

# **Delineation of Floodplains for the Visitor Center Area of Frijoles Canyon and Other Related Technical Support**

Update #1 to the 2012 Hydrologic Modeling Technical Memorandum



**Prepared for:**  
United States Department of the Interior  
National Park Service  
Bandelier National Monument

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**US Army Corps  
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## **1. PURPOSE**

The purpose of this technical memorandum is to update the methods, assumptions, and the resulting discharge values of the post-fire conditions hydrologic modeling presented in a 2012 Hydrologic Modeling Technical Memorandum for the Frijoles Canyon Watershed as prepared by the US Army Corps of Engineers – Albuquerque District.

The update described in this report, uses 2013 precipitation and stage data gathered from NEXRAD and USGS stage gages. The updated discharges will be used as input to an updated hydraulic model that will compute water surface elevations within the canyon at known cross-sections. The National Park Service will use the water surface elevations and inundation mapping in the planning of future projects. The information will also aid in the assessment of the efficiency and necessity of the Emergency Action Plan and/or Early Warning System. A flood frequency analysis was not completed as part of this report; however, data from a stream flow gaging station installed downstream of the Park's Visitor Center was used to help calibrate the model.



## 2. HYDROLOGIC ANALYSIS

### 2.1. General Watershed Characteristics

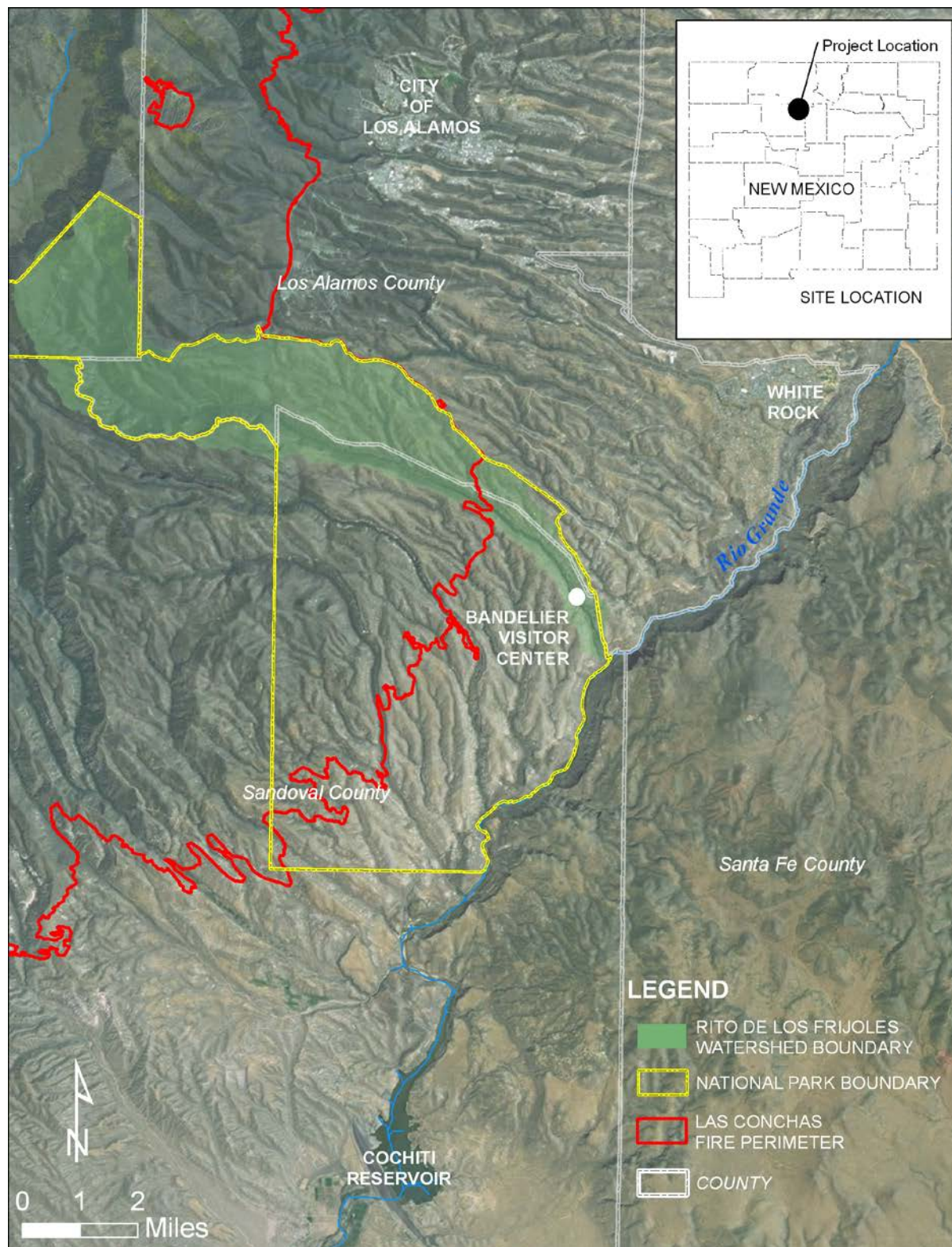
Frijoles Canyon is a west bank tributary of the Rio Grande and the canyon is located in north-central New Mexico. Figure 1 is a project location map illustrating the study area with respect to the state of New Mexico. The watershed is almost entirely contained within the boundaries of the Bandelier National Monument. The monument is home to one of the southwest's premier archeological preserves with thousands of documented sites spread throughout the park. Several of the park's ruins, like Tyuonyi Pueblo, line the overbanks of the Rito de Los Frijoles, which is the primary drainage feature within the canyon. Prior to the 2011 Las Conchas Fire and resultant flooding, the Rito de Los Frijoles was known as a trout fishery with rainbow and brook trout. The Rito de Los Frijoles headwaters originate near Cerro Grande located on the rim of the Valles Caldera in the Jemez Mountains.

