values distributed on a 2.5 minute grid for the contiguous 48 states (Daly et al., 1994). Table 1 compares the Pomeroy, WA precipitation data with the precipitation data from a grid about 25 km south of Pomeroy near the center of the School Fire.

The soils and vegetation databases for both **WEPP Windows** and **GeoWEPP** are contained in the **WEPP Windows** directory structure. Included in these databases are the soils and vegetation information developed by Elliot (2004) for disturbed forest hillslopes, including wildfire.

GeoWEPP

The **WEPP Windows Watershed Version** is difficult to manage. A GIS interface, **GeoWEPP**, was developed to make this tool more useful (Renschler, 2003). The current version of **GeoWEPP** displays input and output information in **ArcView**. A version for **ArcGIS** is under development. **GeoWEPP** develops a drainage network for the region selected, and then

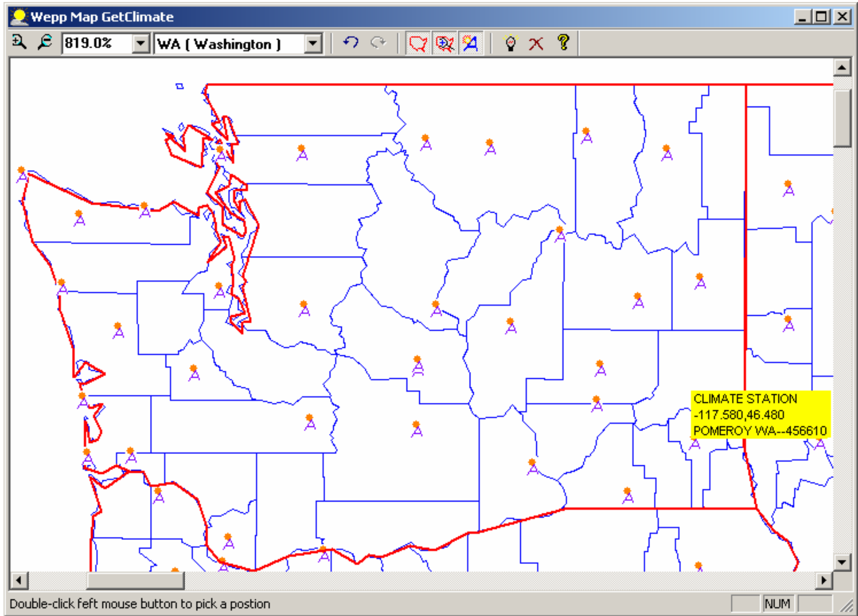

Figure 1. Map feature of WEPP Windows interface with the nearest climate station to the wildfire highlighted by the cursor. This view shows the location of weather stations in Washington State.

defines the channel network and hillslope polygons for a watershed that is selected by defining the watershed outlet. **GeoWEPP** utilizes two modes: "Flowpath" and "Watershed." "Flowpath" mode predicts and erosion for every pixel within the selected watershed. "Watershed" mode predicts sediment delivery from each hillslope polygon and stream channel segment identified by **GeoWEPP**.

WEPP Watershed

Once **GeoWEPP** has built the **WEPP** watershed structure, the watershed project file can be opened by the **WEPP Windows Watershed Version,** and a return period analysis for precipitation, runoff and sediment delivery is carried out. By running **WEPP Windows Watershed** Version for a number of years, the return period analysis for half the length of the run and for shorter periods can be determined. This feature is particularly useful for predicting peak runoff rates from small watersheds above road culverts and bridges.

ERMiT

In order to evaluate the benefits of erosion mitigation following wildfire, an online interface for **WEPP** has been developed. This interface, called the Erosion Risk Management Tool (**ERMiT)**, predicts the probability of single storm hillslope erosion rates for the given hillslope topography and fire severity (Robichaud et al., 2006). It then estimates erosion recovery rates for the five years following a wildfire. **ERMiT** also predicts the benefits of mitigation treatments during the recovery period for seeding, mulching, and installing log erosion barriers on the contour. **ERMiT** combines the stochastic climate with probability distributions of soil erodibility and spatial variability in burn severity to estimate the hillslope sediment delivery that exceeds for a given probability.

ERMiT requires the hillslope horizontal length and the top, average of the middle of the hill, and the toe hillslope steepness. A perl program (geowepper.pl) was developed to search

Table 1. Average monthly maximum and minimum temperatures and precipitation amounts for the Pomeroy, WA weather station, and the values used for the School Fire analyses.

