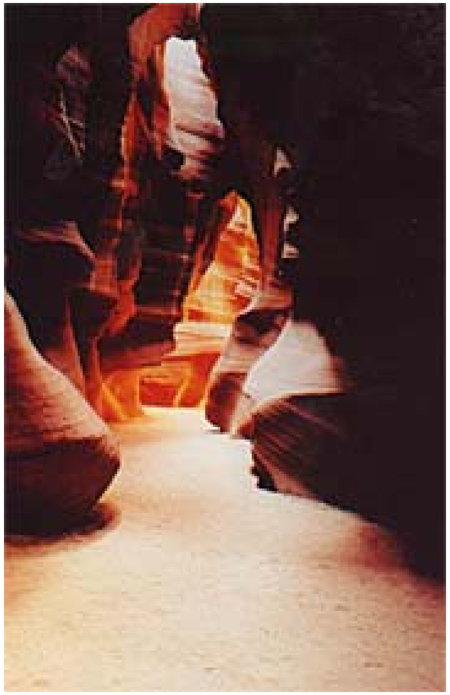
CBRFC/Western Region

Flash Flood Analysis Project

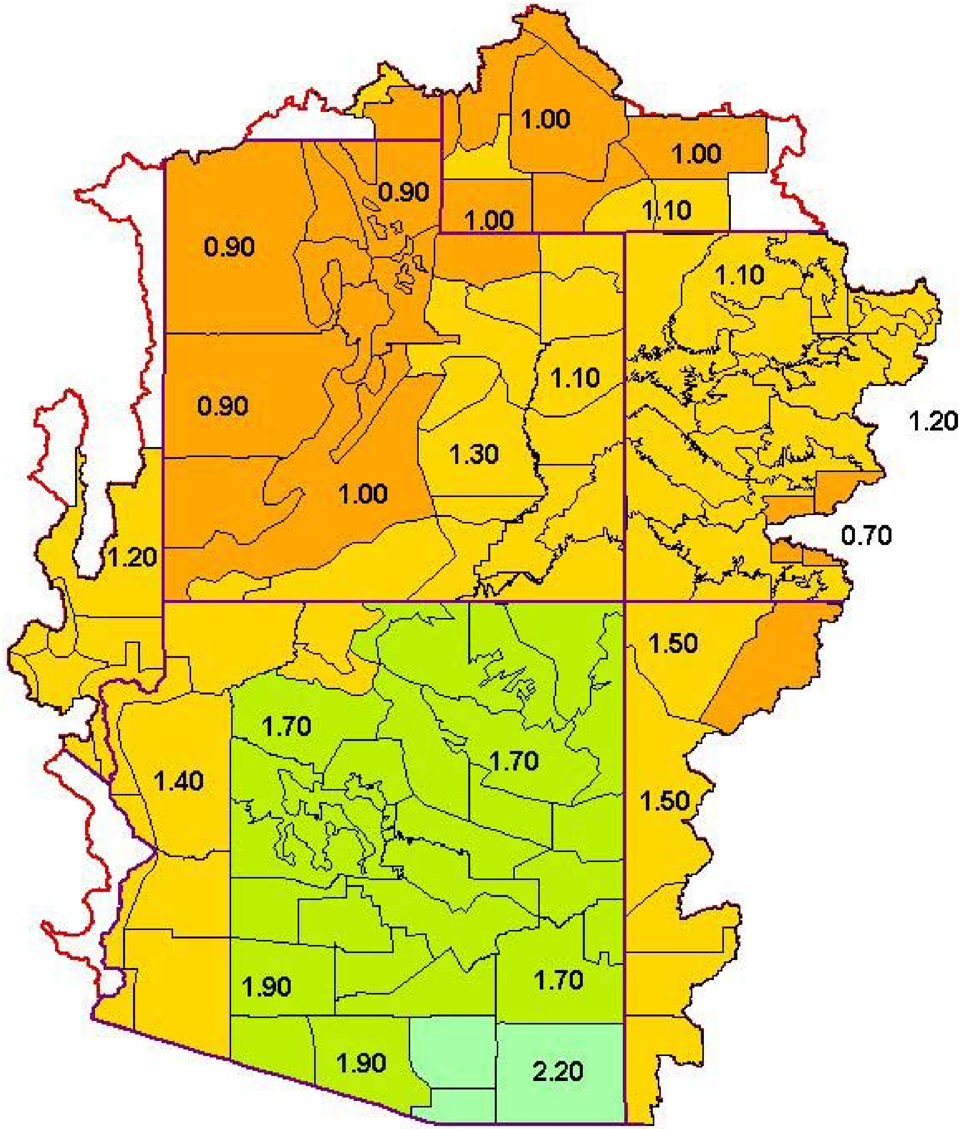
Alternative methods for determining flash flood potential and guidance

Greg Smith
Colorado Basin River Forecast Center

Gypsum Wash – Near Las Vegas, NV



1-Hour CBRFC Flash Flood Guidance

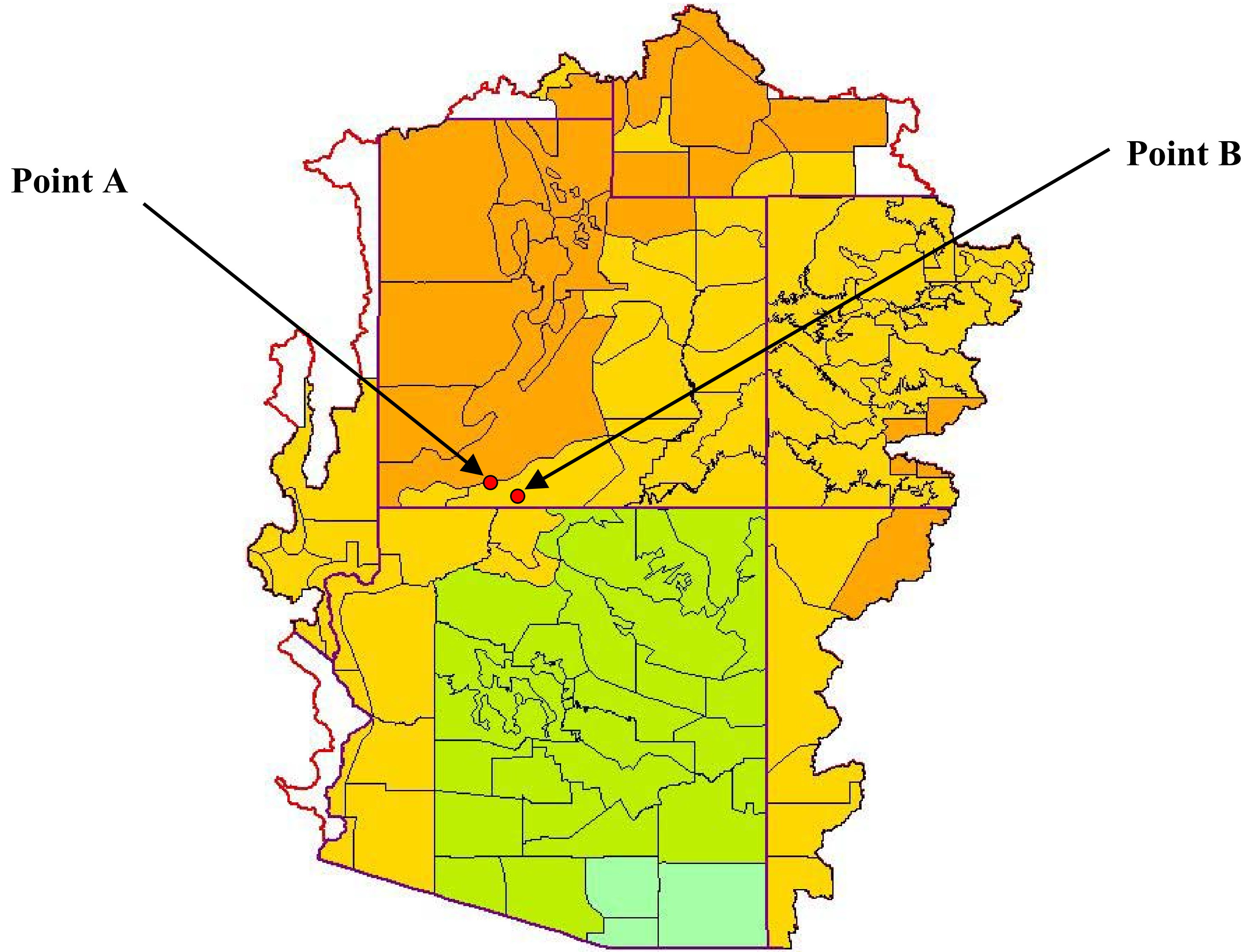


Flash Flood Guidance
Inches

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

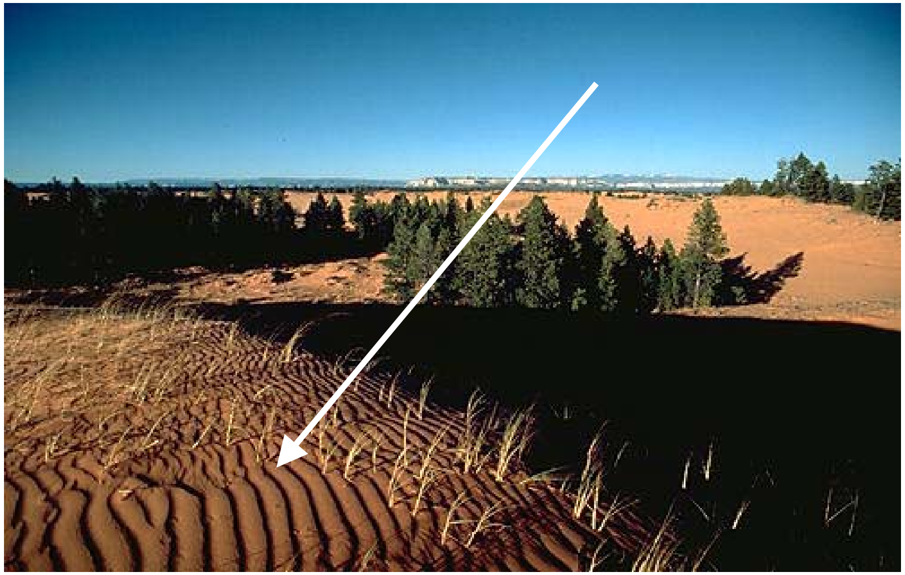
August 2001

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.