Elevations within the modeled area range from approximately 10,199 feet above mean sea level (MSL) at Cerro Grande down to 5,370 feet MSL at the confluence of the Rio Grande. The confluence of Frijoles Canyon and the Rio Grande is approximately 11.5 miles upstream of Cochiti Dam.

Volcanic eruptions and subsequent erosion have shaped the landscape of Frijoles Canyon into its present form. The Rito de Los Frijoles has carved its way through the Bandelier tuff, which is the exposed basal unit of the Pajarito Plateau, resulting in vertical cliffs in some areas. The watershed is largely undeveloped, and is characterized by vertical-walled canyons. The cooler canyon bottom supports pine, elder, willows and cottonwoods. On the drier mesa tops above the canyon, various pinon and juniper dominate. Higher up on the mountain slopes, various types of fir, ponderosa pine, and aspen dominated the once thick forests.

In July 2011 the Las Conchas Forest Fire burned approximately 156,000 acres of land within the Jemez Mountains of North Central New Mexico. 10,742 acres burned within the Frijoles Canyon watershed. Recent history has shown that the magnitude of large storm flow increases dramatically after wildfires (DeBano and others, 1998). After the La Mesa Fire in 1977, peak



**Figure 1 – Site Location Map**

flows at the most downstream stream flow gaging station in Frijoles Canyon increased to about 160 times the maximum-recorded flood prior to the fire (Veenhuis, 2002). Normal precipitation events on fire-altered watersheds may result in increased runoff mobilization of large debris, and accelerated rates of erosion. These effects occur due to a decrease in surface infiltration as the heat of the fire physically alters the surface permeability along with destroying the forest floor vegetation. This results in a significant loss of rainfall storage in the soil, with a consequent reduction in runoff attenuation capability. Ash accumulation on the forest floor further reduces soil infiltration and enhances precipitation runoff (DeBano and others, 1998).

## **2.2. Hydrologic Model Parameters**

The hydrologic analysis was conducted using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) Hydrologic Modeling System (HMS) version 3.5 to numerically model the watershed. HEC-HMS simulates the precipitation-to-runoff process while accounting for storage and attenuation throughout a watershed. The watershed model contains multiple subbasins that were delineated using HEC-geoHMS version 5.0, along with other tools contained within the ArcGIS Spatial Analyst Toolbox version 9.3. The geoHMS tool was run within ESRI ArcGIS ArcMap version 9.3. HEC-geoHMS is a pre-processing tool specifically designed by the USACE to aid in the delineation of watersheds specific to a HEC-HMS analysis.

Modifications to the HEC-HMS model presented in the 2012 Hydrologic Memorandum focused primarily on updating: 1) the NEXRAD precipitation calibration, 2) modifying the initial and constant loss rate values, and 3) using an updated transform method. Upon reviewing the preliminary output for the calibration events, the 2013 models needed minor adjustments in order to accurately portray current conditions observed at the USGS gaging station (08313350) near the Visitor Center. The adjustments made are described in the following sections.

### **2.2.1. Precipitation**

The HEC-HMS model described in this update, relies upon NEXRAD precipitation data. USACE downloads daily, calibrated Level III NEXRAD data from NOAA's West Gulf River Forecast Center (WGRFC) to assist with real-time basin modeling. Level III NEXRAD data sets



from the USACE archive were used for Frijoles Canyon precipitation estimates. Use of NEXRAD for basin modeling allows for natural storm spatial and temporal distribution, which assists with model calibration and refinement of resulting flows.

