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

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Gypsum Wash – Near Las Vegas, NV
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
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.
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*
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
Flash Flood Guidance a critical input to FFMP

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

Soil moisture (SAC-SMA)
Complete model coverage (scale issues)
Rainfall intensity
Critical threshold
What is this project about

Capitol Reef National Park

FFG is similar for all basins

Rules of thumb the same for all basins
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

Flow Response Time

Slower  ←  Rapid

Flash Flood Potential

Lower  ←  Greater
Try to qualify the flash flood threat
FFPI Method:

Obtain raster (gridded) datasets representing the features of interest
Utilizing a Geographic Information System (GIS)

**FFPI Method:**

- Resample and Georegister Data
- Consistent resolution
- Same projection/datum

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

Overlapping grid cells representing same location on the surface of the Earth
### FFPI Method: Re-classifying datasets

#### Switched Scale Types

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**Legend:**

- **Decreasing**
  - 0 - 10
  - 10 - 20
  - 20 - 30
  - 30 - 40
  - 40 - 50
  - 50 - 60
  - 60 - 70
  - 70 - 80
  - 80 - 90
  - 90 - 110
  - No Data

- **Increasing**
  - Decreasing
  - Hydrologic Response

- **Switched Scale Types**
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
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)

1  2  3  4  5  6  7  8  9  10

Greater response / potential

Lesser response / potential
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 **scientifically meaningful**.

“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
Increased our level of understanding about the drainages.
Ripe Situation: Abundant Moisture, light winds, vertical wind shear profile conducive to back-building and training cells

By 20Z activity popping over higher terrain

Water Vapor Imagery

KICX composite radar reflectivity
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.
Revised to an 8,000 CFS rise in just over an hour.
Accounting For Effect of Wildfires
**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

No change in low burn areas

Significant Increase in High Burn Areas

Moderate Increase in moderate burn areas

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?
Antecedent Precipitation Index (API)
Colorado Basin River Forecast Center
08/19/2005 12 GMT

Legend
- < 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 4.5
- 4.5 - 5.5
- 5.5 - 6
- > 6

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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