Flash Flood Guidance Issues

CBRFC/Western Region
Flash Flood Analysis Project

Presented to SVR WX/FF WDM - COMET
September 2002

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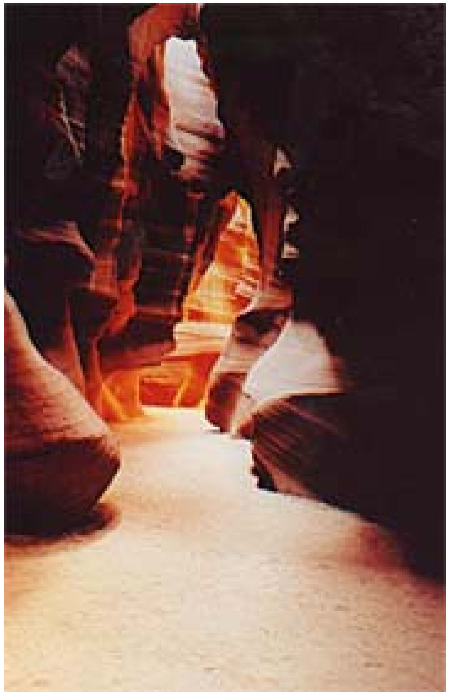


"FFG differs dramatically between RFC's in my area"

"There are abrupt discontinuities in FFG within a single RFC"

"Gridded FFG for some (western) RFC's is missing "

Why ? **Why ?** **Why ?**

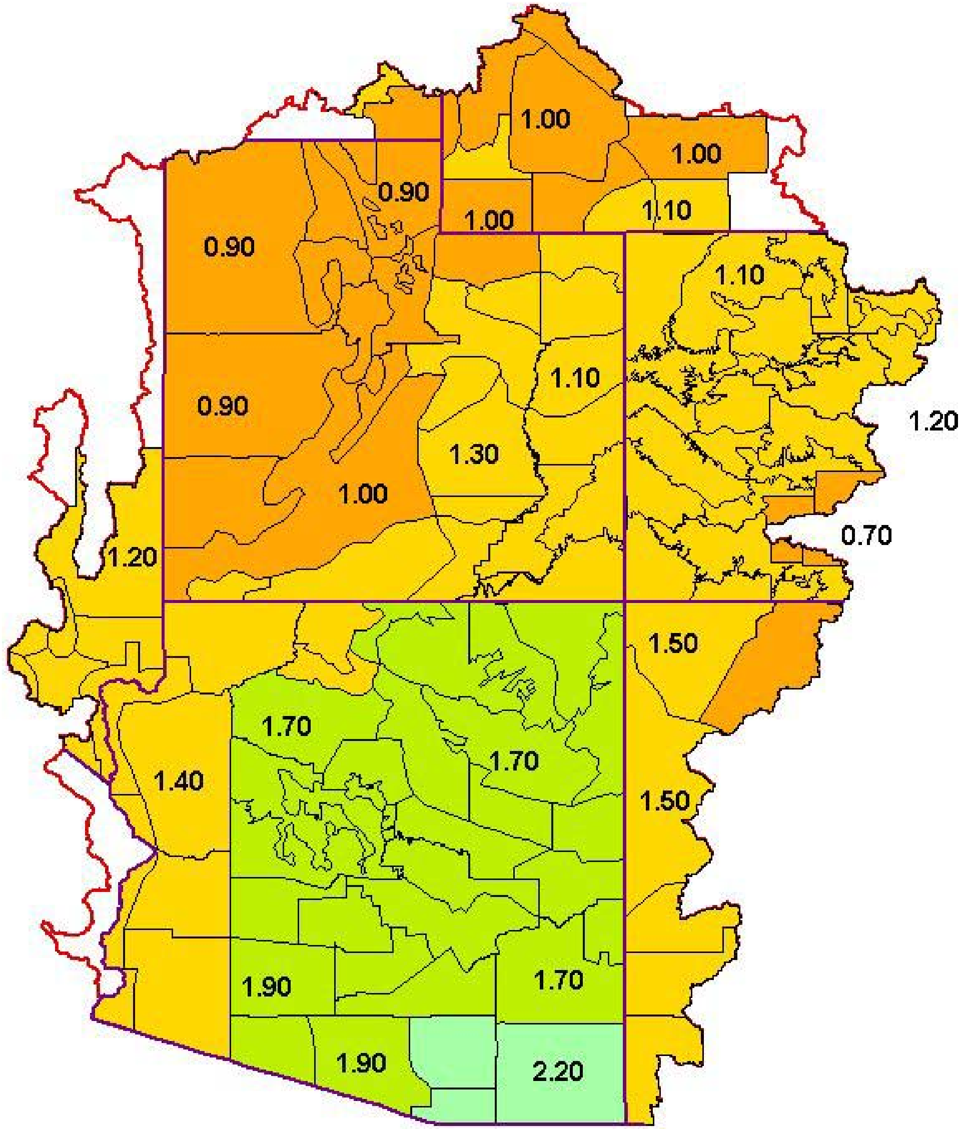
Historically – Little or no coordination between RFC's regarding FFG methods

- Different perceptions of what constitutes a flash flood
- Methods were developed independently to meet local needs
- No national program or requirement for a single methodology

Methods may have included:

- Empirical in nature – precipitation return frequency studies
- Develop runoff curves (typically for large basins > 100 mi^2)
- Other
- National program recently implemented (limitations encountered)

1-Hour CBRFC Flash Flood Guidance

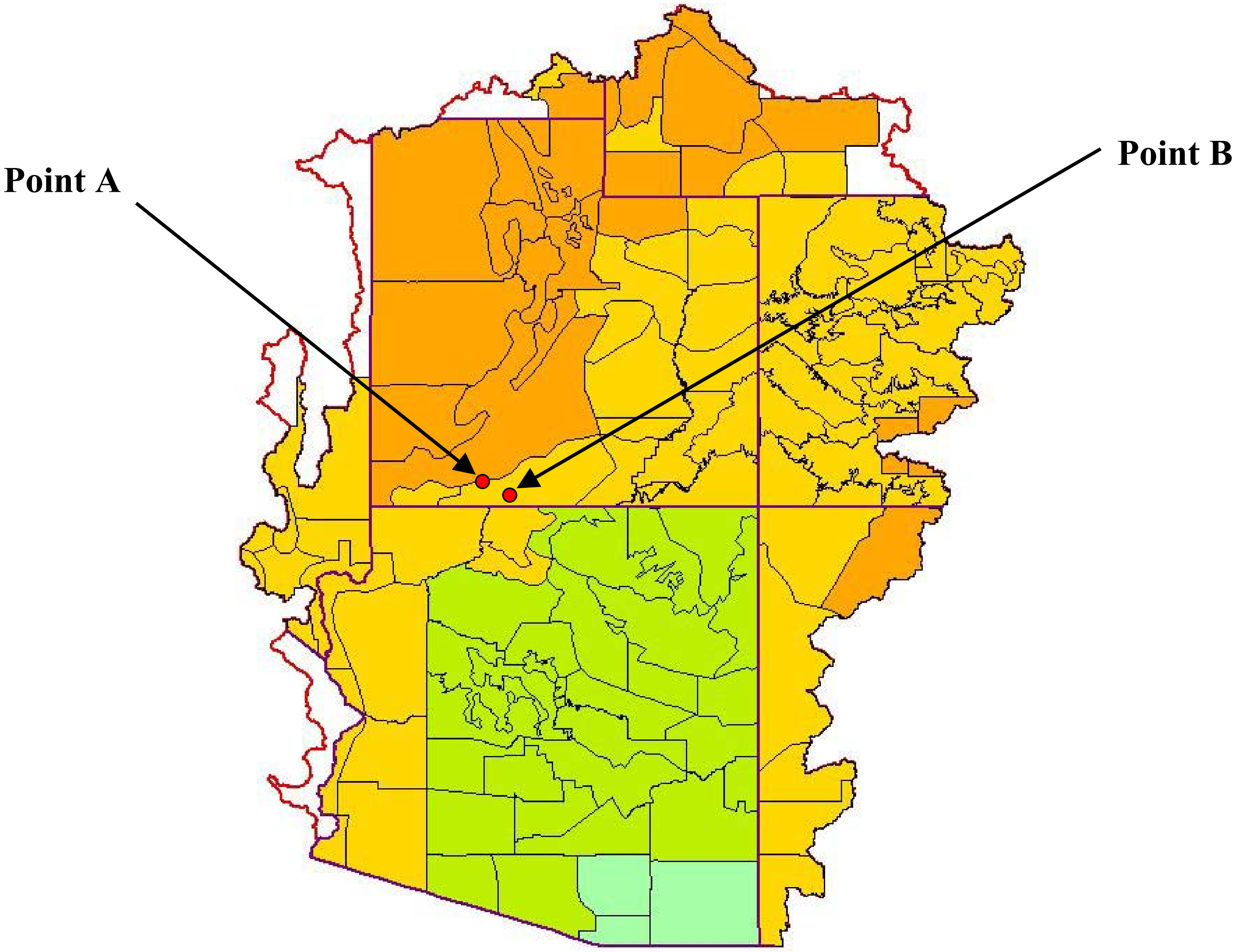


Flash Flood Guidance
Inches

- 0.01 - 0.50
- 0.51 - 1.00
- 1.01-1.50
- 1.51 - 2.00
- 2.01 - 2.50

August 2001

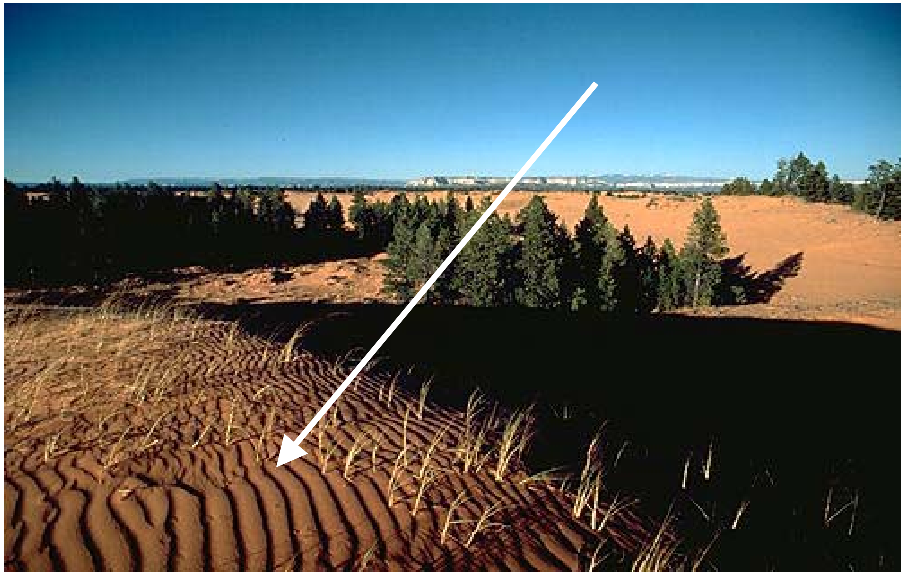
A Comparison of Flash Flood Guidance



POINT A

Parunuweap Canyon on the East Fork of the Virgin River – well known classic flash flood canyon about 10 miles northwest of point B.

