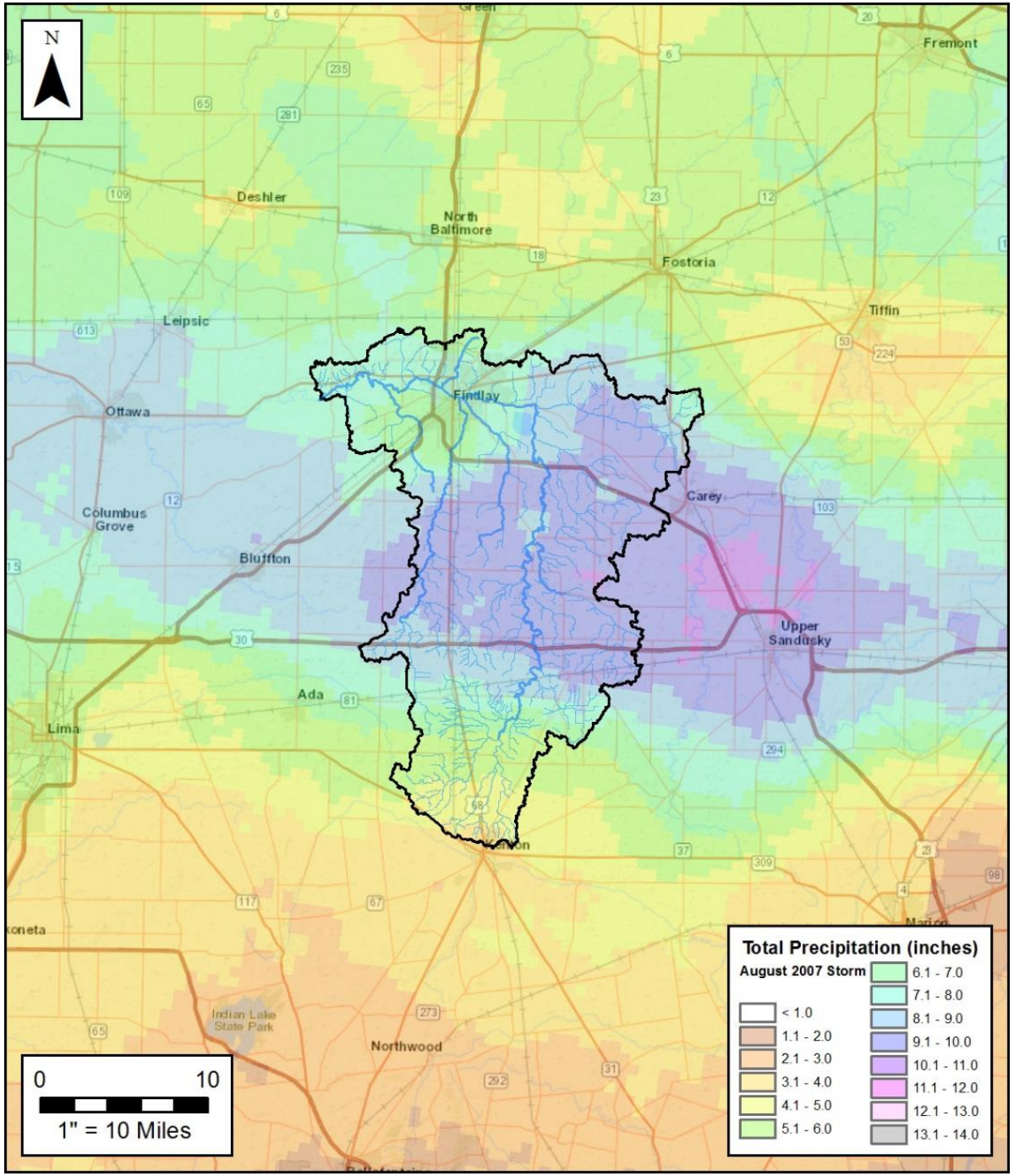
2018 OHIO STORMWATER CONFERENCE
11th Annual

May 9 - 11, 2018

Presenter:

Erman Caudill, PE, CFM
Senior Water Resources Engineer

Stantec
Lexington, KY



Hydrology:
Old Science, New Applications for the Blanchard River in Ohio

Maumee River Watershed Conservancy District

Hancock County Flood Risk Reduction Program

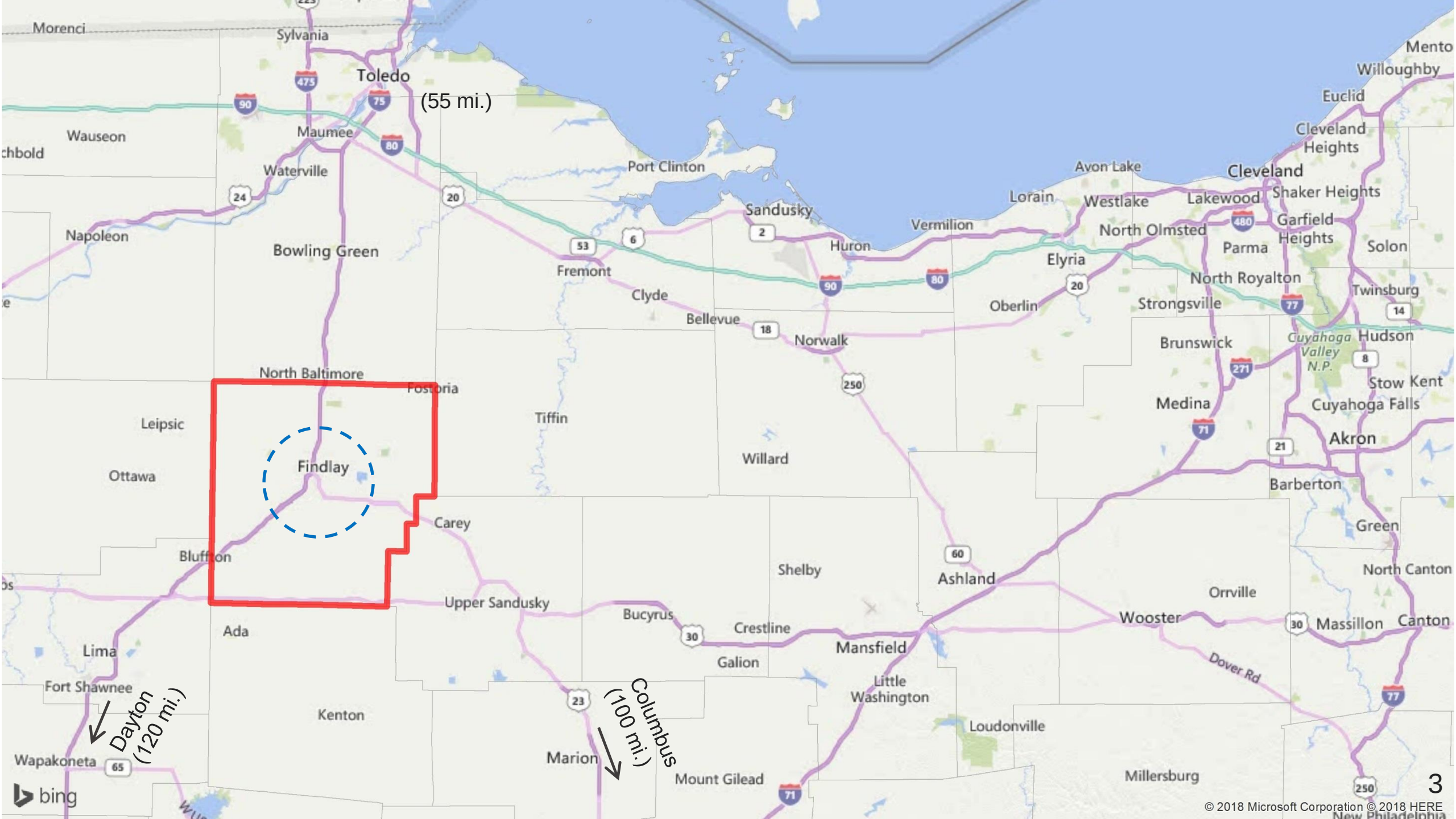
Stantec

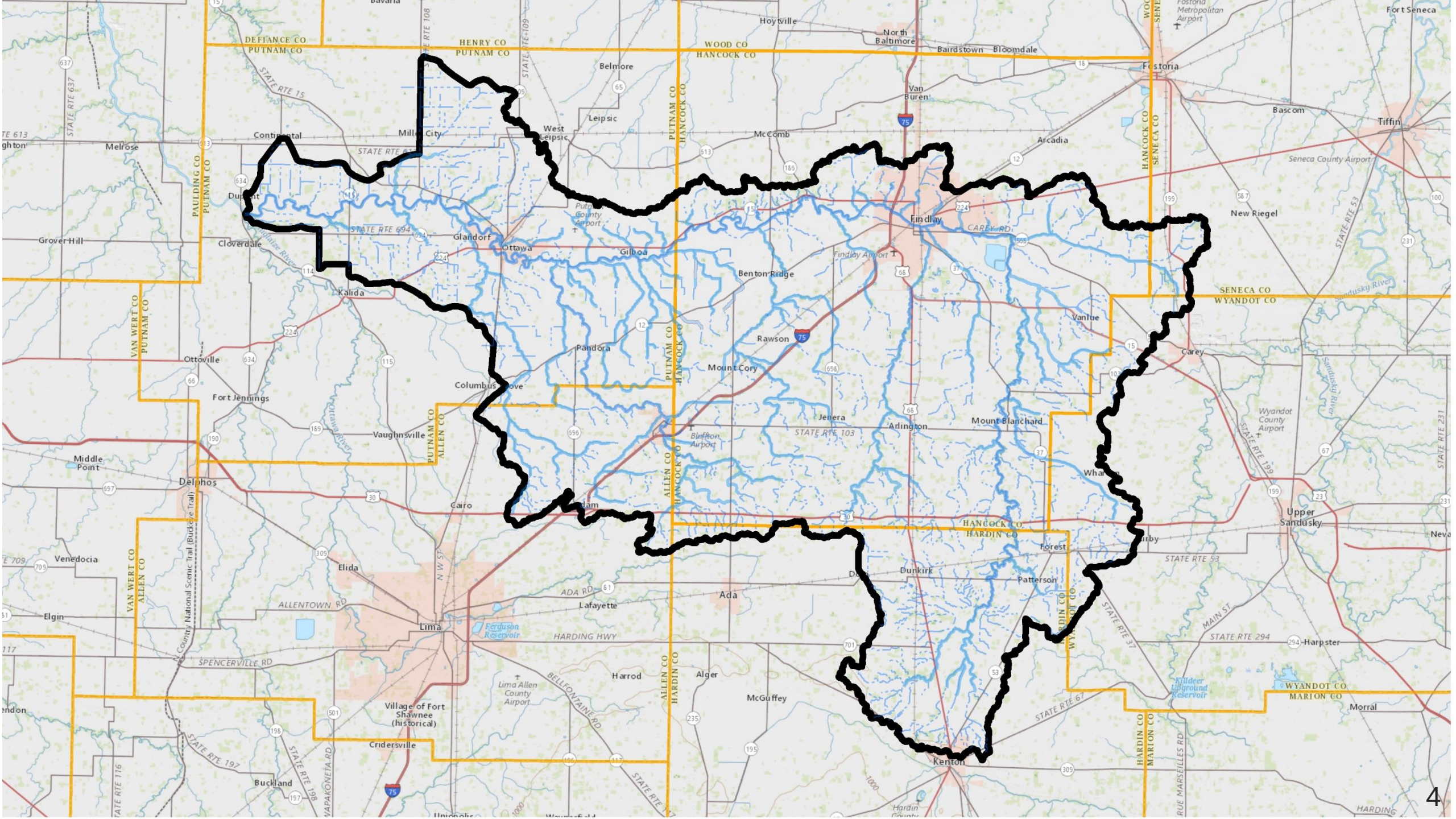
Maumee Watershed Conservancy District

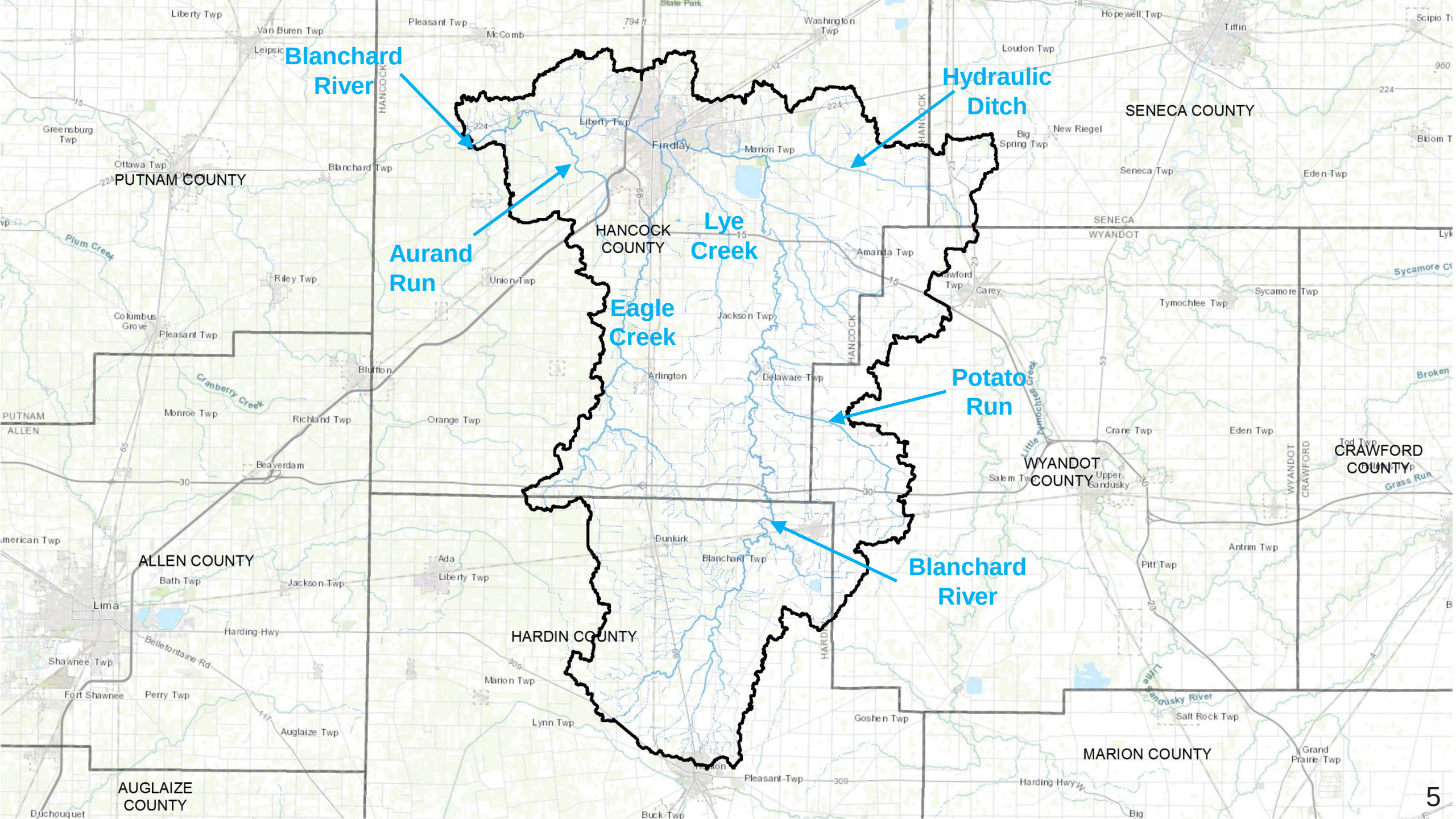
Agenda

1. Background
2. Hydrologic Modeling 101
3. Previous Modeling
4. New Modeling
   - Spatial Variation
   - Temporal Patterns
5. Flood Mitigation Concepts

Source:
Bing Image Search
May be subject to copyright.


Toledo
(55 mi.)
Findlay
Dayton
(120 mi.)
Columbus
(100 mi.)
Morenci
Sylvania
Wauseon
Maumee
Waterville
Napoleon
Bowling Green
Port Clinton
Sandusky
Fremont
Clyde
Bellevue
Norwalk
Huron
Vermilion
Lorain
Avon Lake
Westlake
Cleveland
Lakewood
Shaker Heights
Cleveland Heights
Euclid
Willoughby
North Olmsted
Parma
Garfield Heights
Solon
Elyria
Oberlin
North Royalton
Strongsville
Twinsburg
Brunswick
Cuyahoga Valley N.P.
Hudson
Stow Kent
Cuyahoga Falls
Akron
Barberton
Medina
North Baltimore
Fostoria
Tiffin
Willard
Leipsic
Ottawa
Carey
Bluffton
Upper Sandusky
Ada
Lima
Fort Shawnee
Kenton
Wapakoneta
Marion
Mount Gilead
Shelby
Ashland
Bucyrus
Crestline
Galion
Mansfield
Little Washington
Loudonville
Wooster
Orrville
North Canton
Massillon
Canton
Green
Dover Rd
Millersburg
bing
© 2018 Microsoft Corporation © 2018 HERE


DEFIANCE CO
PUTNAM CO
HENRY CO
PUTNAM CO
WOOD CO
HANCOCK CO
Hoytville
North Baltimore
Bairdstown
Bloomdale
Fostoria
Fort Seneca
Belmore
Van Buren
Bascom
Tiffin
Leipsic
West Leipsic
McComb
Arcadia
Continental
Melrose
Grover Hill
Cloverdale
Glandorf
Ottawa
Gilboa
Findlay
New Riegel
Seneca County Airport
Findlay Airport
Benton Ridge
Kalida
Vanlue
Rawson
Pandora
Mount Cory
Ottoville
Carey
Columbus Grove
Fort Jennings
Jenera
Arlington
Mount Blanchard
Bluffton Airport
Wyandot County Airport
Vaughnsville
Middle Point
Delphos
Cairo
Upper Sandusky
Venedocia
Elida
Forest
Dunkirk
Patterson
Lafayette
Ada
Elgin
Lima
Ferguson Reservoir
Harrod
Alger
McGuffey
Lima Allen County Airport
Village of Fort Shawnee (historical)
Cridersville
Buckland
Kenton
Harpster
Killdeer Underground Reservoir
Morral
PAULDING CO
VAN WERT CO
ALLEN CO
HANCOCK CO
HARDIN CO
WYANDOT CO
MARION CO
SENECA CO
STATE RTE 15
STATE RTE 694
STATE RTE 103
STATE RTE 53
STATE RTE 37
STATE RTE 294
STATE RTE 67
STATE RTE 197
STATE RTE 198
STATE RTE 199
CAREY RD
ADA RD
ALLENTOWN RD
HARDING HWY
SPENCERVILLE RD
BELLEFONTAINE RD
MAIN ST
Auglaize River
Ottawa River
Sandusky River
County National Scenic Trail (Buckeye Trail)


Blanchard River
Hydraulic Ditch
Aurand Run
Lye Creek
Eagle Creek
Potato Run
Blanchard River
HANCOCK COUNTY
PUTNAM COUNTY
SENECA COUNTY
WYANDOT COUNTY
CRAWFORD COUNTY
ALLEN COUNTY
HARDIN COUNTY
MARION COUNTY
AUGLAIZE COUNTY
Findlay
Lima
Liberty Twp
Marion Twp
Blanchard Twp
Union Twp
Jackson Twp
Arlington
Delaware Twp
Amanda Twp
Crawford Twp
Carey
Pleasant Twp
Riley Twp
Bluffton
Orange Twp
Richland Twp
Monroe Twp
Beaverdam
Bath Twp
Shawnee Twp
Perry Twp
Fort Shawnee
Auglaize Twp
Dunkirk
Ada
Lynn Twp
Goshen Twp
Pleasant Twp
Buck Twp
Crane Twp
Eden Twp
Tymochtee Twp
Sycamore Twp
Salem Twp
Upper Sandusky
Pitt Twp
Antrim Twp
Salt Rock Twp
Grand Prairie Twp
Big Spring Twp
New Riegel
Seneca Twp
Loudon Twp
Hopewell Twp
Tiffin
Washington Twp
McComb
Van Buren Twp
Leipsic
Ottawa Twp
Greensburg Twp
Columbus Grove
Cranberry Creek
Plum Creek
Little Tymochtee Creek
Sandusky River
Grass Run
Broken
Sycamore Cr
Bellefontaine-Rd
Harding-Hwy
794 ft
State Park

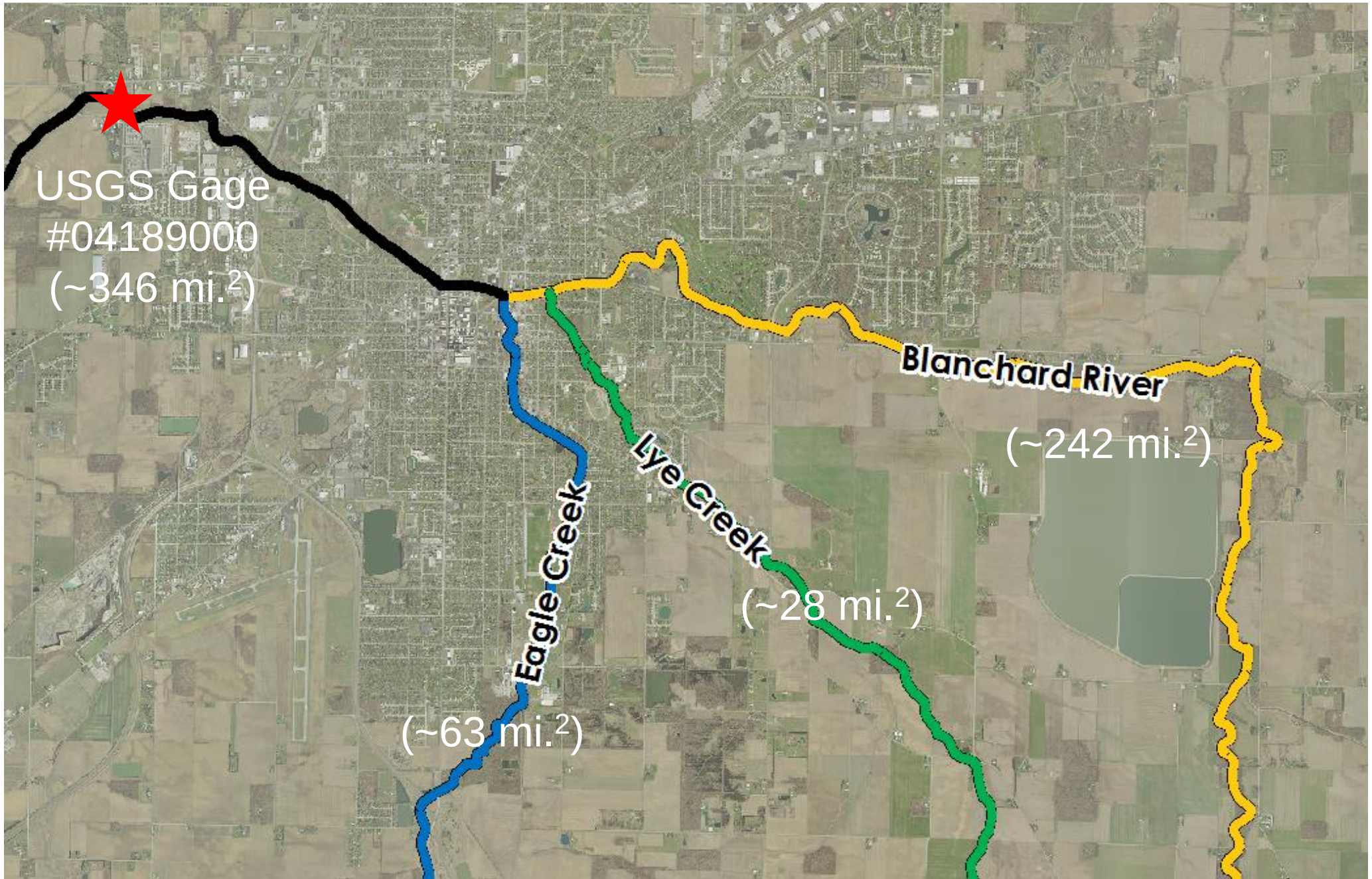
City of Findlay, Hancock Co. Ohio

Source:
Google Image Search
May be subject to copyright.