	Pomeroy, WA			School Fire, WA		
Month	Max Temp (° C)	Min Temp (° C)	Precip. (mm)	Max Temp (° C)	Min Temp (° C)	Precip. (mm)
Jan	4.00	-4.22	52.58	-0.05	-7.59	95.39
Feb	7.99	-1.44	37.85	3.94	-4.81	67.67
Mar	11.76	0.21	38.10	7.71	-3.16	59.03
Apr	16.54	2.93	27.69	12.49	-0.44	50.40
May	21.09	6.28	32.26	17.04	2.91	56.57
Jun	25.79	9.98	27.69	21.74	6.61	50.58
Jul	30.89	12.22	12.45	26.84	8.85	26.77
Aug	30.34	11.84	18.29	26.29	8.47	33.32
Sep	25.49	7.94	19.05	21.44	4.57	44.17
Oct	18.18	3.44	29.97	14.13	0.07	50.30
Nov	9.44	-0.36	45.72	5.39	-3.73	89.05
Dec	4.97	-3.09	51.82	0.92	-6.46	107.04
Total			393.47			730.29

GeoWEPP files simulation, and display these hillslope values, their labels, and the area of each hillslope polygon for use in ERMiT or other interfaces.

The School Fire

Starting on August 5, 2005, the School Fire burned more than 20,000 ha (50,000 acres) in the Blue Mountains south of Pomeroy, Washington (Umatilla National Forest, 2005). More than 250 personnel suppression representing federal, state, and local authorities were involved in the fire. The fire was contained by August 25, 2005, although fire fighters continued to extinguish hot spots for several more weeks.

Near the end of the fire, the authors spent three days completing the main soil erosion prediction analysis for the BAER team (Elliot et al., 2005). Additional runoff analyses were completed by the Umatilla National Forest hydrologist using regional USGS runoff curves (Clifton, 2005).

Analytical Methods

This section describes the general approach to wildfire analysis undertaken on the School Fire, and is generally recommended for BAER analysis by the authors. The School Fire is used as an example of the applications, but the methods described may need to be modified to suit site specific conditions on other fires.

Topographic Information

The first step in the analysis was to obtain the necessary GIS data files from the Natural Resource Conservation Service (NRCS) online “Geospatial Data Gateway” (http://datagateway.nrcs.usda.gov/). This used to be a pubic web site, but access is now restricted to USDA employees and members of the public who obtain permission from NRCS officials. The Data gateway allows the user to select an area of interest, and to request a 7.5x7.5 Digital Raster Graphic (DRG) 1:24,000 scale file and the USGS Digital Elevation Model