Current Method Implies Similar Hydrologic Response



POINT B

Sand dunes near Moquith Mountain.

1-Hour Flash Flood Guidance on this date = 1.10” for both point A and B.

1 Hour Flash Flood Guidance = 1.10”

FFG for 8/15/2001

1 Hour Flash Flood
Guidance = 1.00”

FFG for 8/15/2001

1 Hour Flash Flood Guidance = 1.00”

FFG for 8/15/2001

1 Hour Flash Flood Guidance = 1.00” for both the barren clay hills in the foreground and alpine mountainous country in the background

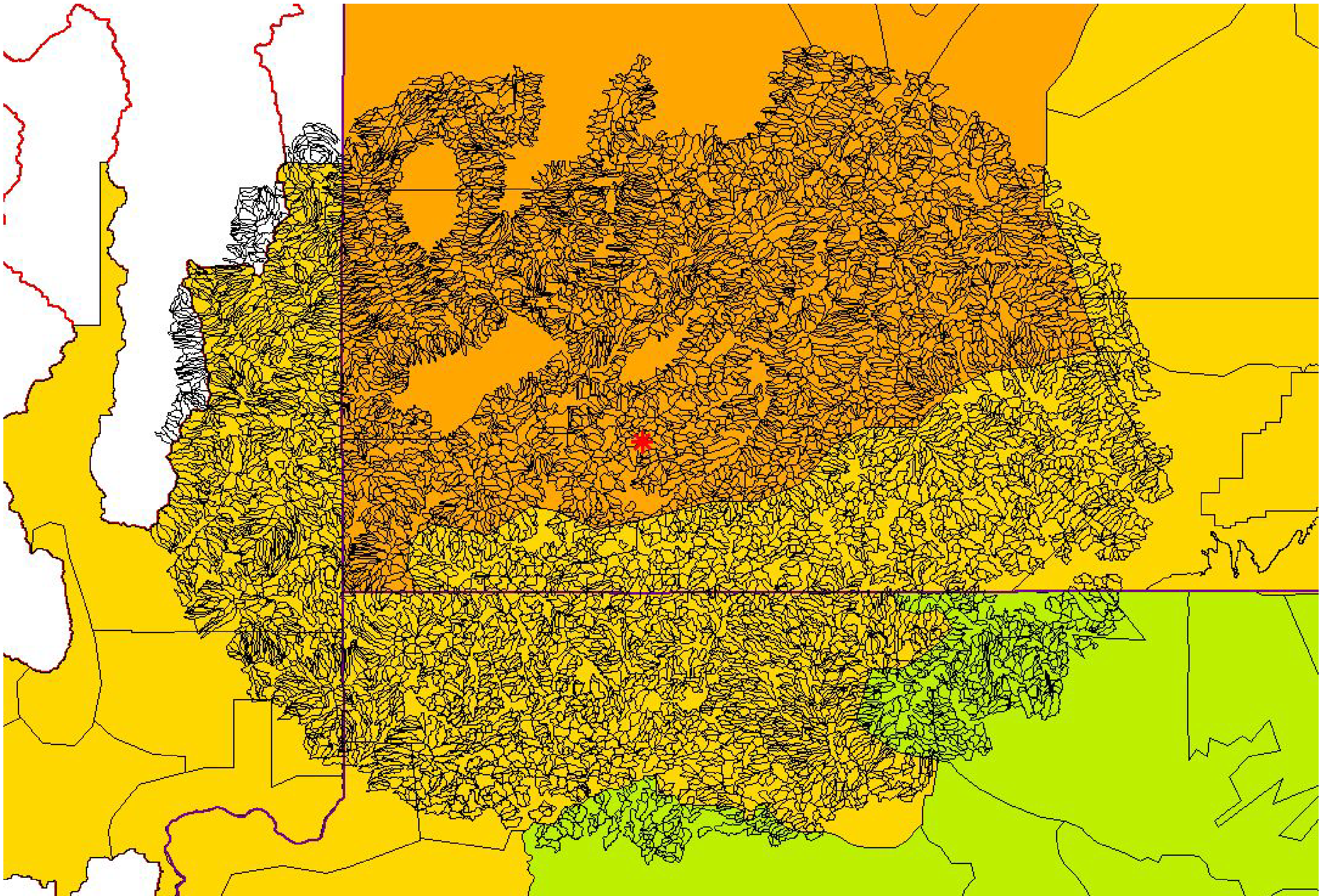
Photos courtesy Southern Utah Wilderness Alliance

FFG for 8/15/2001

Flash Flood near Hanksville, UT July 1990

KICX AMBER basins overlayed with current zone guidance

Tools like this emphasize the need for greater spatial detail flash flood potential or guidance information



Modernized Guidance – ThreshR/FFG System

Modernized program attempts to do this by providing guidance on 4km HRAP Grid

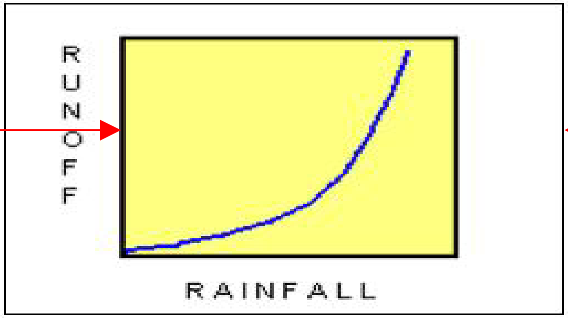
Threshold Runoff:

A fixed value of runoff required to initiate flooding. It is based on geographic and hydrologic features of the stream channel and basin.

Flash Flood Guidance System:

Derives an amount of rainfall that is controlled by soil moisture state from the SAC-SMA model at the RFC and the threshold runoff value.

threshold runoff
(Input to FFG System)



rainfall-runoff curve generated by sac-sma model independent of threshr value.

Modernized Guidance – ThreshR/FFG System

UTAH: USGS Regression for Northern Mountain Elevation Region A

$$Q10 = .071A^{0.815} E^{2.70}$$

Q10 = 10 yr peak discharge   A = Area   E = Elevation

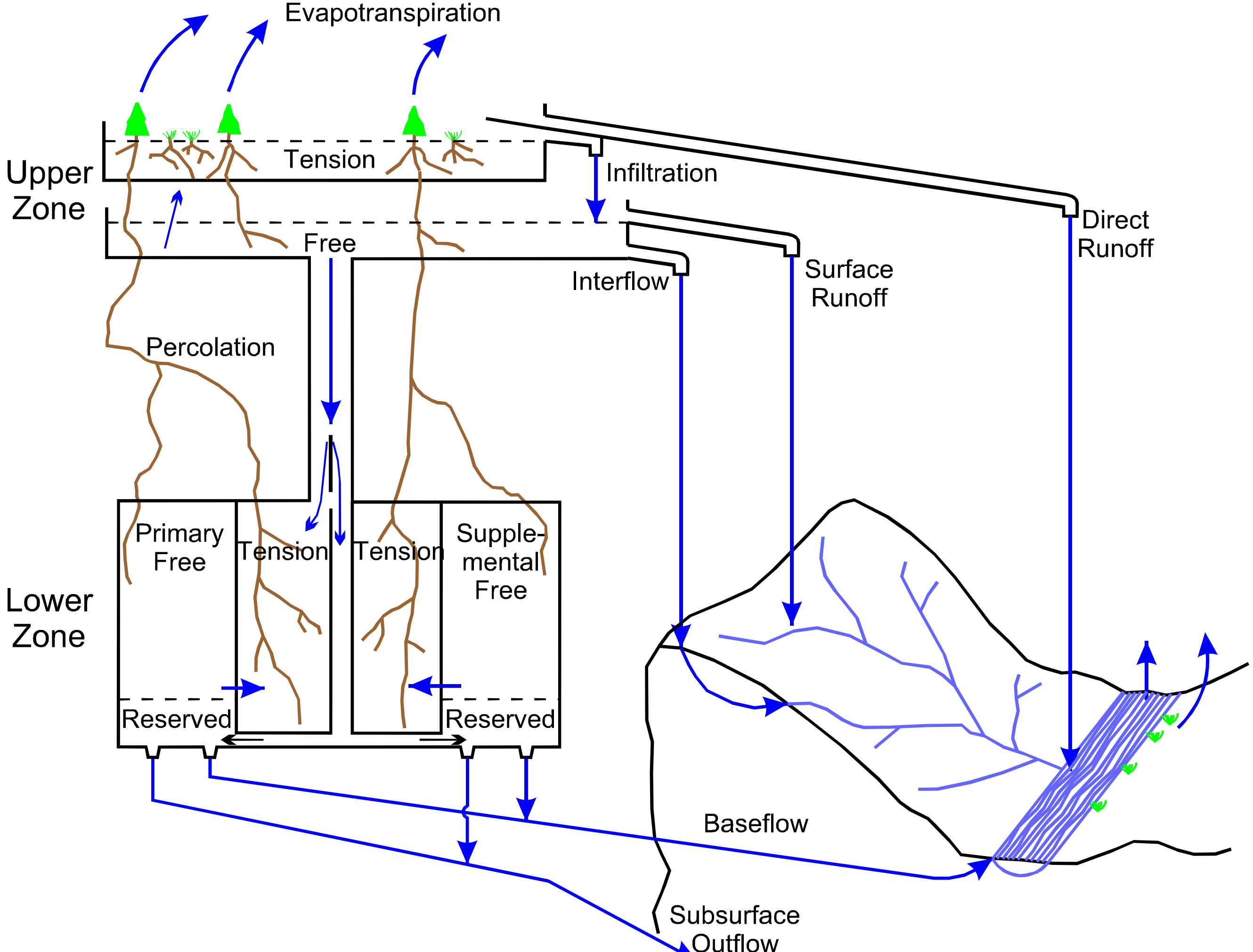
Snyder Unit Hydrograph Method

$$qp = 640\ Cp\ A / t_p$$

$$t_p = C_t (LL_c)^{0.3}$$

Primary Limitation

Use of SAC-SMA model at a flash flood scale



Amber (flash flood) basin size vs. NWSRFS calibrated basins

SAC-SMA Issues

Calibrations for this model are typically for large basins (frequently exceeding 100 sq. miles) vs. flash flood basins that occur on basins as small as 5 sq. miles.