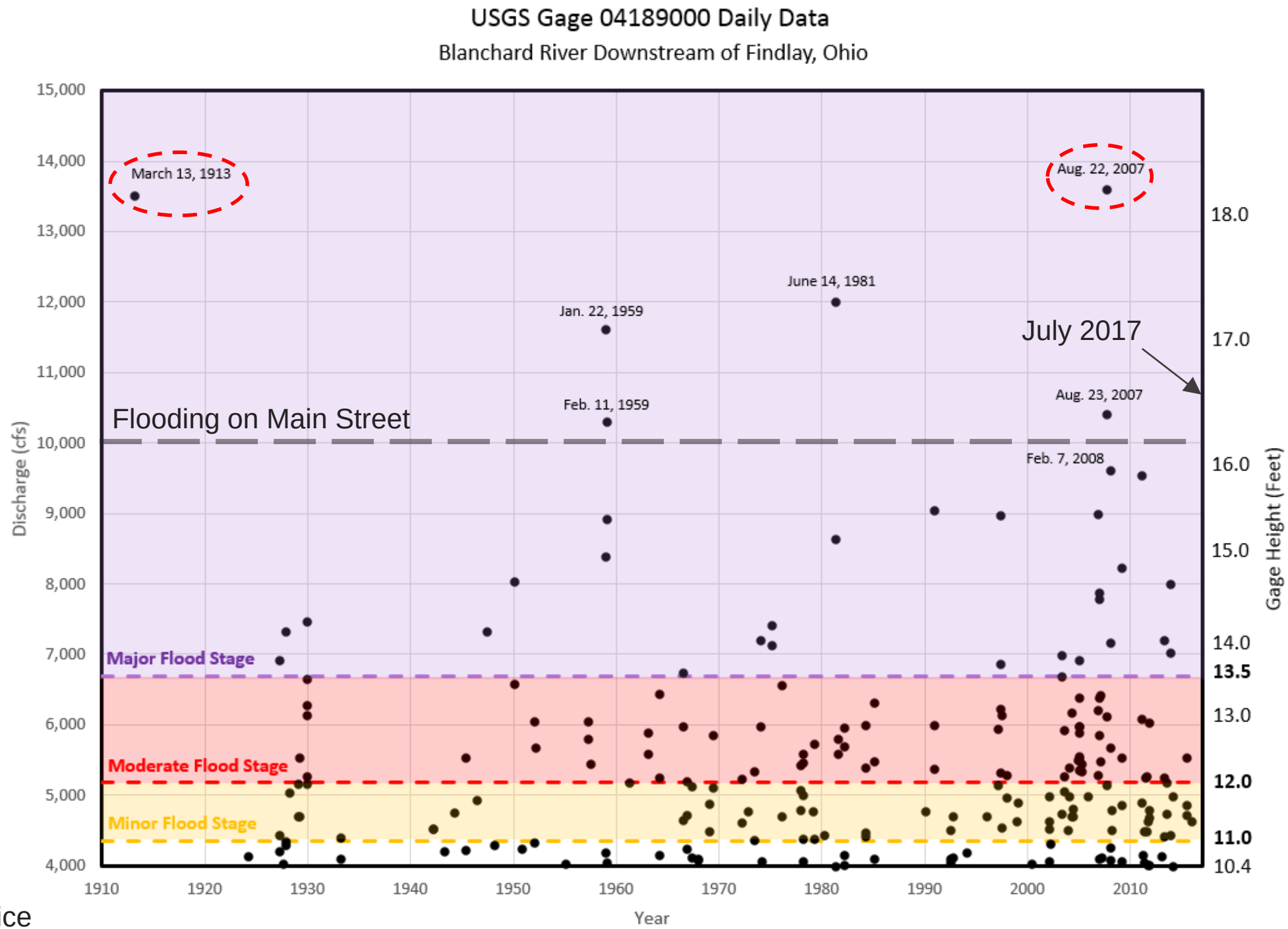
Source:
Google Image Search
May be subject to copyright.

City of Findlay, Hancock County, Ohio

Where Does the Water Come From?

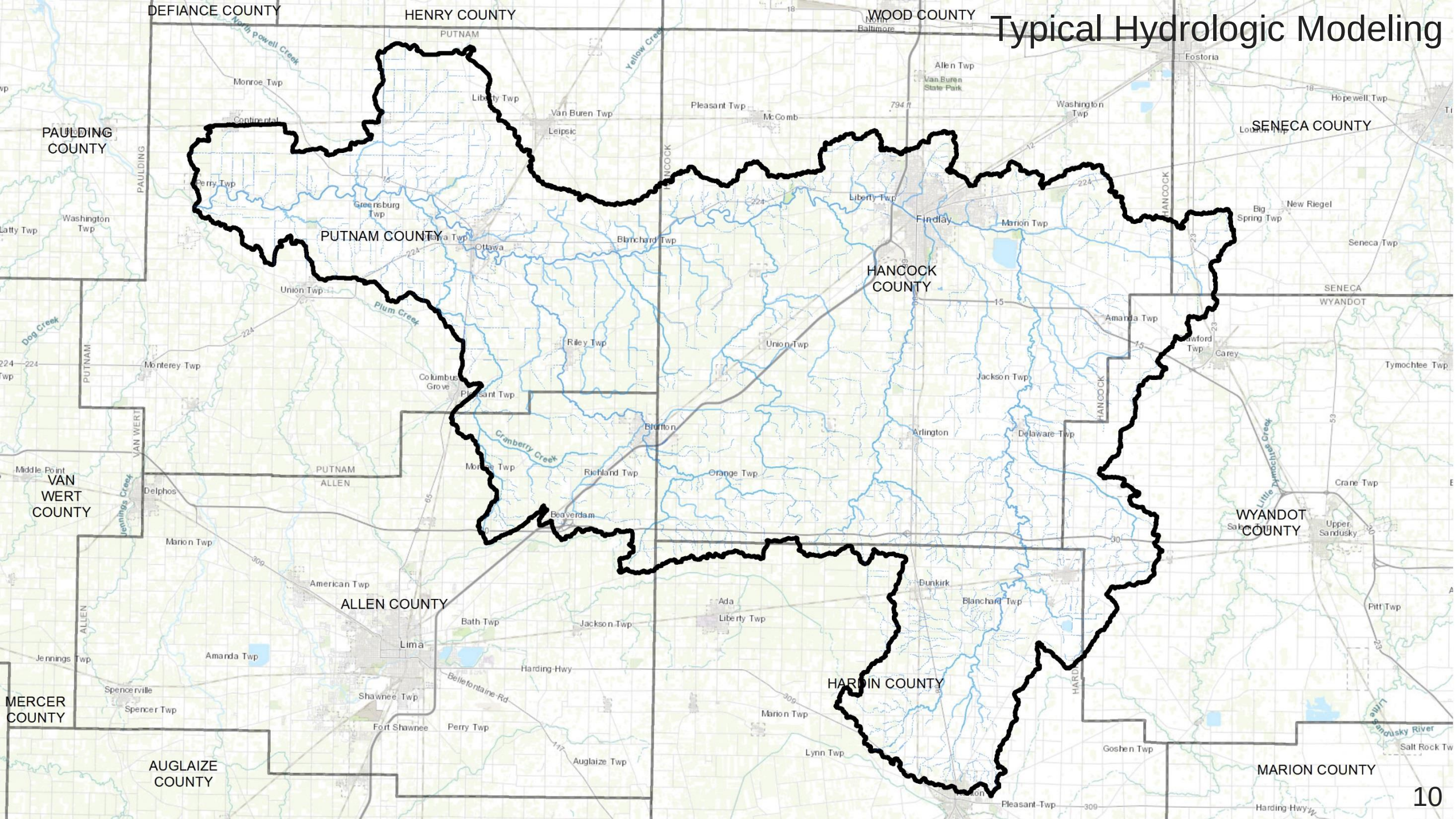


City of Findlay, Hancock County, Ohio

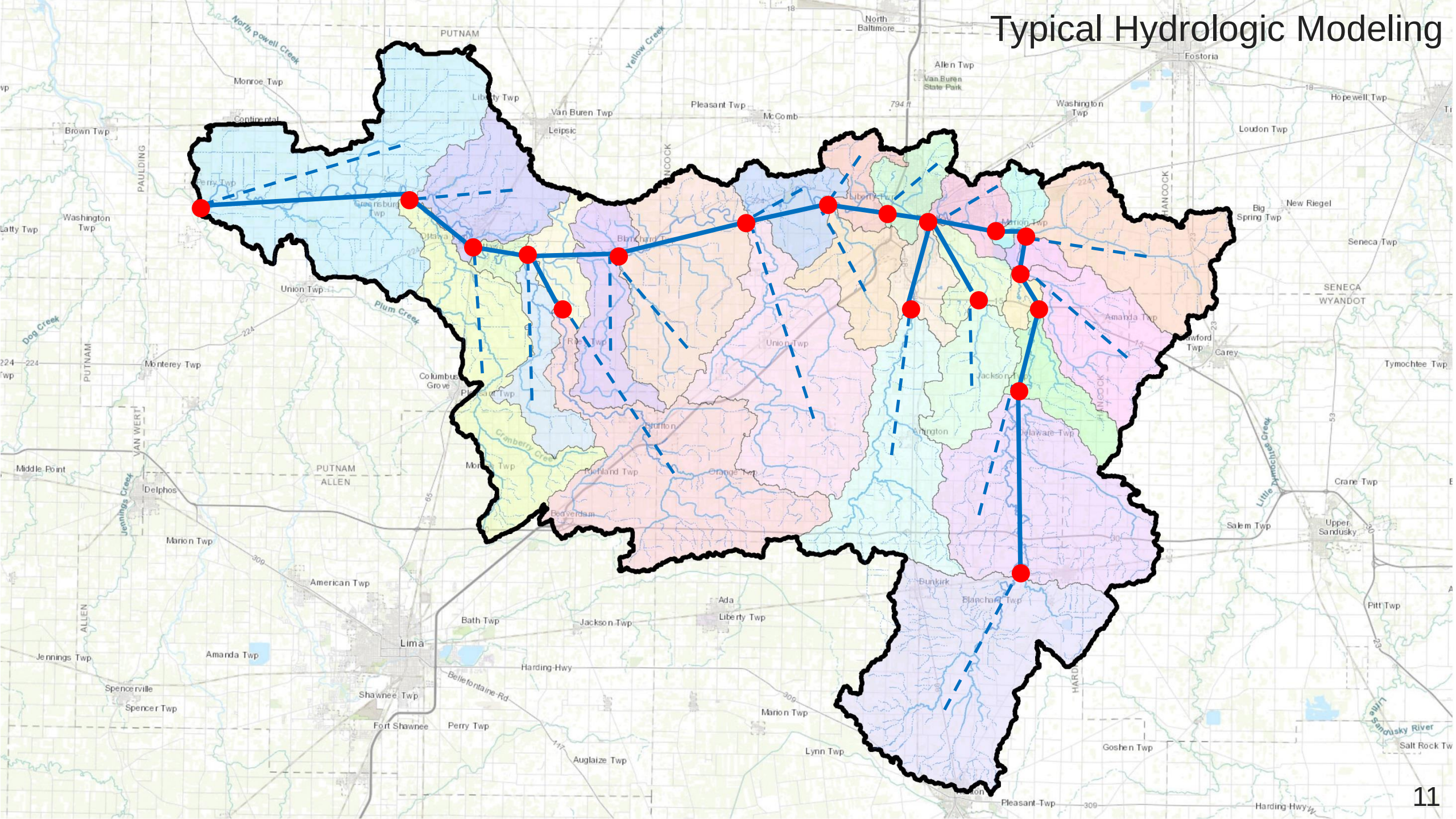


Flood Stages by National Weather Service

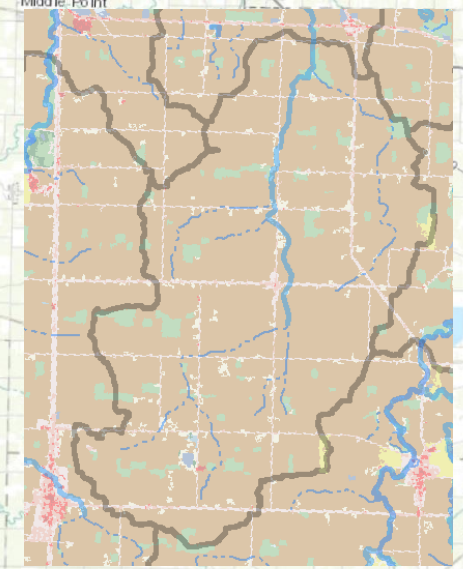
Typical Hydrologic Modeling

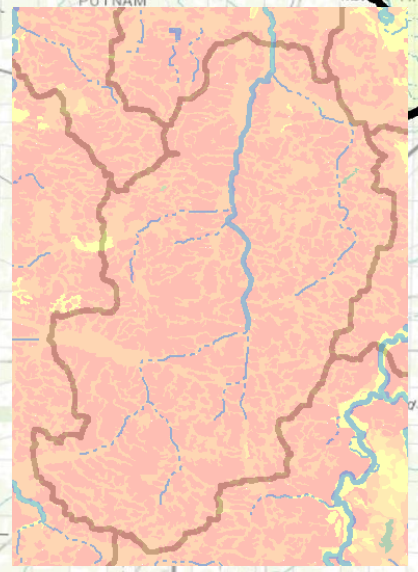


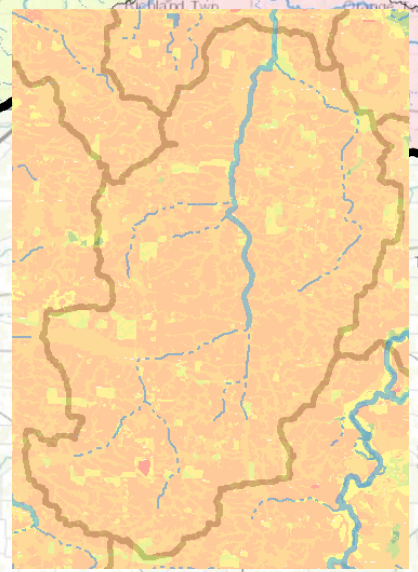
Typical Hydrologic Modeling



Typical Hydrologic Modeling





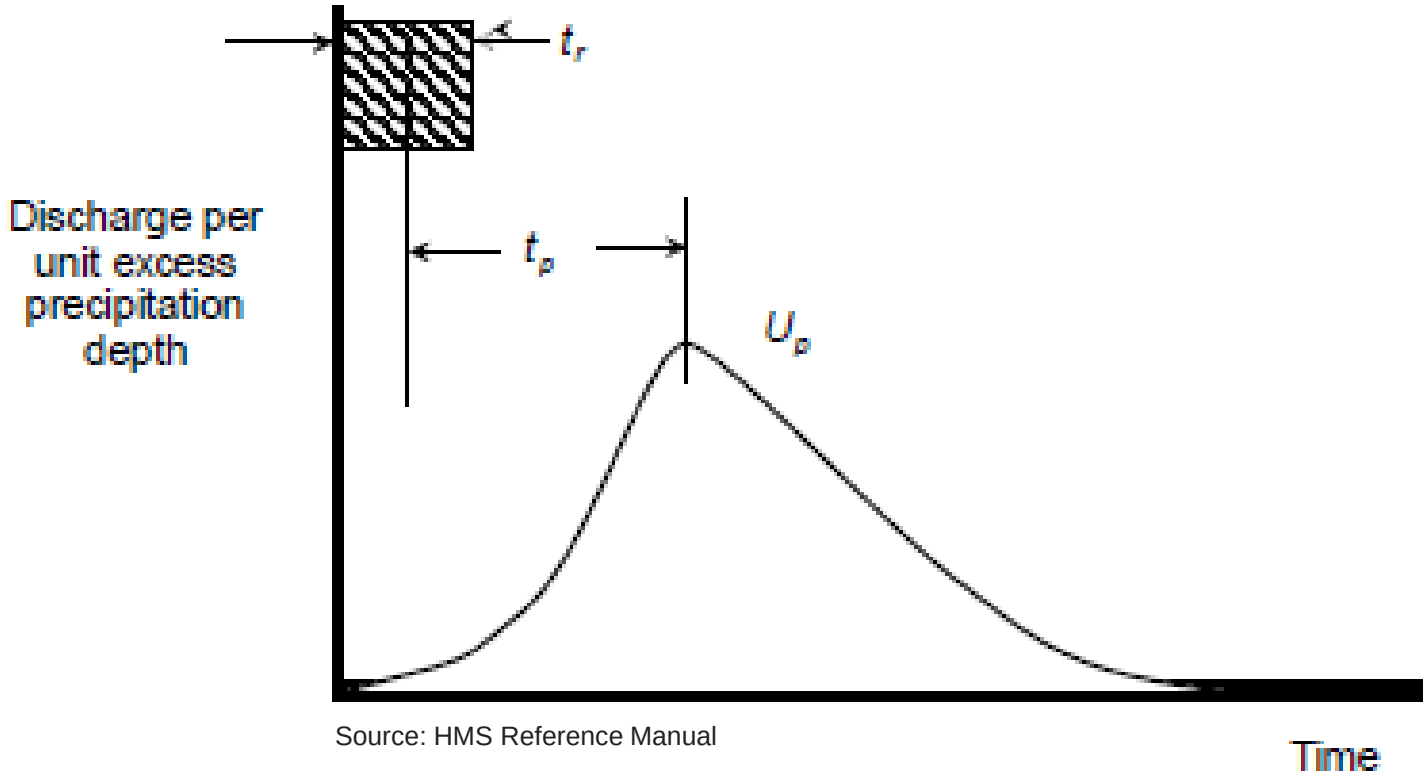


Landuse / Landcover + Hyd. Soil Group → SCS Curve #

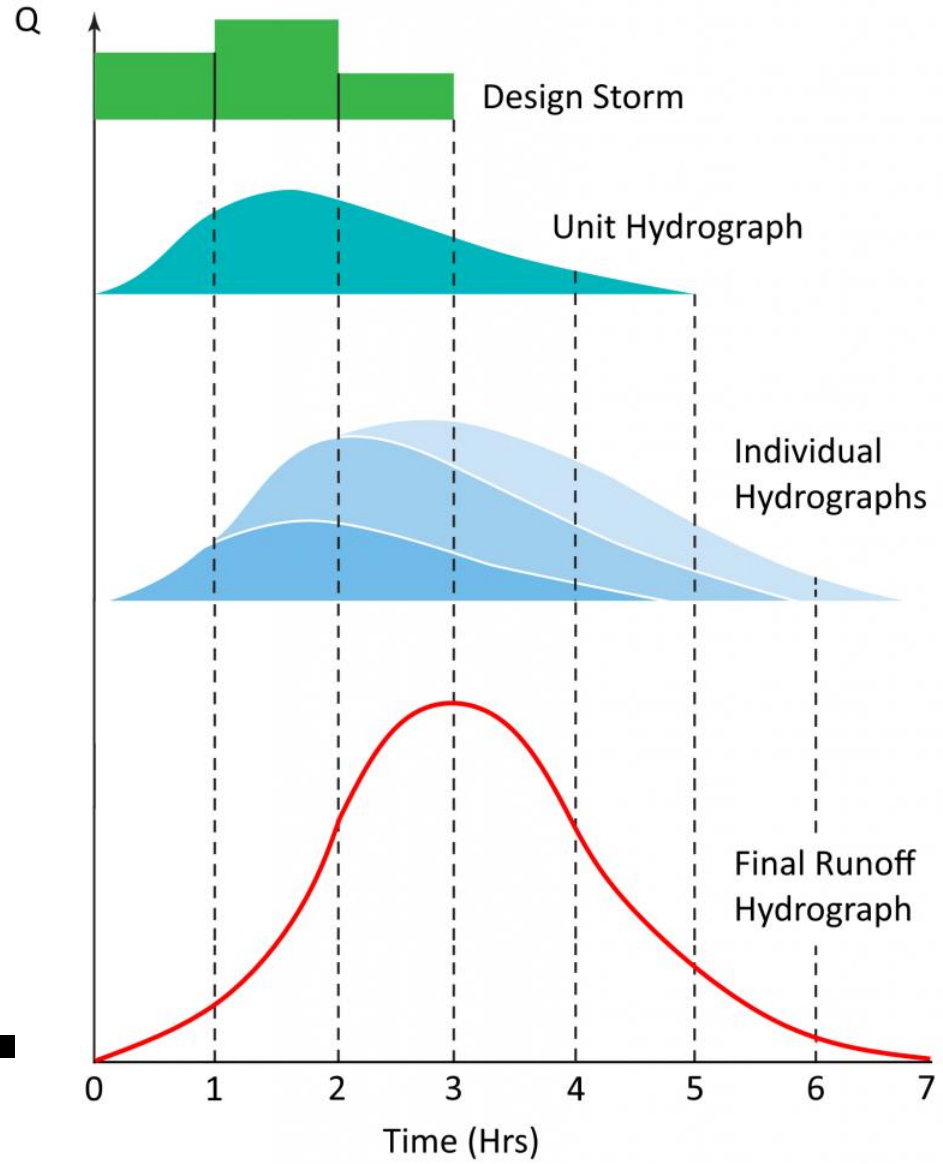
<u>Others</u>
Area
% Impervious
Time of Conc.
Storage
Reach Parameters
Etc.

