BAER Assessment Soils Report – Rim Fire

Stanislaus National Forest (R5-STF) – Mi-Wok and Groveland Ranger Districts
Yosemite National Park and Wilderness

*****DRAFT: To be finalized by 10/4/2013 when additional information is received*****

September 27, 2013

(Granite Creek Watershed above Holm Powerhouse, tributary to Cherry Creek;
This area burned with similar stand-replacement severity in the 1973 Granite Fire)

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1. POTENTIAL VALUES AT RISK

A list of potential values at risk and threats to critical values were developed by the BAER team, comprised of various National Forest employees. The team worked cooperatively with the DOI BAER team on the Yosemite NP side as well. Input was also received from other federal and state agencies, private entities, and local residents. Several risks to the soil resources exist which include both direct and indirect effects from the fire.

These threats affecting soil resources include:

- Loss of soil hydrologic function from high soil burn severity affecting porosity and structure.
- Loss of soil productivity through accelerated erosion and mass-wasting.
- Increased off-highway vehicular traffic (off-trail access due to lack of vegetation).
- Increased invasive exotic plant establishment, destabilizing native plant-soil ecosystem function.

Additional considerations relevant to soils resources include erosion and deposition threats to cultural resources, and the influence of eroded materials toward stream bulking and debris-flow initiation as well as culvert clogging and road failures; these threats tend to be site specific in nature, and identified threats (and potential solutions) arise from inter-disciplinary evaluation and assessment among BAER team specialists.

2. AFFECTED SOIL RESOURCES

The Rim Fire burned over 250,000 acres in the greater Tuolumne River and Clavey River drainages, encompassing areas of the Stanislaus National Forest, Yosemite National Park, and private inholdings. Following wildfires in the U.S., Burned Area Emergency Response (BAER) teams are mobilized by agencies within the US Department of Agriculture (USDA) and the US Department of Interior (DOI) to assess immediate post-fire watershed conditions and determine if secondary emergencies may exist due to threats of flooding or soil erosion or slope instability. The development of a post-fire soil burn severity map is a key component of the rapid assessment process. The soil burn severity map enables all BAER team specialists to identify potential values at risk, prioritize field reviews, and quickly evaluate if there are unacceptable risks to critical values within or downstream of the fire area.

The soil burn severity (SBS) map shows approximately 37% of the fire burned at moderate soil burn severity and 7% high (see SBS map in Appendix A). The rest of the fire area was either low soil burn severity (39%), or very low/unburned (17%). It is very important to understand the difference between *fire intensity* and *burn severity*, and *soil burn severity* as defined for watershed condition evaluation in BAER assessments. Fire intensity or burn severity as defined by fire, fuels, or vegetation specialists may consider such parameters as flame height, rate of spread, fuel loading, thermal potential, canopy consumption, tree mortality, etc. For BAER purposes, mapping is not simply vegetation mortality or above-ground effects of the fire – soil burn severity considers additional surface and below-ground factors that relate to soil hydrologic function, runoff and erosion potential, and vegetative recovery potential. See Appendix B for details on SBS mapping methods and applicable references.

The dominant soils within the Rim Fire are mostly loams, sandy loams, and loamy sands with gravelly to extremely gravelly texture modifiers, indicating high natural infiltration rates, and high rock content in many areas. These soils range from shallow to deep, reflecting a wide range of soil productivity and soil hydrologic groups. Specific dominant soils include Badgerpass, Canisrocks, Fiddletown, Gerle, Holland, McCarthy, Josephine, Sites, Waterwheel, and Wintoner families (these soils each comprising > 5,000 acres). Rock outcrop is also common – even dominant – in several map units, which is not technically soil; it does not generally produce sediment, but commonly produces runoff which may erode adjacent slopes below.

There are 15 major soil families in 143 soil map units, which differ by dominant component and slope phase (Table 1 and Appendix A). The major hydrologic soil groups within the fire are hydrologic groups A, B and D which are deep to shallow soils with moderate to rapid runoff rates. Hydrologic soil groups are groupings based on the premise that soils found within a climatic region that are similar in depth to a restrictive layer or water table, transmission rate of water, texture, structure, and degree of swelling when saturated, will have similar runoff responses. The classes are based on the following factors: 1) intake and transmission of water under conditions of maximum yearly wetness, i.e. thoroughly wet, 2) soil not frozen, 3) bare soil surface, 4) maximum swelling of expansive clays (if applicable). The slope of the soil surface is not considered when assigning hydrologic soil groups. There are 4 hydrologic soil groups: *Group A*—Soils with low runoff potential when thoroughly wet; *Group B*—Soils with moderately low runoff potential when thoroughly wet; *Group C*—Soils with moderately high runoff potential when thoroughly wet; *Group D*—Soils with high runoff potential when thoroughly wet. The group C and D soils present higher risks for runoff and erosion in a post-fire environment.

Soil Family	Surface Texture	Hydrologic Soil Group	% Soil Rock Fragments
Badgerpass	loamy sand	A	0-40
Canisrocks	loamy sand	A	0-85
Craneflat	gravelly coarse sandy loam	D	0-85
Dystric Lithic Xerochrepts	cobbly loam	D	10-50
Fiddletown	gravelly sandy loam	B	35-60
Gerle	sandy loam	B	2-30
Holland	loam	B	0-15
Josephine	gravelly loam	C	10-30
Lithic Xerumbrepts	loamy sand	D	10-40
McCarthy	gravelly sandy loam	A	35-60
Rock Outcrop	null	null	null
Sites	gravelly loam	C	0-25
Typic dystroxerepts	loamy coarse sand	B	0-20
Ultic Haploxeralfs	sandy loam	C	0-10
Waterwheel	coarse sandy loam	A	0-10
Wintoner	gravelly loam	B	0-30

Table1 – Major soil types and select properties/interpretations in the Rim Fire area.

3. POST-FIRE RESOURCE CONDITION ASSESSMENT

The soil burn severity map (Appendix A) shows multiple watersheds that contain the majority of moderate soil burn severity (37%) and high soil burn severity (7%) areas. The most impacted areas are Jawbone Creek, Reed Creek, Cherry Creek, Granite Creek, the greater Tuolumne River (mainstem, South and Middle Forks), as well as the headwaters of Middle Tuolumne and Cottonwood & Ackerson Creeks in the Park. All of these areas coalesce in the mainstem Tuolumne and drain down to Don Pedro Reservoir, about 3 miles downstream of the fire perimeter. These impacted upstream areas are very likely to produce accelerated runoff and erosion, posing risks for flooding and sedimentation to affect water quality, roads, private infrastructure (including hydroelectric powerhouses), and private camps. Sediment and floatable debris are likely to impact Don Pedro Reservoir. The magnitude of these risks depends in large part upon the magnitude of coming storm events, particularly in the first winter, but also in the next several winter seasons until natural vegetative recovery advances to reclaim soil cover on bare post-fire slopes.

Soil burn severity was assessed following principles described in Parsons et al., 2010. Soil burn severity is assessed by looking at above ground cover (trees, shrubs, forbs, grass) and surface cover, soil char (depth of soil heating), soil structure, destruction of soil organic matter, destruction of soil porosity and fine roots, as well as water repellency strength and depth. See Appendix B for more detail. Water repellency was running from 2 to 4 inches deep depending on soil texture and vegetation that was burned. Landscapes on metamorphic terrain (roughly the west half of the fire) were rolling to steep mixed conifer areas that burned moderate to high, with soil heating effects down to 1 inch depth and strong water repellency down to 2-3 inches. Char and soil organic matter destruction was also present. These soils generally have strong structure due to being well developed soils with finer textures of loam to heavy loam (see Figure 2 below). In landscapes on granitic terrain (roughly the east half of the fire) were rolling to steep mixed conifer areas that burned moderate to high, with soil heating effects down to 2 inches and strong water repellency down to 3-4 inches. Deep char and soil organic matter destruction was also present. These soils generally had weak structure due to being less developed soils with lesser clay and organic matter contents, and having sandy loam to loamy sand textures.

It should be noted that most soils have varying aggregate stability due to factors of clay accumulation through weathering, soil microorganisms, soil organic matter, and fine roots, but when subjected to intense soil heating soil structure can be degraded or destroyed. This can leave topsoil as loose, unconsolidated single-grained material which is readily subject to erosion processes. This occurred in many areas that had heavy accumulations of fuel and long residence time. Notably, the big wind-driven crown-run days with severe above-ground vegetative mortality were observed to have predominantly moderate soil burn severity due to shorter fire residence time; seed banks in these soils are largely intact, boding well for natural vegetative recovery.

Structure or aggregate stability is present in the upper 1 to 3 inches of most soils and is an important soil property protecting the soil from wind and water erosion. In the high soil burn severity areas in granitic soils, soil structure was destroyed down to 1-2 inches depth, and fine roots and organic matter were consumed, leaving loose unconsolidated single-grained surface material. In the metamorphic soils, structure and organic matter were affected only down to 1/2 to 1 inch, with finer roots generally charred but present. In both terrains, soil cover is completely lacking in high SBS areas (except for rock and debris cover); potential soil cover

in the form of heat-killed conifer needles ("brown-crowns") is present in about 2/3 of the moderate SBS areas and lacking in the remaining 1/3, so this latter portion of moderate SBS areas may be expected to have a higher watershed response (similar to high SBS) with larger storm events (~ 10-year return-interval or greater).

Figure 1 – Pictures of soil burn severity showing soil char and water repellency

Granitic soil with 1 in. soil char in moderate SBS

Strong water repellency 2 inches below white ash

Metamorphic soil with shallow soil char in mod. SBS

Granitic soil with destroyed structure in high SBS

Burned Area Reflectance Classification (BARC) imagery from the Remote Sensing Applications Center (RSAC) in Salt Lake City, UT was utilized by the Rim Fire BAER soil scientists, and modified to better reflect actual soil burn severity as observed in the field. 80+ field verified soil burn severity points were collected to adjust the BARC to match the true fire effects on the soil (Appendix D). Subsequent watershed response modeling efforts use the soil burn severity map as a key input. SBS is summarized by watershed in table 2. Destructive soil heating was present in about 44% of the landscape, found in larger contiguous areas within Ackerson, Bear, Corral, Granite, Jawbone, Lovell, Lower Cherry, and Reed Creek drainages, as well as the Upper Middle Fork of the Tuolumne River. Jawbone Creek, Lower Cherry Creek, and Upper Middle Fork Tuolumne are the top three watersheds with the most acreage of high SBS.

		Soil Burn Severity (acres)				
HUC 6 Watershed	**No Data**	**Unb/V.Low**	**Low**	**Moderate**	**High**	**Total**
Bean Creek-North Fork Merced River	16	524	2,914	1,548	25	5,026
Big Creek	1	3	5	0		9
Bull Creek	10	179	701	379	8	1,277
Cascade Creek	2	23	6	0		31
Crane Creek-Merced River	4	257	42	7	0	310
Falls Creek	12	0				13
Frog Creek	6	281	258	95	3	644
Grapevine Creek-Tuolumne River	14	3,601	8,727	5,970	128	18,440
Hetch Hetchy Reservoir-Tuolumne River	23	3,537	1,174	314	63	5,111
Jawbone Creek-Tuolumne River	3	1,721	6,570	15,366	3,823	27,482
Kendrick Creek	3	37	20	0		60
Kibbie Creek	18	1,033	1,527	464	35	3,077
Lower Cherry Creek	30	1,779	5,568	10,582	2,463	20,423
Lower Clavey River		1,379	7,693	8,051	750	17,874
Lower Middle Tuolumne River	3	1,027	4,456	8,485	955	14,925
Lower North Fork Tuolumne River	21	365	3,084	2,079	120	5,669
Lower South Fork Tuolumne River	4	1,546	9,036	8,591	799	19,977
Middle Clavey River	23	4,236	10,757	2,883	496	18,395
Miguel Creek-Eleanor Creek	34	2,244	3,816	4,946	685	11,725
Moss Creek-Merced River	2	7	13	7		29
Poopenaut Valley-Tuolumne River	7	4,682	6,228	6,063	1,058	18,038
Reed Creek	12	3,991	6,544	3,947	1,655	16,149
Upper Cherry Creek	10	314	381	158	18	880
Upper Middle Tuolumne River	13	2,246	5,692	6,532	2,425	16,907
Upper South Fork Tuolumne River	26	8,052	13,806	8,341	1,279	31,504
West Fork Cherry Creek	1	28	40	6	4	80
Grand Total	**297**	**43,093**	**99,057**	**94,816**	**16,793**	**254,056**
Percent	**0.1%**	**17%**	**39%**	**37%**	**7%**	**100%**

Table 2 - Soil Burn Severity by watershed. Note that acreage is based upon imagery as of 9/9 and the fire perimeter as of 9/13; "no data" represents newly burned acres between the 9th and 13th without imagery. The SBS map needed to be finalized for the larger team to proceed with assessments and modeling, so further updates have not occurred. The fire has continued to slowly expand in the NE at Low SBS, with total acreage as of 9/23 at 257,130 (1.2% larger) and still at 84% containment. Most watershed results here are unchanged.

Table 3 presents erosion hazard ratings by watershed, calculated by dominant soil map unit component, and adjusted for soil conditions within soil burn severity classes respectively. Specifically, variables for infiltration rate, runoff from adjacent areas, and soil cover are modified as applicable for soil burn severity. With soil heating effects and removal of soil cover, erosion rates generally bumped from low to moderate for lightly burned landscapes and from moderate to high or very high for heavily burned landscapes. 14% of the fire area

has a high EHR, with Jawbone and Lower Cherry Creeks having the highest amounts of potential sediment source hazard.