Calibrations are based on historical 6 hour precipitation and temperature data (much of it derived from daily data) as well as mean daily streamflow. The model executes on 6 hour time steps - unrepresentative of western flash flood events.

Many calibrations are primarily developed for seasonal events such as snowmelt, volumetric water supply and synoptic scale events and do not produce realistic runoff values for short duration precipitation input.

Parameters are not on a scale for flash flood application

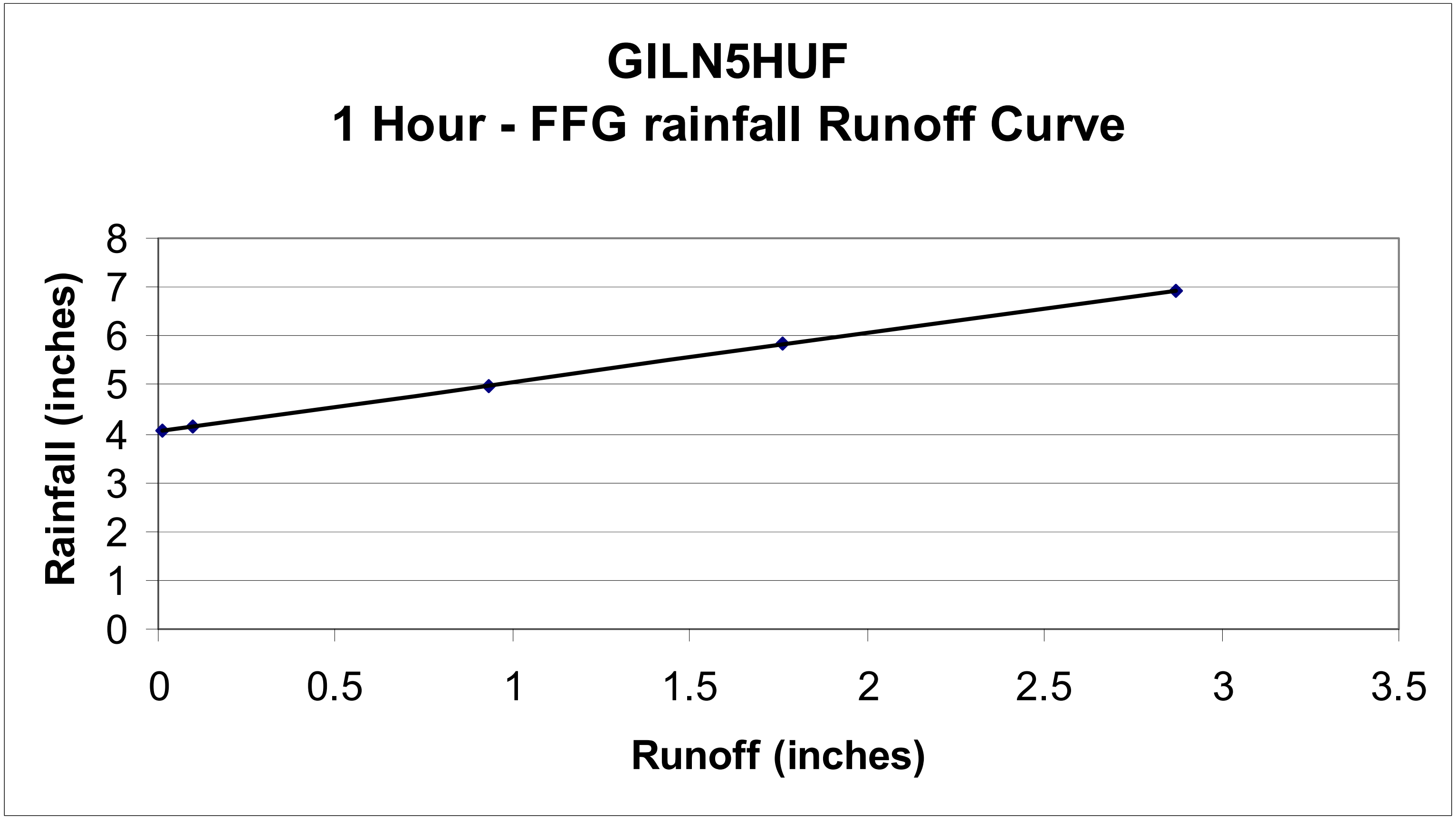
Precipitation catchment and intensity will be underrepresented due to the time scale and spatial scale of MAP areas that are much larger than individual convective cells.

Upper zone tension water tanks that are required to fill before generating runoff will not react properly to high intensity short duration rainfall. Deficits are frequently high in semi-arid areas and following extended periods of dry weather.

SAC-SMA rainfall-runoff curve in the Gila River Basin

Due to tension water deficits 4” of precipitation is required before runoff is generated

Even with Threshold Runoff set to zero !



Modernized vs. Current Flash Food Guidance Output

Threshold Runoff is set to zero

ZCZC SLCFFGAZ CSW
FOUS65 KSR 220825
FFGAZ
ZONE FLASH FLOOD GUIDANCE
COLORADO BASIN RIVER FORECAST C

ISSUED 0800 AM MDT TUE MAY 22 2001

Flash Flood Guidance is primarily dependen
Flash Flood Guidance for urban areas and s
indicated.

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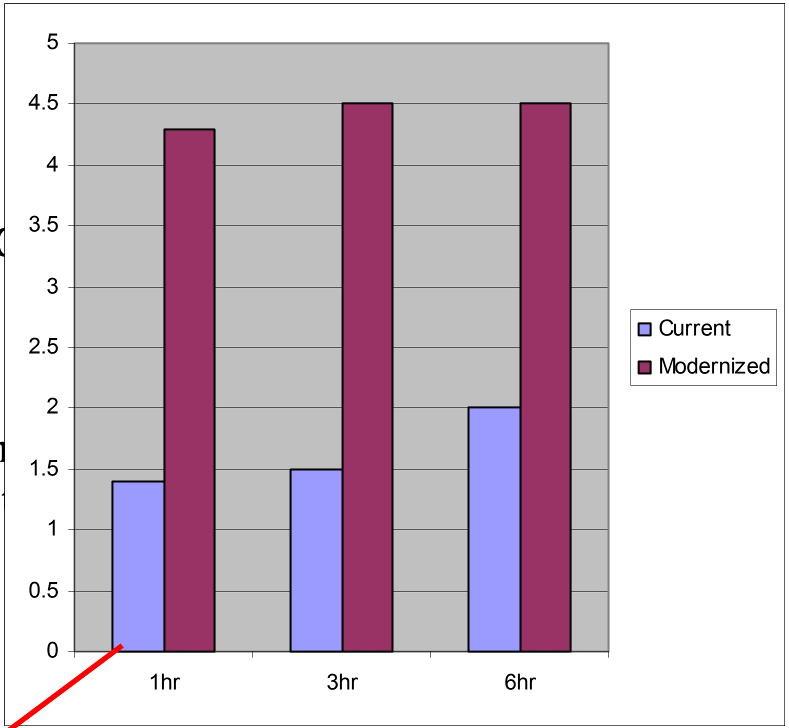

:IDENT	1HR	3HR	6HR
:======	====	====	====
AZZ001	3.4/	3.6/	3.7
AZZ002	4.3/	4.5/	4.5
AZZ003	4.3/	4.5/	4.5
AZZ004	3.4/	3.6/	3.7

:IDENT	1HR	3HR	6HR
:======	====	====	====
AZZ001	1.4/	1.5/	2.0
AZZ002	1.4/	1.5/	2.0
AZZ003	1.4/	1.5/	2.0
AZZ004	1.6/	2.1/	2.3

FFG Quotes

It is better that FFG is absent than inaccurate.

-Brian McInerney, SH SLC

A constant frame of reference (of 1 inch per hour) allows the forecaster using AMBER/FFMP to self-calibrate.

With the advent of FFMP, (i.e. the widespread use of amber), FFG will become much more important and will be reviewed much more critically. (We need to be careful about what we give them).

FFG Quotes, cont.

"For some of the Narrower canyons, as little as a 30 cfs flow can cause significant difficulties. In 1993, two people drowned in Kolob Creek when the stream was flowing at less than 40 cfs. And, many of the narrowest canyons are located in areas where their entire drainage is made up of slickrock.

We have a lot of flash floods that we consider significant because they cause flows through tributaries of the North Fork yet do not show up as a large rise on the North Fork river gauge."

Ray O'Neil, Backcountry permit office supervisor, Zion Nat'l Park

Where does that leave us ?

Current FFG Method

- ⇧ Empirical in nature, grounded in some truth.
- ⇧ Favors rainfall intensity over soil moisture as a driving force behind flash flooding
- ⇩ Dependent on unrealistic long term drought index for temporal variation
- ⇩ No account for changes to surface hydrologic response caused by urbanization or fire etc.
- ⇩ No direct account for spatial distribution of physiographic properties
- ⇩ Not robust – FFG lacks spatial variation
- ⇩ Modernized FFG programs/methods – inadequate for Western Region needs

Where does this leave us ?

Modernized FFG Method

Severe scale limitations due to its dependence on SAC-SMA

Application and scale/dataset concerns associated with ThreshR

More emphasis that soil moisture is the driving force behind flash flooding

Lacks verification / reality checks along the way

Assumes a single uniform method is applicable across the nation

We need to look at alternative methods for producing FFG information.

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Flash Flood Analysis Project

Take a big step back – View from a <u>flash flood potential</u> perspective

Is it even possible to create accurate guidance values ?