Hydrologic Modeling

Unit Hydrograph Theory



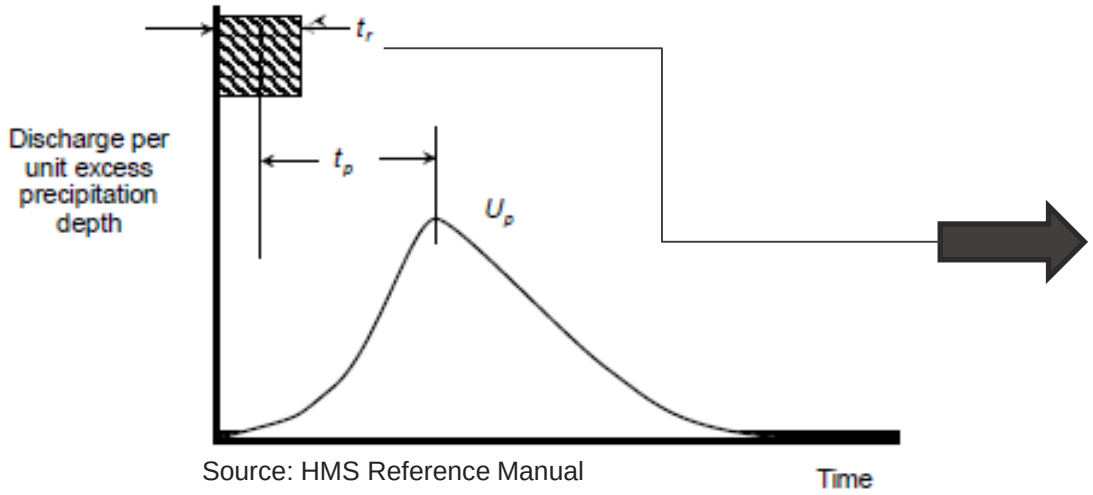
Source: HMS Reference Manual



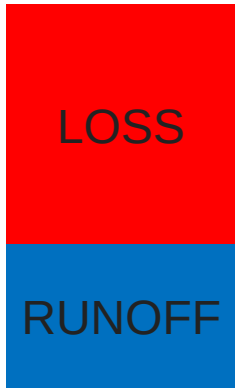
Source: Hydrology Studio.com

Hydrologic Modeling

Precipitation Extraction



Source: HMS Reference Manual



Commonly Used Loss Options in HEC-HMS:

- SCS Curve Number: Landuse + Hyd. Soil Group
- Green and Ampt: Soil Texture + Soil Conductivity
- Soil Moisture Accounting: Storage + Soil Params.

+ Grid Based Variations

SCS Loss Equations

$$S = \frac{1000}{CN} - 10$$

$$I_a = 0.2S$$

$$P_e = \frac{(P - I_a)^2}{P - I_a + S}$$

Commonly Used Hydrograph Transformations in HEC-HMS:

- Snyder Unit Hydrograph
- SCS Unit Hydrograph

Synthetic, Shape Defined by Watershed Parameters

- Clark Unit Hydrograph *- Same, but accounts for storage & routing*
- Mod-Clark Unit Hydrograph *- Grid based version of Clark UH*
- Kinematic Wave *- Mass Balance + Routing*

HMS Input Parameters:

Snyder UH

T_{Lag}

C_{Peak}

SCS UH

T_{Lag}

Clark / Mod-Clark

$T_{Concentration}$

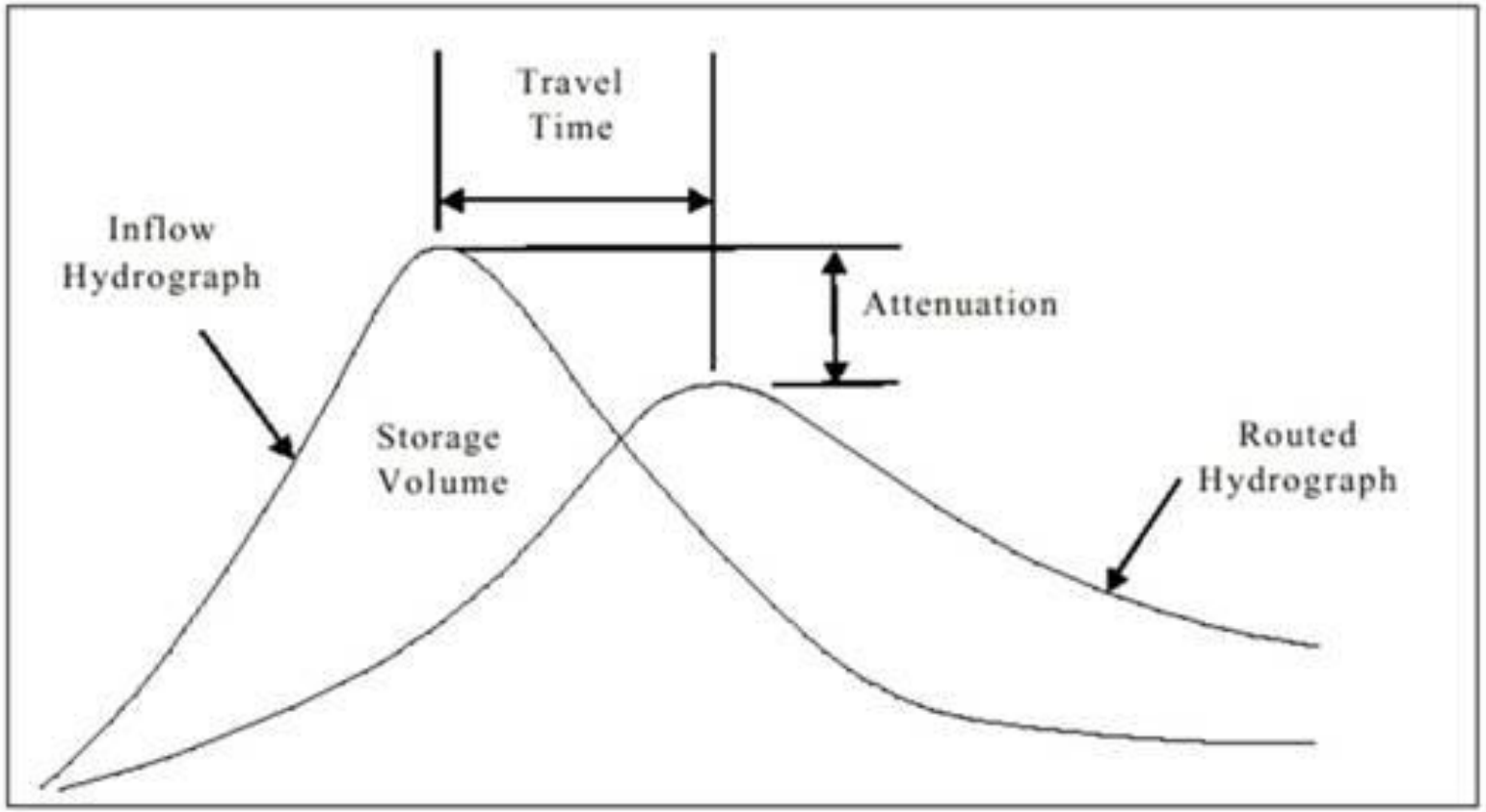
$C_{Storage}$

Kinematic Wave

Planes:	Channel:
Length	Length
Slope	Slope
Roughness	Shape
Area	Roughness
# Steps	Geometry

Channel Reach Routing

- Travel Time
- Attenuation

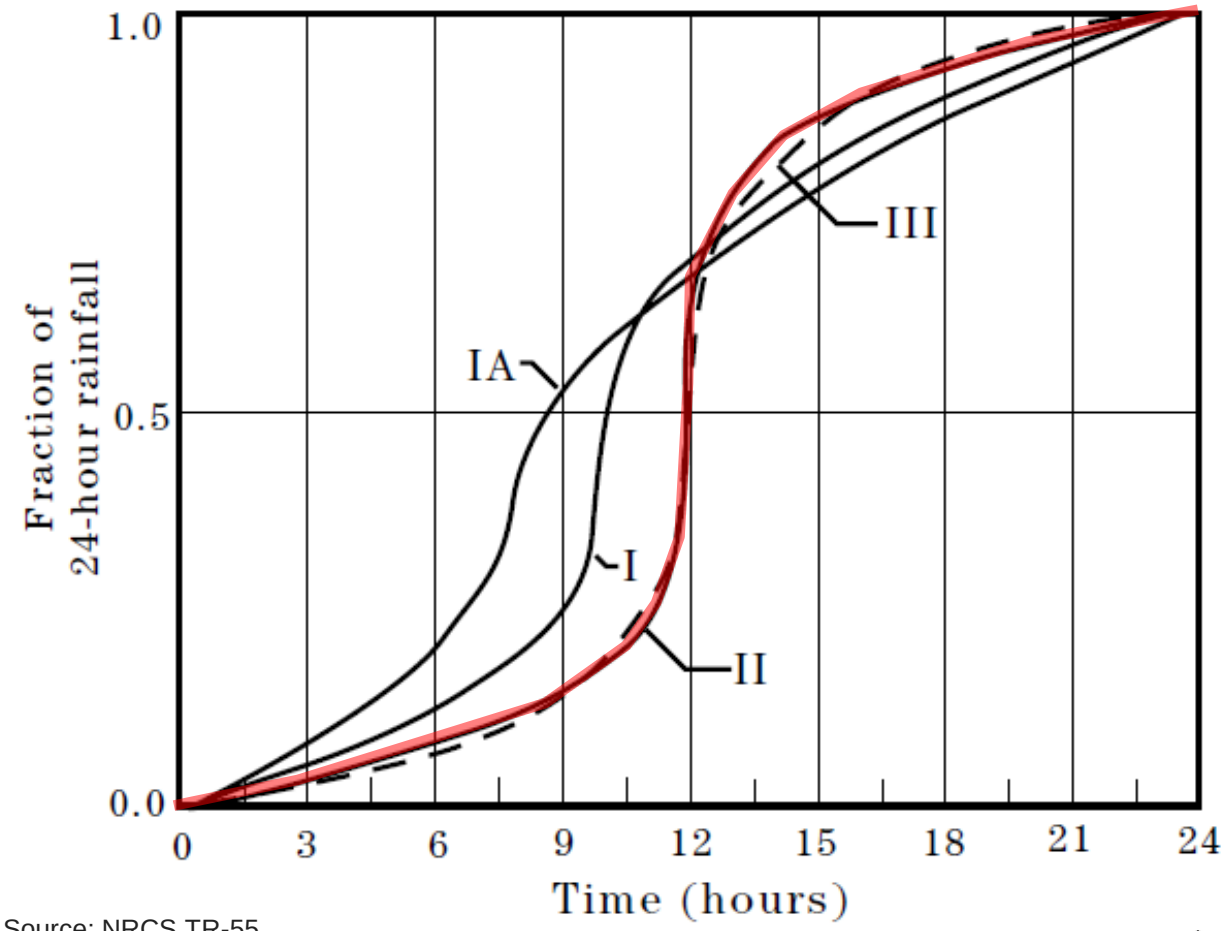


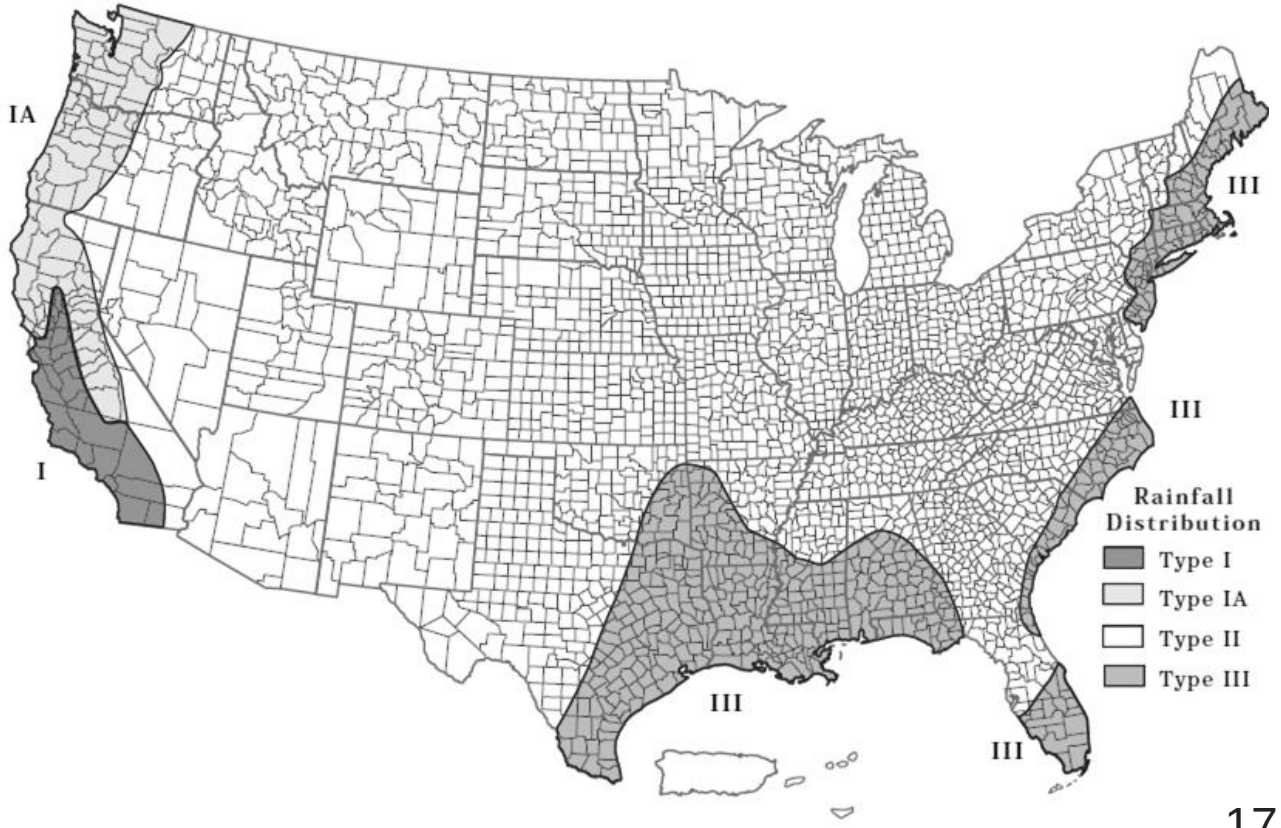
Source: hydrology.usu.edu – Matthew Hill

Commonly Used Reach Routing Available in HEC-HMS:

- Lag (No Attenuation)
- Modified Puls
- Muskingum
- Muskingum-Cunge
- Kinematic Wave

SCS Type Storm Temporal Patterns



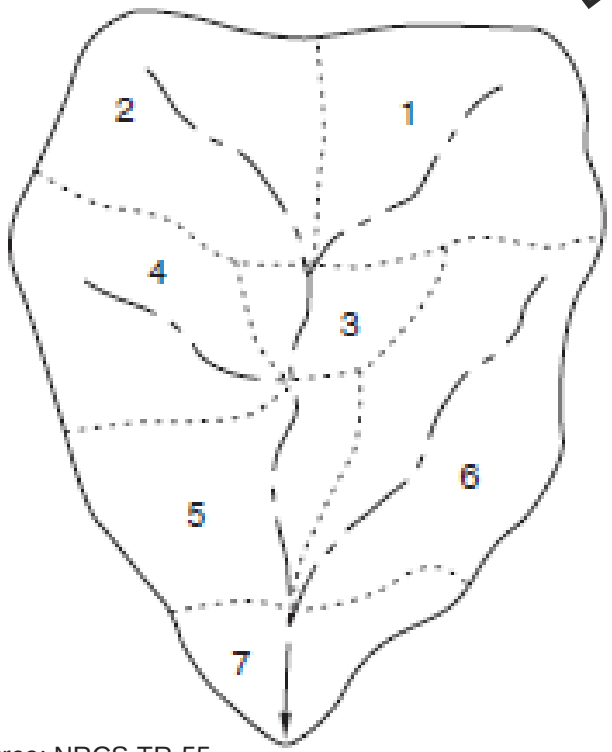


Source: NRCS TR-55

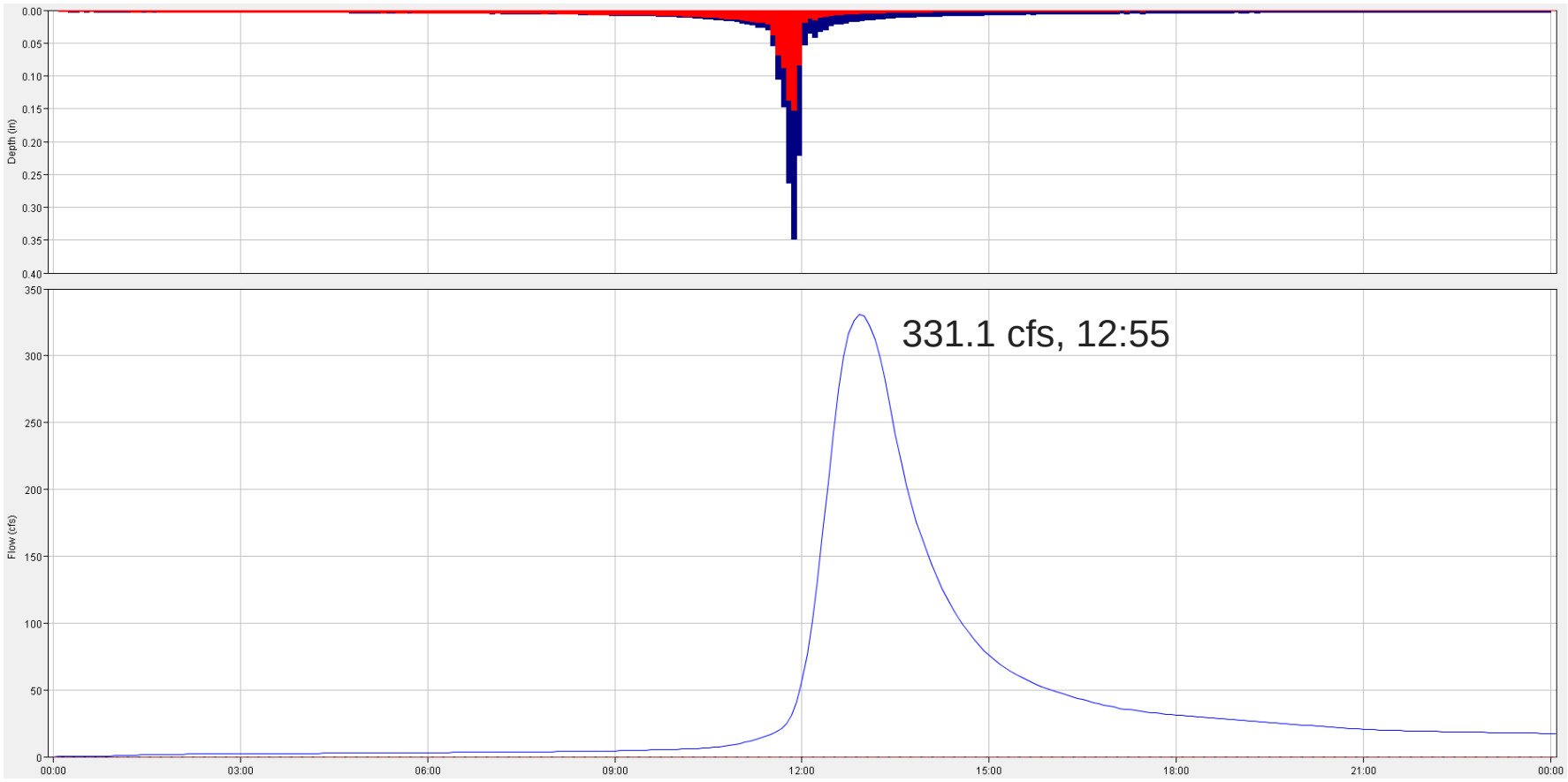
Example Hydrograph Generation

Subbasin No. 1
Area = 1 sq.-mi.
SCS Curve Number = 80
% Impervious = 10%
Time Step = 5 minutes

SCS Unit Hydrograph
Lag Time = 60 min
SCS Type II Storm
24-Hour Duration, P = 3-Inches



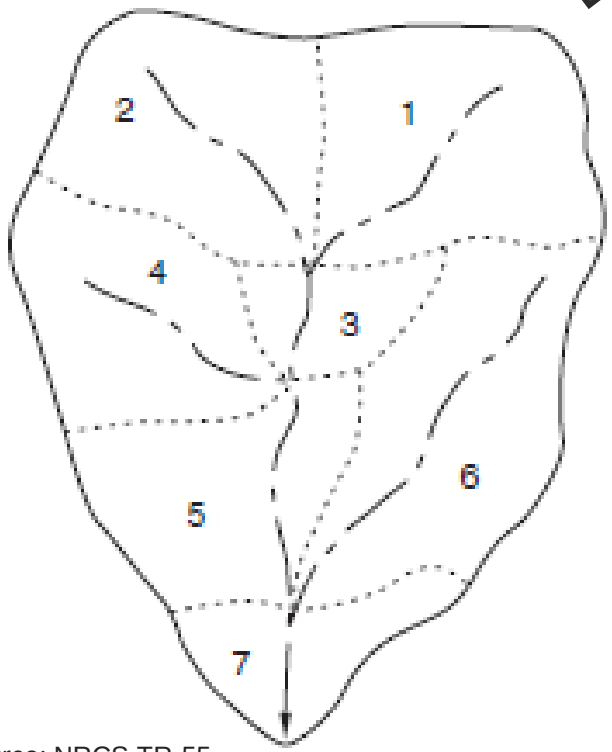
Source: NRCS TR-55



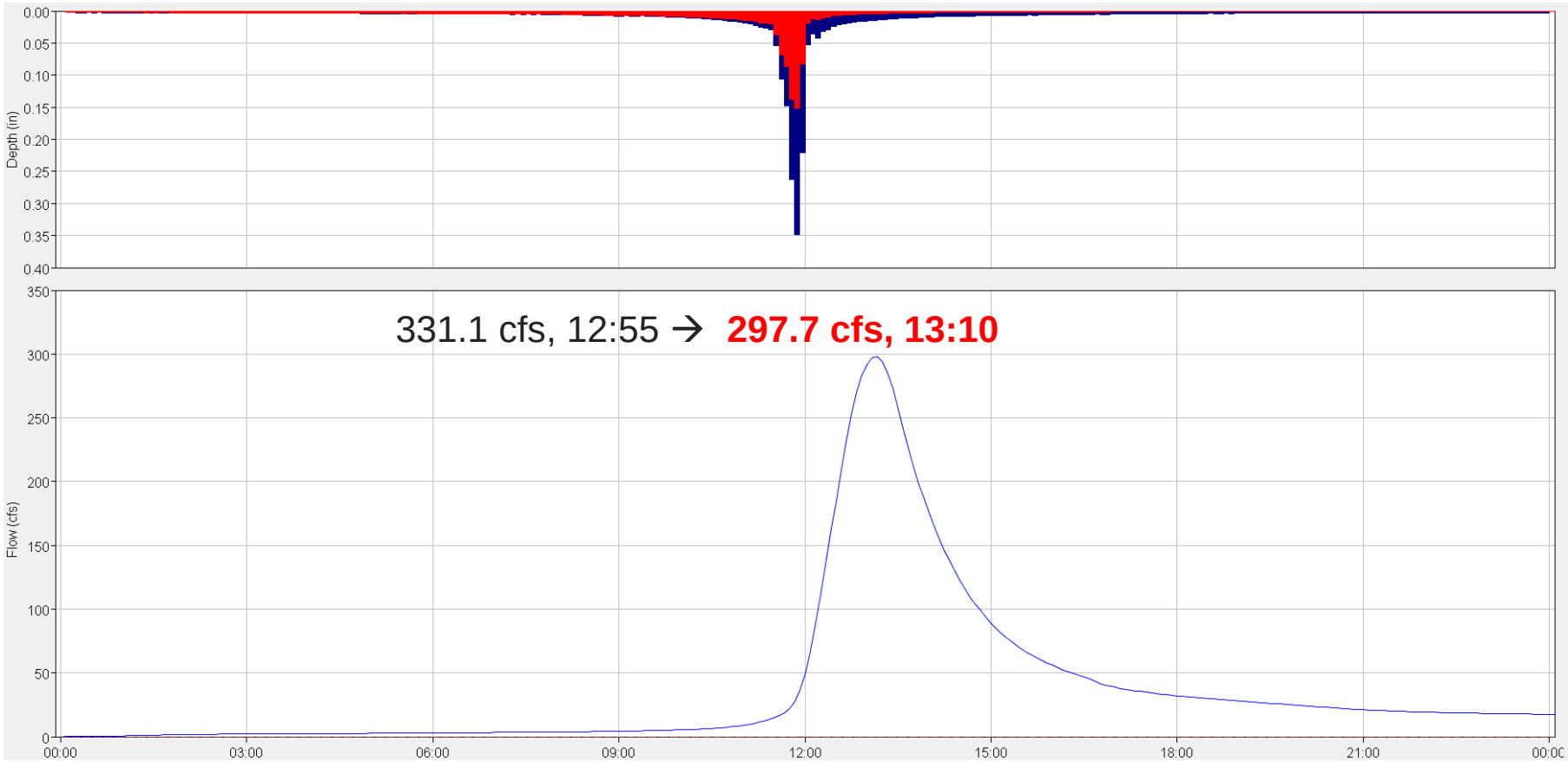
Example Hydrograph Generation

Subbasin No. 1
Area = 1 sq.-mi.
SCS Curve Number = 80
% Impervious = 10%
Time Step = 5 minutes