Two events in 2013 were qualified candidates for use when re-calibrating the HMS model. The key candidate criterion was an event size above 2,000 cfs with valid data sources for precipitation and runoff. The July 25<sup>th</sup> – 26<sup>th</sup> and September 12<sup>th</sup> – 13<sup>th</sup> 2013 rainfall events had measure peaks at the USGS gage near the Visitor Center of 5,410 cfs and 2,140 cfs respectively. The July 2013 event had had an accumulated basin wide precipitation total of 1.09 inches. The September 2013 event accumulated 3.36 inches distributed over the entire watershed. Figures 2 and 3 present the NEXRAD precipitation data for specific events used in this update.

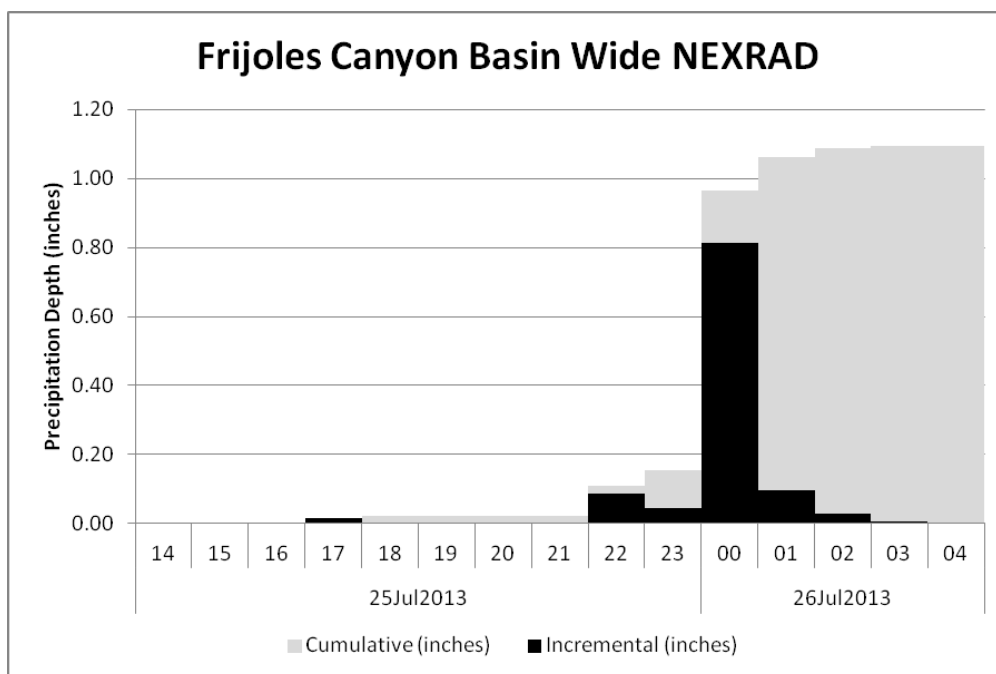


**Figure 2 - July 25-26, 2013 Event**



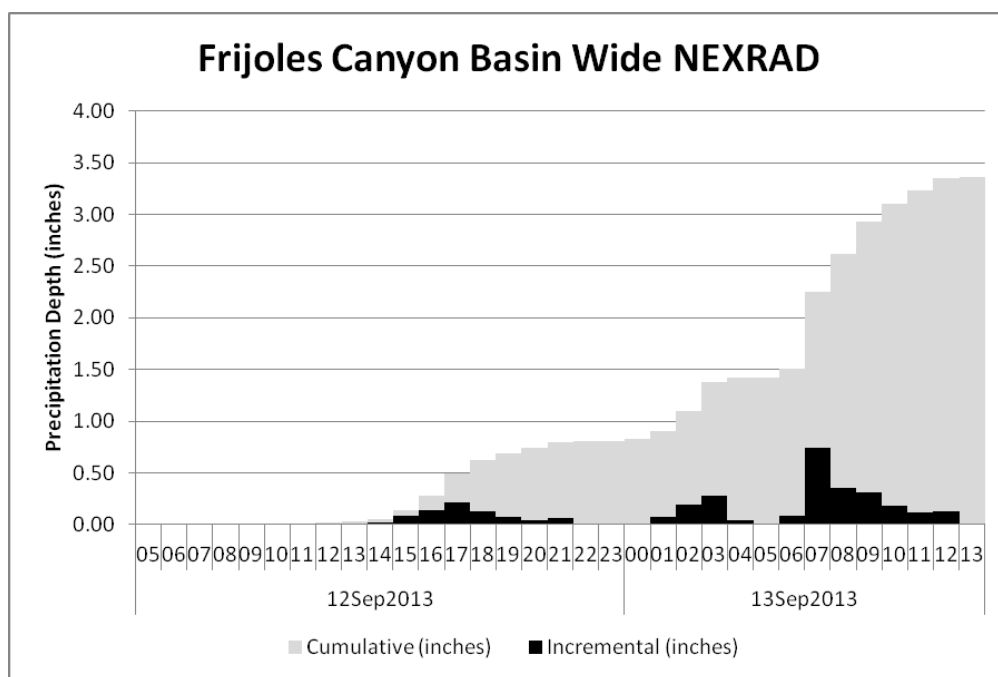


**Figure 3 - September 12-13, 2013 Event**

### Computation Interval

Calibrated NEXRAD data is provided by the WGRFC in one-hour time intervals. Each grid captures one hour of precipitation. A one-hour time step is too long to capture high intensity, short duration events. HEC-HMC allows for reduced time steps using NEXRAD by distributing the total rainfall for the hour by the step interval. For example, if two inches of rain fall in one hour and we have a thirty-minute time step, one inch of rain would fall during each step. A fifteen-minute time step was used for this 2013 Update. The fifteen-minute time step offers a small enough resolution to adequately capture the peak discharge when combined with the improved spatial coverage of the NEXRAD.

### 2.2.2. Subbasin Area

Unchanged from the HEC-HMS model presented in the 2012 Hydrologic Memorandum.



