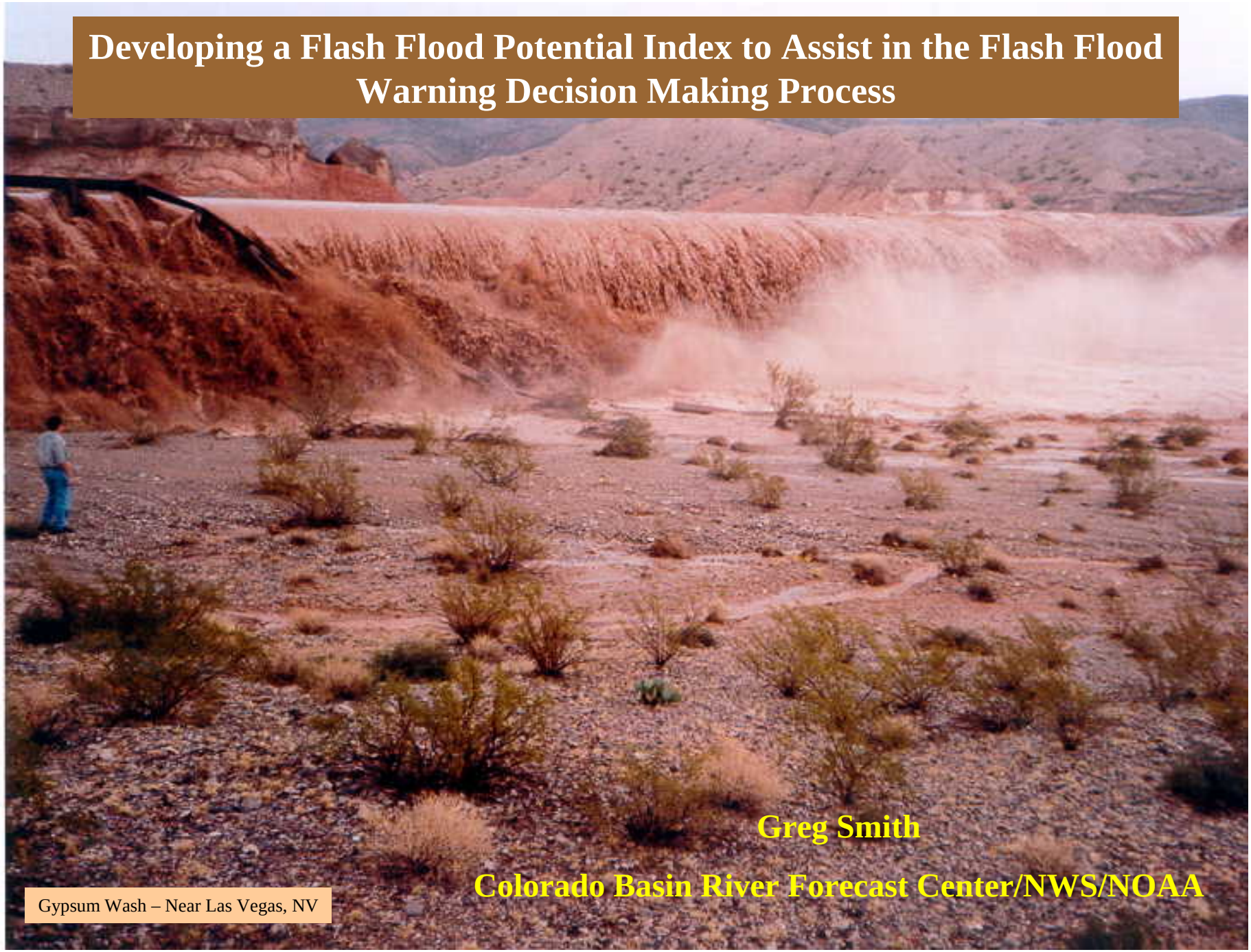
Developing a Flash Flood Potential Index to Assist in the Flash Flood Warning Decision Making Process

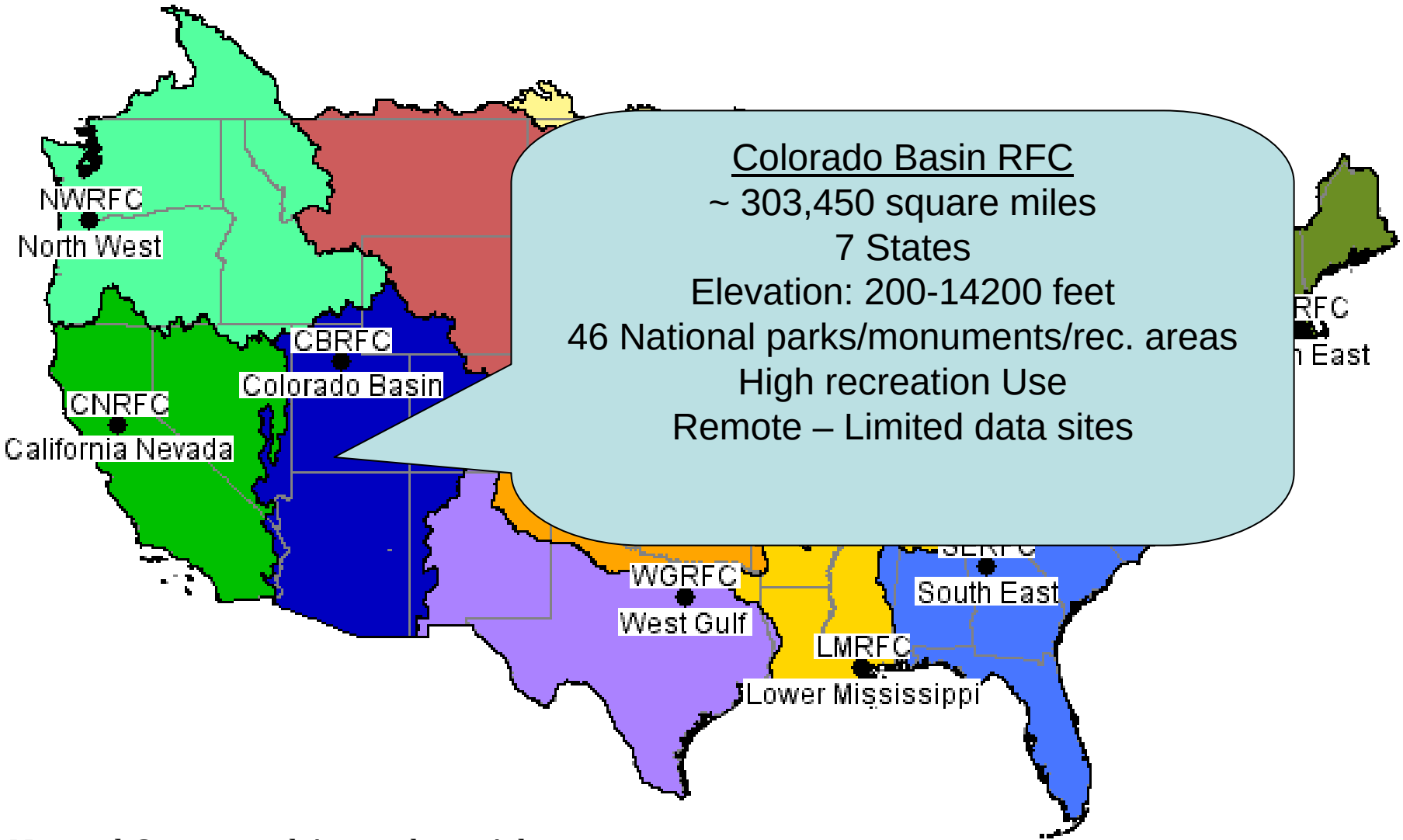


Greg Smith

Colorado Basin River Forecast Center/NWS/NOAA

Gypsum Wash – Near Las Vegas, NV

National Weather Service
River Forecast Centers



Colorado Basin RFC
~ 303,450 square miles
7 States
Elevation: 200-14200 feet
46 National parks/monuments/rec. areas
High recreation Use
Remote – Limited data sites

Lets Go On A Hike!

AT A GLANCE

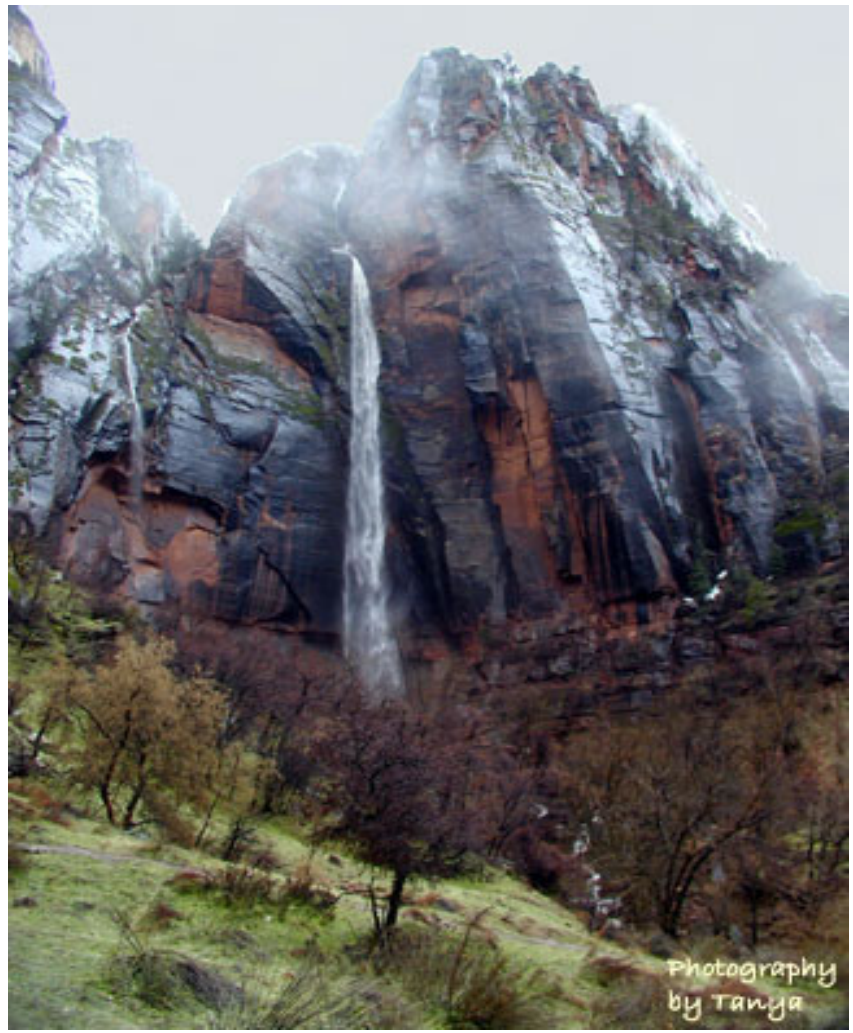
- **canyon walk in knee-deep water**
- **real risk of flash floods**
- **5 days, 4 nights**
- 37.5mi (60.4km) plus side-trips
- best months Oct & late Apr-May
- worst month is Aug
- medium-hard hiking with the odd severe section, depending on conditions
- no public transportation to trailheads

Paria may be the longest and most flash-flood prone canyon in the world.