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

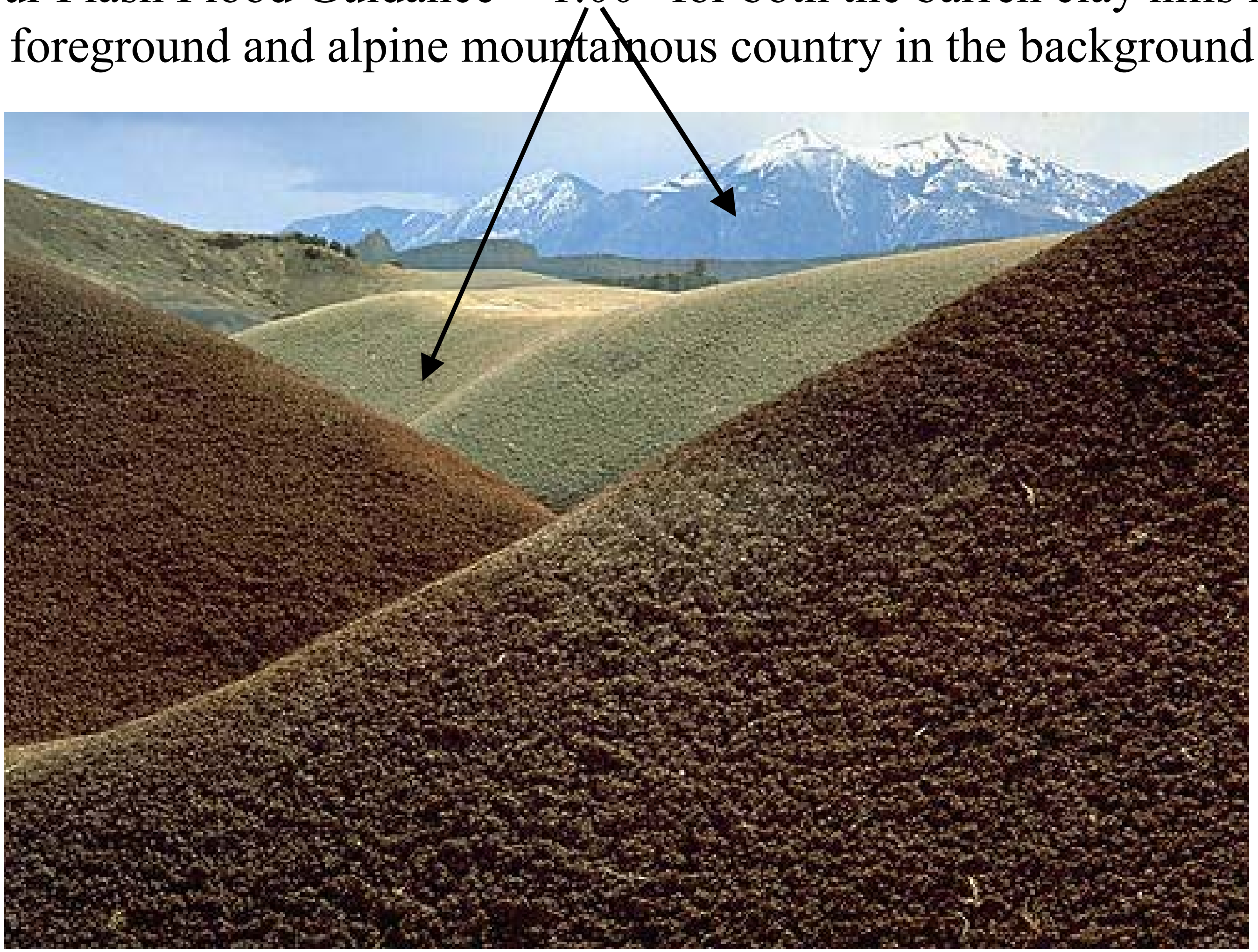
1 Hour Flash Flood Guidance = 1.00”

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



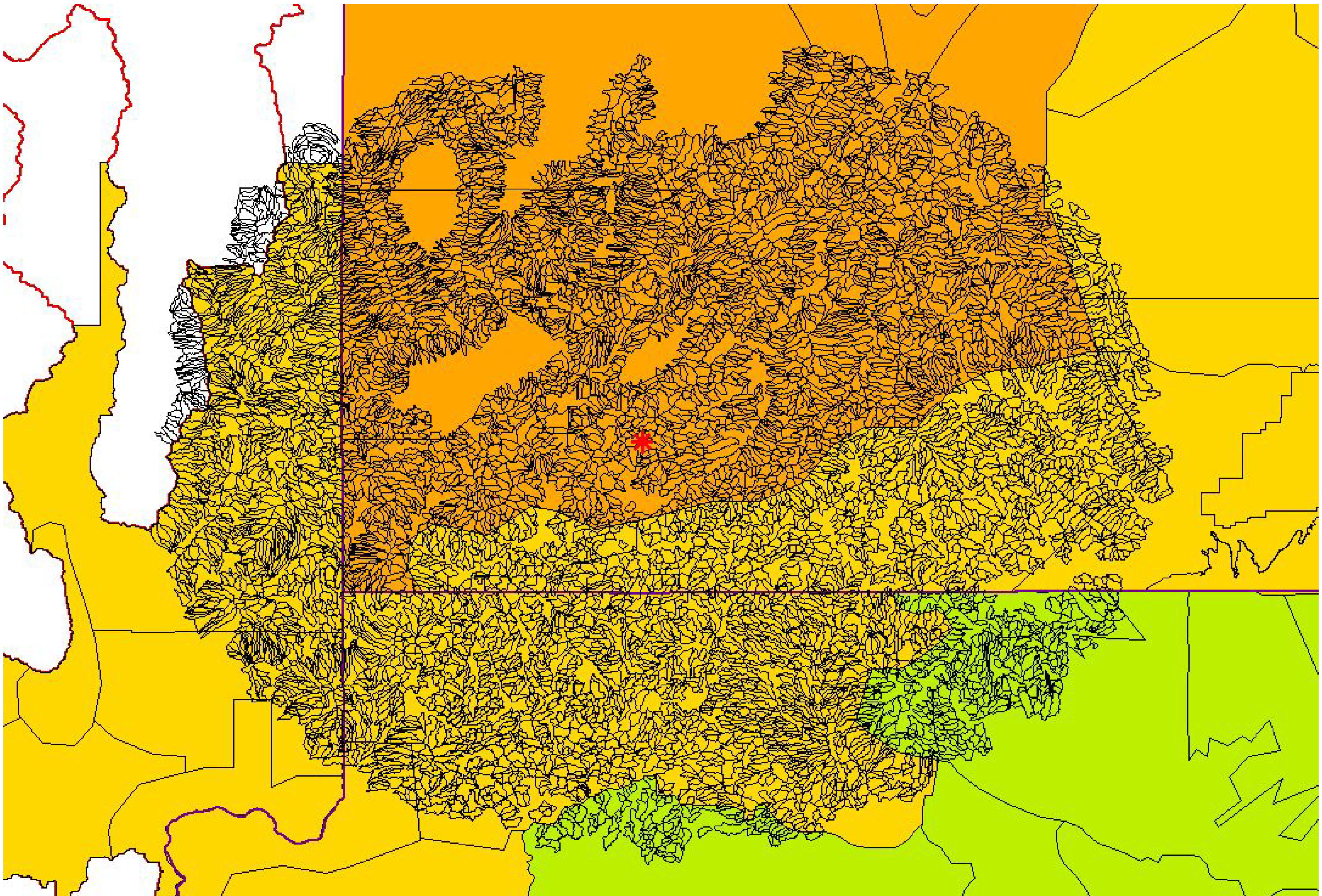
Photos courtesy Southern Utah Wilderness Alliance

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

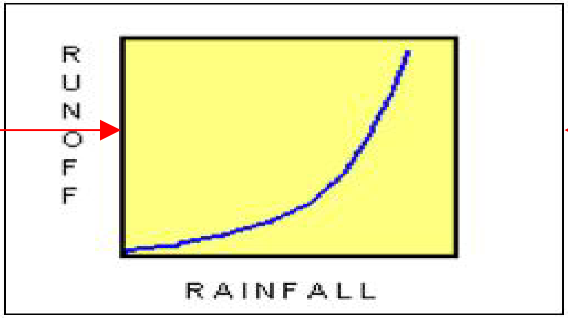
Threshold Runoff:

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

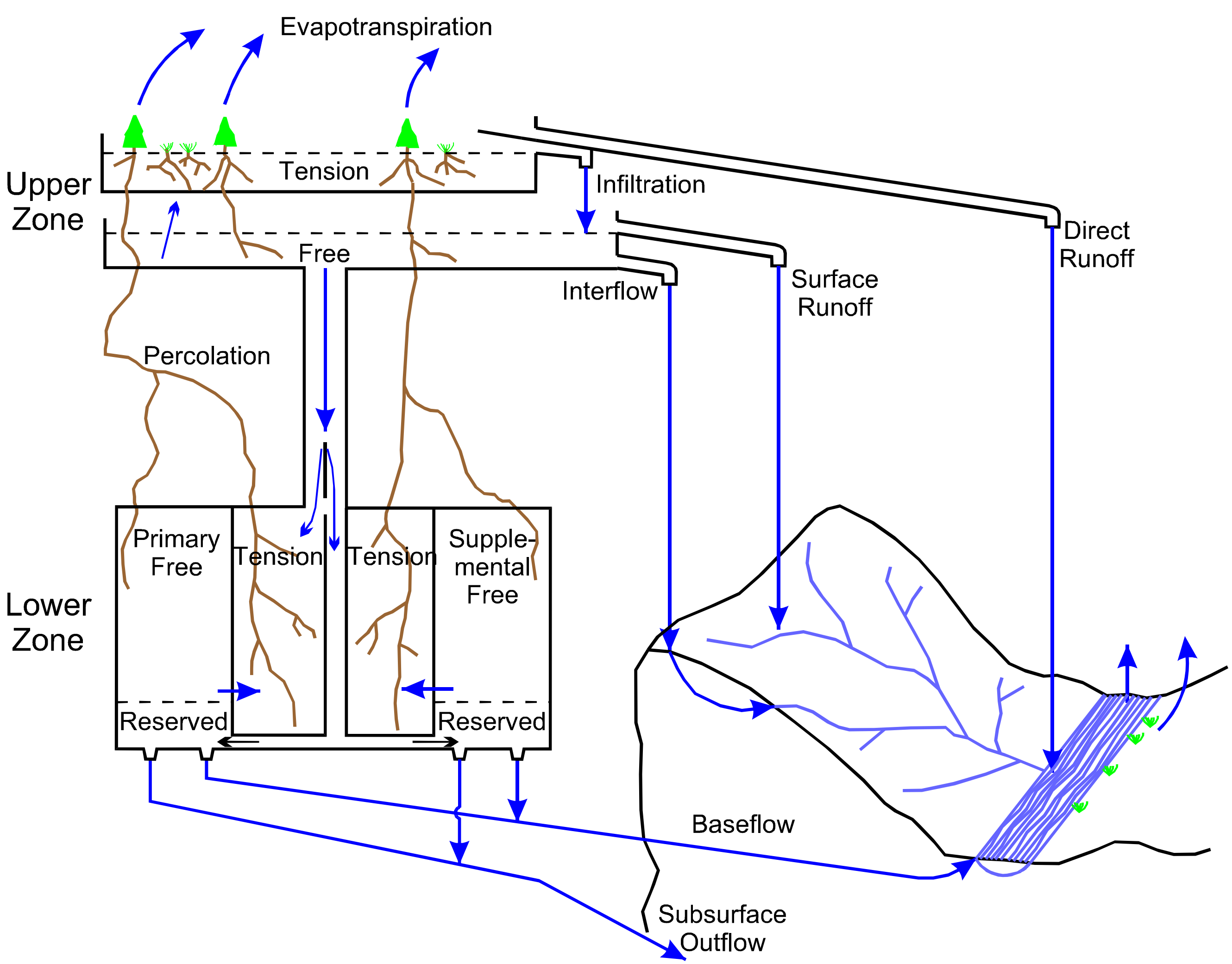
Snyder Unit Hydrograph Method

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

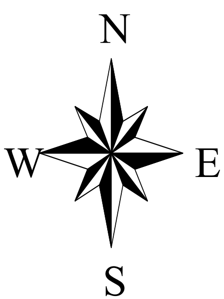
$$t_p = C_t (LL_c)^{0.3}$$

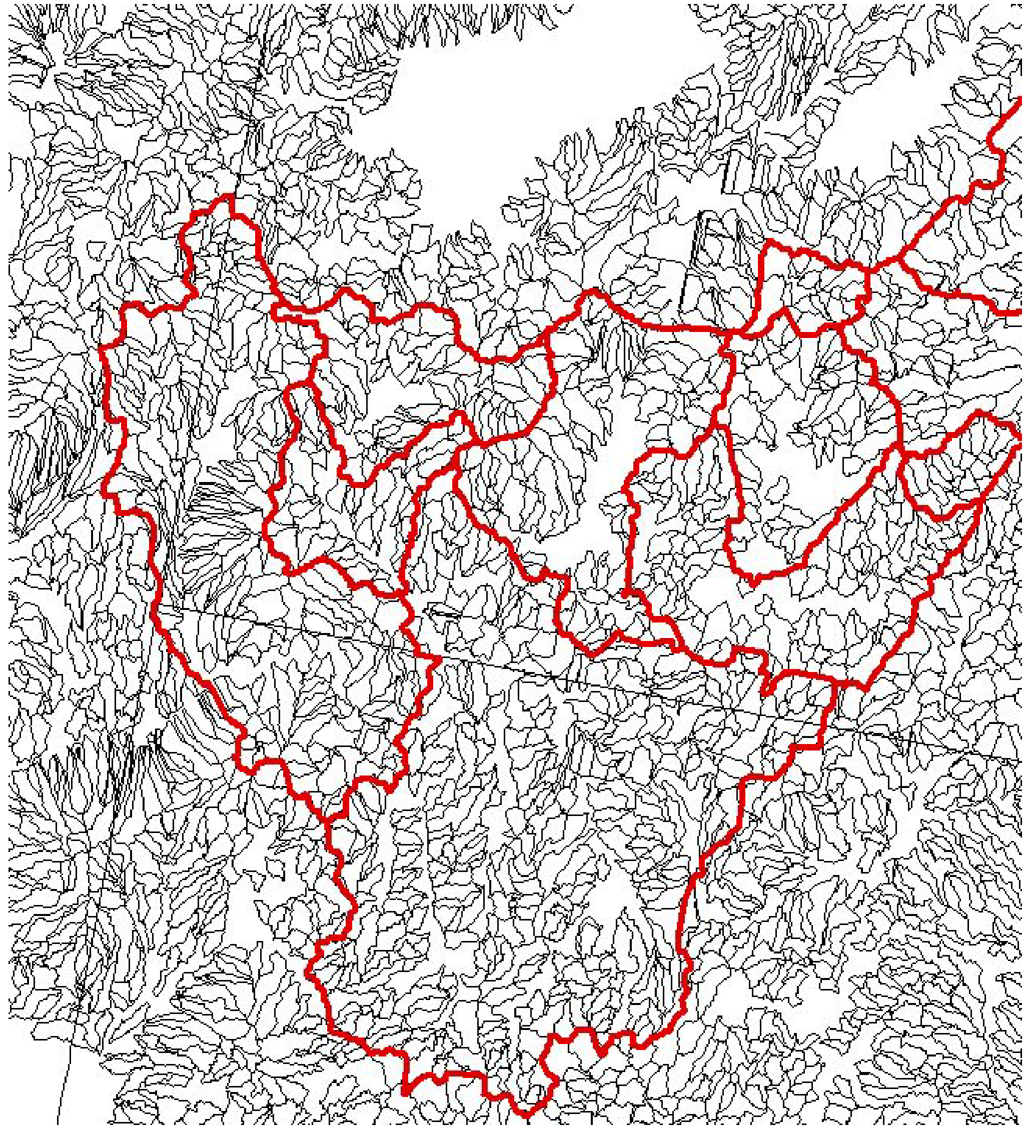
Primary Limitation

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

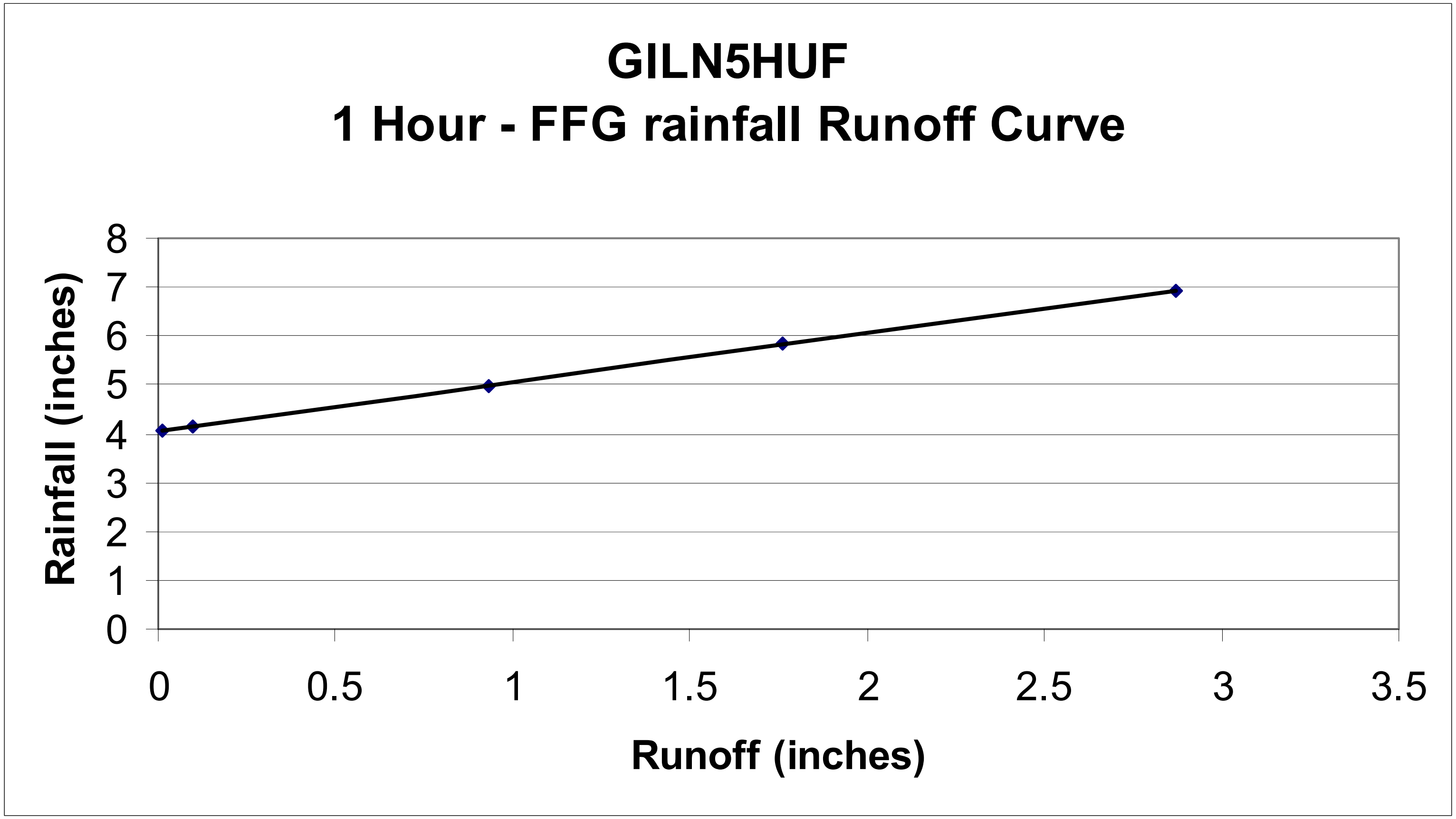
Precipitation catchment and intensity will be underrepresented due to the time scale and spatial scale of MAP areas that are much larger than individual convective cells.