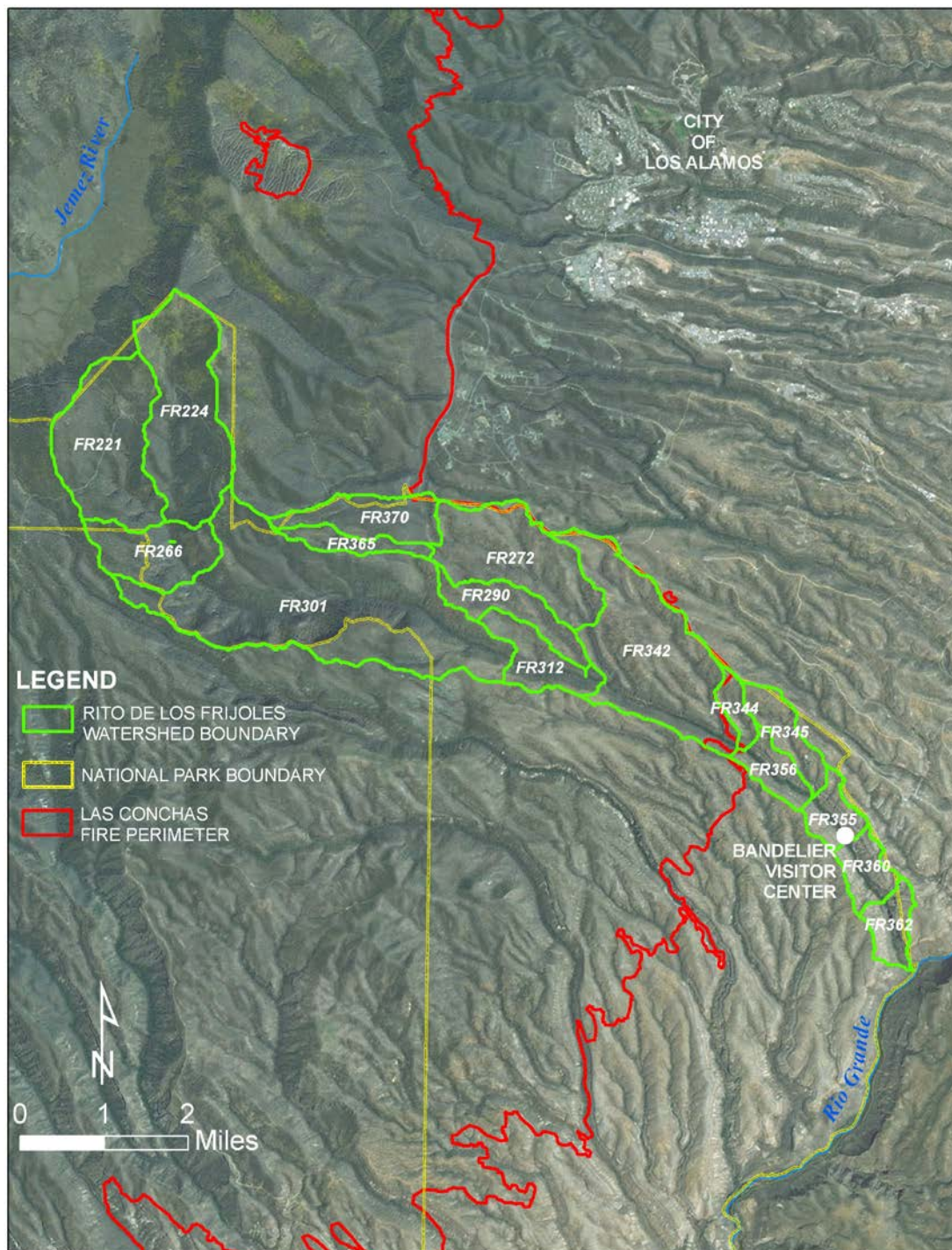


**Figure 4 – Basin Map**

### 2.2.3. Initial Loss and Constant Loss Rates

In determining the initial and constant loss values for the 2013 model update, the values used in the model presented in the 2012 Hydrologic Memorandum were used as starting points. Figure 5 illustrates the spatial extent of the 2011 Las Conchas burn as estimated from a Burn Severity ArcGIS shapefile directly obtained from the US Forest Service, US Department of Agriculture (USDA) Remote Sensing Application Center in Salt Lake City, Utah (USDA, 2011). The burn severity shapefile was interpreted from Landsat imagery taken on July 3rd, July 5th, and September 21, 2011 along with field verification. The area affected by the burn is primarily located in subbasins FR221, 224, 266, 272, 290, 301, 312, 342, 365, and 370.

Initial and constant loss rates remain largely unchanged from the 2012 Hydrologic Memorandum. The exception is FR272 and FR342 which can be attributable to the change in using a different transform method. Bold values in Table 1 note the changes made.

**Table 1 – 2013 Updated Initial Loss and Constant Loss Rates per Subbasin**

| SubBasin | 2012 Hydrologic Memo<br>Loss (Initial and Constant) |                       | Updated<br>Loss (Initial and Constant) |                       |
|----------|-----------------------------------------------------|-----------------------|----------------------------------------|-----------------------|
|          | Initial Loss                                        | Constant Loss<br>Rate | Initial Loss                           | Constant Loss<br>Rate |
| FR224    | 0.04                                                | 0.01                  | 0.04                                   | 0.01                  |
| FR221    | 0.04                                                | 0.01                  | 0.04                                   | 0.01                  |
| FR266    | 0.04                                                | 0.01                  | 0.04                                   | 0.01                  |
| FR301    | 0.00                                                | 0.00                  | 0.00                                   | 0.00                  |
| FR272    | 0.05                                                | 0.015                 | <b>0.0375</b>                          | <b>0.0113</b>         |
| FR370    | 0.04                                                | 0.01                  | 0.04                                   | 0.01                  |
| FR365    | 0.04                                                | 0.01                  | 0.04                                   | 0.01                  |
| FR312    | 0.04                                                | 0.01                  | 0.04                                   | 0.01                  |
| FR290    | 0.04                                                | 0.01                  | 0.04                                   | 0.01                  |
| FR342    | 0.10                                                | 0.05                  | <b>0.05</b>                            | <b>0.02</b>           |
| FR344    | 0.65                                                | 0.30                  | 0.65                                   | 0.3                   |
| FR345    | 0.65                                                | 0.30                  | 0.65                                   | 0.3                   |
| FR356    | 0.65                                                | 0.30                  | 0.65                                   | 0.3                   |
| FR355    | 0.65                                                | 0.30                  | 0.65                                   | 0.3                   |
| FR360    | 0.10                                                | 0.05                  | 0.1                                    | 0.05                  |
| FR362    | 0.10                                                | 0.05                  | 0.1                                    | 0.05                  |