Photos: southern Utah wilderness alliance

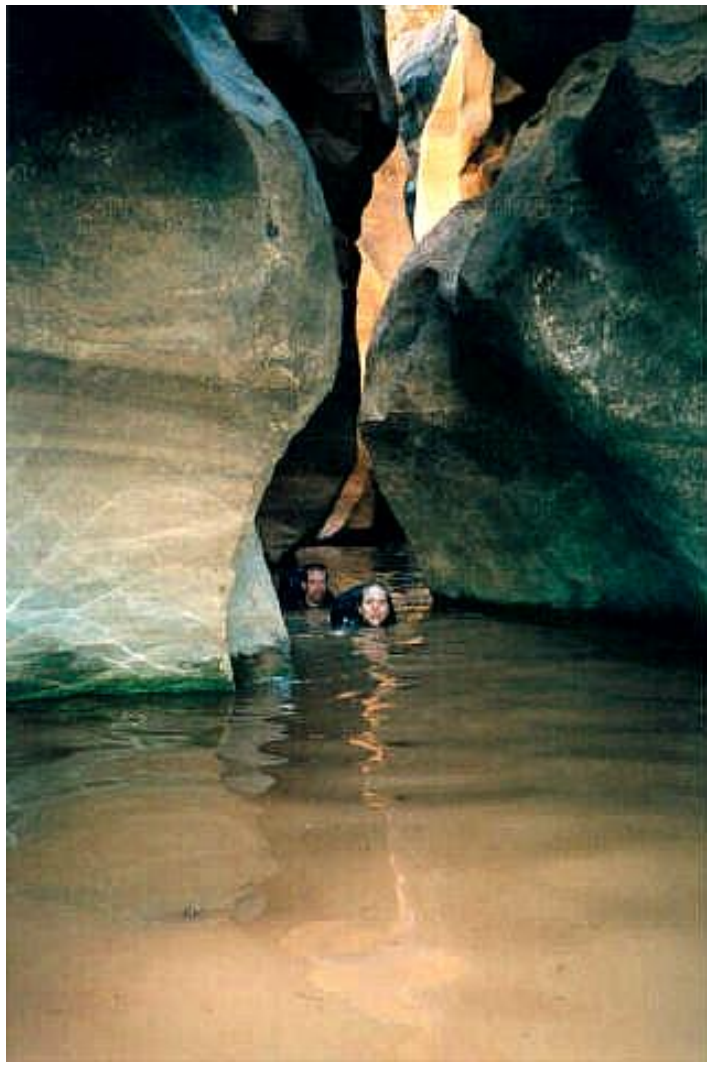
CBRFC Flash Flood Factors: *Variety of soils/terrain conditions - Impervious (slickrock)*

Effect: *Reduce/negate soil moisture, emphasis rainfall intensity/rate*



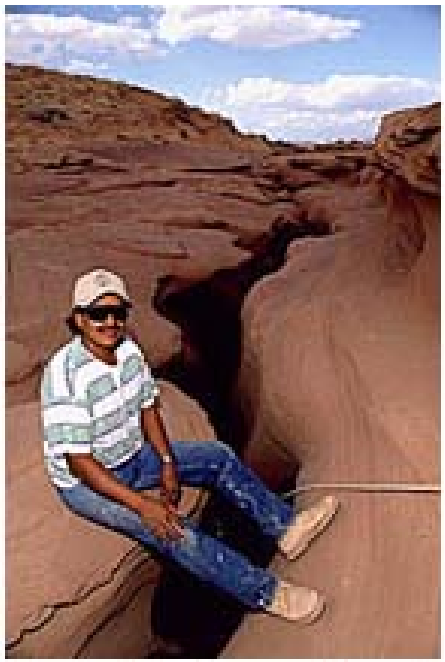
CBRFC Flash Flood Factors: *Channels duplicate as trails / Recreation*

Effect: *Difficult to establish a threshold or critical flow level – rapid response critical*



CBRFC Flash Flood Factors: *Slot canyons & small drainages*

Effect: *Timing of rainfall, threshold levels, isolated/airmass storms*



Ernie Lister, a Navajo Guide at the entrance to Lower Antelope Canyon.

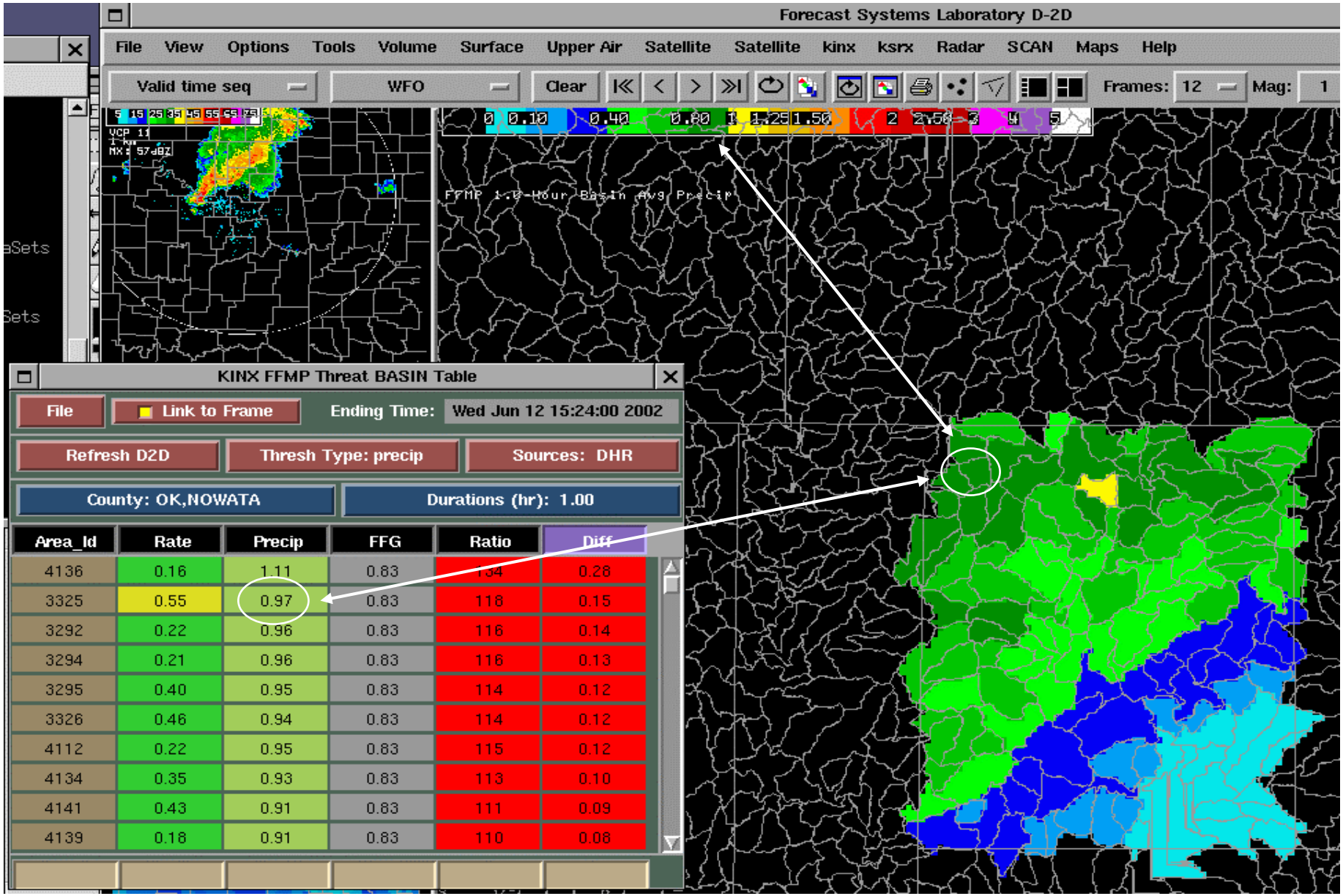
Field Operations:

Flash Flood Monitoring and Prediction (FFMP)

- **FFMP Utilizes the NWS WR 88D Radar:**
  - **Continuously monitor rainfall rate/accumulation.**
  - **Calculates rainfall accumulation over pre-defined drainage basins.**
  - **Compares rainfall accumulation to flash flood guidance.**

Field Operations:

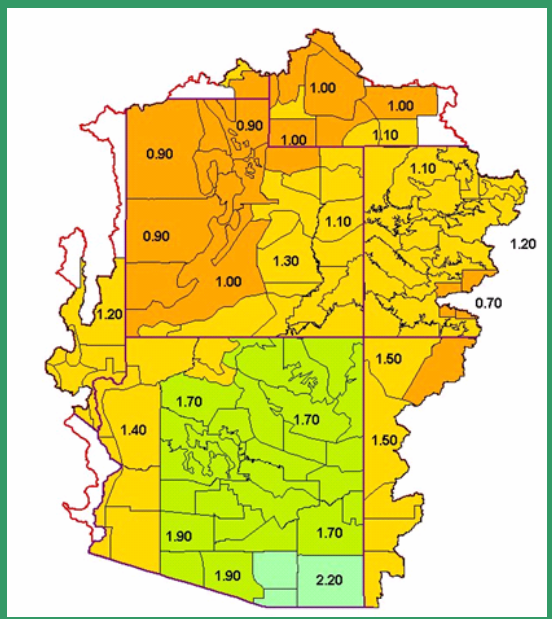
FFMP Basin Average Precipitation



Field Operations:

Flash Flood Guidance a critical input to FFMP

Local RFC Methods



Local WFO Methods

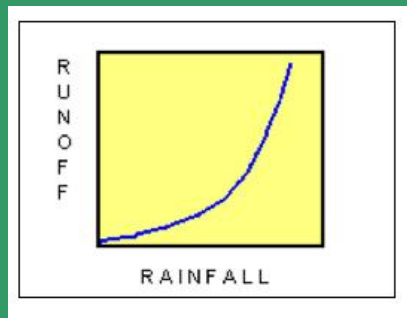
WFO Rules of Thumb:

- **Empirically derived**
- **> .75” or more in 1 hr or less**

Simple Met driven FF Index:

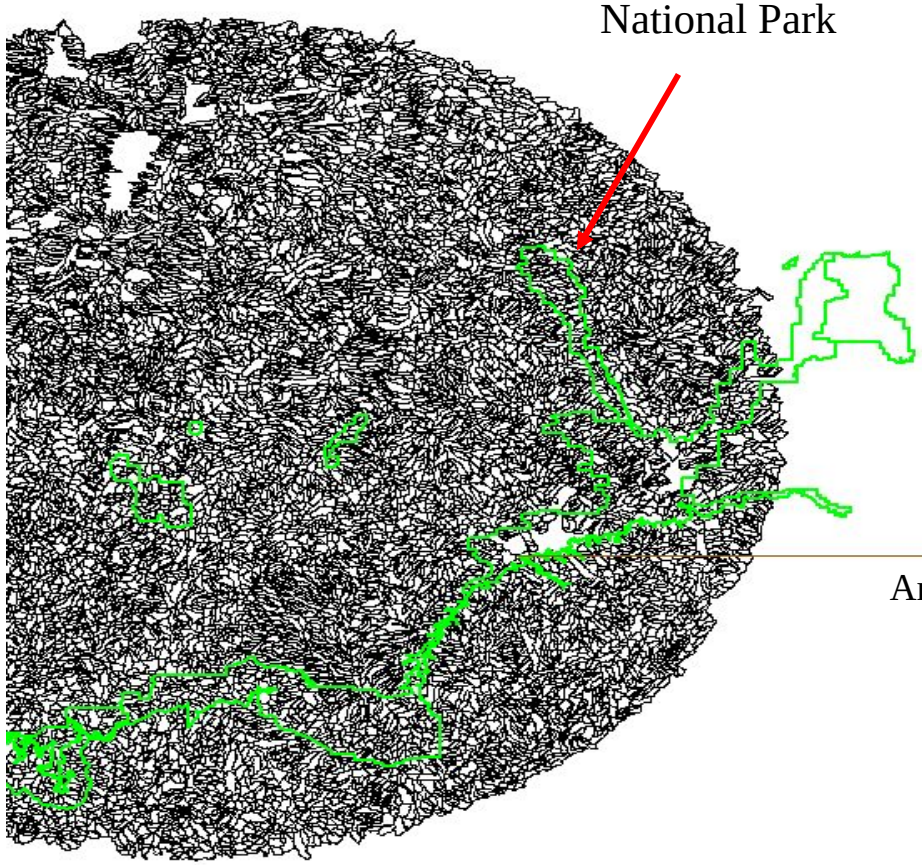
- **500 MB wind Speed**
- **Atmospheric cap**
- **Atmospheric trigger**
- **Precipitable Water**

National : model generated



- **Soil moisture (SAC-SMA)**
- **Complete model coverage (scale issues)**
- **Rainfall intensity**
- **Critical threshold**

FFMP Basins for Cedar City Utah Radar (KICX)



FFG is similar for all basins

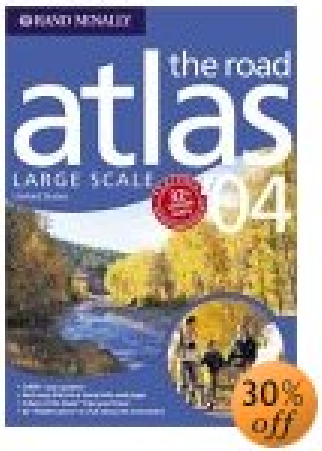
Rules of thumb the same for all basins

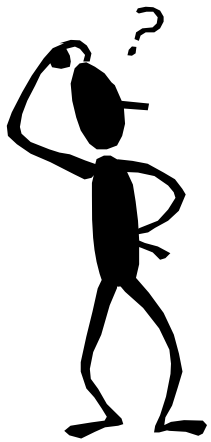
Utah | Colorado

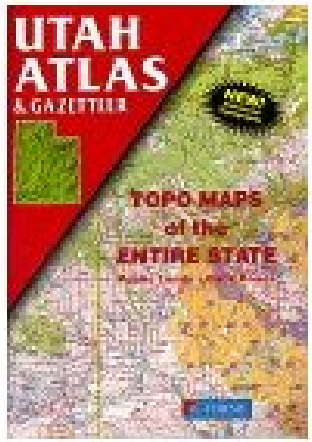
Arizona | New Mexico

Accumulating Knowledge About A River Basin

Evaluating The Flash Flood Threat







Difficult & Time Consuming During Active Weather

Hundreds or Thousands of Basins Under One Radar Umbrella !!

