



**COLORADO**  
Department of  
Transportation



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Colorado Water  
Conservation Board  
Department of Natural Resources

# Post-Flood Hydrologic Evaluation

Kevin Houck, Colorado Water Conservation Board  
Steven Humphrey, Muller Engineering / CDOT Flood Recovery Office



# Innovative Techniques

- Agency partnership
- Teaming effort
- Rainfall runoff models of this size/scale
- Systematic calibration approach
- Regional DARF curves
- Watershed wide discharge profiles



# Partnership & Teaming



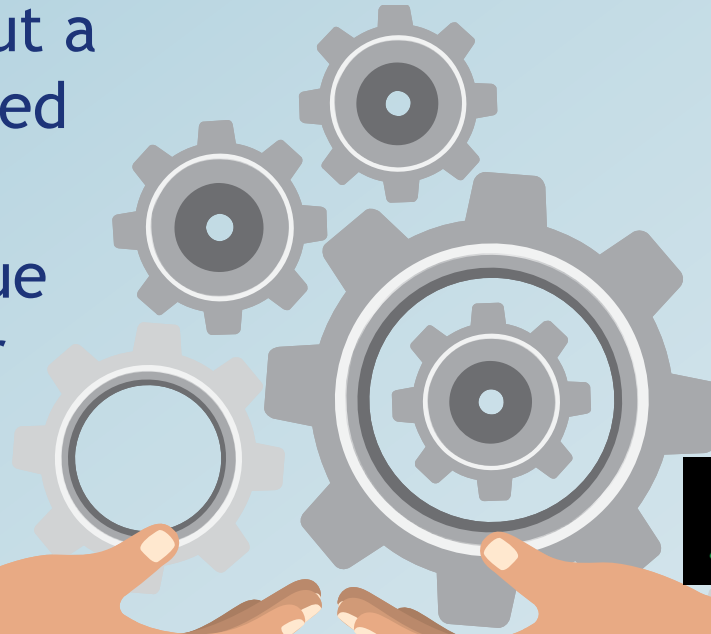
FEMA





# CDOT and CWCB Partnership

- Partnership began in October/November of 2013 during the response phase
- The two organizations rarely worked together, but a new bond was formed during the flood
- Recognized the value of working together and establishing a team mentality



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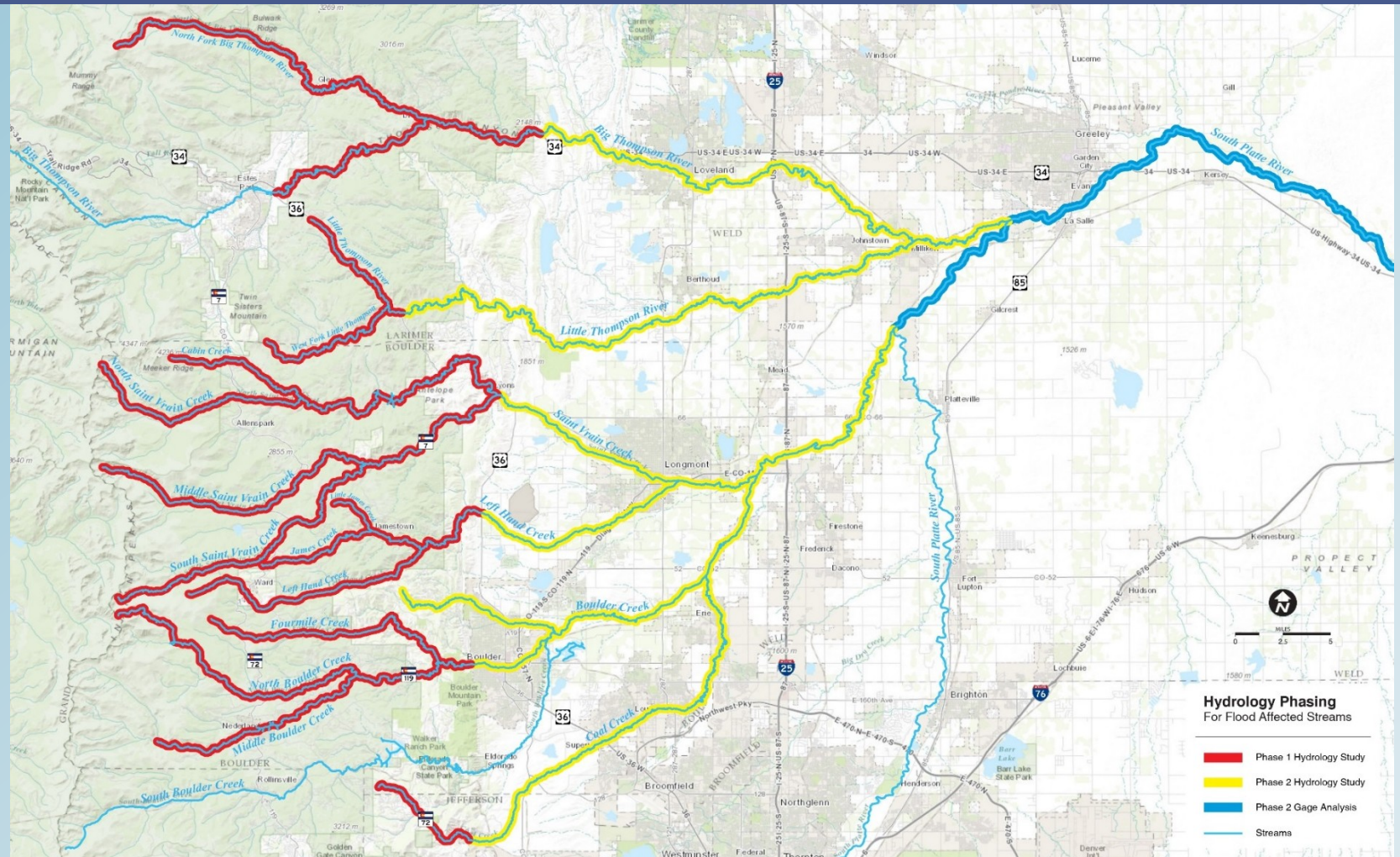


# Hydrology Studies

- Recognized an unmet need for design hydrology for the permanent repair projects
- Identified seven flood affected watersheds that are critical to CDOT's reconstruction efforts
  - Big Thompson River
  - Little Thompson River
  - St. Vrain Creek
  - Lefthand Creek
  - Boulder Creek
  - Coal Creek
  - South Platte River