		Erosion Hazard Rating (acres)				
Row Labels	**Unrated**	**Low**	**Moderate**	**High**	**V. High**	**Total**
Bean Creek-North Fork Merced River	16	180	4,094	736		5,026
Big Creek	1	3	5			9
Bull Creek	10	55	970	241		1,277
Cascade Creek	2	29	1			31
Crane Creek-Merced River	4	292	14			310
Falls Creek	12		0			13
Frog Creek	6	319	319	0		644
Grapevine Creek-Tuolumne River	14	2,122	13,791	2,513		18,440
Hetch Hetchy Reservoir-Tuolumne River	62	1,451	3,492	80	26	5,111
Jawbone Creek-Tuolumne River	3	6,075	13,161	8,243		27,482
Kendrick Creek	3	33	24	0		60
Kibbie Creek	18	1,479	1,552	27		3,077
Lower Cherry Creek	39	6,552	9,588	4,244		20,423
Lower Clavey River		642	13,730	3,501		17,874
Lower Middle Tuolumne River	12	2,183	9,896	2,834		14,925
Lower North Fork Tuolumne River	21	222	3,639	1,788		5,669
Lower South Fork Tuolumne River	4	1,694	14,941	3,338		19,977
Middle Clavey River	23	6,052	10,962	1,357		18,395
Miguel Creek-Eleanor Creek	41	3,435	7,024	1,224		11,725
Moss Creek-Merced River	2	18	8			29
Poopenaut Valley-Tuolumne River	7	3,492	12,001	2,524	14	18,038
Reed Creek	12	9,736	5,223	1,178		16,149
Upper Cherry Creek	10	323	453	94		880
Upper Middle Tuolumne River	13	6,469	10,067	358		16,907
Upper South Fork Tuolumne River	26	14,860	16,420	198		31,504
West Fork Cherry Creek	1	50	29			80
Grand Total	**361**	**67,768**	**151,407**	**34,480**	**40**	**254,056**
Percent	**0.1%**	**27%**	**60%**	**14%**	**0.0%**	**100%**

Table 3 - Erosion Hazard Ratings by watershed, using the California Soil Survey Committee EHR system and adjusted for post-fire soil conditions. "Unrated" areas represent a portion of rock outcrop units, and exclusion of "dam" and "water" map units in the fire. See the perimeter-acreage caveat in table 2.

Quantitative erosion and sedimentation modeling utilized the FS-WEPP ERMiT model (batch ERMiT module), which is fundamentally based on single hillslopes and single storm runoff events (not annual estimates). The Water Erosion Prediction Project (WEPP) model is a process-based technology for prediction of soil erosion by water at plot, hillslope, and watershed scales. In particular, WEPP utilizes observed or generated daily climate inputs to estimate surface hydrology process components (infiltration, runoff, ET), which subsequently impacts the rest of the model, including subsurface hydrology (percolation, subsurface lateral flow), hillslope erosion

(interrill & rill detachment, sediment transport, re-deposition), in-channel processes (detachment, flow routing, sediment transport, deposition), as well as vegetative recovery. ERMiT is almost uniquely suited to modeling effectiveness of a variety of hillslope-scale treatments conventionally employed for erosion control in post-burn landscapes. Particulars and documentation may be found at http://forest.moscowfsl.wsu.edu/fswepp/.

Custom climates were generated for the fire area using the PRISM module integrated in ERMiT (Appendix C), and the model was run for a range of storm-runoff recurrence intervals (which is somewhat different from standard storm-recurrence-intervals used in hydrologic models). Stated model output accuracy is +/- 50%; therefore the absolute numbers are considered best estimates only. However, this model is particularly useful because it can 1) be easily tailored to particular slopes to assess potential sediment source areas on a relative basis; 2) help prioritize areas for potential hillslope treatments, if that is determined necessary later in the assessment; and 3) model the probable success of such treatments in terms of reduction in sediment production, over the course of several years post-fire.

Numerous representative soil-hillslopes and iterations were modeled at fire, watershed, and sub-shed scales (pour-points) by Curtis Kvamme and Kellen Takenaka on the soils team. Hillslopes were modeled in ArcMap GIS using the hillslope delineator tool, exported to Excel for ERMiT Batch runs and tabular analyses, and returned to GIS for geospatial representation and analysis. ERMiT tabular output is summarized in table 4; detailed tabular and spatial products are on file with the soils team. Note that estimates are based upon watershed area within the fire perimeter only; unburned watershed area outside the fire perimeter was not modeled.

There are also unburned/very low SBS acres within the fire perimeter. ERMiT does not produce output for this condition, as it was not part of the original empirical research data that went into building the model. ERMiT values for the 5th out-year post-burn are typically applied to unburned/very low acreage; this would assume that erosion rates return to pre-fire levels after 5 years, which may not be accurate for a given locale. For this fire, we did not apply base values for these acres (17% of the fire area), so reported erosion estimates represent only accelerated erosion as a result of the fire in Low to High SBS classes (83% of the area), not total erosion including a baseline for unburned/very low acres. For rapid assessment purposes, this is considered adequate, and preferable to using unrelated models or anecdotal data for a portion of the fire area and combining results. As an interpretive visual, tons/acre values are roughly equivalent to that many sheets of paper (stacked) being removed from the soil surface, and 1000 tons of sediment volume would fill about 120 standard 10-yard dump-trucks.

It should be noted that ERMiT models sheet and rill erosion only, not gully or mass-wasting processes. Estimates of hillslope re-deposition and stream delivery are based upon vertical profile of individual hillslopes. ERMiT is recently capable of modeling sediment routing to a specific outlet (i.e. pour-point) in conjunction with the hillslope delineator tool. Hydrologic models are better suited for flow routing, using stream-energy variables such as stream gradient and roughness coefficient (Mannings-n), driven by design storm inputs. A bulking factor for sediment entrainment is conventionally used to determine the erosive force of runoff within-channel, which also roughly estimates sediment routing. A crude estimate is 0-20% stream gradient = 20% sediment delivery, 20 to 40% is 40% delivery, and >40% is 60% sediment delivery. Models are generally unable to make such estimates precisely, lacking site-specific empirical data for calibration, which exists in few places.

		Average tons/ac. - No Treatment		
Soil-Slope (whole-fire scale)	**Acres**	**2-Year**	**5-Year**	**10-Year**
Aquandic Humaquepts (0 to 2 percent slopes)	1,797	0.0	0.3	0.6
Badgerpass (0 to 15 percent slopes)	393	3.2	12.2	17.3
Badgerpass (5 to 45 percent slopes)	1,947	0.4	1.6	2.4
Canisrocks (0 to 25 percent slopes)	1,122	2.6	10.8	15.8
Canisrocks (15 to 55 percent slopes)	443	5.4	17.1	23.7
Canisrocks (30 to 75 percent slopes)	312	6.1	17.4	24.0
Clarkslodge (0 to 30 percent slopes)	1,591	0.0	9.6	16.3
Craneflat (15 to 45 percent slopes)	2,249	1.0	3.9	7.3
Craneflat (30 to 80 percent slopes)	175	2.1	8.6	18.4
Crazymule (0 to 20 percent slopes)	35	2.0	5.2	7.9
Dystric Lithic Xerochrepts (35 to 110 percent slopes)	10,777	9.5	17.6	24.5
Dystric Xerochrepts (35 to 50 percent slopes)	942	5.3	14.7	25.5
Dystric Xeropsamments (5 to 35 percent slopes)	1,410	0.0	3.9	6.5
Dystric Xerorthents (30 to 80 percent slopes)	669	0.8	2.4	4.0
Entic Cryumbrepts (1 to 10 percent slopes)	94	7.8	16.3	36.3
Fiddletown (15 to 35 percent slopes)	10,174	5.1	12.6	17.5
Fiddletown (35 to 70 percent slopes)	5,903	5.2	12.8	17.7
Gerle family (35 to 50 percent slopes)	229	0.1	4.6	7.7
Gerle family (5 to 35 percent slopes)	4,401	0.0	4.3	7.2
Glacierpoint (30 to 65 percent slopes)	16	1.2	8.8	20.8
Half Dome (30 to 60 percent slopes)	1,584	1.9	4.4	6.3
Happyisles (0 to 15 percent slopes)	244	0.0	4.0	6.6
Holland family (35 to 50 percent slopes)	6,145	1.6	3.8	5.8
Holland family (5 to 35 percent slopes)	29,425	2.6	5.9	8.8
Humic Dystroxerepts (30 to 70 percent slopes)	3,576	2.9	7.7	12.3
Humic Dystroxerepts (5 to 35 percent slopes)	5,492	1.3	3.8	5.9
Josephine family (35 to 50 percent slopes)	11,728	0.0	6.1	10.1
Josephine family (5 to 35 percent slopes)	22,409	0.0	5.9	9.9
Lithic Xerumbrepts (35 to 70 percent slopes)	9,629	2.1	8.1	17.0
Lithic Xerumbrepts (5 percent slopes)	396	2.3	8.5	18.3
Marmotland (0 to 15 percent slopes)	66	3.0	11.4	16.0
McCarthy family (5 to 35 percent slopes)	6,091	0.4	2.9	5.8
Nevadafalls (5 to 30 percent slopes)	6,161	1.2	4.5	6.9
Oxyaquic Dystroxerepts (0 to 20 percent slopes)	54	0.0	9.9	15.2
Oxyaquic Xerofluvents (1 to 4 percent slopes)	1,555	0.0	9.9	15.2
Pinole-Holland (5 to 35 percent slopes)	1,071	1.4	3.2	4.9
Rock outcrop (0 to 45 percent slopes)	13,458	4.0	15.7	26.6
Sites family (5 to 35 percent slopes)	1,479	1.2	4.0	7.1
Tuolumne (30 to 65 percent slopes)	1,639	6.8	12.1	16.9
Typic Dystroxerepts (15 to 45 percent slopes)	8,927	0.1	6.8	11.0
Ultic Haploxeralfs (35 to 60 percent slopes)	7,221	0.0	1.9	3.2
Ultic Haploxeralfs-Typic Dystroxerepts (5 to 25 % slopes)	688	2.0	8.2	11.5
Ultic Palexeralfs (10 to 35 percent slopes)	1,343	0.7	2.4	3.1
Waterwheel (15 to 45 percent slopes)	6,933	1.9	6.6	10.5
Waterwheel (35 to 70 percent slopes)	1,120	2.3	9.1	13.1
Wintoner (15 to 40 percent slopes)	16,836	0.9	5.5	10.9
Xeric Dystrocryepts (0 to 25 percent slopes)	202	1.5	5.8	8.5
Xerolls (1 to 10 percent slopes)	526	4.8	10.5	13.8
Average Rate	**210,675**	**2.2**	**7.9**	**12.7**
Minimum Rate		**0.0**	**0.3**	**0.6**
Maximum Rate		**9.5**	**17.6**	**36.3**
Average Amount (tons)		**464,913**	**1,655,988**	**2,669,316**

Table 4 - ERMiT- estimated "whole-fire" sediment production for a range of storm-runoff events. Total acres do not include unburned/very low SBS; thus values represent fire-accelerated erosion rates above "baseline."

Background erosion levels for unburned areas are believed to be on the order of 0.2 to 0.5 tons/acre; table 4 indicates a 5- to 10-fold increase in sediment for a 2-year runoff event, 15- to 40-fold increase for a 5-year event, and a 25- to 60-fold increase for a 10-year event. Of course percentage increases can appear dramatic when starting with small numbers. In absolute terms the per acre erosion rates are not particularly alarming, relative to other soils and fires. Some of the individual soil-hillslopes do have substantial erosion rates that are a potential concern for soil integrity, such as Entic Cryumbrepts, Dystric Xerochrepts, and several family-level soils (table 4). When these soils occupy significant acreage in the fire, the risks are important to assess for potential treatments. Erosion delivered to stream channels will have a bulking factor of 15 to 25%. Sediment levels will be most pronounced for the 10-year event, raising additional concerns for roads and downstream values.

The Automated Geospatial Watershed Assessment (AGWA) tool, designed as an integrated and highly flexible model, was tested on the Rim Fire. This model integrates flow and sediment modeling, and can be used for wide-ranging watershed scales, which presents some distinct advantages for rapid assessment and interpretation. The model developer from the University of Arizona, Dr. Phillip Guertin, and his graduate student, Gabriel Sidman, were onsite for many days working to parameterize the model for our Sierra Range watersheds and assist both the USFS and DOI BAER teams in modeling flow and sediment effects of the fire. See Appendix G for results and additional information. This model showed very good promise on the fire, and may be considered for primary modeling purposes for future fires if FS BAER specialists (hydro or soils) become qualified and skilled in using the model.

4. EMERGENCY DETERMINATION

Soil productivity and hydrologic function were determined to be values at risk for the soil resource. Soils here are inherently productive (Forest Survey Site Class 2-5) due to the geographic and climatic setting. The ecosystems here are also fire-adapted, so periodic post-fire erosion is a natural ecological and geomorphic process. However, when heavy accumulations of fuel, drought conditions, and strong winds combine in a late-season fire, damage to soils can be extensive. Almost the entire fire area flows downstream to Don Pedro Reservoir, so water quality and reservoir capacity will be impacted by sediment, and flows will transport woody debris to the reservoir; this is not a Forest Service critical value, but it is a collateral beneficiary if upslope treatments can be implemented. The assessment team identified emergency threats to critical values at risk and land treatments are recommended for ecosystem stability and protection of soil productivity. Using the BAER risk assessment (Appendix F):

- The <u>probability of damage or loss</u> of soil hydrologic function and productivity is likely, because of extensive areas with bare soils created by the fire, and lacking “potential cover” in the form of needle-cast. Some erosion and off-site transport of topsoil will occur with certainty; it is only a matter of how much due to the magnitude of storm events to come. Loss of enough soil to inhibit natural recovery and therefore expose soils to prolonged erosion risk is likely.
- The <u>magnitude of consequences</u> is moderate, because most soils have already been impacted in the last few decades with high severity fire, and past consequences involved widespread gully

erosion and surface/rill erosion. Soils in such areas are still recovering from past fires, and additional soil loss could substantially impact soil productivity and hydrologic function.

- Risk Matrix: The risk rating for soil productivity damage or loss is high. Soils have some degree of inherent resilience, and vegetation will still grow, but at slower natural recovery rates due to exacerbated nutrient and organic matter deficits without soil stabilization measures.

5. TREATMENTS TO MITIGATE THE EMERGENCY

Matication and aerial helimulch treatments using ag-straw are proposed, with the objective of establishing soil cover in a portion of high soil burn severity areas, where current soil cover and potential soil cover (in the form of dead-needlecast) is entirely lacking.