Clark Unit Hydrograph
Time of Concentration = 1.5 hr.
Storage Coefficient = 0.75 hr.
SCS Type II Storm
24-Hour Duration, P = 3-Inches



Source: NRCS TR-55

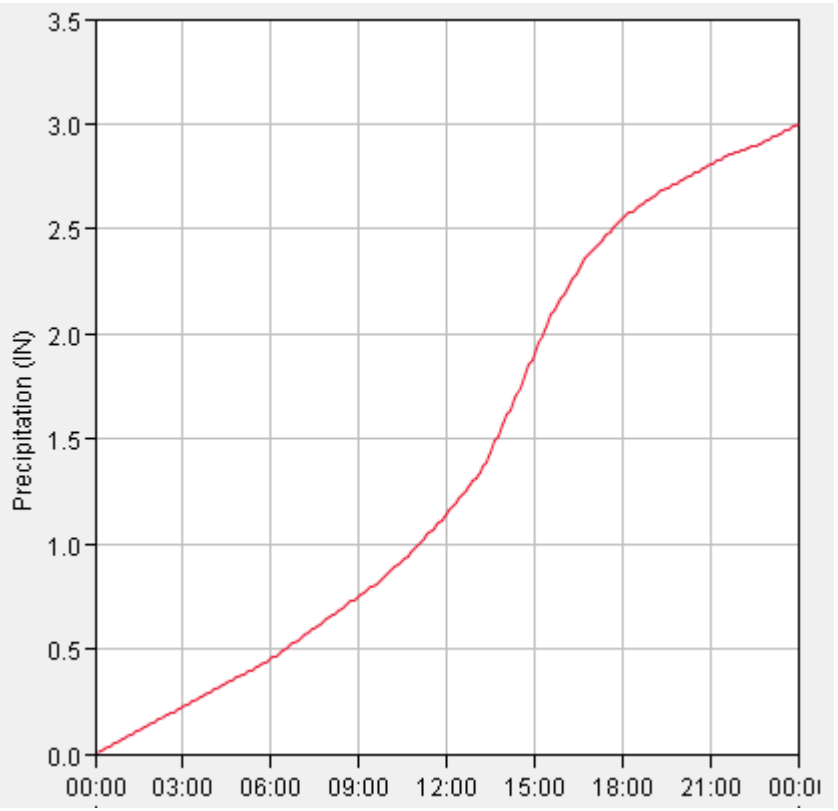


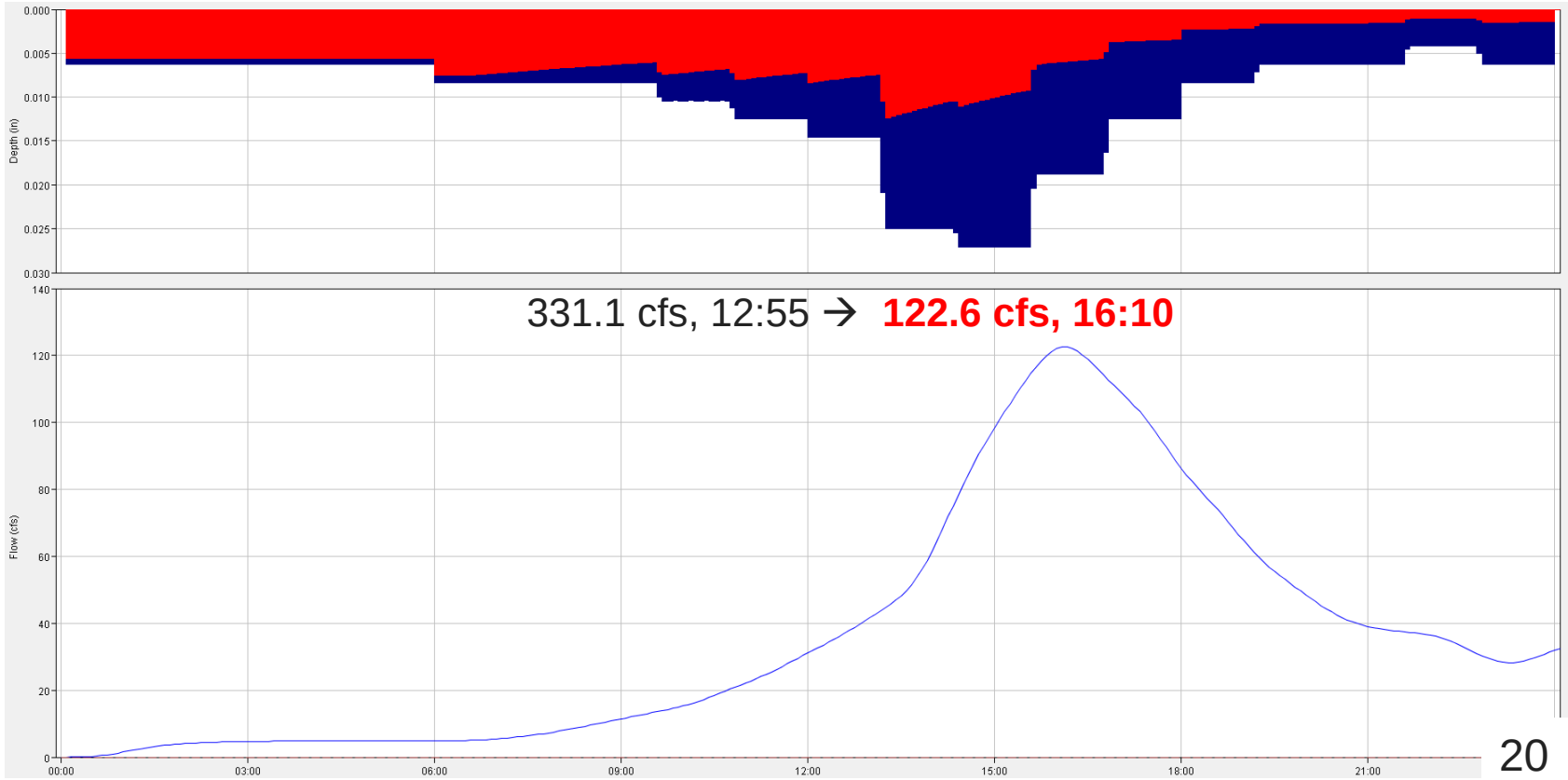
331.1 cfs, 12:55 → **297.7 cfs, 13:10**

Example Hydrograph Generation

Subbasin No. 1
Area = 1 sq.-mi.
SCS Curve Number = 80
% Impervious = 10%
Time Step = 5 minutes

SCS Unit Hydrograph
Lag Time = 60 minutes
Huff 3rd Quartile Storm
24-Hour Duration, P = 3-Inches





Hydrologic Modeling
Storm Durations

Example Hydrograph Generation

Subbasin No. 1
Area = 1 sq.-mi.
SCS Curve Number = 80
% Impervious = 10%
Time Step = 5 minutes

SCS Unit Hydrograph
Lag Time = 60 min
SCS Type II Storm
Various Durations

Duration	Average recurrence interval (years)						
	1	2	5	10	25	50	100
5-min	**0.338** (0.307–0.373)	**0.401** (0.363–0.442)	**0.479** (0.432–0.528)	**0.541** (0.488–0.596)	**0.620** (0.557–0.682)	**0.681** (0.609–0.749)	**0.742** (0.660–0.814)
10-min	**0.525** (0.477–0.580)	**0.625** (0.567–0.691)	**0.744** (0.672–0.821)	**0.834** (0.753–0.920)	**0.948** (0.852–1.04)	**1.03** (0.924–1.14)	**1.12** (0.994–1.23)
15-min	**0.644** (0.584–0.711)	**0.765** (0.694–0.845)	**0.913** (0.825–1.01)	**1.03** (0.927–1.13)	**1.17** (1.05–1.29)	**1.28** (1.14–1.41)	**1.39** (1.23–1.52)
30-min	**0.852** (0.773–0.941)	**1.02** (0.928–1.13)	**1.25** (1.13–1.38)	**1.43** (1.29–1.57)	**1.65** (1.49–1.82)	**1.83** (1.63–2.01)	**2.00** (1.78–2.20)
60-min	**1.04** (0.944–1.15)	**1.26** (1.14–1.39)	**1.57** (1.42–1.73)	**1.81** (1.64–2.00)	**2.15** (1.93–2.36)	**2.41** (2.15–2.65)	**2.68** (2.38–2.94)
2-hr	**1.21** (1.10–1.35)	**1.46** (1.33–1.63)	**1.84** (1.66–2.04)	**2.14** (1.93–2.37)	**2.55** (2.29–2.82)	**2.89** (2.58–3.19)	**3.25** (2.88–3.58)
3-hr	**1.29** (1.18–1.42)	**1.55** (1.41–1.72)	**1.94** (1.77–2.15)	**2.26** (2.05–2.50)	**2.71** (2.44–2.98)	**3.07** (2.75–3.38)	**3.46** (3.08–3.80)
6-hr	**1.51** (1.37–1.67)	**1.81** (1.65–2.00)	**2.26** (2.06–2.49)	**2.63** (2.39–2.89)	**3.17** (2.85–3.47)	**3.61** (3.24–3.96)	**4.09** (3.63–4.48)
12-hr	**1.74** (1.60–1.92)	**2.09** (1.91–2.29)	**2.60** (2.37–2.85)	**3.02** (2.75–3.31)	**3.63** (3.29–3.96)	**4.14** (3.72–4.51)	**4.70** (4.19–5.11)
24-hr	**2.04** (1.90–2.20)	**2.44** (2.28–2.64)	**3.01** (2.81–3.25)	**3.48** (3.23–3.75)	**4.14** (3.83–4.46)	**4.68** (4.31–5.05)	**5.26** (4.81–5.67)
2-day	**2.37** (2.23–2.53)	**2.83** (2.66–3.02)	**3.47** (3.26–3.69)	**3.98** (3.73–4.24)	**4.71** (4.39–5.02)	**5.31** (4.93–5.66)	**5.93** (5.48–6.33)

Source: NOAA Atlas 14

24-Hour: 3.0 inches → 331.1 cfs @ 12:55

6-Hour: 2.26 inches → 266.0 cfs @ 4:05

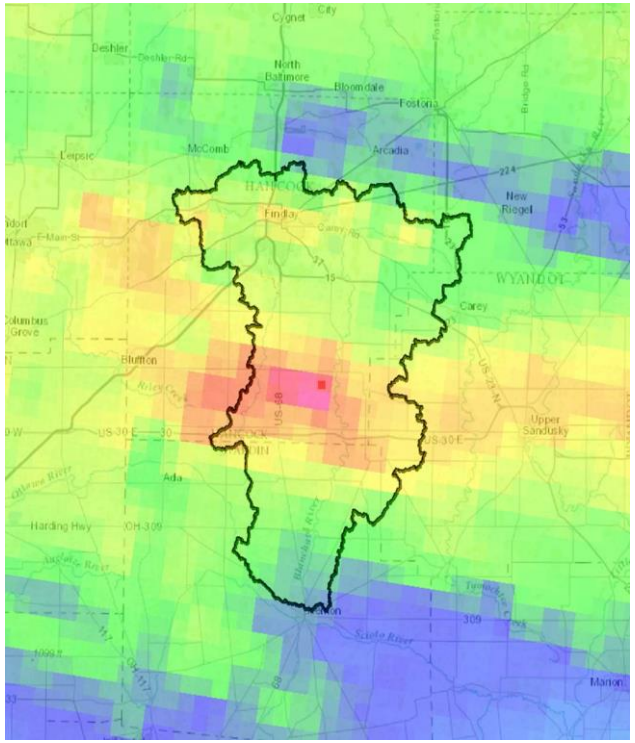
12-Hour: 2.60 inches → 294.9 cfs @ 7:00

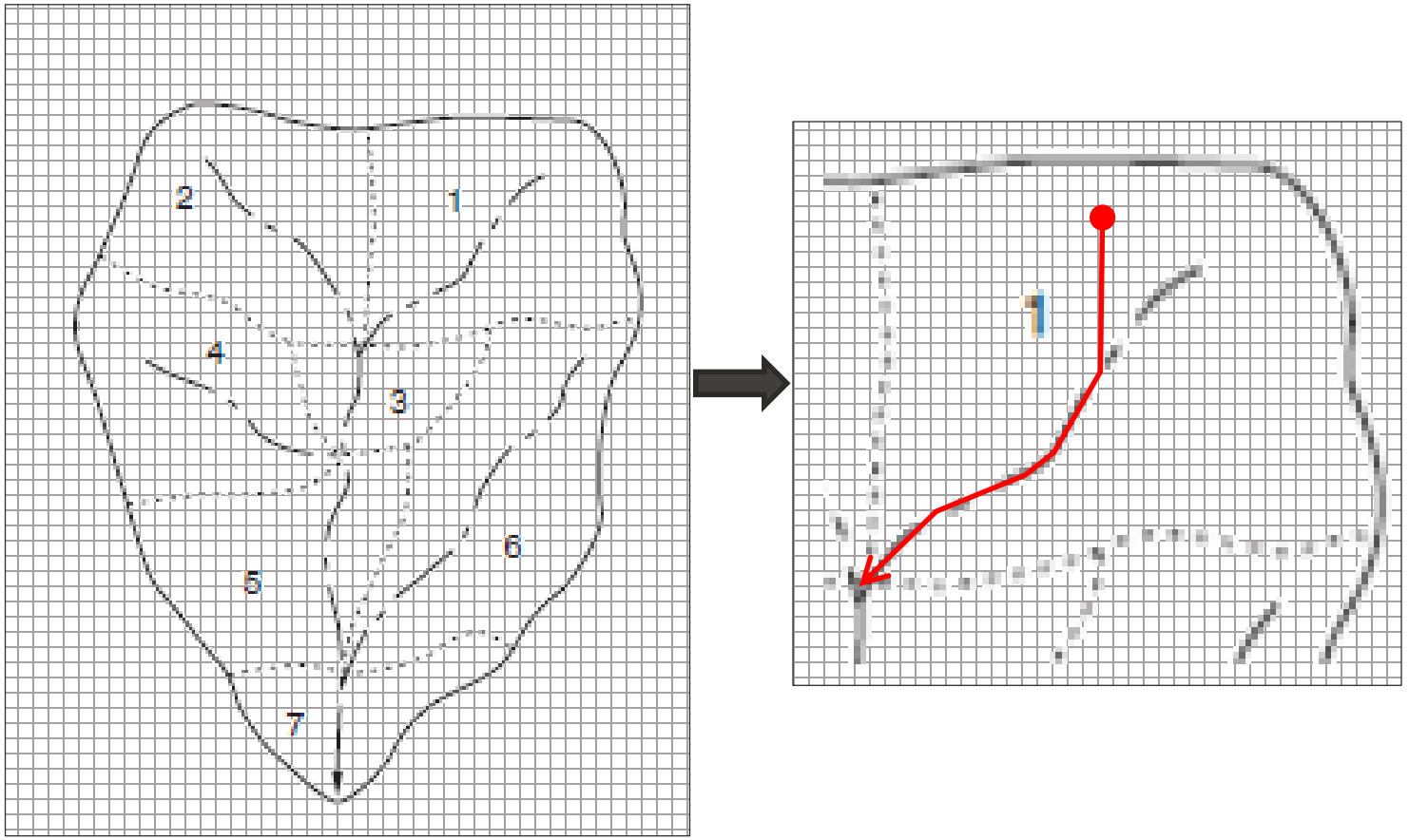
Same Recurrence Interval !

Hydrologic Modeling
Gridded Precipitation (RADAR)

HEC-HMS Gridded Precipitation Schema

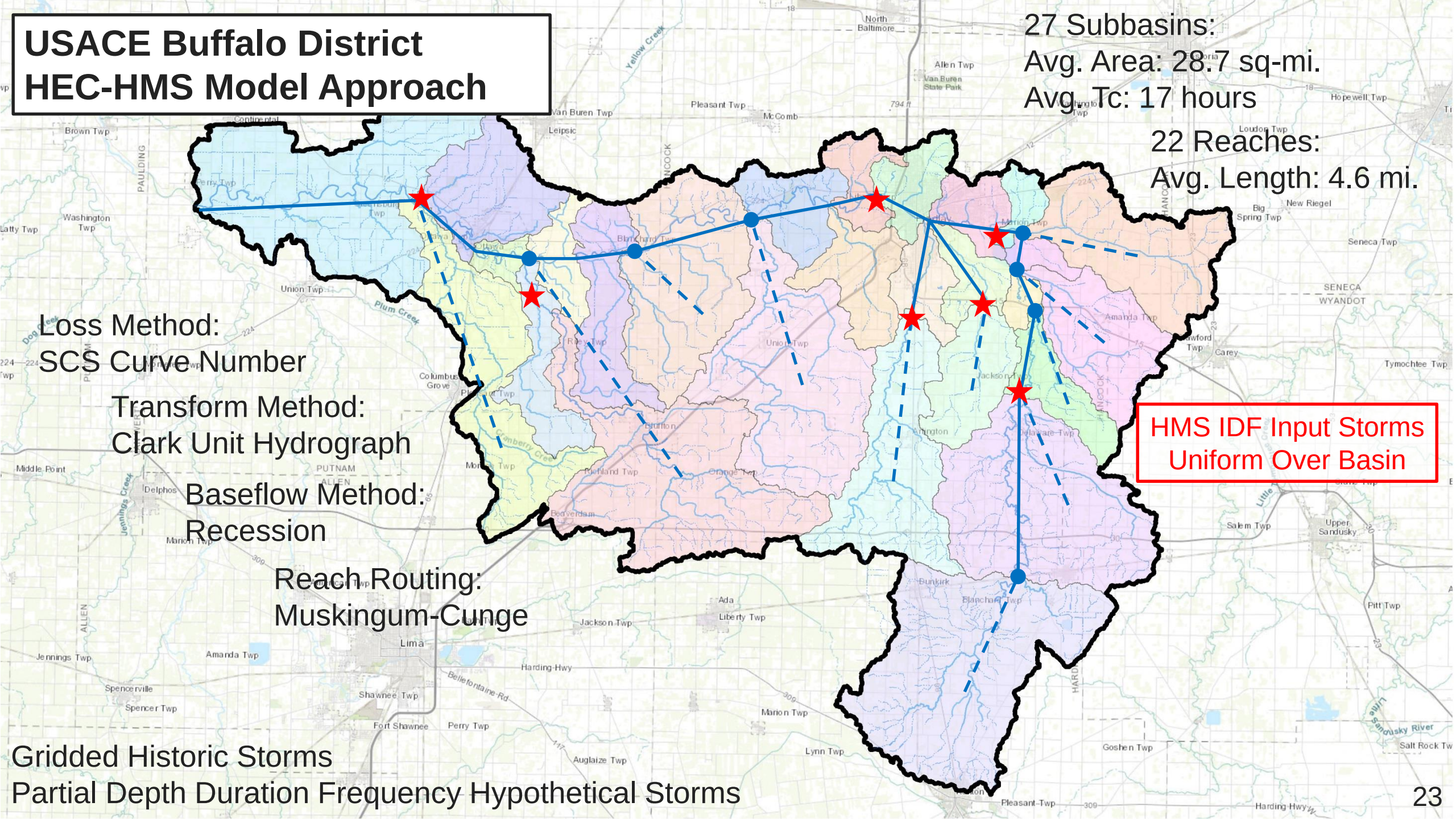
- SHG = USA Contiguous Albers Equal Area Conic USGS Projection
- Must Have Grid Param File From HEC-GeoHMS / ArcHydro





