HYDROLOGY STUDY FOR FALL RIVER, UPPER BIG THOMPSON RIVER, BLACK CANYON CREEK AND DRY GULCH

DR. ANDREW EARLES, P.E., D.WRE
SHANNON TILLACK, P.E.
WRIGHT WATER ENGINEERS, INC.

April 19, 2016 Public Meeting

Overview of Presentation

- Motivation and purpose of study
- Overview of watersheds and published hydrology
- Approach to updating hydrology
- Progress and schedule
- Questions and comments

Motivation and Purpose

Funding Source

- Community Block Development Grant -

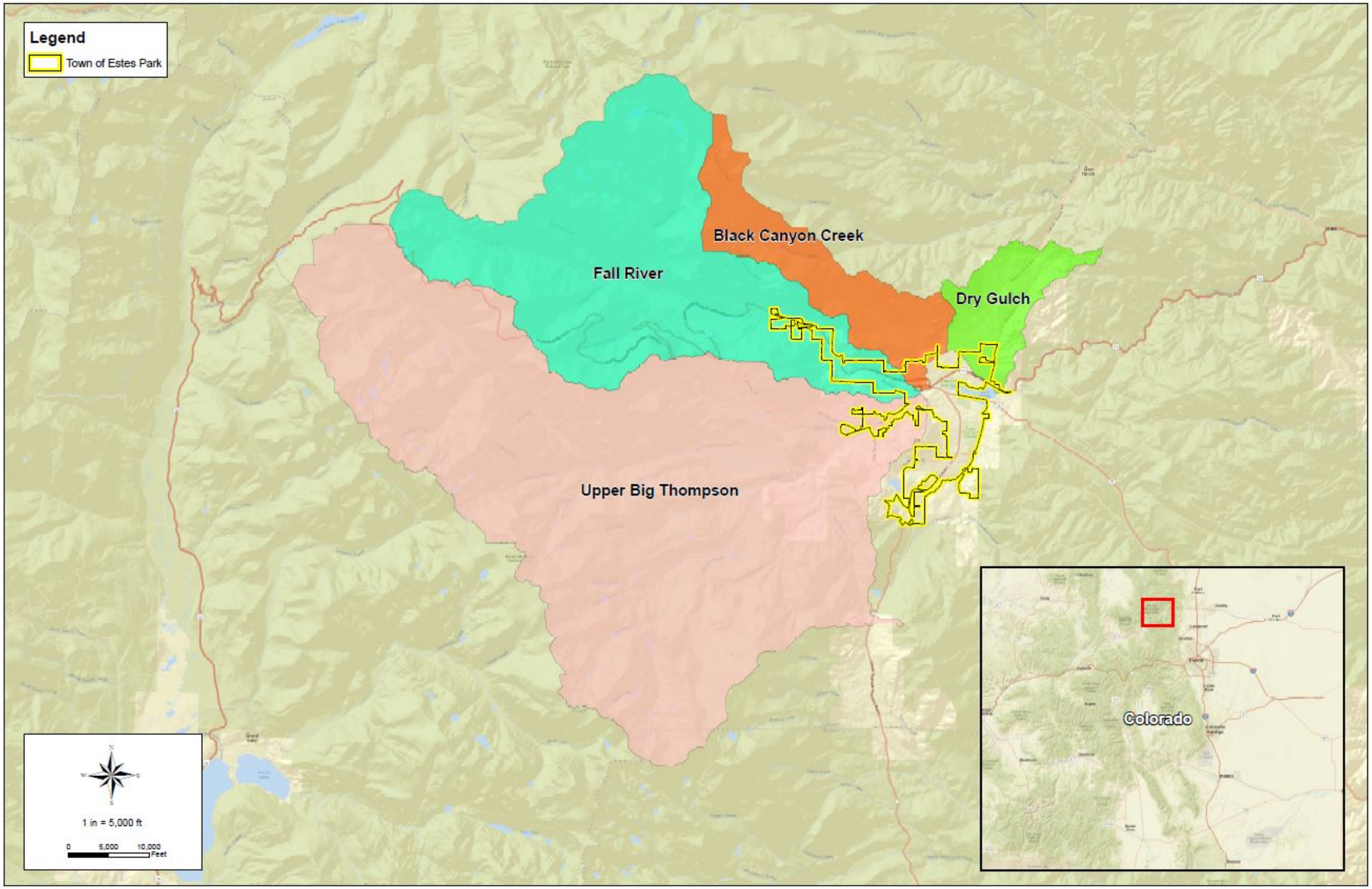
Disaster Recovery Round 2 Planning Grant

- Administered by the Colorado Department of Local Affairs

Flood Risk

- Four streams studied run through urban areas and affect infrastructure and property along streams.
- Causes of flooding include intense rainfall, which has the potential to occur when soils are saturated, or when snow is melting.
- Other potential hazards include increased runoff from wildfire areas, climate variability, and debris damming/breaching.
- Current peak discharge estimates published in Flood Insurance Study (FIS) date to 1977 (revised in 1985).

Overview of Watersheds



Severe Flood Damage from Mountain Streams

Goals of Study

- Develop peak discharge estimates for 2- (50%), 5- (20%) 10- (10%), 25- (4%), 50- (2%), 100- (1%), 200- (0.5%), and 500-year (0.2%) return period design events for design points in watersheds
- Review, evaluate and incorporate previous studies and observations from September 2013 flood in analysis
- Use multiple methods to assess reasonableness of modeled peak discharges
- Obtain expert peer review on results and recommendations
- Let science and sound engineering guide the way

Governing Principles

1. Use scientifically accepted methods and sound engineering principles

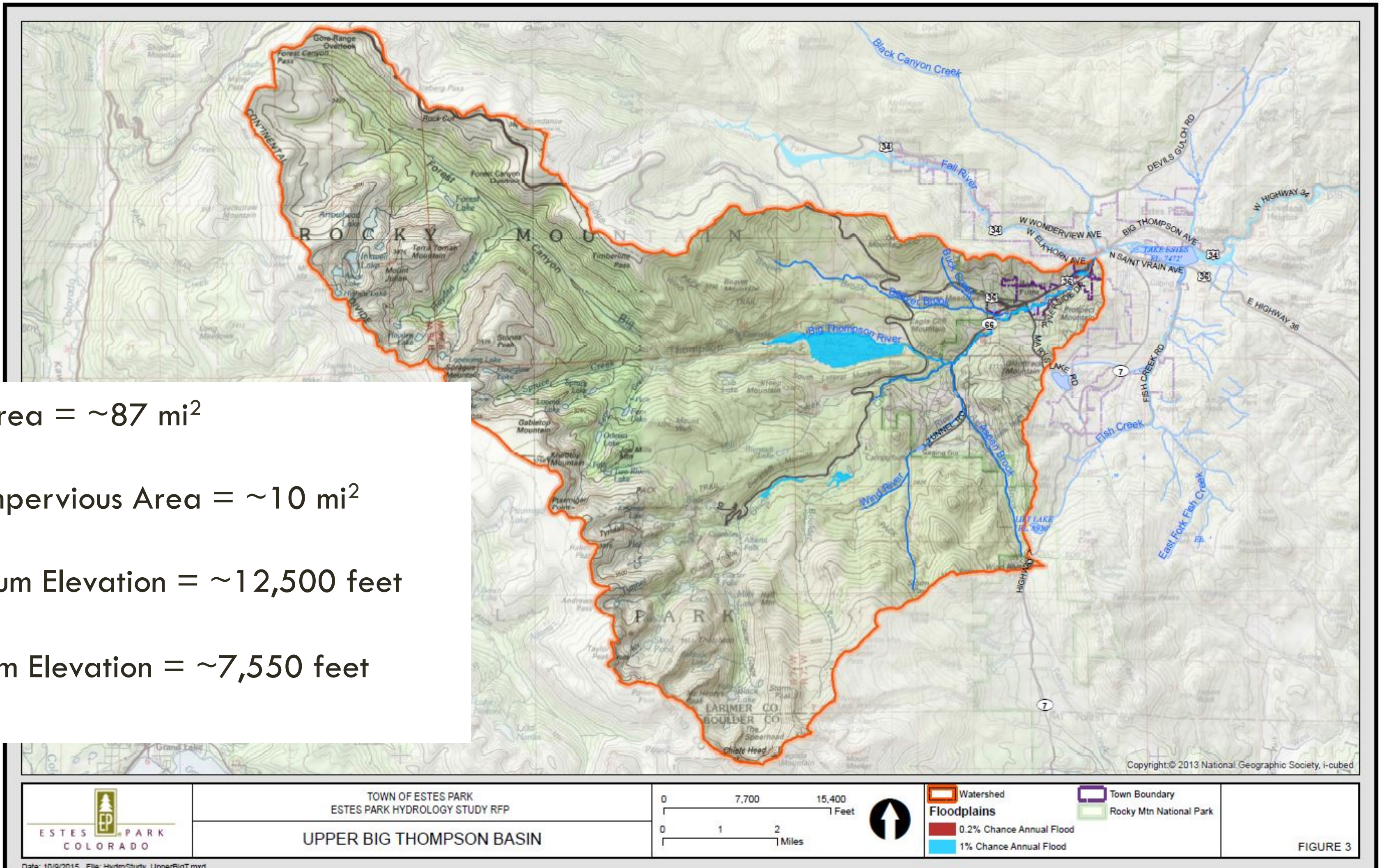
2. Tie hydrology back to reality by comparing with actual rainfall/runoff events

Revised hydrology will be used for:

- New floodplain mapping
- Floodplain Administration
- Planning and mitigation projects