# CDOT and CWCB Hydrology Analysis



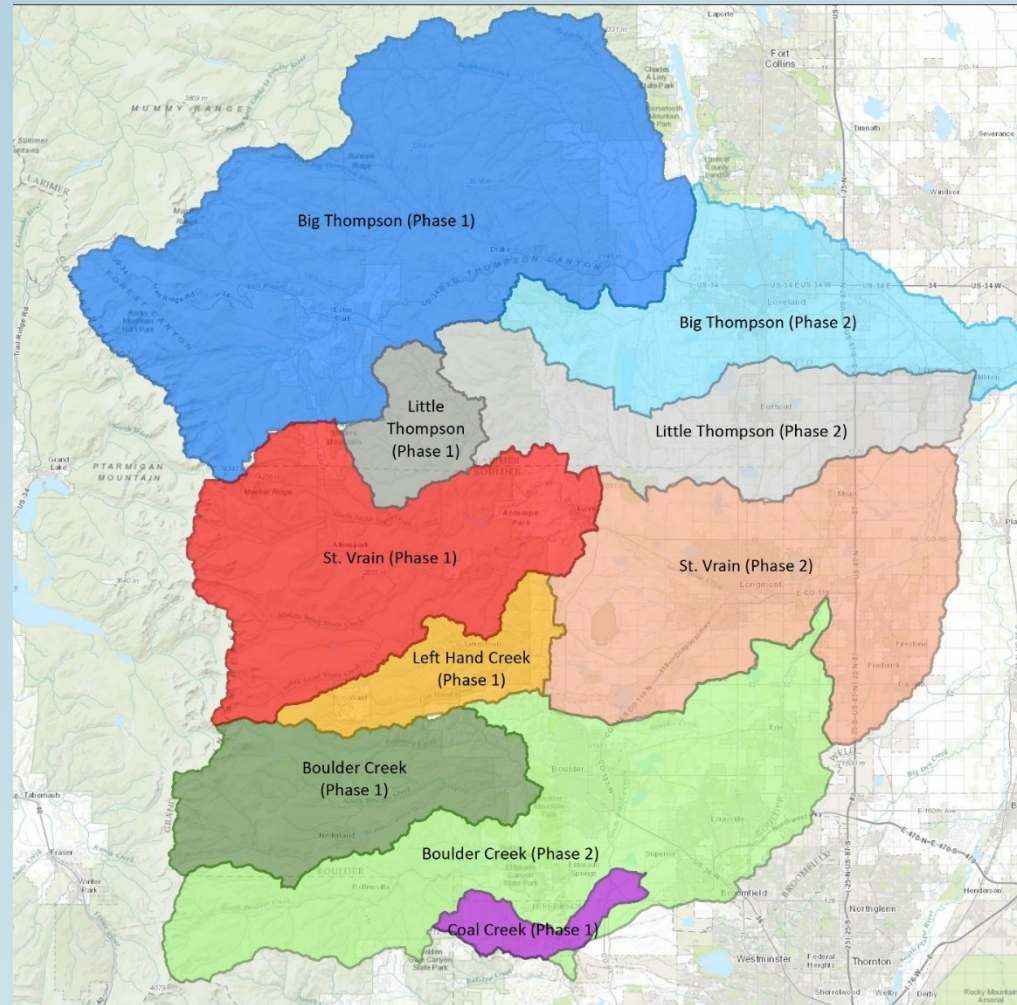


# Rainfall Runoff Model - Size/Scale

829 sq mi Big Thompson

978 sq mi St. Vrain

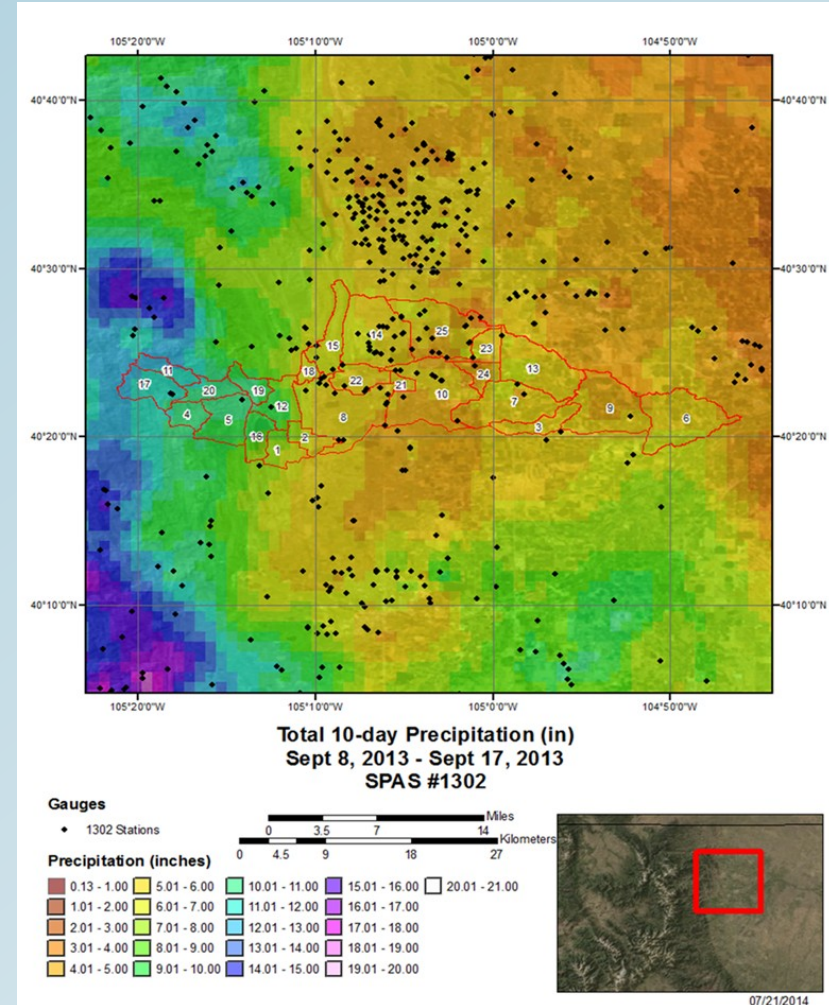
1807 sq mi modeled





# Calibration

## 1. Detailed rainfall data for 2013 event





# Calibration

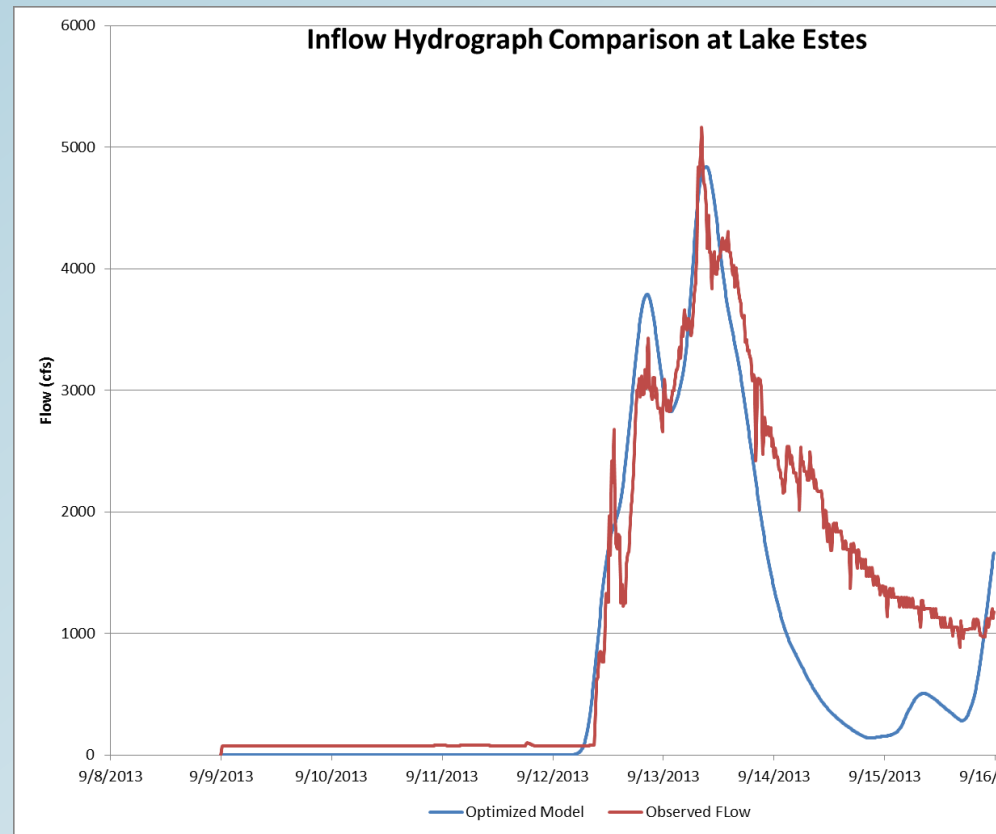
1. Detailed rainfall data for 2013 event
2. 2013 peak discharges estimates