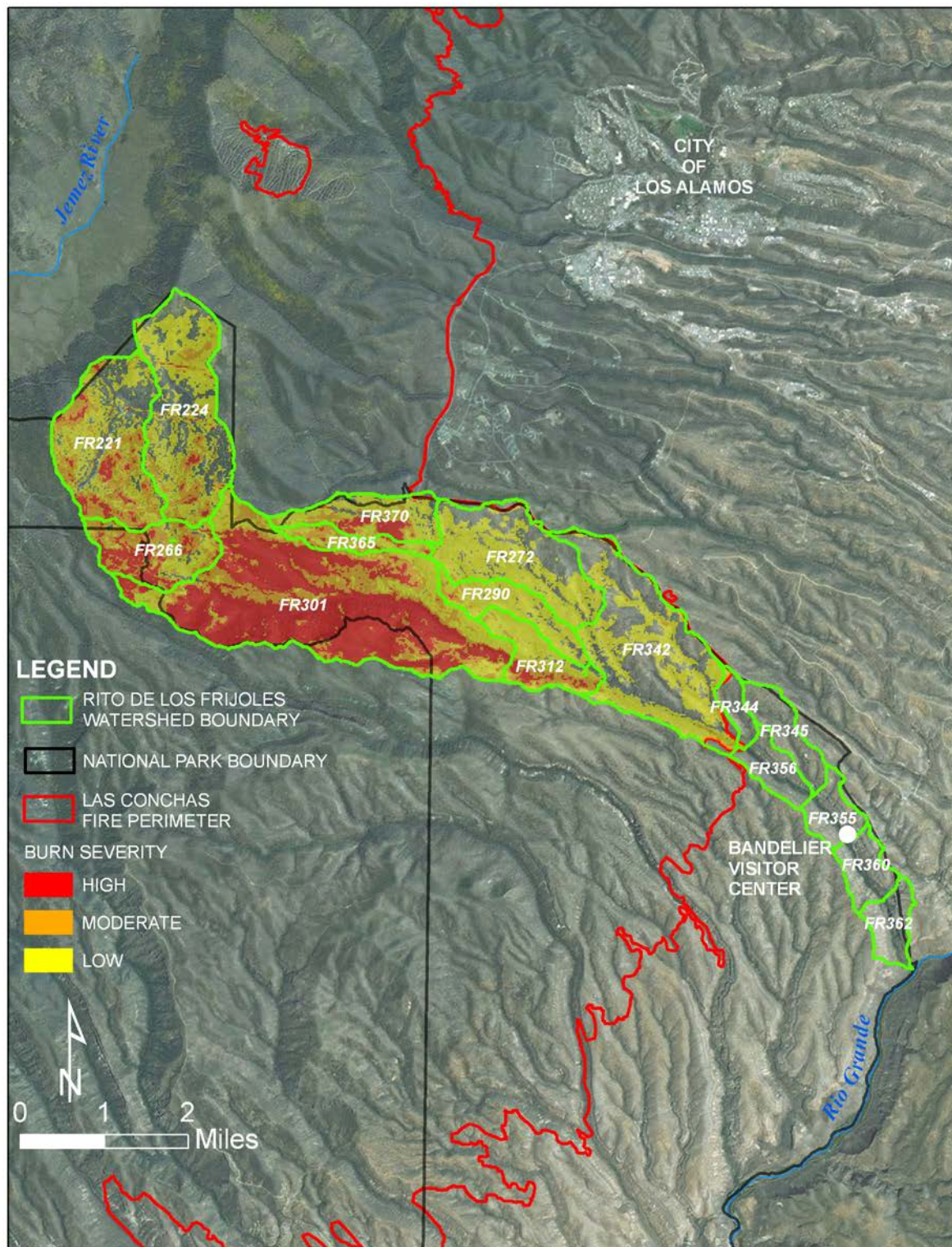


Figure 5 – Burn Severity Map



## 2.2.4. Percent Impervious

Unchanged from the HEC-HMS model presented in the 2012 Hydrologic Memorandum.

## 2.2.5. Unit Hydrograph Information

The USACE Hydrologic Engineering Center recommend using the ModClark transform method when employing gridded precipitation such as NEXRAD. The model presented in the 2012 Hydrologic Memo was calibrated using the Clark Unit Hydrograph Method, which relies on lumped or average rainfall distribution over the entire watershed. Modified Clark Method or ModClark is a quasi-distributed model specifically developed to capture spatially and temporally variable nature of gridded precipitation. Using precipitation averaging provides valid results but discounts variability in real world storm tracks, which can be critical for individual sub-basins.

Both the ModClark and Clark Unit Hydrograph methods, use the same values of Time of Concentration (TC) and Initial Storage. The final values from the 2012 Hydrologic Memorandum were used as a baseline for the 2013 Update. Very small changes were required to update the model, bold values in Table 2 note the changes made.

**Table 2 – 2013 Updated Transform Values per Subbasin**

| SubBasin | 2011 Hydrologic Memo<br>Transform (Clark Unit Hydrograph) |                 | 2013 Update<br>Transform (ModClark) |                 |
|----------|-----------------------------------------------------------|-----------------|-------------------------------------|-----------------|
|          | TC                                                        | Initial Storage | TC                                  | Initial Storage |
| FR224    | 0.51                                                      | 0.6125          | 0.51                                | 0.6125          |
| FR221    | 0.51                                                      | 0.6125          | 0.51                                | 0.6125          |
| FR266    | 0.30                                                      | 0.6125          | 0.30                                | 0.6125          |
| FR301    | 0.89                                                      | 0.6125          | 0.89                                | <b>0.4594</b>   |
| FR272    | 0.62                                                      | 0.6125          | <b>0.31</b>                         | <b>0.4594</b>   |
| FR370    | 0.48                                                      | 0.6125          | 0.48                                | 0.6125          |
| FR365    | 0.45                                                      | 0.6125          | 0.45                                | 0.6125          |
| FR312    | 0.32                                                      | 0.6125          | 0.32                                | 0.6125          |
| FR290    | 0.60                                                      | 0.6125          | 0.60                                | 0.6125          |
| FR342    | 0.76                                                      | 0.6125          | <b>0.38</b>                         | <b>0.4594</b>   |
| FR344    | 0.42                                                      | 0.6125          | 0.42                                | 0.6125          |
| FR345    | 0.64                                                      | 0.6125          | 0.64                                | 0.6125          |
| FR356    | 0.45                                                      | 0.6125          | 0.45                                | 0.6125          |
| FR355    | 0.34                                                      | 0.6125          | 0.34                                | 0.6125          |
| FR360    | 0.41                                                      | 0.6125          | 0.41                                | 0.6125          |
| FR362    | 0.39                                                      | 0.6125          | 0.39                                | 0.6125          |



### 2.2.6. Reach Routing Parameters

Unchanged from the HEC-HMS model presented in the 2012 Hydrologic Memorandum.