Mastication was considered the most practical method to occur in a timely manner, though production rates are relatively slow and only several hundred (820) acres were considered achievable prior to damaging storms. Mastication units were thus prioritized for the more erodible soil types on slopes gentle enough for such operations (15-35%). Mastication will target on-site standing dead plantation trees; selected units have a high proportion of basal area in 6-12 inch (dbh) size classes, from which continuous ground cover can be produced in an efficient manner using an excavator-mounted rotary drum cutting head. Mulching with wood chips at an equivalent rate of 1-1.5 tons/acre will reduce erosion from average anticipated rate (2-year storm) of 3.79 to 0.42 tons/acre, which is an 82% decrease in erosion (WEPP-ERMiT see Appendix B).

Of course, the majority of erosion source areas are on steeper slopes, which can only be feasibly treated by aerial methods. Helimuch treatments were evaluated as an option on high soil burn severity slopes of 25-55% gradient, using ag-straw mulch application at a rate of 1.5 tons/acre. Nearly 7,200 acres of high SBS on suitable slopes were identified, with operational considerations reducing this figure to approximately 5,070 acres. This is still a huge operation, with very short timeframes to probable damaging events. Given the timing and possible contracting delays, it is estimated that this treatment has a small probability (10%) of being implemented in a timely manner. Despite this, the Forest Supervisor decided that these treatments should be moved forward and funding requested in the hopes that winter weather holds off and contracting & implementation goes smoothly. Such treatments would undoubtedly benefit the soil resource and reduce erosion substantially on treated acres (similar 80% reduction per treated acre according to cursory ERMiT runs).

Much initial treatment evaluation was focused on the Granite Creek watershed (sub-shed of Lower Cherry Creek), mainly due to the initial perception that the Holm Powerhouse (Hetch-Hetchy facility) could be at risk from flooding and debris flows. Subsequent assessment and modeling largely alleviated emergency-level concerns over this facility. The entire watershed was burned similarly (moderate to high SBS) in the 1973 Granite Fire, without damage to the facility; it also weathered the 1997 100-year flood events undamaged. Throughout the entire fire area, downstream values at risk other than Don Pedro Reservoir have not been identified. Therefore proposed land treatments do not have collateral benefits beyond soil productivity and reservoir capacity downstream. However, a high proportion of this fire has now burned repeatedly in the last several decades, so soil productivity is elevated as a critical value at risk of its own. Eventual proposed

treatment units are concentrated in several watersheds having feasible access and staging areas (see treatment map).

6. DISCUSSION AND RECOMMENDATIONS

This fire was somewhat unusual in having such extensive and recent fire history, with much of the fire area now burned repeatedly in the last several decades. There are productive timber soils (such as Gerle and Wintoner, forest survey site class 2 and 3) which are located in high soil burn severity areas in several watersheds, concentrated mainly in Granite, Corral, Reed, and Jawbone Creeks. These areas suffered extensive fire damage where surface soil structure and porosity was highly degraded to loose unconsolidated topsoil, readily transportable by water. Portions of Granite Creek suffered extensive erosion after the 1973 fire, along with landslide instability. With the recent extensive burning, timber productivity sites could drop in these areas from a site class of 2 to 3 or from a site class of 3 to 4. These soils are at risk and need cover to reduce anticipated erosion. These slopes have easy access with paved roads above and below, are lower elevation so less snow, have easily treatable slopes, and are on sandy loam soils. Using low-pressure masticators of less than 6 psi with 24 inch track, one could operate on moist soils during the wet season without causing detrimental compaction or displacement. On steeper slopes (up to 55%), aerial mulch treatments are the only feasible option. Replanting with conifers as soon as possible is the long term solution to reduce soil water pore pressure that triggers landslide instability in places such as Granite Creek.

7. REFERENCES

Parsons, A, PR Robichaud, SA Lewis, C Napper, JT Clark, 2010. Field Guide for Mapping Post-Fire Soil Burn Severity. USFS Rocky Mountain Research Station, General Technical Report RMRS-GTR-243.

Robichaud, P.R.; Elliot, W.J.; Pierson, F.B.; Hall, D.E.; Moffet, C.A.; Ashmun, L.E. 2007b. Erosion risk management tool (ERMiT) user manual, version 2006.01.18. Forest Service Gen. Tech. Rep. RMRS-GTR-188. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 25 p.

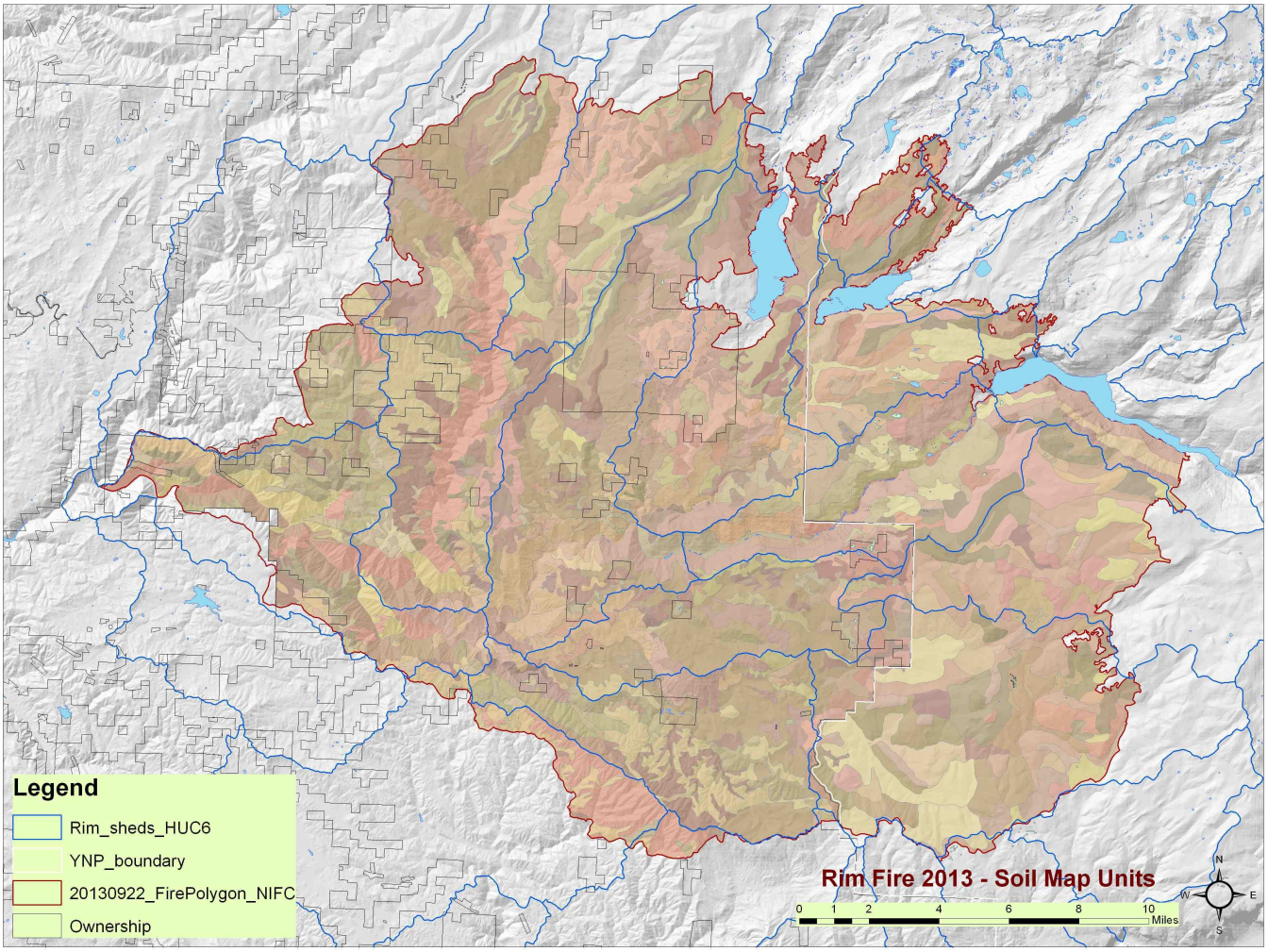
Rust, Brad, 2009. Lakehead Fuel Treatment Using Low-Pressure Masticators During the Winter. USFS Shasta-Trinity National Forest, Physical Science Department.

Water Erosion Prediction Project model Erosion Risk Management Tool (WEPP-ERMiT), 2007. Robichaud P.R., Elliot W.J., Moffet C.A. et.al.

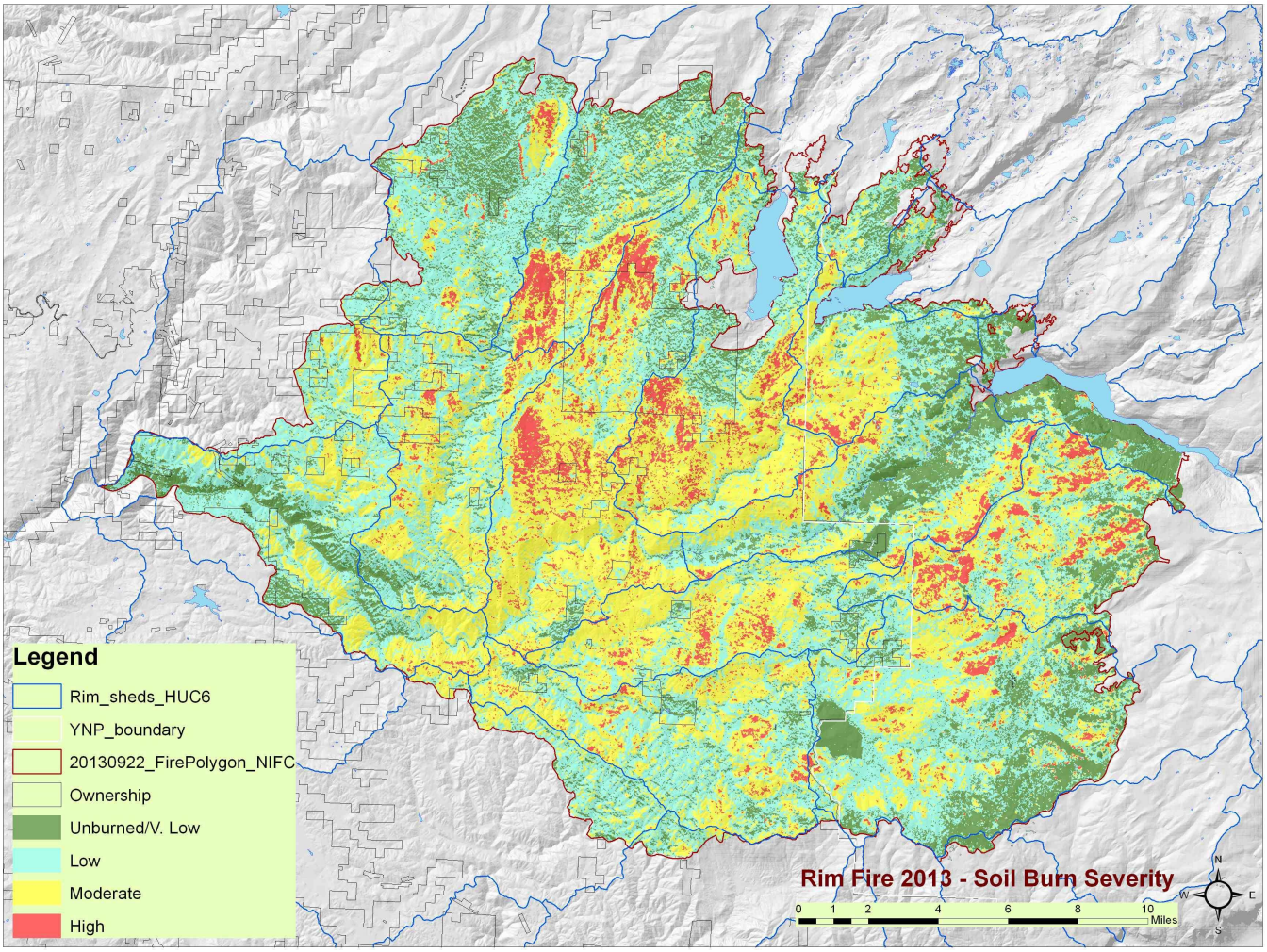
APPENDIX A – MAPS

The scale of the Rim Fire, at over 250,000 acres, makes it difficult to present map products that are useable at this print-scale. The maps here are to provide examples of what was mapped and assessed. Larger pdf-format maps and/or GIS layers can be provided upon request from the primary contacts on page 1.

Map 1 – Soil Map Units. The legend is not included because map units are not discernible at this scale. Spatial and tabular soil data was obtained from NRCS at: http://datagateway.nrcs.usda.gov/. The Stanislaus National Forest soil survey (CA-731) and the Yosemite National Park soil survey (CA-790) cover the over-whelming majority of the area. Small portions of the western-most watershed are covered by the Tuolumne County soil survey, which is currently in progress, so data there is not certified or publicly available; provisional data was however made available by NRCS Sonora staff, and utilized for analyses (not shown).