# Calibration

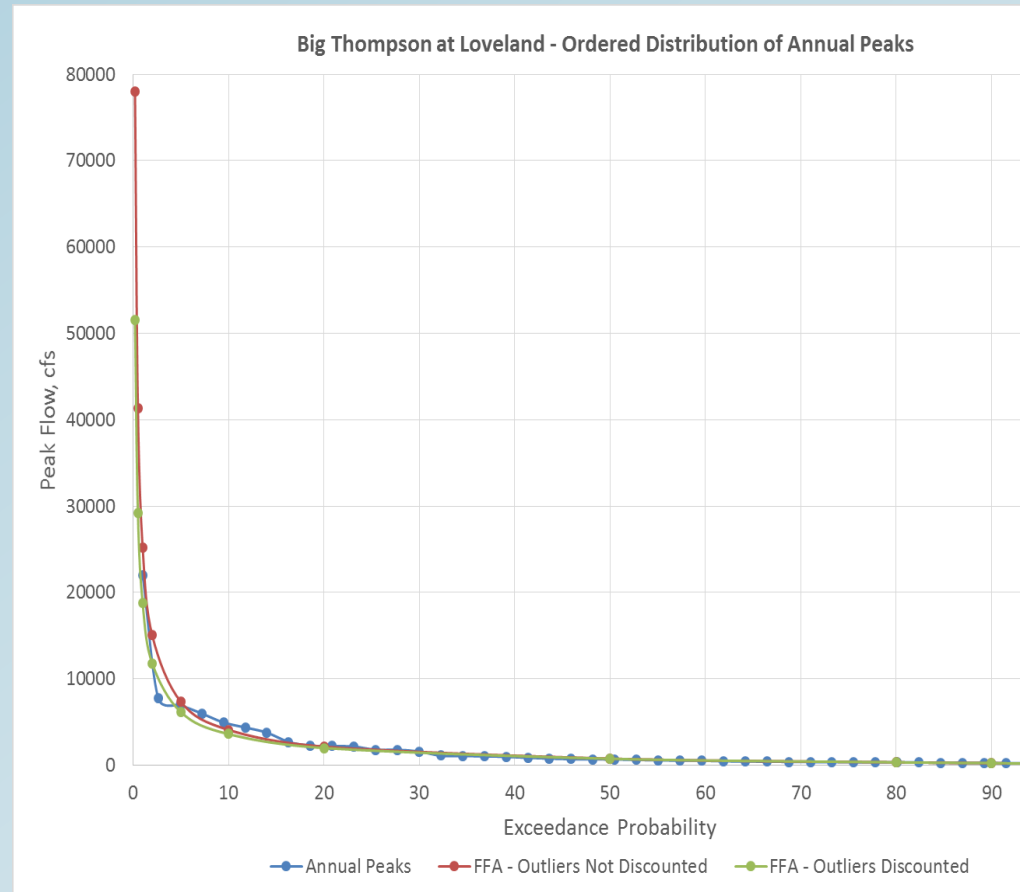
1. Detailed rainfall data for 2013 event
2. 2013 peak discharges estimates
3. Hydrographs at reservoirs





# Calibration

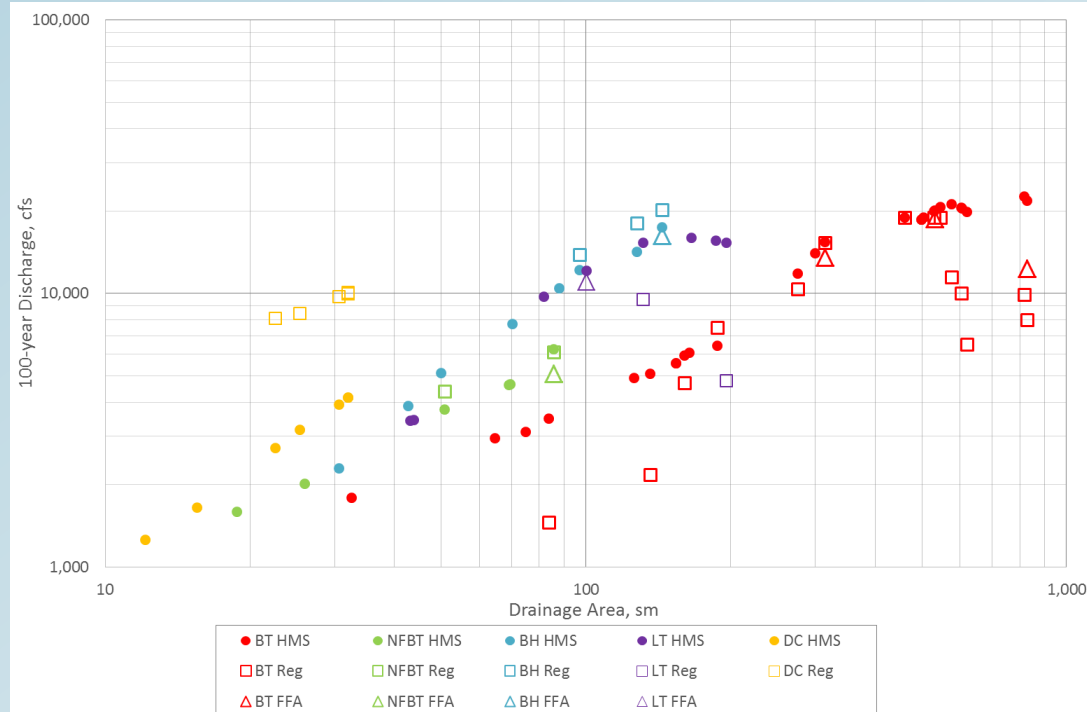
1. Detailed rainfall data for 2013 event
2. 2013 peak discharges estimates
3. Hydrographs at reservoirs
4. Updated flood frequency analyses





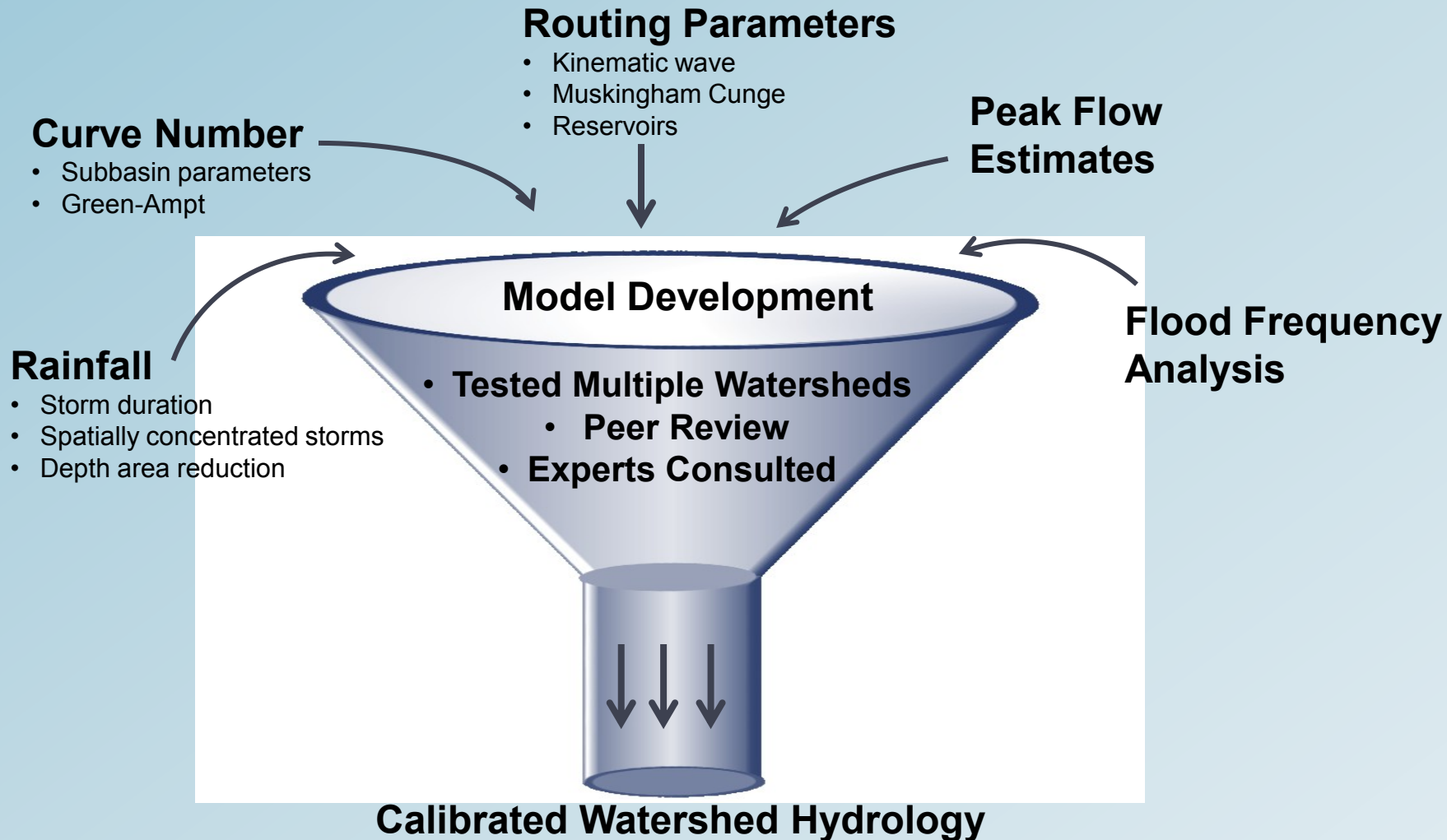
# Calibration

1. Detailed rainfall data for 2013 event
2. 2013 peak discharges estimates
3. Hydrographs at reservoirs
4. Updated flood frequency analyses
5. Comparison of unit discharges