Watersheds and Published Hydrology

Upper Big Thompson



Total Area = ~87 mi^2

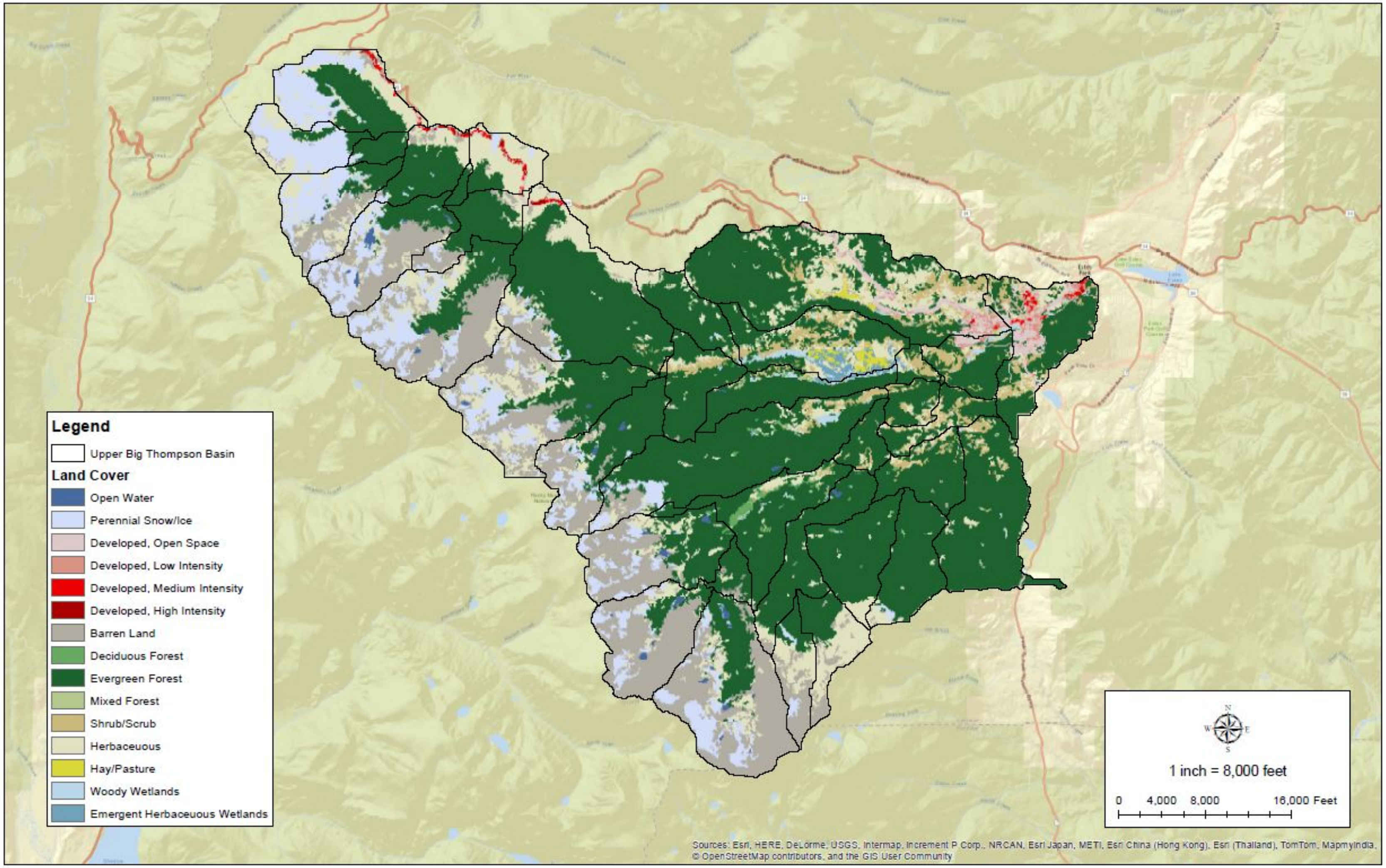
Total Impervious Area = ~10 mi^2

Maximum Elevation = ~12,500 feet

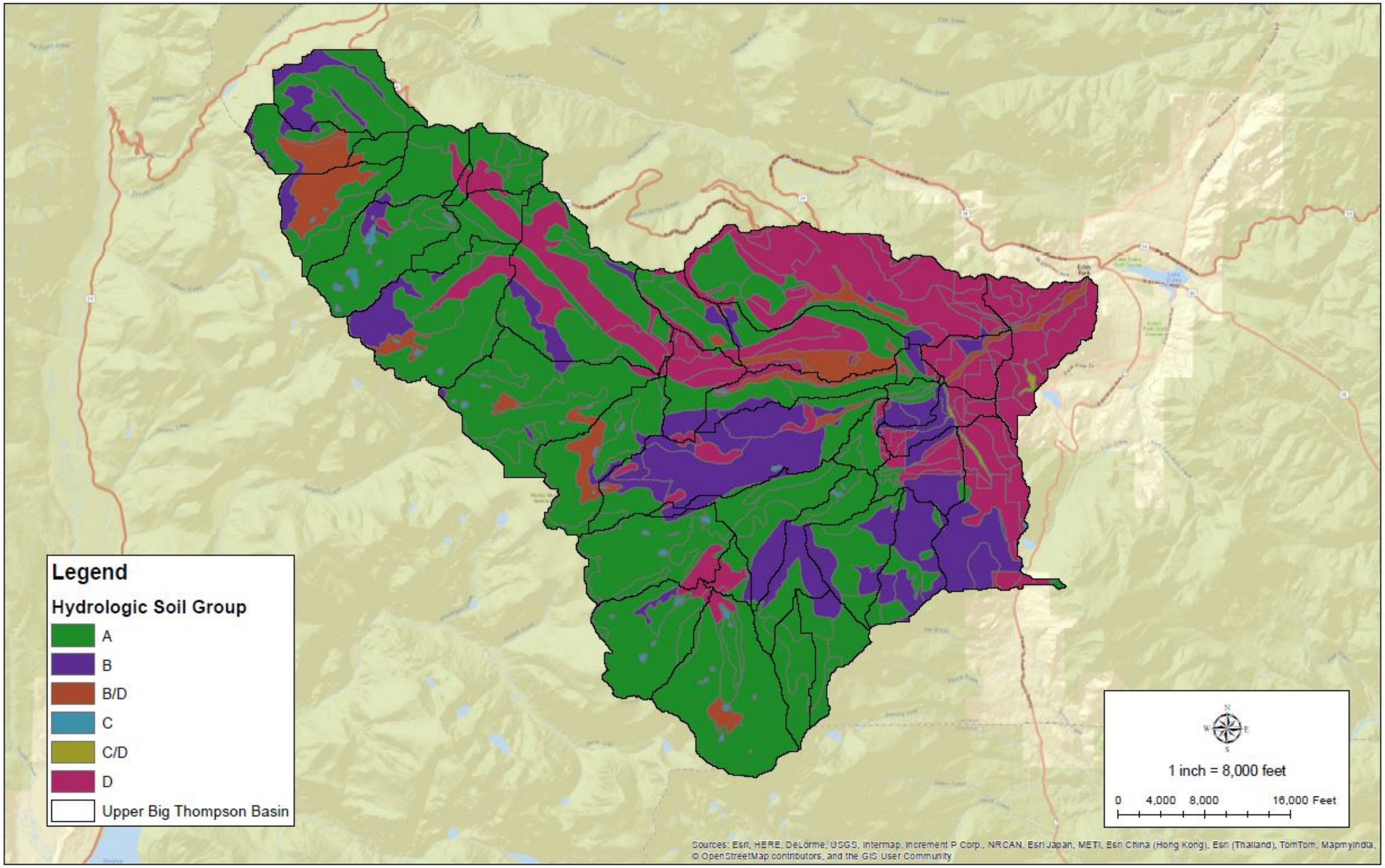
Minimum Elevation = ~7,550 feet

Upper Big Thompson

Upper Big Thompson Watershed



Upper Big Thompson Watershed



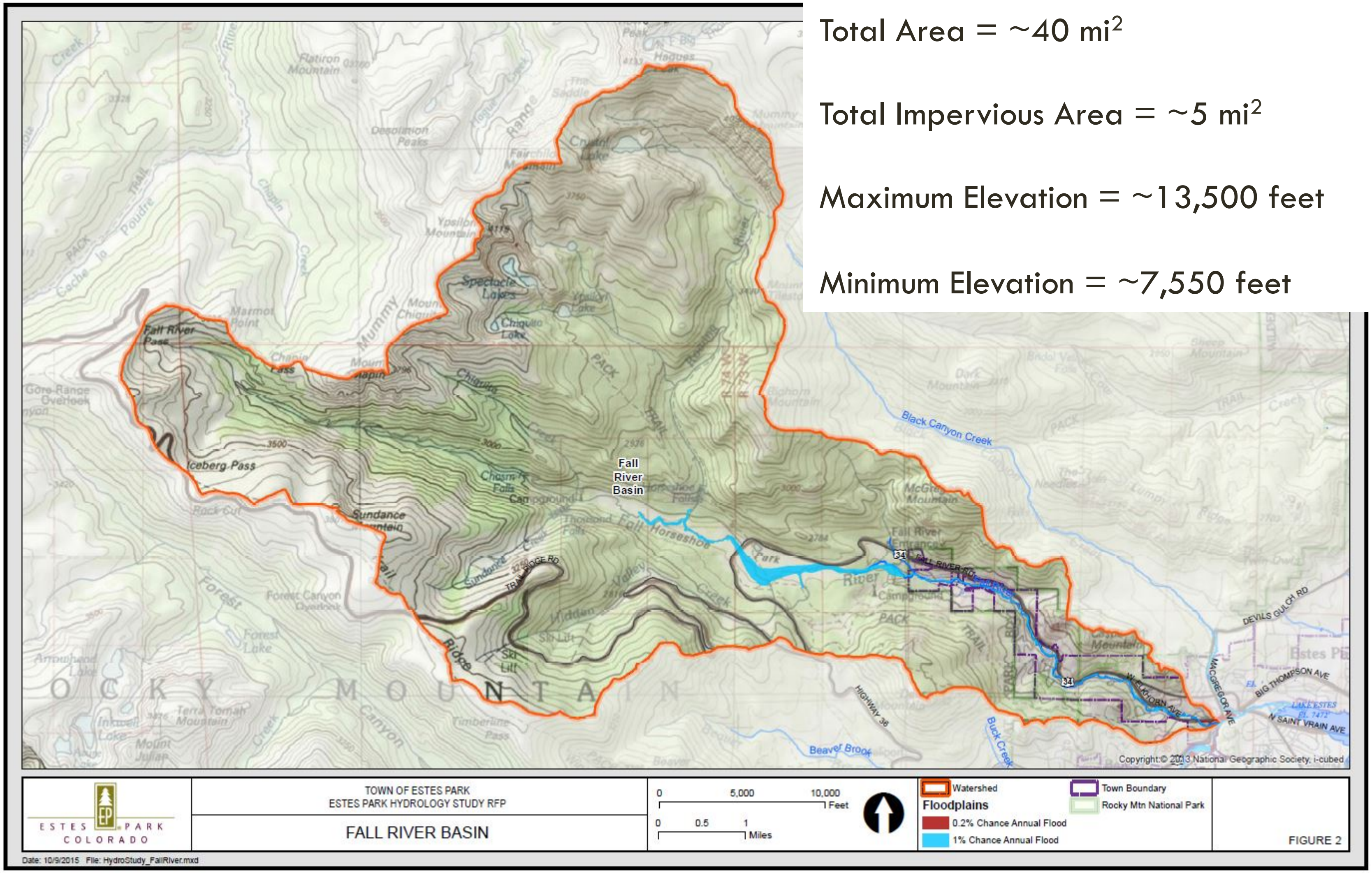
Fall River

Total Area = ~40 mi^2

Total Impervious Area = ~5 mi^2

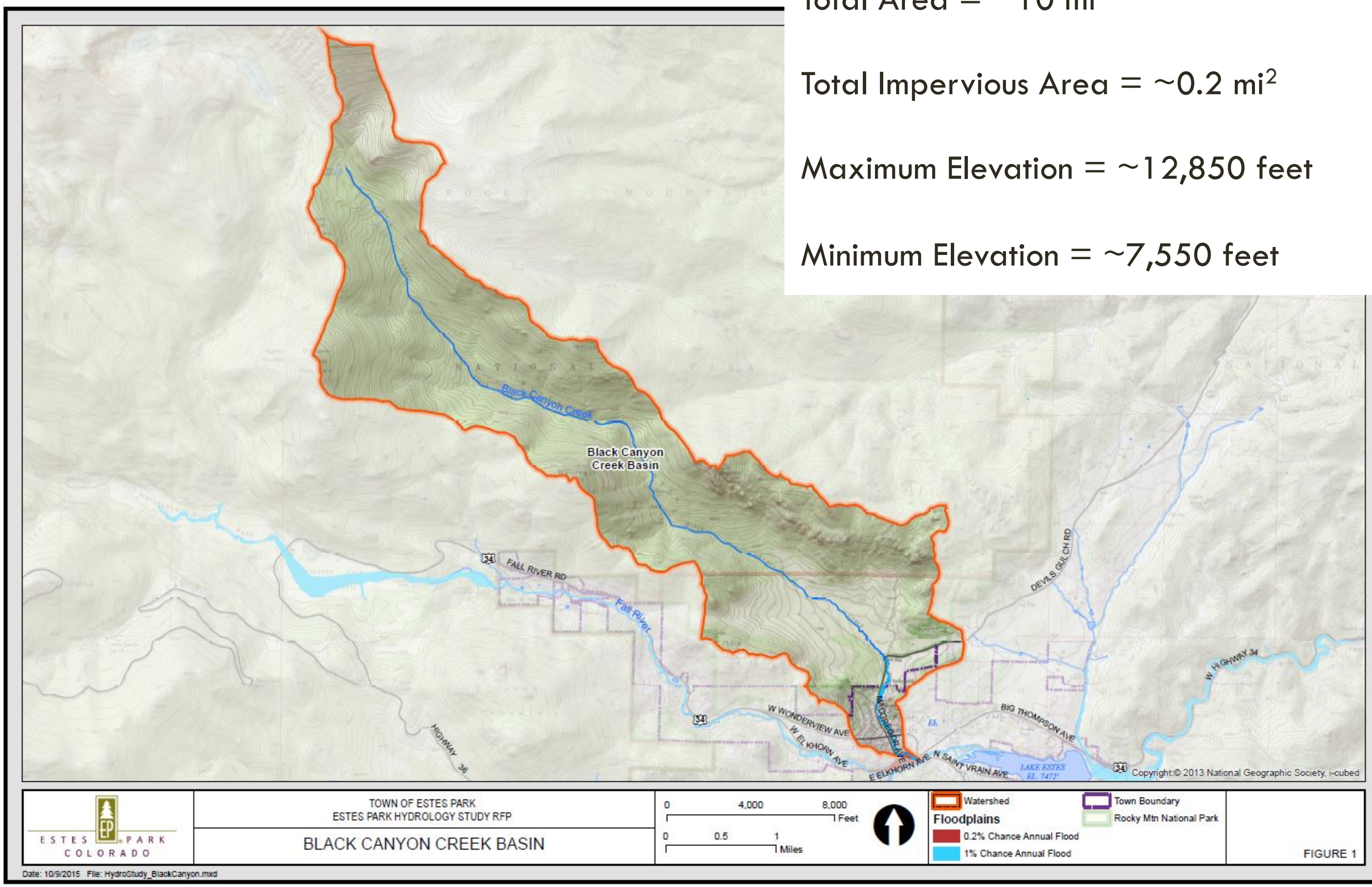
Maximum Elevation = ~13,500 feet

Minimum Elevation = ~7,550 feet



Fall River

Black Canyon Creek



Total Area = ~10 mi^2

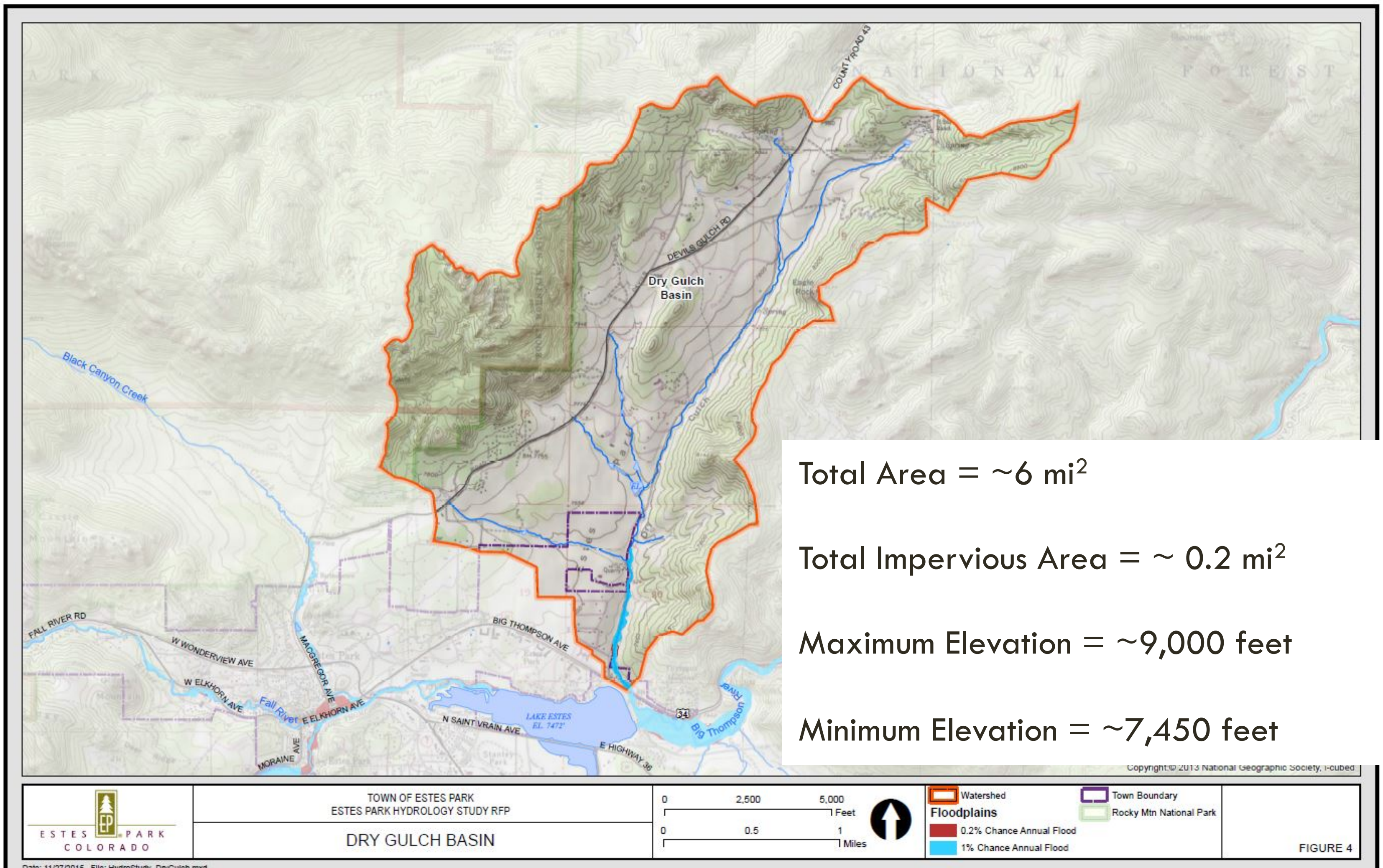
Total Impervious Area = ~0.2 mi^2

Maximum Elevation = ~12,850 feet

Minimum Elevation = ~7,550 feet

Black Canyon Creek

Dry Gulch



Total Area = ~6 mi^2

Total Impervious Area = ~ 0.2 mi^2

Maximum Elevation = ~9,000 feet

Minimum Elevation = ~7,450 feet

Dry Gulch

Hydrology from FIS

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Big Thompson River					
At Lake Estes Below Dry Gulch	156	2,250	3,800	4,700	7,200
At Lake Estes	137.5	1,510	1,1990	2,180	2,600
At St. Vrain Avenue	136.9	1,510	1,1990	2,180	2,600
At Confluence with Fall River	87.1	980	1,340	1,460	1,760
