Memorandum

DATE: December 5, 2016

TO: **Lucinda Andreani; Coconino County**

FROM: Joe Loverich, PE, CFM; JE Fuller, Inc.

RE: **Coconino County Post-Wildfire Flood and Debris-Flow Risk Assessment: Fort Valley Fire Modeling and Assignment of Post-Wildfire Curve Numbers**

Registered Professional Engineer (Civil)
CERTIFICATE NO.
45648
JOSEPH BERNARD LOVERICH
Date Signed 12/5/16
ARIZONA U.S.A.
Expires 12/31/2018

Introduction

The purpose of this project is to conduct an assessment of the potential for debris flows and post-fire flooding, as well as their impacts to downstream communities in the immediate aftermath of a reasonable-scenario wildfire in northern Arizona. Two pilot study areas, Williams and Fort Valley, were selected for detailed pre- and post-wildfire debris and flooding analysis.

Williams

An Environmental Impact Statement (EIS), which included burn severity modeling, was prepared by the Kaibab National Forest (KNF) for the Bill Williams Mountain Area. That data was provided to JE Fuller to use in modifying the runoff curve numbers to represent post-wildfire conditions.

Fort Valley

The majority of this pilot area was not included in the Forest Service fire modeling prepared for the Four Forest Restoration Initiative (4FRI) Environmental Impact Statement, therefore JE Fuller performed fire modeling to determine runoff curve number changes in the post-wildfire hydrologic modeling performed as a part of the project.

This memorandum describes the processes and procedures used to perform fire modeling in the Fort Valley area as well as the resulting runoff curve numbers. Since the fire modeling was completed for Bill Williams pilot area by the KNF, a discussion of the fire modeling is not included and only the resulting curve numbers are discussed.

Fort Valley Area Burn Severity Modeling

Modeling Parameters

FlamMap Version 5 was utilized to perform fire severity modeling for the Fort Valley Watershed. The program utilizes a series of user specified input parameters to approximate fire behavior over a landscape. The input parameters can be calibrated to recent nearby fires and varied to produce reasonable fire behavior results. Many of the parameters utilized, described in Table 1, were provided to JE Fuller by the Coconino National Forest. These parameter files are used to represent conditions in which the fire is burning and, in the case of Fort Valley, parameters were used to closely represent conditions found at the time of the 2010

Schultz Fire. We chose to use parameters similar to the Schultz Fire in order to compare modeling results with previous post-fire responses.

Table 1. Input Parameters

Parameter	Contents
Fuel Moisture File (.fms)	Initial Fuel moisture to represent conditions at the onset of the Schultz Fire. File provided by USFS.
Weather File (.wtr)	Observations in temperature, humidity and precipitation for June 1 – 24, 2010. File Provided by USFS.
Wind File (.wnd)	Observations in wind conditions used to condition dead fuel for June 1 – 24, 2010. File Provided by USFS.
2020 Untreated Landscape File (.LCP)	Contains elevation, slope, aspect, fuel model, canopy cover, stand height, canopy base height, and canopy bulk density data for use in fire modeling. The file provided by USFS shows untreated conditions projected out to the year 2020. This was the data used in the 4FRI fire modeling. Fuel models are represented by a numbering scheme (Scott/Burgan, 2005). This file was modified by JE Fuller as described later.
Initial Wind Speed and direction	The initial wind speed was input at 23 mph at 20' high with an azimuth of 200 degrees as observed during the Schultz Fire. (Beale, Hall, Lata 2014). The wind speed was observed at the start of the Schultz Fire and the wind direction represents the predominant southwest winds in the area.
Wind Ninja	The Wind Ninja tool was utilized to create a gridded wind file based on the terrain and the initial wind input parameters. Diurnal settings were also utilized to model slope winds specific to the time of day when the fire begins. For our modeling, 1:00PM was used as recommended by the USFS.
Fuel Conditioning Period	A 5-day fuel conditioning period was utilized as recommended by the USFS

Model Runs and Landscape File Modification

The input parameters described in Table 1 were held constant for all fire model simulations except for the LCP file. Since this file contains all data in regard to the forest characteristics, modifications were made to represent three burn scenarios described below as (1) Untreated Scenario, (2) Treated Scenario for the entire watershed, and (3) Treated Scenario up to the 8,200 foot elevation contour (approximate limit of the San Francisco Peaks Wilderness Area). All model runs were completed using the Scott/Reinhardt (2001) crown fire calculation method (Stratton, 2009, pp.23) and the outputs selected were Crown Fire Activity and Heat/Unit Area.

Untreated Scenario (Untreated 2020 forest conditions)

An Initial FlamMap run revealed that the crown fire potential and heat per unit area were low along the mid flank (approx. 8,500 feet to 9,500 feet) of the San Francisco Peaks. In contrast, the Schultz burn severity was highest in this elevation range (Figure 1). It appeared that the discrepancy was largely due to the fact that the LCP file listed the area as mixed conifer with a light dead fuel load, so JE Fuller modified the LCP file by adjusting the mixed conifer fire load from light load (161) to heavy load (165). The resulting burn severity more closely matches the burn severity observed after the Schultz Fire as shown in Figure 1. Further justification for this adjustment was obtained during conversations with local USFS contacts (C. Macdonald, M. Lata, personal communication, 2016) and similar calibrations were made for the 2014 Scientific Investigations Report 2014-516 *Potential Post-wildfire Debris-Flow Hazards—A Pre-wildfire Evaluation for the Sandia and Manzano Mountains and Surrounding Areas, Central New Mexico*.

We acknowledge that an extensive calibration routine was not completed to exactly match the patterns of the Schultz Fire and that the aspect, vegetation, and wind conditions are not completely similar on opposite sides of the mountain. One point of comparison is to note that approximately 40% of the total Schultz fire area was classified as high burn severity. The Untreated scenario that we modeled for Ft Valley resulted in approximately 30% of the area being classified as an active crown fire (a proxy for high burn severity). Although the percent of high burn severity is lower in our model, the modeled area is larger and includes more land with flatter slopes. With this in mind, the modeling completed is reasonable for this planning level study.

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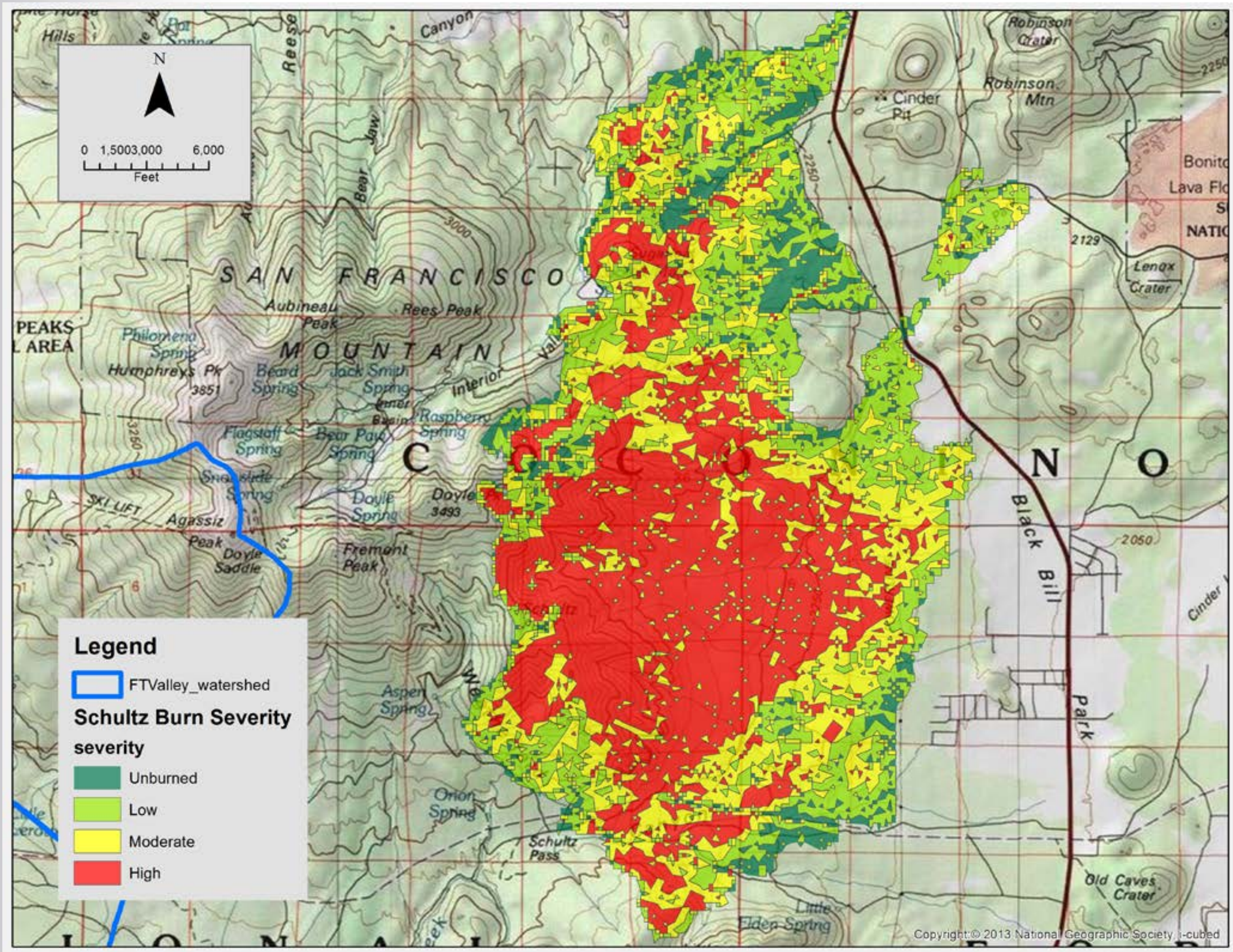