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

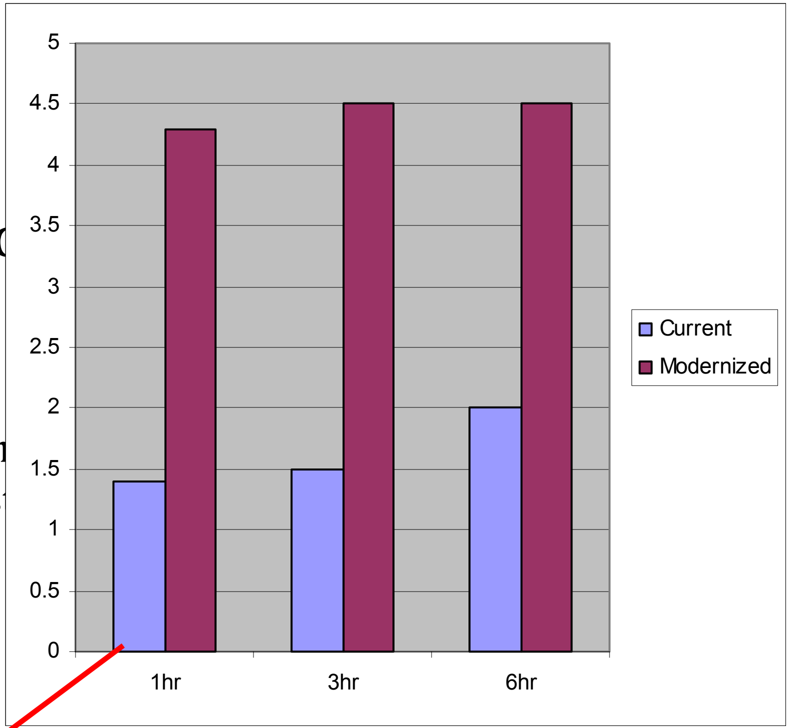
Threshold Runoff is set to zero

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.

.B SLR 20010522 Z DH12/DC200105220825



: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 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 this leave us ?

Current FFG Method

Empirical in nature – based on precipitation frequency studies

More emphasis on rainfall intensity as the driving force behind flash flooding

Dependent on unrealistic long term drought index for temporal variation

Not very robust - lacks spatial variation

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

CBRFC/Western Region
Flash Flood Analysis Project

Take a big step back – View from a flash flood potential 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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Flash Flood Analysis Project

Utilize GIS tools/methodology to carry out such an analysis

- **Acquire static raster datasets to describe:**
  - **Basin geography (slope and shape information)**
  - **Soil information & derived hydrologic properties**
    - **Pedotransfer functions required for certain soil datasets**
  - **Vegetation coverage information**
  - **Forest coverage/canopy information**
  - **Land use information, etc.**
- **Perform analysis on raster datasets using GIS map algebra**
  - **Assign FF potential indicators based on combined properties**

CB
Flash

Move from a stati

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

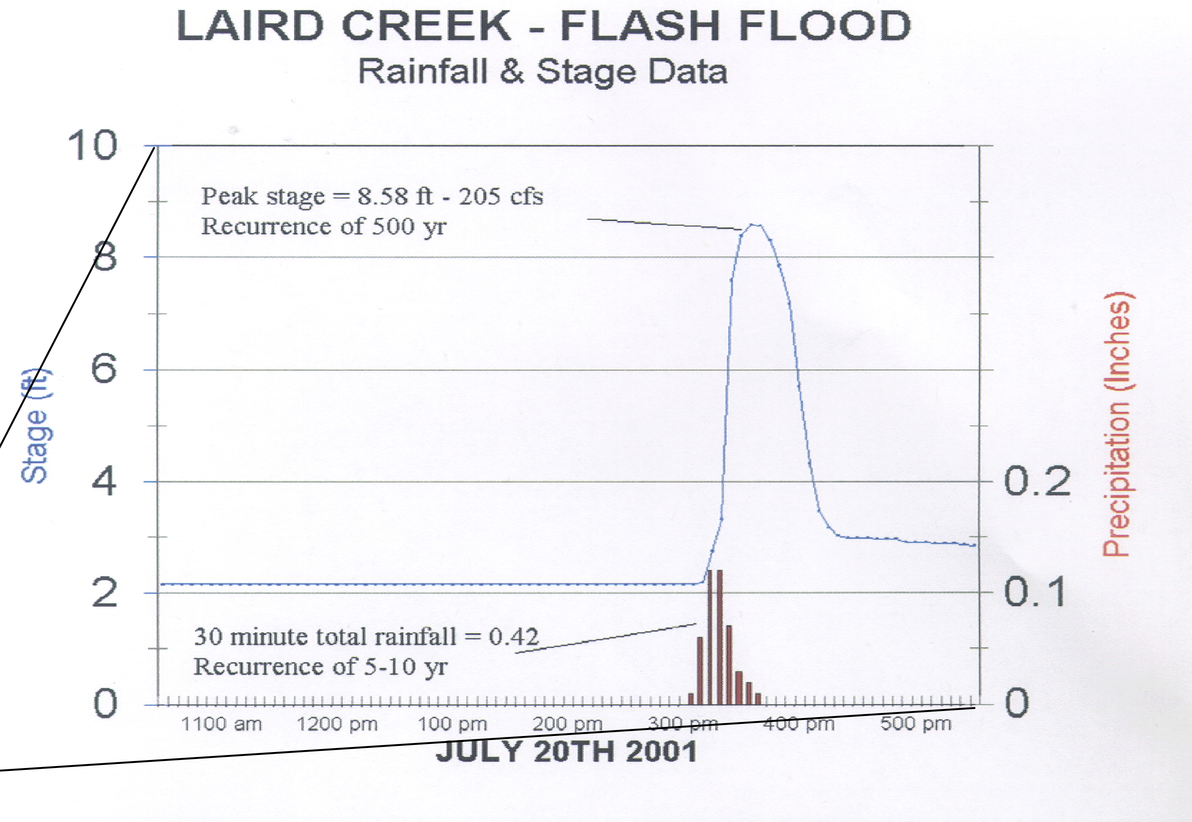

Figure 16. Rainfall, stage and discharge data from the July 20th storm at Laird Creek near Sula, Montana.

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

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Flash Flood Analysis Project

Verify results:

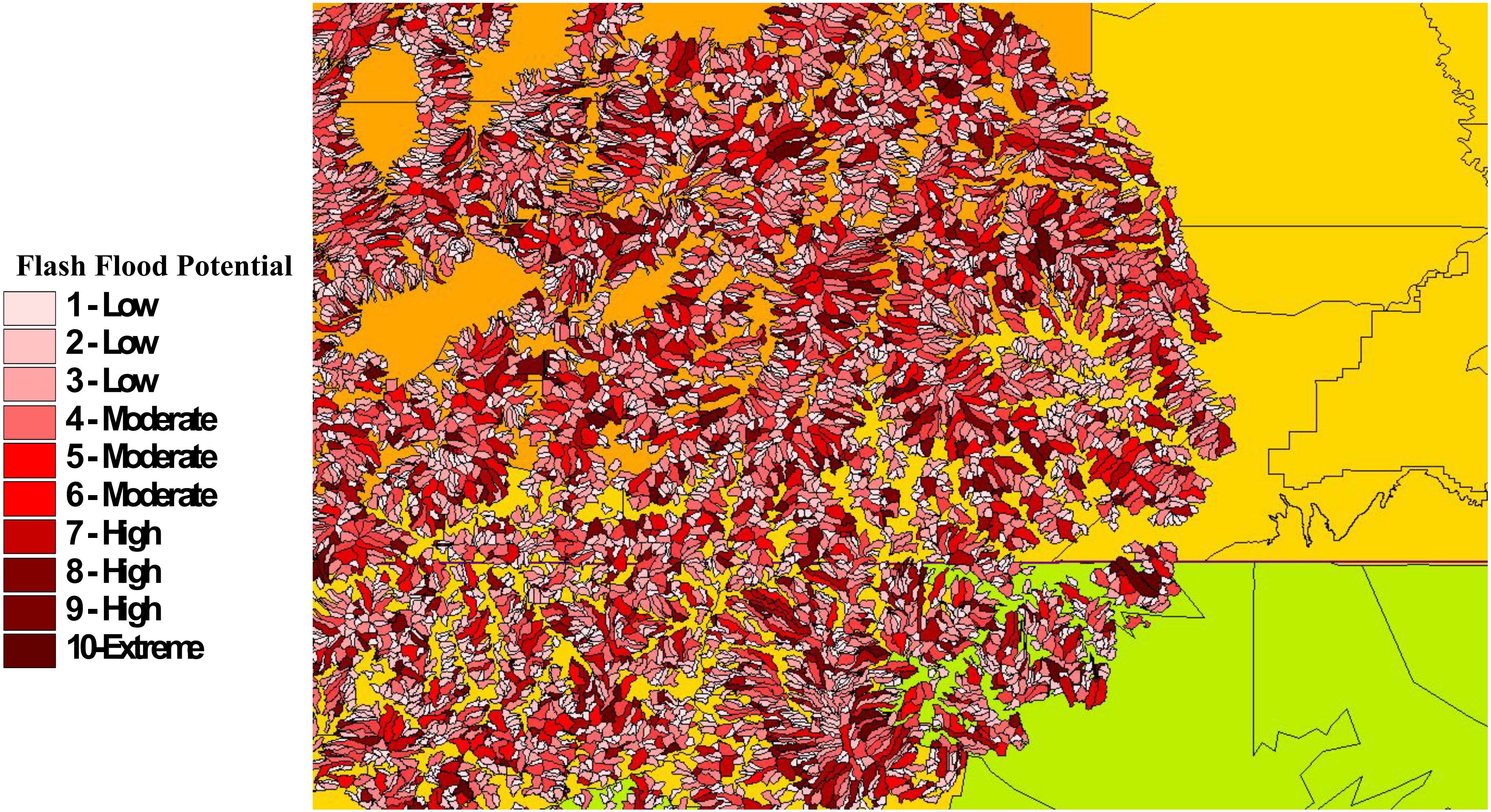
- **Based on documented flash flood events**
- **Based on local knowledge of flash flood prone areas**