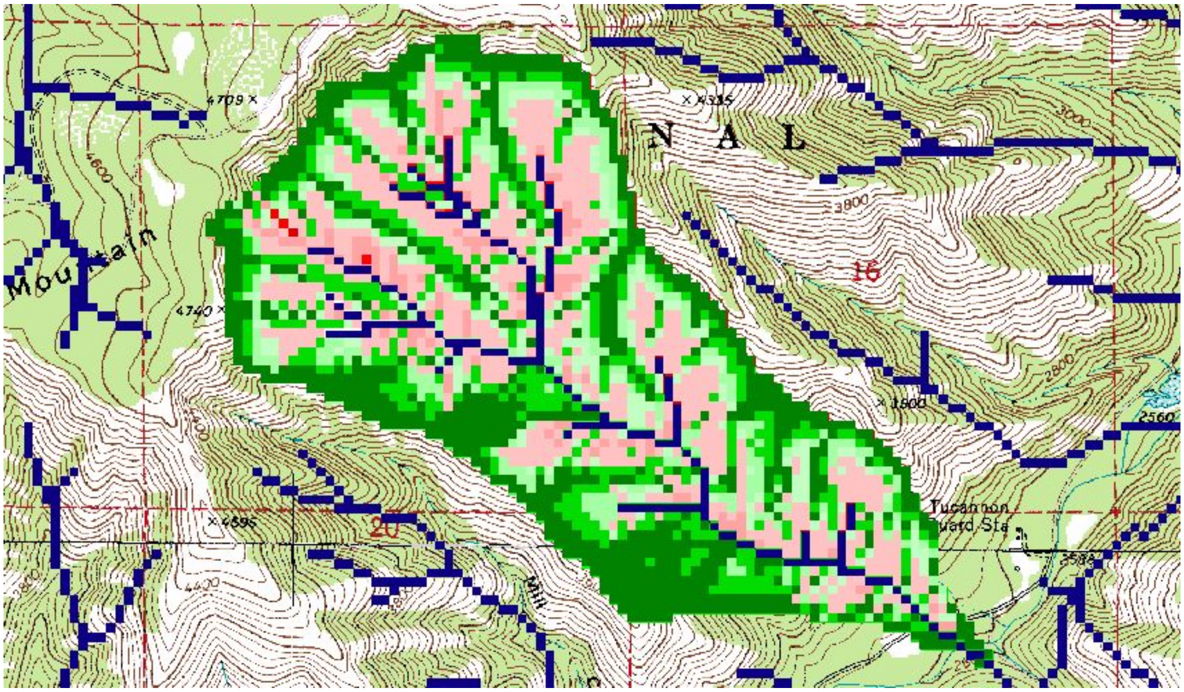

Figure 2. Results of a single "Flowpath" analysis for a 230 ha (568 acre) subwatershed on the School Fire, WA. The green pixels had a predicted erosion rate of less than 1 Mg/ha, the light pink pixels- 1 to 2 Mg/ha, the dark pink pixels- 2 to 3 Mg/ha, and the red pixels 3-4 Mg/ha. The DRG is displace north and west of the DEM on this site

(DEM) for the selected area. The vector projection should be NAD83. The "Vector Extent" is standard, and the vector file format is an "ESRI Shape File". The DRG does not always align with the DEM (Figure 2), but it is generally close enough for the **GeoWEPP** application. Advanced GIS adjustments can be made once the files are downloaded to ensure that the two GIS layers are in alignment if that is critical.

Climate Information

In order to predict site-specific erosion, a site-specific weather file is needed. The nearest climate station is identified either by using the mapping feature in **WEPP Windows** (Figure 1), or by doing an initial **GeoWEPP** run, in which the nearest climate station is identified.

The station nearest to the School Fire is at Pomeroy, WA. The fire was located about 25 km (15 miles) south of Pomeroy. The Pomeroy weather station is located at a lower elevation (580 m (1900 ft)) than the fire, which averaged around 1250 m (4100 ft). The **Rock Clime** online interface was used to select the desired **PRISM** precipitation data, and the temperatures were adjusted for adiabatic lapse rate (Table 1).

Creating a One-year Weather File with a 10-year Erosion Event

The desired weather sequence was generated for 100 years using the Rock Clime interface, and downloaded to the appropriate directory within the PC's **WEPP** directory structure (Elliot et al., 1999). The **WEPP Windows** interface Run Options were set to run for 50 years, write an "Events File" and carry out a Return Period Analysis. A typical slope from a **GeoWEPP** run for the burned area 650 m (2100 ft) long, steepness ranging from 32 to 56 percent, high severity silt

Return Periods

Return Period (years)	Daily Runoff Volume (mm)	Daily Sediment Leaving (t/ha)	Daily Peak Rate (mm/hr)	Daily Precipitation (mm
2	1.2	0.7	0.9	23.5
5	4.9	8.1	2.7	30.4
10	12.5	17.6	4.9	33.6
20	17.2	73.8	6.8	35.1
25	17.5	76.8	11.7	35.9

Figure 3. Return Period Analysis screen from WEPP Windows for a typical hillslope on the School Fire, WA.

loam soil (the dominant texture on the site), and a high severity fire with about 30 percent ground cover were selected. The model was run, and the ten year return period erosion noted (Figure 3) as 17.6 t/ha (1.76 kg/m^2 or 7.8 ton/acre). The **WEPP** Summary Event by Event file was searched to find the 1.76 kg/sq m erosion rate. It occurred on June 24, in year 28. The downloaded weather file was then opened with a text editor and truncated so that it had only the header information and Year 28 containing a 10-year event. The one-year file was then saved under a different name. Two weather files were now available for running the **WEPP** interfaces for the fire analysis– a 100-year weather sequence, and a one-year sequence containing the storm that caused the amount of erosion that would be exceeded only once in 10 years.