At Crags Drive in Estes Park	87	980	1,340	1,460	1,760
Black Canyon Creek					
At Confluence with Big Thompson River	10	130	200	230	310
At Estes Park Corporate Limits	9.3	120	190	210	290
Dry Gulch					
At Confluence with Big Thompson River	6.25	1,200	2,150	2,600	4,100
Fall River					
At Confluence with Big Thompson River	39.9	450	610	680	830
At Estes Park Corporate Limits	37.3	450	610	680	830
At Upstream Detailed Study Limit	37.3	450	610	680	830

Big Thompson River: Based on weighting of gauge records and regression equations

Black Canyon Creek: Based on regression equations

Dry Gulch: Based on regression equations

Fall River: Based on weighting of gauge records and regression equations

Other Studies and Relevant Documents

- Previous Studies
  - Natural Resource Conservation Service, December 2013, *Colorado Front Range Flood of 2013: Peak Flow Estimates at Selected Mountain Stream Locations*
  - CDOT Study, August 2014, *Hydrologic Evaluation of the Big Thompson Watershed Post September 2013 Flood Event*
  - Matrix Design Group, August 2014, *Fish Creek Watershed Hydrology Evaluation Public Infrastructure Project*
  - Farnsworth Group, May 2015, *Final Drainage Report: Dry Gulch Road Rehabilitation*