Output – Thematic layer of relative flash flood potential

- **A data layer for spatial variation of FFG**
- **Add basin geometry component to FFG output weighting**
- **Gridded output if desired**
- **Interpolate to Amber basin layer if desired**

Amber Basin Flash Flood Potential

hypothetical example



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Flash Flood Analysis Project

Develop ability to generate FFG guidance values

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

... 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?

CBRFC/Western Region Flash Flood Analysis Project

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

CBRFC/Western Region Flash Flood Analysis Project

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**

CBRFC/Western Region Flash Flood Analysis Project

Example

- **A first shot analysis for the CBRFC area using readily available data**
  - **Four raster data layers used**
  - **Data resolution somewhat coarse**
  - **Equal weighting given to each data layer**
  - **Flash Flood Indicators assigned (1-10) – equal interval re-classification**
  - **Datasets re-sampled to consistent resolution**
  - **Datasets were all geo-registered prior to manipulation**
  - **Arc Info map algebra routines utilized to yield a mean FFI layer.**

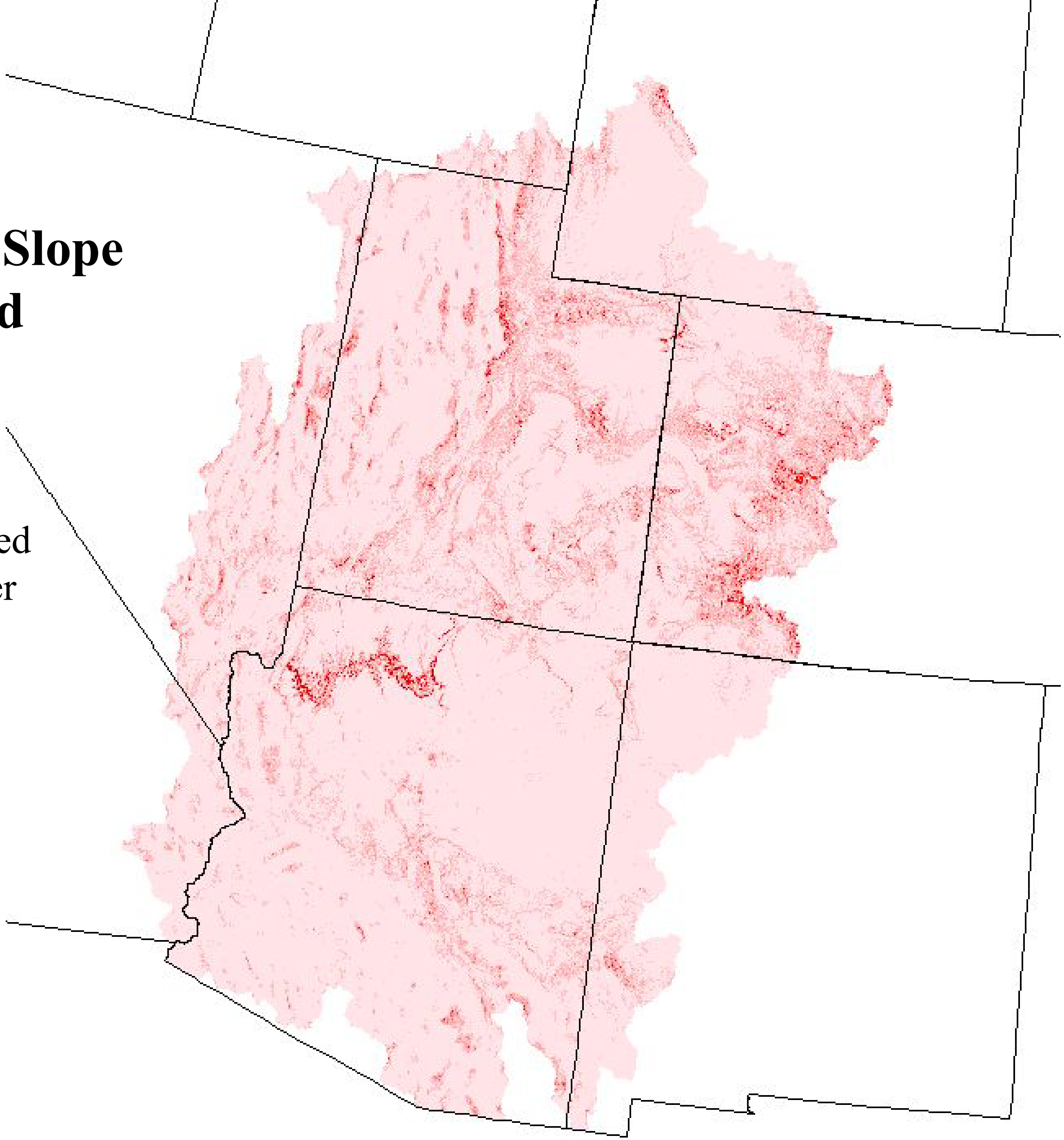
CBRFC/Western Region Flash Flood Analysis Project

Example

Datasets:

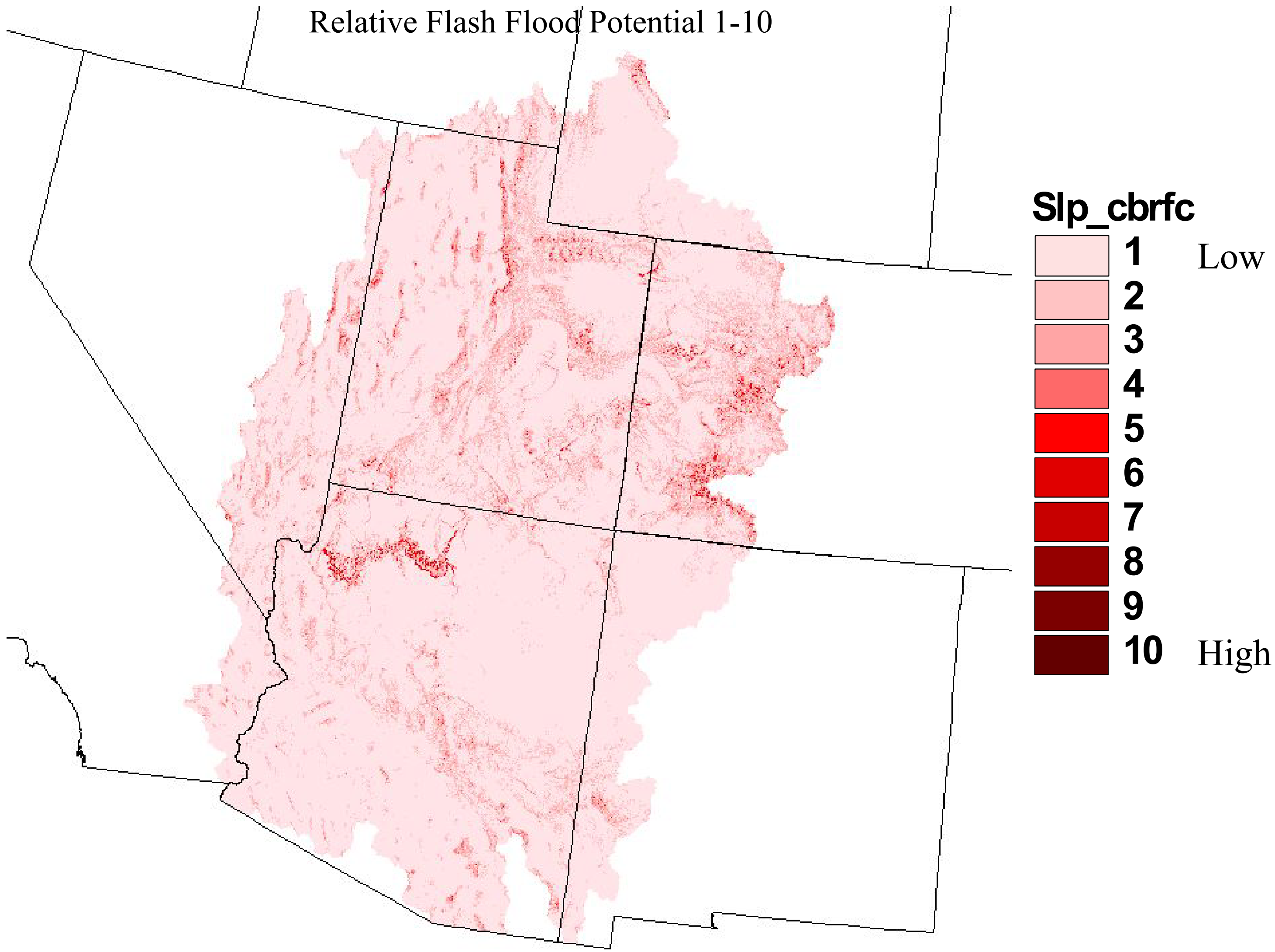
- **Percent slope grid derived from 90 m DEM**
  - **Re-sampled to 400 meter – Coarse !**
  - **Terrain – Steepness factor**