Figure 1 – Schultz Fire Burn Severity (provided by USFS)

Treated Scenario for Entire Watershed (Mechanical Thinning for the Whole Watershed)

Forest treatments can be accomplished in several ways, but typically by mechanical thinning (Pollet, Omi, 2002). This has the effect of reducing the Canopy Bulk Density, increasing the Crown Base height, and modifying the fuel model to represent a lower fuel load on the ground. To represent treated conditions in the study area, the untreated LCP file was modified by JE Fuller as described below:

- Landscape codes 165 (Mixed Conifer high load) were changed to code 161 (mixed conifer low load).
  - For landscape codes of 161, the Crown Base Height (CBH) was raised to 12 feet
  - For landscape codes of 161, the Canopy Bulk Density (CBD) was decreased to 0.06
- Landscape codes 188 were adjusted to code 122
  - For 122, CBH was raised to 22 feet
  - For 122, CBD was lowered to 0.03
  - For 122, Canopy Cover (CC) was lowered to 25%

Justification for the parameter modifications used for the treated landscape files were based upon conversations with the USFS and the following cited references:

Table 3.3-2 within the *Bill Williams Mountain Restoration Project, Fire and Fuels Specialist Report (Uebel, 2015, 17p.) is shown below.*

Table 3.3-2 Fire and Fuels Extension to the Forest Vegetation Simulator post treatment results by alternative.

FVS/FFE Calculation Results Post Treatment						
Forest Type	Criteria	Desired Condition	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Dry Mixed Conifer	Canopy Base Height (feet)	>10	4	12	20	10
	Canopy Bulk Density (kg/m3)	<.08	0.15	0.06	0.05	0.07
	Surface Fuel Loading (tons/acre)	<15	30	16	15	19
Ponderosa Pine /Pine-Oak	Canopy Base Height (feet)	>18	10	22	22	21
	Canopy Bulk Density (kg/m3)	<0.05	0.07	0.03	0.03	0.03
	Surface Fuel Loading (tons/acre)	<10	19	8	8	8
Pinyon-Juniper Woodlands	Canopy Base Height (feet)	>10	14	15	15	15
	Canopy Bulk Density (kg/m3)	<.05	0.04	0.01	0.01	0.01
	Surface Fuel Loading (tons/acre)	<6	8	3	3	3

For the Bill Williams EIS, Alternative 1 represents existing conditions and Alternative 2 represents treated conditions. Note the changes in CBD and CBH between the alternatives for the Bill Williams EIS. The changes made to the CBH and CBD for the Bill Williams EIS were similar to the treated landscape models for Fort Valley. Additionally, the 4FRI Fire Ecology, Fuels, & Air Quality Specialist Report *(Lata, 20515)* notes that the desired condition is for average CBD to be less than 0.05 kg/m3 in ponderosa pine and the desired condition is for CBH to be greater than 18 feet in ponderosa pine. Changing landscape type from 188 to 122 (Ponderosa Pine to Grassland) was done for fire modeling purposes and is consistent with the 4FRI treated forest modeling (Lata, 2015).

Treated Scenario up to 8,200 feet (approximate elevation of the wilderness boundary). No mechanical treatment specified above the wilderness boundary.

A portion of the modeled area is within the San Francisco Peaks Wilderness area. It is our understanding that per the Wilderness Act of 1964, mechanical thinning is restricted, and therefore, LCP modifications are excluded in this area for the third scenario. The wilderness boundary on the south side of the Peaks is approximately 8200' in elevation and although the elevation varies to the west side of the mountain, this was the limiting elevation set for the LCP file modifications due to software limitations.

Burn Severity Analysis

The purpose of the fire modeling is to provide burn severity classifications for determining hydrologic curve number adjustments; these data are also being used for modeling the potential for post-fire debris-flows. FlamMap produces various fire behavior outputs including, fireline intensity, rate of spread, heat/unit area, crown fire activity, etc. These outputs can be interpreted by the user to determine the burn severity of a fire. It is important to note that the individual outputs, such as heat/unit area or crown fire activity, only specify components of fire intensity and there is not necessarily a direct relation between each component and burn severity. There is a significant amount of research in regard to analyzing and identifying fire severity and burn severity for burnt areas. However, there is not a significant amount of information about interpreting FlamMap fire behavior outputs to determine burn severity (Tillery, et al. 2014).

One way that was used to determine burn severity was to classify the Heat/Unit Area (HUA) values generated in FlamMap. The Soil and Water Specialist Report (Runyon, 2015) for the Flagstaff Watershed Protection Project referenced that soil burn severity was determined utilizing HUA values and adjusted to account for conditional crown fire. The HUA values were categorized to determine the values that corresponded to the burn severity categories.

Another way correlate burn severity to the FlamMap results is by crown fire activity. A study in the area of the Sandia and Manzano Mountians in New Mexico (Tillery, et al., 2014) utilized crown fire activity as the metric for determining burn severity. The Bill Williams Mountain Restoration Project, Fire and Fuels Specialist Report (Uebel, 2015, 17p.) and Bill Williams Mountain Restoration Project, Hydrology Report (McDonald, 2015) also reference that burn severity was based on crown fire activity.

Based on this research, JE Fuller related the burn severity to the crown fire activity per the following criteria and are shown on the following figures.

Active Crown Fire – High Burn Severity

Passive Crown Fire – Moderate Burn Severity

Surface Fire – Low Burn Severity

No Fire – No Burn Severity.