Soil and Vegetation Information

The predominant soil in the School Fire is a silt loam, developed from volcanic ash deposits. A satellite image had been obtained shortly before the erosion prediction analysis, and from the image areas of “Low”, “Moderate” and “High” burn severity were identified using agency protocols. The BAER team leaders had defined ground residue cover for these three levels of disturbance (Table 2). Table 2 also shows the soil and vegetation files associated with each of these severities.

Vegetation Cover Calibration

In order to obtain the correct amount of cover, the soil and management files for a given condition (Table 2) were imported into **WEPP Windows**, as was the calibration hillslope (650 m (2100 ft) long, steepness ranging from 32 to 56 percent). The downloaded 100-year School Fire climate was selected for the calibration. WEPP Windows comes equipped with a cover calibration tool that allows the user to adjust the biomass energy ratio until the desired cover as shown in Table 2 was achieved for each fire severity.

Sequence of Runs

Once the initial climate, soil, and management files were set up, the erosion estimation could commence, following a sequence of four runs.

Watershed Definition Run

The area of the fire was divided into subwatersheds, and the most critical areas for analysis were specified by the BAER Team. Those subwatersheds immediately upstream of values at

Table 2. Soil and vegetation conditions associated with different levels of fire severity as defined by the School Fire BAER team. All soil textures were silt loam. The names refer to the file names in the **WEPP Windows** database, “Forest\Disturbed WEPP” directory.

Condition	Soil Name	Cover Name	Cover amount (%)
Unburned	“20-yr Forest	100-yr forest	100
Low severity	“Low severity”	“Low severity …”	90
Moderate severity	“Low severity”	“…Cover after fire”	30
High severity	“High severity”	“…Cover after fire”	10

risk, such as a campground or historic ranger station, were given top priority for analysis. Those areas that had had the greatest amount of high severity fire were given second priority, and a large subwatershed, Pataha Creek, that was only partially burned, but that was upstream from the town of Pomeroy, WA, was a third priority.

For each of the priority subwatersheds the outlet was defined in **GeoWEPP**. The **GeoWEPP** “default” soil and management files were set at high severity for all but Pataha Creek, which was set at undisturbed. For the first run, **GeoWEPP** was run for one year in Watershed mode to define all of the hillslope polygons. The hillslope polygons that were not in the default category were then manually altered using the **GeoWEPP** “Change Hillslope” function to one of the other three conditions described in Table 2.

Upland Erosion Distribution Run

Once the hillslopes in the watershed were altered, the climate file with the 10-year event was selected, and **GeoWEPP** was run in the “Watershed and Flowpath” mode. The “Flowpath” mode does one run for approximately every 0.4 ha (1 acre), and can require considerable computer time for long runs. By running it for the year with the 10-yr exceedance event, there is a one in ten chance that the erosion rates predicted in the subwatershed will be exceeded. If other hillslope erosion exceedance values are desired, then other one-year climate files can be generated. The resulting map can then be saved for combining with similar maps during the summary phase of the analysis. Figure 2 is an example of a 230 ha (568 acre) subwatershed run using the “Flowpath” method for a year containing the 10-year return period storm. In Figure 2, the north facing slopes were generally low severity, which is why there are fewer pixels on those slopes with erosion exceeding 1 Mg/ha. The reason for the “Watershed” run is to build a **WEPP Watershed** project for the next step in the analysis.

Subwatershed Return Period Analysis Run

When **GeoWEPP** is run, the soils, vegetation and climate databases are read from the **WEPP Windows** directory. The topographic and **WEPP** project files are stored in the **GeoWEPP** directory. The watershed project file that describes the topographic components that make up the watershed (ww2.prw) is one of those project files. This file can be opened from **WEPP Windows**. The **WEPP Windows** graphics are not available, but all of the watershed structure file is in place. By opening these files in **WEPP Windows**, we could then complete a return period analysis of the subwatershed. For this run, the climate in **WEPP Windows Watershed Version** is changed to the 100-yr School Fire climate that was downloaded from the Internet. Under run options, 50 years of run are specified, and a Return Period analysis requested. Figure 4 gives the return period analysis results for the example subwatershed.