Percent Slope Grid



Re-sampled
400 meter
DEM

Reclassified Percent Slope Grid



CBRFC/Western Region Flash Flood Analysis Project

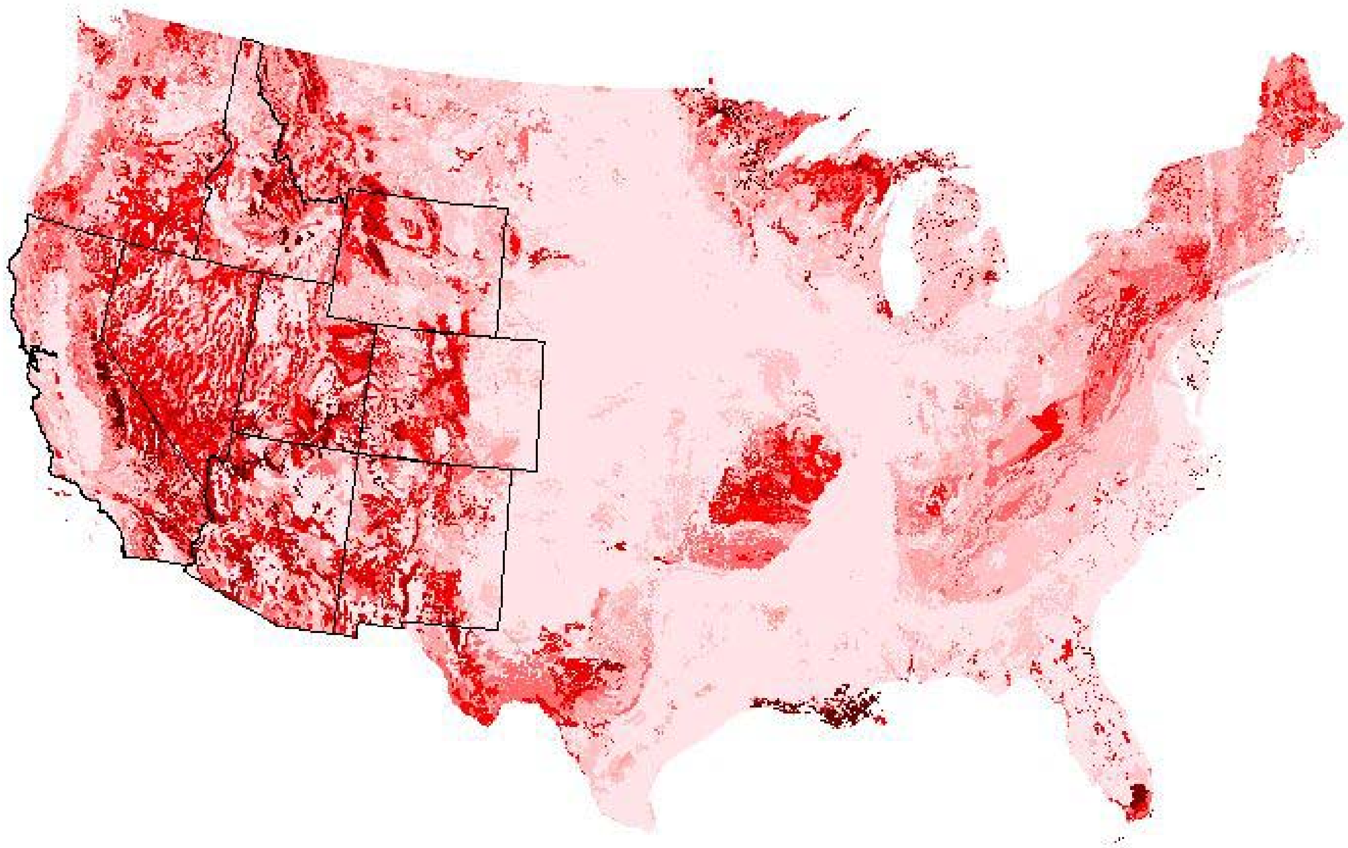
Example

Datasets:

- **Rock volume grid (STATSGO)**
  - Mean volumetric percent of rock in soil layer > 2mm
  - Infiltration of precip affected by amount of rock fragments
  - Data 1 km resolution re-sampled to 400 meter
  - Bilinear method used for re-sampling

Rock Volume Grid

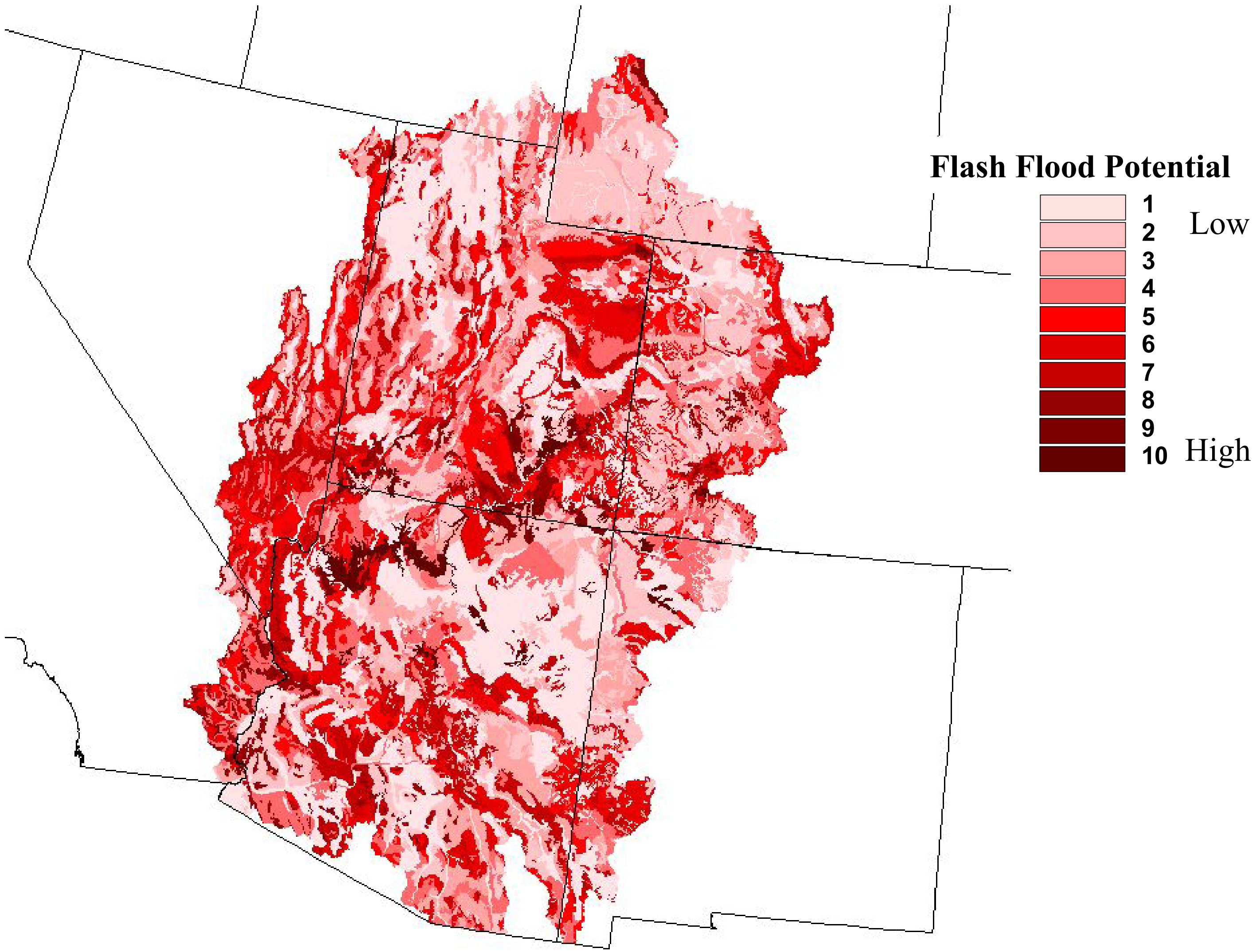
Rock fragments in the soil > 2mm



source: STATSGO

Reclassified Rock Volume Grid

Relative Flash Flood Potential 1-10



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Example

Datasets:

- **Fractional soil grid (STATSGO)**
  - Percent of sand, silt, and clay in the soil layer
  - Top STATSGO layer(s) used
  - Pedotransfer functions exist for this data type
  - Data 1 km resolution re-sampled to 400 meter
  - Bilinear method used for re-sampling