- **What physiographic properties make an area susceptible to flash flooding – can we identify these ?**

- **What changes in these features or properties increase/decrease an area's susceptibility to flash flooding.**

- **Identify areas susceptible to flash flooding, relative to one another, based solely on these properties.**

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Utilize GIS tools/methodology to carry out such an analysis

- **Acquire static raster datasets linked to hydrologic response:**
  - **Basin geography (slope and shape information)**
  - **Soil information & derived hydrologic properties**
  - **Vegetation coverage information**
  - **Forest coverage/canopy information**
  - **Land use information, etc.**
- **Perform analysis on raster datasets using GIS map algebra**
  - **On individual layers – assign relative flash flood potential indicators**
  - **Merge layers – yield single gridded relative flash flood potential layer**

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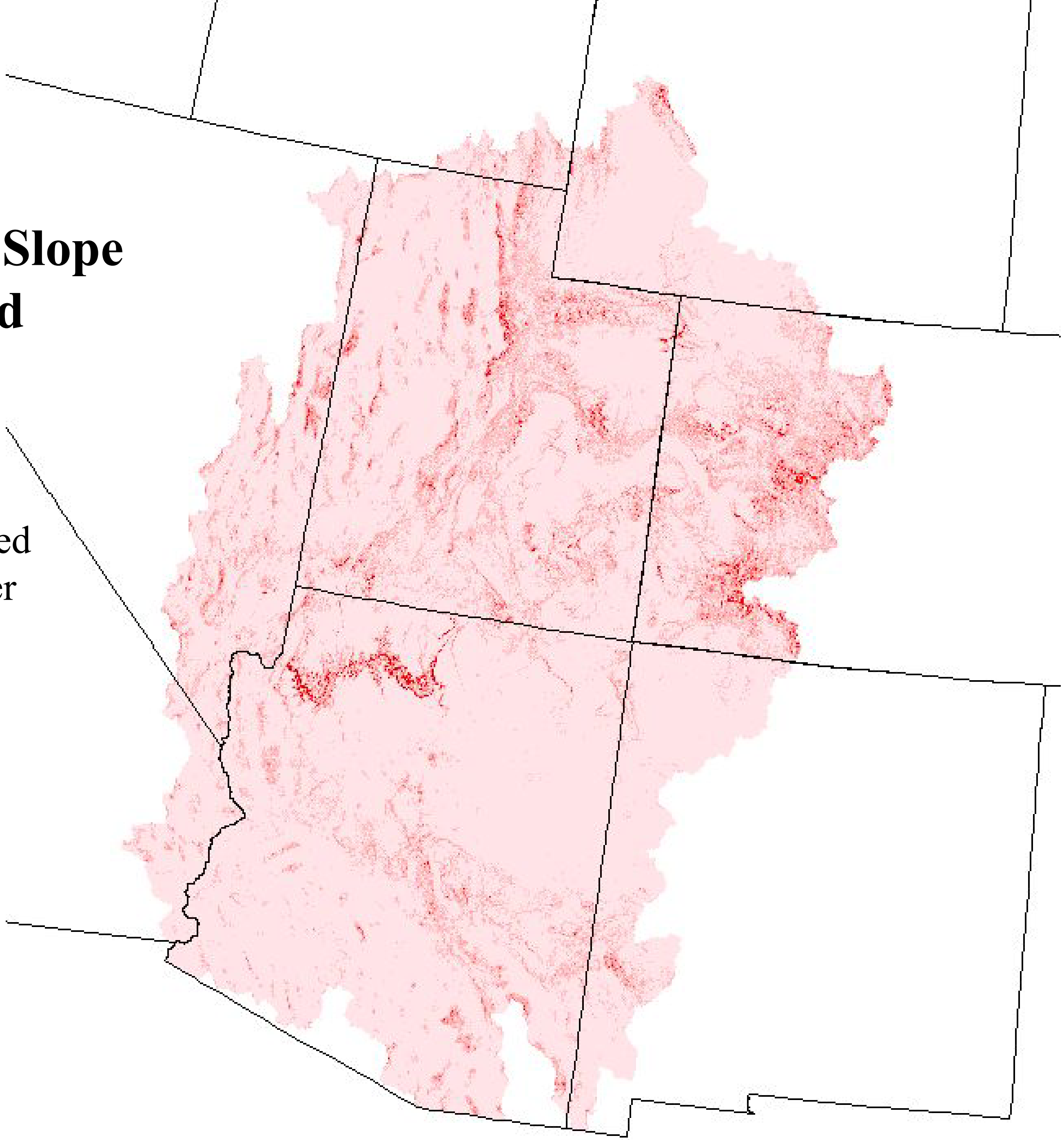
Example

- **A first shot analysis for the CBRFC area using readily available data**
  - **Four raster data layers used – (re-sampled to 400 meter grid – coarse!)**
    - **Percent Slope Grid (terrain steepness factor)**
    - **Rock Volume Grid (% rock fragments – affecting infiltration) - STATSGO**
    - **Fractional Soil Grid (% clay, sand etc.) – USGS STATSGO**
    - **Forest Density Grid - NOAA AVHRR**
  - **Datasets were all geo-registered prior to manipulation**
  - **Datasets re-sampled to consistent resolution – Bilinear method**
  - **Equal weighting given to each data layer**
  - **Flash Flood Indicators assigned (1-10) – equal interval re-classification**
  - **Utilized Arc-Info map algebra routines to output a single gridded layer**