The peak runoff rate predictions aid in determining the adequacy of structures within the subwatershed. The peak runoff rate predictions can be combined for all of the subwatersheds and peak rates plotted against area. If logarithm values are selected for both axes, a linear

Return Periods

Return Period (years)	Runoff Volume (m^3)	Sediment Leaving (t)	Peak Runoff Rate (m^3/sec)	Daily Precipitation (mm
2	8301.1	1856.2	2.6	25.8
5	14947.2	39293.9	4.4	30.4
10	19359.1	85369.2	5.6	33.6
20	26194.5	611153.5	7.4	35.1
25	34204.9	2011875.3	9.4	35.9

Figure 4. Return period analysis on example subwatershed

relationship can be developed. This relationship can be applied to all flow structures within the burned area if the surface area above the structure is known. Figure 5 shows the graph (in English Units) that was developed for the School Fire analysis.

Figure 4 also shows that there is a 10 percent chance that the subwatershed sediment yield will exceed 85,369 Mg (77,600 tons), or 371 Mg/ha. This value appears to be unrealistic when the 10-year return period “Flowpath” results in Figure 2 showed that most pixels were eroding at less than 4 Mg/ha, and is likely due to an error within the **WEPP** watershed sediment routing routines that occasionally leads to such gross overestimations of sediment delivery (Conroy, 2005). Users should use caution when interpreting return period sediment values from the watershed interface.

ERMiT Erosion Mitigation Analysis Runs

The final set of runs is with the **ERMiT** online interface to evaluate the effectiveness of mitigation treatments on each of the hillslopes. If there is sufficient time, all of the hillslopes in every subwatershed can be evaluated. In the case of the School Fire, there was not enough time to do all of the hillslopes, particularly in the large watersheds. In these situations, a random sample of hillslopes can be analyzed, or hillslopes that appeared to be causing the greatest amounts of sediment delivery by inspecting the **GeoWEPP** Flow Path results can be selected (Figure 2). In the example subwatershed in Figure 2, there were 59 hillslopes. **ERMiT** requires the user to specify the top, average, and bottom steepness of each hillslope polygon analyzed, as well as the slope length and fire severity. A soil texture and fire severity (low, moderate, or high) are also specified. **ERMiT** then determines the erosion exceedance rate for no treatment, and for mulching, seeding, and log erosion barriers.

Figure 6 shows the **ERMiT** outputs from a single **ERMiT** run for one of the high severity south facing hillslopes on the example watershed. In the watershed run, this hillslope was the polygon that showed the greatest sediment delivery per unit area. The hillslope was 150 m (492 ft) long, with a slope at the top of 52 percent, an average slope of 42 percent, and a slope at the toe of 24 percent.

Figure 6 shows that there is a 10 percent chance that hillslope sediment yield will exceed 18.6 t/ha (8.3 t/a) on this hillslope. If the hillslope is mulched at 1 Mg/ha (0.45 tons/acre) straw, then there is a ten percent chance that hillslope sediment yield will exceed 3.43 Mg/ha (1.53 tons/acre). Alternatively, if log erosion barriers 0.3 m (1 ft) diameter are installed at 15 m (50 ft) spacing, then there is a ten percent chance that hillslope sediment yield will exceed 4.19 Mg/ha (1.9 tons/acre).