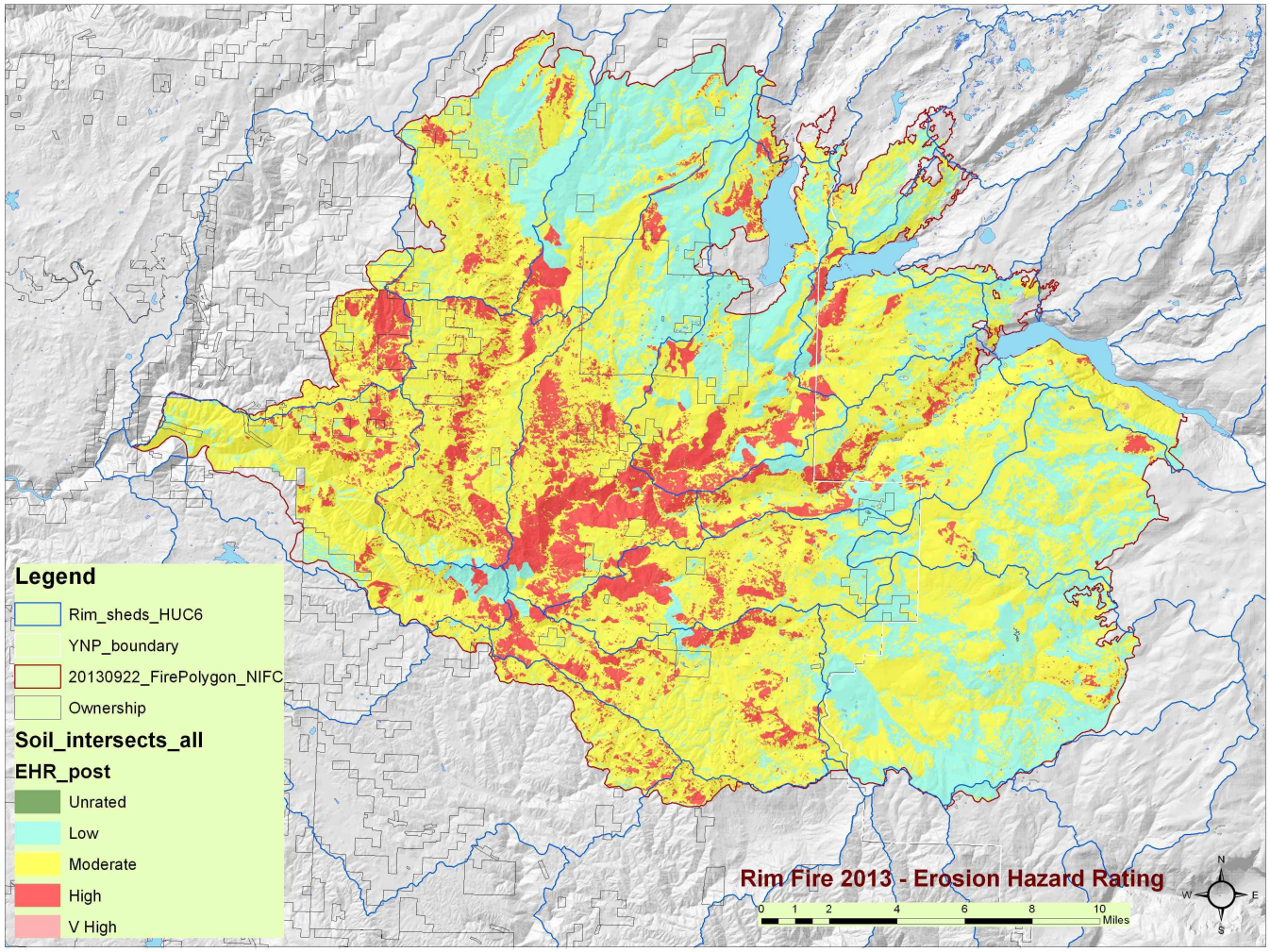


Map 2 – Soil Burn Severity Map. See Appendix B for mapping conventions. The map is a modified composite of portions of 3 satellite imagery acquisitions through 9/9/2013; the fire area that continued burning after this date was not captured in this map (the "fingers" north of the lakes continued burning slowly and generally at low SBS). This map is primarily utilized for modeling post-fire watershed response (flow and erosion responses).



The soil burn severity map identifies the fire-induced changes in soil and forest floor properties that may affect infiltration, runoff, and erosion potential. The field-validated map is a key product for the entire BAER team to rapidly identify potential areas of concern, prioritize field reconnaissance, and identify areas where post-fire conditions may create unacceptable risk to critical values. The map is also a key input for further modeling watershed response, identifying flood and debris flow hazards to downstream values, and assessing effectiveness of potential treatments to manage risks.

Map 3 – Soil Erosion Hazard Rating (EHR) Map. EHRs were developed using the standard California Soil Survey Committee system, with post-burn effects factored in; specifically, fire effects upon infiltration characteristics, soil cover, and runoff from adjacent areas are tailored by soil map unit and soil burn severity as observed in the field. This is a generalized rating system that is not highly specific to particular locations, but is used in identifying relative post-fire sediment source areas as a result of inherent soil erodibility combined with fire effects.



APPENDIX B – Soil Burn Severity Mapping Methods

FIELD GUIDE FOR MAPPING POST-FIRE SOIL BURN SEVERITY - DEFINITIONS

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Definitions:

Fire (Burn) Severity: The effect of a fire on ecosystem properties, often defined by the degree of mortality of vegetation. The severity of a fire depends on the fire intensity and the degree to which ecosystem properties are fire resistant. For example, a fire of exactly the same fireline intensity might kill thin-barked trees but have little effect on thick-barked trees. Therefore, *fire (burn) severity* is, in part, a function of the ecosystem being burned and is not simply indexed from fireline intensity. If a fire has a long residence time, fire (burn) severity will usually increase (Agee 2007).

Ground Char (Burn): Visual estimate of soil burn severity that serves as an indicator of the percent of the ground surface that has been charred and of potential root and pore damage or soil heating (Figure 1) (Ryan 1982).

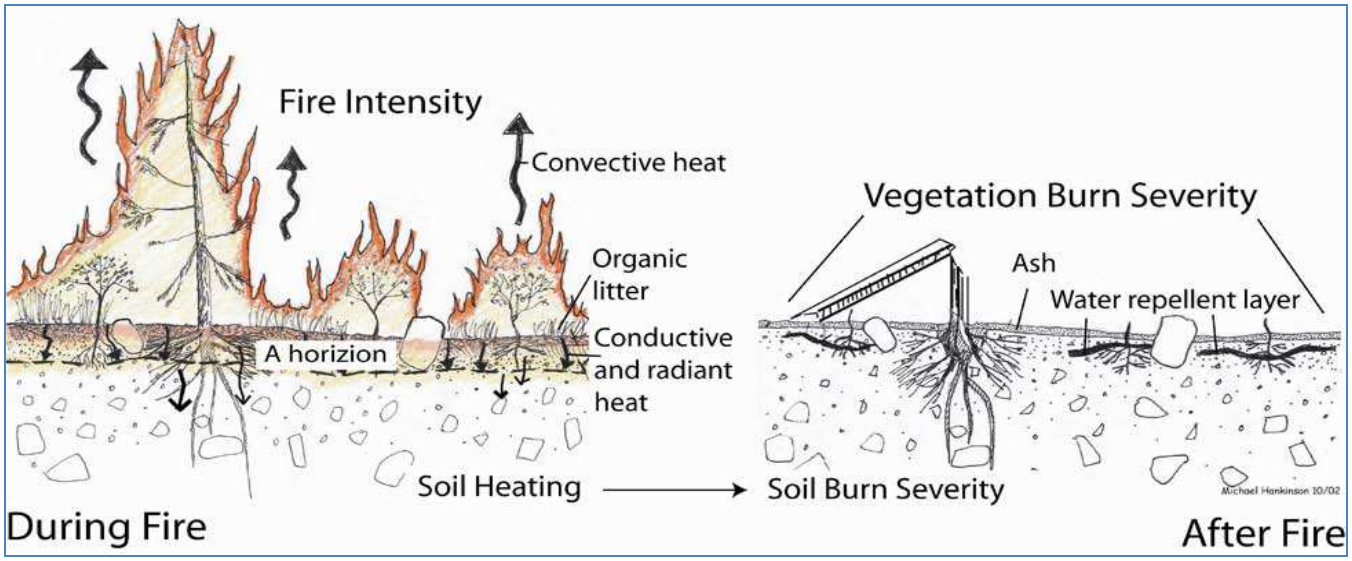

Figure 1. Illustrates the effect of fire intensity on above-ground vegetation and below-ground soil properties

Soil Burn Severity: The fire-induced changes in physical, chemical, and biological soil properties that impact hydrological and biological soil functions; the classification of post-fire soil based on fire-induced changes in these properties. *Soil burn severity* is an important category of fire effects included in the broader definition of fire (burn) severity. During post-fire assessments, there has been an intentional effort to use the term "soil burn severity" to differentiate post-fire soil properties from fire effects on vegetation (such as tree mortality), and/or general fire effects on long-term ecosystem health.

Soil Heating: An increase in soil temperature as a result of heat transfer from the combustion of surface fuel and smoldering combustion of organic soil horizons. Because of the variability of fuel consumption, soil heating typically is non-uniform across landscapes. In many cases, the highest soil temperatures are associated with high fuel consumption and/or complete duff/forest floor consumption which are affected by the duration and intensity of the fire.

Water Repellent Soils (Water Repellency): Resistant to penetration by water; not wettable. With fire-induced soil water repellency, soil particles are coated with hydrophobic compounds. When organic material burns at high intensity, the hydrophobic organic compounds often vaporize, and some of the vaporized compounds move down into the soil. When the vapors reach a soil depth where the temperature is low enough, the hydrophobic compounds condense and coat the soil particles at that depth, generally 0.25 to 2.0 inches (0.5 to 5 cm) below the surface. In some isolated cases, water repellency can extend to 6 inches in depth (15 cm).

Ground Cover: Ground cover refers to effective organic cover as it pertains to mitigation of runoff and erosion and includes litter, duff, and woody debris. Cover may also be called "soil cover" or "organic ground cover".

Severity Indicators:

Low soil burn severity: Surface organic layers are not completely consumed and are still recognizable. Structural aggregate stability is not changed from its unburned condition, and roots are generally unchanged because the heat pulse below the soil surface was not great enough to consume or char any underlying organics. The ground surface, including any exposed mineral soil, may appear brown or black (lightly charred).

Moderate soil burn severity: Some of the pre-fire ground cover (litter, ground fuels) may be consumed, but generally not all of it. Sub-surface fine roots may be scorched but rarely completely consumed over much of the area. The color of the ash on the surface will generally be blackened and there may be patches of gray ash. If all ground cover was consumed, there may be potential for recruitment of ground cover from scorched needles or leaves remaining in the canopy that will soon fall to the ground.

High soil burn severity: All or nearly all of the pre-fire ground cover and surface organic matter (litter, duff, fine roots) are generally consumed and charring may be visible on larger roots. Bare soil or ash is exposed and susceptible to erosion and aggregate structure may be less stable. White or gray ash (up to several centimeters in depth), indicate that there had been considerable ground cover or fuels that were consumed. Sometimes very large tree roots are entirely burned extending from a charred stump hole. Soil color is often gray, orange, or reddish at the ground surface where large fuels were concentrated and consumed.

RIM FIRE SOIL BURN SEVERITY MAPPING

Many soil burn severity data points were assessed in the field (Appendix D), according to the criteria above, and distributed throughout the fire area in accessible areas. Two helicopter reconnaissance flights were taken to assess watershed-wide burn severity patterns and view (and photograph) areas inaccessible on the ground.

Several Burned Area Reflectance Classification (BARC) satellite imagery acquisitions were made available through 9/9 from the FS Remote Sensing Application Center (RSAC), with various portions of each obscured by smoke and clouds. Usable portions of each were divided out, adjusted, and combined together for a single soil burn severity (SBS) map covering the entire fire area. A single clear acquisition covering the entire fire was

finally obtained on 9/17, but the pieced-together version was already finalized for modeling efforts to proceed in a timely manner. This last acquisition was also modified according to field data; it very closely resembled the pieced-together version, and had no new burn patches that were significantly different, so we were satisfied that the previously finalized version being used for modeling purposes was just as accurate, and adequate to proceed with work in progress.

Systematic adjustments were made to each BARC map to match as closely as possible the GPS field data points. It is often necessary with such a large fire to break out and adjust the SBS by major watersheds to maximize matching accuracy; this was not necessary with this fire because of the several BARC images being modified independently for different portion of the fire area (so the partially-useful imagery became an advantage at this point). We were able to obtain 90%+ matching of field data points, with nearly every point being within 1-2 pixels of the correct SBS as adjusted. This was a very good result, particularly for a very large fire.

It was immediately apparent during the first 1-2 field days that aboveground fire severity and vegetation mortality was not matching well with belowground soil heating effects. Particularly in the huge fire progression days with wind-driven crown-runs, aboveground mortaility was severe and complete, but soil heating was largely only moderate, attributed to short fire residence time. This has been observed before in our experience with other large fires. As a result, the areas initially BARC-mapped as high were partially downgraded to moderate SBS. This should be viewed as good news, as fire-devastated areas have largely intact soils, and natural recovery rates should be fairly normal in the great majority of the fire area. Only 7% of the fire area has severely fire-affected soils, with the seed bank largely destroyed, so natural recovery rates will be slower and soil exposure to erosion processes prolonged.

APPENDIX C – WEPP-ERMiT Climate Parameters and "Total-Fire" Output

Climate parameters for the Rim Fire were generated by the PRISM module integrated with ERMiT. Monthly and daily climate data interpolated for the fire area is used to statistically generate 2-year, 5-year, and 10-year "runoff-events" for event-based erosion modeling; these are roughly equivalent to "storm-event recurrence intervals" used in hydrologic modeling, but in proper terms they are different parameters.