Source: NRCS TR-55

USACE Buffalo District
HEC-HMS Model Approach



27 Subbasins:
Avg. Area: 28.7 sq-mi.
Avg. Tc: 17 hours

22 Reaches:
Avg. Length: 4.6 mi.

Loss Method:
SCS Curve Number

Transform Method:
Clark Unit Hydrograph

Baseflow Method:
Recession

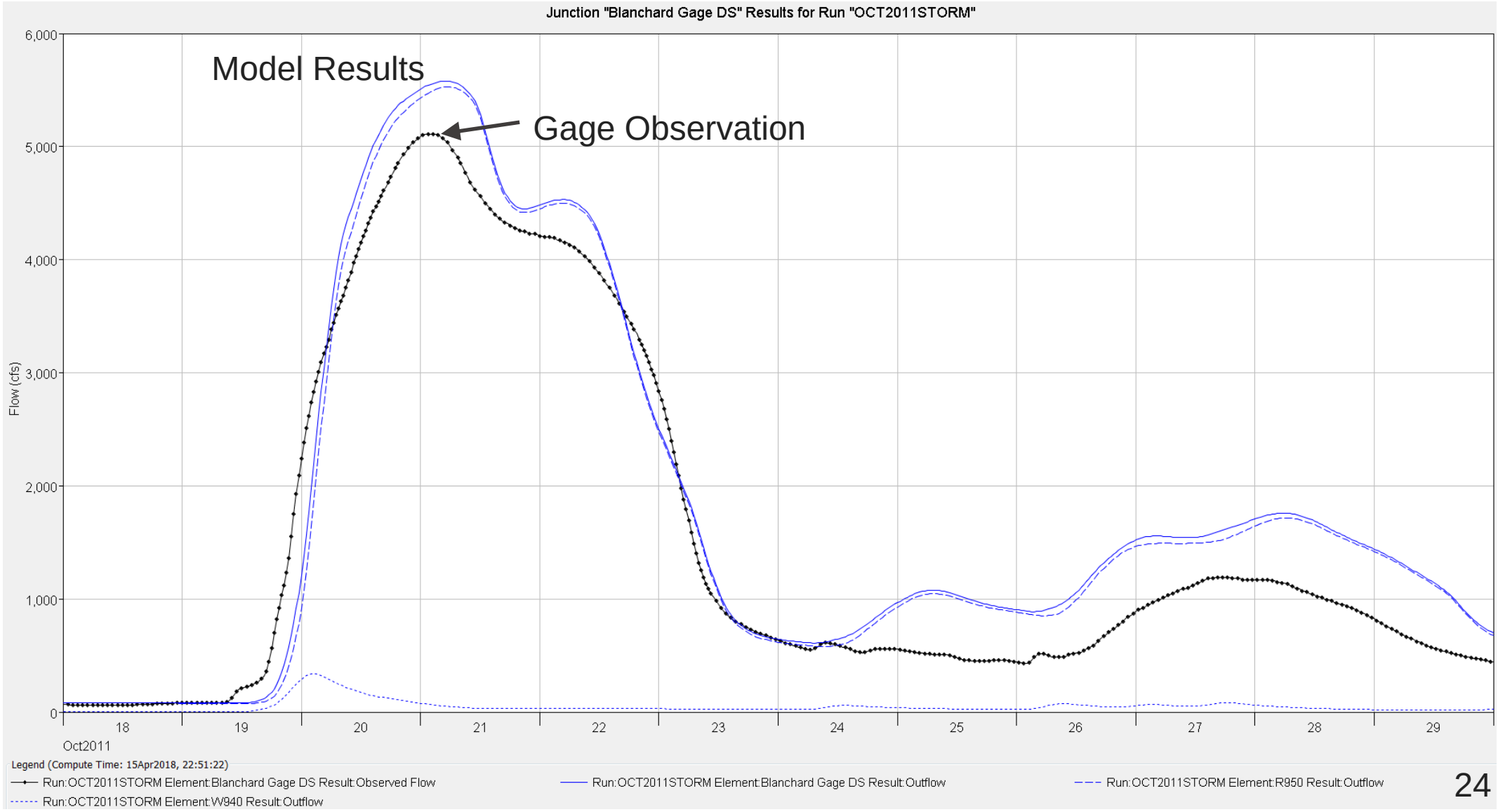
Reach Routing:
Muskingum-Cunge

HMS IDF Input Storms
Uniform Over Basin

Gridded Historic Storms
Partial Depth Duration Frequency Hypothetical Storms

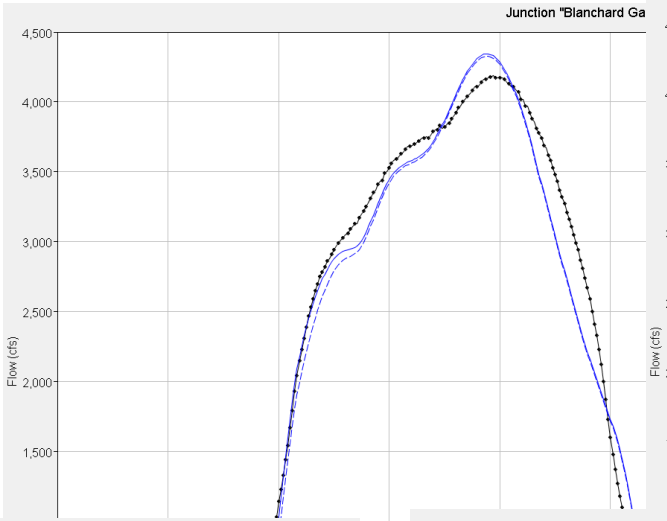
USACE HEC-HMS Model

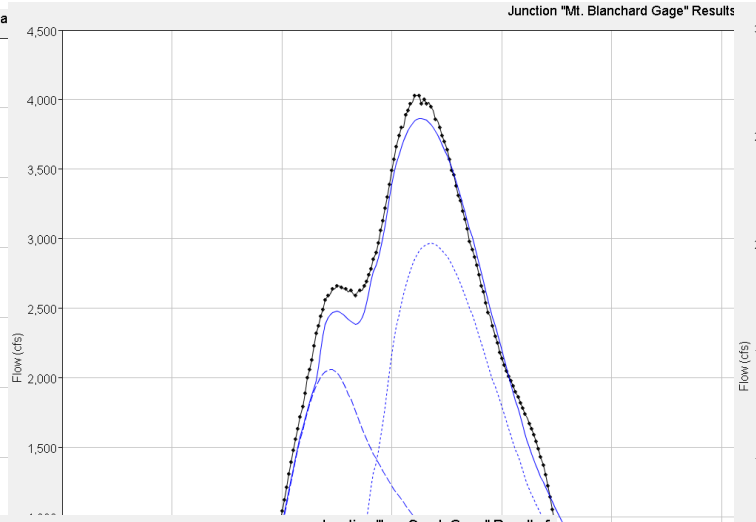
Previous Calibration – October 2011

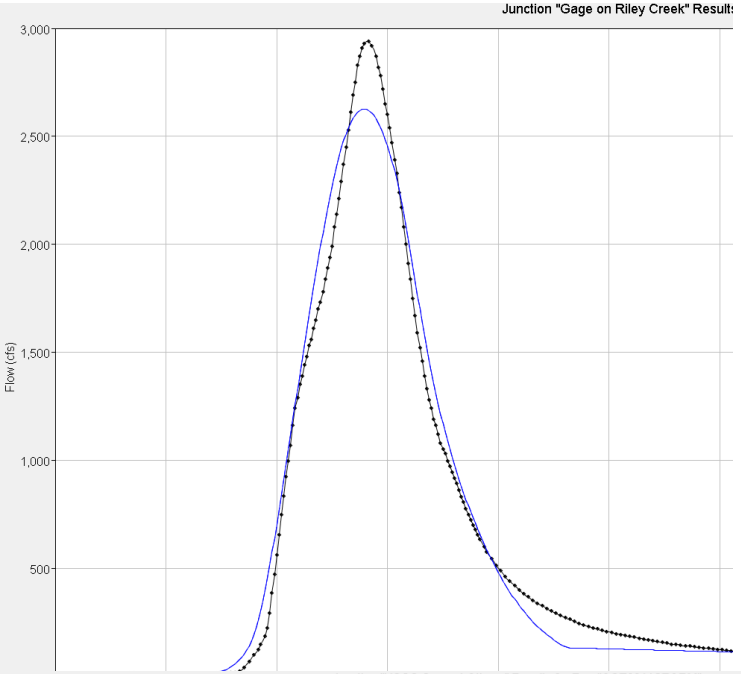


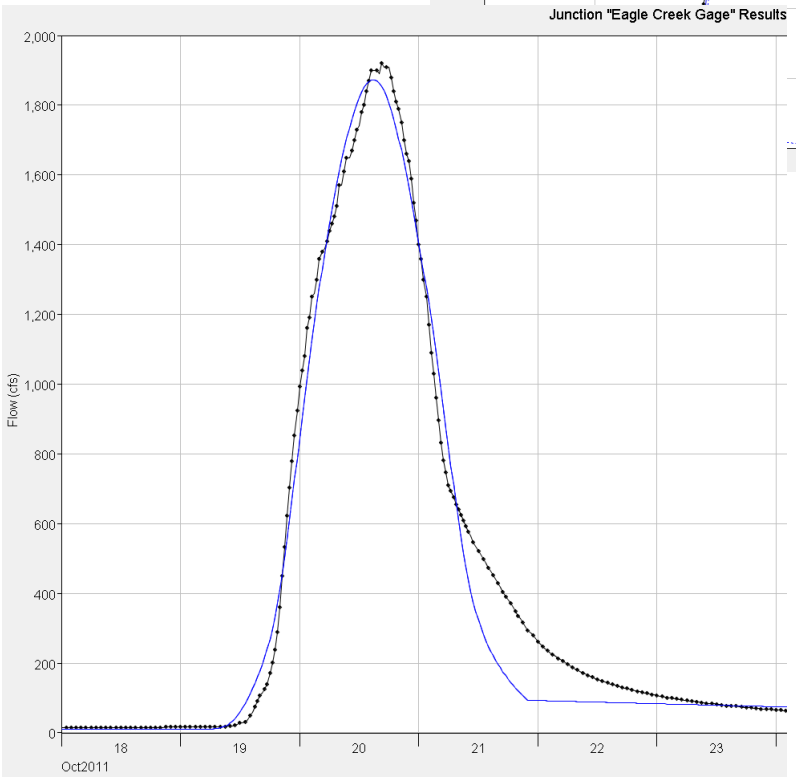
Previous Calibration – October 2011

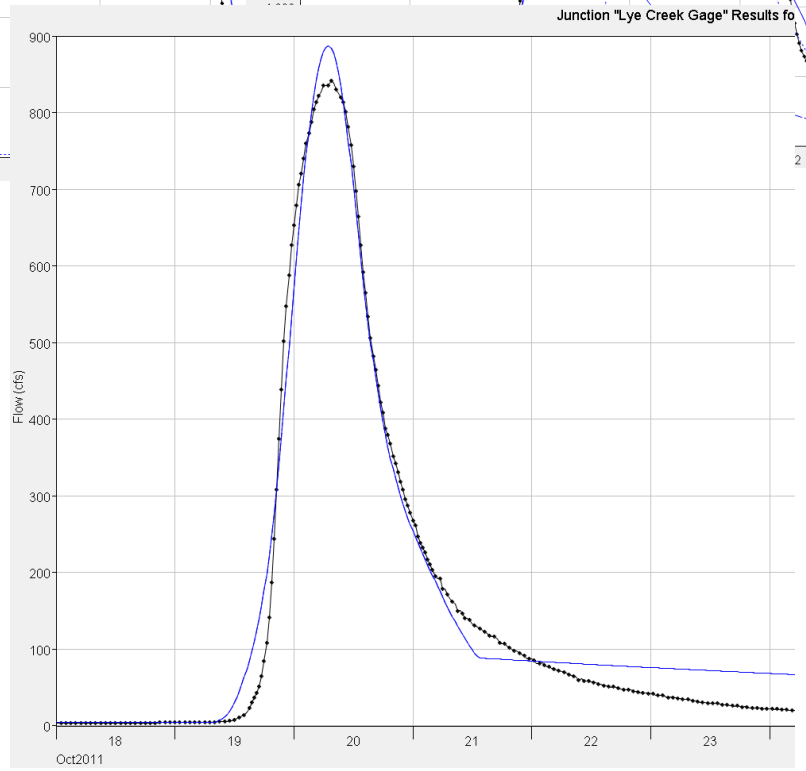
USACE HEC-HMS Model

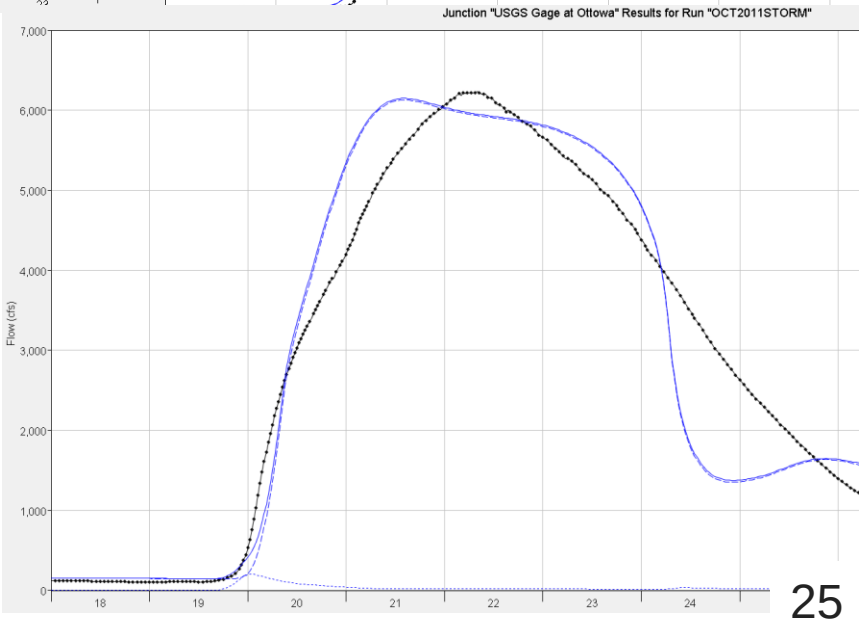






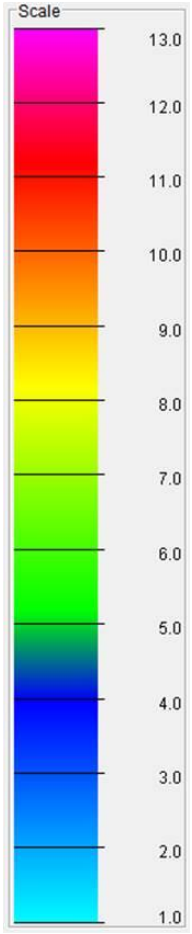


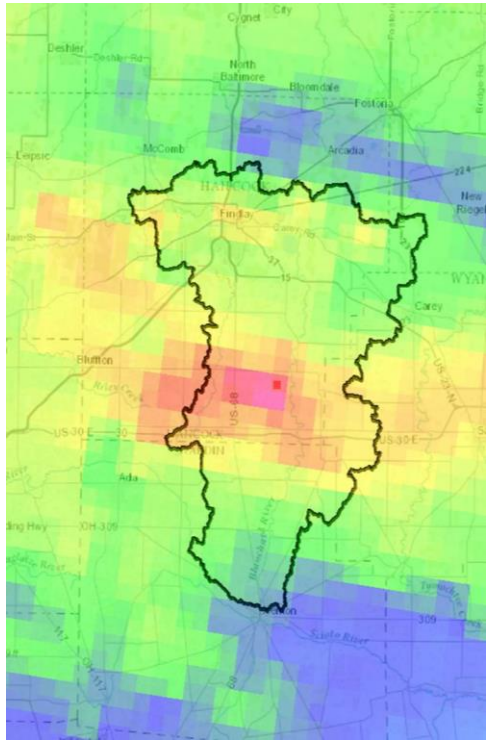