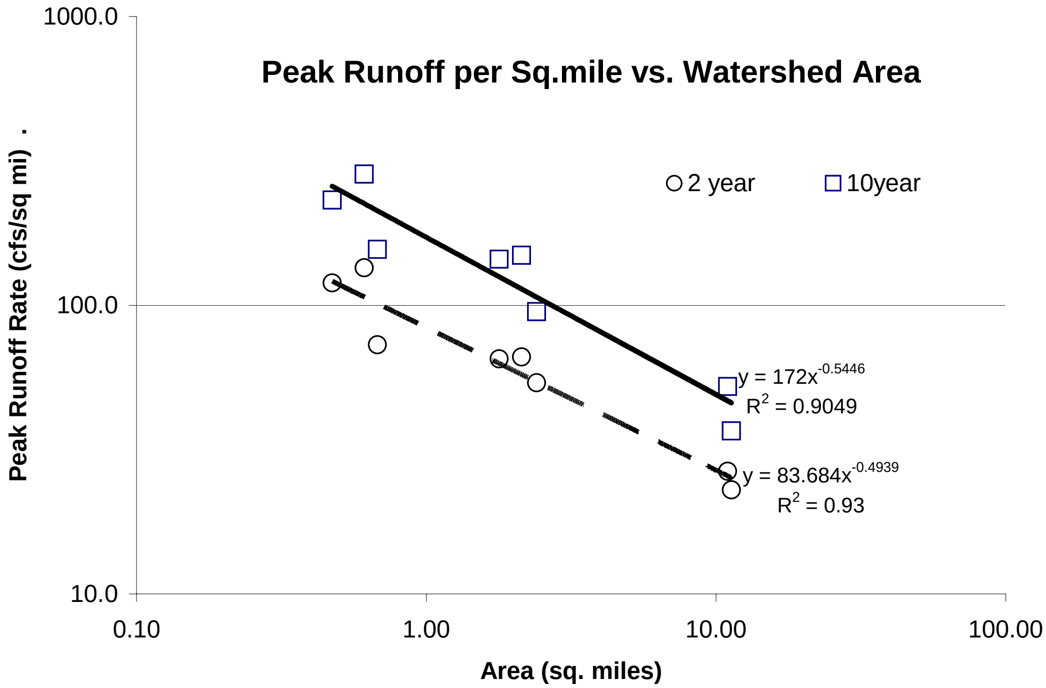

Figure 5. Example of peak runoff rate versus area as reported for School Fire, WA in English units (based on Elliot et al., 2005).

Discussion

A set of steps to carry out a BAER soil erosion and sediment delivery analysis has been described. Each step requires certain assumptions, and each step has some model limitations that may need to be considered.

When the BAER team defined the fire severity categories, the cover remaining for the high severity condition (10 percent) may have been underestimated. Cover generally includes any surface rock and large woody debris as well as unburned duff and litter. This value should be estimated by onsite inspection after the fire. Time for such field visits is limited and in some cases, if the fire is still active, such field data collection can be risky.

The analysis was carried out using the most recent satellite image that was available, but as the fire was still active, not all of the burned area could be successfully analyzed. The erosion estimates can be no better than the data used to develop the input files. Carrying out erosion predictions before the fire is completely contained will always mean that it is not possible to accurately complete the analysis on some areas of the fire.

When developing the cover files in **WEPP Windows** to match the BAER team specifications, file name length may be a problem with some Windows systems. Hopefully this will not be a problem with a version of **GeoWEPP** for **ArcGIS** that is under development. In the meantime, users of the **ArcView** version of **GeoWEPP** may need to shorten the name of the **WEPP** management file to a short single word before commencing with the cover calibration step. It is

Mitigation Treatment Comparisons					
Probability that sediment yield will be exceeded	Event sediment delivery (t ha^{-1})				
	Year following fire				
10 % go	1st year	2nd year	3rd year	4th year	5th year
Untreated	18.64	11.2	1.99	1.05	0.17
Seeding	18.64	3.52	1.34	0.89	0.17
Mulch (1 t ha^{-1})	3.43	3.14	1.99	1.05	0.17
Mulch (2 t ha^{-1})	2.43	2.78	1.99	1.05	0.17
Mulch (3.5 t ha^{-1})	2.26	2.35	1.99	1.05	0.17
Mulch (4.5 t ha^{-1})	0.33	2.23	1.99	1.05	0.17
Erosion Barriers: Diameter 0.3 m Spacing 15 m go ?					
Logs & Wattles	4.19	0	0	0	0

Figure 6. Main output table from an **ERMiT** run for 150 m long hillslope with steepness of 52 percent at the top, 42 percent average, and 24 percent at the toe, for a high severity fire and the School Fire climate.

now suggested that all cover amounts be calibrated from the “Grass” file, as the name is short, and the calibrated results are reasonable. If the user prefers the vegetation properties of one of the other vegetation options, then he/she is advised to shorten the file name before initiating the cover calibration procedure, for example, shorten “Low severity fire every year” to “Low”.

Specifying which hillslopes are “moderate” or “low” severity is a tedious part of the total analysis. Methods are under development to more closely link the spatial analysis features of a GIS to the severity maps, which should make this step much easier. The current distribution of **GeoWEPP** includes an example of this technology, but on the School Fire, the burn severity map was not in the format required to use this feature.

The results of the flow path method (Figure 2) show that most erosion in the example subwatershed is below 4 Mg/ha for the year with a 10-yr erosion event. The **ERMiT** run predicted a 10 percent probability that erosion would exceed 18.6 Mg/ha. The **GeoWEPP** run accounted only for variability in climate, whereas **ERMiT** accounted for variability in climate, soil, and spatial burn pattern, leading to a greater predicted erosion rate. The results of the **GeoWEPP** run are intended to provide users with a map of where the areas of high erosion are likely to occur, and not necessarily detailed erosion estimates. If the user desired improved estimates from **GeoWEPP**, then he/she would have to run the model for more years. **ERMiT** runs WEPP for both the years of the desired events, and the years preceding the desired events (Robichaud et al., 2006). In future analyses, it may be desirable to do the same with the **GeoWEPP** analysis, and run the “flowpath” analysis for two years, the year with the 10-year event, and the year the precedes it.