- The Motivation -

Arrival of FFMP emphasized need for improved & finer resolution FF info

Limitations of Legacy and Modernized FFG methods required alternate approach

Legacy method/rules of thumb - Lacks spatial resolution for new applications

=> Basins with different physical features have a similar hydrologic response

Modernized methods – challenge due to:

=> Scale issues – model coverage issues – soil moisture – bankfull definitions

Local office request for additional FF information and better guidance

Flash Flood Potential Index Concept:

Create a simple theoretical index that accounts for those physical features of the land that influence the hydrologic response to intense rainfall.

Drainage basins would be ranked (ordinal scale) with higher index values indicative of a greater hydrologic response to heavy rainfall or greater flash flood potential/threat.

Utilize this information to:

- Identify flash flood prone areas (briefing tool)
- supplement FFMP (using the same basins as FFMP) – classify basins
- Use with areal or rule of thumb FFG to better qualify basins response
- Incorporate into alternative method for generating FFG

Physical features may include:

Hydrologic Response To Heavy Rainfall

- Wildfire Effects -

Flow Magnitude

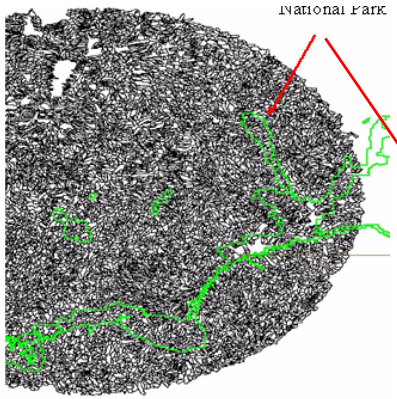
Less ⟷ **More**

Slower ⟷ **Rapid**

Flow Response Time

Flash Flood Potential

Lower ⟷ **Greater**

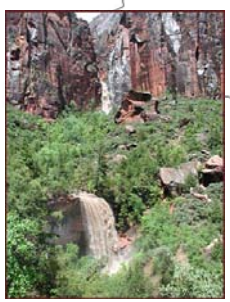


Land Use ?

Soil type ?

Vegetation type and density ?

Fire activity ?



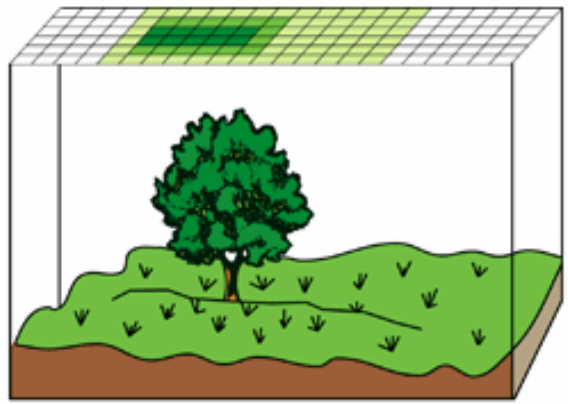
Slopes?

Try to qualify the flash flood threat

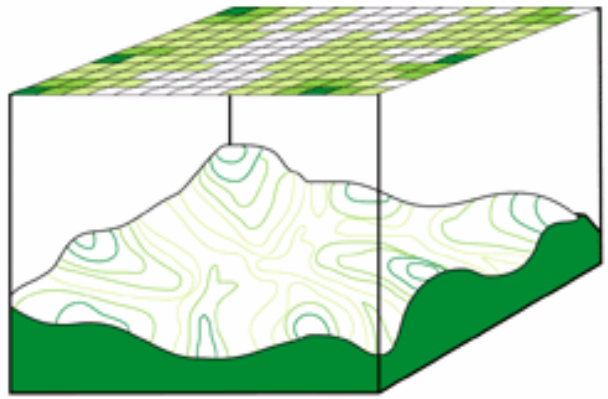
FFPI Method:

Obtain raster (gridded) datasets representing the features of interest

Forest Density

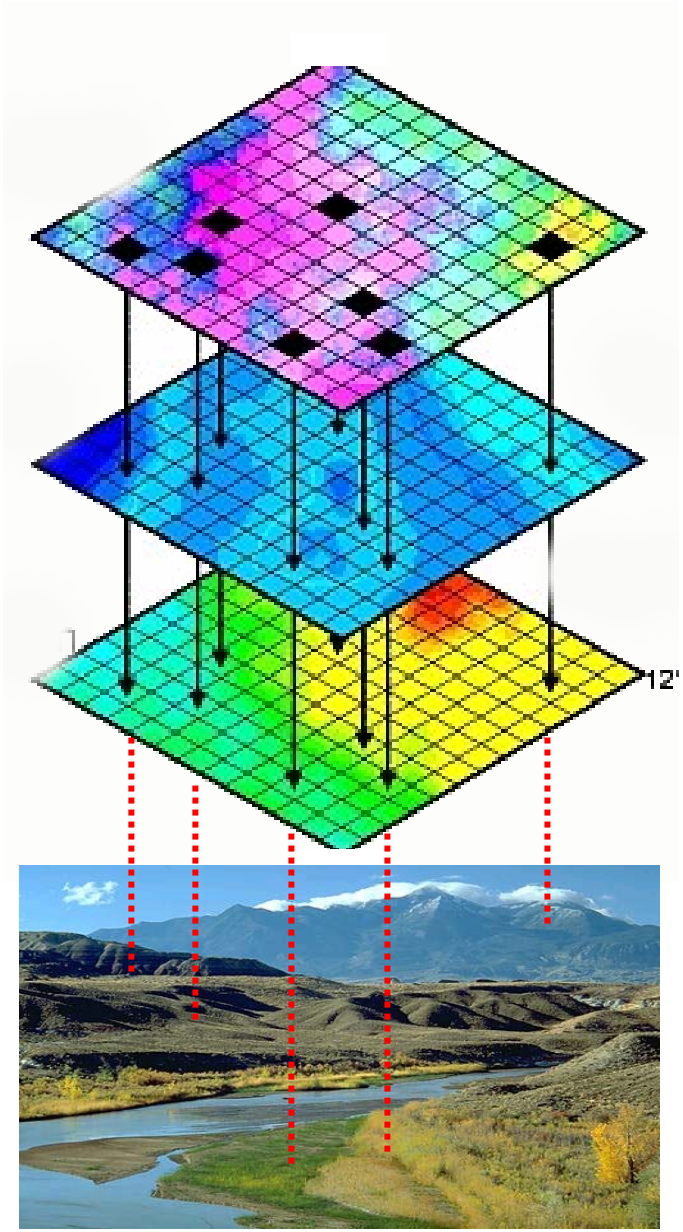


Elevation/Slope



FFPI Method:

Utilizing a Geographic Information System (GIS)



- Soil type
- Forest density/cover
- Slope
- Land use/urbanization

Resample and Georegister Data

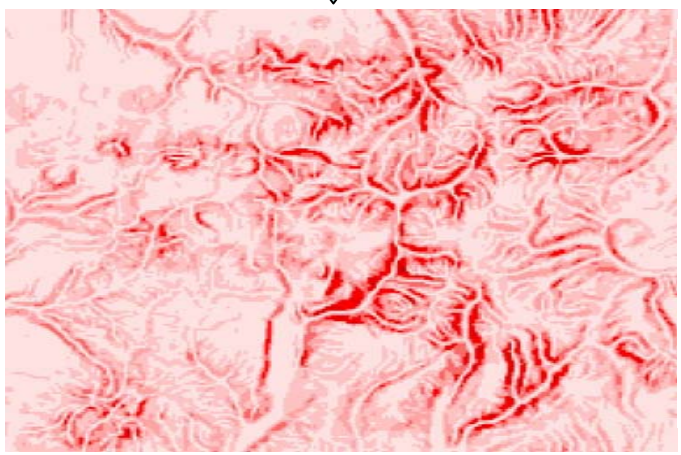
Consistent resolution

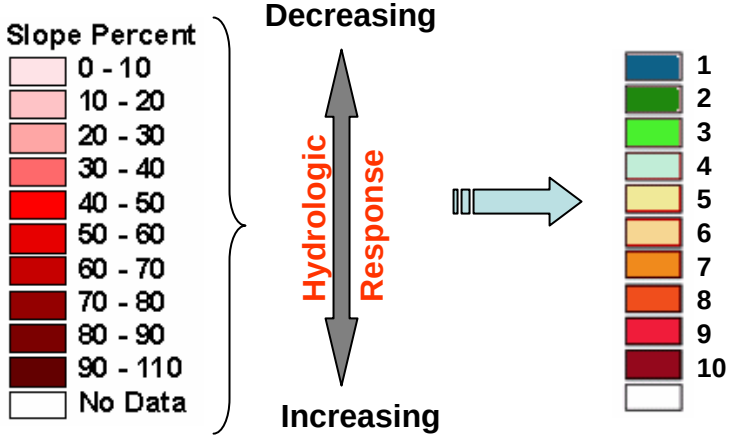
Same projection/datum

Overlapping grid cells representing same location on the surface of the Earth

FFPI Method: Re-classifying datasets

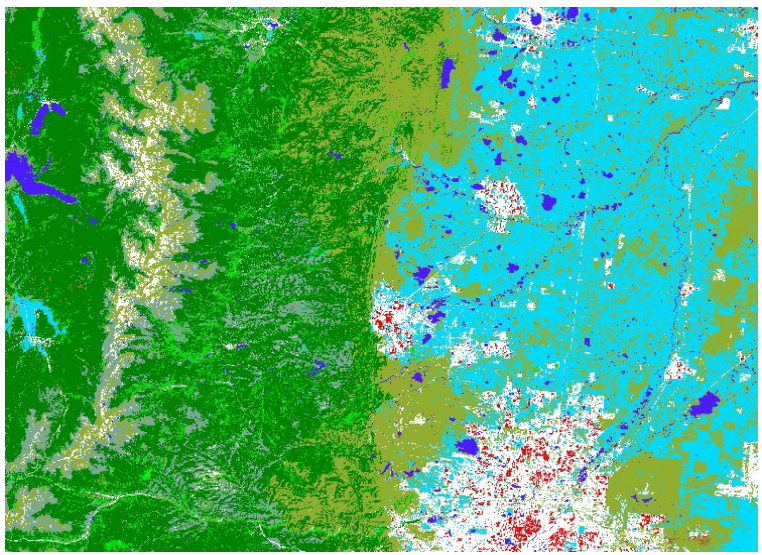
7	10	10	9	7	8	8
9	9	9	7	7	9	7
9	8	8	7	7	6	6
6	5	6	6	4	5	3
2	3	5	6	4	4	4
2	3	5	2	2	2	4
2	2	3	2	2	2	3