## 3. 2013 UPDATE CALIBRATION RESULTS

The models feature a junction labeled J9 that coincides with the USGS reference stream gage at the Visitors Center (08313350). Its location is shown in Figure 6. Peak discharges at J9 were used to validate the 2013 updated model. Initially, the events for July and September 2013 were run through the 2012 Hydrologic Memorandum model to set a baseline for calibration. After switching the transform method to ModClark, subsequent iterations yielded the final model transform and initial and constant loss rates.

Table 3 illustrates the output for 2013 update calibration. Events with peaks captured at the reference stream gage include the 2013 calibration events as well as the flood of August 21, 2011. The August 2011 event was not used to calibrate the 2013, rather this event provided validation that the updated 2013 model produced consistent results. The 2013 update shows slightly reduced peak flows compared to the USGS reference stream gage. NEXRAD has historically shown an underestimation of precipitation especially in canyon lands and mountainous regions where the radar signal can be blocked by ridge tops. Model outputs were calibrated to within 5% of the reference gage for July and September 2013 events. The large event on September 13<sup>th</sup> was not captured by the USGS stream gage. However, it is assumed that the modeled output for the September 13<sup>th</sup> is consistent with previous large events in the basin.

**Table 3 - 2013 Calibration Values at Junction J9**

| Event Date         | USGS 08313350 |            | 2013 Update (Peak @ J9) |            |                 |              |
|--------------------|---------------|------------|-------------------------|------------|-----------------|--------------|
|                    | Peak Time     | Peak (CFS) | Peak Time               | Peak (CFS) | delta USGS Gage | % delta USGS |
| July 26, 2013      | 01:50         | 5410       | 01:00                   | 5370       | -93             | -1.72%       |
| September 12, 2013 | 17:11         | 2140       | 17:45                   | 2407       | -107            | -5.00%       |
| September 13, 2013 | No Data       | No Data    | 08:00                   | 5897       | No Data         | No Data      |
| August 21, 2011    | No Data       | 7022       | 18:15                   | 6771       | -251            | -3.57%       |