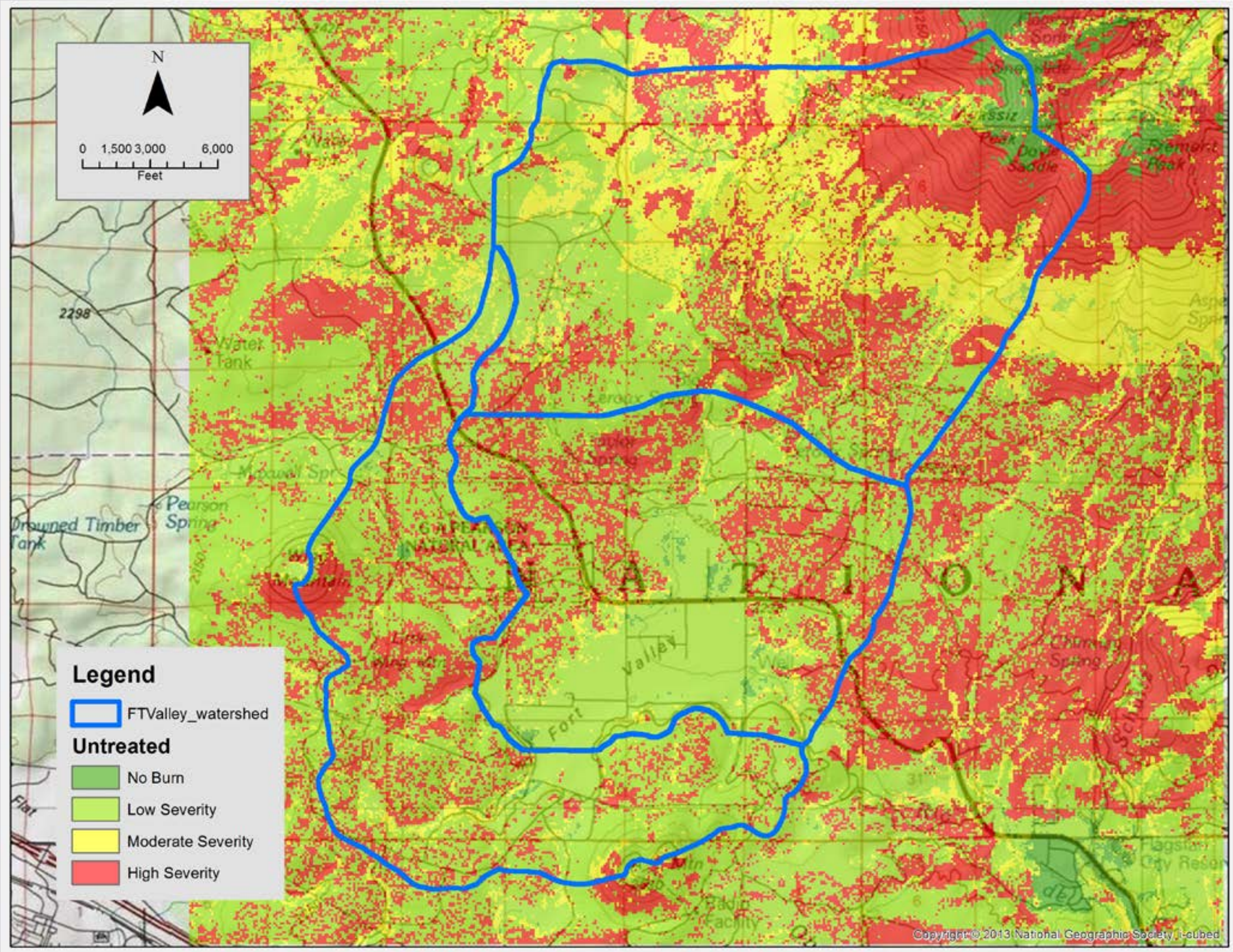

Figure 2 – Existing Conditions Burn Severity

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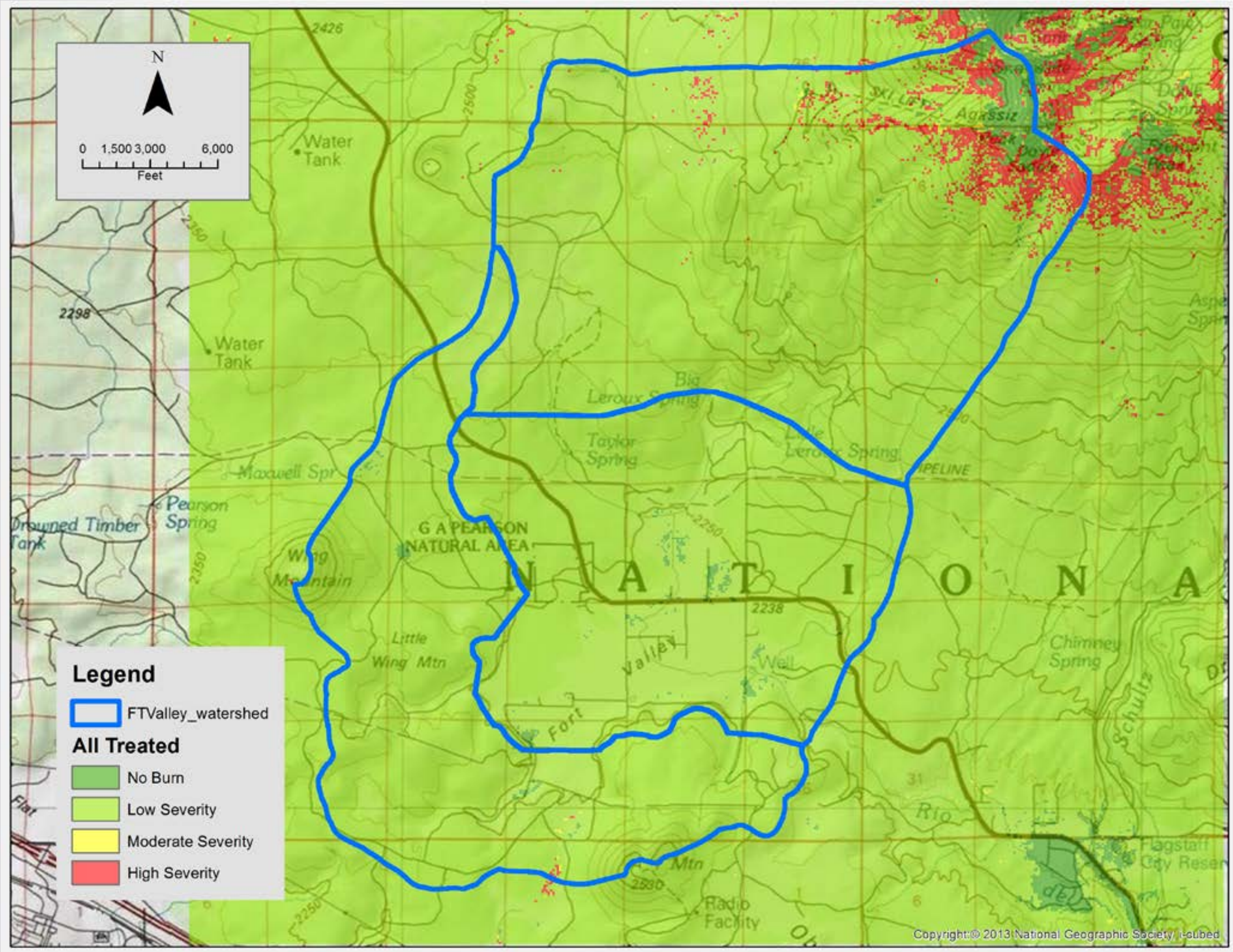