# Calibration



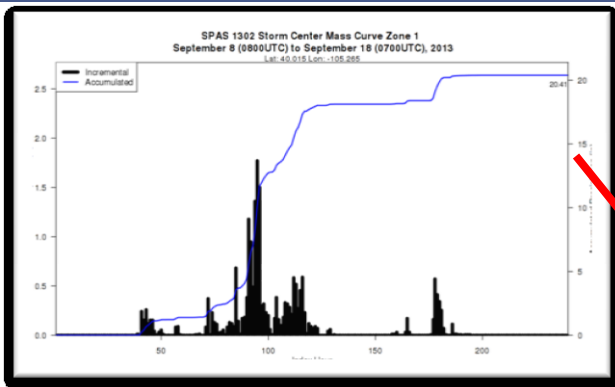


# Site-Specific DARF

- CDOT Flood Hydrology Committee tasked Applied Weather Associates to:
  - Derive 24-hour ARFs for the Front Range of Colorado for area sizes of 1- to 1000-sqmi.
  - Derive basin specific ARFs for the September 2013 rainfall event for four basins (Boulder Creek, St. Vrain Creek, Big Thompson River, and Thompson River basin)
- The Phase II 24-hour ARF curve extends out to 1,000-sqmi and are only applicable to Phase II of the CDOT September 2013 Flood Study

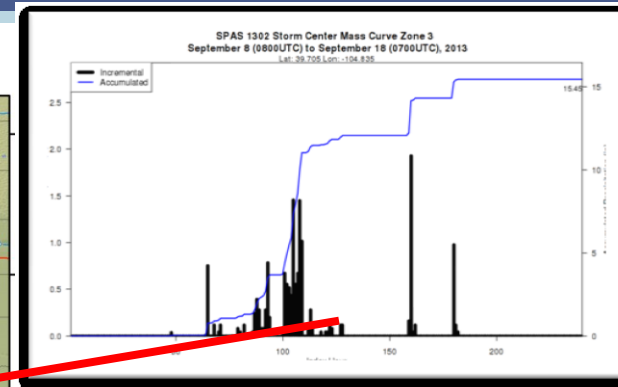
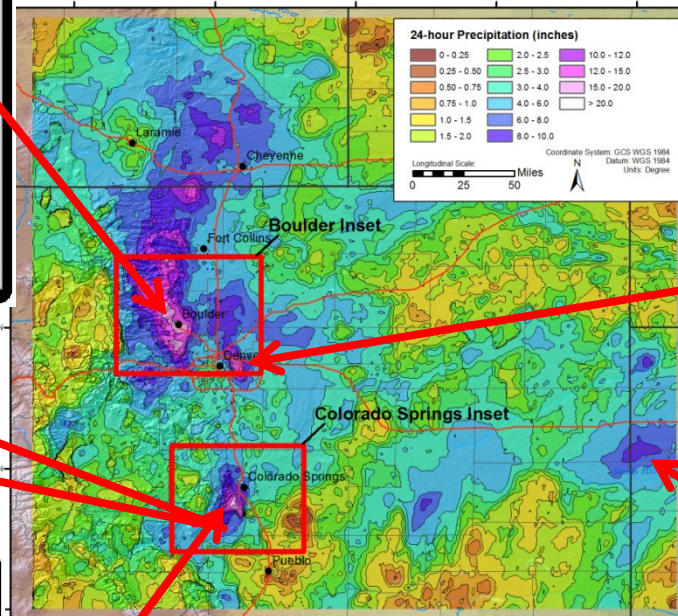


# Site-Specific DARF

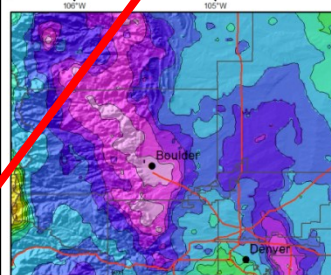
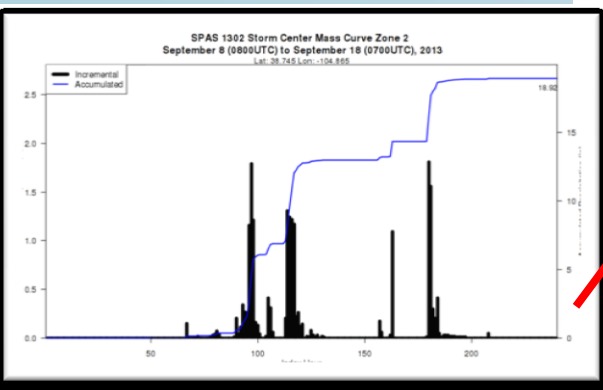


New Colorado 24-hr  
rainfall record: 11.85"  
USGS gauge near Fort  
Carson (prior record 11.08")

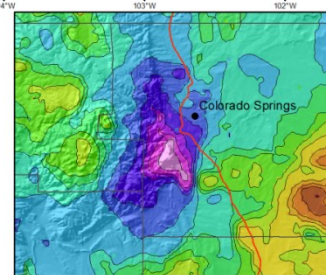
Total Storm Precipitation (inches)  
September 8 (800 UTC) - September 18 (700 UTC), 2013



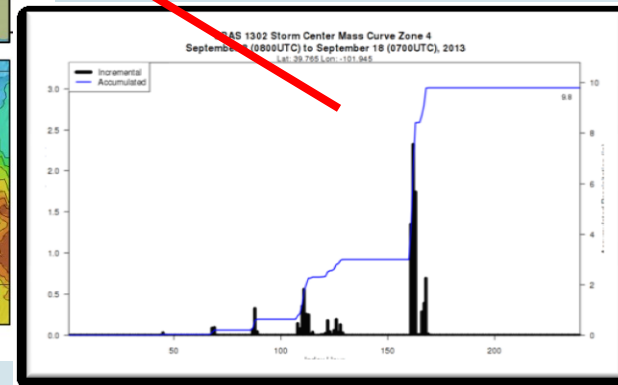
Total 10-day  
Precipitation From  
SPAS  
5 min x 1 km<sup>2</sup>



Boulder Inset



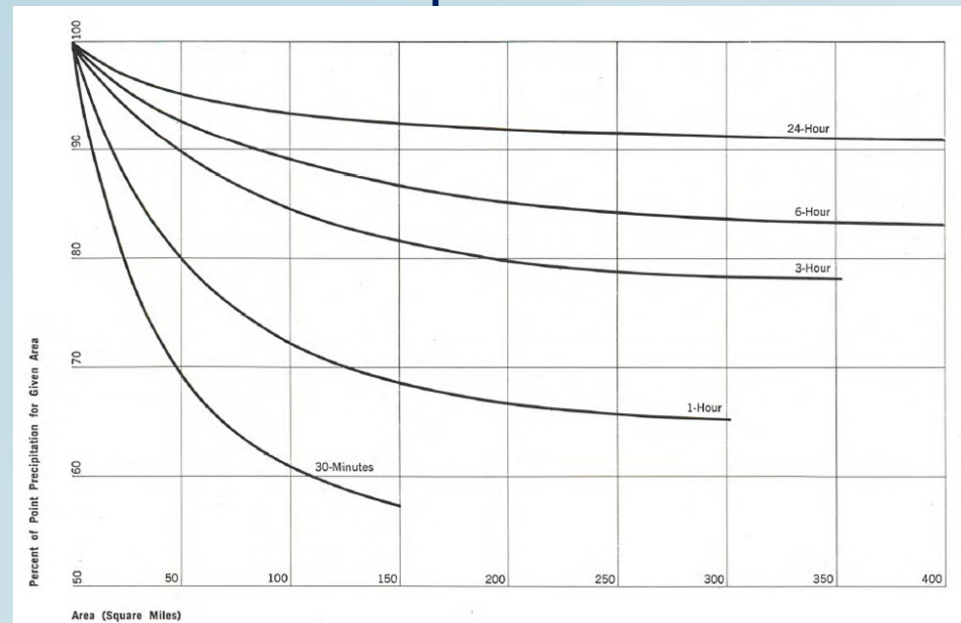
Colorado Springs Inset





# Site-Specific DARF

- NOAA defines an ARF as the ratio between area-averaged rainfall to the maximum depth at the storm center
- The most common sources for generalized ARFs from the NOAA Atlas 2 and Technical Paper 29





# Site-Specific DARF

- AWA calculated ARFs using a storm centered depth-area approach based on gridded hourly rainfall data from the Storm Precipitation Analysis System (SPAS)
  - Used SPAS hourly precipitation grids for calculation