Climate parameters for Rim Fire +
37.95°N 119.78°W; 3400 feet elevation
62 years of record

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	48.3	28.0	5.19	8.9
February	52.6	29.4	5.60	9.5
March	56.2	31.9	5.23	10.7
April	63.0	36.9	3.13	7.6
May	69.9	42.9	1.64	6.1
June	77.9	49.0	0.73	2.9
July	86.3	55.5	0.20	0.9
August	86.0	54.8	0.25	1.3
September	81.0	50.0	0.72	2.8
October	71.5	41.9	2.05	4.8
November	58.2	33.8	4.13	6.9
December	49.3	29.5	5.55	8.4
Annual			34.41	70.7

Climate parameters for Rim Fire North +
37.95°N 119.78°W; 4600 feet elevation
62 years of record

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	48.3	28.0	5.19	8.9
February	52.6	29.4	5.60	9.5
March	56.2	31.9	5.23	10.7
April	63.0	36.9	3.13	7.6
May	69.9	42.9	1.64	6.1
June	77.9	49.0	0.73	2.9
July	86.3	55.5	0.20	0.9
August	86.0	54.8	0.25	1.3
September	81.0	50.0	0.72	2.8
October	71.5	41.9	2.05	4.8
November	58.2	33.8	4.13	6.9
December	49.3	29.5	5.55	8.4
Annual			34.41	70.7

Climate parameters for Rim Fire South +
37.95°N 119.78°W; 3400 feet elevation
62 years of record

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	48.3	28.0	5.19	8.9
February	52.6	29.4	5.60	9.5
March	56.2	31.9	5.23	10.7
April	63.0	36.9	3.13	7.6
May	69.9	42.9	1.64	6.1
June	77.9	49.0	0.73	2.9
July	86.3	55.5	0.20	0.9
August	86.0	54.8	0.25	1.3
September	81.0	50.0	0.72	2.8
October	71.5	41.9	2.05	4.8
November	58.2	33.8	4.13	6.9
December	49.3	29.5	5.55	8.4
Annual			34.41	70.7

Many modeling iterations were run at different scales, and for particular watersheds and sub-watersheds of interest (to assess threats to specific values at risk). Most of these are not reported here, as they are largely incidental to the standard assessment process, but all outputs are retained and on file with the BAER soils team. Overall erosion rates are not particularly high compared to some other fires, but due to the sheer size of the fire, sediment output amounts (tons) are huge, and may pose serious management concerns for Don Pedro Reservoir downstream. ERMiT model accuracy is stated to be +/- 50%.

ERMiT output below is generalized for the entire fire area. A 50% probability is equivalent to a 2-year runoff event, 20% = 5-year event, and 10% = 10-year event. These provide a range of values that may reasonably be expected in the coming winter. We do not generally model for 20-50 year events or greater, because such events tend to overwhelm fire effects and any BAER treatments we could design to manage such low-probability/high-magnitude risks.

Total Fire - Output Data:

Probability %	50
ar after fire (1-5)	1

Summary For All Hillslopes		
	Average Sediment Delivery tons/acre	Total Sediment tons
Untreated	3.61	617253.5
Seeding	3.61	617253.5
Mulch: 0.5 tons/acre	0.83	132393.9
Mulch: 1 tons/acre	0.69	99479.9
Mulch: 1.5 tons/acre	0.68	97673.5
Mulch: 2 tons/acre	0.67	95766.8

Probability %	20
Year after fire (1-5)	1

Summary For All Hillslopes		
	Average Sediment Delivery tons/acre	Total Sediment tons
Untreated	10.43	1924733.0
Seeding	10.43	1924733.0
Mulch: 0.5 tons/acre	3.01	485276.5
Mulch: 1 tons/acre	2.44	389794.7
Mulch: 1.5 tons/acre	2.40	382300.1
Mulch: 2 tons/acre	2.36	375671.4

Probability %	10
ar after fire (1-5)	1

Summary For All Hillslopes		
	Average Sediment Delivery tons/acre	Total Sediment tons
Untreated	15.92	3014993.0
Seeding	15.92	3014993.0
Mulch: 0.5 tons/acre	4.89	817408.0
Mulch: 1 tons/acre	3.44	538584.3
Mulch: 1.5 tons/acre	3.36	521092.4
Mulch: 2 tons/acre	3.29	498313.6

APPENDIX D – Soil Burn Severity Point Field Data

FireName	SiteID	SurveyDate	GroundCover	AshColor	AshDepthMM	SoilStruct	RootAlt	InfiltMeth	InfiltTime	ObSoilBurn	Comment	AspectDir	SlopePCT	SlopeLenFT	SlopePos	SoilText	SurfRockPC	SoilCommen	PreFireVeg	VegComment
Yosemite	y1	9/11/2013	0 - 20 Percent	White	25.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Weak (< 10 sec)	Moderate	wr 2in	Northwest	0	0			0			
Yosemite	y2	9/11/2013	0 - 20 Percent	White	20.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Weak (< 10 sec)	Moderate	sl wr surface	West	5	100	Foot Slope	Other	10	sl	Forest	m-conifer
Yosemite	y3	9/11/2013	0 - 20 Percent	Black	15.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Weak (< 10 sec)	Moderate	soil char to 1in	Northeast	35	200	Midslope	Other	30	cosl	Chaparral	old burned timber reburn brush
Yosemite	y4	9/11/2013	0 - 20 Percent	White	0.00	DegradedPowdery	ModerateConsumption	WaterDrop	None	High			0	0			0			
Yosemite	y5	9/11/2013	0 - 20 Percent	White	25.00	DegradedPowdery	ModerateConsumption	WaterDrop	None	High	cosl	West	5	50	Midslope	Other	0	1 in char	Forest	m conifer
Yosemite	y6	9/11/2013		Black	0.00	OriginalStructure	NoChange	WaterDrop	Strong (>40 sec)	Low			0	0			0			
Yosemite	y7	9/11/2013	0 - 20 Percent	White	35.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	Moderate	m plus	Northwest	25	500	Midslope	Other	30			
Yosemite	y8	9/11/2013	0 - 20 Percent	White	0.00	SlightlyAltered	VeryFineConsumed	WaterDrop	None	Moderate			0	0			0			
rim	1	9/10/2013	0 - 20 Percent	Gray	0.00	OriginalStructure	NoChange	WaterDrop	Weak (< 10 sec)	Moderate	mod plus	South	48	300	Foot Slope	Other	10	sandy loam	Forest	m conifer
rim	2	9/10/2013	0 - 20 Percent	White	0.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	High	wr 2'	Southeast	25	300	Upper Slope	Loam	30	gl	Forest	m conifer
rim	3	9/10/2013	20 - 50 Percent	Black	25.00	SlightlyAltered	NoChange	WaterDrop	Weak (< 10 sec)	Moderate	wr 1'	Southwest	20	500	Midslope	Loam	10	holland grantic	Forest	m-conifer
rim	4	9/10/2013	0 - 20 Percent	White	30.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	High	wr 1-4in	Northeast	35	500	Midslope	Other	30	clallan sl	Forest	m-conifer
rim	5	9/10/2013	0 - 20 Percent	White	35.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Moderate (10-40 sec)	Moderate	mod plus	North	15	150	Upper Slope	Loam	20	clahan	Forest	m conifer
rim	6	9/10/2013	0 - 20 Percent	Gray	25.00	OriginalStructure	NoChange	WaterDrop	Moderate (10-40 sec)	Moderate	wr 1in	Northwest	30	200	Upper Slope	Loam	20	holland	Forest	m conifer
rim	7	9/10/2013	0 - 20 Percent	Gray	4.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Moderate (10-40 sec)	Moderate	holland	South	15	100	Midslope	Loam	35	wr 2in	Forest	m conifer
rim	8	9/10/2013	0 - 20 Percent	Gray	20.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	Moderate	wr 2in, mod plus	West	30	300	Midslope	Loam	25	holland	Forest	m conifer
rim	9	9/10/2013	0 - 20 Percent	Black	5.00	SlightlyAltered	NoChange	WaterDrop	Weak (< 10 sec)	Moderate	wr surface	Southeast	30	500	Upper Slope	Loam	15	holland l+	Forest	m conifer
rim	10	9/10/2013	0 - 20 Percent	White	25.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Moderate (10-40 sec)	Moderate	wr to 2-4in mod plus	East	10	50	Foot Slope	Loam	15	holland	Forest	m conifer
rimBAER	11	9/14/2013	0 - 20 Percent	White	50.00	DegradedPowdery	ModerateConsumption	WaterDrop	None	High	wr on surface	South	10	100	Midslope	Other	30	sl	Forest	m conifer
rimBAER	12	9/14/2013	0 - 20 Percent	White	48.00	DegradedPowdery	ModerateConsumption	WaterDrop	Strong (>40 sec)	High	wr 1-4in high		0	0		Other	30			
rimBAER	13	9/14/2013	0 - 20 Percent	Gray	2.00	SlightlyAltered	NoChange	WaterDrop	Weak (< 10 sec)	Moderate	wr surface		0	0		Other	10	sl	Forest	
rimBAER	14	9/14/2013	0 - 20 Percent	Gray	3.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	Moderate	wr 2in	West	10	500	Midslope	Other	5	sl	Forest	
rimBAER	15	9/14/2013	0 - 20 Percent	White	48.00	DegradedPowdery	VeryFineConsumed	WaterDrop	Strong (>40 sec)	High	wr to 3in		0	0			0			
rimBAER	16	9/14/2013	0 - 20 Percent	Gray	0.00	SlightlyAltered	NoChange	WaterDrop	None	Moderate	4mm char	Southeast	35	300	Midslope	Loam	3	pucked vary soil burn	Forest	
rimBAER	17	9/14/2013	0 - 20 Percent	Black	10.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	Moderate	char to 1 in, wr 2in, mod plus	South	30	0			0			
rimBAER	18	9/14/2013	0 - 20 Percent	White	4.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	High	5mm char, 4 in wr		0	0		Other	0	sl	Forest	
Rim	19	9/12/2013	0 - 20 Percent	Black	1.00	OriginalStructure	NoChange	WaterDrop	None	Moderate	3mm char, wr 4in	Southeast	10	300	Upper Slope	Loam	30	challan	Chaparral	brush
rimBAER	20	9/12/2013	20 - 50 Percent	Black	10.00	OriginalStructure	NoChange	WaterDrop	Moderate (10-40 sec)	Low	msbs1in	Southwest	10	150	Foot Slope	Loam	15		Forest	oak woodland
rimBAER	21	9/12/2013	20 - 50 Percent	Black	6.00	SlightlyAltered	NoChange	WaterDrop	None	Moderate		North	0	0	Midslope	Loam	15	challan	Forest	m conifer
rimBAER	22	9/12/2013	> 50 Percent	Black	7.00	SlightlyAltered	NoChange	WaterDrop	Moderate (10-40 sec)	Moderate	sbs to 5mm, mod low sbs	Northwest	30	500	Midslope	Loam	40	vgloam, wr to 3in	Forest	m-conifer
rimBAER	23	9/12/2013	0 - 20 Percent	Black	15.00	SlightlyAltered	VeryFineConsumed	WaterDrop	None	Moderate	mod low	West	10	0	Midslope	Loam	15		Forest	m conifer
rimBAER	24	9/12/2013	20 - 50 Percent	White	12.00	SlightlyAltered	NoChange	WaterDrop	Strong (>40 sec)	Moderate	12mm char	South	15	500	Midslope	Loam	5	challan	Forest	m conifer
rimBAER	25	9/12/2013	> 50 Percent	White	37.00	DegradedPowdery	ModerateConsumption	WaterDrop	Moderate (10-40 sec)	Moderate	soil char - 21mm	South	15	200	Midslope	Loam	5	holland wr to 6in	Forest	m conifer
rimBAER	26	9/12/2013	20 - 50 Percent	Black	5.00	SlightlyAltered	VeryFineConsumed	WaterDrop	None	Moderate	sl; wr to 2	West	35	0	Upper Slope	Other	40	sl	Chaparral	moderate brush
rimBAER	27	9/12/2013	> 50 Percent	Black	5.00	SlightlyAltered	NoChange	WaterDrop	Moderate (10-40 sec)	Low	wr 2in	Northwest	30	100	Midslope	Other	35	cbcosl	Chaparral	brush & rock
rimBAER	28	9/12/2013	20 - 50 Percent	White	25.00	DegradedPowdery	ModerateConsumption	WaterDrop	None	Moderate		Northwest	3	0		Other	25	mod repelancy down to 2 inches ;co sl	Forest	
rimBAER	29									mod plus										
rimBAER	30									high										
rimBAER	31									mod										
rimBAER	32									high										
rimBAER	33									mod plus										
rimBAER	34									mod										
rimBAER	35									mod										
rimBAER	36									mod										
rimBAER	37									mod plus										
Yosemite	Y9									mod										
Yosemite	Y10									mod										
Yosemite	Y11									mod										
Yosemite	Y12									high										
Yosemite	Y13									high										
Yosemite	Y14									mod										
Yosemite	Y15									low										
rimBAER	38									mod										
rimBAER	39									low										
rimBAER	40									mod										
rimBAER	41									mod										
rimBAER	42									mod_low										
rimBAER	43									mod										
rimBAER	44									mod										
rimBAER	45									mod										
rimBAER	46									low										
rimBAER	47									mod										
rimBAER	48	9/14/2013	0 - 20 Percent	White	50.00	DegradedPowdery	ModerateConsumption	WaterDrop	None	High	wr on surface	South	10	100	Midslope	Other	30	sl	Forest	m conifer
rimBAER	49	9/14/2013	0 - 20 Percent	White	48.00	DegradedPowdery	ModerateConsumption	WaterDrop	Strong (>40 sec)	High	wr 1-4in high		0	0		Other	30			
rimBAER	50	9/14/2013	0 - 20 Percent	Gray	2.00	SlightlyAltered	NoChange	WaterDrop	Weak (< 10 sec)	Moderate	wr surface		0	0		Other	10	sl	Forest	
rimBAER	51	9/14/2013	0 - 20 Percent	Gray	3.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	Moderate	wr 2in	West	10	500	Midslope	Other	5	sl	Forest	
rimBAER	52	9/14/2013	0 - 20 Percent	White	48.00	DegradedPowdery	VeryFineConsumed	WaterDrop	Strong (>40 sec)	High	wr to 3in		0	0			0			
rimBAER	53	9/14/2013	0 - 20 Percent	Gray	0.00	SlightlyAltered	NoChange	WaterDrop	None	Moderate	4mm char	Southeast	35	300	Midslope	Loam	3	pucked vary soil burn	Forest	
rimBAER	54	9/14/2013	0 - 20 Percent	Black	10.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	Moderate	char to 1 in, wr 2in, mod plus	South	30	0			0			
rimBAER	55	9/14/2013	0 - 20 Percent	White	4.00	SlightlyAltered	VeryFineConsumed	WaterDrop	Strong (>40 sec)	High	5mm char, 4 in wr		0	0		Other	0	sl	Forest	
rimBAER	56									high SBS										
rimBAER	57									high										
rimBAER	58									mod+										
rimBAER	59									mod+										
rimBAER	60									mod+										
rimBAER	61									mod+										
rimBAER	62									low										
rimBAER	63									Moderate										
rimBAER	64									Low										
rimBAER	65									Low										

For most recent fires, remote sensing and GIS provide a means to greatly improve the speed, precision, and accuracy of post-fire mapping efforts. Soil burn severity mapping, however, is never done solely through the use of remote sensing without the benefit of field verification. Ecosystems and fire behavior provide sufficient variation such that field observations and refinement of remote sensing products are required. Once the initial image classification has been done, the soil scientist or other specialist must verify the soil conditions in the field prior to the map being used for subsequent watershed response modeling efforts.