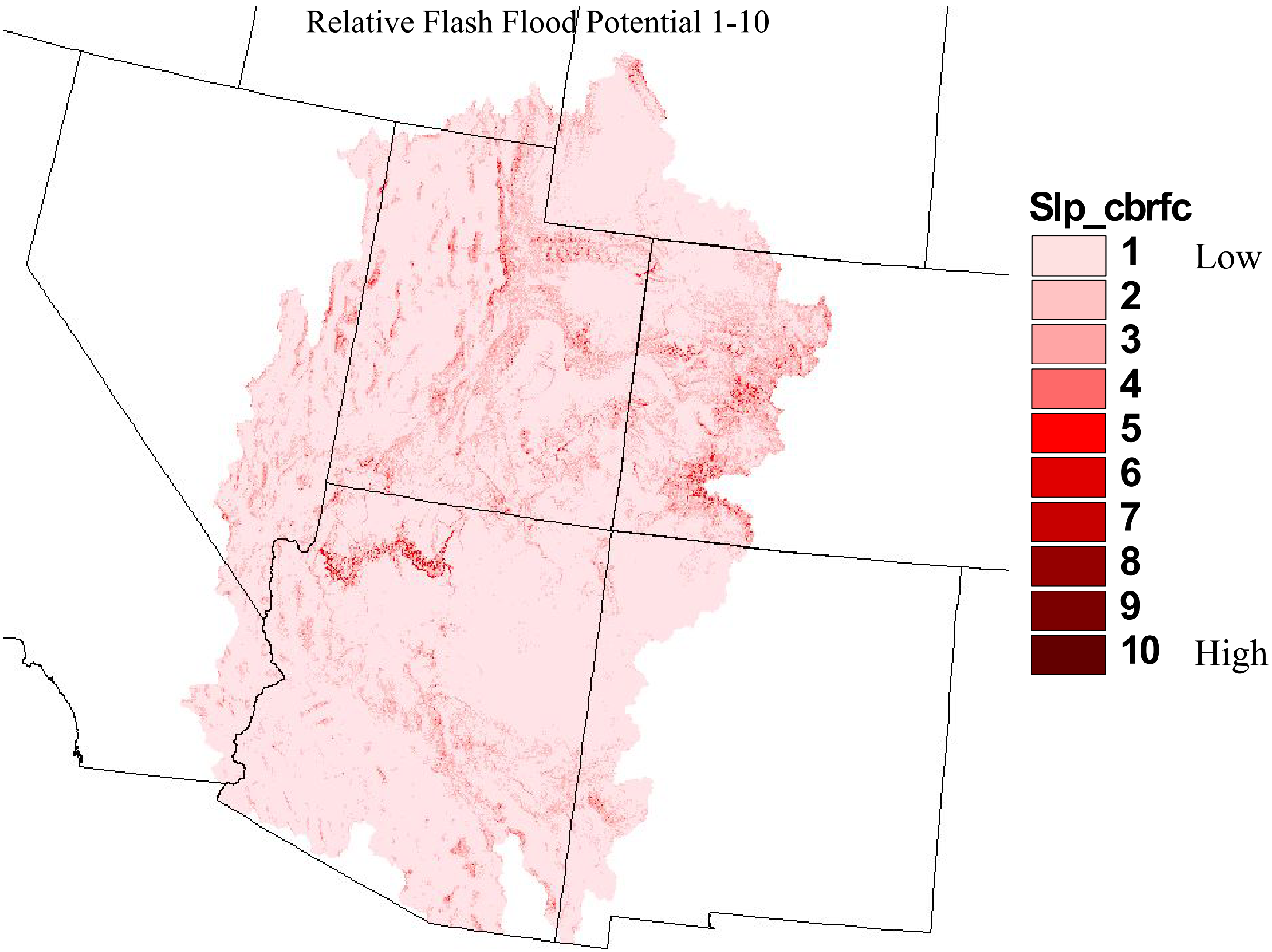
Percent Slope Grid



Re-sampled 400 meter DEM

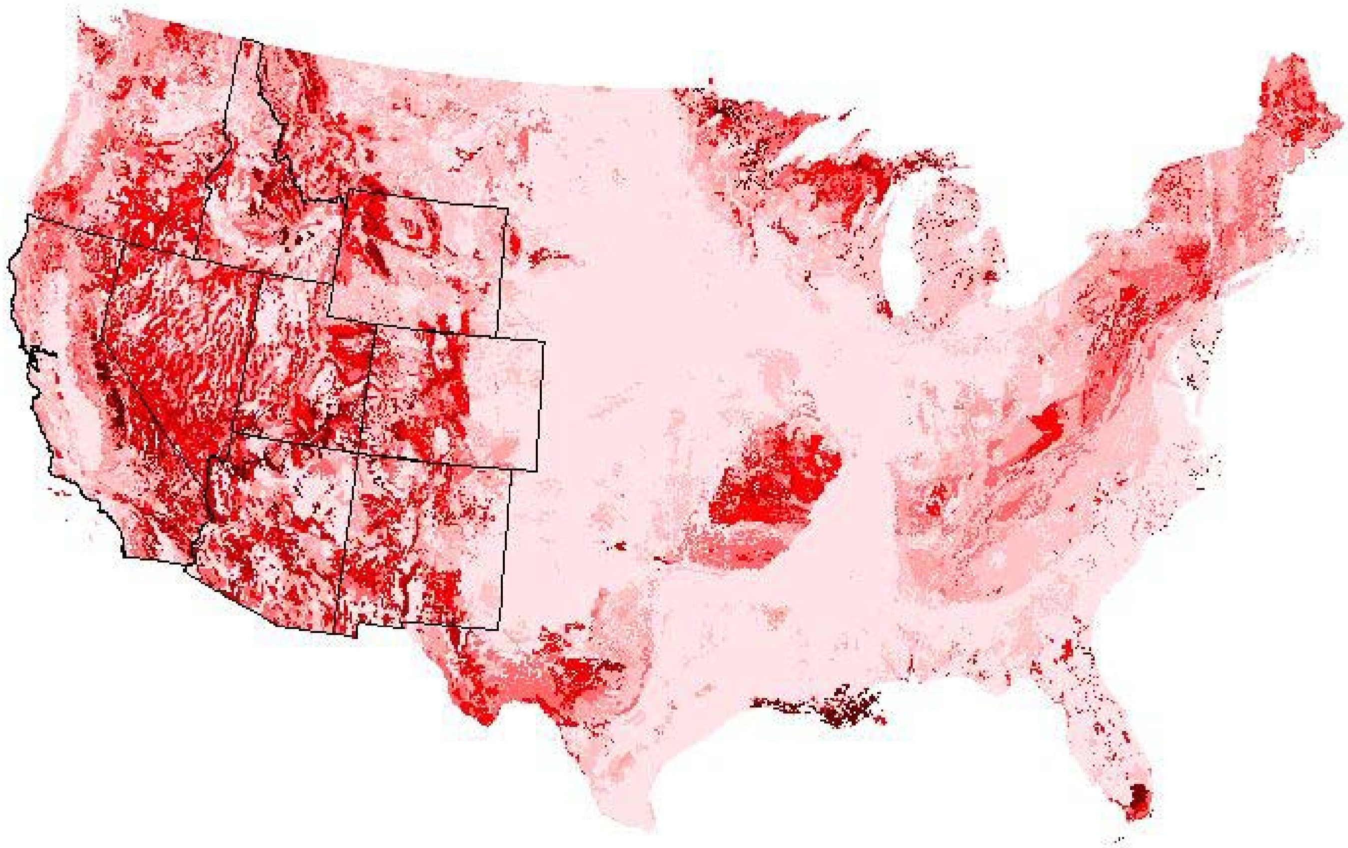
Reclassified Percent Slope Grid

Relative Flash Flood Potential 1-10



Rock Volume Grid

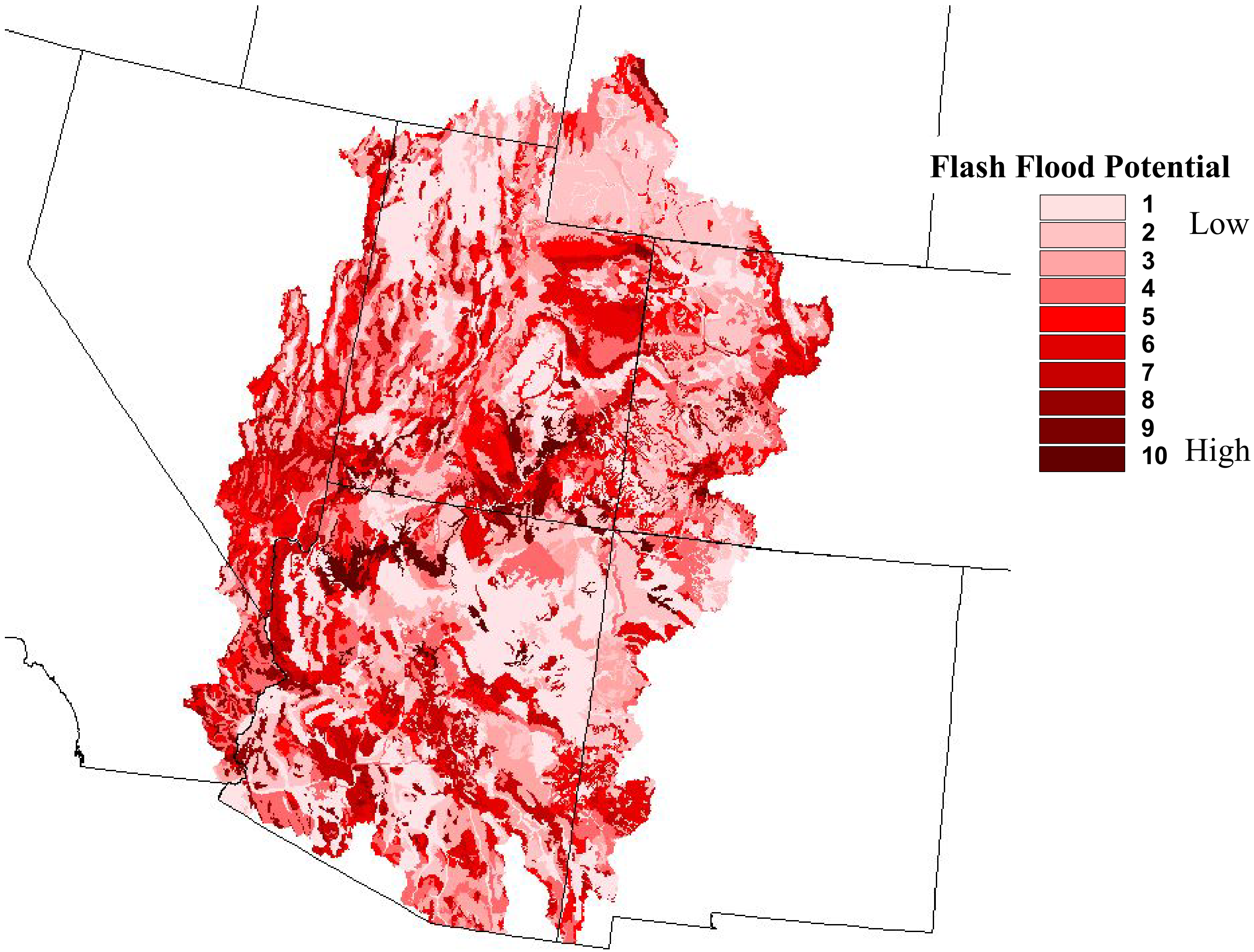
Rock fragments in the soil > 2mm



source: STATSGO

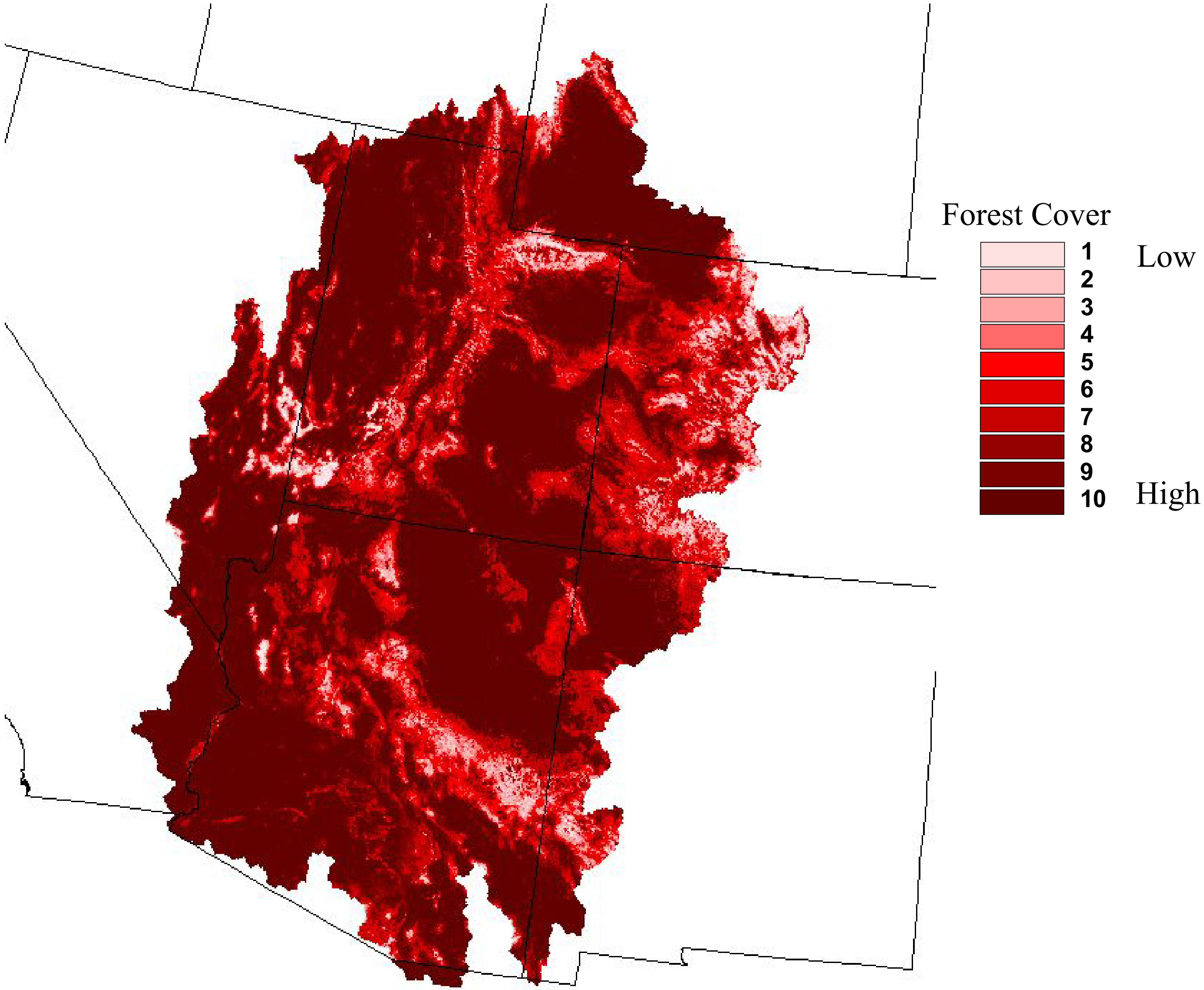
Reclassified Rock Volume Grid

Relative Flash Flood Potential 1-10



Percent Forest Cover

Reclassified Percent Forest Cover

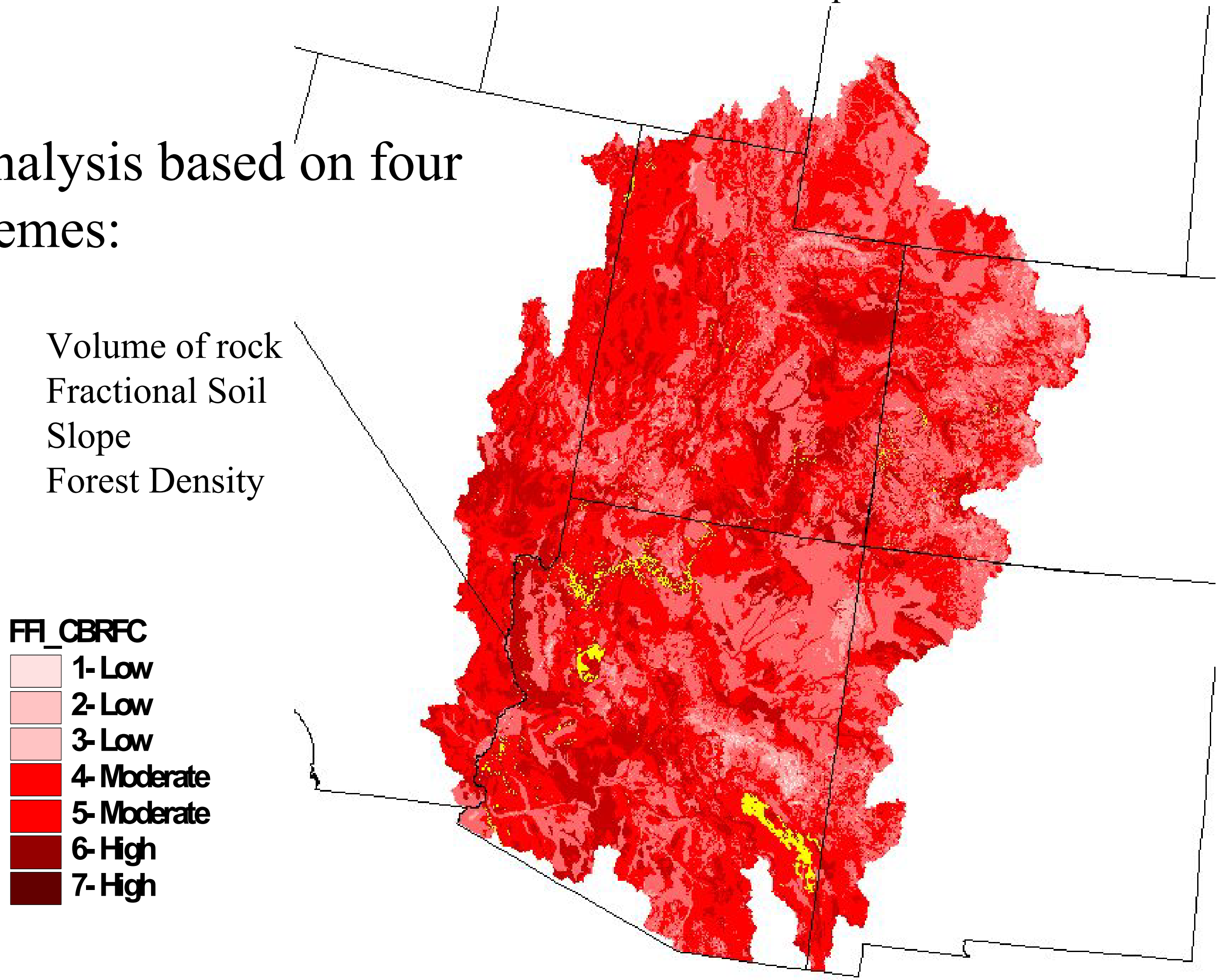