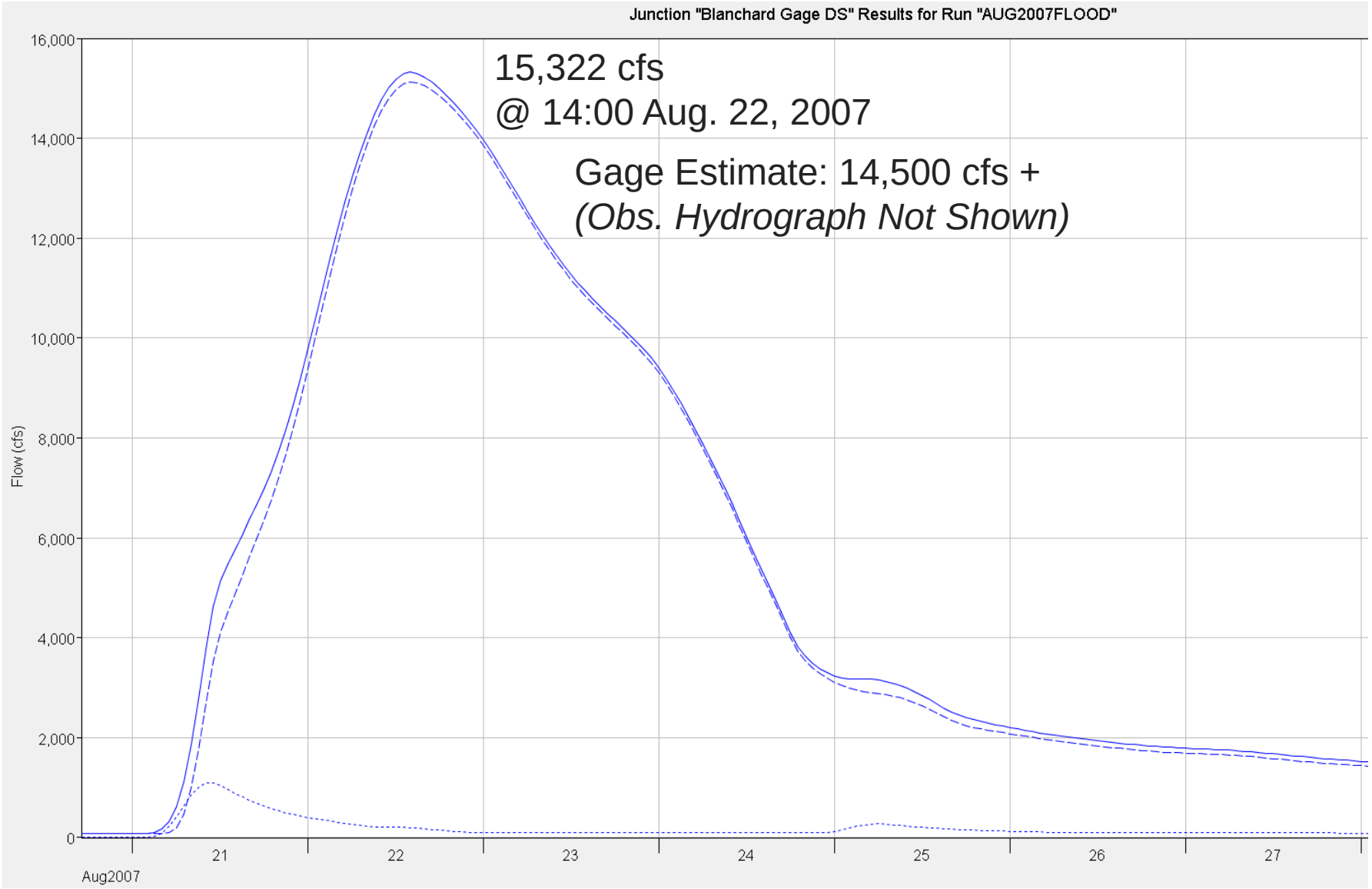


August 2007 Flood

USACE HEC-HMS Model



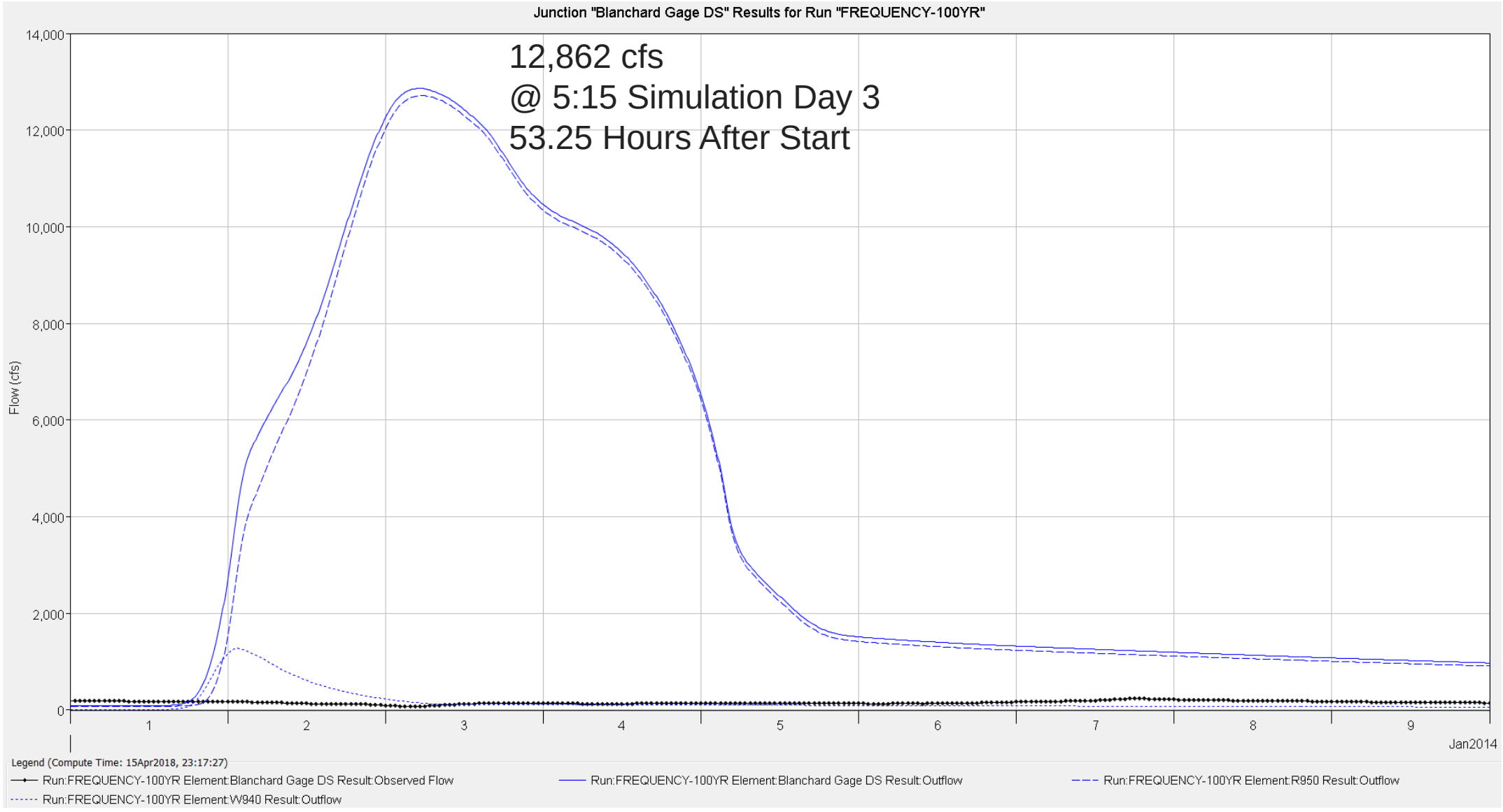




USACE HEC-HMS Model

1% Annual Chance (100-Year) Flood Event

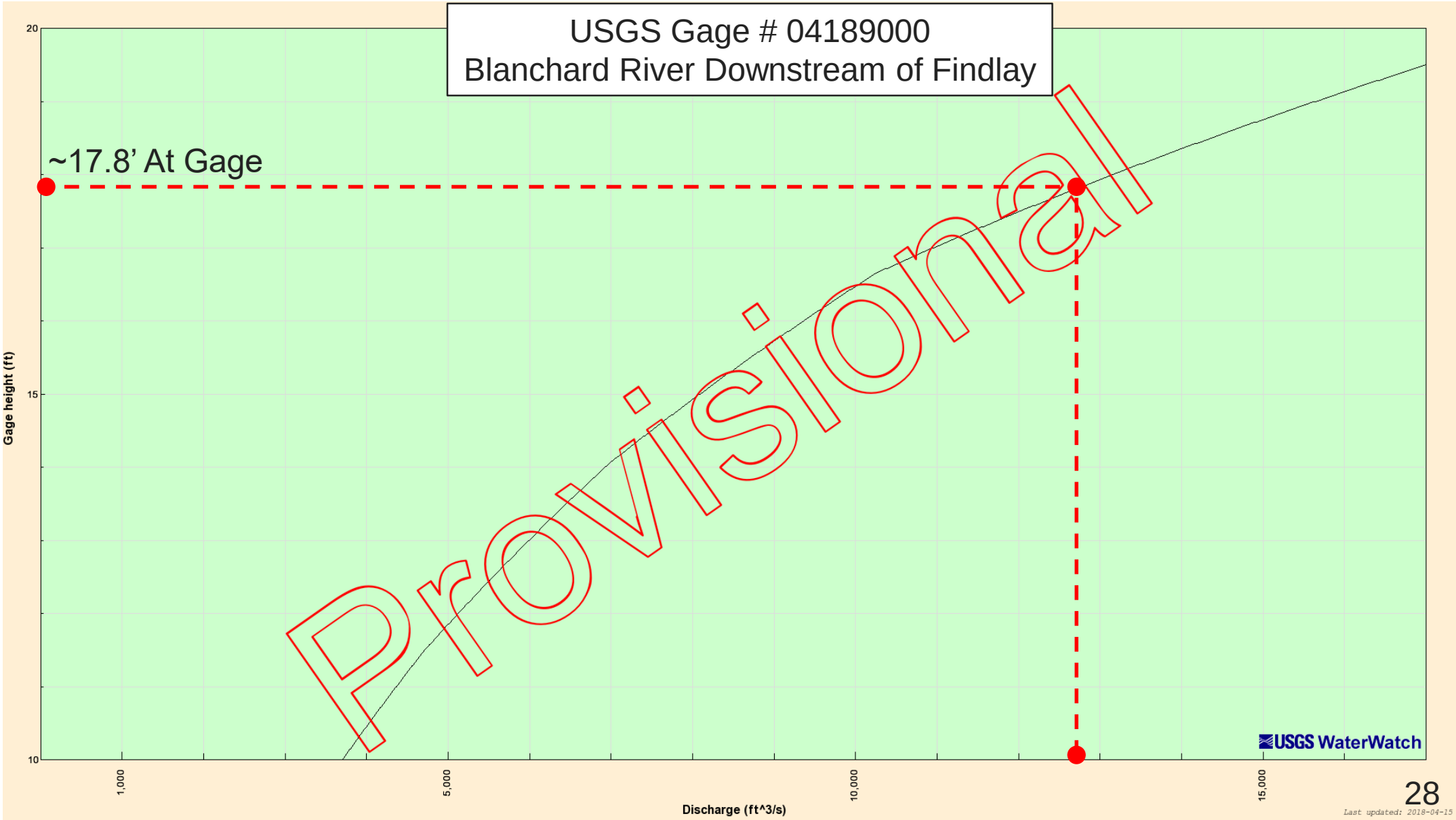
HEC-HMS Frequency Storm



USACE HEC-HMS Model

1% Annual Chance (100-Year) Flood Event

HEC-HMS Frequency Storm = 12,862 cfs

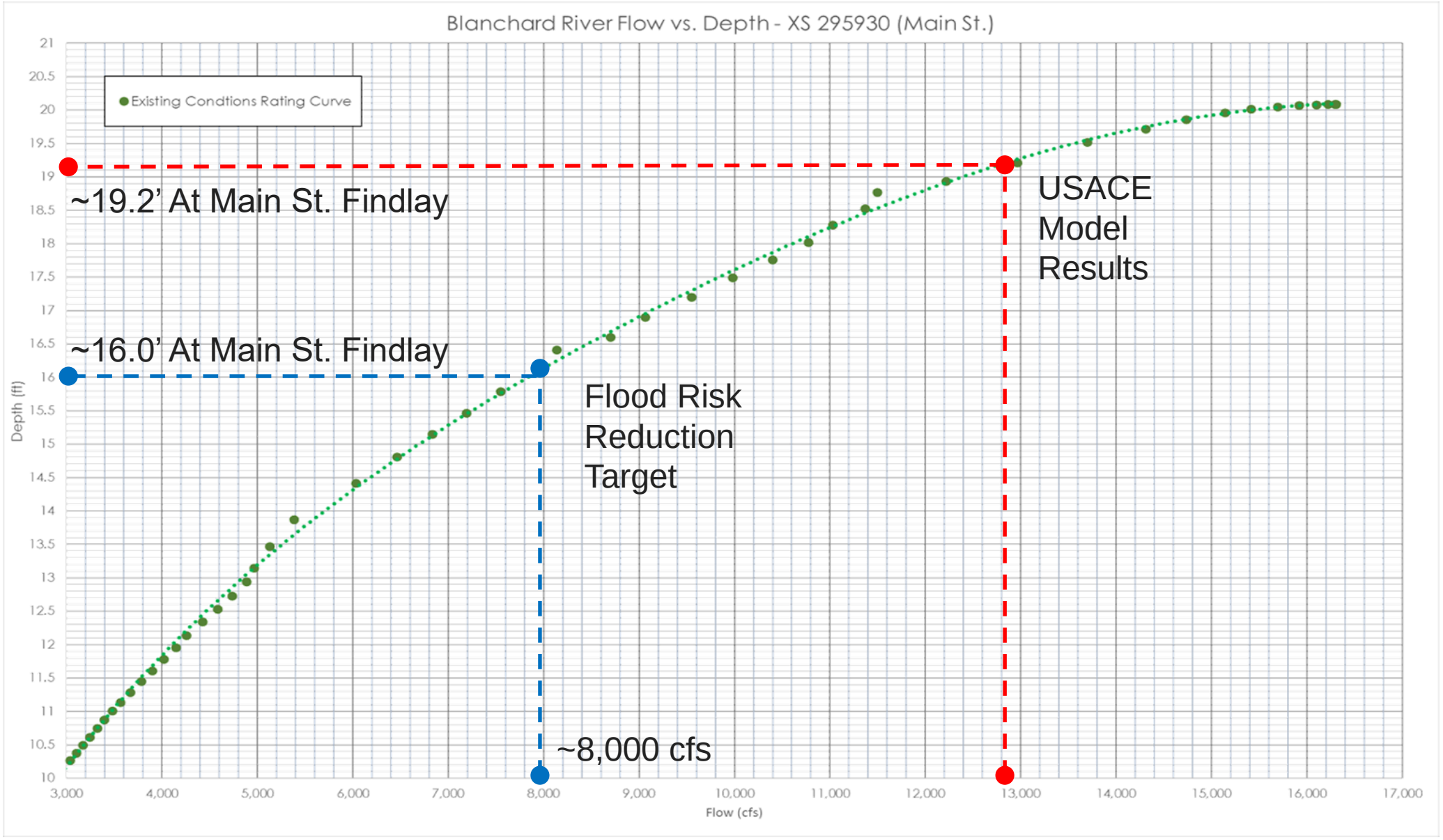


Source: USGS

USACE HEC-HMS Model

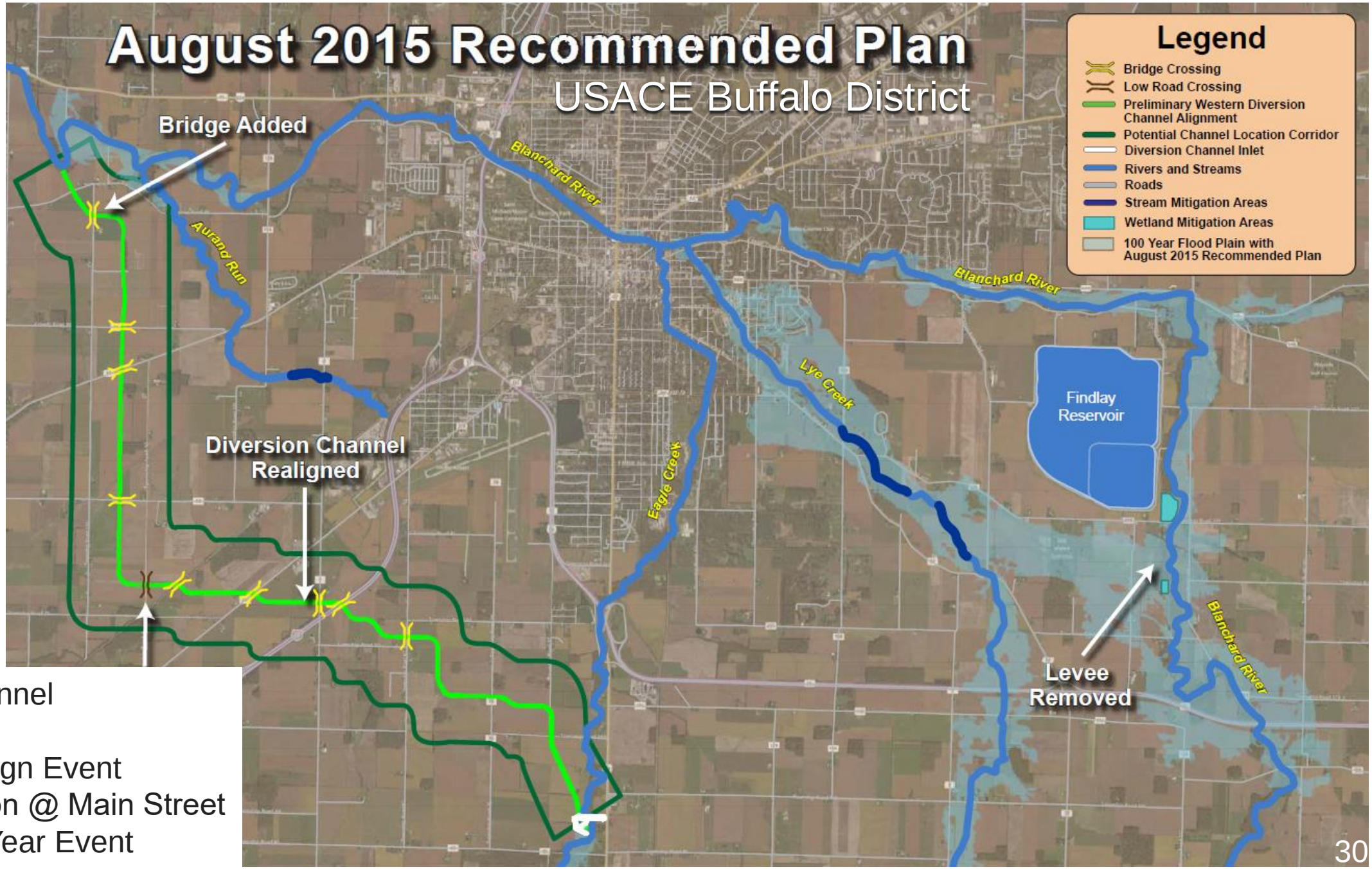
1% Annual Chance (100-Year) Flood Event

HEC-HMS Frequency Storm = 12,862 cfs



Stantec

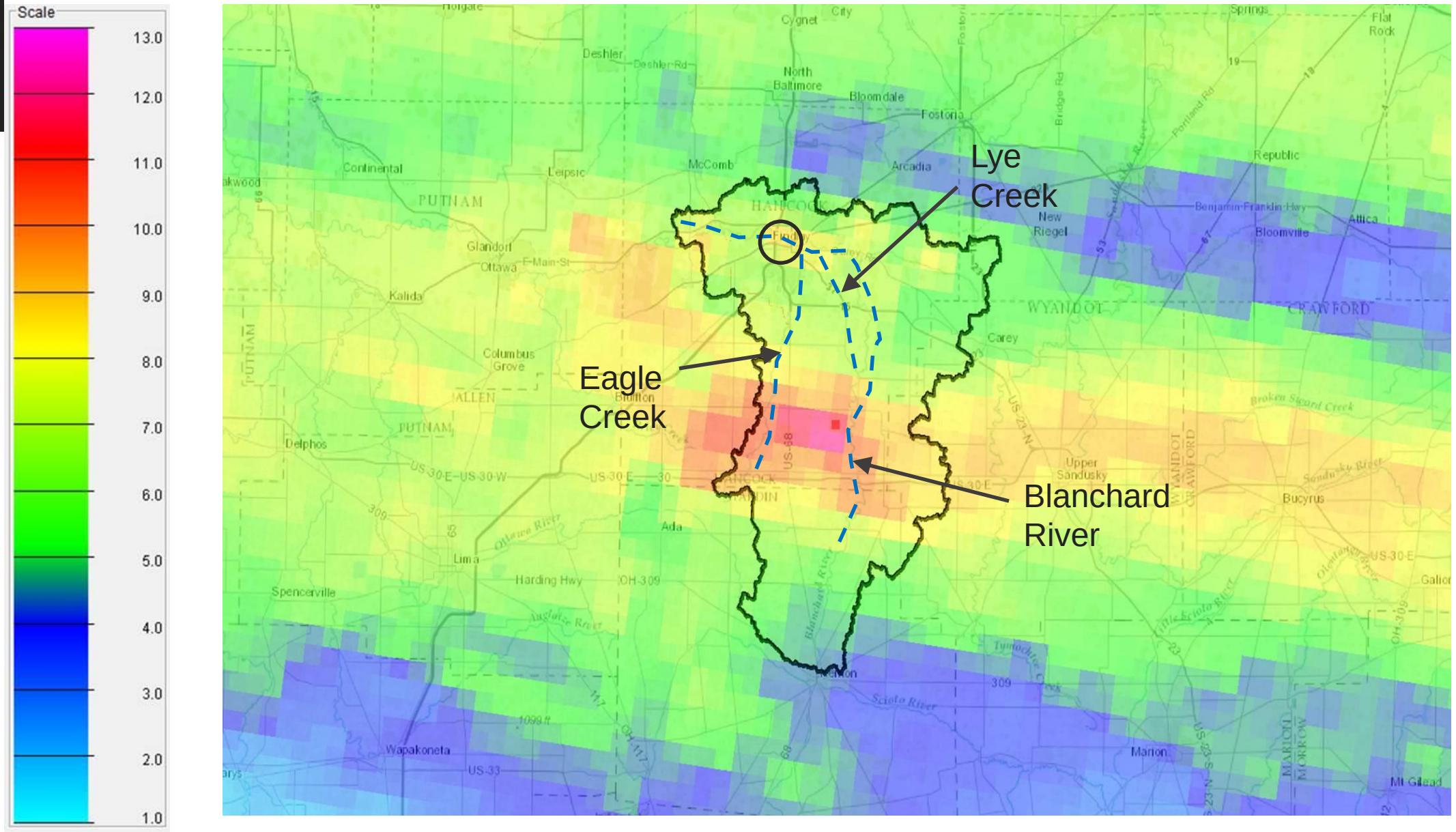
Conceptual Flood Risk Reduction Measures



9.2 Mile Channel
9 Bridges
25-Year Design Event
< 2’ Reduction @ Main Street During 100-Year Event

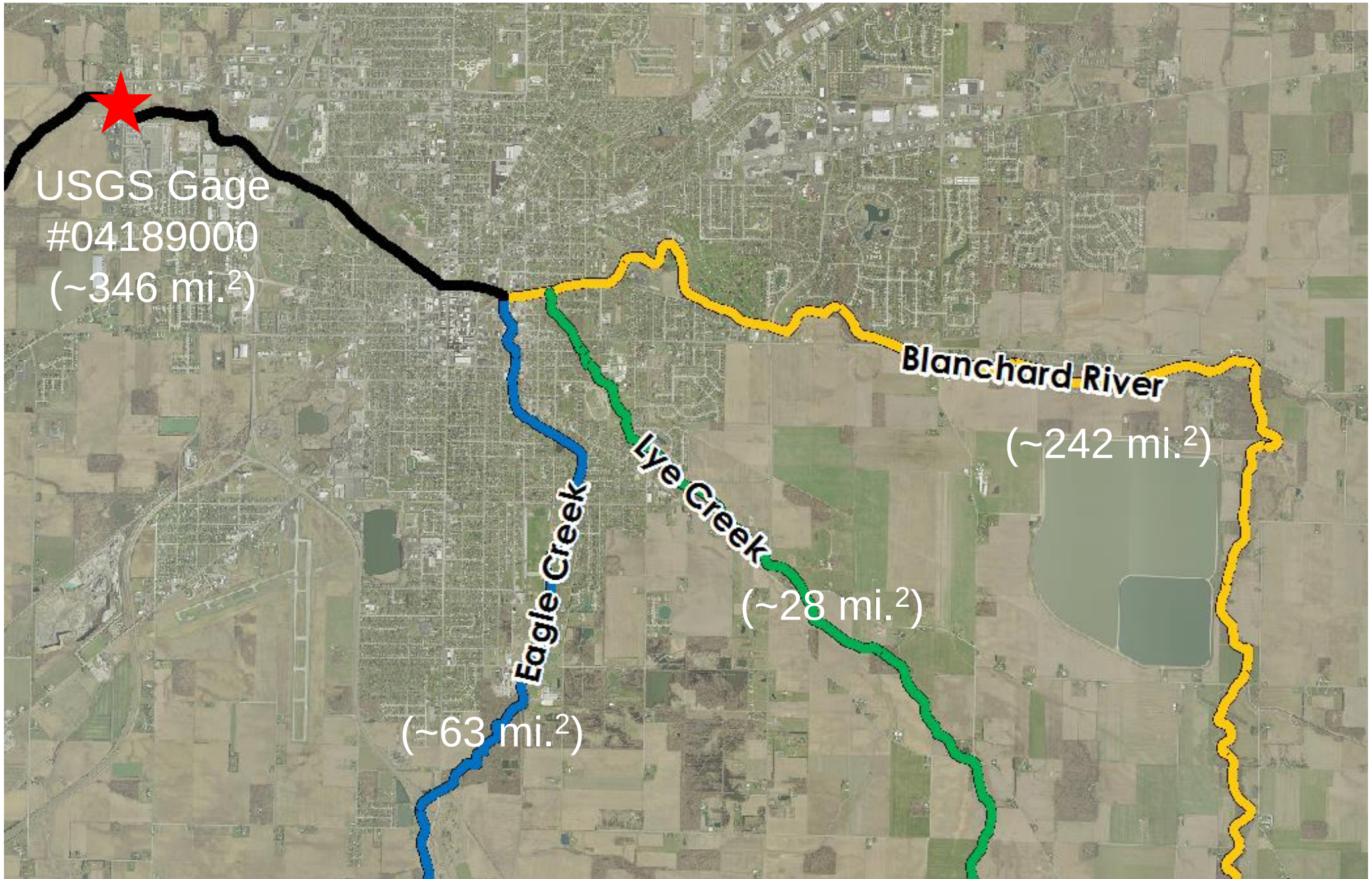
August 2007 Flood

USACE HEC-HMS Model



Blanchard River Watershed Runoff

Where Does the Water Come From?