Figure 3 – Fully Treated Burn Severity

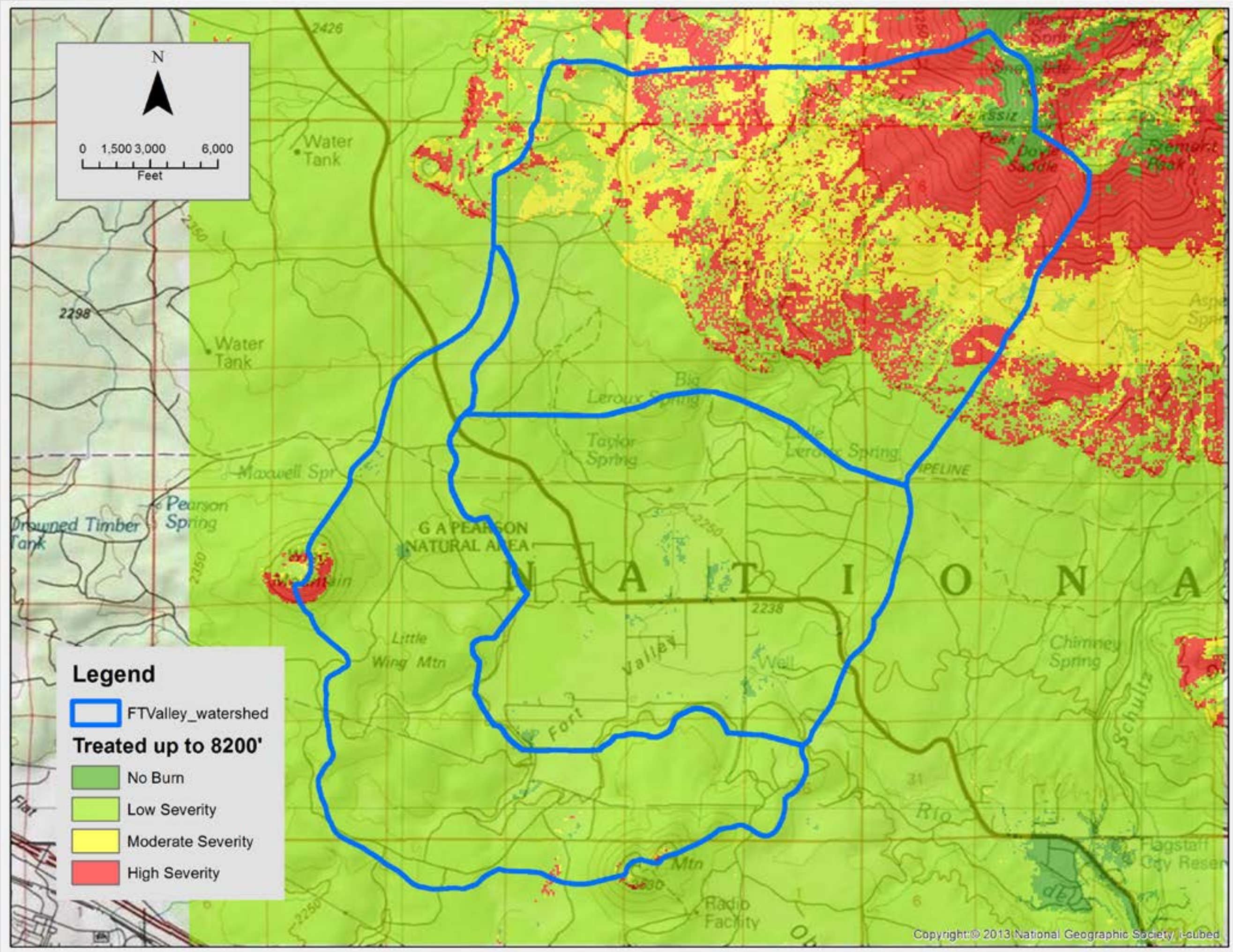

Figure 4 – Treated (Excluding Wilderness Area) Burn Severity

Bill Williams Area Burn Severity Modeling

Burn severity modeling results were provided to JE Fuller from the Kaibab National Forest. The following figures show the results presented in the *Bill Williams Mountain Restoration Project, Fire and Fuels Specialist Report (Uebel, 2015, 17p.).*