Flash Flood Potential Indicators

static relative flash flood potential

Analysis based on four themes:

Volume of rock
Fractional Soil
Slope
Forest Density



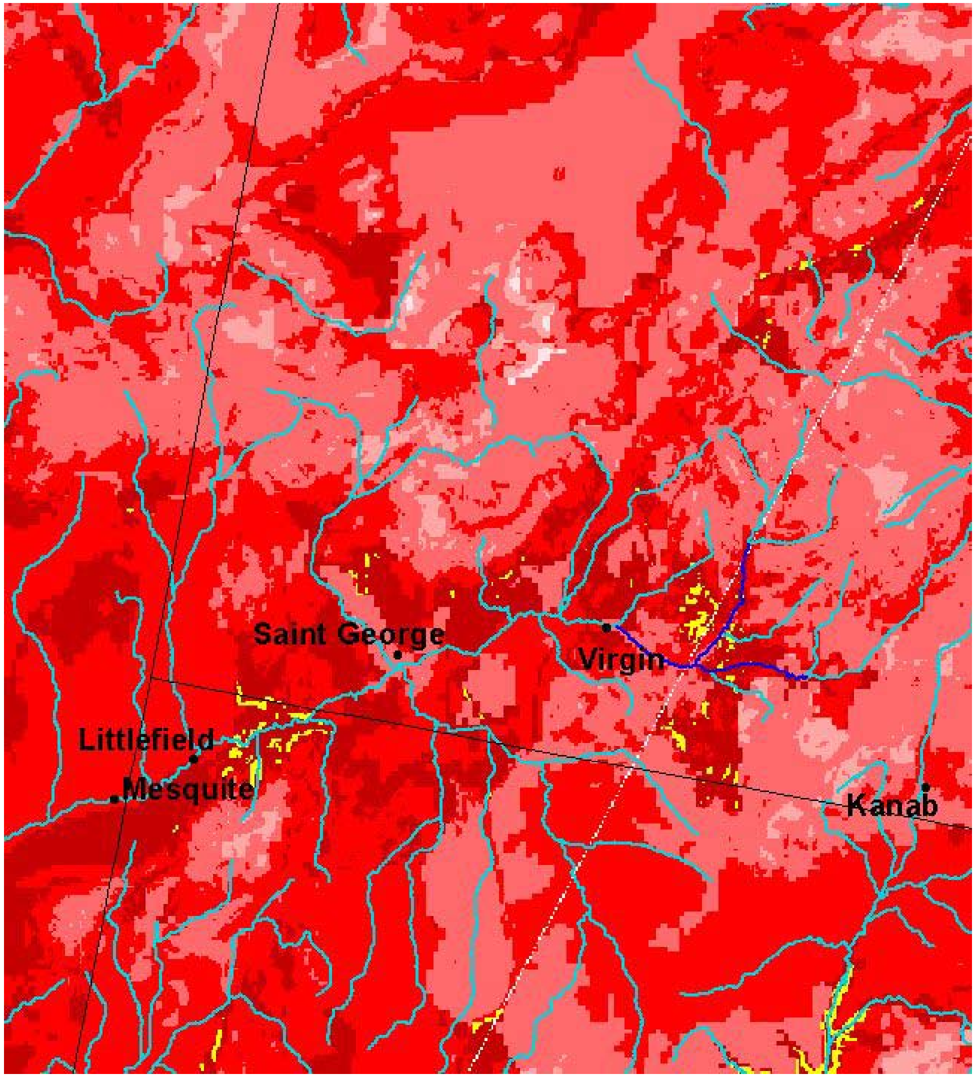
Flash Flood Potential Indicators

static relative flash flood potential

North and East Fork
Virgin River

FFI_CBRFC

- 1- Low
- 2- Low
- 3- Low
- 4- Moderate
- 5- Moderate
- 6- High
- 7- High



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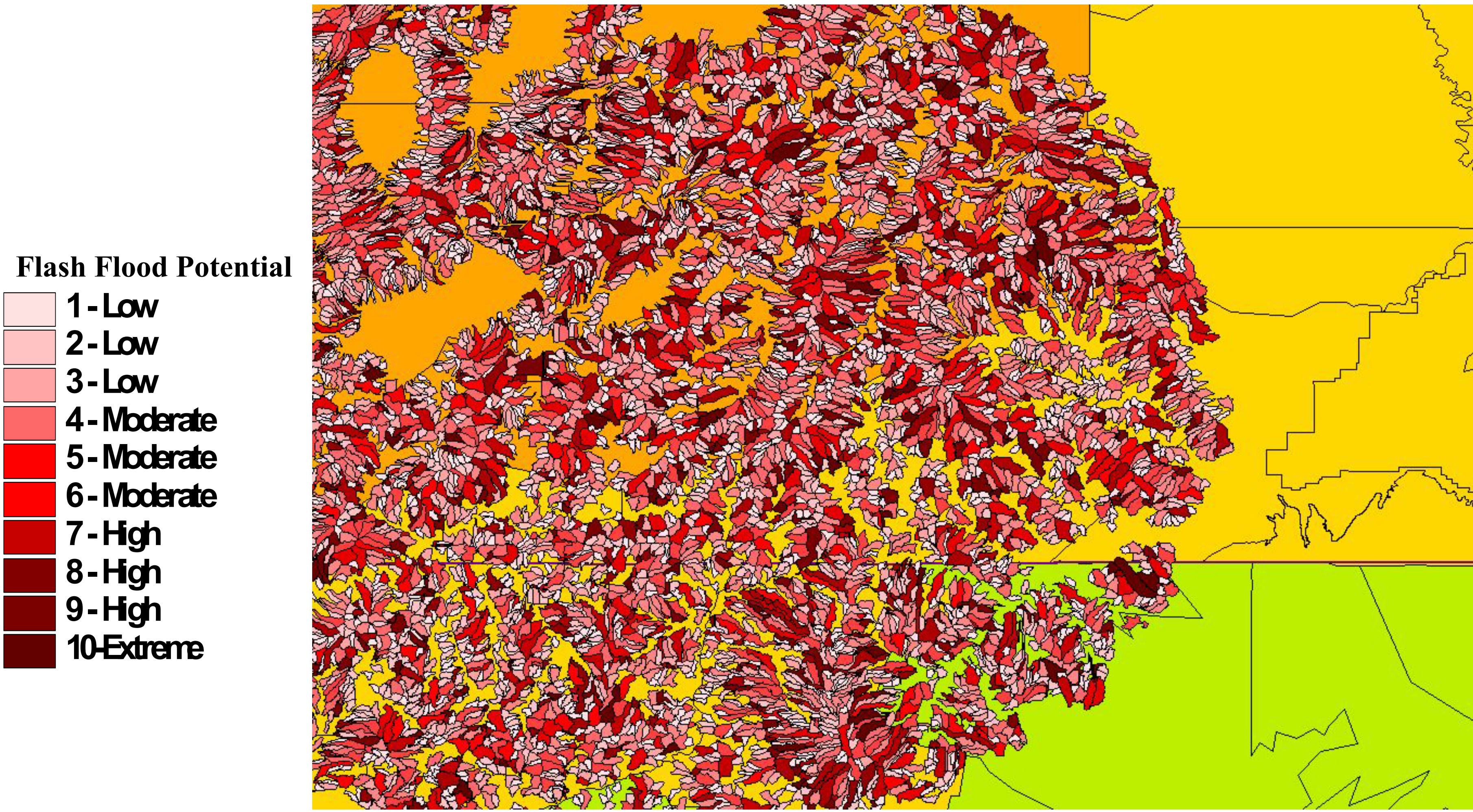
Flash Flood Analysis Project