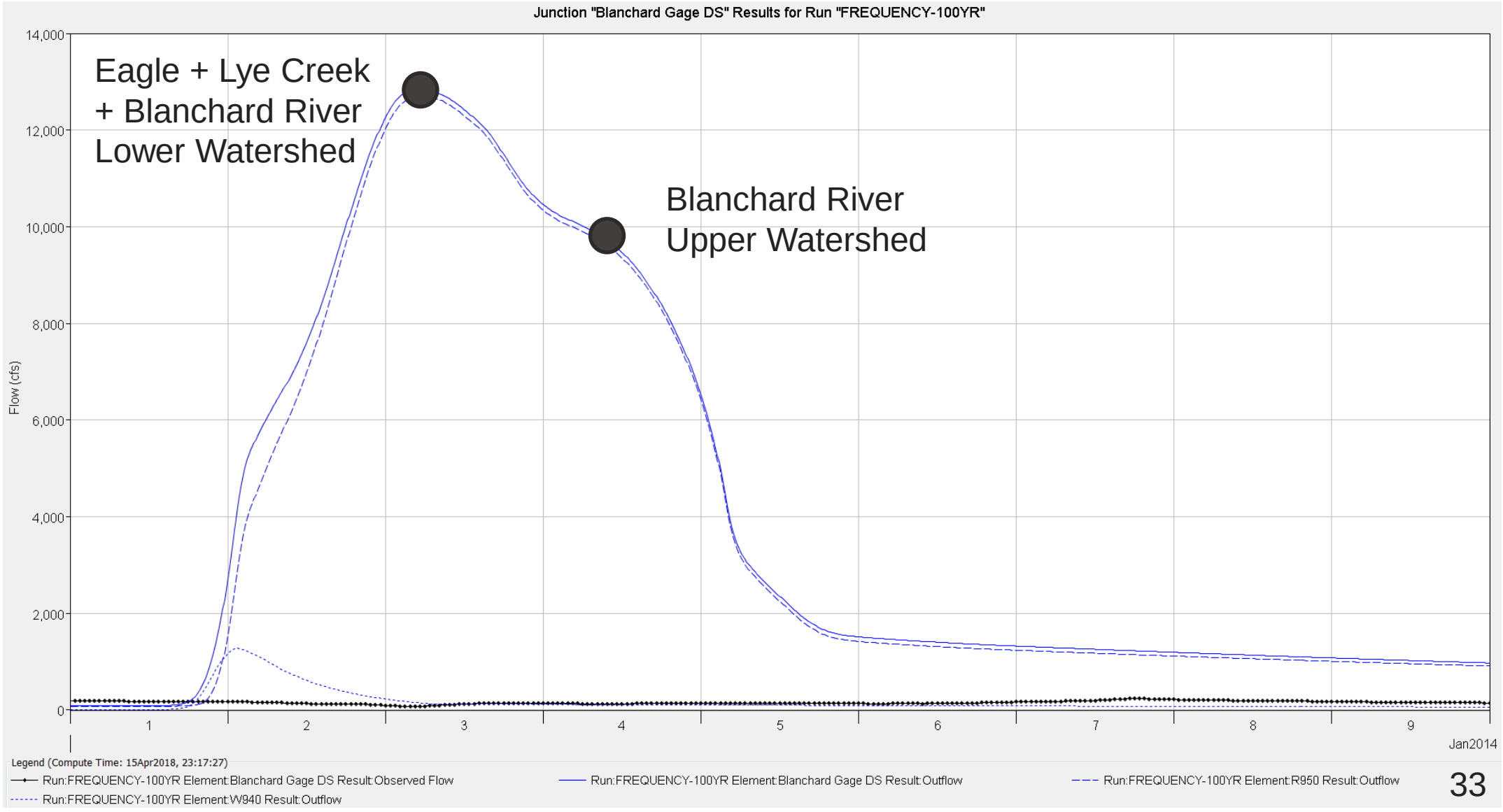


Stantec

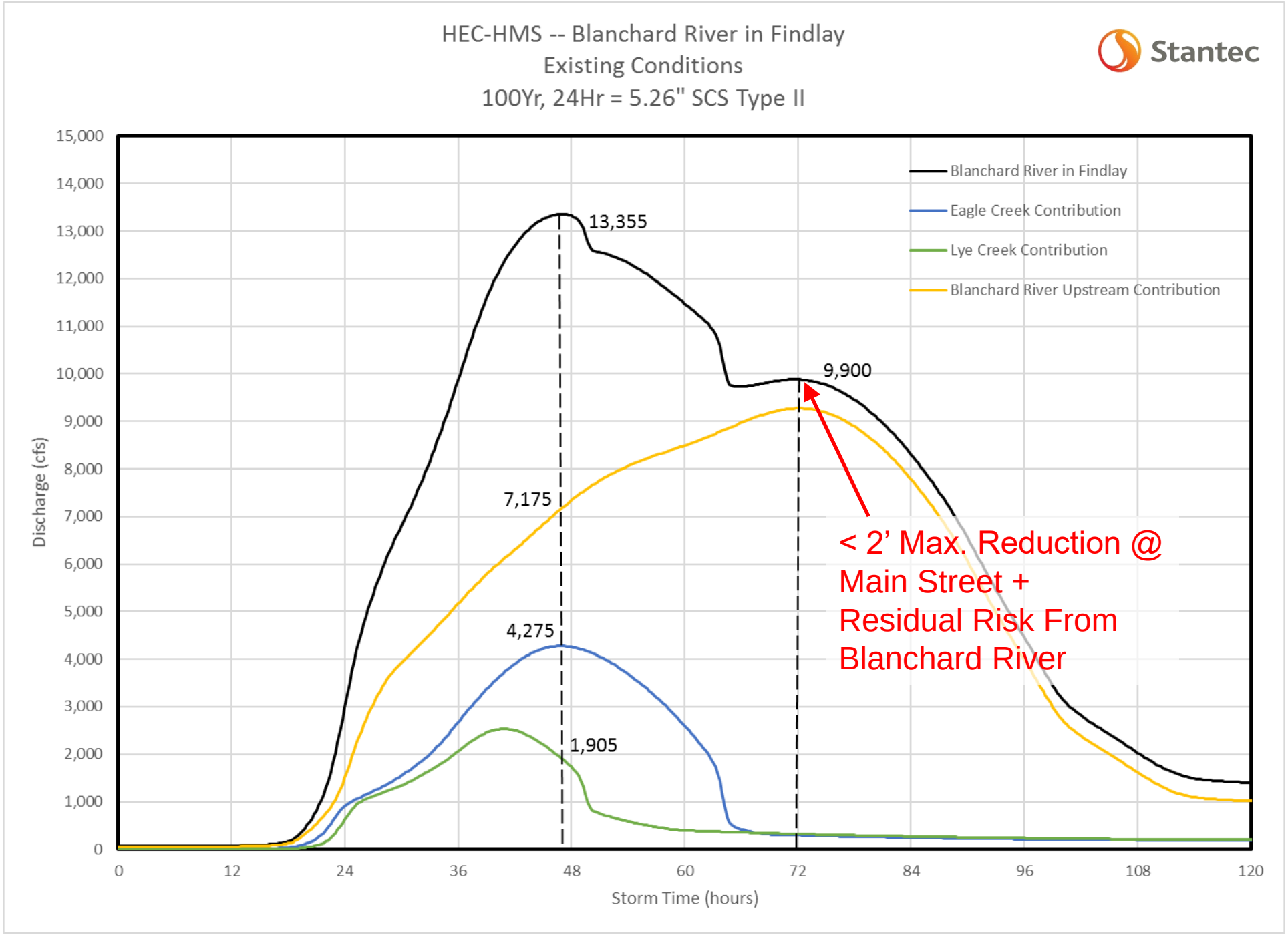
USACE HEC-HMS Model

1% Annual Chance (100-Year) Flood Event

HEC-HMS Frequency Storm



Stantec Flood Reduction Planning



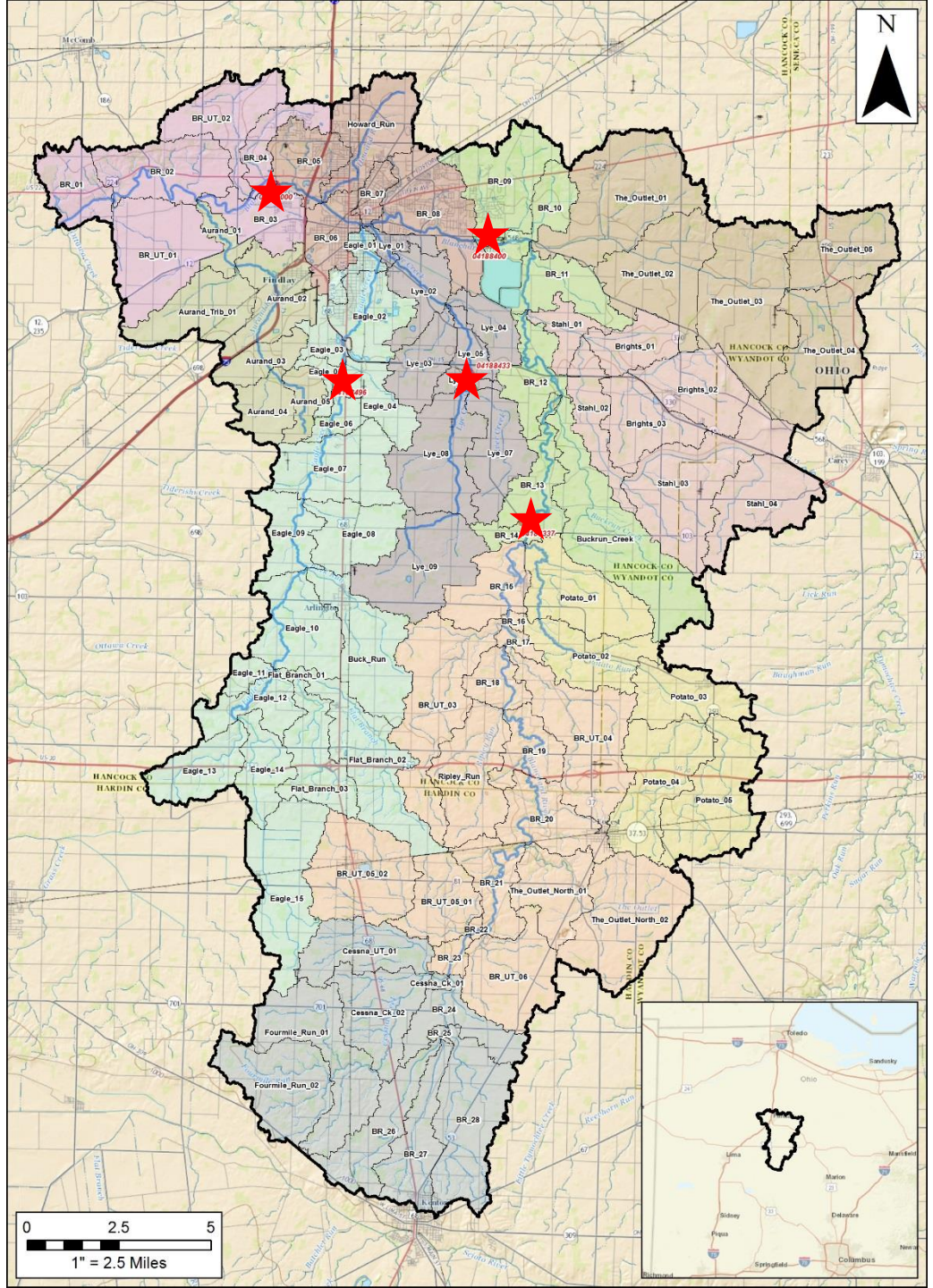
SCS Type II Storm Used For Conceptual Planning

Stantec Hydrology Study

Stantec Hydrologic Study

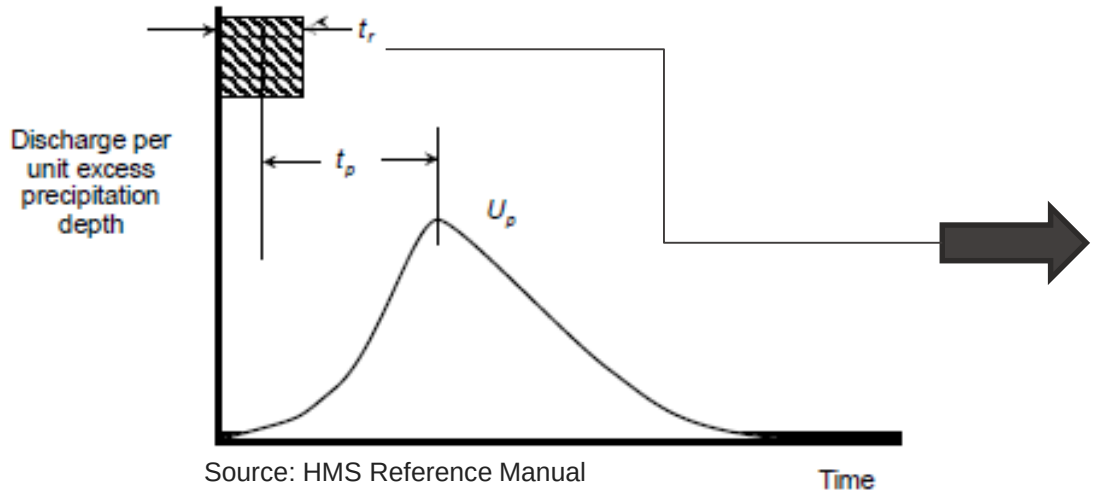
- Focused Area: 96 Subbasins
- 60 Reaches
- Gridded SCS CN Losses
- ModClark (Grid) Transform
- Recession Baseflow
- Mod-Puls + Lag Routing
- Additional Calibration
- Revised Input Storms
- Spatial & Temporal Variation
- Checked with Gage Analyses