switched scale types

FFPI Method: Re-classifying datasets



Categorical: Land Use

High Intensity Residential

Commercial/Industrial/Transportation

Bare Rock

Low Intensity Residential

Quarries-Strip Mines-Gravel Pits

Shrubland

Row Crops

Orchards/Vineyards

Deciduous Forest

Evergreen Forest

Mixed Forest

Grassland

Pasture-Hay

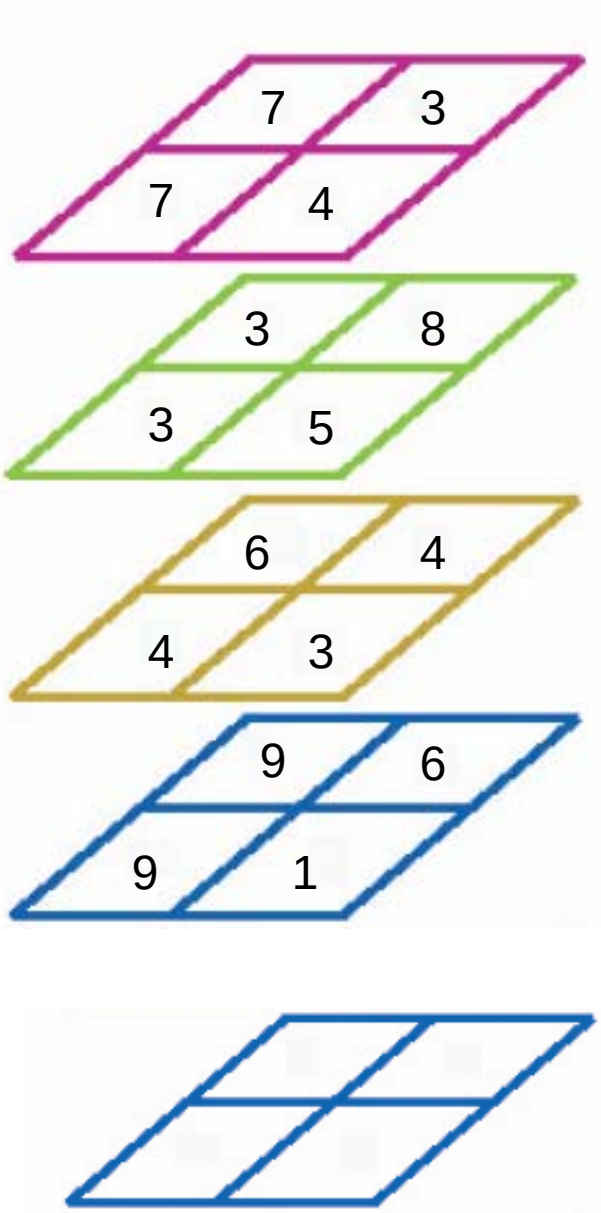
Woody Wetlands

Perennial ice - snow

Open Water

Rank

FFPI Method: Create a single FFPI layer



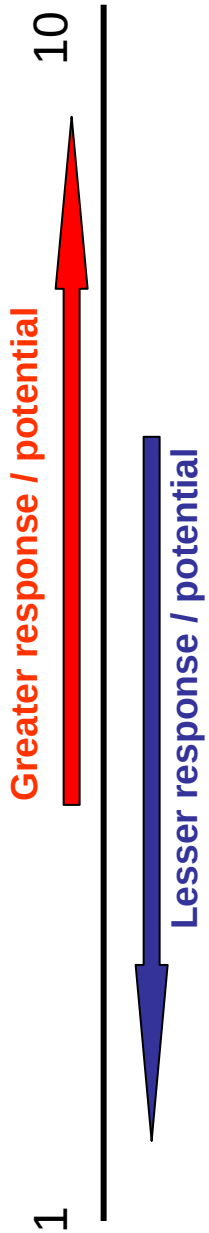
Slope Layer

Forest Density Layer

Land Use Layer

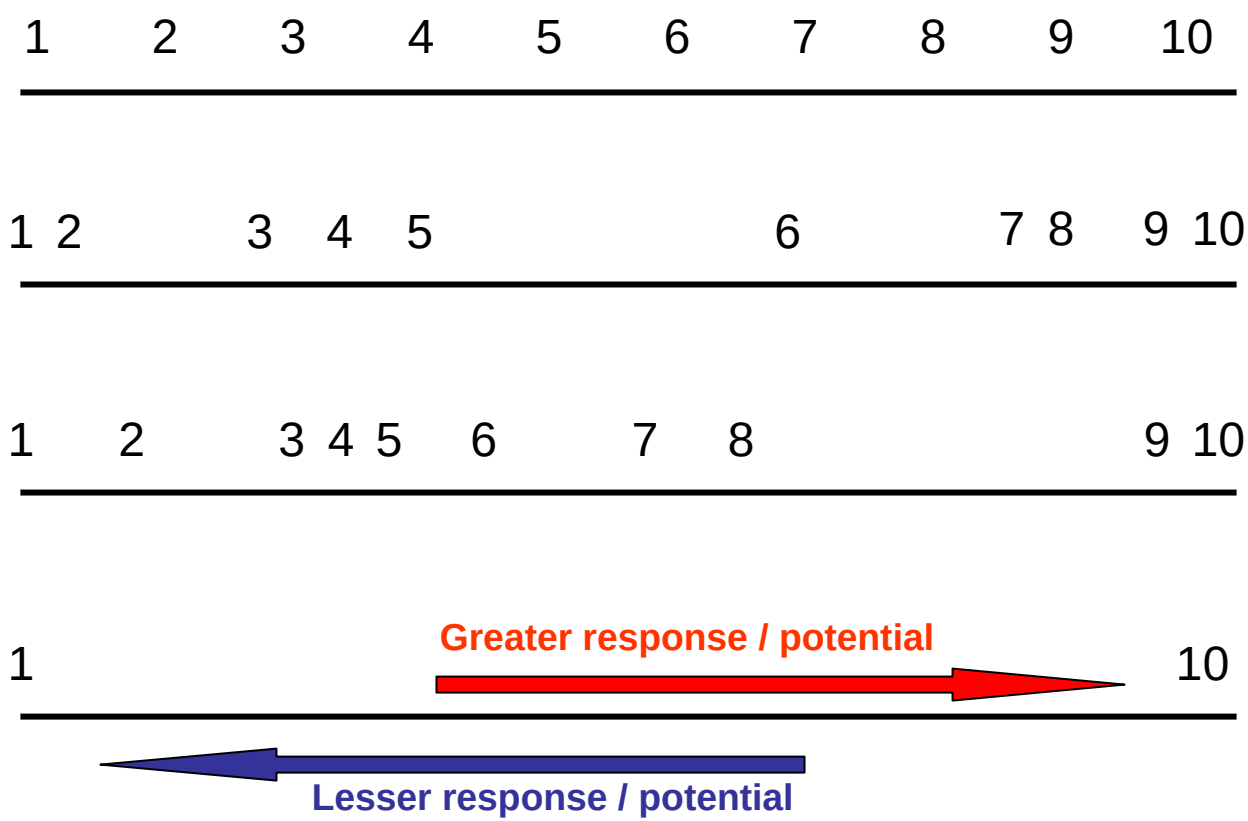
Soil Layer

Flash Flood Potential Index Layer



FFPI Method:

Scale Issues (not all data can be viewed equally)



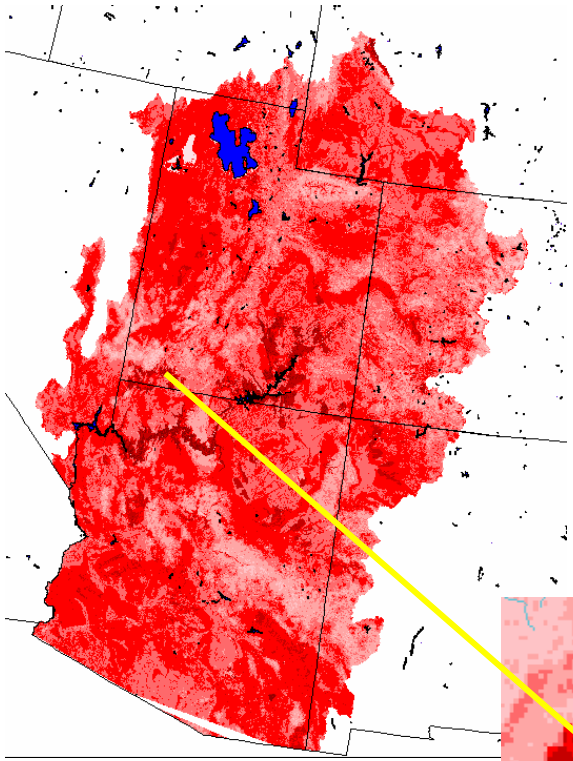
Scientific Meaning vs. Mathematical Statistics

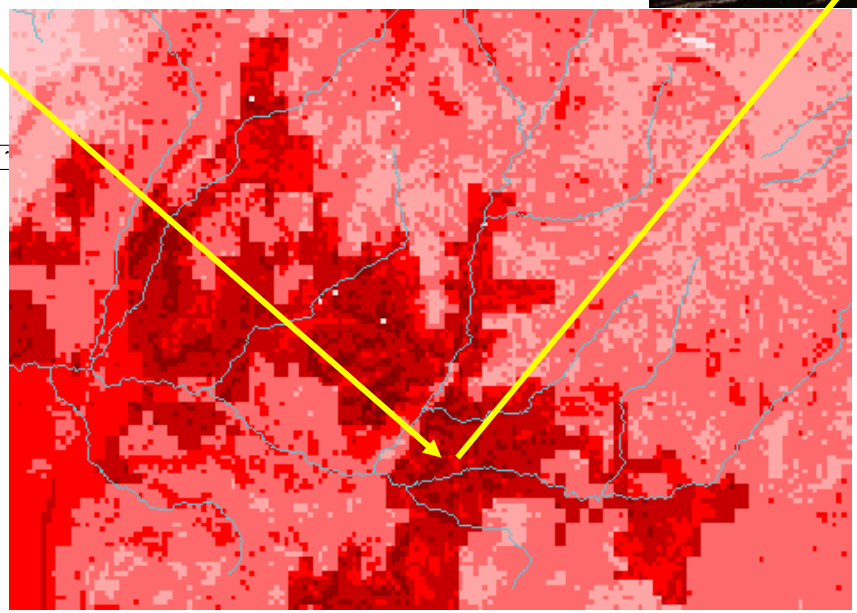
- **Statistical methods involving addition expect numbers being fed are from an interval or ratio scale of measurement.**
- **A common scale is desired and will be pursued.**
- **Statistically limited but <u>scientifically meaningful</u>.**

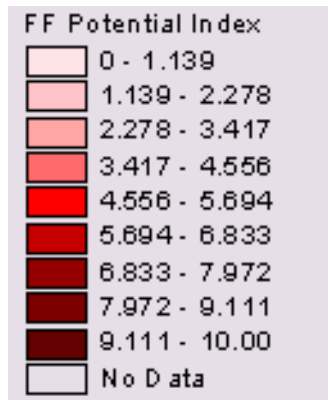
“Experience has shown in a wide range of situations that the application of proscribed statistics to data can yield results that are scientifically meaningful, useful in making decisions, and valuable as a basis for further research" (Turkey 1962).

“Approaches to statistics that start from an a prior scale type and then proscribe the kinds of hypothesis that may be considered or the statistical methods and tests that may be computed based on that scale type are simply bad science and bad data analysis” (Velleman, *The American Statistician* 1993).

Relative FFPI in a Gridded Format







Summarize Grids to FFMP Basin Layer

STATSGO Dominant Soil Texture

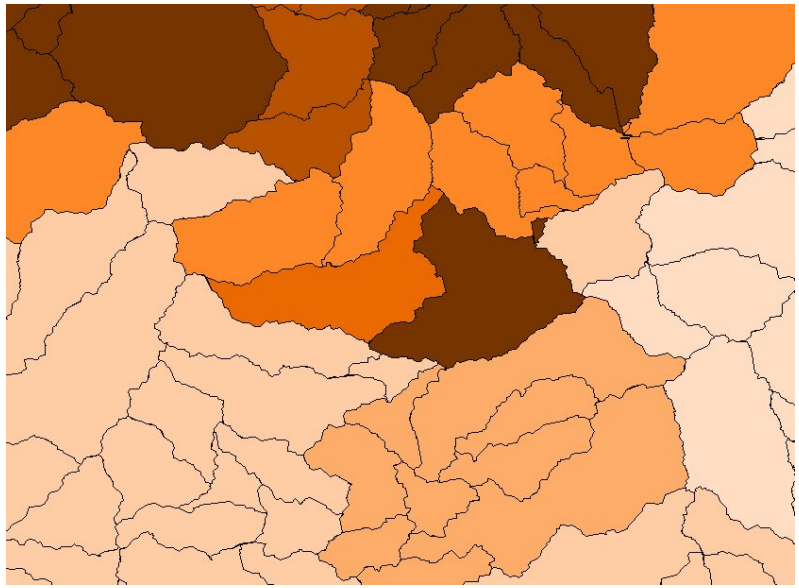
MLRC Land Use / Land Cover

NOAA AVHRR Forest Density Grid

USGS DEM (derived % slope Grid – Terrain)