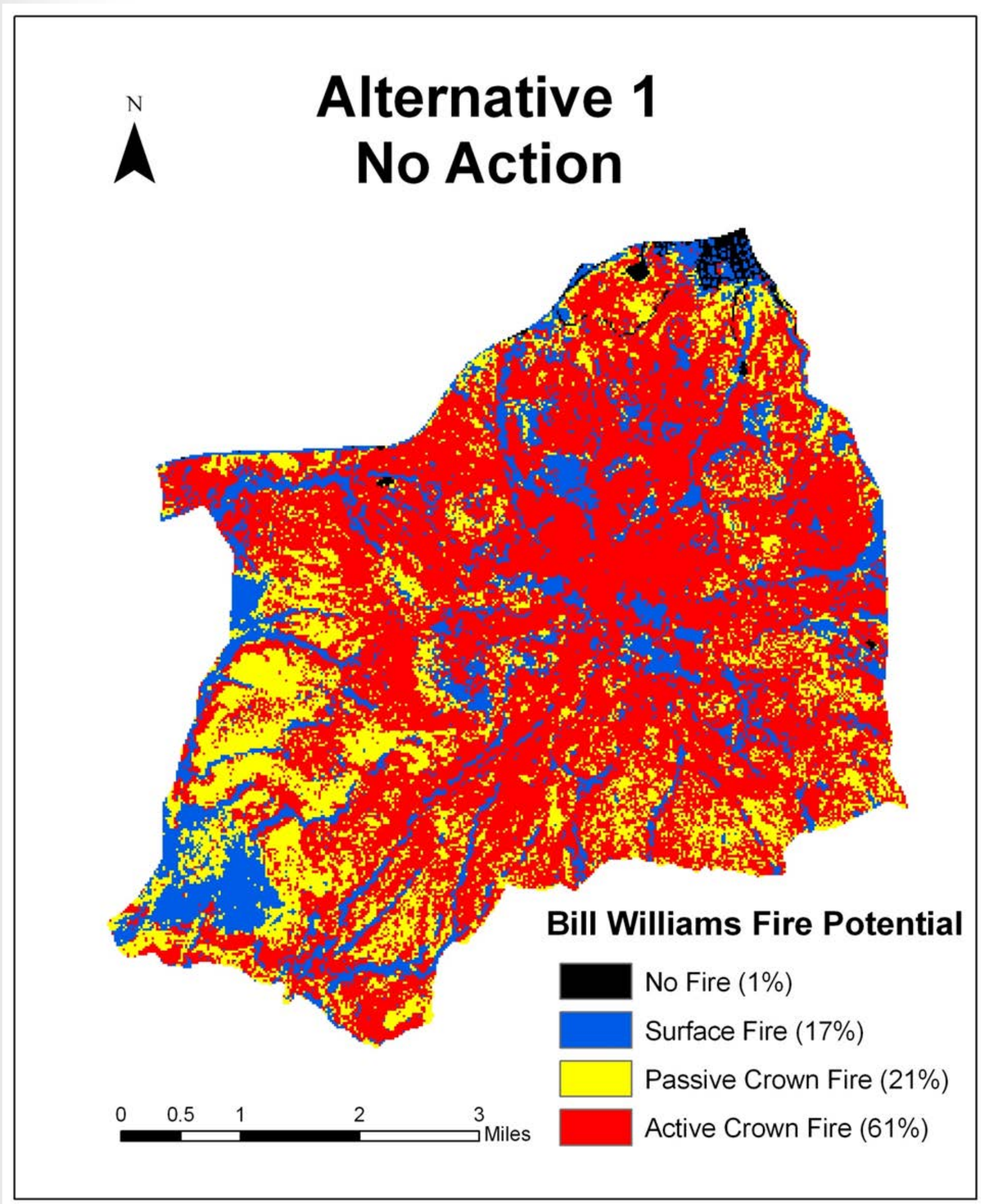

Figure 5 – Williams Fire Modeling Results – Alternative 1, No Action

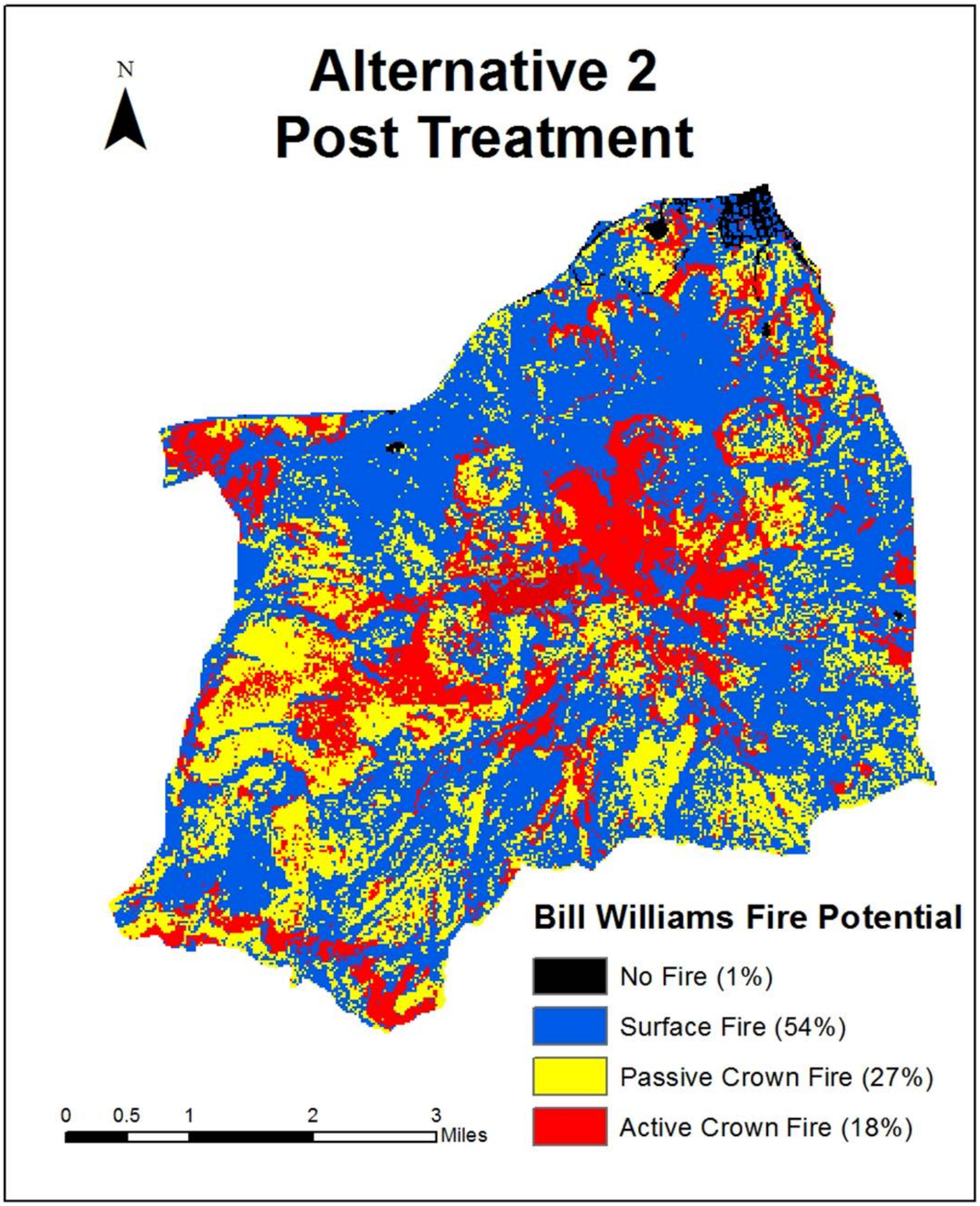

Figure 6 – Williams Fire Modeling Results – Alternative 2, Treatment

Runoff Curve Numbers

Fire modeling was performed to approximate the post-fire flooding potential of a treated watershed versus an untreated watershed. Curve number selection for the FLO-2D model was the sole parameter that was adjusted between the treated and untreated models.

BAER Teams typically utilize Wildcat 5 (Hawkins, Barreto-Munoz, 2016), a hydrological modeling tool, to determine post wildfire runoff. The Wildcat 5 manual contains several tables that were reviewed to understand the ways in which curve numbers could be modified based on burn severity. Table 4-06 was selected for use in both the Bill Williams Mountain area and the Fort Valley Area to maintain consistency between the study areas.

Table 4-06—Post-fire Curve Numbers (CNs) based on fire severity or conditions during fire on Santa Fe National Forest, NM.

Fire/condition	Post-fire CN
High burn severity with water repellency	95
High burn severity without water repellency	90–91
Moderate burn severity with water repellency	90
Moderate burn severity without water repellency	85
Low burn severity	Pre-fire + 5
Straw mulch with good cover	60
Seeding with LEBs[a] – 1 yr after fire	75
LEBs[a] without water repellency	85

[a] Log erosion barriers installed on the contour at the recommended spacing.

Sources: Foltz and others (2007: 57); Greg Kuyumjian, U.S. Forest Service, Okanogan-Wenatchee National Forest, Wenatchee, WA, pers. comm.

To produce conservative results, we assumed that all high and moderate burn severity areas will have water repellency and so the resulting curve numbers will be 95 and 90, respectively. Initial runoff calculations after the Schultz Fire utilized curve numbers based on the soil types and burn severity. Although a different approach was used for this planning level project, the resulting curve number range between the Schultz Fire area and the Ft. Valley area were similar. The following figures show the pre- and post-wildfire curve numbers used for the Fort Valley FLO-2D Modeling.