CBRFC/Western Region Flash Flood Analysis Project

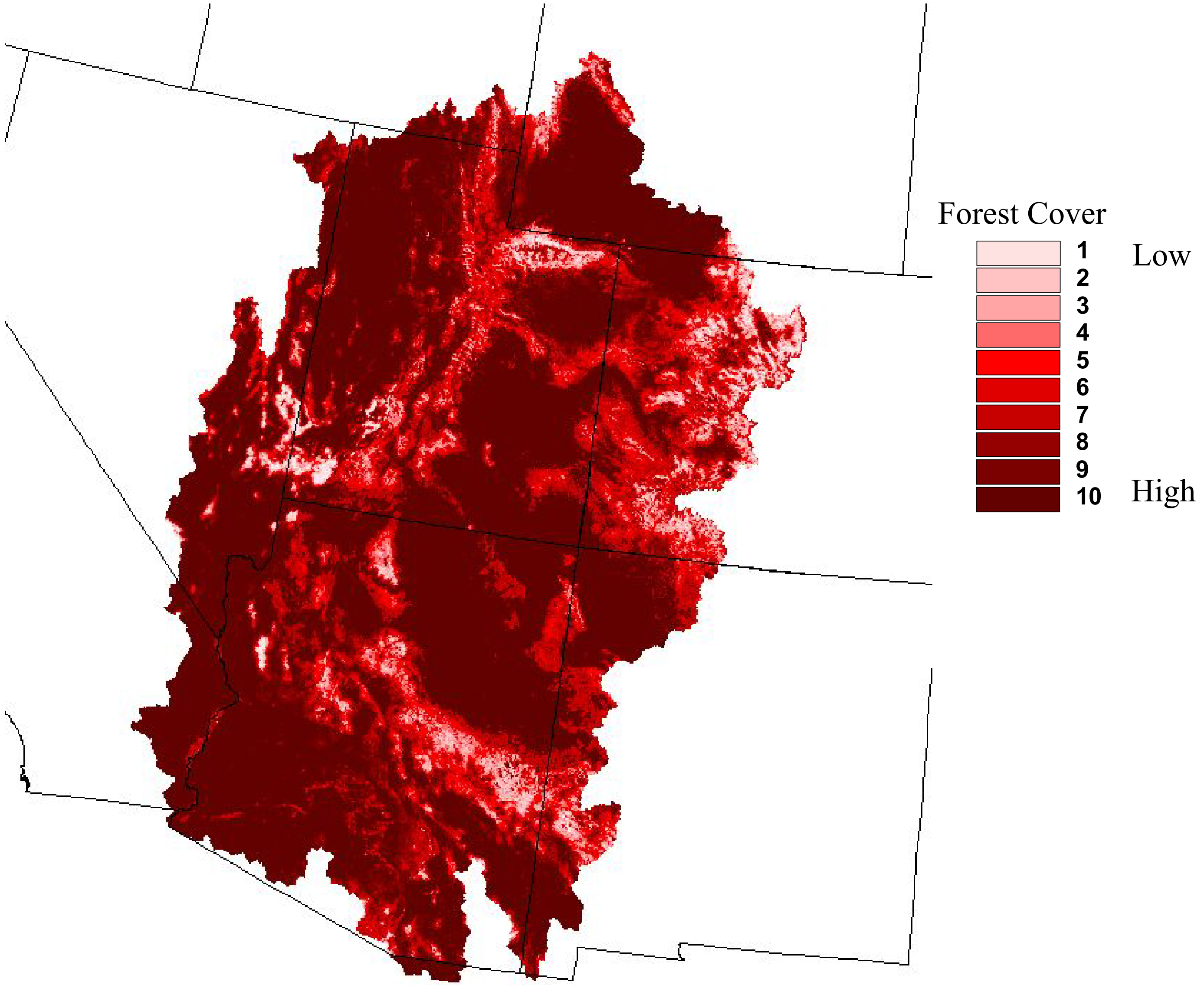
Example

Datasets:

- **Percent forest cover**
  - **- Remote sensed data – NOAA AVHRR**
  - **- Data ~ 1 km resolution re-sampled to 400 meter**
  - **- Bilinear method used for re-sampling**

Percent Forest Cover

Reclassified Percent Forest Cover

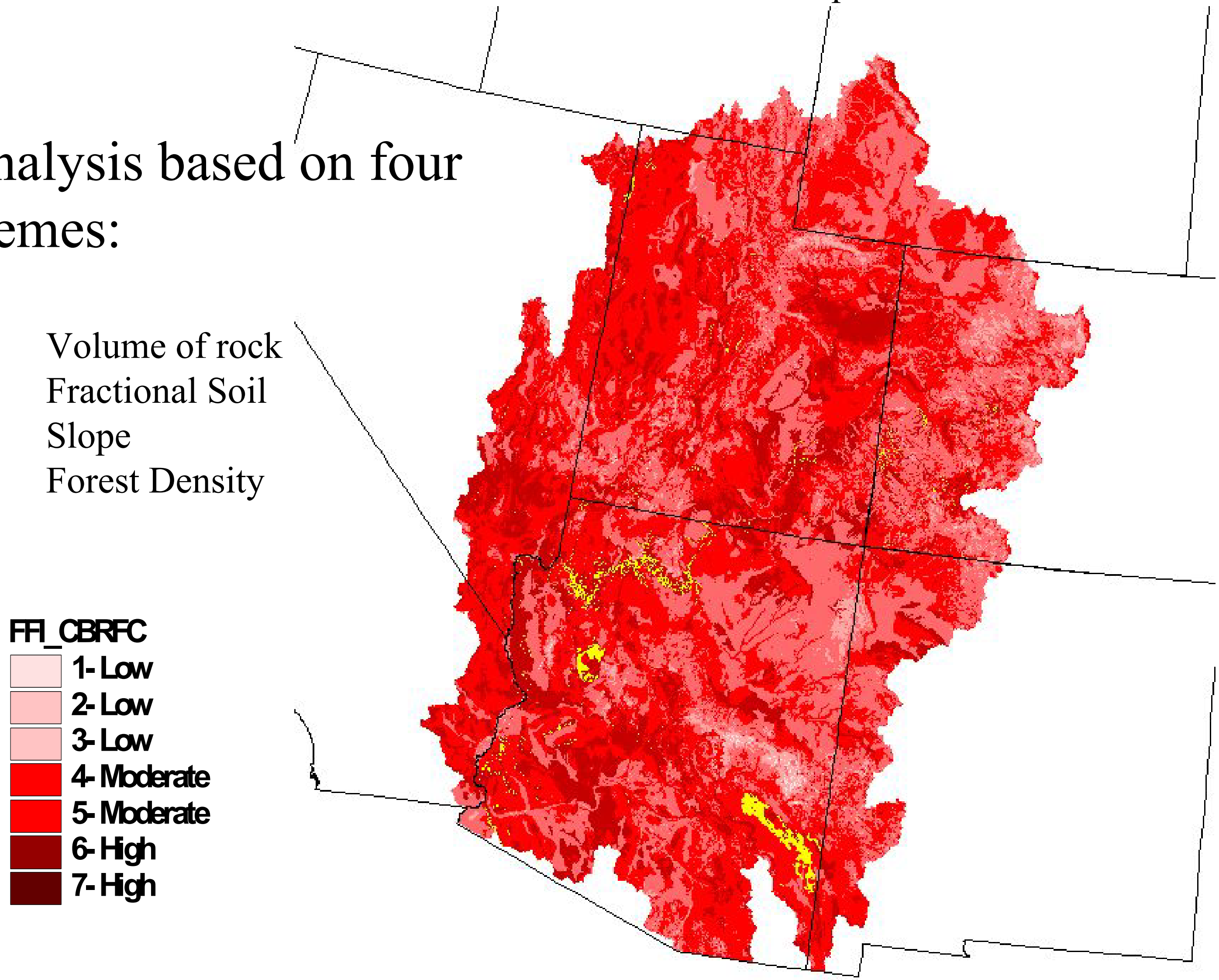


Flash Flood Indicators

static relative flash flood potential

Analysis based on four themes:

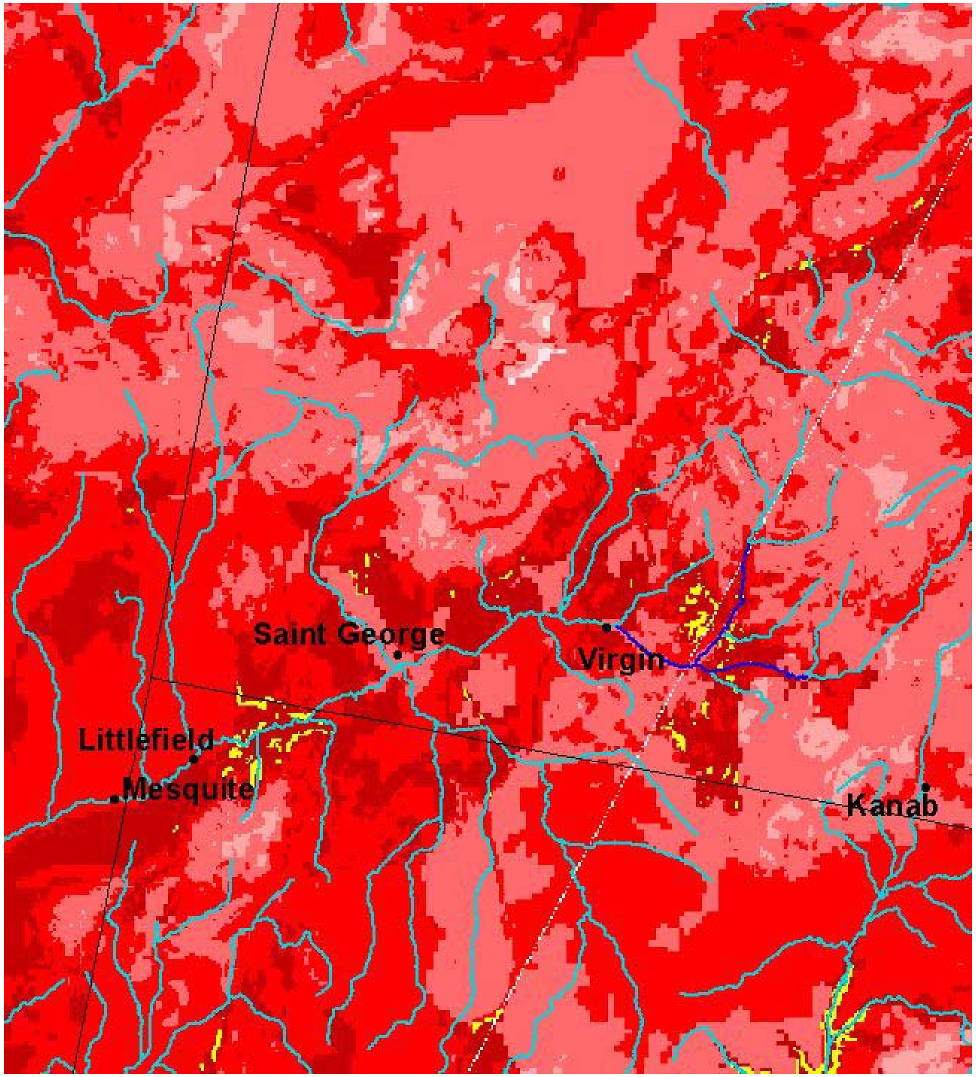
Volume of rock
Fractional Soil
Slope
Forest Density