Fire Burn Areas / Severity coverage

FFMP Basins



Relative Flash Flood Potential

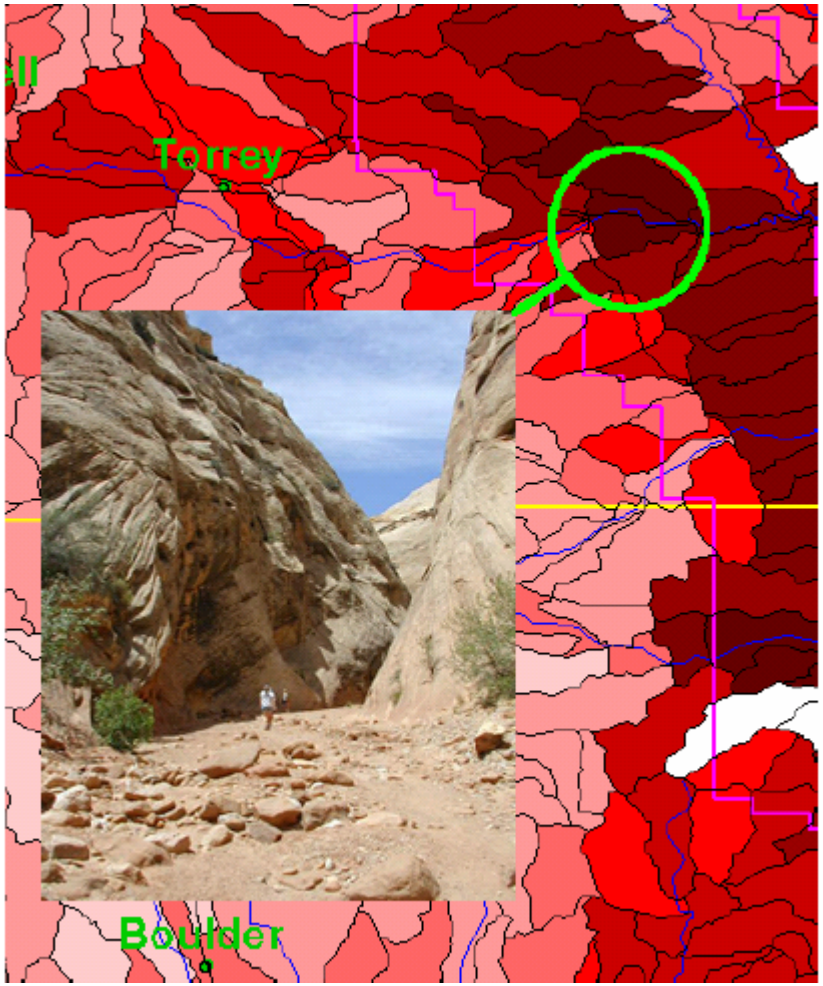
Low

High

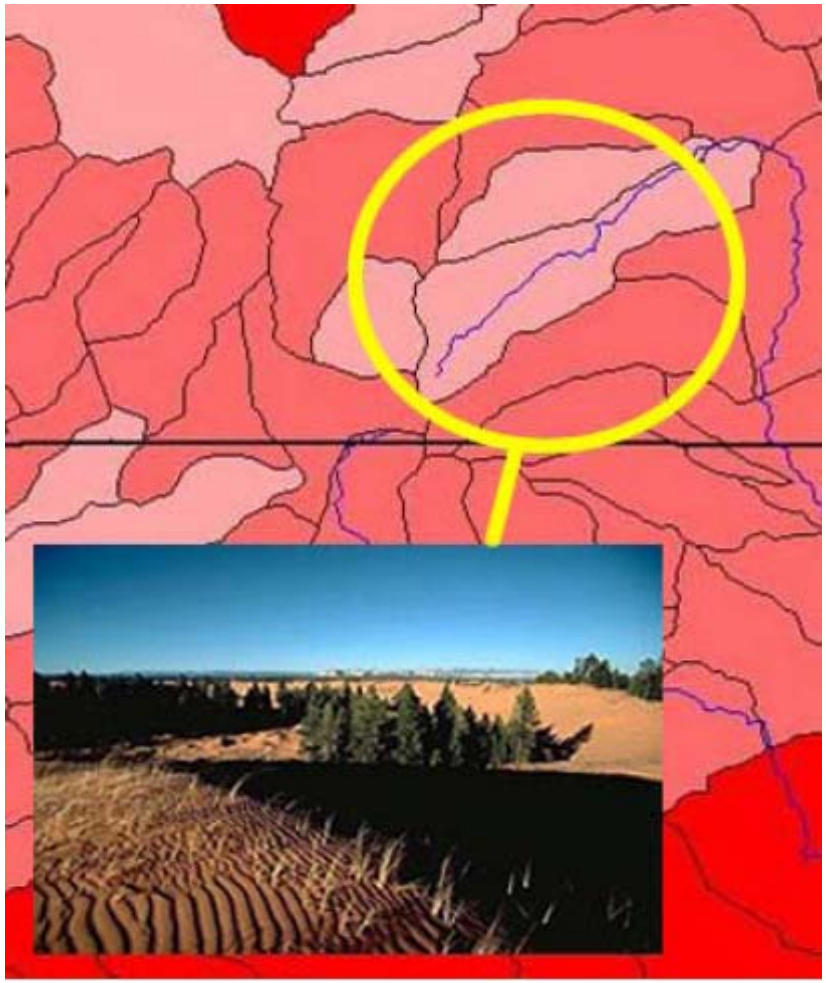
An indication of rapid hydrologic response

Comparing FFPI Basins and Reality

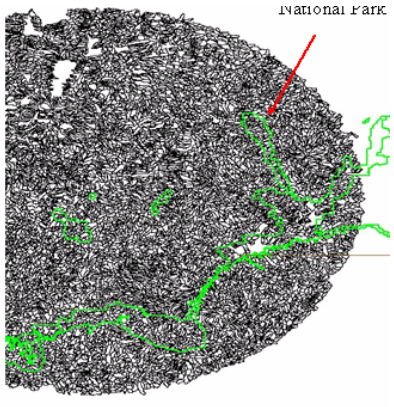
Higher FFPI values (darker shades) – Basins in Capitol Reef National Park



Lower FFPI values (lighter shades) – Moquith Mountain area – gradually sloped, sandy basins

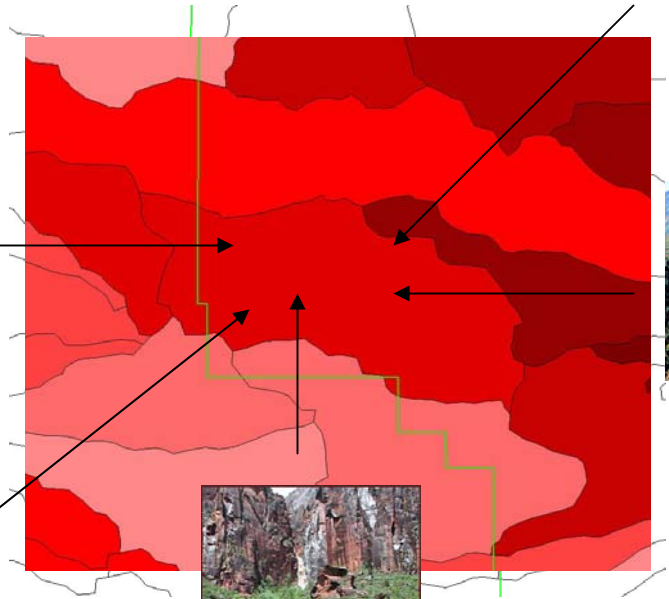


Basins defined by FFPI



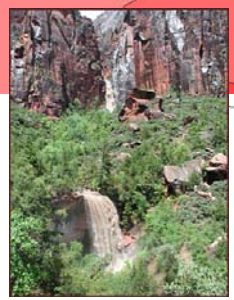
Land Use ?

Soil type ?



Vegetation type and density ?

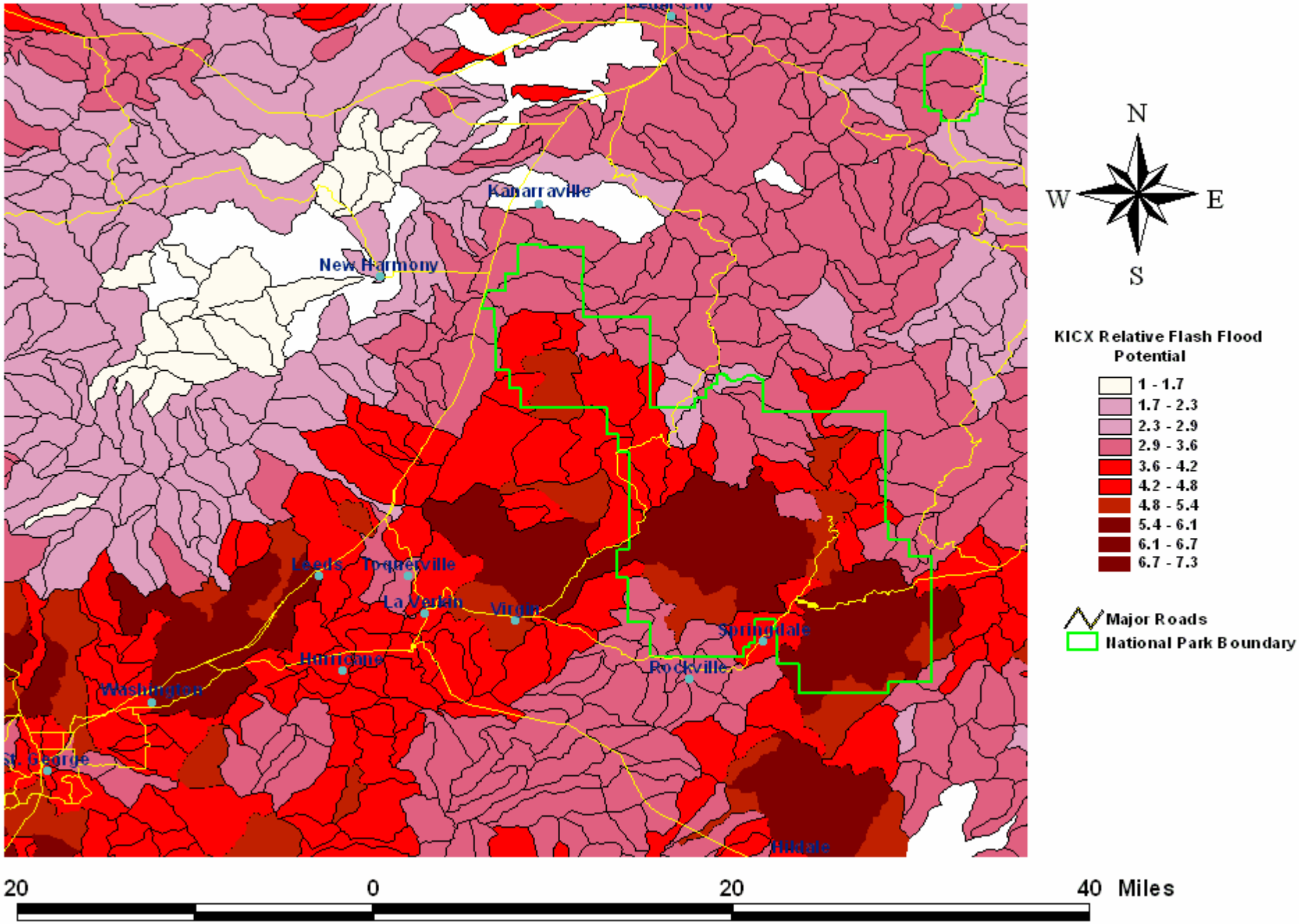
Fire activity ?



Slopes?