Other Studies and Relevant Documents

- Relevant Documents
  - Department of Natural Resources and Colorado Water Conservation Board, November 2010, *Rules and Regulations for Regulatory Floodplains in Colorado*
  - United States Department of Agriculture, June 1986, *Urban Hydrology for Small Watersheds, Technical Release 55*
  - American Society of Engineers, 2009, *Curve Number Hydrology*
  - US Army Corps of Engineers, May 2009, *HEC-GeoHMS Geospatial Hydrologic Modeling Extension User's Manual*
  - US Army Corps of Engineers, July 2015, *Hydrologic Modeling System HEC-HMS User's Manual*

Approach

HEC-geo HMS

USGS Bulletin 17B Flood Frequency Analysis

September 2013 Peak Discharge Frequency Analysis

Unit Peak Discharge Comparisons

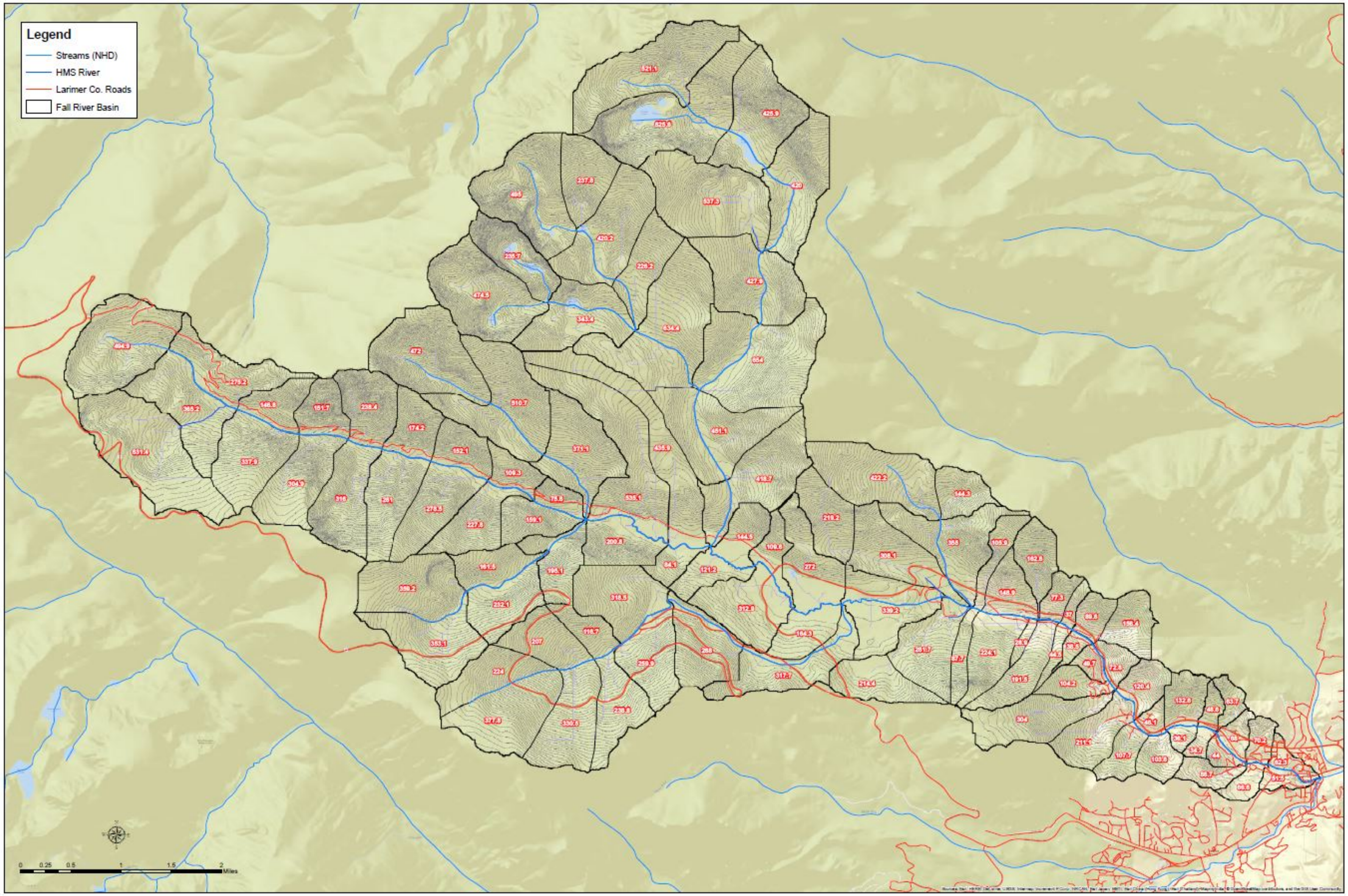
Multi-faceted Approach

- Hydrologic Model (HEC-geo HMS) – use best available mapping with design storm approach
- Stream gauge peak flow analysis, evaluation of concurrent peak discharges and saturated/runoff conditions
- Comparison of unit peak discharges from 2013 data in context of rainfall experienced
- Previous studies

HEC-HMS

- Hydrologic Modeling System (HMS) developed by United States Army Corps of Engineers Hydrologic Engineering Center (HEC)
- Commonly applied to estimate peak discharges in modeling studies for un-gauged watershed or watersheds with limited periods of gauge records.
- Accepted by FEMA

Watershed Discretization



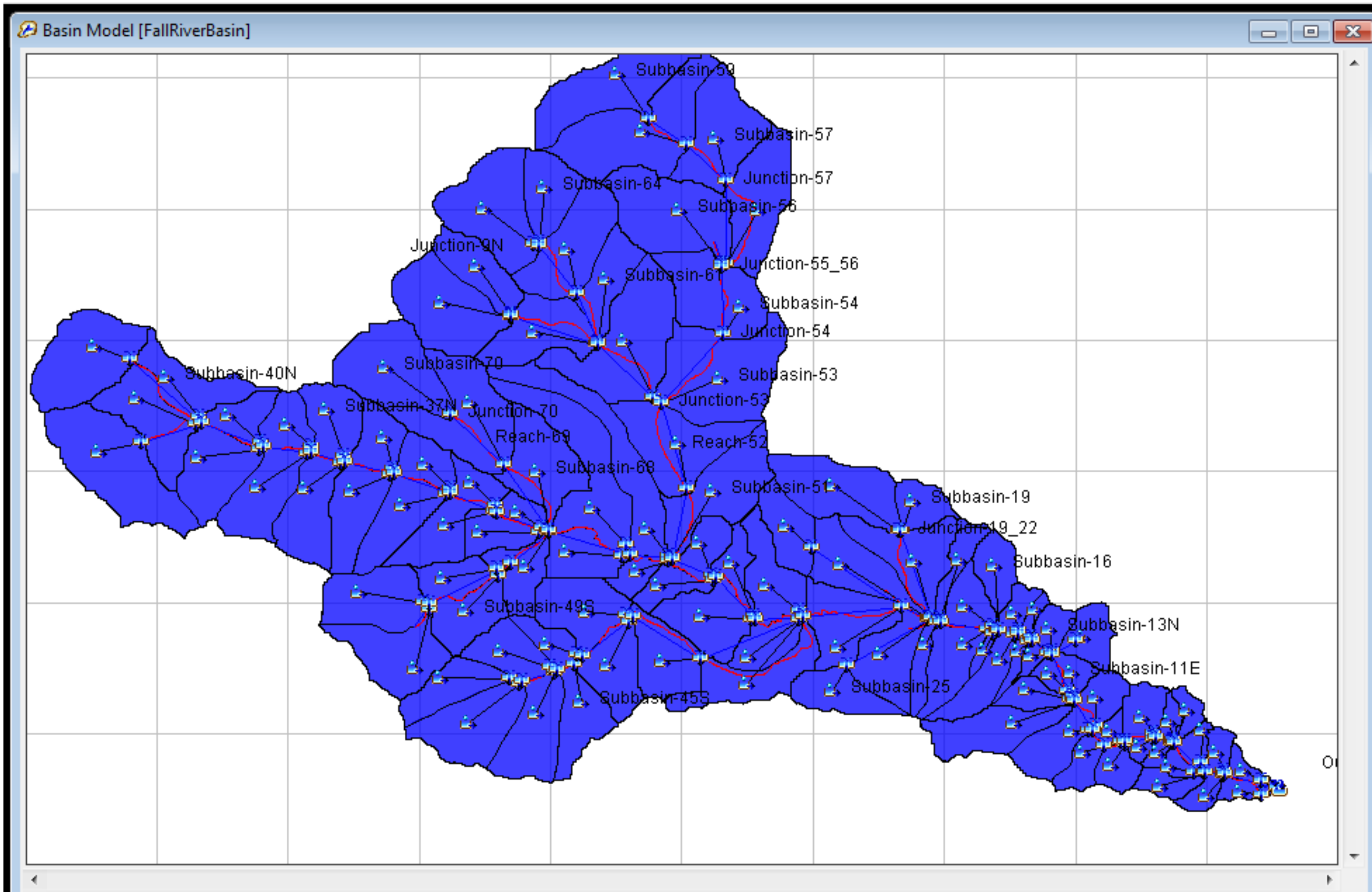
Data

- Watershed Map
- Digital Elevation Model
- Stream Data
- Soil Survey
- Land Cover

Model Parameterization

- Automated through use of GIS
  - Curve Number
  - Basin Geometric Parameters (slopes, flow accumulation, length to centroid)
  - Flow Path Geometry (lengths, slopes and elevations of conveyance elements)
- Other Parameters
  - Unit Hydrograph
  - Channel Routing
  - Storage Assumptions
  - Crossings