The initial WEPP run to determine the year with the 10-year erosion event (Figure 3) provided a 10-year value (17.6 Mg/ha) similar to **ERMiT** (Figure 6, 18.6 Mg/ha), showing that both **WEPP** hillslope technologies give similar results, even though the parameterization methods for these two approaches is very different. The extreme over prediction of watershed erosion rates (Figure 4) from the watershed run is cause for concern. This does not always happen, and the source of this over prediction in the WEPP code needs to be identified and repaired.

The relationship between the peak runoff rate and the subwatershed area in Figure 5 is similar to that developed by Clifton (2005) using USGS regional watershed curves. The **WEPP** predictions were greater than the USGS predictions on smaller watersheds, where surface runoff would dominate, and where the USGS curves did not readily consider fire effects. On larger areas, however, the **WEPP** predictions were somewhat smaller than the USGS curves, likely due to the increasing role of shallow lateral flow and groundwater in the hydrology of larger watersheds. The current versions of **WEPP** do not account for these sources of runoff, which becomes increasingly important with larger watersheds.

In this example, Figure 6 showed that the mulching treatment and the log erosion barriers appear to be similar in their effectiveness at reducing soil erosion. The relative effectiveness of these treatments tends to depend on the climate. In climates that have more summer thunderstorms, log erosion barriers tend to perform less well as the greater runoff amounts tend to reduce the effectiveness of this treatment. Mulching generally performs well in all climates, although it is usually more expensive, and can introduce unwanted invasive weeds into the forest.

Summary

We have presented the steps necessary to complete an erosion analysis to support a BAER team. The steps in the analysis are:

1. Download the necessary GIS files and weather data.
2. Determine the year with the 10-year erosion event and make a single year weather file for that year (Note, it may be better to make a two-year weather file and include the year preceding the 10-year event as well.
3. In WEPP Windows, calibrate the desired vegetation to obtain the necessary cover.
4. Prioritize the subwatersheds to be analyzed.
5. In **GeoWEPP**, select the desired subwatershed for analysis and specify the dominant soil and vegetation in the subwatershed.
6. Run an initial year of **GeoWEPP** “Watershed” mode for each subwatershed to define the hillslope polygons.
7. Alter the vegetation and soil files for the hillslope polygons that are not in the default condition.
8. Run the subwatershed for a single year with the climate file containing the 10-yr erosion event, in “Watershed and Flowpath” mode.
9. The “Flowpath” results display the pixels that will likely be at greatest risk from upland erosion, and therefore benefit the most from mitigation treatment. Save this result for the overall GIS summary.
10. Open the watershed file in **WEPP Windows Watershed** interface and carry out a return period analysis for a 50-year run, to determine peak runoff rates.
11. Use the **geowepper** program to find the hillslope topographies for running **ERMiT**.
12. Run **ERMiT** for all of, or a selection of the hillslopes to determine the benefits of mitigation.
13. Prepare reports and summaries as needed.

The School Fire BAER erosion analysis followed these steps. Within the limited time available (3 days), ten subwatersheds within the fire area were modeled with these tools (covering 18,823 acres, or about 38 percent of the total burned area). From these analyses, we found that on the average, there is a 20 percent chance that the erosion rate in the watershed will be greater than 15.7 Mg/ha (7 tons per acre) if untreated, and that there is a 10 percent probability that erosion will exceed 22.4 Mg/ha (10 tons/acre) if left untreated. As a result of this analysis, critical burned areas were treated with mulch, and monitoring is ongoing to determine treatment effectiveness.

Conclusion

We have presented a methodology for using three different erosion tools based on the WEPP technology for BAER analysis. These tools can show where erosion risk is the greatest, the peak flood flow rates as a function of watershed area, and the estimated benefits of postfire mitigation treatments of mulching, seeding, and log erosion barriers. Areas requiring further work are to develop the technology to incorporate severity maps into wildfire analysis, and to determine the source of the apparent sediment delivery bug in the **WEPP Windows Watershed** interface.

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