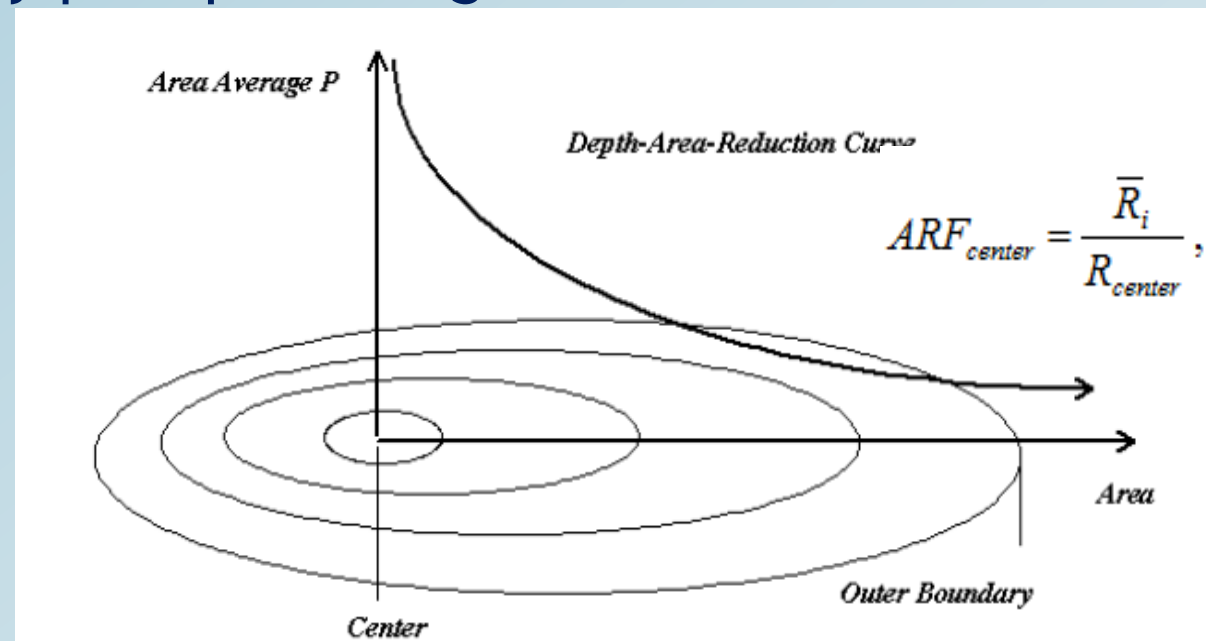


Figure 1 Illustration of Decay of Rainfall Depth from the Storm Center.



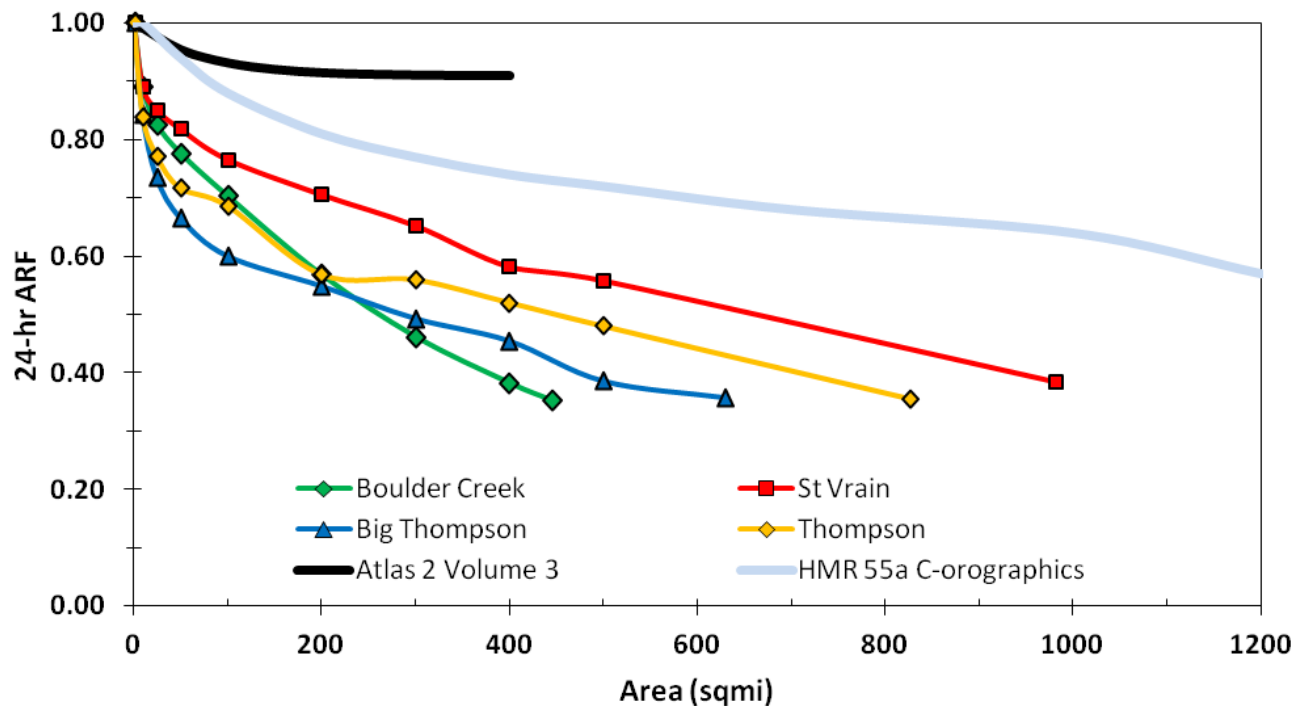
# Site-Specific DARF

- The hourly gridded rainfall data, based on gauge adjusted radar data, were used to derive basin specific ARFs
- Four basins Were used to derive the 24-hour basin specific ARFs
  - Boulder Creek, St Vrain, Big Thompson, Thompson River
- Calculated the point maximum (1-mi<sup>2</sup>) 24-hour rainfall within each basin (storm center)
- The maximum average basin 24-hour rainfall depth for standard area sizes (1-, 10-, 25-, 50-, 100-, 200-, 300-, 400-, and 500-mi<sup>2</sup>) up to the basin total area were calculated