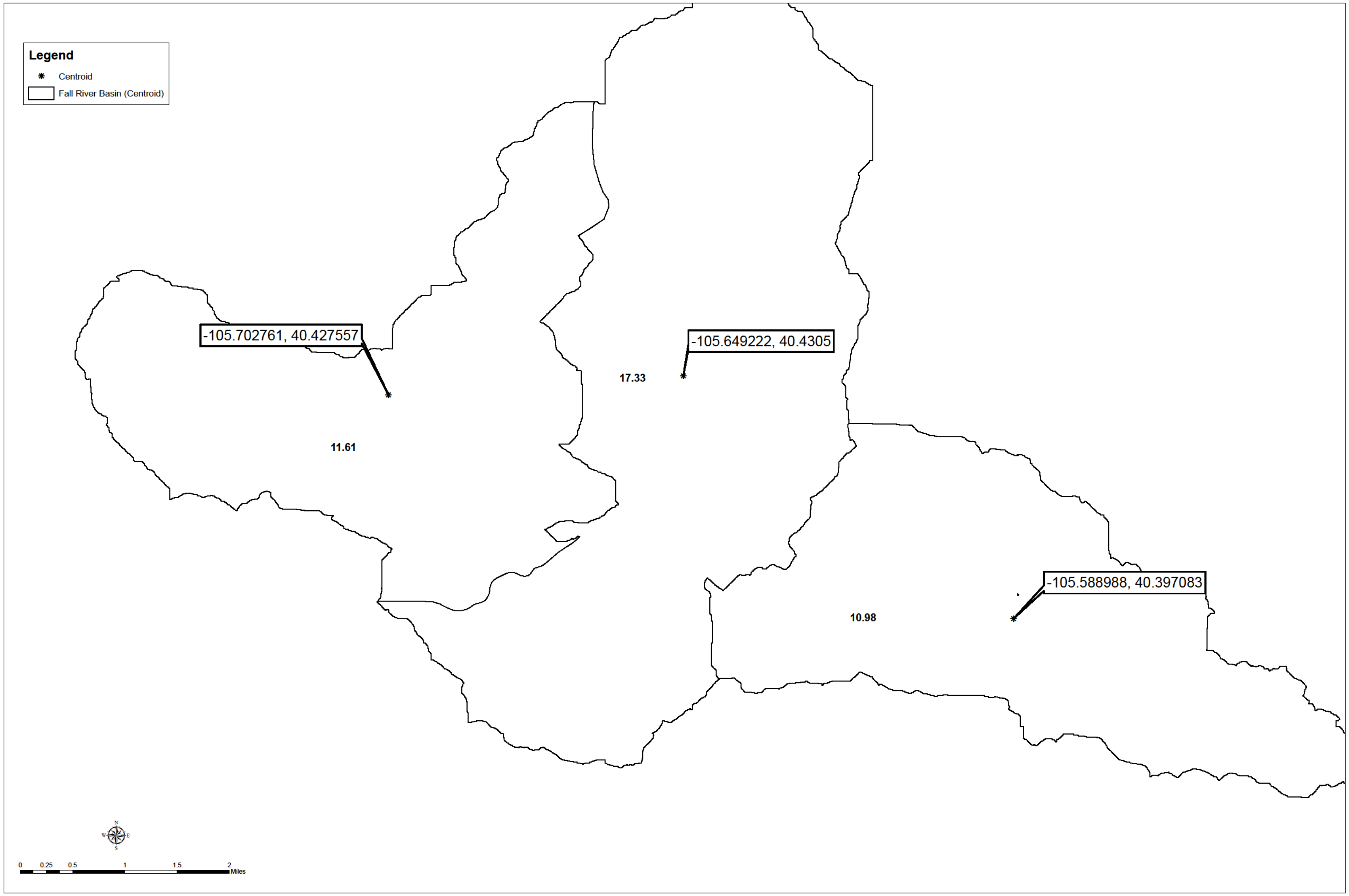
HEC-HMS Model Network

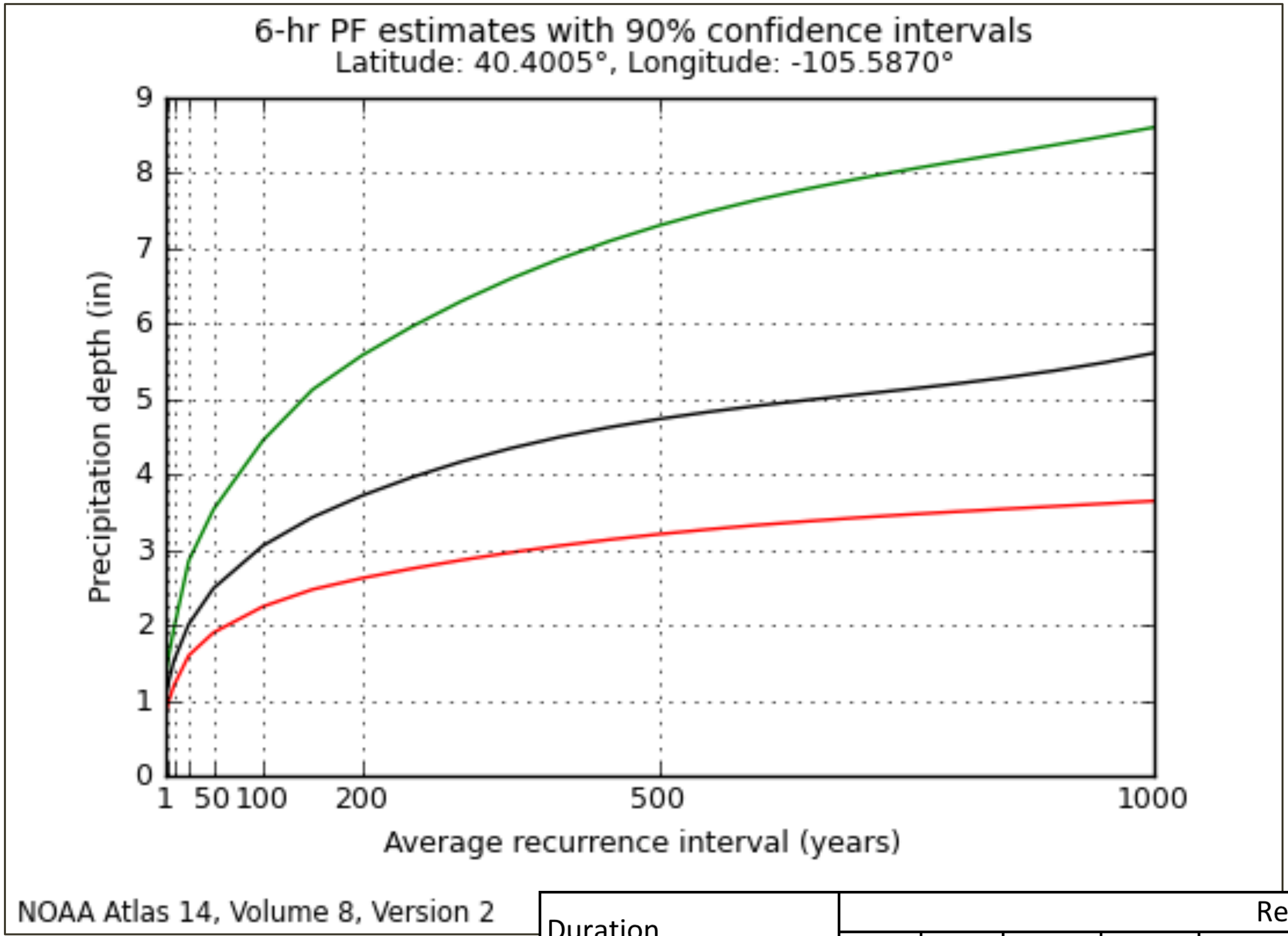


Precipitation Data

- NOAA Atlas 14
  - 1-, 3-, 6-, 12, and 24-hour depths
- Sub-watersheds assigned to precipitation zones to account for orographic effects