Increased our level of understanding about the drainages

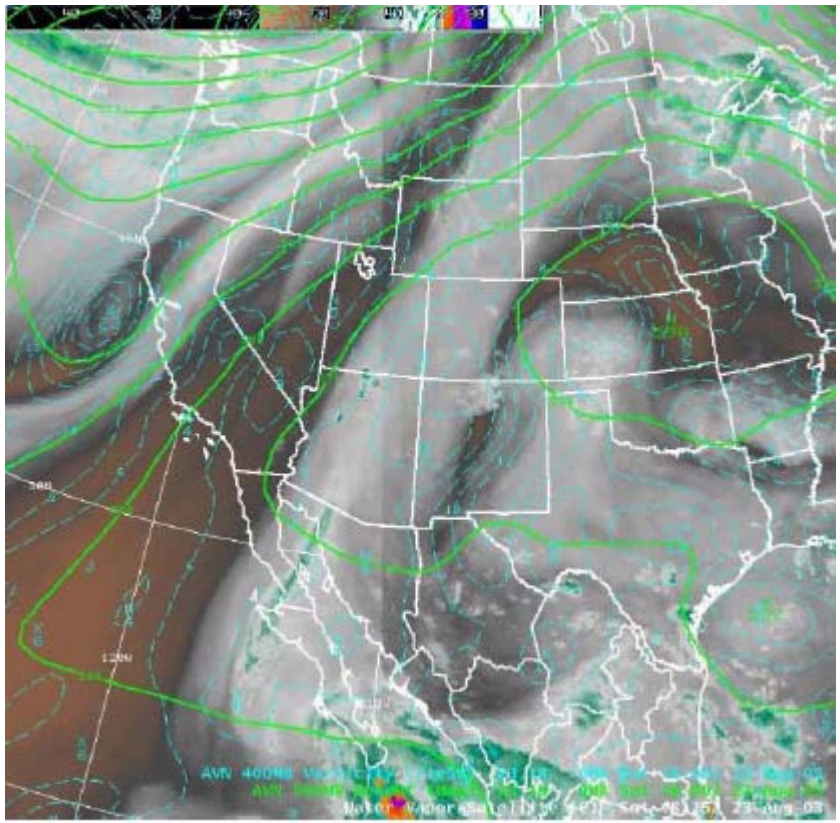
Basin Layer FFPI for Southwest Utah (KICX Radar Basins)



Operational Use

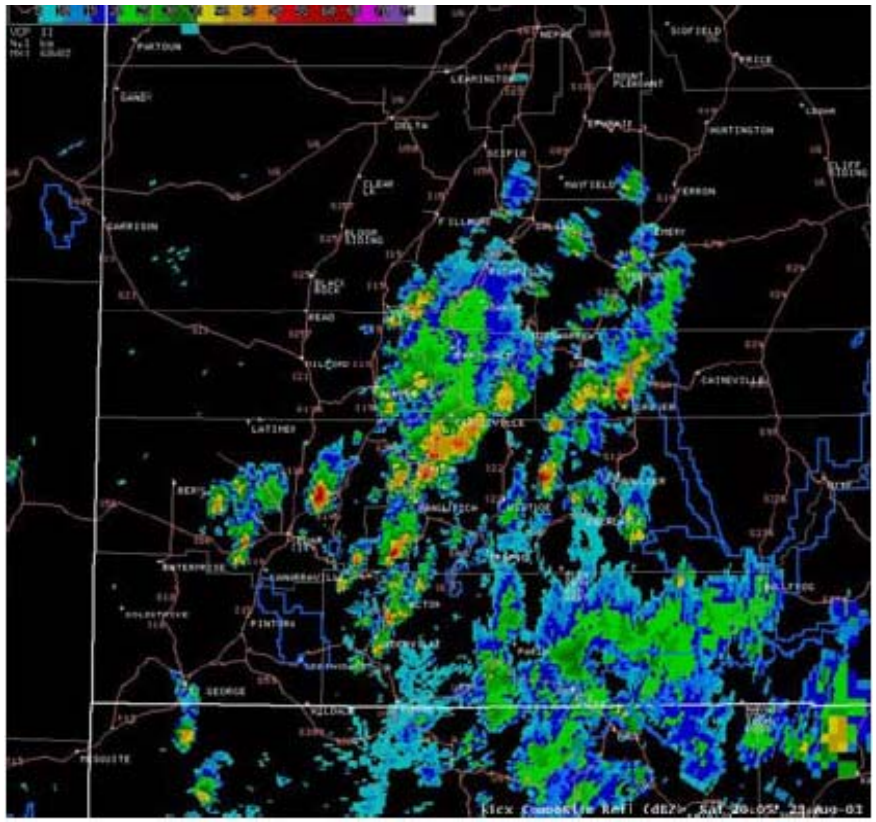
WFO – Salt Lake City

Ripe Situation: Abundant Moisture, light winds, vertical wind shear profile conducive to back-building and training cells



Water Vapor Imagery

By 20Z activity popping over higher terrain

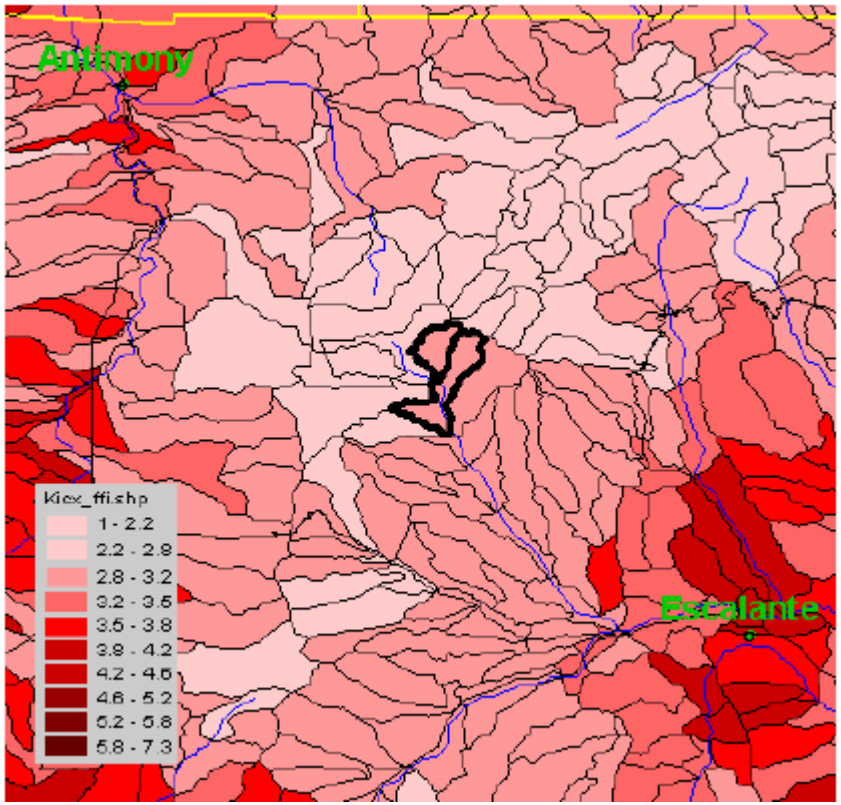


KICX composite radar reflectivity

Operational Use

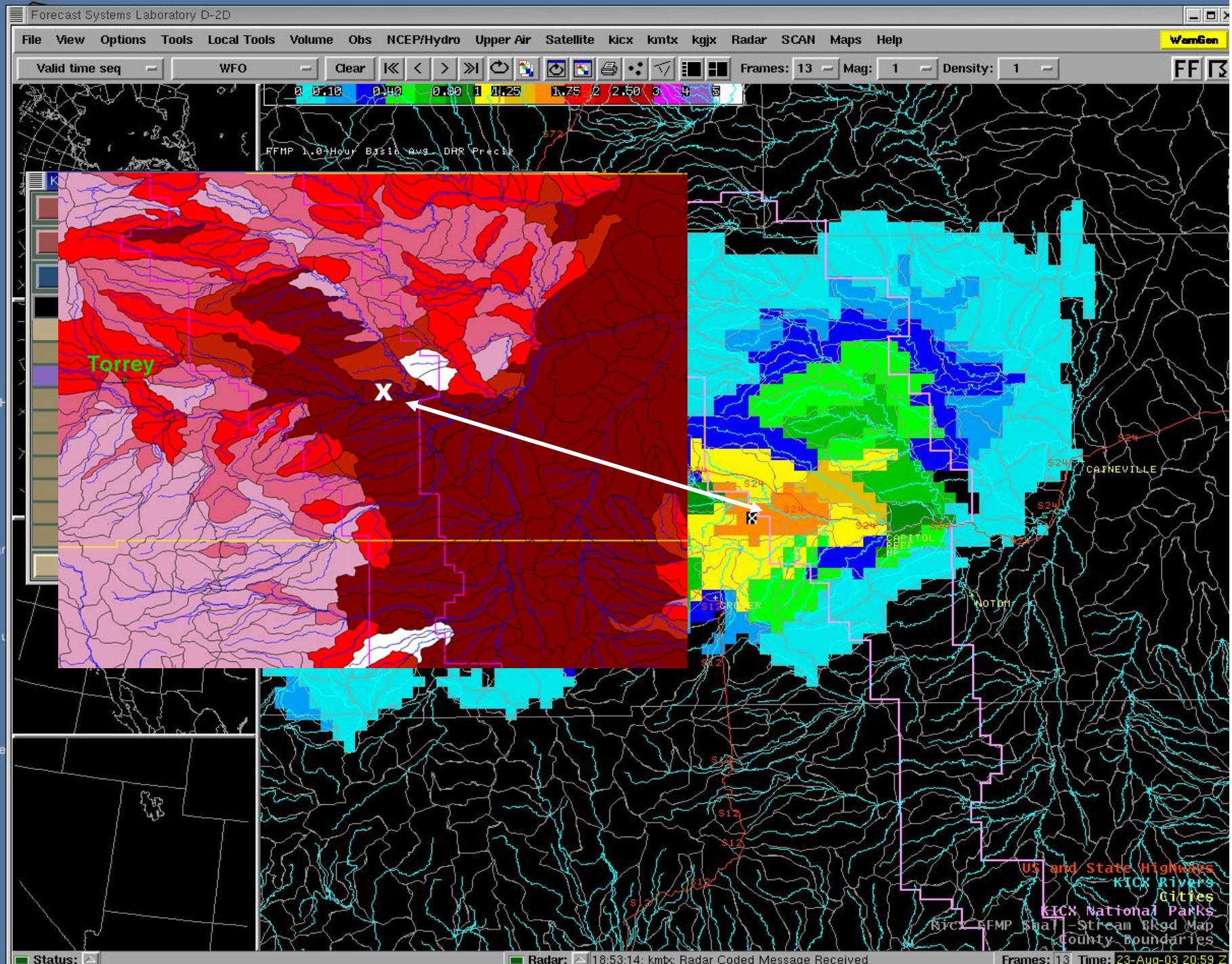
WFO – Salt Lake City

FFPI Display: These basins on the North Fork received the heaviest rainfall rates with total rainfall amounts exceeding FFG by over ½ inch.



Basins of the North Fork drainage that feed the Escalante River. Basins are on the eastern slope of the range but it is heavily forested.

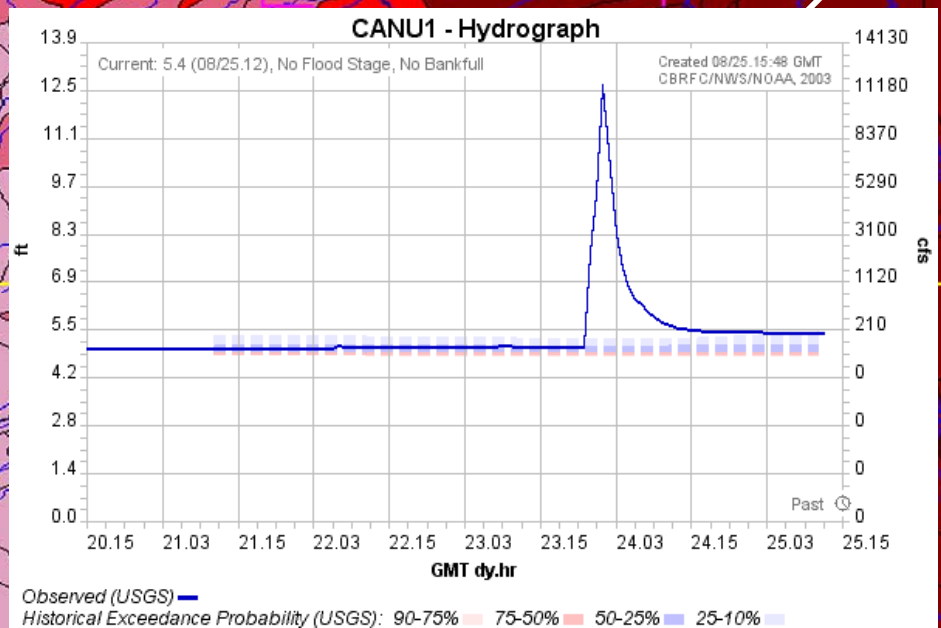
Radar reflectivity (above) and storm total precip (below). FFG was exceeded but a FF Warning was not issued.