Output – Thematic layer of relative flash flood potential

- **A data layer for spatial variation of current FFG**
- **Initial output is gridded**
- **Interpolate to FFMP/AMBER or other geographic layer**
- **Add basin geometry component to FFG output weighting**

KICX AMBER/FFMP Basin Flash Flood Potential

hypothetical example



CB
Flash

Move from a stati

- **Seasonal bas**
  - Vegetation
  - Snowpack
- **Event based**
  - Fire effects
  - Land use o

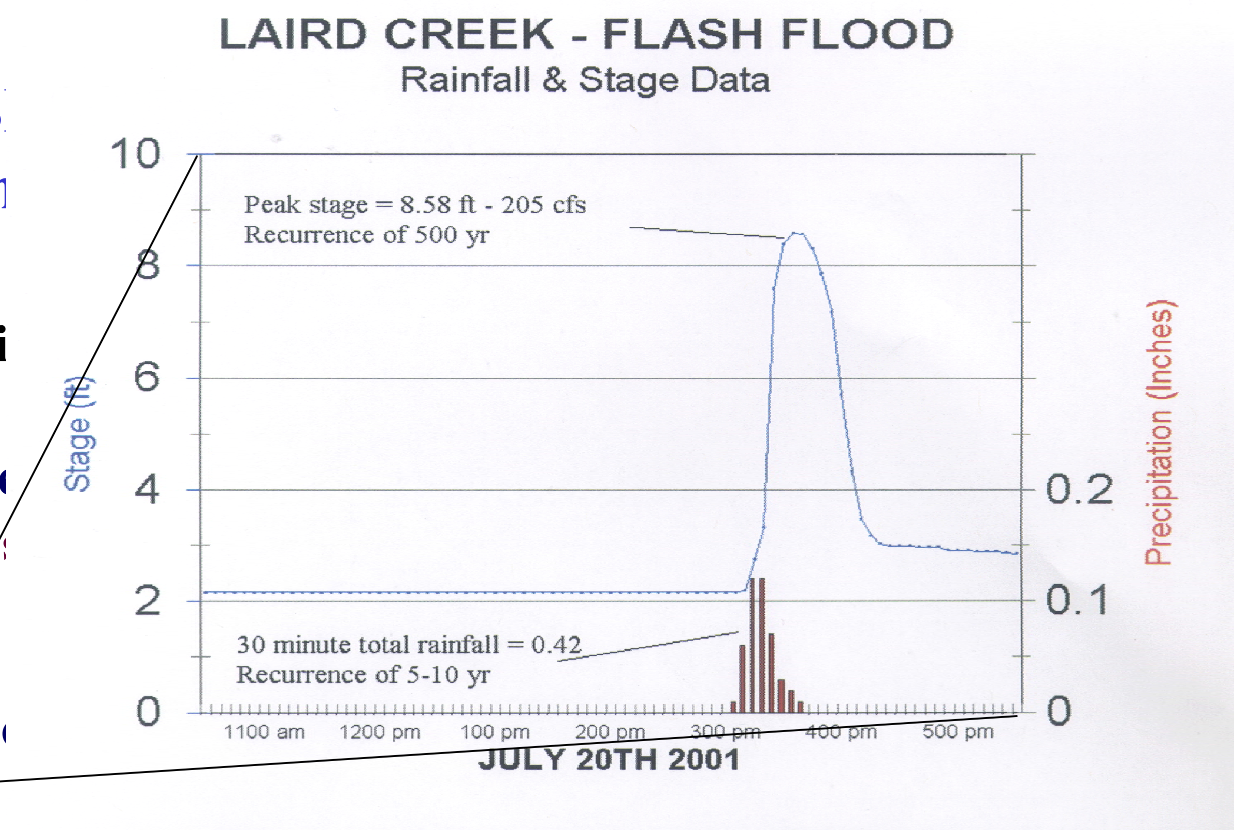
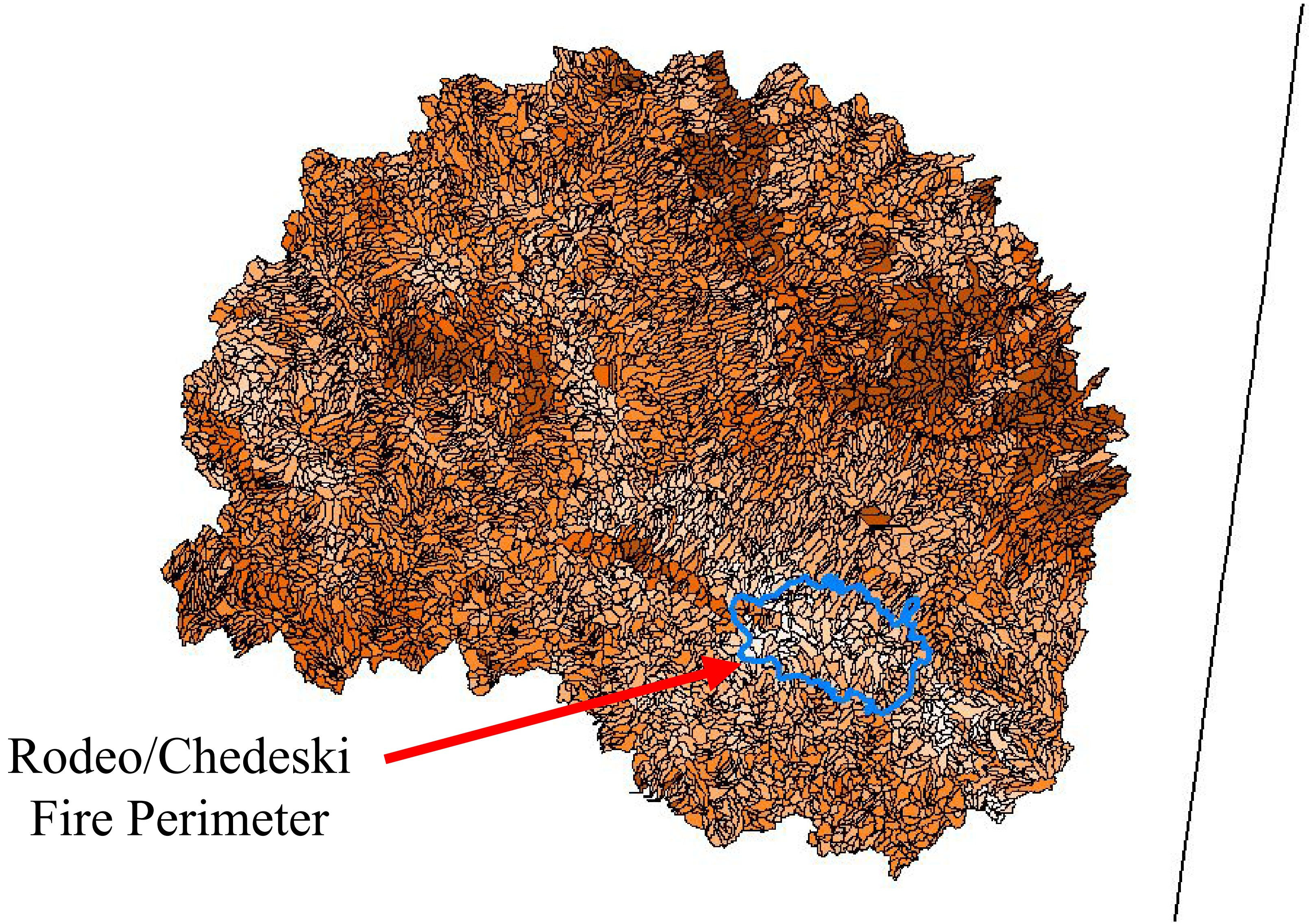


Figure 16. Rainfall, stage and discharge data from the July 20th storm at Laird Creek near Sula, Montana.