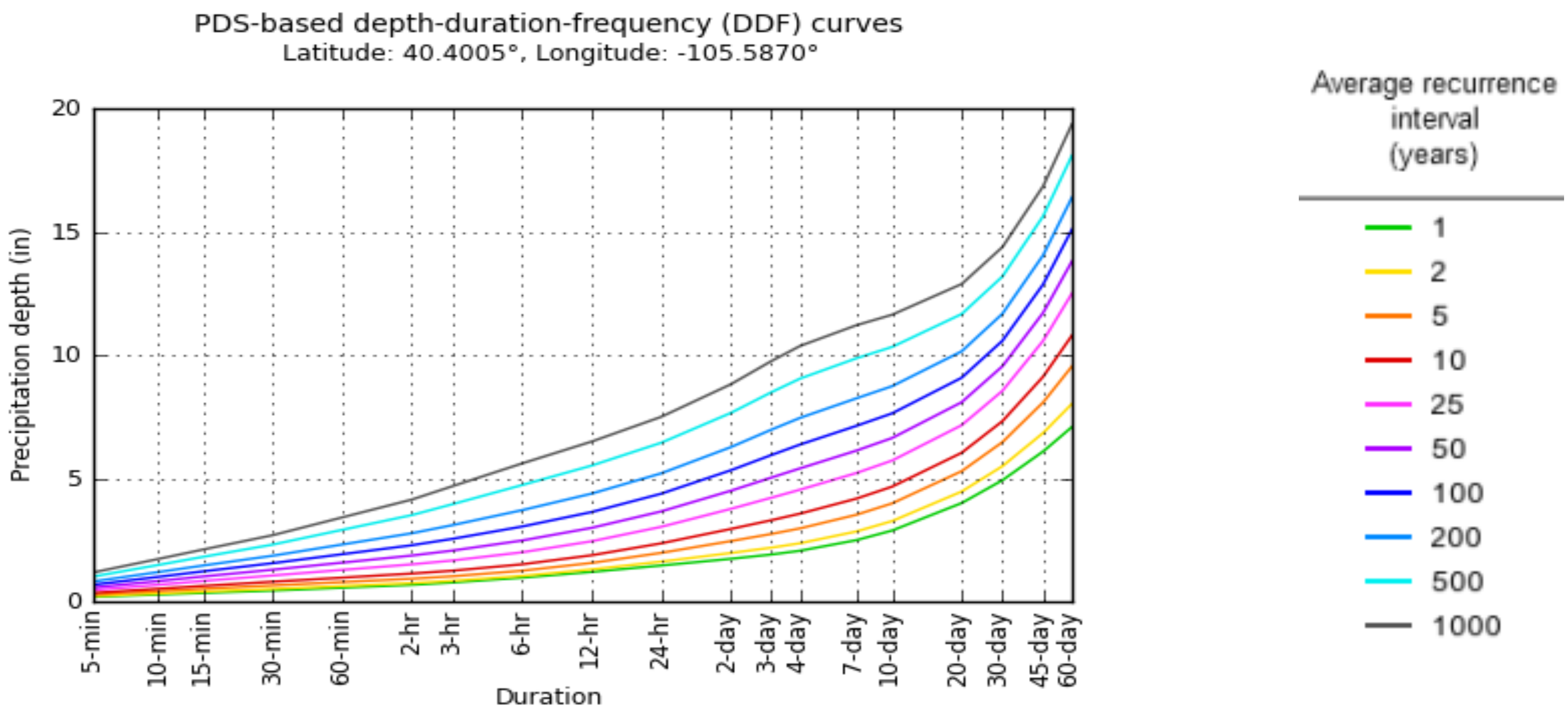
Precipitation Data

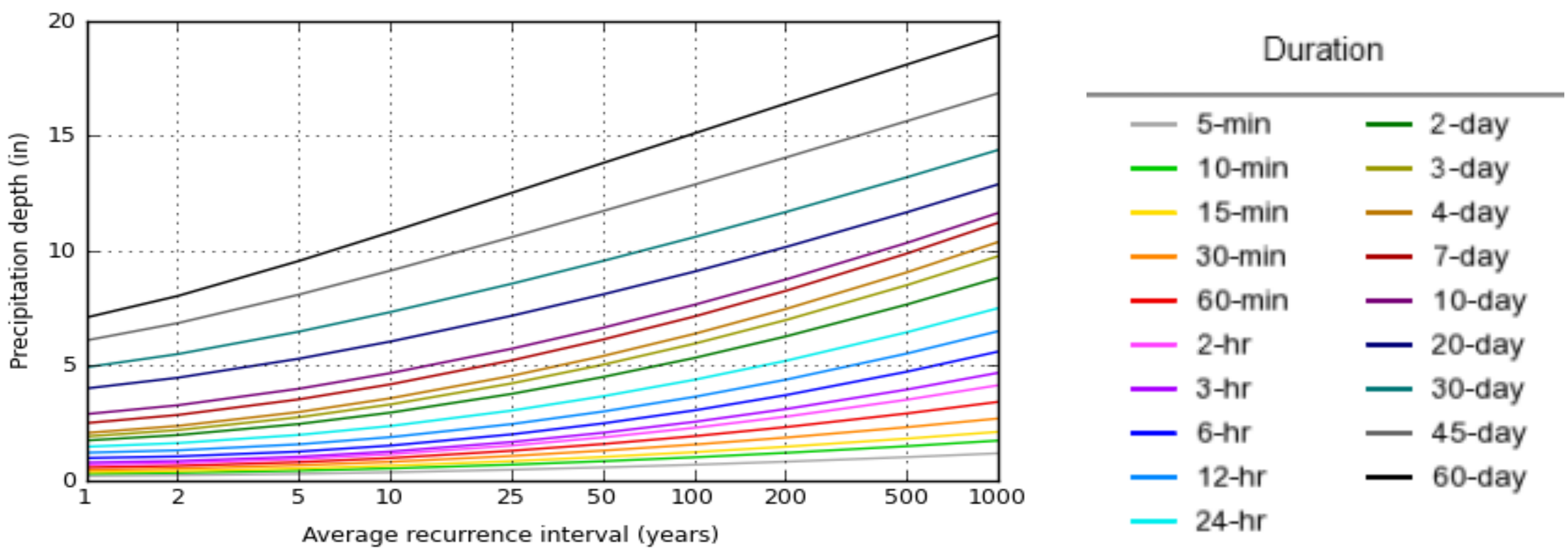




NOAA ATLAS 14

Duration	Return Period									
	1	2	5	10	25	50	100	200	500	1000-yr
5-min:	0.20	0.23	0.30	0.36	0.48	0.58	0.69	0.83	1.02	1.19
10-min:	0.30	0.34	0.44	0.53	0.70	0.85	1.02	1.21	1.50	1.74
15-min:	0.36	0.42	0.53	0.65	0.85	1.03	1.24	1.48	1.83	2.12
30-min:	0.46	0.53	0.67	0.82	1.07	1.30	1.57	1.87	2.32	2.70
60-min:	0.58	0.65	0.81	0.98	1.30	1.59	1.93	2.33	2.92	3.42
2-hr:	0.69	0.76	0.94	1.15	1.52	1.88	2.30	2.78	3.52	4.15
3-hr:	0.79	0.85	1.04	1.26	1.68	2.08	2.56	3.11	3.96	4.69
6-hr:	0.98	1.05	1.26	1.52	2.01	2.49	3.05	3.72	4.74	5.61
12-hr:	1.22	1.32	1.58	1.89	2.46	3.00	3.64	4.39	5.52	6.50
24-hr:	1.48	1.63	1.99	2.37	3.04	3.67	4.38	5.21	6.45	7.50