Forecast Systems Laboratory D-2D
File View Options Tools Local Tools Volume Obs NCEP/Hydro Upper Air Satellite kicx kmtx kgjx Radar SCAN Maps Help
WarnGen
Valid time seq
WFO
Clear
Frames: 13
Mag: 1
Density: 1
0 0.10 0.40 0.80 1 1.25 1.75 2 2.50 3 4 5
FFMP 1.0-Hour Basic Avg DHR Precip
Torrey
X
CAINEVILLE
CAPITOL REEF NP
NOTOM
US and State Highways
KICX Rivers
Cities
KICX National Parks
KICX FFMP Small-Stream Bkgd Map
County Boundaries
Status:
Radar:
18:53:14: kmtx: Radar Coded Message Received
Frames: 13 Time: 23-Aug-03 20:59 Z

Flood Rescue

Torrey

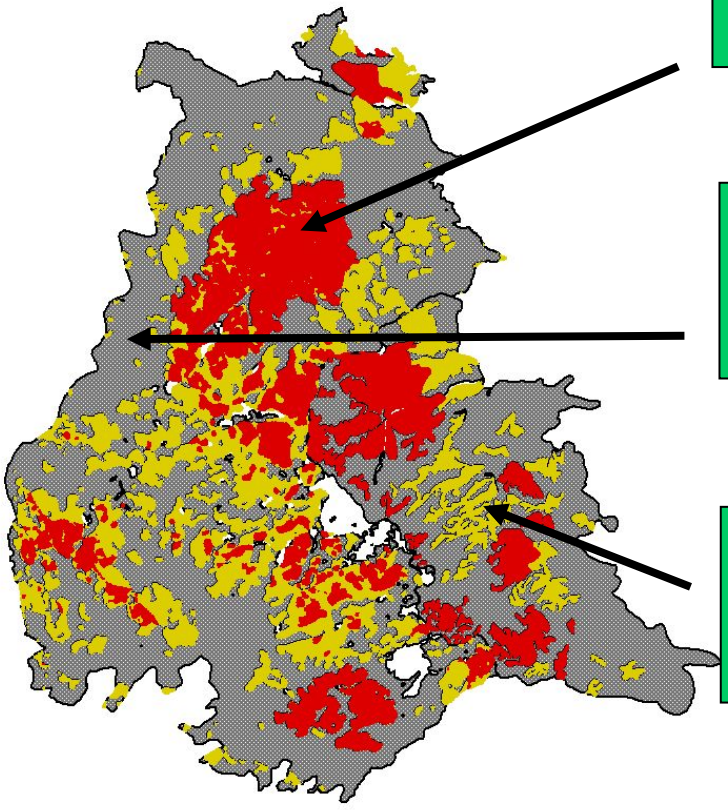
X



Revised to an 8,000 CFS rise in just over an hour

Accounting For Effect of Wildfires

John McColgan – BLM Firefighter



High Burn Severity:
All vegetation blackened, deep soil heating killing roots/seeds, “baking” of the soil surface.

Low Burn Severity:
Most vegetation untouched by fire. No significant Effect on soil properties or water repellency.

Moderate Burn Severity:
Patchwork of green and burnt areas. Intermediate Between “high” and “low” severity levels.

The Challenge: How to apply fire burn severity information ?

Forest Density Layer :

- **High Burn Area – Completely removed forest density**

  Maximized hydrologic response for this layer

- **Moderate Burn Areas - Reduced forest density by 50%**

  Moderate increase to hydrologic response for this layer

- **Low or non burn areas – No change to existing forest density**

  No change to hydrologic response for this layer.

The Challenge: How to apply fire burn severity information ?

Soil Type Layer :

- **High Burn Area – Assume hydrophobic soil**

  Maximized hydrologic response for this layer

- **Moderate Burn Areas – Mix of baked / non-baked soil exists**

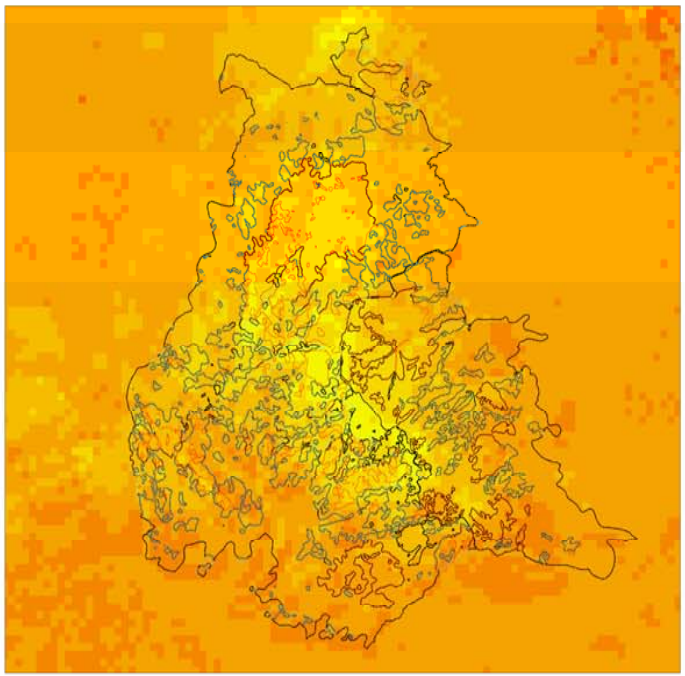
  Moderate increase to hydrologic response for this layer

- **Low or non burn areas – No change to existing soil properties**

  No change to hydrologic response for this layer.

Affect of Fire on Hydrologic Response and Gridded Relative Flash Flood Potential

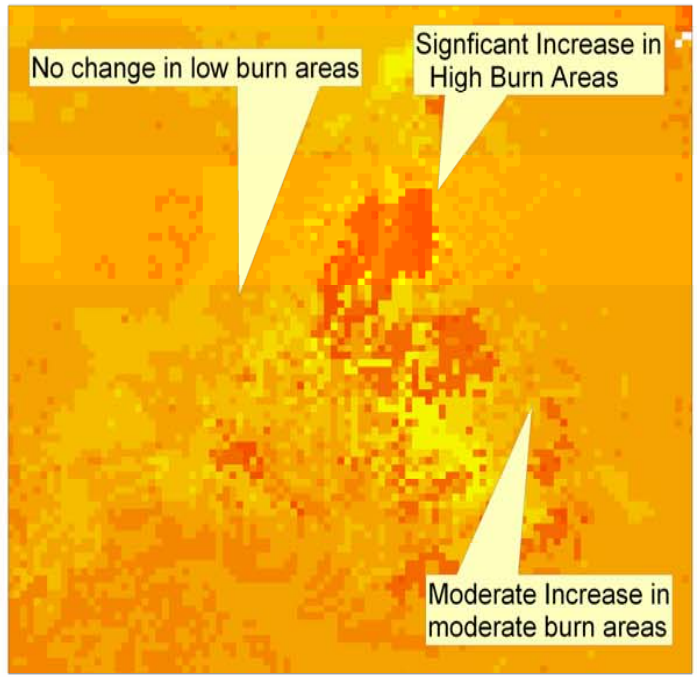
* Preliminary Results *



Burn Severity Layers Applied

Relative Flash Flood Potential Index

1 LOW
2
3
4
5
6
7
8
9
10 HIGH



Prepared by: Greg Smith - Colorado Basin River Forecast Center - NWS/NOAA

Possible Applications & Use

- Supplement FFMP: Classify – rank basins response characteristics
- Use with areal / rule of thumb FFG to better qualify potential FF threat
- Identify Flash Flood prone areas (utilize as a briefing tool)
  - Identify areas for further study & familiarization
  - Location of cooperative spotters and gages
- Utilize in alternate statistical FFG methods (relate to event data)
- Other interests
  - UDOT – Prioritize culvert replacement / enlargement
  - International Interest

AHPS and FFPI

Near term

Deliver FFPI output to test sites – acquire and incorporate feedback- (re)define CONOPS

Review methodology (scale issues / categories– weighting schemes – data application)

Incorporate finer resolution data – Including a soil moisture component

Refine method for incorporating wild-fire information

Documentation / Platform

Longer term

Explore methods for determining FFG (statistical – event data/FFPI relationships)

Explore human risk factor component

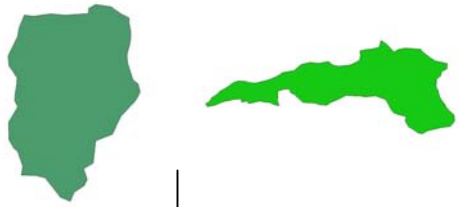
Determine future of FFPI

Interim product replaced by distributed model?

Long term product – has merit as an additional stand alone product/tool ?

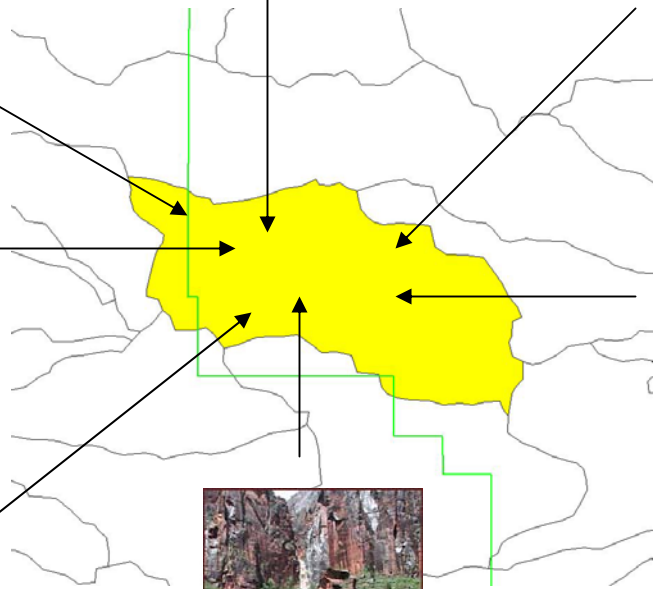
This is inside a national park; is that a risk factor to consider?

Geometry of basin



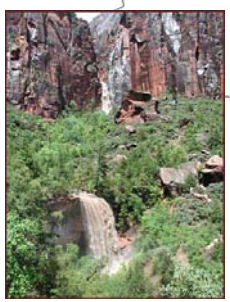
Land Use ?

Soil type ?



Vegetation type and density ?

Fire activity ?

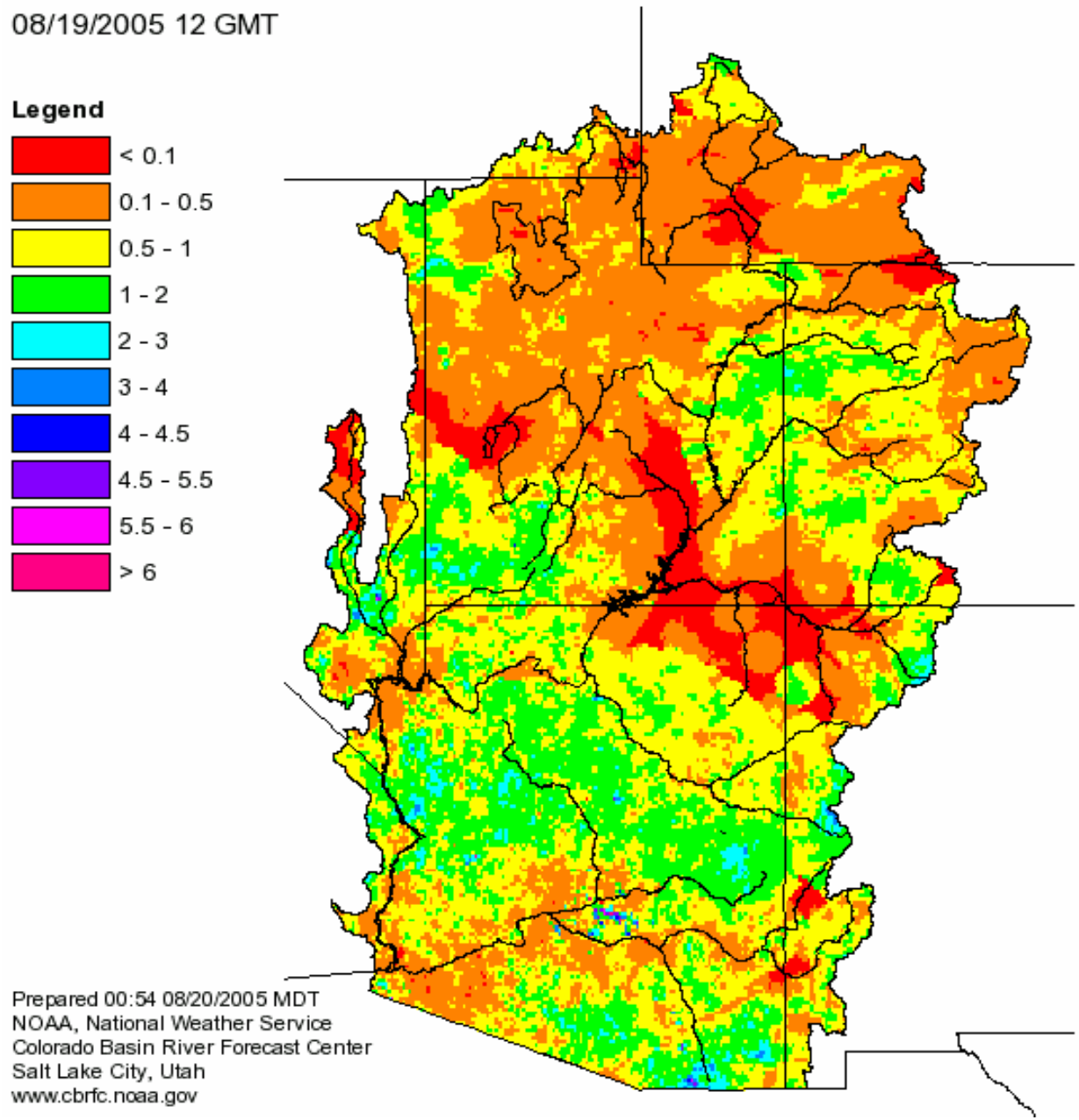


Slopes?