# Site-Specific DARF

- 2013 ARFs decrease much more quickly than NOAA Atlas 2

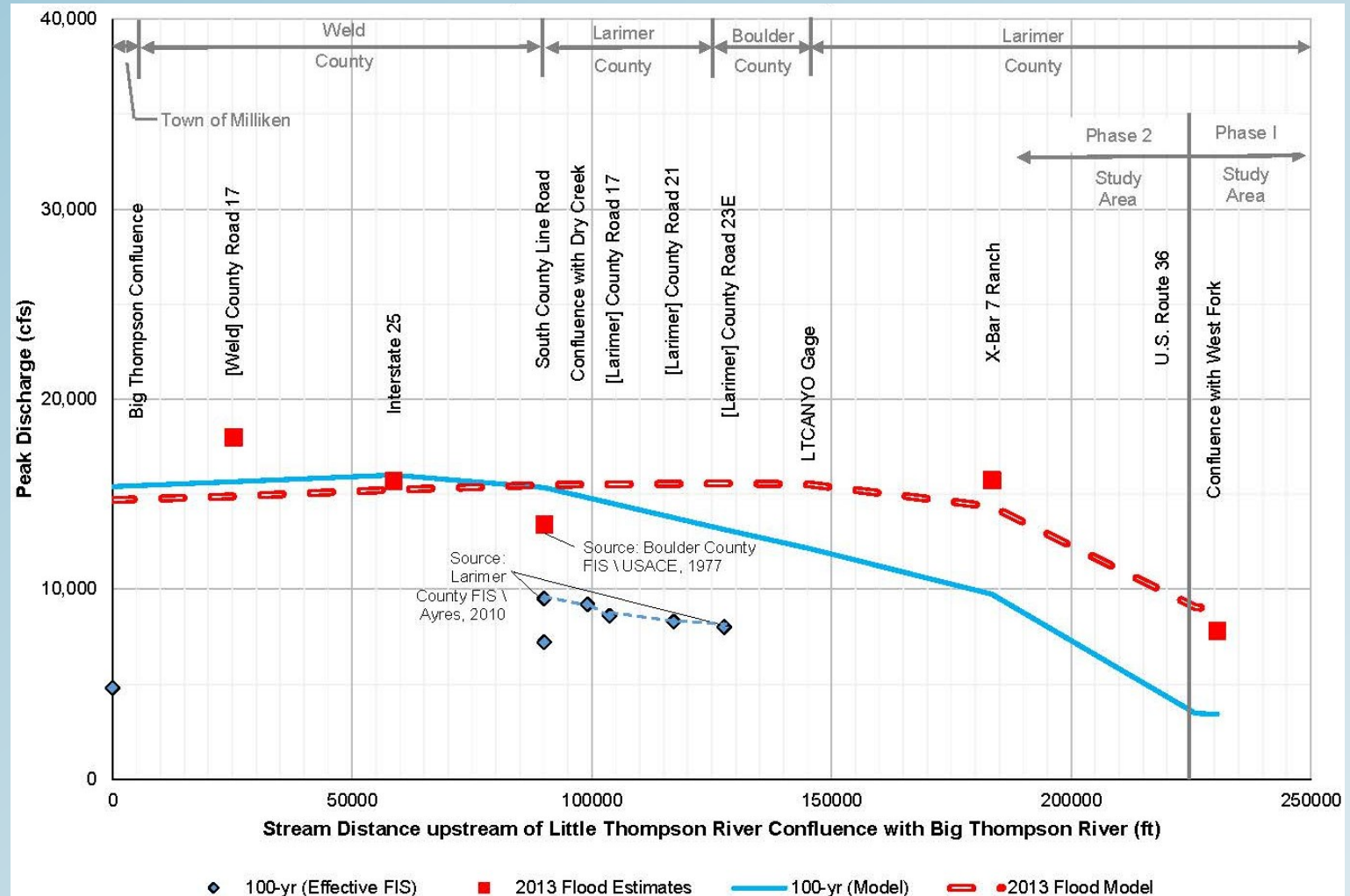


Basin	Area (mi <sup>2</sup> )	ARF
Boulder Creek	446	0.352
St. Vrain Creek	982	0.384
Big Thompson River	630	0.357
Thompson River	827	0.355



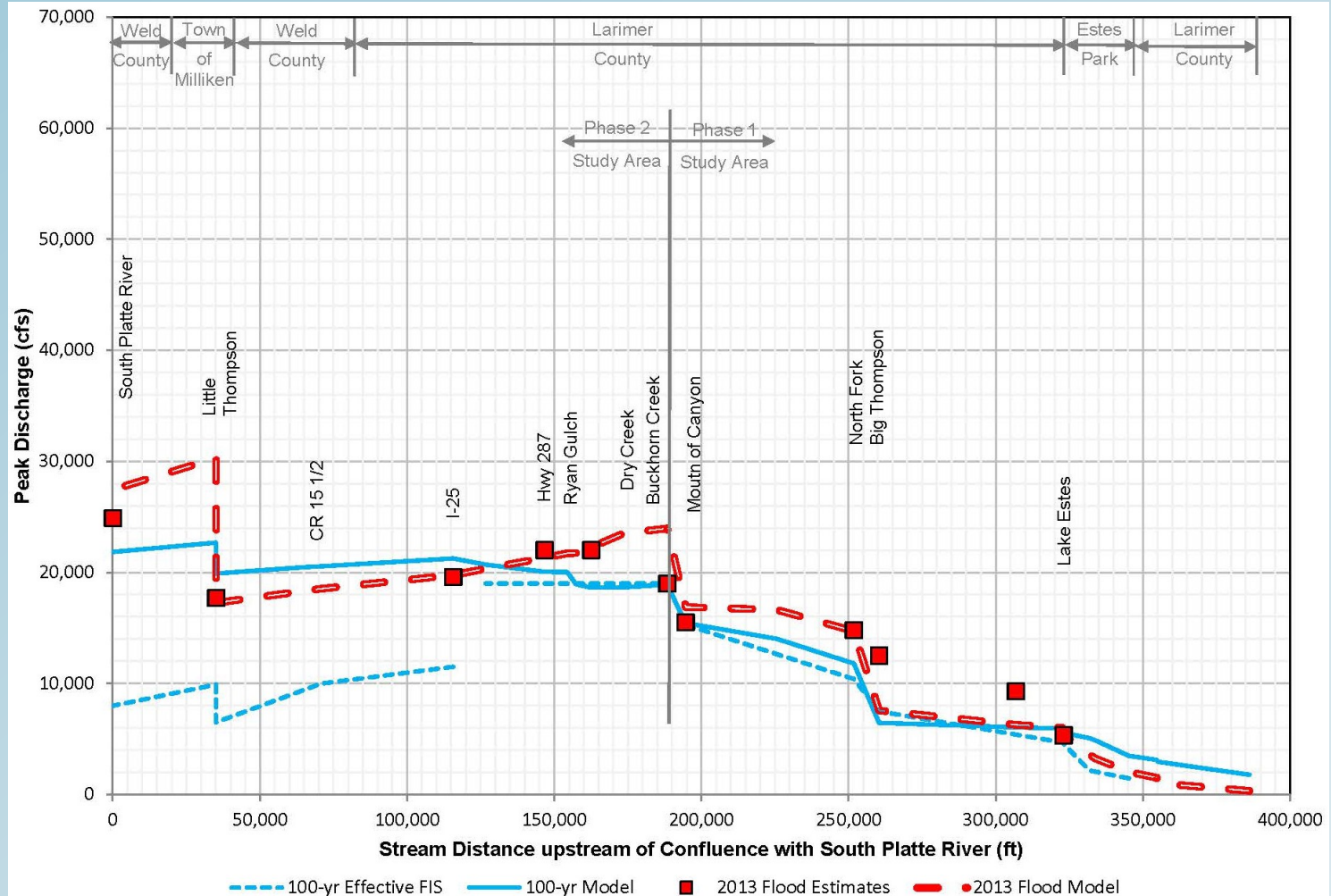
# Little Thompson River

## Peak Discharge Profile





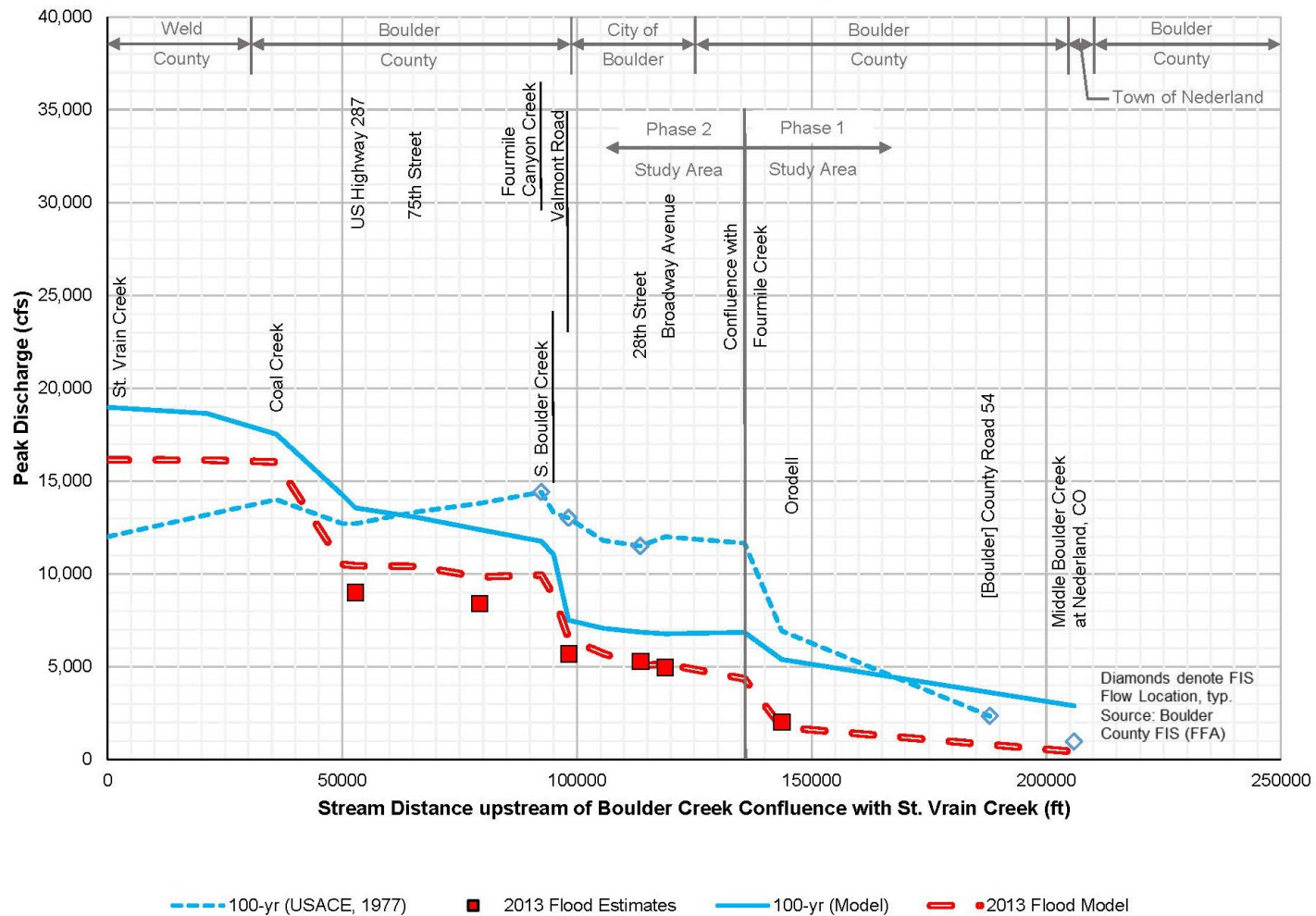
# Big Thompson River Peak Discharge Profile