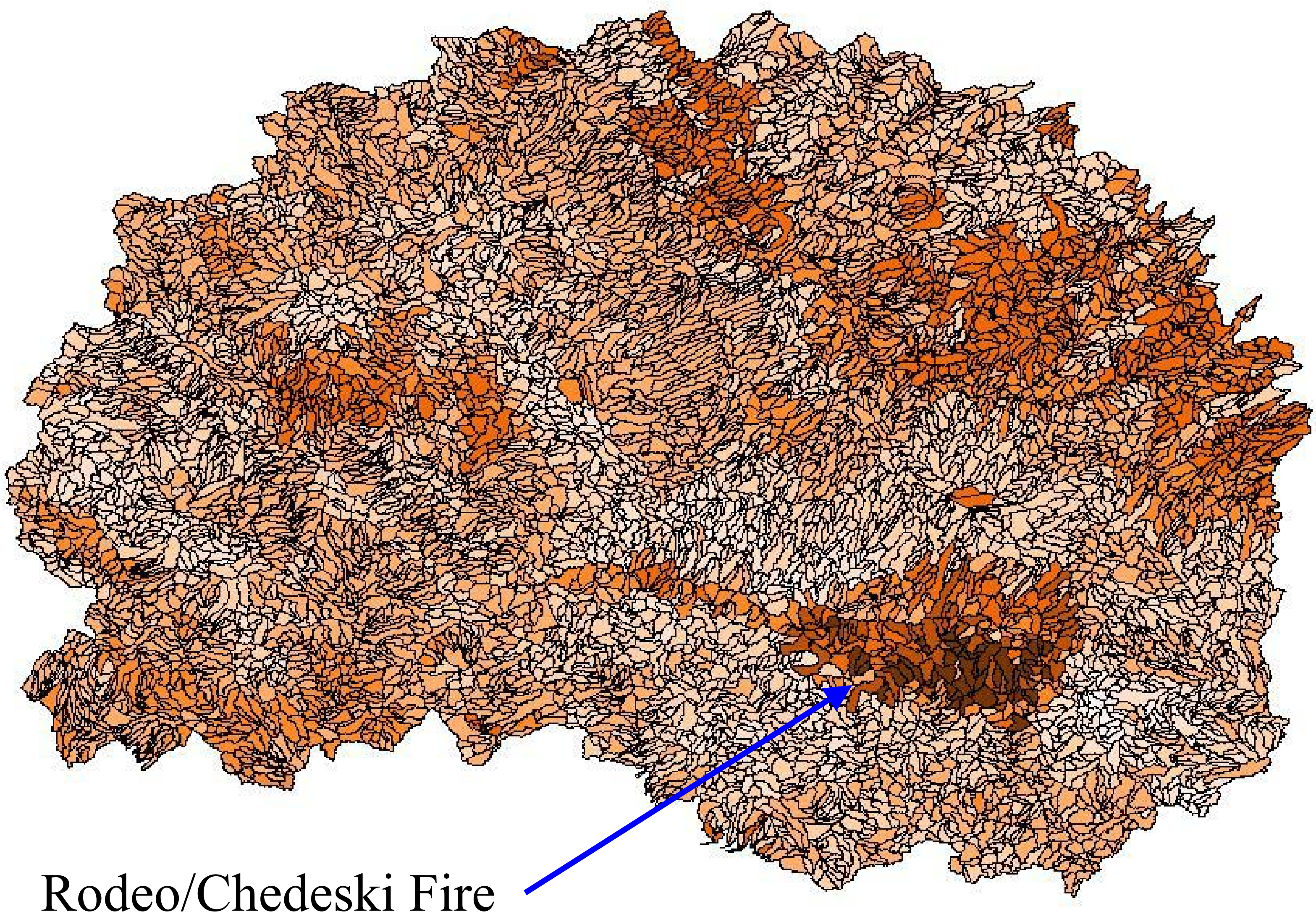
- **Daily based on:**
  - Precipitation component
  - Modeled soil moisture index

Flagstaff FFMP/AMBER Basins – Flash Flood Potential Layer



Flagstaff FFMP/AMBER Basins – Flash Flood Potential Layer

Fire Event Included (3 levels of burn intensity)



from the ThreshR component?

?

raphic datasets linked to flash flooding

information (basis for guidance)

framework

ntial relationship between areas/basins

esses features affecting western flash floods?

ory and USGS statistical procedures

lue to achieve bankfull flow

on across all areas

ic datasets

ures affecting western flash floods?

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Flash Flood Analysis Project

Develop ability to generate FFG guidance values

- **Assign a FFG value to each of the FFPI categories**
  - **Simple assignment**
  - **Regression approach using layer info and observed info**
  - **Other?**
- **Incorporate precipitation return frequency information**
  - **May vary by physiographic characteristics**
  - **May vary regionally by climate, etc.**
- **Incorporate distributed model component**
- **Incorporate observed flash flood event information**
  - **Important to ground in observational truth**

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Flash Flood Analysis Project

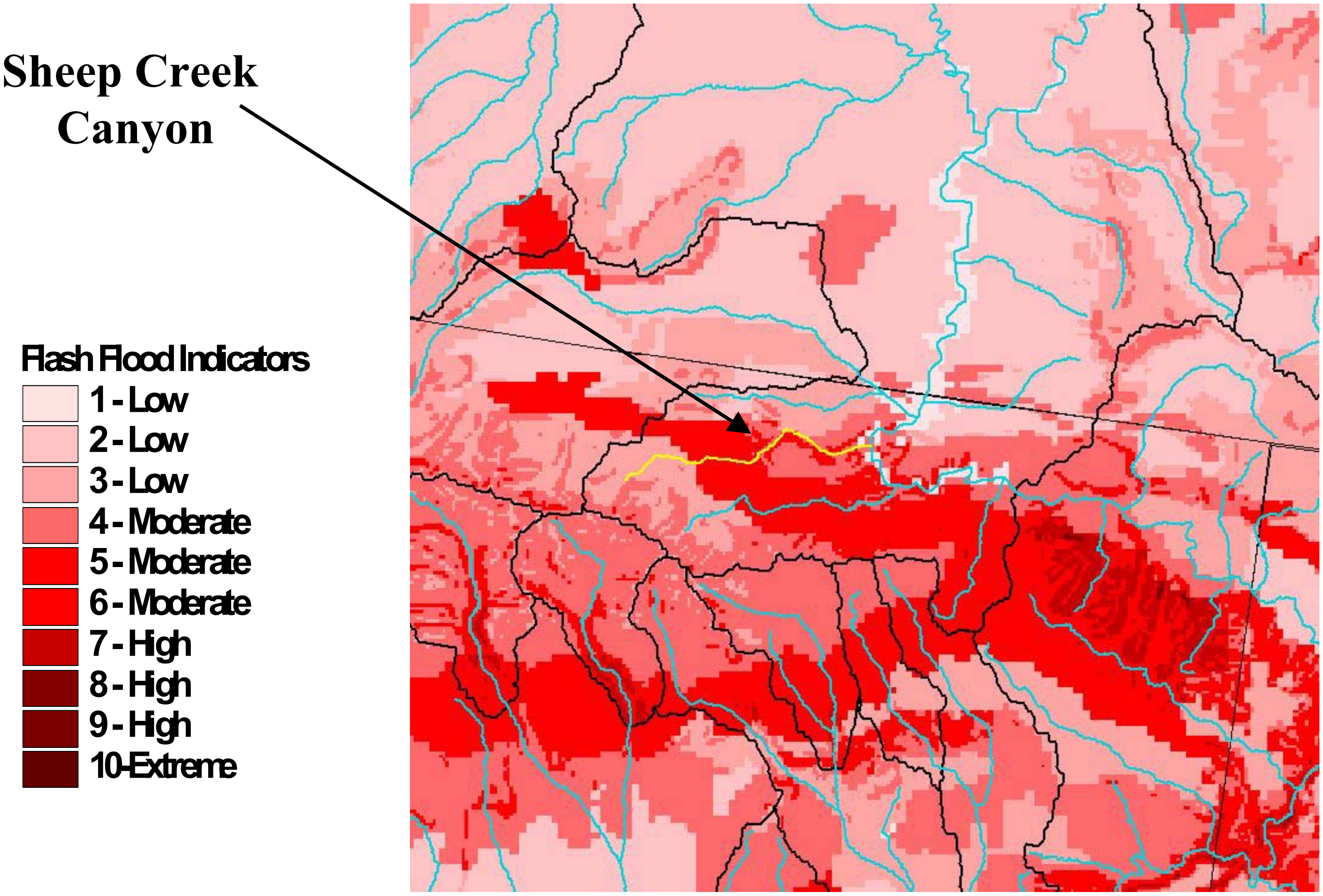
How do you verify output ?

- **Based on documented flash flood events**
- **Based on local knowledge of flash flood prone areas**
  - **Create thematic data layers of observed events and known areas**
  - **Determine common characteristics re-apply elsewhere**
- **Other**

Important to ground analysis in observational truth

Flash Flood Indicators

static relative flash flood potential



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Numerous GIS considerations to keep in mind

- Error Propagation
    - Quantitative attributes, positional, categorical
- DEM uncertainties and derived attributes
- Determining proper datasets for application-correlation of datasets
- Data Representation
    - Soil attributes – Pedotransfer functions propagate error.
    - Data collection process and previous re-sampling methods
- Varying resolution and coverage between datasets
- Properly geo-register datasets prior to analysis

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Numerous GIS considerations to keep in mind

DEM

- **Scale Limitations**

1 arc-second (~30m) delineate to:	5 km^2	(min < 1 km^2)
3 arc-second (~100m) delineate to:	40 km^2	(min 5 km^2)
15 arc-second (~400m) delineate to:	1000 km^2	(min 60 km^2)
30 arc-second (~1 km) delineate to:	4000 km^2	

- **Computational concerns**
- **Storage-Space concerns**

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Conclusions ? – Directions ?

- Only visual analysis possible at this point in time
  - Comparison with known/expected flash flood areas
  - Some positives but not enough info for anything conclusive yet
- Need for data layers of observed/documented events
  - Perhaps also a starting point for guidance values
- Determine additional valid datasets for use
  - Acquire-derive additional-finer resolution data layers
  - Review decisions about each layers hydrologic response contribution
- Determine weighting schemes for data layers
  - Weigh layers based on contribution to hydrologic response
    - Fire events (hydrophobic soils)

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Conclusions ? – Directions ?

- **Define Study Area – Focus Analysis**
  - Identify a sub area for more in depth analysis (Virgin River)
  - Obtain finer resolution DEM and other data if available
  - Focus on documenting events in this area
  - Visit to obtain local knowledge if necessary (i.e. Park Service)

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How best to document these events ?

- **Can we get the WFO SH or Hydro Focal Point involved ?**
  - **Assist in documenting event parameters**
  - **Parameters that could be derived would be determined by the RFC**
  - **A simple interface to document these events – databased at RFC**
  - **Future and at least some historical information is desired**

<u>It is imperative observed information be collected if this program is to improve</u>

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To document or not to document – what do we call a flash flood ?

It's probably best just to focus on the initial concepts we are working with when deciding whether to document an event.

Primarily trying to relate surface physiographic characteristics conducive to a hydrologic response of exceptional high and/or sudden discharge that is on a similar scale as the short duration high intensity rainfall. If an event falls into this type of hydrologic response category.. document it.

If it is questionable.. document it.

Team Members

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