Antecedent Precipitation Index (API)

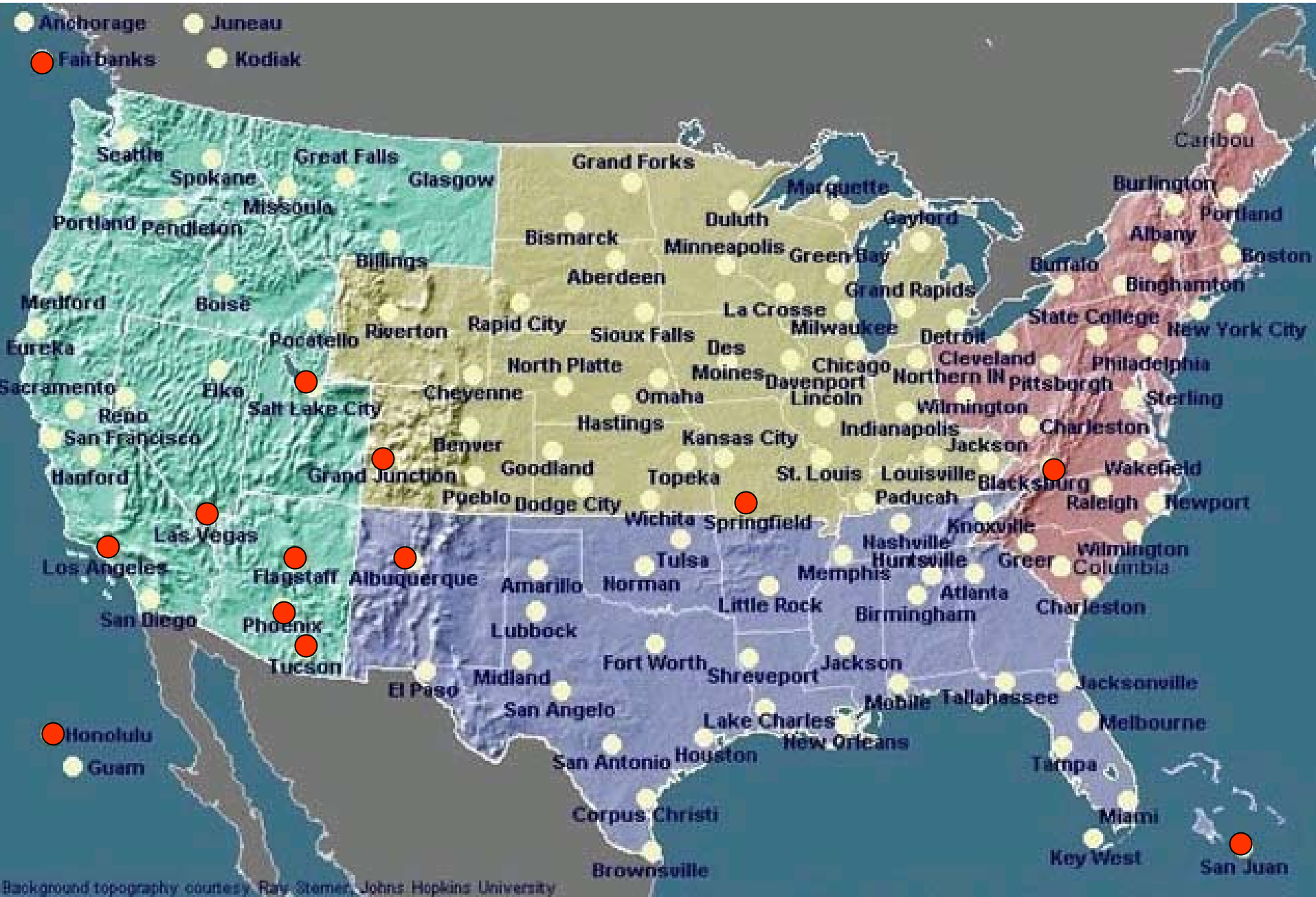
Colorado Basin River Forecast Center

08/19/2005 12 GMT

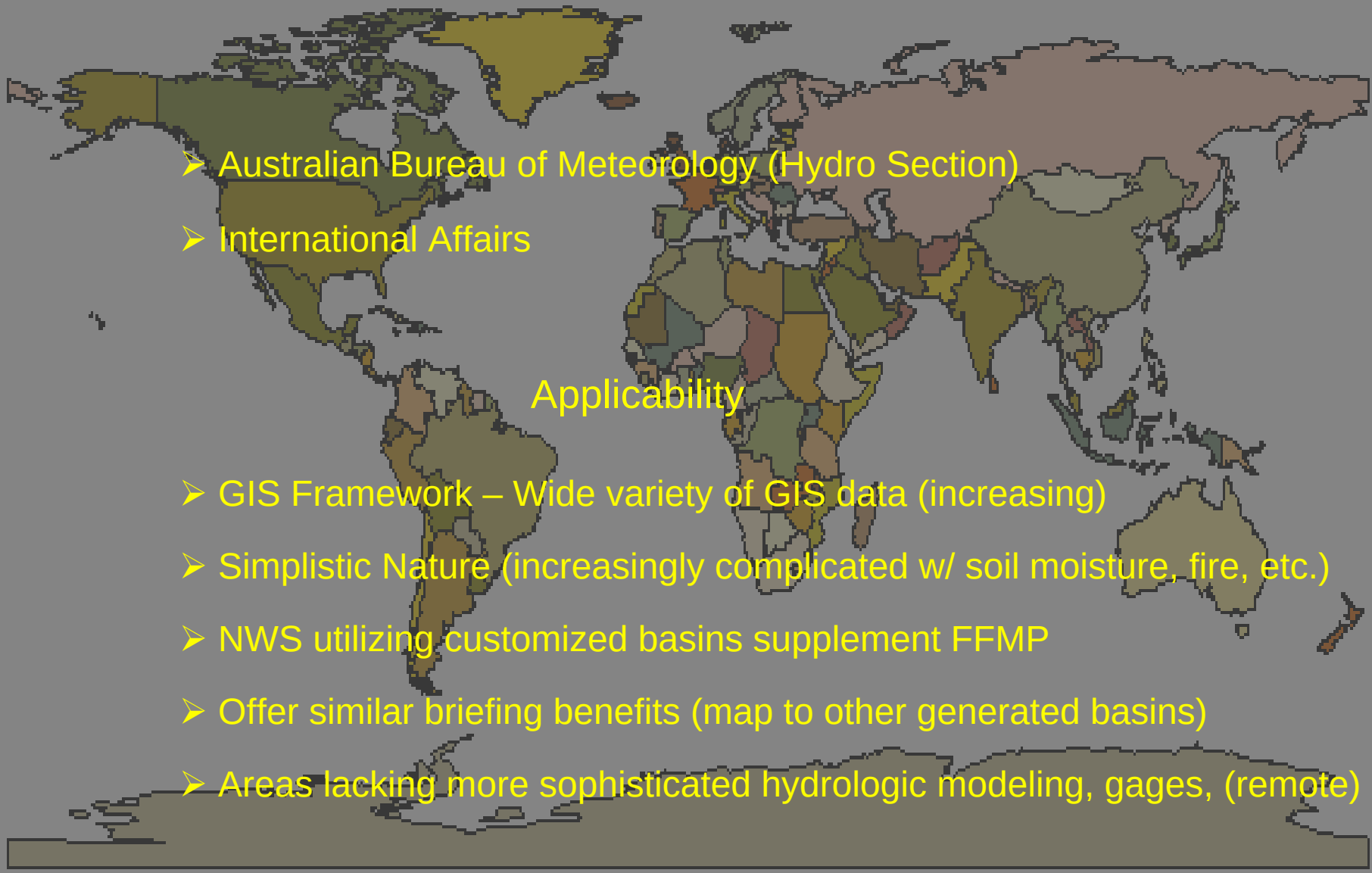


Prepared 00:54 08/20/2005 MDT
NOAA, National Weather Service
Colorado Basin River Forecast Center
Salt Lake City, Utah
www.cbrfc.noaa.gov

FFPI Status: Coordinating offices that will review FFPI



International Interest



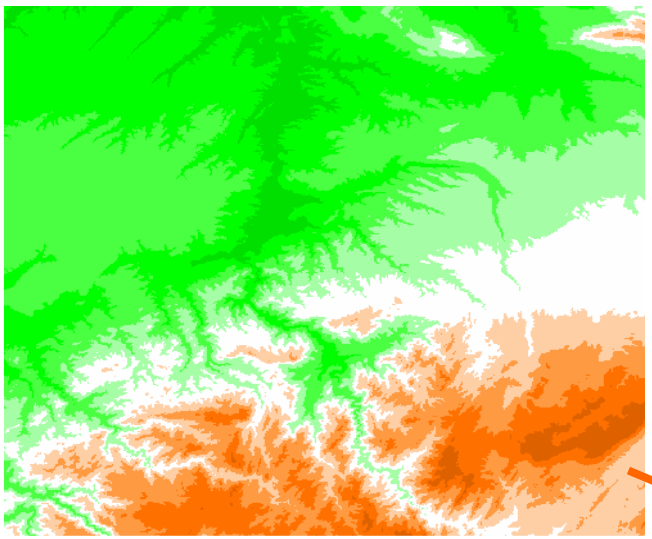
- Australian Bureau of Meteorology (Hydro Section)
- International Affairs

Applicability

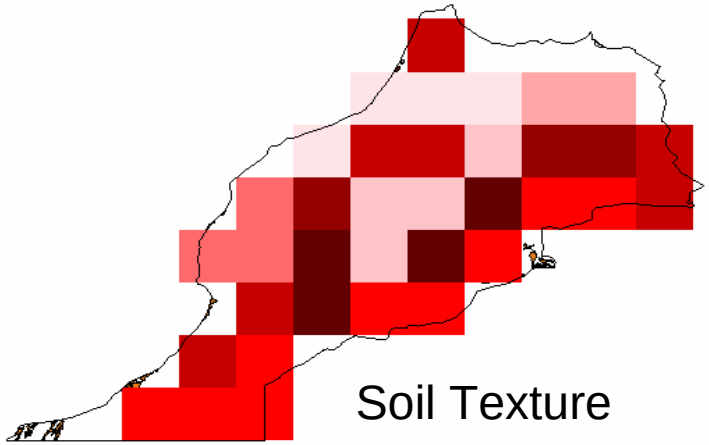
- GIS Framework – Wide variety of GIS data (increasing)
- Simplistic Nature (increasingly complicated w/ soil moisture, fire, etc.)
- NWS utilizing customized basins supplement FFMP
- Offer similar briefing benefits (map to other generated basins)
- Areas lacking more sophisticated hydrologic modeling, gages, (remote)

International Interest

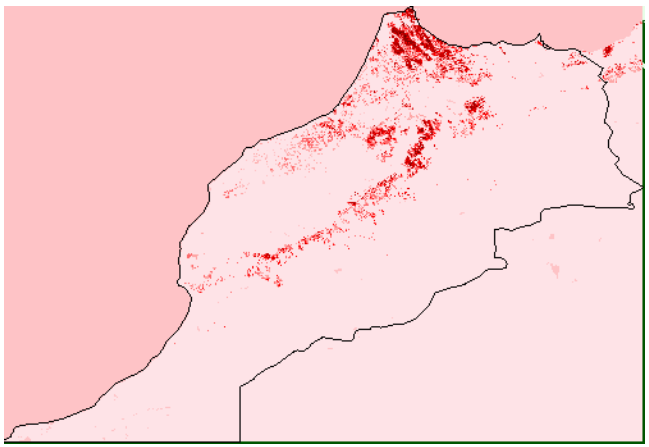
International Interest: Example of Morocco Datasets



Elevation/Slope



Soil Texture



Tree Density


Questions ?
Ideas ?
Suggestions ?
By Bo Beck