# Boulder Creek

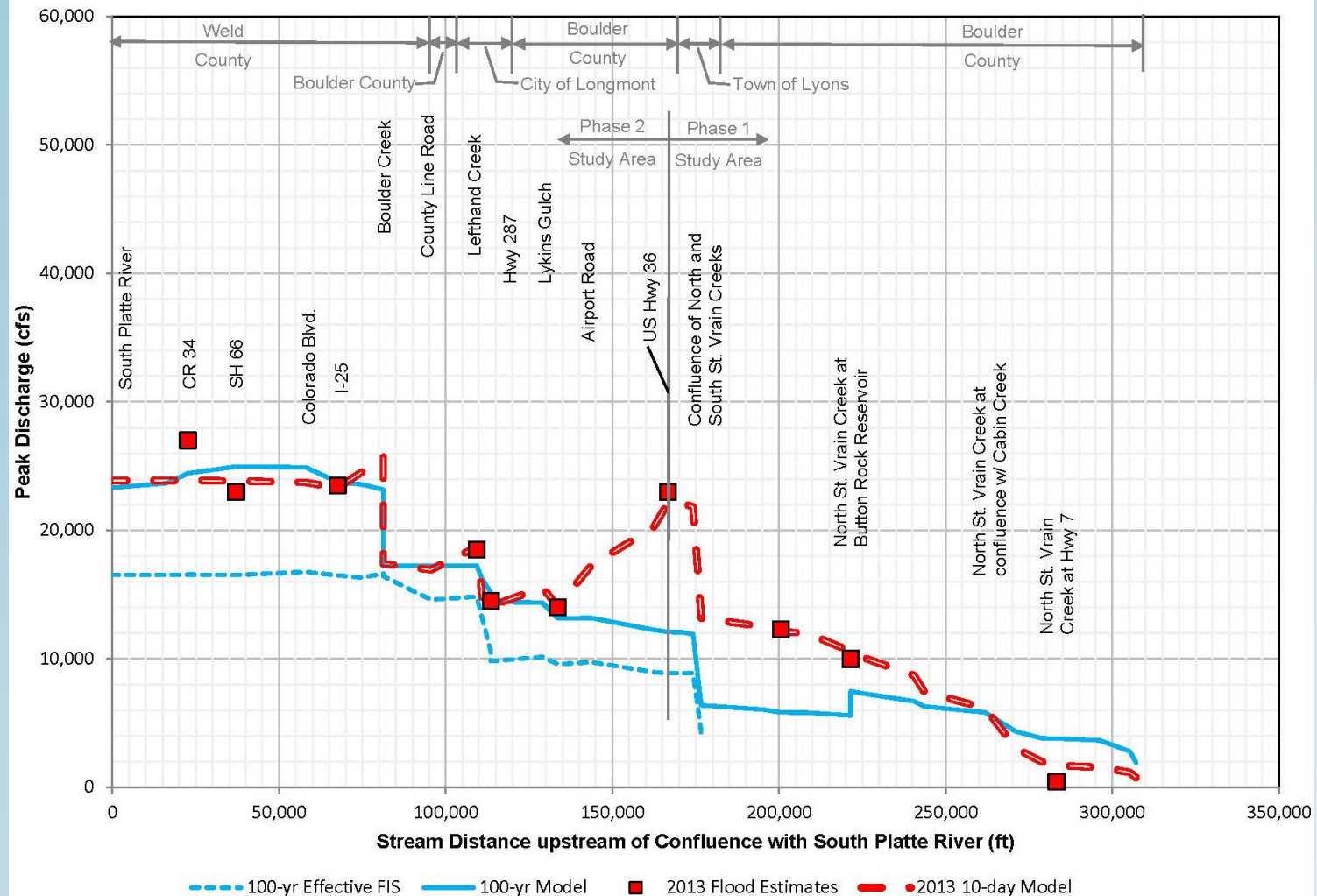
## Peak Discharge Profile





# St. Vrain Creek

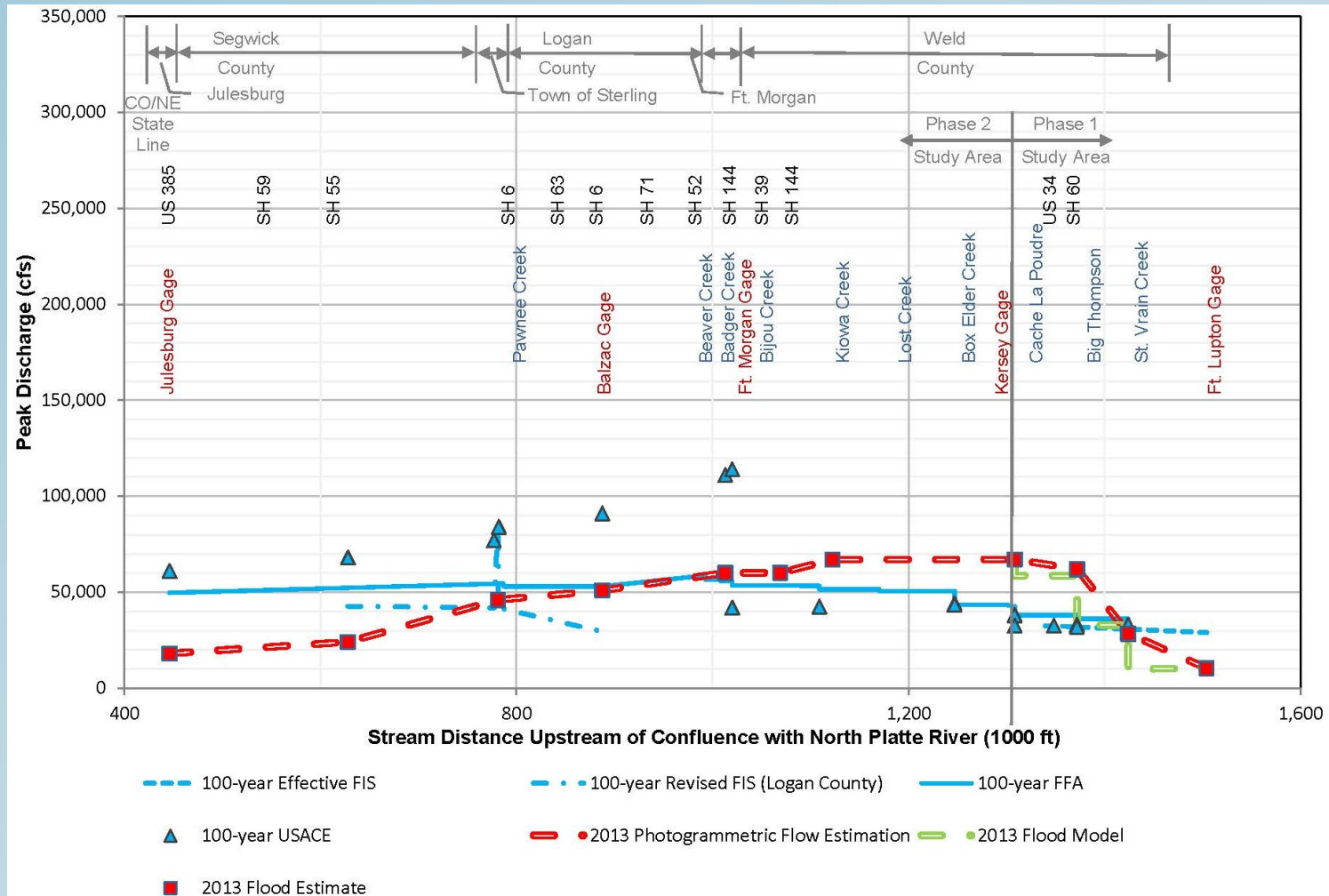
## Peak Discharge Profile





# South Platte River

## Peak Discharge Profile






# FEMA Best Available Data Memo

- Allows for and encourages the use of best available data
  - Which is defined as either the existing regulatory rates or the revised hydrology developed as part of this effort; whichever is more conservative
- Approved memos for both Phase 1 and Phase 2