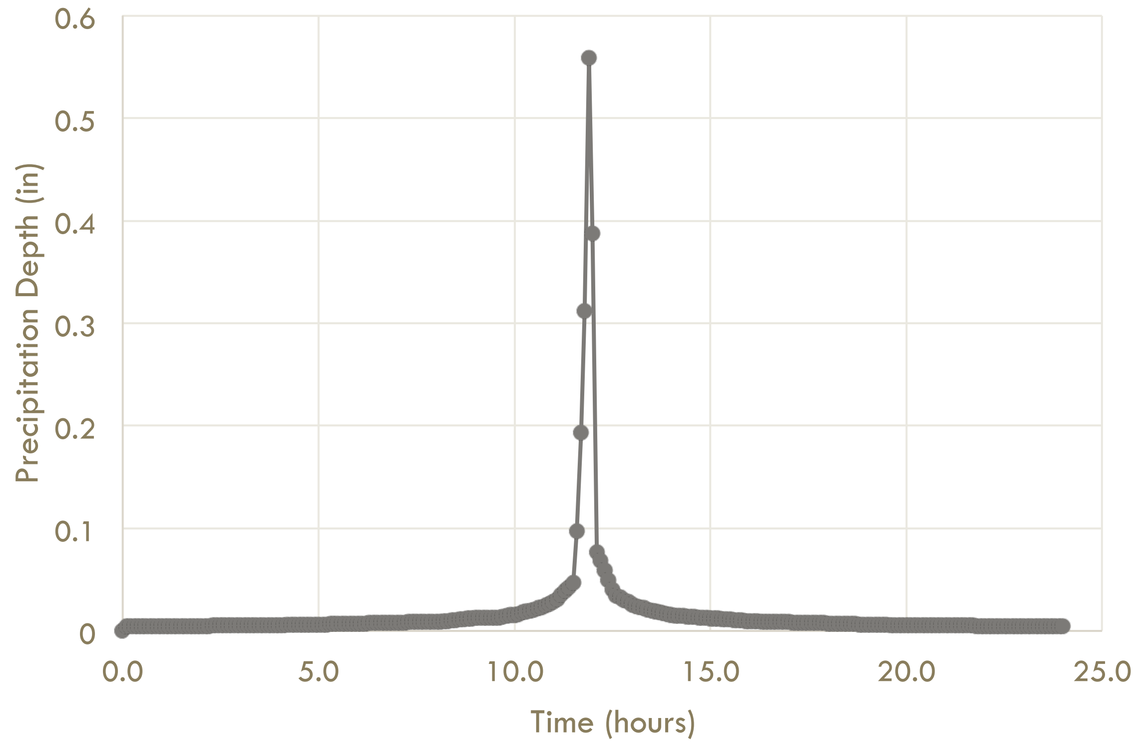


NOAA Atlas 14, Volume 8, Version 2

Created (GMT): Thu Mar 31 21:09:59 2016

Precipitation Input – Design Storms

- SCS Type II Distributions
- 24-hour, 12-hour, 6-hour, 3-hour



Depth Area Reduction Factors

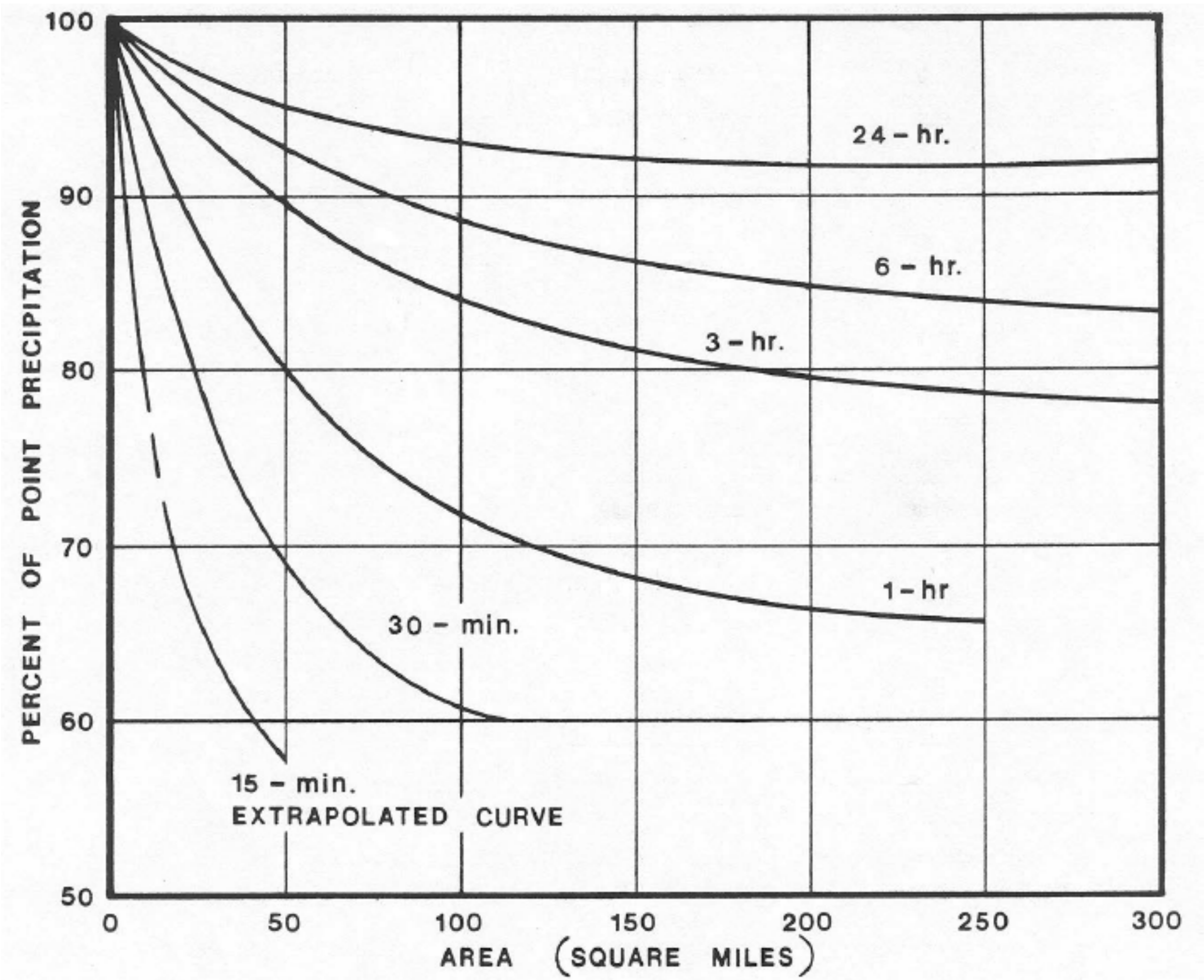
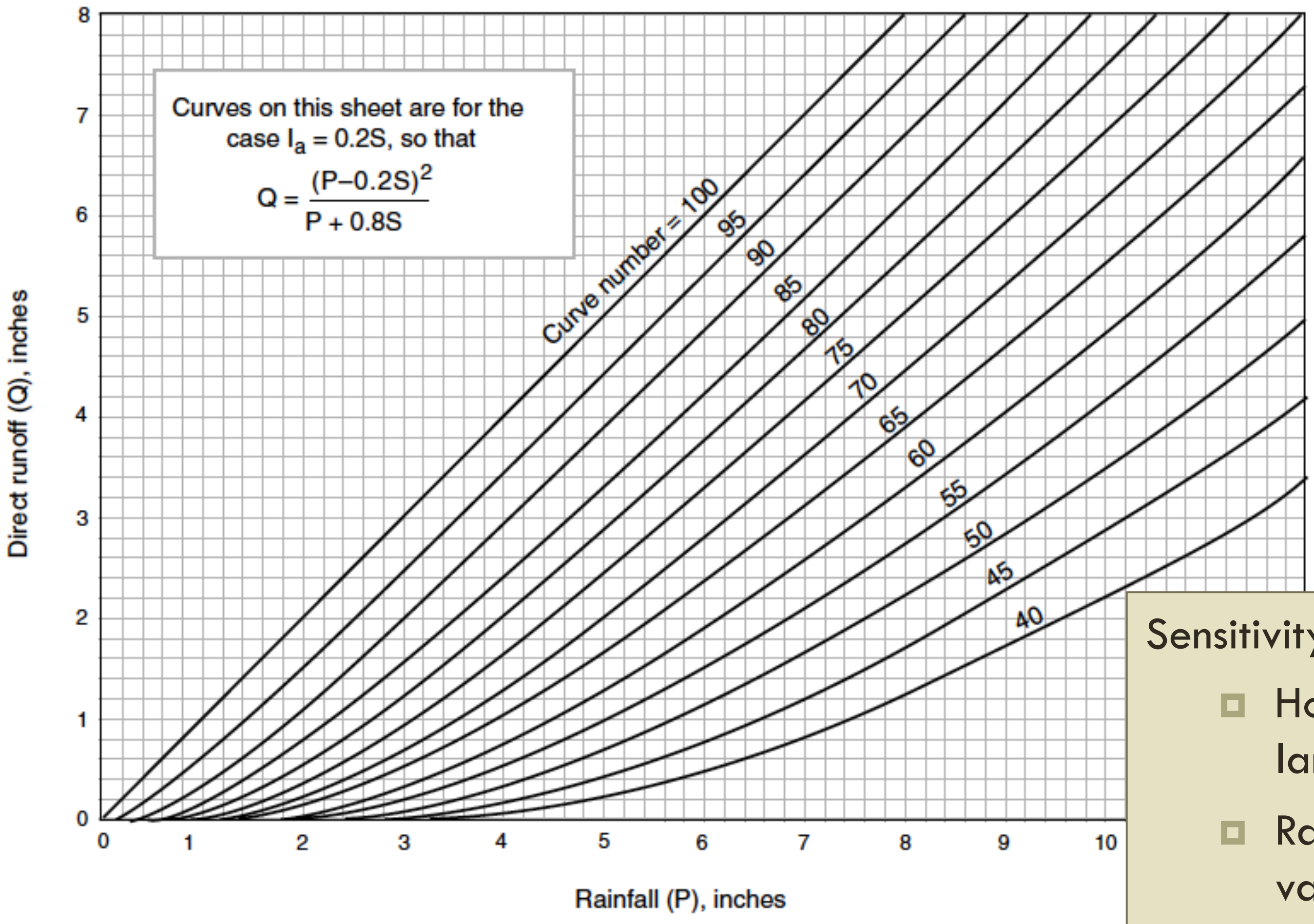


Figure 5-13. Depth reduction factor (DRF) curves for infrequent storm events

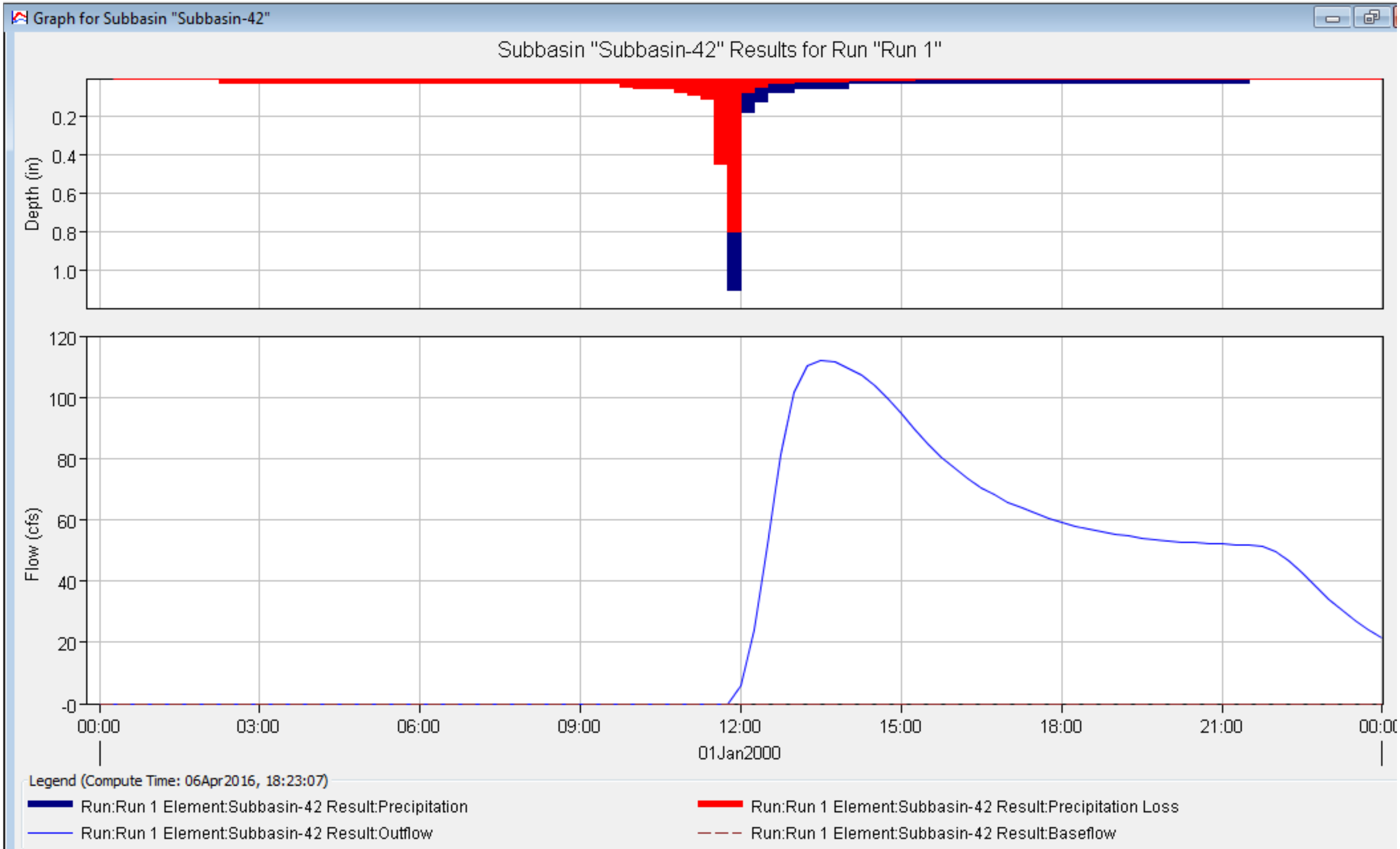
Technical Details – Loss Method



Sensitivity

- Homogeneity of sub-basin land use
- Ranges of published CN values based on soil type
- Antecedent Moisture Condition

Technical Details – Loss Method



Technical Details – Unit Hydrograph

- Snyder unit hydrograph figure and equations

$$t_l = C_t(L_{ca}\,L)^{0.3} \tag{9.24}$$

where
- t_l = the lag time (hr) between the center of mass of the rainfall excess for a specified type of storm and the peak rate of flow
- L_{ca} = the distance along the main stream (mi) from the base to a point nearest the center of gravity of the basin
- L = length of the main stream channel (mi) from the base outlet to the upstream end of the stream and including the additional distance to the watershed divide
- C_t = a coefficient representing variations of types and locations of streams

- Snyder UH used for Fish Creek study
- Cp and Ct factors are calibration parameters

Technical Details – Unit Hydrograph

- Snyder unit hydrograph figure and equations

$$t_{lR} = t_l + 0.25(t_R - t_r) \tag{9.27}$$

where t_{lR} = the adjusted lag time (hr)
t_l = the original lag time (hr)
t_R = the desired unit-hydrograph duration (hr)
t_r = the original unit-hydrograph duration = $t_l/5.5$ (hr)

$$Q_P = \frac{640\, C_P A}{t_{lR}} \tag{9.28}$$

where Q_P = the peak discharge (cfs)
C_P = the coefficient accounting for flood wave and storage conditions; it is a function of lag time, duration of runoff-producing rain, effective area contributing to peak flow, and drainage area
A = the watershed size (mi^2)
t_{lR} = the lag time (hr)

Technical Details - Routing

- Kinematic wave equations and illustration

$$Q = \alpha A^m$$

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q$$

$$\frac{\partial A}{\partial t} + \alpha m A^{(m-1)} \frac{\partial A}{\partial x} = q$$

This equation is a kinematic-wave approximation of the equations of motion. HEC-HMS represents the overland flow element as a wide rectangular channel of unit width; $\alpha=1.486S^{1/2}/N$ and $m=5/3$. N is not Manning's n, but rather an overland flow roughness factor (Table 6-1).