Flash Flood Indicators

static relative flash flood potential

North and East Fork
Virgin River

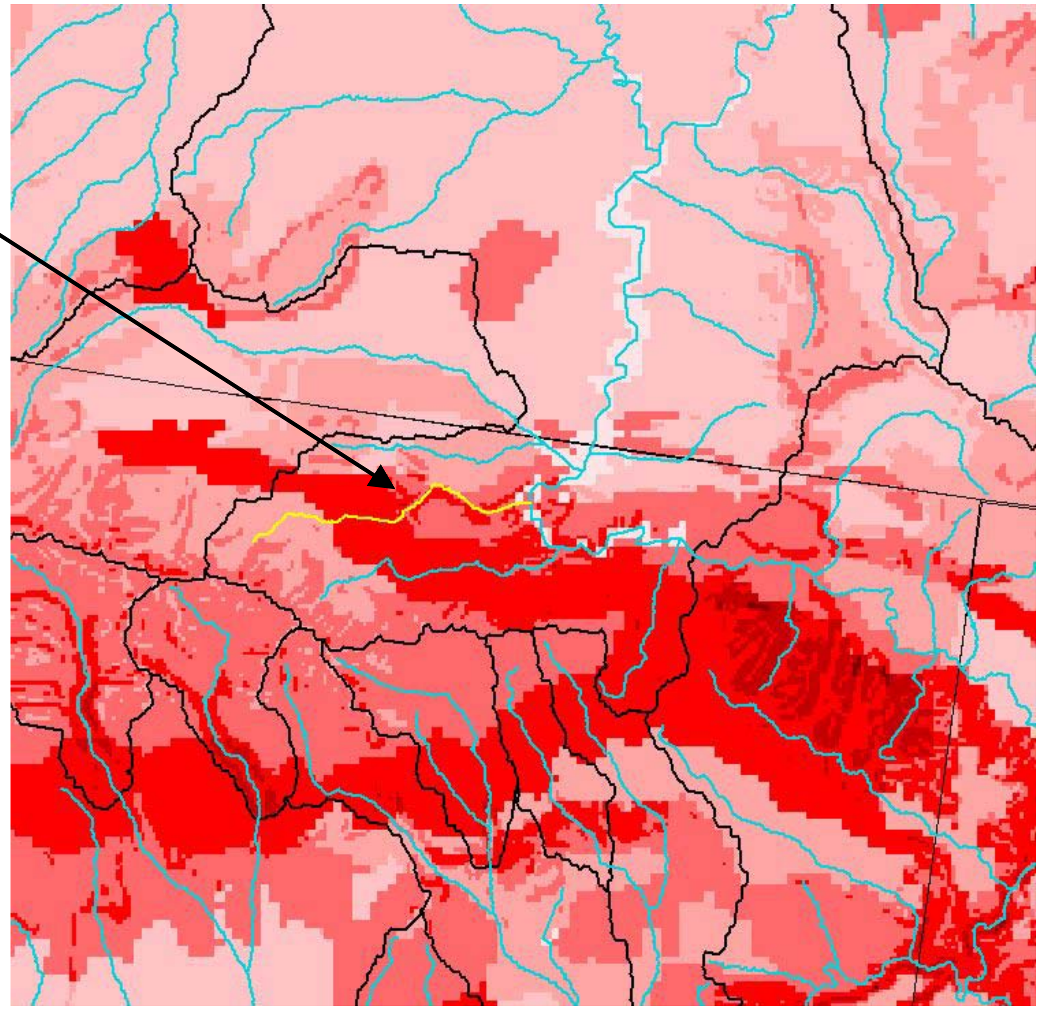


FFI_CBRFC
- 1- Low
- 2- Low
- 3- Low
- 4- Moderate
- 5- Moderate
- 6- High
- 7- High

Flash Flood Indicators

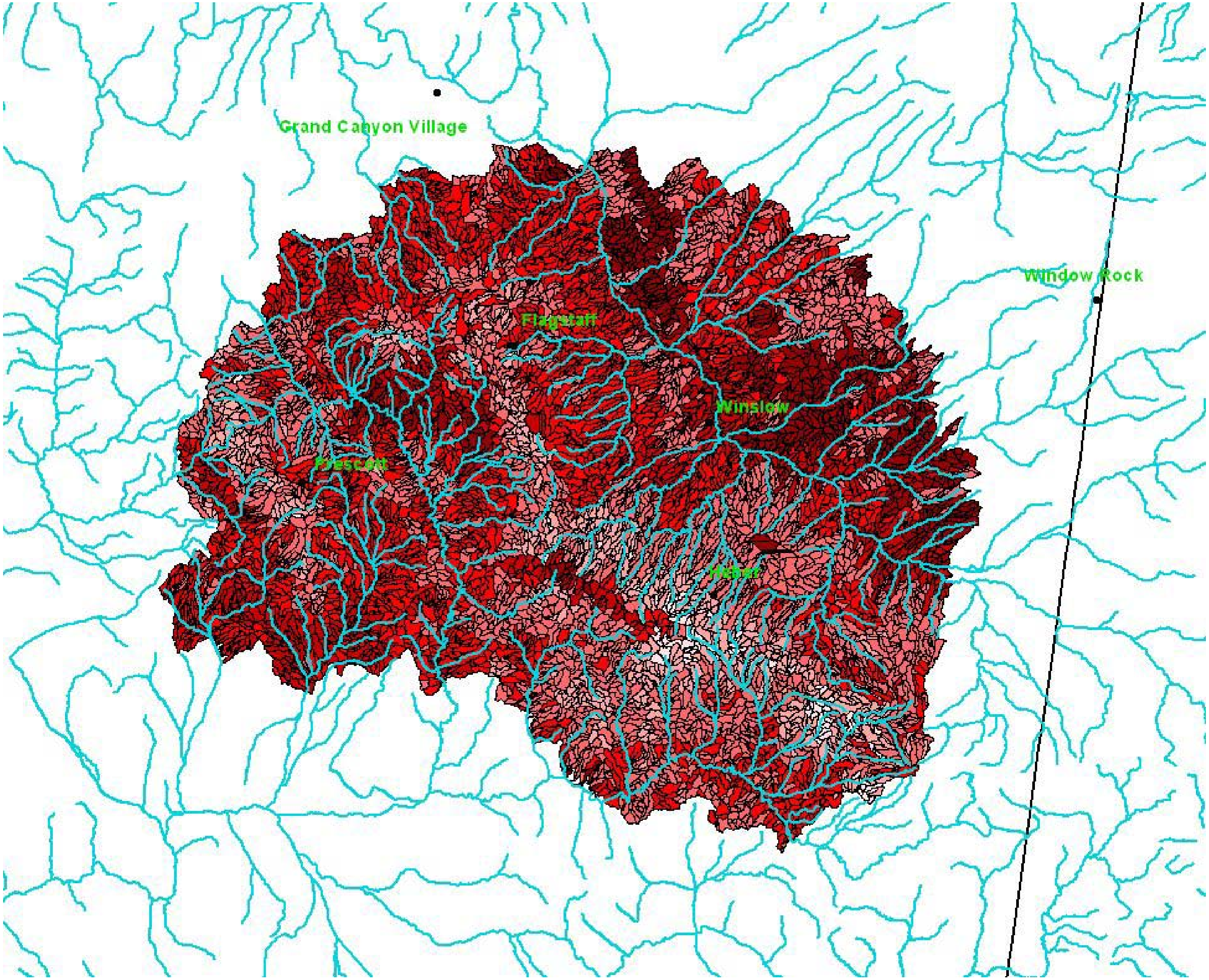
static relative flash flood potential

Sheep Creek Canyon



Flash Flood Indicators

- 1 - Low
- 2 - Low
- 3 - Low
- 4 - Moderate
- 5 - Moderate
- 6 - Moderate
- 7 - High
- 8 - High
- 9 - High
- 10-Extreme



Grand Canyon Village
Window Rock
Flagstaff
Winslow
Prescott
Heber

CBRFC/Western Region Flash Flood Analysis Project

Example

Can we draw any conclusions ?

- **Only visual analysis at this point in time**
  - **Comparison with known/expected flash flood areas**
  - **Some positives but inconclusive**
- **Need for data layers of observed/documented events**
  - **Starting point for guidance values**
- **Determine valid datasets for use**
- **Determine weighting schemes for data layers**

CBRFC/Western Region Flash Flood Analysis Project

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**

It is imperative observed information be collected if this program is to improve

CBRFC/Western Region Flash Flood Analysis Project

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.

CBRFC/Western Region Flash Flood Analysis Project

Where Next?

- **Continue with analysis – More rigorous**
  - Utilize observed event information
  - Seek out and test additional datasets
  - Re-visit assumptions regarding hydrologic relationships of datasets
  - Create a layer of flash flood potential for interested WFO
- **Finer resolution DEM**
  - Identify a sub area for more in depth analysis
  - Utilize finer resolution DEM and other data if available

Team Members

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Melissa Goering (WFO Tucson)