U.S. Department of Homeland Security  
Region VII  
Denver Federal Center, Building 710  
P.O. Box 25107  
Denver, CO 80225-0107

 **FEMA**

November 6, 2014

RR-4145 CRCC

MEMORANDUM FOR: James McPherson, Federal Disaster Recovery Coordinator  
Colorado DR 4145

FROM: Roger Jones, Public Assistance Branch Director DR 4145  
Ryan Pietramali, Risk Analysis Branch Chief  
Portia Ross, EHP Advisor DR 4145

SUBJECT: Special Response Memorandum - Guidance for use of Colorado Front Range Hydrologic Evaluations (Phase I) in complying with 44 CFR Part 9 and Executive Order 11988 (Floodplain Management) for areas seeing an update.

Due to the catastrophic nature of the September 2013 flooding in the Colorado Front Range, the Federal Emergency Management Agency (FEMA) is committed to providing guidance for communities in situations where the effective Flood Insurance Rate Map (FIRM) and accompanying Flood Insurance Study (FIS) do not represent current conditions. In these instances, FEMA recommends the use of Best Available Data to inform recovery projects in regulatory floodplains. Using Best Available Data during rebuilding efforts ensures a resilient Colorado recovery while providing the maximum benefit to the local communities. It also ensures Federal, State, and local resources are used to mitigate future flood damage.

Following the 2013 flood event FEMA's Cooperating Technical Partner the Colorado Water Conservation Board (CWCB) partnered with the Colorado Department of Transportation (CDOT) to update the hydrology and determine current flood frequency discharges for the Colorado Front Range watersheds. These studies include analysis of historical flooding, flood frequency analysis, and detailed hydrologic rainfall runoff modeling. FEMA has reviewed the studies and determined that they meet the requirements set forth by the Standards for Flood Risk Analysis and Mapping, issued May 27, 2014 and may be considered Best Available Data by communities.

Best Available Data can be either: 1) the existing flood hazard data adopted by the community and reflected on the effective FIS or FIRM or 2) preliminary flood hazard data (new CWCB/CDOT data). In order to achieve the lower level of risk due to future flood events, the applicant must apply the more conservative data that anticipates the higher estimated flows and flood elevations, and therefore requires more regulatory restrictions on where and how structures

hydrologic Evaluation; Phase I

option process to formally accept the

approach with Phase I including r headwaters to the canyon mouths;

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c available through the CWCB [Pages/2013FloodResponse.aspx](https://www.cwcb.org/Pages/2013FloodResponse.aspx).

lude the same hydrologic analyses o the confluence with the South

1) projects funded through FEMA's recovery decisions. For FEMA ligated as of the date of this memo, special response memorandum or the data contained in the current effective FIRM and corresponding FIS, whichever anticipates higher flows and results in more effective conveyance and flood mitigation. Local floodplain development permits will be required.

[www.fema.gov](http://www.fema.gov)

[www.fema.gov](http://www.fema.gov)





# Floodplain Mapping and Management

## Floodplain Mapping

- SB245 requires CWCB to create new floodplain mapping for mainstem and tributary rivers affected by 2013 flood
- This mapping must include updated hydrology where applicable
- Erosion zones and debris flow zones also mapped, not regulatory
- 3-Year Program, \$6.8 million of state funds

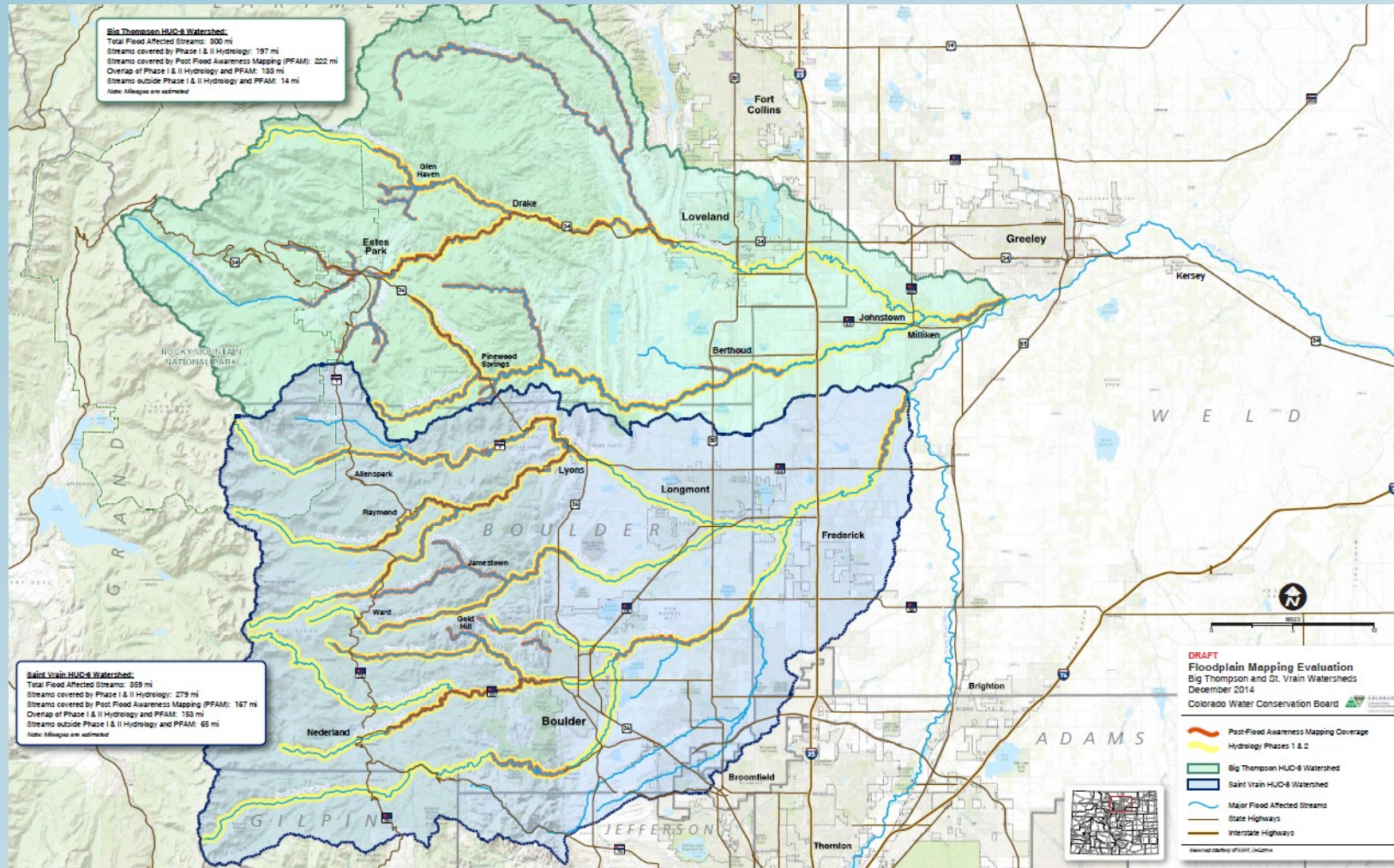
## Floodplain Management

- Local communities are strongly encouraged to use new maps for landuse decisions, mandatory after placement on FEMA maps
- This is not mandatory for NFIP or State of Colorado rules
- This will become mandatory when data is placed on FEMA maps





# Floodplain Mapping and Management





# Project Summary

- Innovative Techniques

- Agency partnership
- Teaming effort
- Rainfall runoff models of this size/scale
- Systematic calibration approach
- Regional DARF curves
- Watershed wide discharge profiles

- Great Partnership
- Career Defining Project
- Moving Colorado's Flood Recovery Forward