Field evaluations of soil burn severity collected information on current ground cover, ash color, ash depth, surface soil structure, surface roots and pores, water repellency strength and depth, surface soil texture, soil type, surface rock, parent material, pre-fire vegetation, aspect, slope percent, slope length, and slope position. These field data points focused on the major BARC burn severity breaks between high and moderate reflectance values and the break between moderate and low reflectance. This data was critical to make proper mapping adjustments. For hydrology and erosion modeling, the breaks between high/moderate soil burn severity classes and moderate/low classes are critical for subsequent modeling efforts to correctly represent the fire area.

Soil burn severity field data was collected on 80+ points throughout the burn area. Field verified points were used to adjust the initial Burned Area Reflectance Classification (BARC) map to better reflect actual soil burn severity as observed. Refinement of the BARC using this field SBS data achieved better than 90% accuracy in matching field data with adjusted mapping.

APPENDIX E – BAER Risk Assessment

Probability of Damage or Loss	Magnitude of Consequences		
	Major	Moderate	Minor
	RISK		
Very Likely	**Very High**	**Very High**	**Low**
Likely	**Very High**	**High**	**Low**
Possible	**High**	**Intermediate**	**Low**
Unlikely	**Intermediate**	**Low**	**Very Low**

Probability of Damage or Loss: The following descriptions provide a framework to estimate the relative probability that damage or loss would occur within one to three years (depending on the resource):

- Very likely- nearly certain occurrence (>90%)
- Likely- likely occurrence (>50% to < 90%)
- Possible- possible occurrence (>10% to <50%)
- Unlikely- unlikely occurrence (<10%)

Magnitude of Consequences:

- Major- Loss of life or injury to humans; substantial property damage; irreversible damage to critical natural or cultural resources.
- Moderate- Injury or illness to humans; moderate property damage; damage to critical natural or cultural resources resulting in considerable or long term effects.
- Minor- Property damage is limited in economic value and/or to few investments; damage to natural or cultural resources resulting in minimal, recoverable or localized effects.

APPENDIX F – Land Treatment Costs

Proposed land treatments include mastication and aerial helimulch using ag-straw at an application rate of 1.5 tons/acre. Land-unit refinements (methods, acres) and cost estimates are still in progress, and therefore are not included here.

APPENDIX G – Automated Geospatial Watershed Assessment (AGWA)

By Dr. Phillip Guertin, University of Arizona

Introduction

The Automated Geospatial Watershed Assessment (AGWA) tool (Miller et al. 2007; Goodrich et al. 2012) is a GIS interface developed by the USDA-Agricultural Research Service, the U.S. Environmental Protection Agency, the University of Arizona, and the University of Wyoming to automate the parameterization and execution of a suite of hydrologic and erosion models (RHEM, WEPP, KINEROS2 and SWAT - see: www.tucson.ars.ag.gov/agwa). New tools and functionality have been incorporated into AGWA to assess the impacts of wildfire on runoff and erosion. Through an intuitive interface in AGWA the user selects a watershed outlet. AGWA then delineates and discretizes the watershed using a Digital Elevation Model (DEM) for a chosen model. The discretization, represented by overland flow and channel model elements, is then intersected with terrain, soils, and land cover data layers to derive initial estimates of the requisite model input parameters based on observations, experimental data, and research literature. Using a burn severity map AGWA modifies several model input parameters, including the curve number, percent cover, and hillslope roughness (i.e. Manning's roughness coefficient) to reflect the spatial effect of the wildfire in the case of SWAT. For KINEROS2, changes in cover modifies the saturated soil hydraulic conductivity, interception, hillslope roughness (i.e. Manning's roughness coefficient) and several soil erosion parameters (Canfield et al. 2005; Goodrich et al. 2005). AGWA/KINEROS2 has been deployed successful on several BAER engagements including the Wallow Fire (2011, AZ), Las Conchas Fire (2011, NM), Mountain Fire (2013, CA), and the Elk Fire (2013, ID).

The KINEROS2 (KINematic runoff and EROSion) model was used for the Rim Fire. KINEROS2 is a spatially distributed, event-based watershed rainfall-runoff and erosion model. In KINEROS2, the watershed being modeled is conceptualized as a collection of spatially distributed model elements. The model elements effectively abstract the watershed into a series of shapes, which can be oriented so that one-dimensional flow can be assumed. A typical subdivision, from topography to model elements, of a small watershed in the USDA-ARS Walnut Gulch Experimental is illustrated in Figure 1. Further, user-defined subdivision can be made to isolate hydrologically distinct portions of the watershed if desired (e.g., for large impervious areas, for high burn severity, for abrupt changes in slope, soil type, or hydraulic roughness, etc.). Precipitation input can be either observed data or design storms. Precipitation can be entered using time steps ranging from seconds to hours.

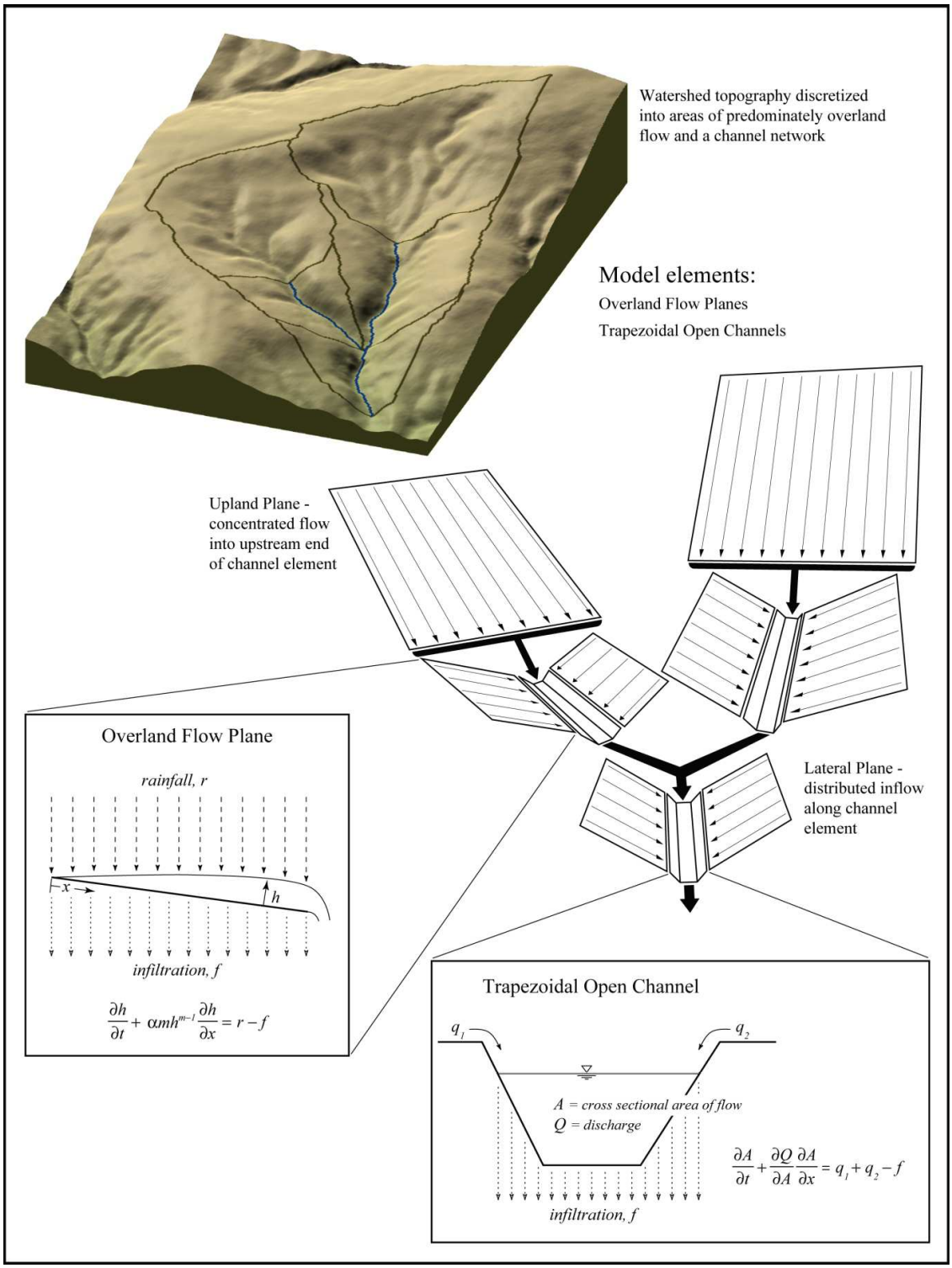

Figure 1. Schematic of the process by which topographic data and channel network topology are abstracted into the simplified geometry of KINEROS2 model elements. Note that overland flow planes (or curvilinear surfaces) are dimensioned to preserve area and average flow length; therefore, planes contributing laterally to channels they may not have widths that match the channel length (from Goodrich et al., 2012).

On the overland flow elements (i.e. hillslopes) KINEROS2 models interception, infiltration, and overland flow. Interception is calculated as the function of vegetation cover. Infiltration is modeled using the Parlange three-parameter model in which the models of Green and Ampt and Smith and Parlange are included as the two limiting cases (Goodrich et al. 2012). In the Rim Fire application the Green and Ampt (1911) representation was used. Infiltration parameters are based on soil and vegetation type. Overland flow is accomplished within KINEROS2 by solving the kinematic-wave equations using a four-point implicit finite difference method using the Manning's hydraulic resistance law. Overland flow parameters are based on terrain and cover data. Unsteady, free-surface flow in channels is also represented by the kinematic approximation to the unsteady, gradually varied flow equations. Channel parameters include channel dimensions, channel geometry (trapezoidal) and roughness. Erosion is computed for upland, channel, and pond elements. Erosion caused by raindrop energy (splash erosion) and erosion (or deposition) caused by flowing water (hydraulic erosion) are accounted for separately, and multiple particle sizes can be treated (Semmens et al. 2008). Erosion parameters are based on terrain (i.e. slope), soil type and land cover type.

Simulation results are created for each overland flow element and channel reach. The runoff and erosion output values represent what is being discharged off the hillslope into the channel or what is being discharged at the channel reach's outlet. The channel reach values represent the accumulative effect of all the overland flow elements and channel reaches above the outlet of the identified channel reach.

Limitations and Uncertainties

The spatial scales for which this model may be used can range from plot (<10 m^2) to large watersheds on the order of 500 square miles (HUC 8 to HUC 10). However, it has only been thoroughly validated for watersheds on the order of 60 square miles (HUC 12 to HUC 14) where sufficient observations exist in experimental watersheds. It was originally developed as an event-based model. Simulation times can vary from tens of minutes for small plots to more than a day for larger watersheds depending on the respective runoff response time.

It should be stressed that the use of any model at any scale is highly dependent on having accurate precipitation data in time and space over the watershed. In the Rim Fire application simple design storms were used with uniform precipitation across the whole watershed at any point in time. The precipitation representation can be a major source of potential error, especially for larger watersheds, for predicting observed runoff. However, recent research at the University of Arizona illustrated that rainfall representation was less important for identifying areas at risk. In a study at Zion National Park they showed that the ranking of channels post-fire relative change did not significantly change between rainfall representations (Gabe Sidman and Phil Guertin, personal correspondence).

RIM FIRE Application

AGWA was used to model the runoff and erosion at the pour points identified by the BAER team within the Rim Fire boundaries and surrounding area. Modeled output variables used in the assessment included peak discharge (cubic feet per second), sediment yield (tons/ac) and total sediment (tons).

The input data used in AGWA were: U.S Geological Survey 10m Digital Elevation Model (DEM), NRCS U.S. General Soils Map (STATSGO) version 2.3.2 and 2006 National Land Cover Database (NLCD). The channel parameters using in the model are in Table 1.

Two return period precipitation events were modeled; 2-year and 10-year. The 2-year event was for 24 hours with total precipitation of 3.55 inches. The 10-year event was for 24 hours with a total precipitation of 5.45 inches. A modified SCS Type II distribution was used for the rainfall intensity over the 24 hour period. The precipitation amounts were optioned from NOAA Atlas 14 (http://hdsc.nws.noaa.gov/hdsc/pfds/).

Using the above data AGWA modeled the pre-fire conditions. After examining preliminary modeling results the cover values for forest and shrub vegetation types were increased to decrease runoff estimates to better match observed return period events within the watershed for median size watersheds. However, the modification decreased the runoff for small watersheds (< 2 square miles) below expected values for the two design storms for some cases. Using the Rim Fire burn severity map the NLCD data was modified and used to model the post-fire response. The pre-fire and post-fire results can then be used to estimate the relative impact of the fire.

Table 1. Channel input parameters.

Parameter	**Selection**
Flow Length	Geometric Abstraction
Hydraulic Geometry	Eastern Arizona / New Mexico sites
Channel Type	Natural (default parameters)
Channel Roughness	0.035 (Manning's n)

Interpretation of the AGWA/KINEROS2 Results

AGWA/KINEROS2 was used to model the relative effect of the fire on runoff and erosion response. KINEROS2 was not calibrated based on observed data in this application. Baseflows adjustments were not included in the simulations so estimated runoff from the model would be lower than the observed runoff, especially on small watersheds and for the smaller 2-year return period precipitation event.