Figure 6 – Site Map near Park Service Visitor's Center

#### 4. HYDROLOGIC RESULTS

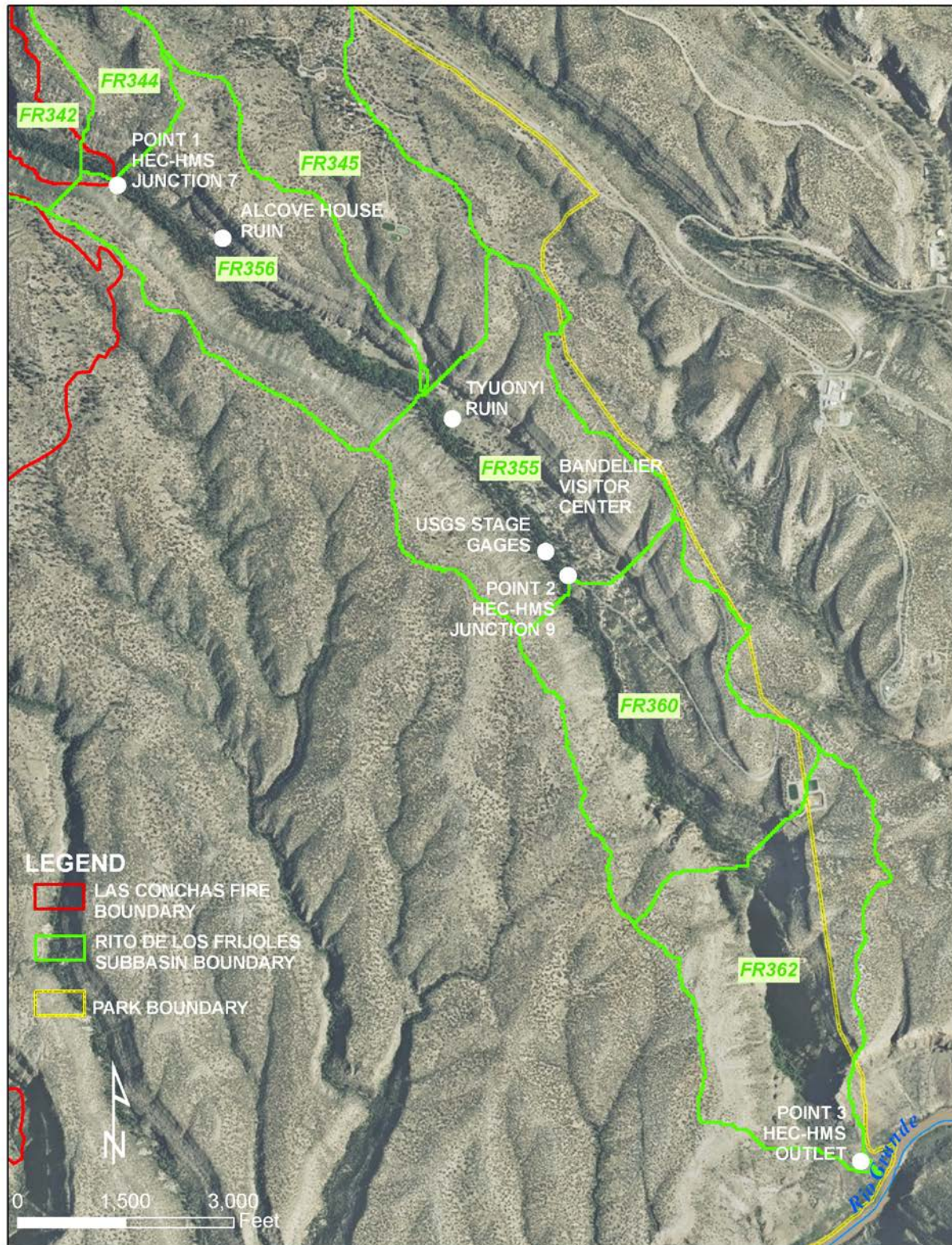
Upon calibrating, the updated model generated peak discharge rates in cubic feet per second (cfs) for the 0.5-, 1-, and 2-inches, as well as those corresponding to the 100-, 500-year and PMP rainfall events. The 0.5-inch, 1-inch, and PMP storm event were modeled as 6-hour duration storms, while the 2-inch, 100-year, and 500-year events were modeled as a 12-hour duration storm. Peak discharges were computed for the following locations: Point 1 – 0.3 miles upstream of Alcove House, Point 2 - just downstream of the Park's Visitor Center, and Point 3 – at the confluence of Frijoles Canyon and the Rio Grande. Figure 7 shows the locations where the peak discharges are given within the watershed and Table 4 presents the flowrates.

The computed discharges indicate that the watershed has not increased its holding capacity and flooding potential remains unchanged from the results generated from those presented in the 2012 Hydrologic Memo.

**Table 4 - Computed Peak Discharges in Frijoles Canyon at Various Locations**

| Precipitation Amount (inch) | Recurrence Interval | Point 1 - Qpeak (cfs)<br>0.3 mi. Upstream of<br>Alcove House<br>Post-Fire | Point 2 - Qpeak (cfs)<br>just downstream of<br>Visitor's Center<br>Post-Fire | Point 3 - Qpeak (cfs)<br>at Outlet to Rio<br>Grande<br>Post-Fire |
|-----------------------------|---------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------|
| 0.5                         | < 1-year            | 1,760                                                                     | 1,710                                                                        | 1,690                                                            |
| 1                           | 1-year              | 4,080                                                                     | 4,030                                                                        | 4,020                                                            |
| 2                           | < 10-year           | 9,170                                                                     | 9,220                                                                        | 9,350                                                            |