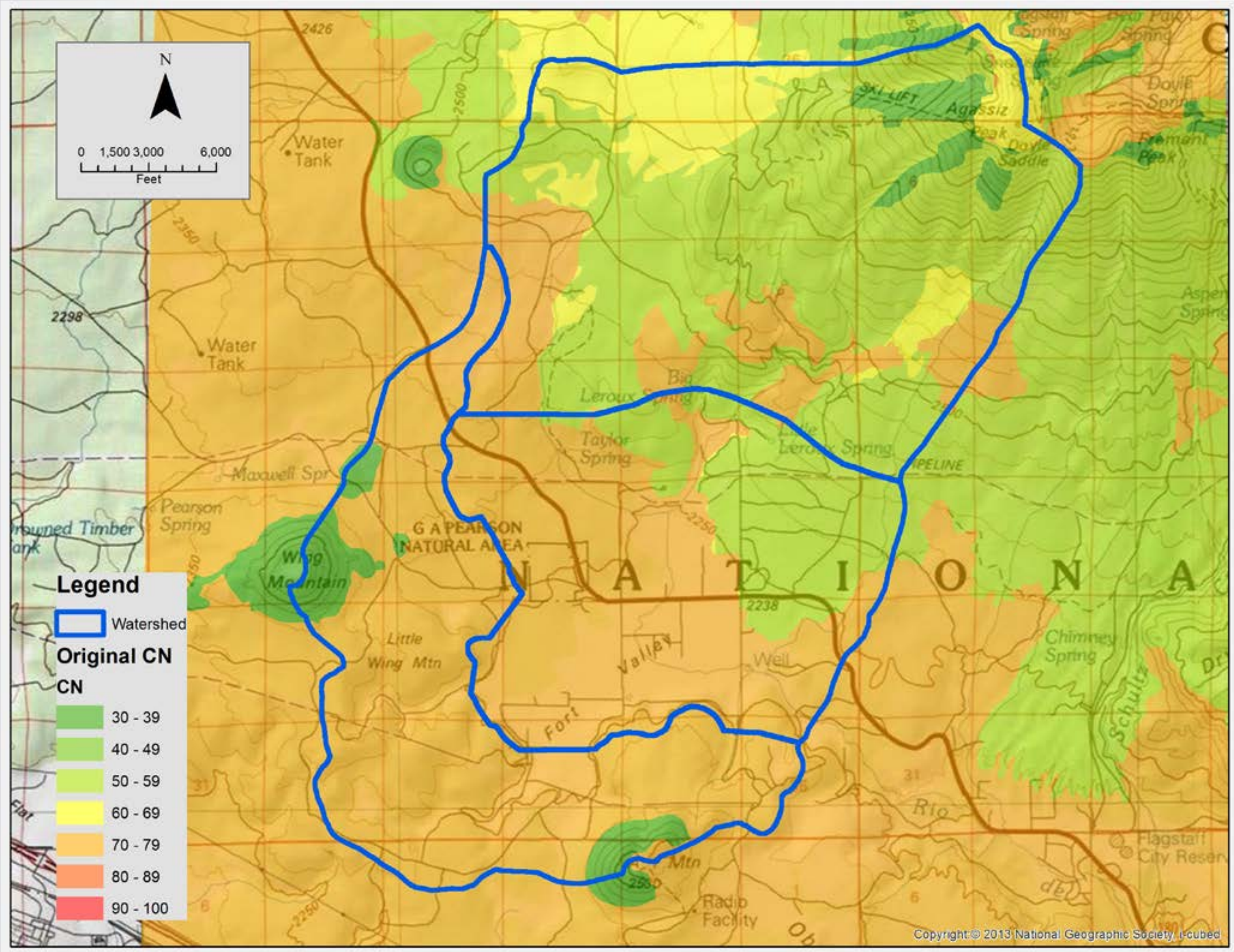

Figure 7 – Fort Valley Curve Numbers – Pre Wildfire

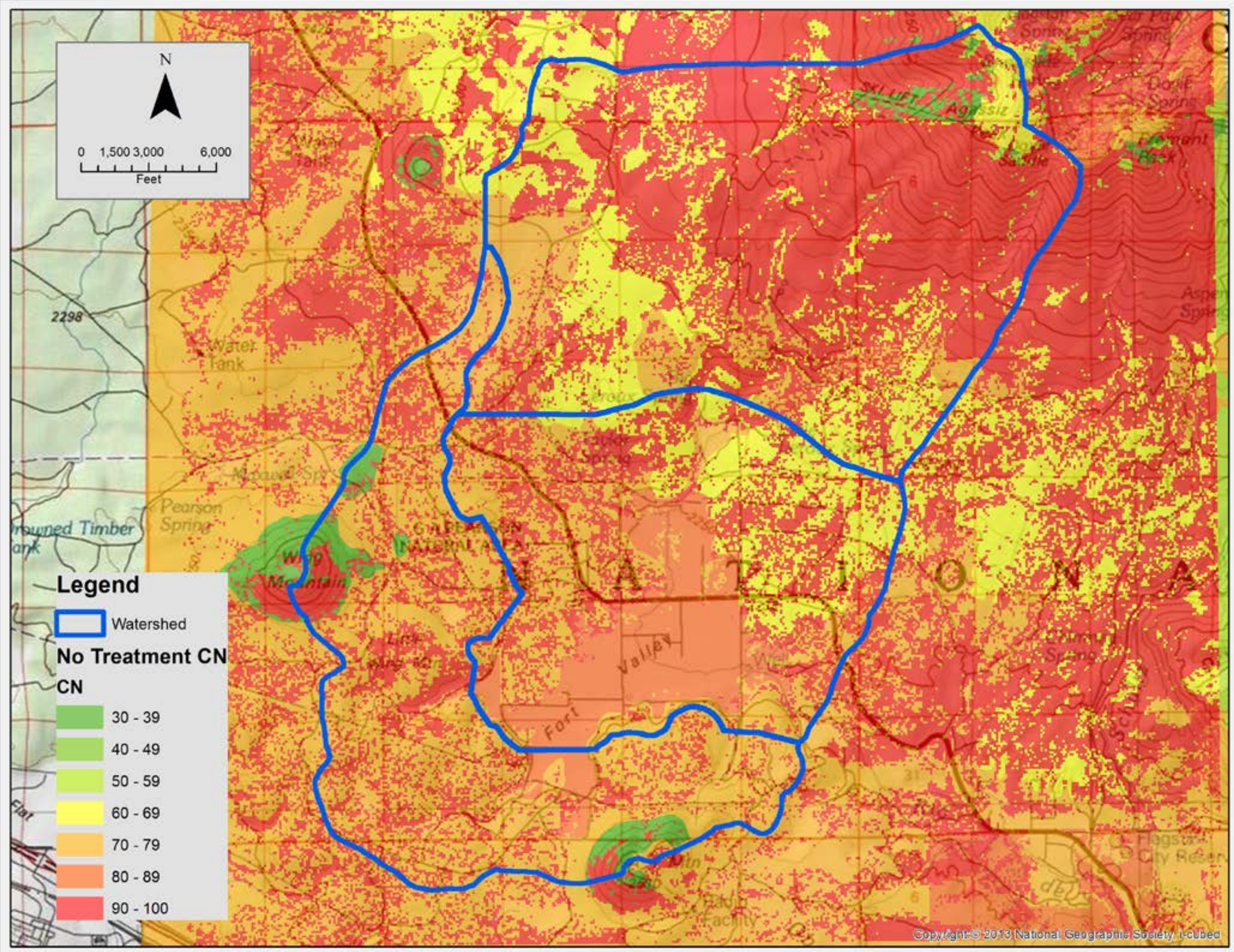

Figure 8 – Fort Valley Curve Numbers – Post Wildfire – No Treatment

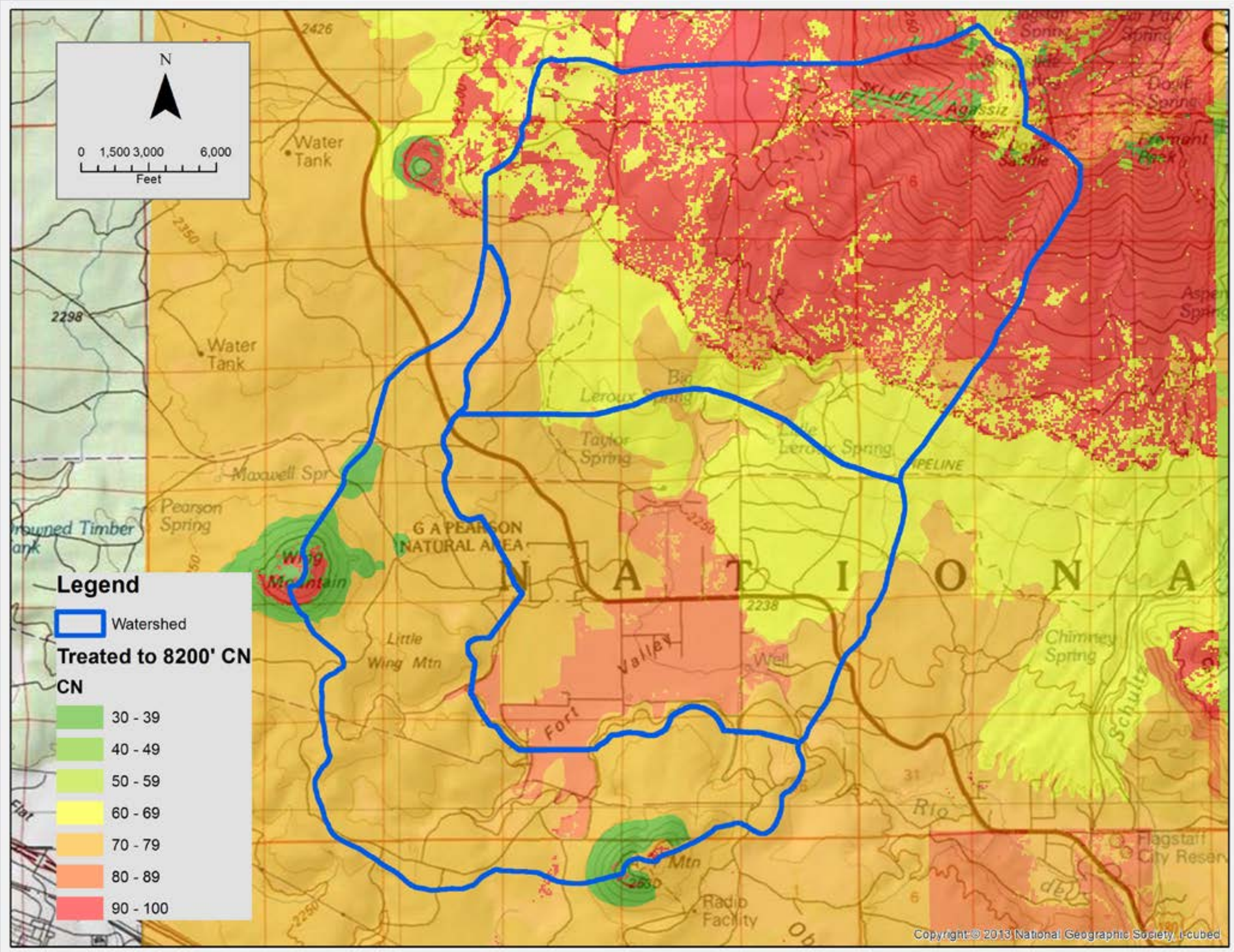

Figure 9 – Fort Valley Curve Numbers – Post Wildfire – Treatment up to 8200'