In a BAER post-fire workshop on the Las Conchas Fire, a local county official noted that it is difficult to defend a single flood peak numerical estimate in an ungauged watershed and that relative change estimates would be easier to explain to the public to draw attention to areas at risk. When KINEROS2 and AGWA are employed in this type of relative change analysis, where the lack of observed data (precipitation and runoff) does not allow calibration and validation, it must be made clear that the model results should only be used as an indicator of areas of the watershed that might experience substantial changes in watershed response. If more quantitative change estimates are required, the relative change analysis described above can be employed to target where a more thorough field data collection and modeling effort might be undertaken.

Another concern expressed from stakeholders is the very high percent change values seen on some watersheds, which sometimes can be over 100,000%. In many cases the high percent change values are the result of very low pre-fire values. For example, on a 3.4 square mile gauged watershed, which was severely burned in the 2001 Aspen Fire, AZ, we compared two events with similar rainfall characteristics. The peak discharge for the pre-fire event was 0.16 cubic feet per second. The peak discharge for the post-fire event was 100 cubic feet per second. The peak discharged increased by a factor of 625 or by 62,400%. These high percent change values typically occur on small watersheds with high burn severity. Managers should also look at the pre-fire and post-fire runoff model predictions to estimate risk in these situations.

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AGWA Results

Automated Geospatial Watershed Assessment Tool Modeling for the Rim Fire, CA
2 Year Return Period Results
3.55 inches of over a 24 hour period
Created by Gabe Sidman and Phil Guertin (dguertin@cals.arizona.edu)
20-Sep-13

Peak Discharge (Qp) = cubic feet per second
Sediment Yield (SY) = U.S. Short Tons per Acre
Total Sediment (TS) = U.S. Short Tons (2000 lb)
Area = Acres
Pre = Prefire Results
Post = Postfire Results
Change = Percent Change = (100 *(Post - Pre) / Pre)
Factor = Post/Pre
ND = Not Defined

Pour Point	Pourpoint	Watershed	Area	Qp-Pre	Qp -Post	Qp-Change	Qp-Factor	SY- Pre	SY-Post	SY-Change	SY-Factor	TS-Pre	TS-Post	TS-Change
0	Cherry Valley Campground	Cherry	111.16147	54.4	119.7	120.1	2.2012987	3.1	7.5	141.9	2.418584	346.5	838.0	141.9
1	Joe Walt Run Sispersed Campground	Jawbone	1407.9077	542.0	1912.2	252.8	3.5281219	4.8	15.8	229.3	3.293345	6746.8	22219.4	229
2	LumsdenBridgeCampground	Don Pedro	89534.6	819.6	3111.7	279.7	3.79681	0.3	3.4	1198.7	12.9867	23237.9	301783.2	1198.7
3	Alder Creek - Lumsden Road Culvert	Alder Creek	267.43828	430.5	836.7	94.3	1.9433421	55.9	97.3	74.0	1.74031	14956.3	26028.6	74.0
4	Carlon Picnic Area	South Fork	5182.1732	287.4	779.1	171.1	2.7108705	0.04	0.2	391.9	4.919494	552.2	1099.4	99.1
5	Stream Crossing Soldier	South Fork	201.87374	111.6	308.9	176.7	2.7671384	4.6	21.9	375.4	4.75407	931.1	4426.3	375.4
6	Berkeley Tuolumne Camp	South Fork	7424.0996	231.7	735.9	217.6	3.1761196	0.1	0.4	473.1	5.731268	540.7	3098.7	473.1
7	Yosemite Lakes Camp	South Fork	9274.3909	817.7	3021.8	269.5	3.6954461	0.2	1.8	811.2	9.111719	1785.7	16270.9	811.2
8	San Jose Family Camp Amplatheater	Middle Fork	2.9866451	0.6	10.7	1622.8	17.227561	0.0145	1.6	10709.8	108.0983	0.043	4.7	10709.8
9	San Jose Family Camp - Yosemite Riverside Inn	Middle Fork	8317.6244	162.8	683.5	319.9	4.1990353	0.0	0.2	424.5	5.244592	299.8	1572.1	424.5
10	Spinning Wheel Campground	Middle Fork	7512.4767	177.3	727.1	310.0	4.0999998	0.2	0.8	341.1	4.410659	1317.9	5812.8	341.1
11	Culvert A 1S30	Middle Fork	150.50182	1.154	220.1	18974.1	190.74118	0.0008	1.1	144549.4	1446.494	0.1	164.9	144549.4
12	Culvert B 1S30	Middle Fork	5.184136	1.8	40.2	2116	22.162063	0.1	11.26	12051	121.5088	48.0	5835.8	12051
13	Riverside Picnic Area	North Fork	7744.8644	1539.2	1604.4	4	1.0423432	2.3	2.4	5	1.05069	17509.0	18396.6	5
14	Ackerson Meadow Residence	South Fork	1164.1117	0.055	55.9	102247	1023.4706	0.000003	0.01	483682	4837.816	0.003	14.3	483682
15	Cherry Lake Road Crossing (ID: ICCOCD18.30)	Reservoirs (NOT ON	1.6430595	0.2	13.8	5576	56.762636	0.0124	6.19	49919	500.1857	0.02	10.2	49919
16	Stream Crossing 1N96 (ID: 01N96CD.30)	Reservoirs	0.0768919	1.0	152.2	15058	151.5802	0.0002	0.43	175327	1754.268	0.00002	0.03327	175327
17	CherryLKRD Upper GraniteCK Xross (ID: ICCOCD16.11)	Reservoirs	73.82841	0.005572	332.1	5959678	59597.782	0.000002	3.41	181810476	1818106	0.000138	251.5	181810476
18	Don Pedro Reservoir	Don Pedro	Not Done - Pour Point in the Reservior - Cannot deliniate Watershed											
19	Don Pedro Dam	PROHIBITIVELY LARG	Not Done - San Pedro Dam - Very Large Watershed											
20	Small Watershed Example	Reservoirs	2.2460542	0.2	14.4	6297	63.96594	0.0201	14.20	70427	705.2735	0.11	78.8	70427
21	Culvert Cherry LK RD (Debris Flow Also)	Reservoirs	5.7385674	0.0	25.6	ND	ND	0.0	4.50	ND		0.0	25.8	ND
22	CherryLKRD Lower Granite Culvert (ID:ICCOCD14.4)	Reservoirs	454.65803	0.8	625.0	78072	781.7175	0.0	9.57	1451733	14518.33	0.3	4351.6	1451733
23	Granite Creek at Dion Holm Power House	Reservoirs	705.27317	3.3	1165.6	35555	356.54519	0.02	23.12	131354	1314.542	12.4	16303.5	131354
24	Cherry Creek at Dion Holm Power House	Reservoirs	26369.304	0.9	1076.3	121780	1218.7996	0.00016	1.43	917823	9179.231	4.1	37601.0	917823
25	Hillslope B/W Powerhouse and Bridge (Debris Also)	Reservoirs	25.471469	0.03	37.5	107790	1078.9004	0.0005	16.38	3001515	30016.15	0.01	417.3	3001515
26	Hillslope Above open ditch	Reservoirs (NOT ON	10.704168	0.0	12.7	ND	ND	0.0	1.17	ND		0.0	12.5	ND
27	Tuolumne at Robert Kirkwood Power House	Poopenaut	3415.5443	1.621	341.6	20969	210.68944	0.0002	0.23	100530	1006.305	0.8	802.3	100530
28	Cottonwood RD and Bear CK Culvert	Clavey	237.49494	328.009	1099.3	235	3.3515401	13.6275	44.76	228	3.284567	3236.5	10630.4	228
29	Jawbone Falls - Restoration Site	Jawbone	53.09996	499.984	1029.2	106	2.0584364	6.2183	14.55	134	2.339747	330.2	772.6	134
30	Camp Tawonga	Middle Fork	7221.728	193.5	756.5	291	3.9096823	0.0383	1.43	3624	37.23794	276.5	10297.7	3624
31	180400091002 Big Creek	Don Pedro	133047.6	15382.5	48467.4	215	3.1508155	4.4	24.7	464	5.642739	581426.8	3280840.1	464
32	180400080306 Crane Creek - Merced River	NOT IN BURN AREA	26903.756	6326.1	6326.1	0	1.0000028	1.0	1.0	0	1.000012	27166.9	27167.2	0
33	180400080307 Moss Creek - Merced River	NOT IN BURN AREA	48997.523	5387.2	5387.2	0	0.9999993	0.8	0.8	0	1	38896.3	38896.3	0
34	180400080401 Bean Creek - North Fork Merced River	NOT IN BURN AREA	2566.3011	4340.5	4340.5	0	1	9.0	9.0	0	1	23115.8	23115.8	0
35	180400080402 Bull Creek	NOT IN BURN AREA	7419.3201	15899.7	18359.1	15	1.1546778	21.6	27.0	25	1.251903	160008.1	200314.6	25
36	180400090303 Kibbie Creek	Kibbie MODELED BY	Not Done - Kibble Creek - Modeled by the NPS											
37	180400090304 Miguel Creek - Eleanor Creek	Reservoirs	10830.51	1.1	833.9	76178	762.78352	0.0010	2.56	246623	2467.232	11.3	27770.3	246623
38	180400090405 Lower Cherry Creek	Reservoirs	27624.86	0.9	1066.0	116175	1162.7454	0.0001	1.06	1137887	11379.87	2.6	29236.3	1137887
39	180400090504 Hetch Hetchy Reservoir - Tuolumne R.	Hetch Hetchy MODE	Not Done - Hutch Hetchy - Done by the NPS											
40	180400090505 Poopenaut Valley - Tuolumne River	Poopenaut	2721.2626	1.624	342.0	20957	210.5697	0.0001	0.17	171621	1717.205	0.3	461.3	171621
41	180400090601 Upper Middle Tuolumne River	Middle Fork	5361.0765	232.6	809.5	248	3.4804234	0.3188	1.48	364	4.635318	1709.2	7922.7	364
42	180400090602 Lower Middle Tuolumne River	Middle Fork	8633.5006	161.5	680.2	321	4.2114973	0.2337	0.91	288	3.882241	2017.9	7834.1	288
43	180400090701 Upper SF Tuolumne River	South Fork	1166.4994	0.001	46.8	6957794	69578.94	0.0001	0.03	18392	184.917	0.2	31.4	18392
44	No Point in Pour Point Table		No Point in Pour Point Table											
45	180400090802 Reed Creek	Clavey	3424.6499	56.921	1123.0	1873	19.728406	0.0611	1.78	2817	29.16642	209.4	6107.1	2817
46	180400090803 Middle Clavey River	Clavey	10577.147	1210.044	3055.9	153	2.5254688	1.3373	4.85	262	3.623391	14144.8	51252.3	262
47	180400090804 Lower Clavey River	Clavey	17690.817	6820.469	19106.2	180	2.8012976	9.6700	27.99	189	2.894401	171069.8	495144.5	189
48a	180400090702 Lower SF Tuolumne River	Don Pedro	11488.114	9856.8	12752.9	29	1.293808	16.9	25.4	51	1.505771	193869.0	291922.4	51
48b	180400090902 Lower NF Tuolumne River	North Fork	136553.7	19464.4	29411.1	51	1.5110175	4.8	10.9	128	2.279577	652998.4	1488560.3	128
49	180400091001 Jawbone Creek - Tuolumne River	Don Pedro	90250.1	759.7	3094.5	307	4.0734134	0.2	1.6	870	9.704867	15261.7	148112.7	870
50	180400091004 Grapevine Creek - Tuolumne River	Don Pedro	148881.2	26610.3	40130.4	51	1.5080743	3.7	8.4	127	2.265861	552093.1	1250966.1	127
51	Cherry Lake Dam	Cherry RESERVOIR C	Not Done - Cherry Lake Dam Reservoir Outlet - No Watershed Area											
52	Lake Eleanor Dam	Elanor RESERVOIR M	Not Done - Lake Eleanor Dam - Modeled by the EPA											
53	Engineered Culvert Under 1N07	Poopenaut	2645	0.0	12.7	ND	ND	0.0	1.17	ND		0.0	12.5	ND
54	Drew Creek	Drew Creek	295.64953	7.0	162.1	2222	23.219013	0.1019	16.00	15598	156.9757	30.1	4729.7	15598
55	Bull Meadow Creek	Clavey	258.53096	1277.170	1415.5	11	1.1082808	131.3405	172.55	31	1.31374	33955.6	44608.8	31
56	Clavey River 1N01	Clavey	15657.418	5010.906	15393.5	207	3.0719982	2.9700	15.80	432	5.321307	46502.2	247452.7	432
57	Grapevine Creek	Grapevine Creek	783.63011	4519.3	4963.5	10	1.0982997	181.3091	249.22	37	1.374581	142079.3	195299.5	37
58	Snow Canyon Creek	Cherry	Snow Canyon Creek - Not Done - No Burn Area above in watershed											
59	Hunter Creek	North Fork	424.01457	5170.3	7890.9	53	1.5261965	49.3	108.3	120	2.197209	20907.0	45937.1	120

Table 1. Results by pour-point for a 2-year storm event.