| 3.3                         | 100-year            | 17,600                                                                    | 18,070                                                                       | 18,340                                                           |
| 4.1                         | 500-year            | 22,880                                                                    | 23,630                                                                       | 24,070                                                           |
| PMP                         | ----                | 64,810                                                                    | 68,360                                                                       | 70,310                                                           |



**Figure 7 – Discharge Location Map**

## **5. HYDROLOGIC ANALYSIS RECOMMENDATIONS**

In performing the hydrologic analysis and in reviewing the results, a number of issues were noted that might warrant additional investigation in the future. These are:

- Continued operation of the USGS Stream gage (08313350). Without a reference gage, there is no reliable way to easily calibrate the hydrologic models.
- Continued acquisition of the LiDAR. Debris flows and landslide may continue to occur in heavily burned regions, altering sub-basin dynamics. LiDAR coverage of the watershed periodically (every 2-3 years, or more) will allow for monitoring of basin stabilization and calculation of volumes of material moving down slope.
- Precipitation monitoring via the OneRain network (or similar system) could be integrated in quasi-real time with the NEXRAD Level III products providing greater model accuracy. Incorporating precipitation gages with the NEXRAD provides ground truthing of the radar data correcting holes generated by mountainous terrain.
- Update the hydrologic model in approximately four to five years to reflect expected ongoing natural recovery of vegetation cover and soils.



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