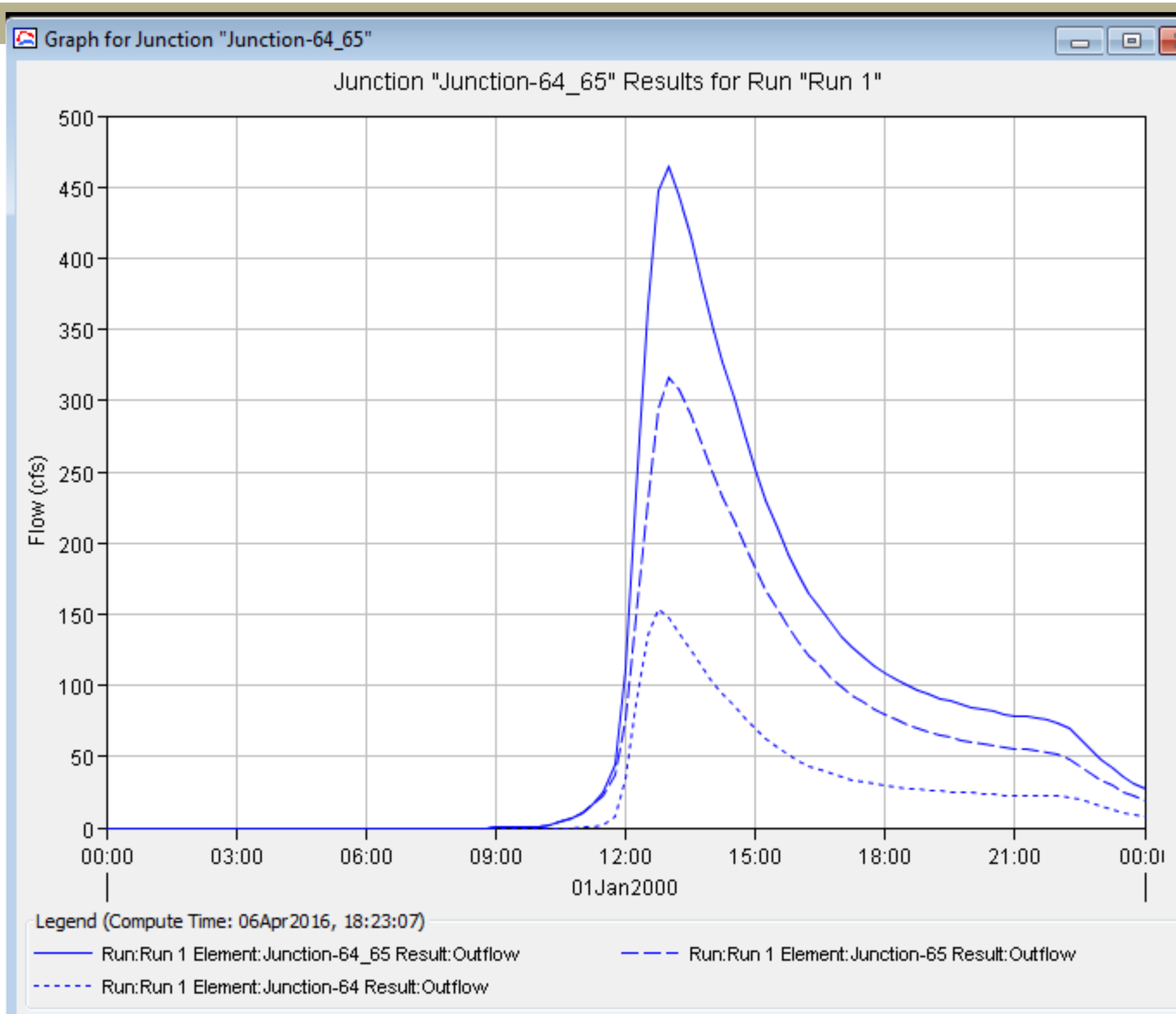
- Sensitivity
  - Initial roughness parameters selected based on typical channel characteristics
  - Slope/velocity considerations

Technical Details - Routing

Table 8-2. Kinematic wave routing model information requirements

Description
Shape of the cross section: Is it trapezoidal, rectangular, or circular?
Principle dimension: bottom width of the channel, diameter of the conduit.
Side slope of trapezoidal shape.
Length of the reach.
Slope of the energy grade line.
Manning *n*, roughness coefficient for channel flow.

Technical Details – Hydrograph Superposition



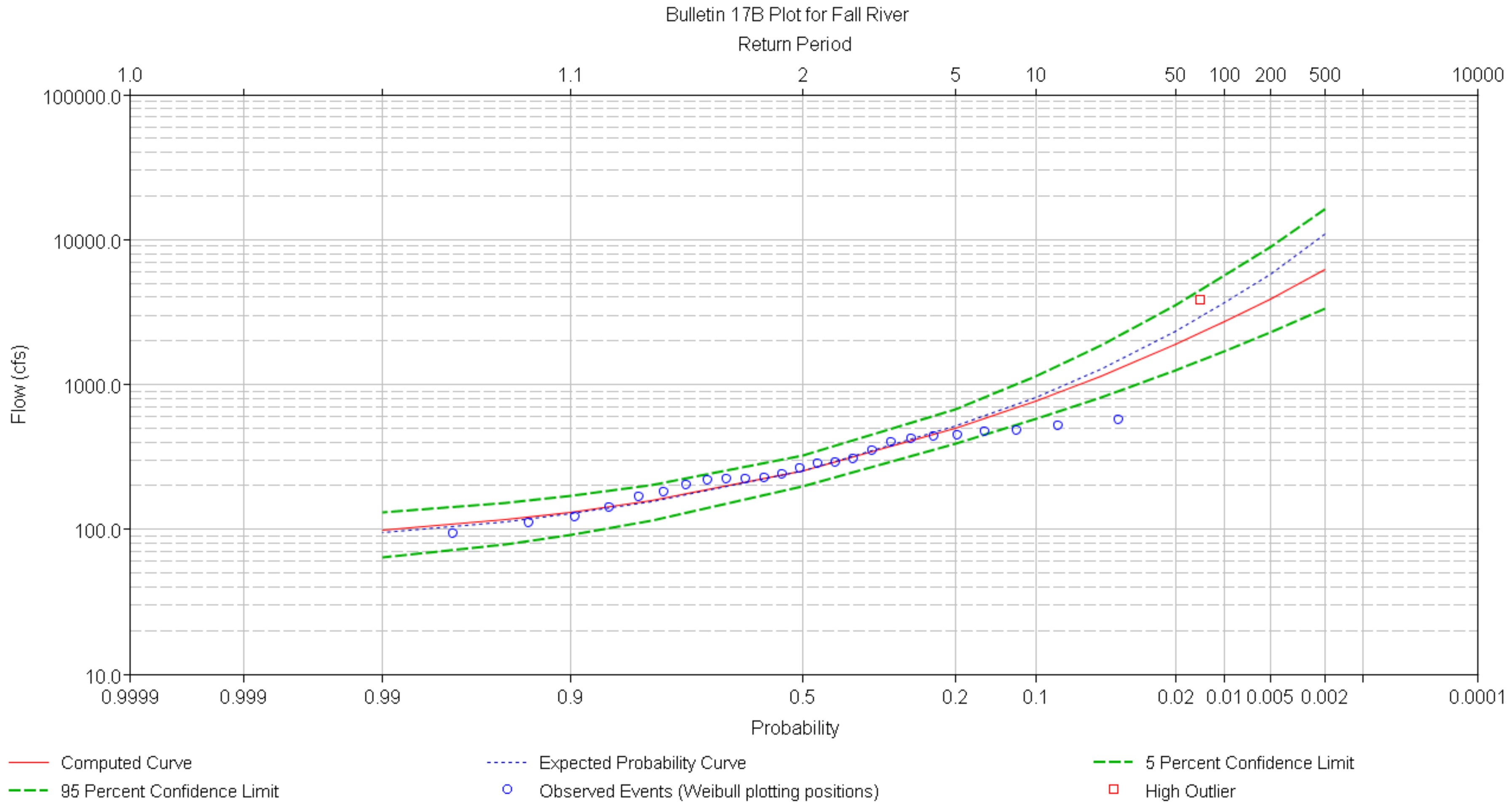
Stream Gauge Analysis

- Bulletin 17B
- Stream Gauges Used in Analysis
  - USGS 06733000 – Big Thompson at Estes Park
    - 52 years
  - USGS 402114105350101 – Big Thompson below Moraine Park
    - 17 years
  - USGS 06732500 – Fall River at Estes Park
    - 26 years

Snowmelt Influence

- Snow melt versus rain influenced
- **Big Thompson at Estes Park**
  - May = 5
  - June = 45
  - July = 2
- **Big Thompson below Moraine Park**
  - May = 4
  - June = 11
  - July = 1
  - September = 1
- **Fall River at Estes Park**
  - May = 1
  - June = 15

Flood Frequency Plots



Other Data

- Dr. Robert Jarrett (retired USGS) 2013 peak flow estimates
- NRCS 2013 peak flow estimates
- Fish Creek hydrology report
- Other reports from 2013 flood
- Regional regression equations

Progress and Schedule

Progress and Projections

Task	FR	UBT	BCC	DG
Data/mapping gathering	✓	✓	✓	✓
Sept 2013 High Water Marks and Precipitation	✓	✓	✓	✓
Design Points	✓	✓	✓	✓
Sub-basin and Stream Delineations	✓	✓	✓	✓
Model Parameter Extraction	✓	✓	Apr	Apr
Preliminary Working Model	Apr	Apr	Apr	Apr
Adjustments and “Calibration” using other Data	Early May	Mid May	Mid May	Late May
Final Model	Late May	Late May	Early June	Early June
Report	July	July	July	July

Next Planned Meetings

- June 14th Board Meeting (tentative)
- June 15th Public Meeting (tentative)

- Town of Estes Park Flood Mitigation:

  www.estes.org/floodmitigation

Questions, Comments and Discussion

Primary Contact for further questions/comments:

Tina Kurtz
Environmental Planner
Town of Estes Park, Community Development Dept.
(970) 577-3732
tkurtz@estes.org