Automated Geospatial Watershed Assessment Tool Modeling for the Rim Fire, CA
10 Year Return Period Results
5.45 inches of over a 24 hour period
Created by Gabe Sidman and Phil Guertin (dguertin@cals.arizona.edu)
20-Sep-13

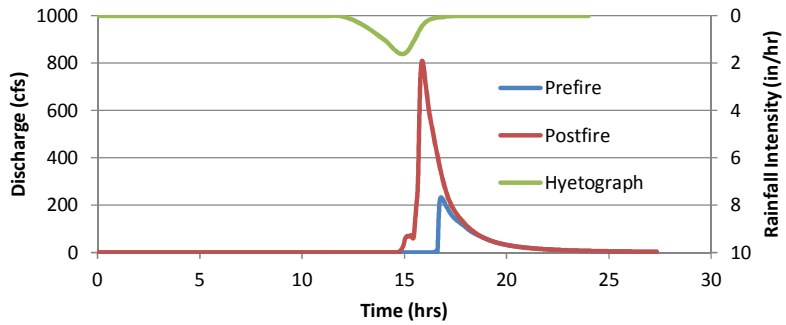
Peak Discharge (Qp) = cubic feet per second
Sediment Yield (SY) = U.S. Short Tons per Acre
Total Sediment (TS) = U.S. Short Tons (2000 lb)
Area = Acres
Pre = Prefire Results
Post = Postfire Results
Change = Percent Change = (100 *(Post - Pre) / Pre)
Factor = Post/Pre
ND = Not Defined

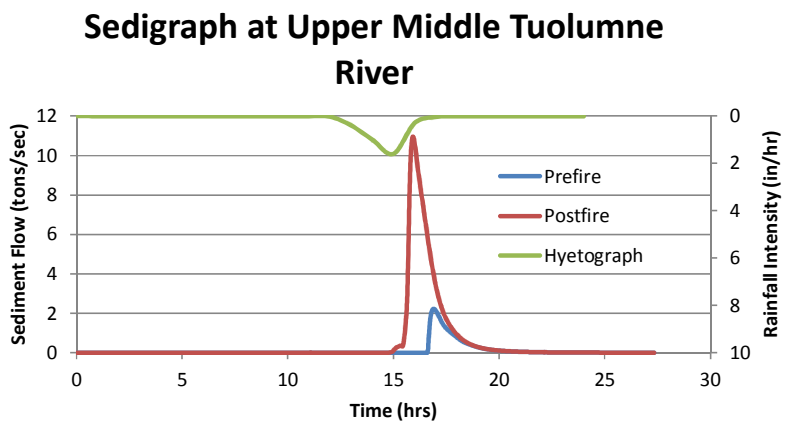
Pour Point	Pourpoint	Watershed	Area**	Qp-Pre	Qp -Post	Qp-Change	QP-Factor	SY- Pre	SY-Post	SY-Change	SY-Factor	TS-Pre	TS-Post	TS-Change
0	Cherry Valley Campground	Cherry	111.1615	400.1	716.8	79	1.79	24.1	47.4	97	1.9704717	2673.9	5268.8	97
1	Joe Walt Run Sispersed Campground	Jawbone	1407.908	3841.9	8697.5	126	2.26	34.7	73.2	111	2.1056089	48923.7	103014.1	111
2	LumsdenBridgeCampground	Don Pedro	89534.6	9463.7	51849.3	448	5.48	13.4	82.5	514	6.1427048	1202198.7	7384752.0	514
3	Alder Creek - Lumsden Road Culvert	Alder Creek	267.4383	1737.7	2181.2	26	1.26	208.8	308.7	48	1.4780859	55847.9	82548.0	48
4	Carlon Picnic Area	South Fork	5182.173	6310.0	14736.2	134	2.34	4.6	15.8	247	3.4743591	23622.5	82073.0	247
5	Stream Crossing Soldier	South Fork	201.8737	547.1	1313.0	140	2.40	33.7	79.0	134	2.3425612	6811.0	15955.2	134
6	Berkeley Tuolumne Camp	South Fork	7424.1	6546.4	20370.3	211	3.11	4.5	16.5	265	3.6520062	33455.6	122180.1	265
7	Yosemite Lakes Camp	South Fork	9274.391	8735.7	25943.8	197	2.97	4.9	24.9	413	5.1269937	44996.3	230695.6	413
8	San Jose Family Camp Amplatheater	Middle Fork	2.986645	33.9	44.1	30	1.30	7.7	14.9	94	1.937085	23.0	44.5	94
9	San Jose Family Camp - Yosemite Riverside Inn	Middle Fork	8317.624	7219.3	20228.7	180	2.80	6.3	31.6	401	5.0128759	52501.2	263182.0	401
10	Spinning Wheel Campground	Middle Fork	7512.477	7228.8	20089.6	178	2.78	11.2	39.4	250	3.5030454	84412.4	295700.3	250
11	Culvert A 1S30	Middle Fork	150.5018	674.9	970.9	44	1.44	7.5	27.8	272	3.7217012	1125.6	4189.3	272
12	Culvert B 1S30	Middle Fork	5.184136	105.0	135.4	29	1.29	39.3	78.7	100	2.0011895	20383.3	40790.8	100
13	Riverside Picnic Area	North Fork	7744.864	10512.8	10778.5	3	1.03	30.9	32.1	4	1.038835	238956.6	248236.5	4
14	Ackerson Meadow Residence	South Fork	1164.112	280.1	4193.1	1397	14.97	0.1	13.7	13006	131.0552	121.9	15977.9	13006
15	Cherry Lake Road Crossing (ID: ICCOCD18.30)	Reservoirs (NOT ON	1.643059	26.8	41.9	56	1.56	14.8	41.1	177	2.7653218	24.4	67.5	177
16	Stream Crossing 1N96 (ID: 01N96CD.30)	Reservoirs	0.076892	138.2	1218.0	781	8.81	0.4	34.2	8629	87.28582	0.0	2.6	8629
17	CherryLKRD Upper GraniteCK Xross (ID: ICCOCD16.11)	Reservoirs	73.82841	168.3	1346.6	700	8.00	1.7	84.8	4877	49.774729	125.8	6260.1	4877
18	Don Pedro Reservoir	Don Pedro	Not Done - Pour Point in the Reservior - Cannot deliniate Watershed											
19	Don Pedro Dam	PROHIBITIVELY LARG	Not Done - San Pedro Dam - Very Large Watershed											
20	Small Watershed Example	Reservoirs	2.246054	25.2	42.2	67	1.67	29.6	80.9	173	2.7297465	164.5	448.9	173
21	Culvert Cherry LK RD (Debris Flow Also)	Reservoirs	5.738567	49.7	137.6	177	2.77	9.9	68.4	589	6.8897841	57.0	392.4	589
22	CherryLKRD Lower Granite Culvert (ID:ICCOCD14.4)	Reservoirs	454.658	542.3	3304.4	509	6.09	13.6	129.5	850	9.5038578	6193.7	58863.9	850
23	Granite Creek at Dion Holm Power House	Reservoirs	705.2732	1672.4	5209.5	212	3.12	47.6	191.0	301	4.0132681	33572.9	134737.1	301
24	Cherry Creek at Dion Holm Power House	Reservoirs	26369.3	3443.5	18023.3	423	5.23	7.2	69.9	874	9.7350993	189206.4	1841942.8	874
25	Hillslope B/W Powerhouse and Bridge (Debris Also)	Reservoirs	25.47147	77.0	192.4	150	2.50	45.8	236.9	417	5.1706909	1166.9	6033.6	417
26	Hillslope Above open ditch	Reservoirs (NOT ON	10.70417	27.3	140.8	417	5.17	4.5	93.5	1987	20.871222	48.0	1001.1	1987
27	Tuolumne at Robert Kirkwood Power House	Poopenaut	3415.544	4089.1	15081.0	269	3.69	5.5	47.3	756	8.5635921	18855.2	161467.8	756
28	Cottonwood RD and Bear CK Culvert	Clavey	237.4949	1541.9	2272.4	47	1.47	61.3	118.1	93	1.9256662	14559.5	28036.7	93
29	Jawbone Falls - Restoration Site	Jawbone	53.09996	1775.9	2414.9	36	1.36	31.6	48.8	55	1.5460891	1676.6	2592.1	55
30	Camp Tawonga	Middle Fork	7221.728	7233.4	19191.8	165	2.65	6.7	27.5	309	4.0917879	48605.1	198881.8	309
31	180400091002 Big Creek	Don Pedro	133047.6	48467.4	127719.0	164	2.64	24.7	56.1	128	2.2751864	3280840.1	7464522.9	128
32	180400080306 Crane Creek - Merced River	NOT IN BURN AREA	26903.76	69159.1	69159.1	0	1.00	21.4	21.4	0	1	575450.6	575450.6	0
33	180400080307 Moss Creek - Merced River	NOT IN BURN AREA	48997.52	68016.1	68018.1	0	1.00	21.9	21.9	0	1	1073332.9	1073332.9	0
34	180400080401 Bean Creek - North Fork Merced River	NOT IN BURN AREA	2566.301	16294.4	16294.4	0	1.00	41.1	41.1	0	1	105581.4	105581.4	0
35	180400080402 Bull Creek	NOT IN BURN AREA	7419.32	50614.4	54416.7	8	1.08	95.7	112.4	17	1.1744851	710232.0	834157.0	17
36	180400090303 Kibbie Creek	Kibbie MODELED BY	Not Done - Kibble Creek - Modeled by the NPS											
37	180400090304 Miguel Creek - Eleanor Creek	Reservoirs	10830.51	2149.5	8394.8	291	3.91	9.1	53.7	493	5.9278713	98176.7	581979.1	493
38	180400090405 Lower Cherry Creek	Reservoirs	27624.86	3814.8	24518.7	543	6.43	6.1	83.2	1263	13.631353	168618.5	2298498.0	1263
39	180400090504 Hetch Hetchy Reservoir - Tuolumne R.	Hetch Hetchy MODE	Not Done - Hutch Hetchy - Done by the NPS											
40	180400090505 Poopenaut Valley - Tuolumne River	Poopenaut	2721.263	4089.6	14958.3	266	3.66	5.1	45.9	794	8.9372406	13973.1	124881.3	794
41	180400090601 Upper Middle Tuolumne River	Middle Fork	5361.076	7271.0	16454.8	126	2.26	21.3	42.4	99	1.9946037	113960.6	227306.2	99
42	180400090602 Lower Middle Tuolumne River	Middle Fork	8633.501	7218.1	20225.0	180	2.80	10.9	41.3	280	3.7959181	93862.4	356293.9	280
43	180400090701 Upper SF Tuolumne River	South Fork	1166.499	287.7	4725.2	1542	16.42	0.3	15.3	4570	46.698871	944.9	44127.5	4570
44	No Point in Pour Point Table		No Point in Pour Point Table											
45	180400090802 Reed Creek	Clavey	3424.65	4808.4	13524.2	181	2.81	16.2	42.5	163	2.6314687	55368.5	145700.4	163
46	180400090803 Middle Clavey River	Clavey	10577.15	10619.2	15462.5	46	1.46	18.0	31.8	76	1.7643097	190779.4	336594.0	76
47	180400090804 Lower Clavey River	Clavey	17690.82	27246.4	47308.6	74	1.74	55.4	112.2	102	2.0234435	980864.8	1984724.6	102
48a	180400090702 Lower SF Tuolumne River	Don Pedro	136553.7	67342.4	142136.5	111	2.11	27.0	57.7	114	2.1353777	3688980.8	7877367.5	114
48b	180400090902 Lower NF Tuolumne River	North Fork	11488.11	33451.1	35070.3	5	1.05	91.2	110.6	21	1.2125805	1047427.7	1270090.5	21
49	180400091001 Jawbone Creek - Tuolumne River	Don Pedro	90250.1	9349.6	52673.8	463	5.63	7.1	56.0	690	7.9001814	639467.6	5051910.2	690
50	180400091004 Grapevine Creek - Tuolumne River	Don Pedro	148881.2	97351.1	158986.5	63	1.63	21.8	43.0	97	1.9704939	3250427.0	6404946.6	97
51	Cherry Lake Dam	Cherry RESERVOIR C	Not Done - Cherry Lake Dam Reservoir Outlet - No Watershed Area											
52	Lake Eleanor Dam	Elanor RESERVOIR M	Not Done - Lake Eleanor Dam - Modeled by the EPA											
53	Engineered Culvert Under 1N07	Poopenaut	2645	27.3	140.8	417	5.17	4.5	93.5	1987	20.871222	48.0	1001.1	1987
54	Drew Creek	Drew Creek	295.6495	971.8	2021.4	108	2.08	78.8	152.3	93	1.9340513	23284.9	45034.2	93
55	Bull Meadow Creek	Clavey	258.531	2492.3	2636.0	6	1.06	312.1	381.7	22	1.2230911	80682.4	98681.9	22
56	Clavey River 1N01	Clavey	15657.42	25405.1	47308.6	86	1.86	30.9	112.2	263	3.6266641	484356.5	1756598.4	263
57	Grapevine Creek	Grapevine Creek	783.6301	8486.9	8862.9	4	1.04	456.8	583.4	28	1.277115	884579.4	1129709.6	28
58	Snow Canyon Creek	Cherry	Snow Canyon Creek - Not Done - No Burn Area above in watershed											
59	Hunter Creek	North Fork	424.0146	14275.3	15852.2	11	1.11	217.8	356.3	64	1.6359194	92360.2	151093.9	64

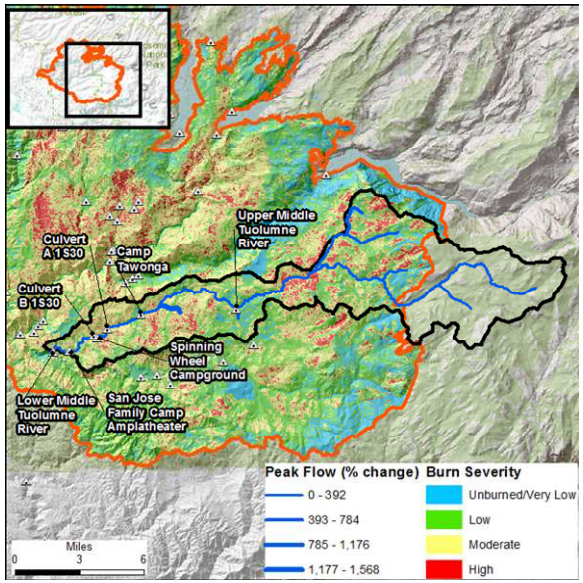
**Note: Areas are all based on the watershed area after clipping out the area above the dams

Table 2. Results by pour-point for a 10-year storm event.

Figure 1. Example of graphical AGWA output, including geographic representation of peak flow increase by stream reach. Each modeled pour-point has equivalent output for both 2-year and 10-year storm events.







3.55", 2 year 24 hour storm			
	Pre-fire	Post-fire	Percent Change
Peak Flow (cfs)	232.6	809.5	248
Sediment Yield (tons/ac)	0.3188	1.48	364
Total Sediment (tons)	1709.2	7922.7	364