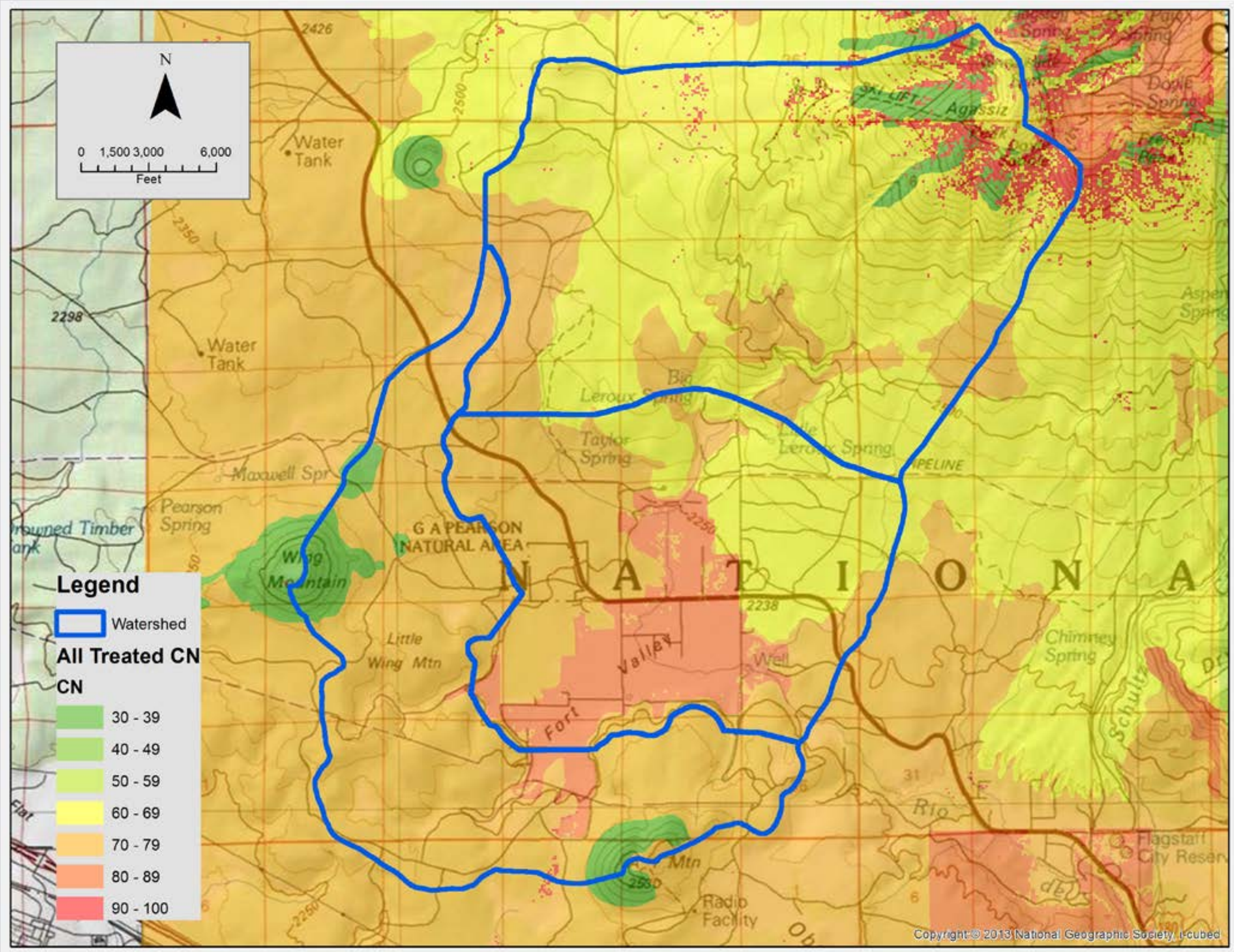

Figure 10 – Fort Valley Curve Numbers – Post Wildfire – All Treated

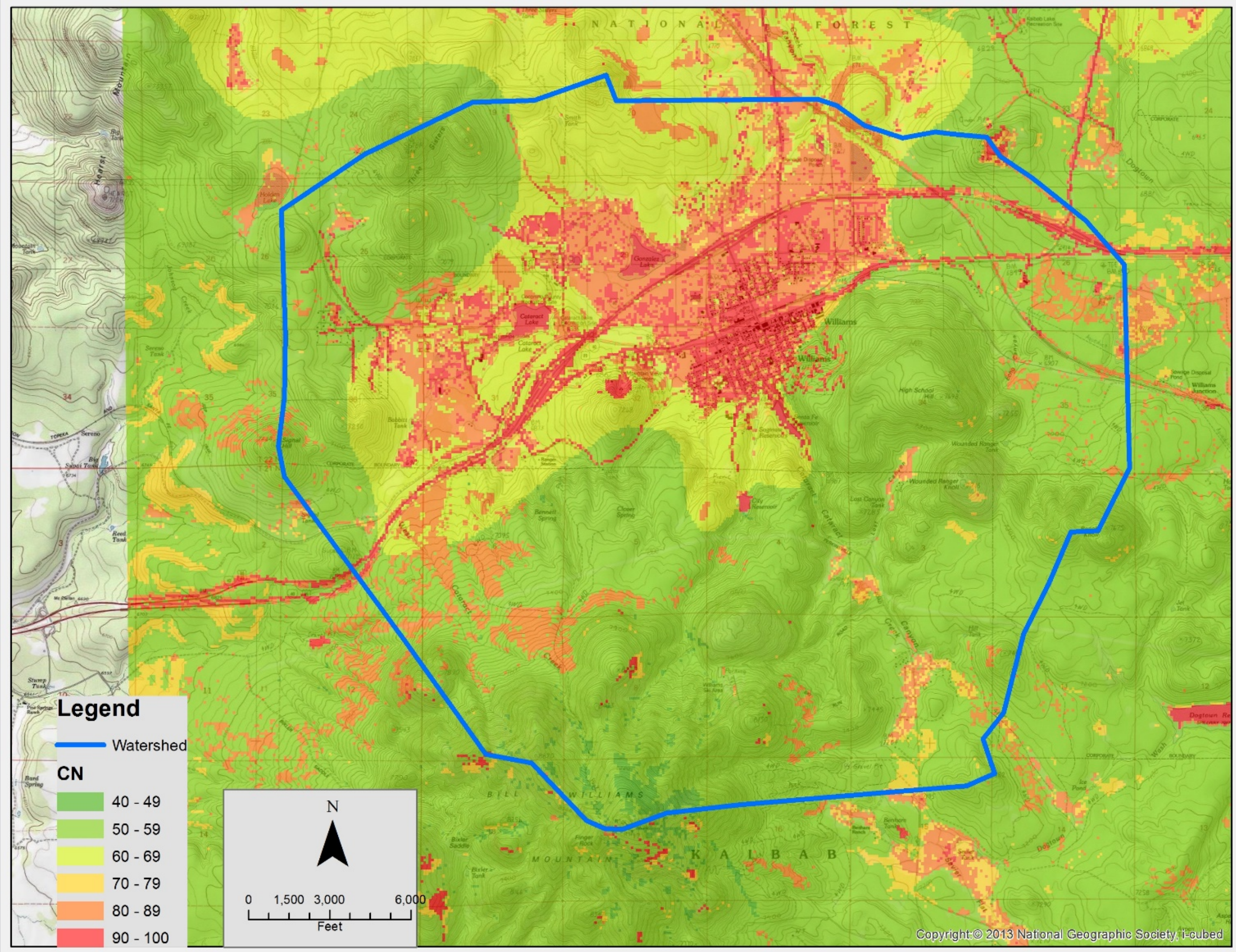

Figure 11 – Bill Williams Curve Numbers – Pre Wildfire

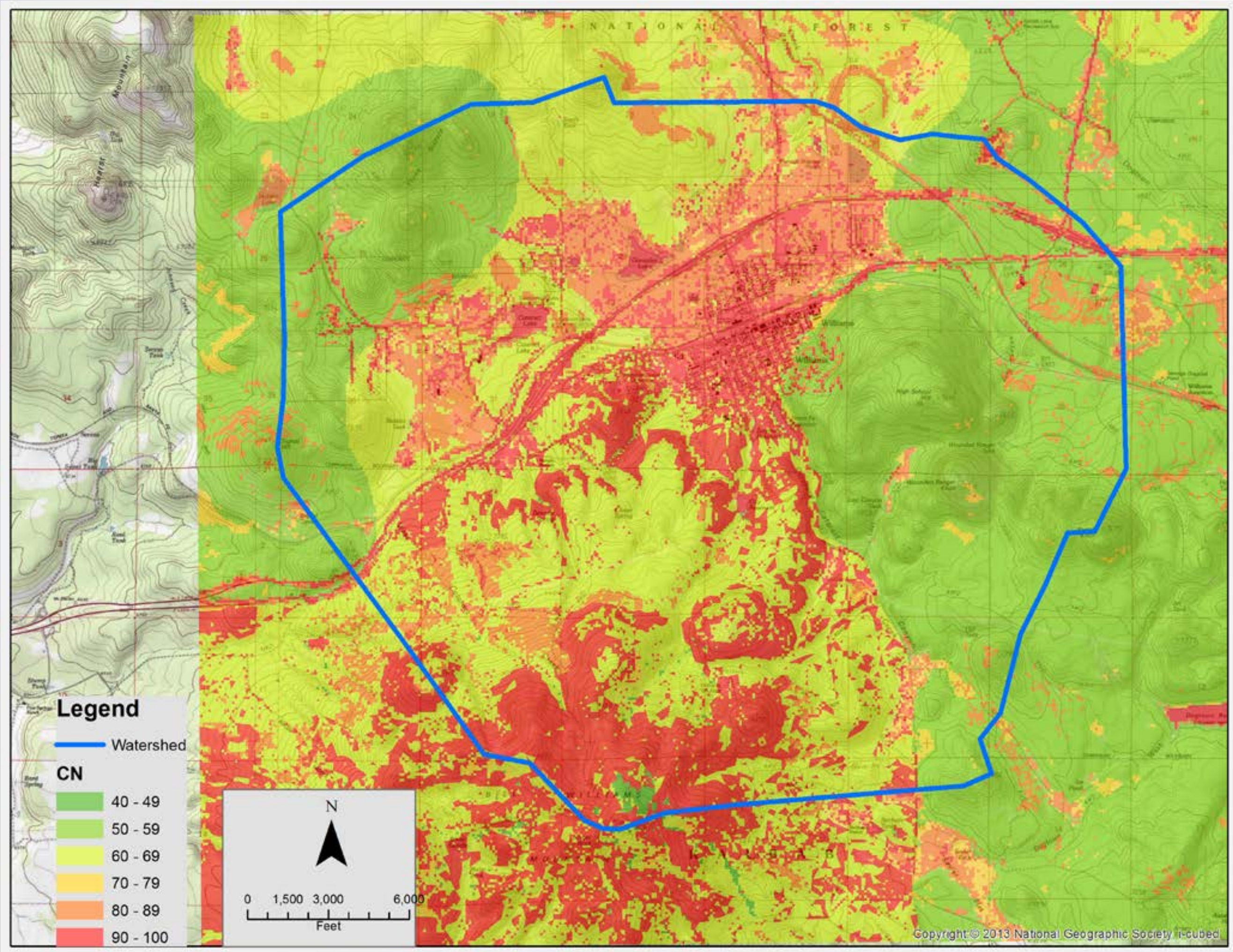

Figure 12 – Bill Williams Curve Numbers – Post Wildfire – All Treated

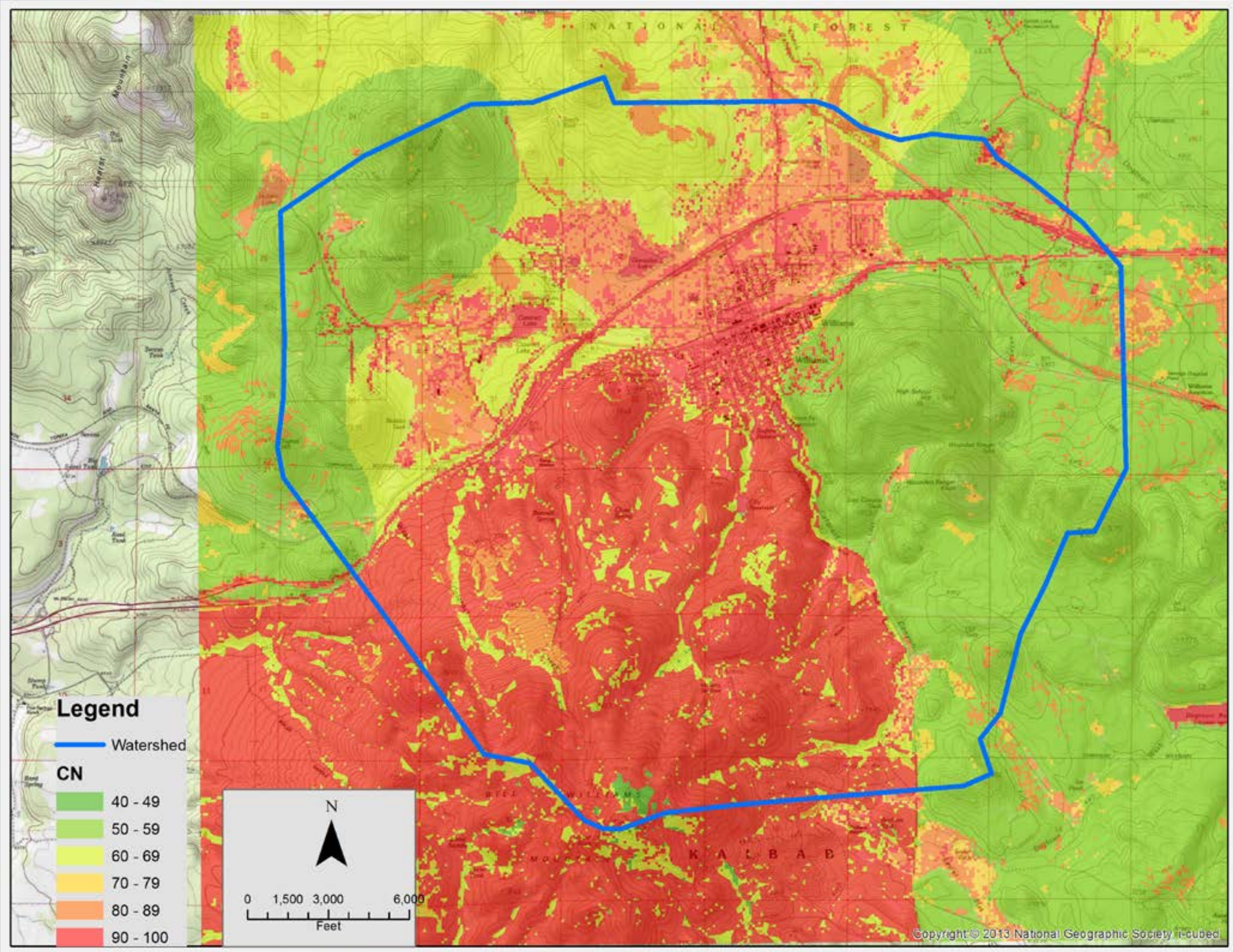

Figure 13 – Bill Williams Curve Numbers – Post Wildfire – No Treatment

References

Hawkins, R.H.; Barreto-Munoz, A, 2016, Wildcat5 for Windows, a rainfall-runoff hydrograph model: user manual and documentation. Gen. Tech. Rep. RMRS-334. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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