Also Revisited Hydraulic Modeling

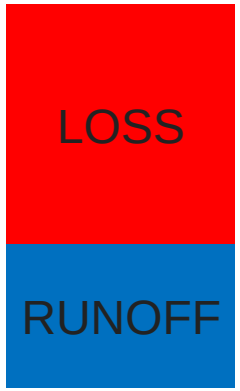


Precipitation Extraction

Gridded SCS Curve Number



Source: HMS Reference Manual



SCS Loss Equations

$$S = \frac{1000}{CN} - 10$$

$$I_a = 0.2S$$

$$P_e = \frac{(P - I_a)^2}{P - I_a + S}$$

$$S = C_{Retention}\left[\frac{1000}{CN} - 10\right]$$

Potential Retention Scale Factor Added
Varies by Subbasin

Initial Abstraction Ratio
Can Vary By Subbasin &
Antecedent Conditions

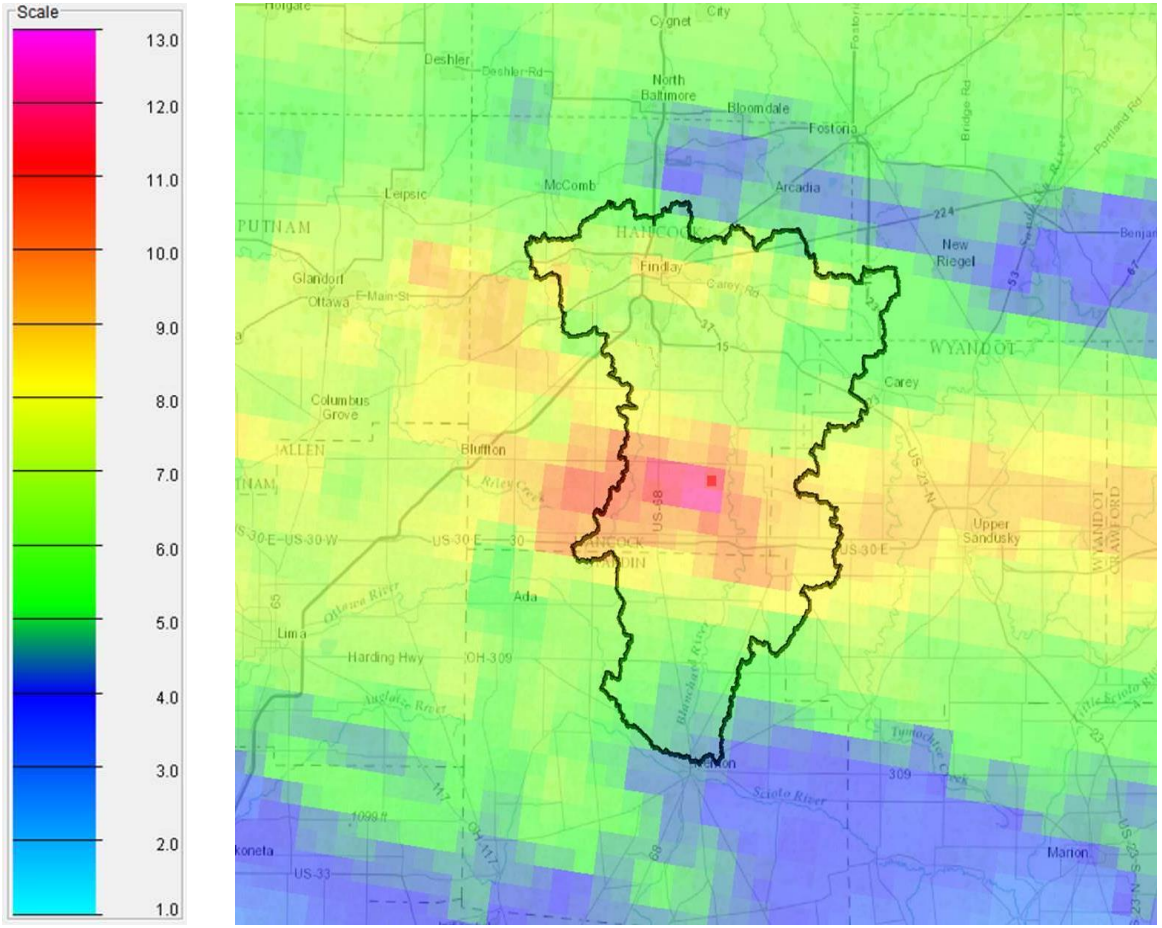
Additional Calibration Parameters

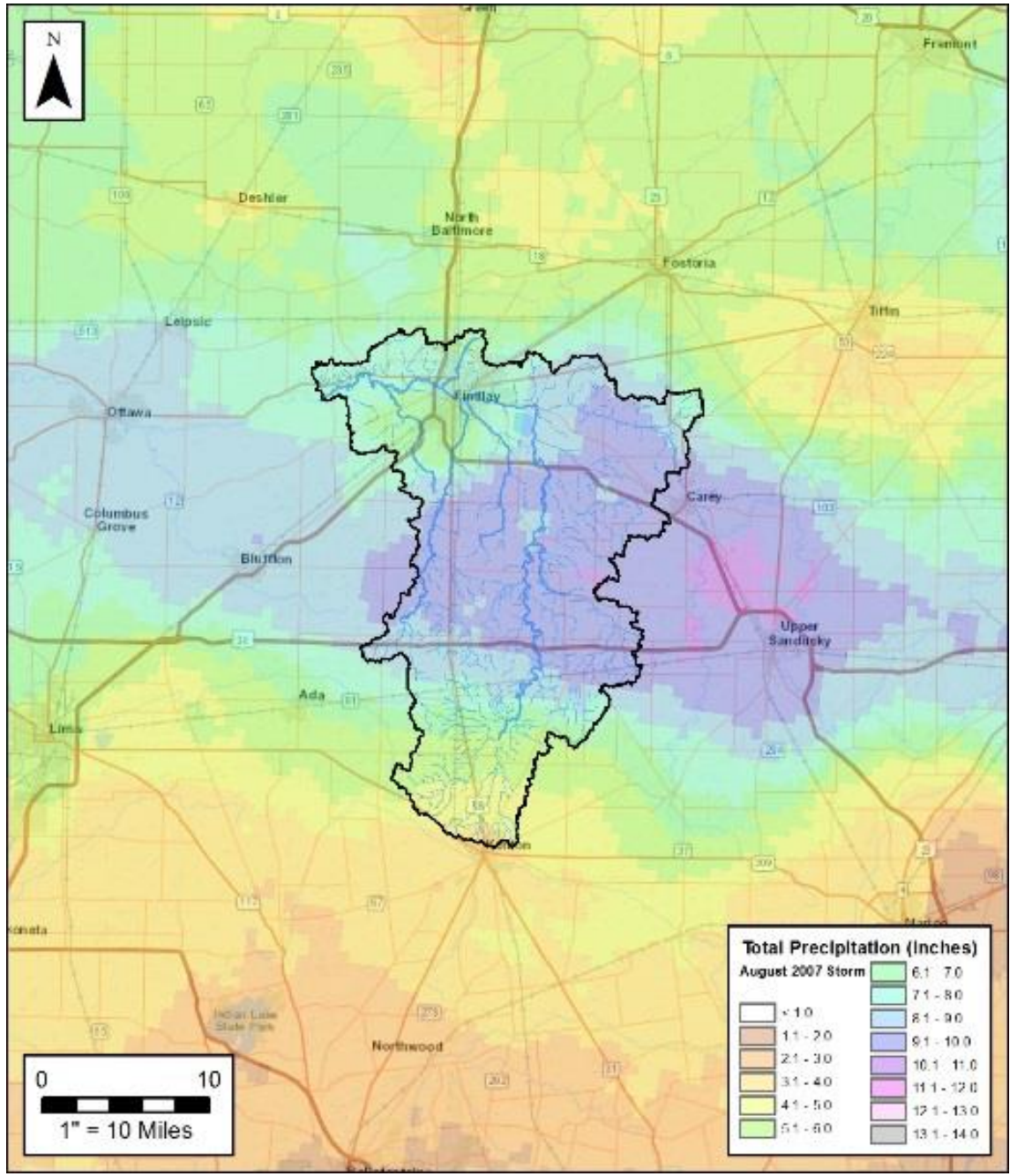
Stantec Hydrology Study

Revised Radar Data

Applied Weather Associates

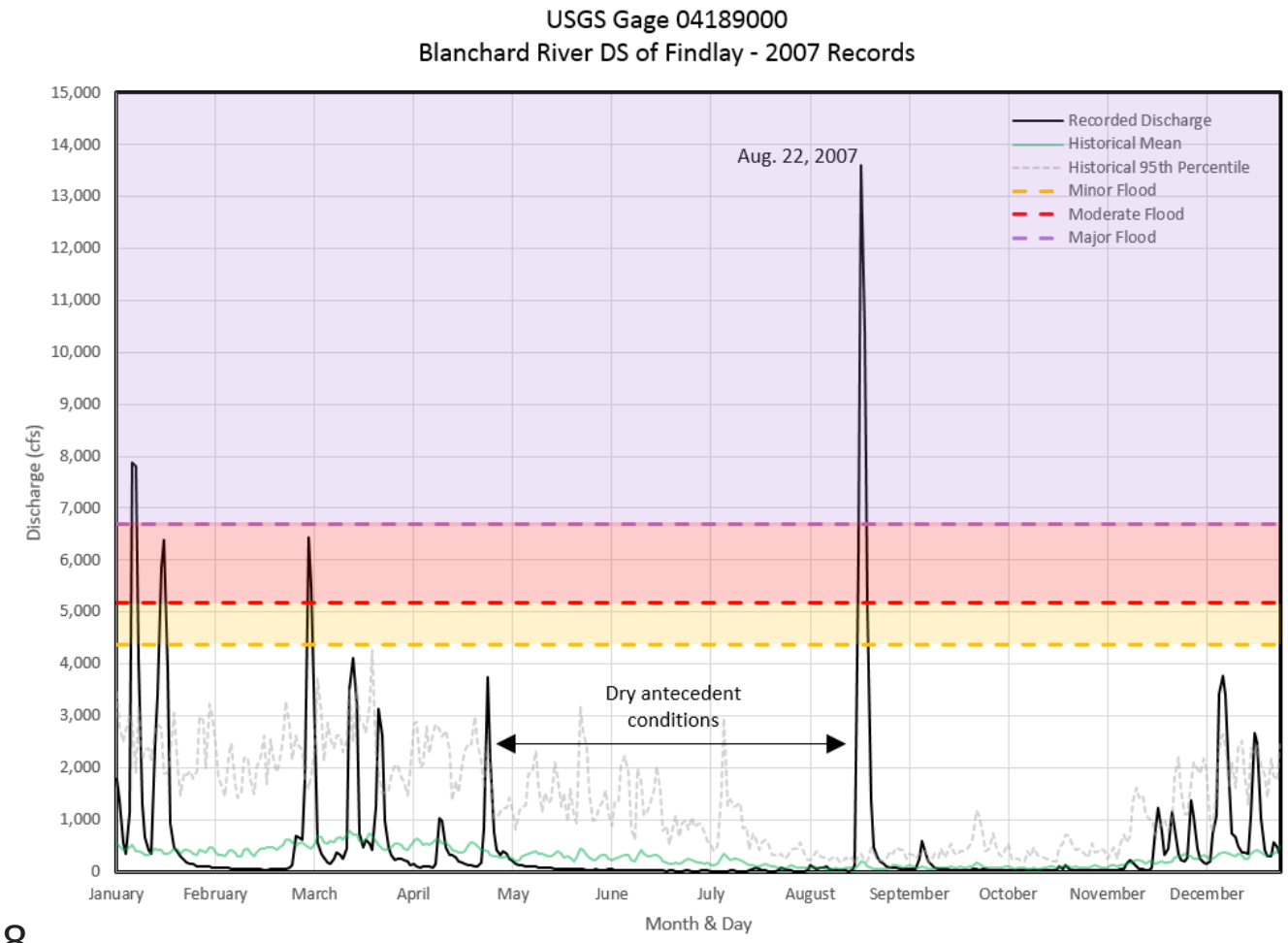
Must Ground-Truth NEXRAD Data

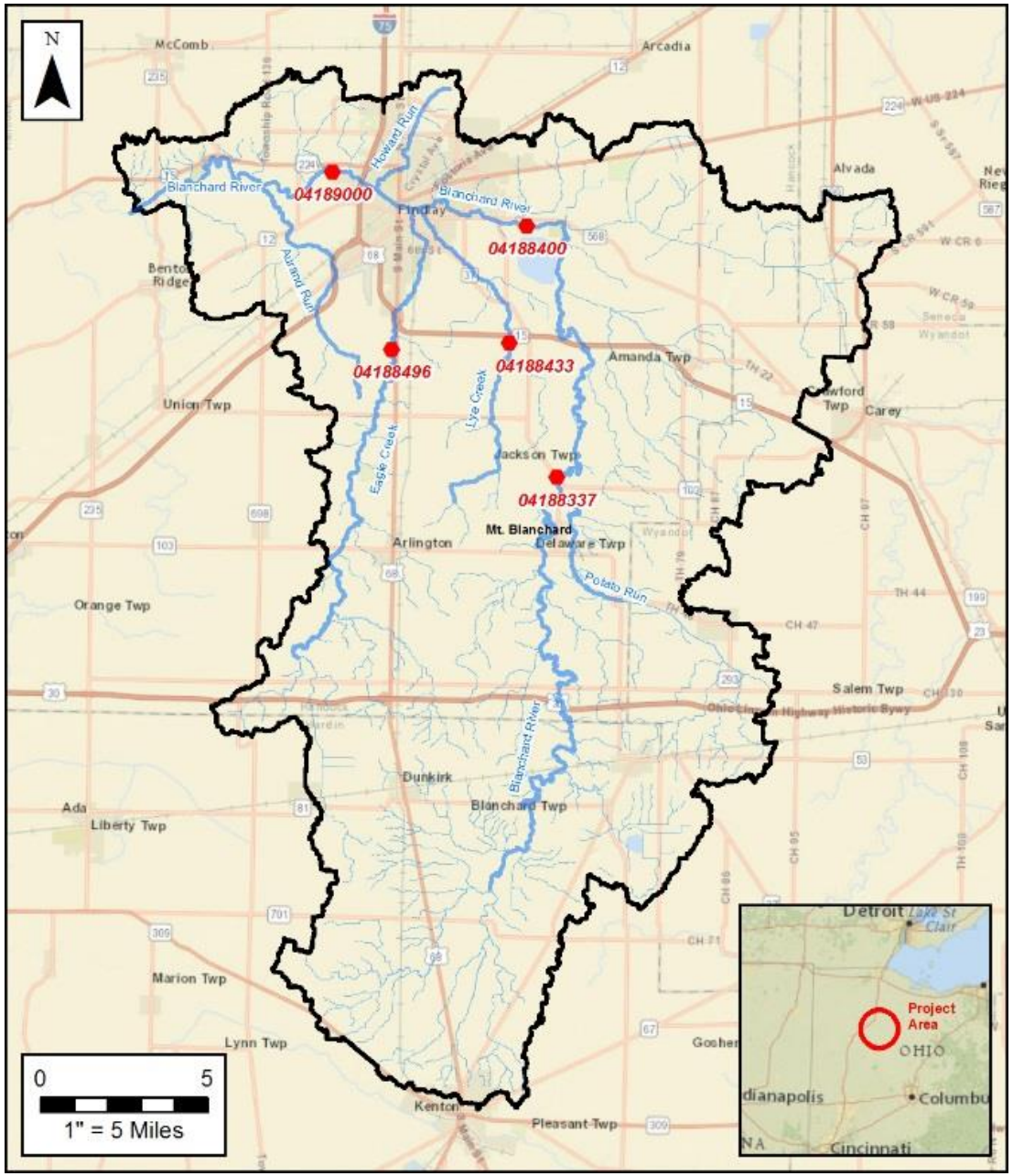




Stantec Hydrology Study

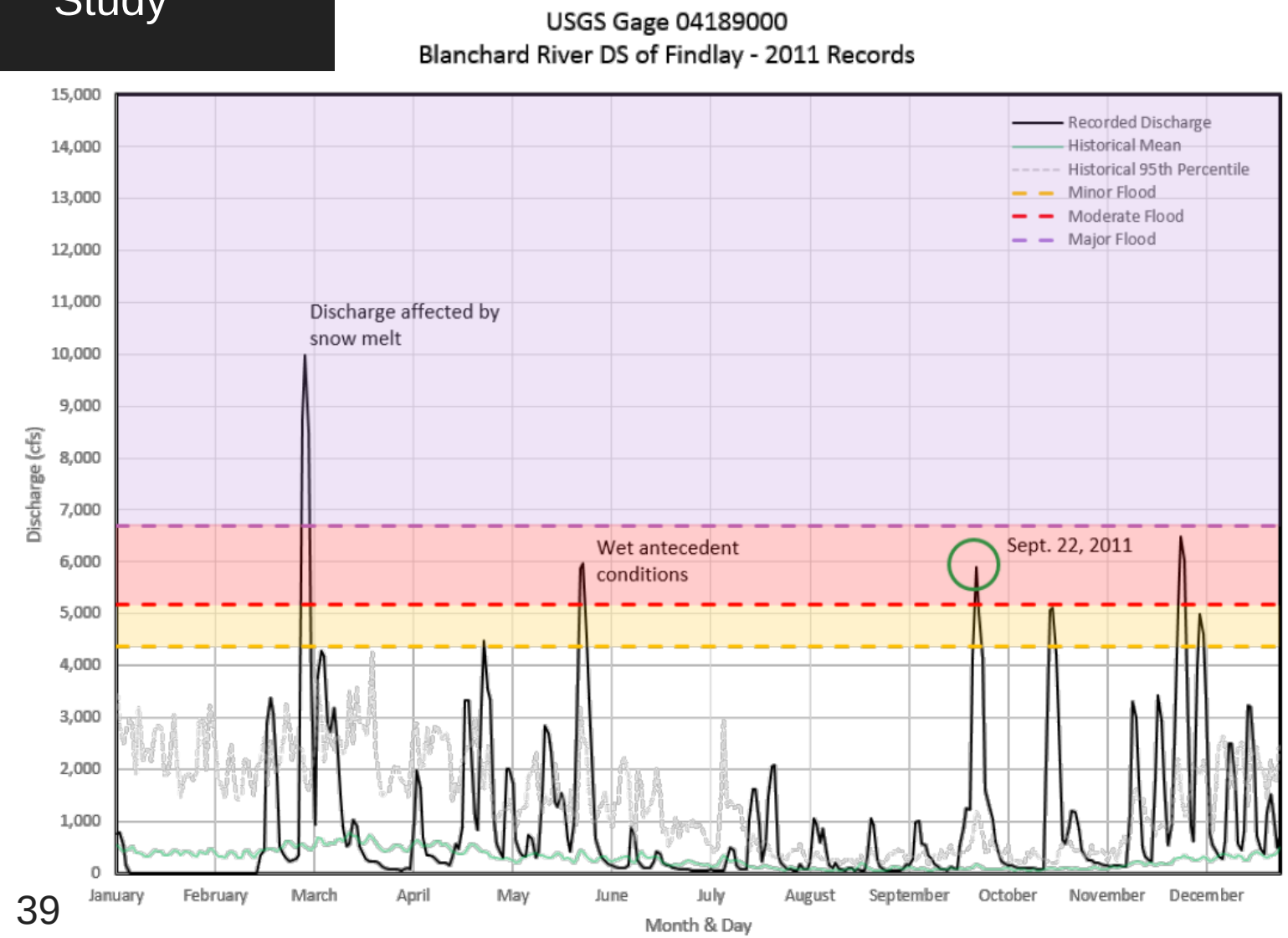
Additional Calibration Event(s)

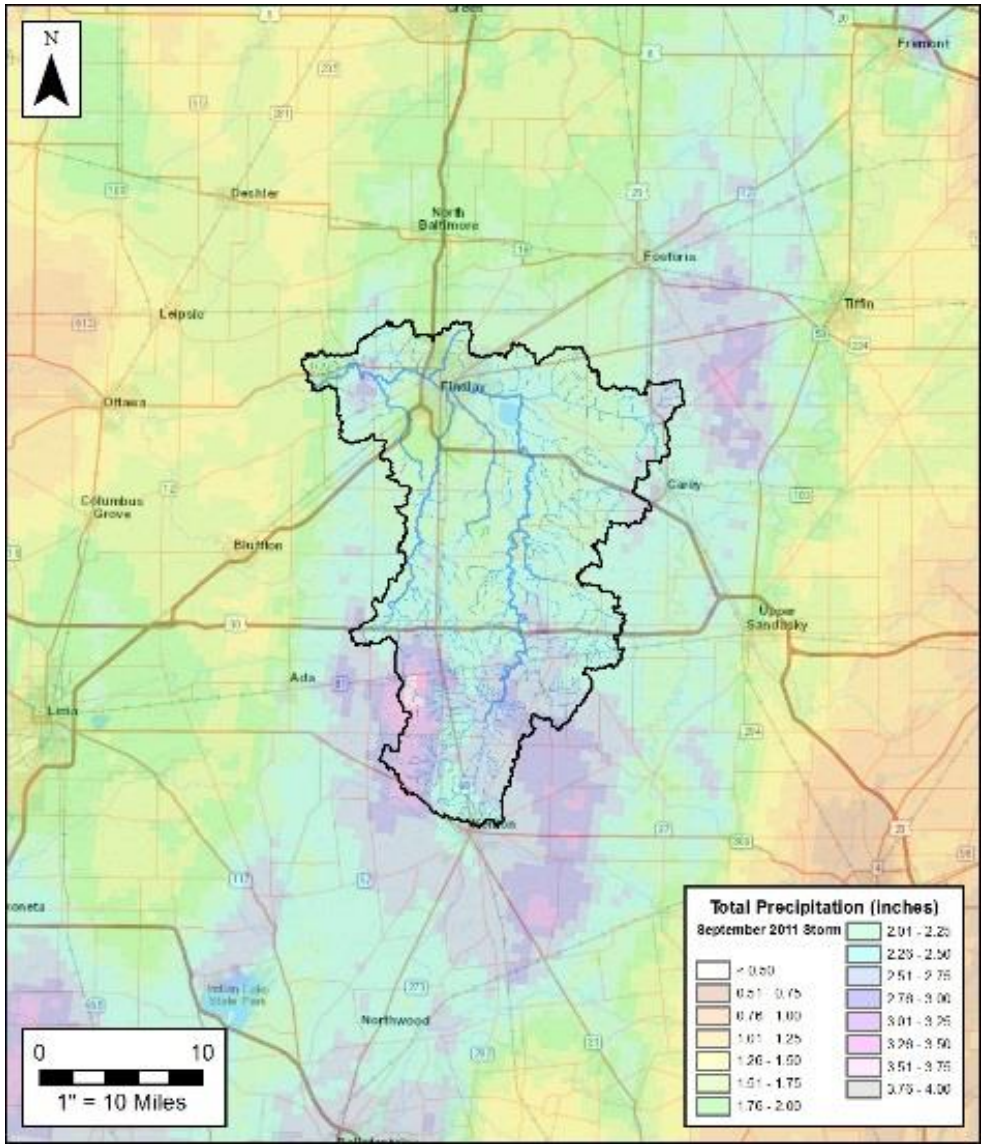




September 2011 Calibration Event

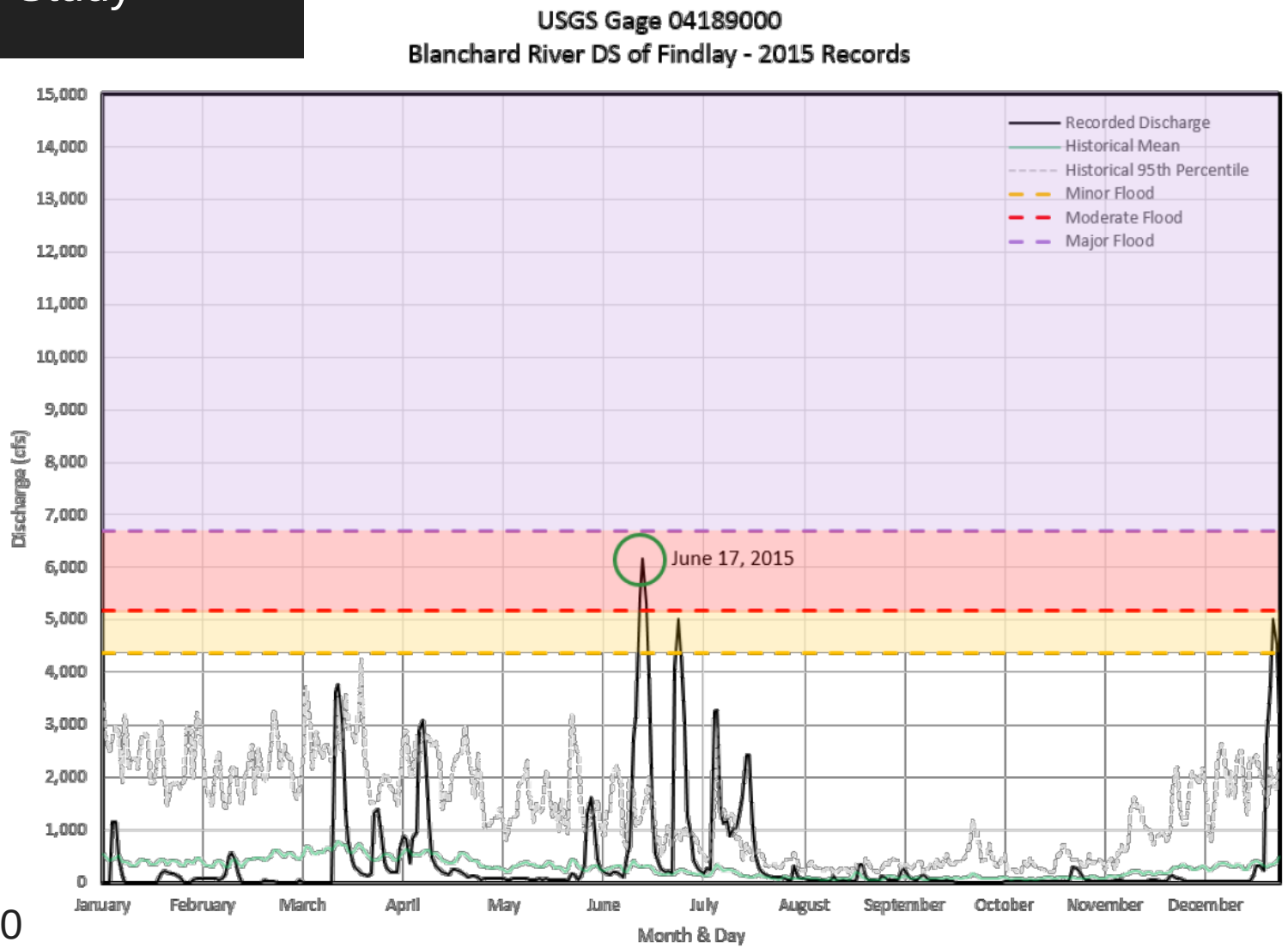
Stantec Hydrology Study

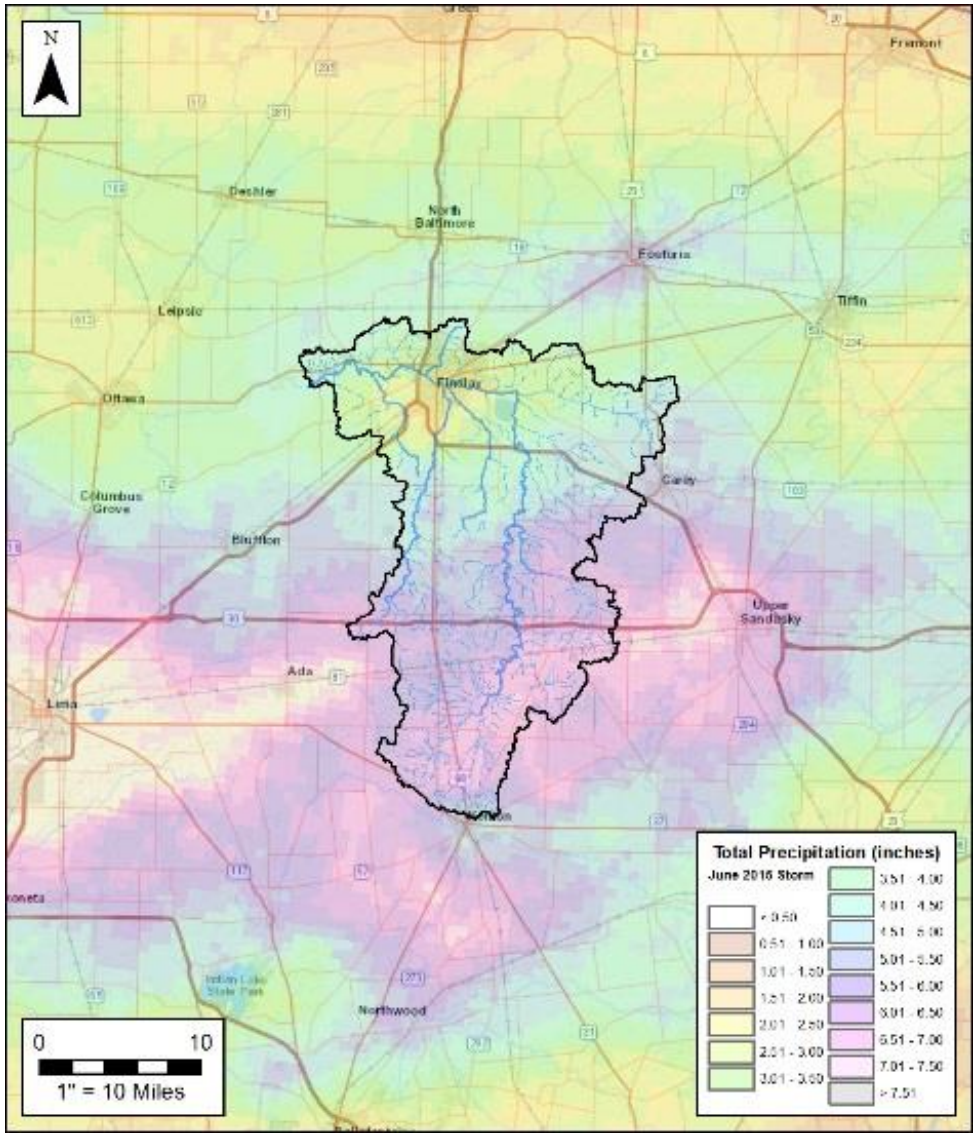




Stantec Hydrology Study

June 2015 Calibration Event

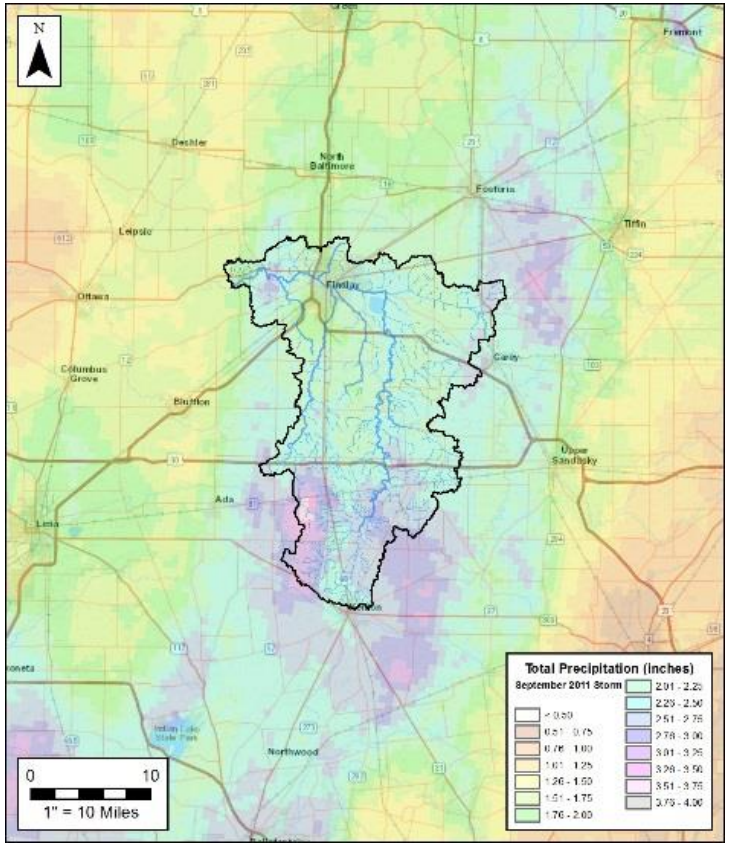




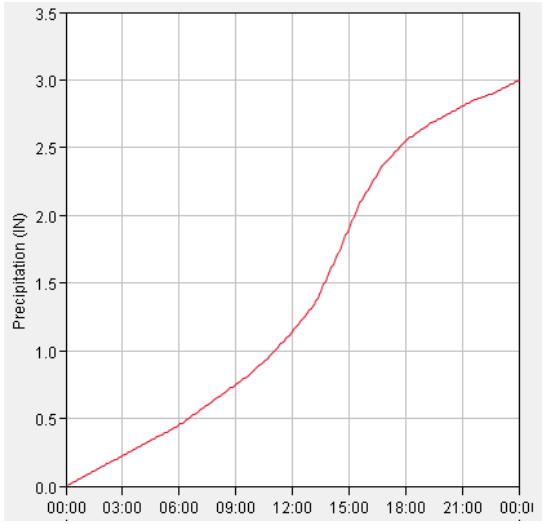
Stantec Hydrology Study

Radar Data to HEC-HMS

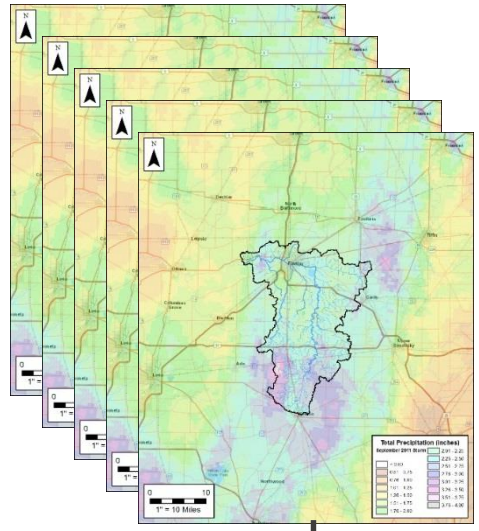
Total Storm Precipitation



Determine Temporal Pattern



Create Raster Grid for Each Time Step



Re-project Each Grid If Needed

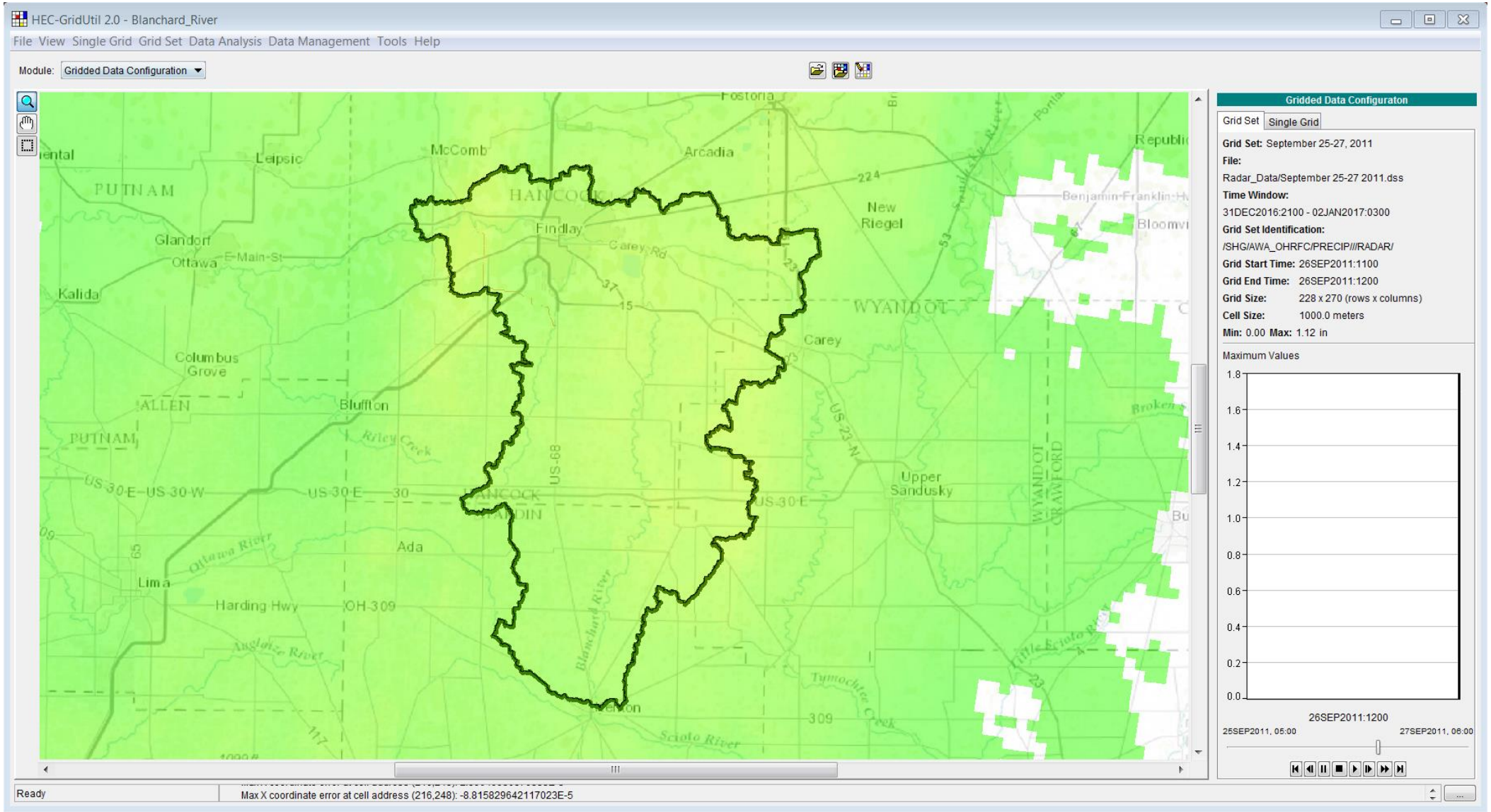
Create ASCII Grids

Assemble ASCII Grids in Correct Order Using Asc2DSSGrid Utility (Command Line Batch File)

Check Series w/ USACE HEC-GridUtil Software

Stantec Hydrology Study

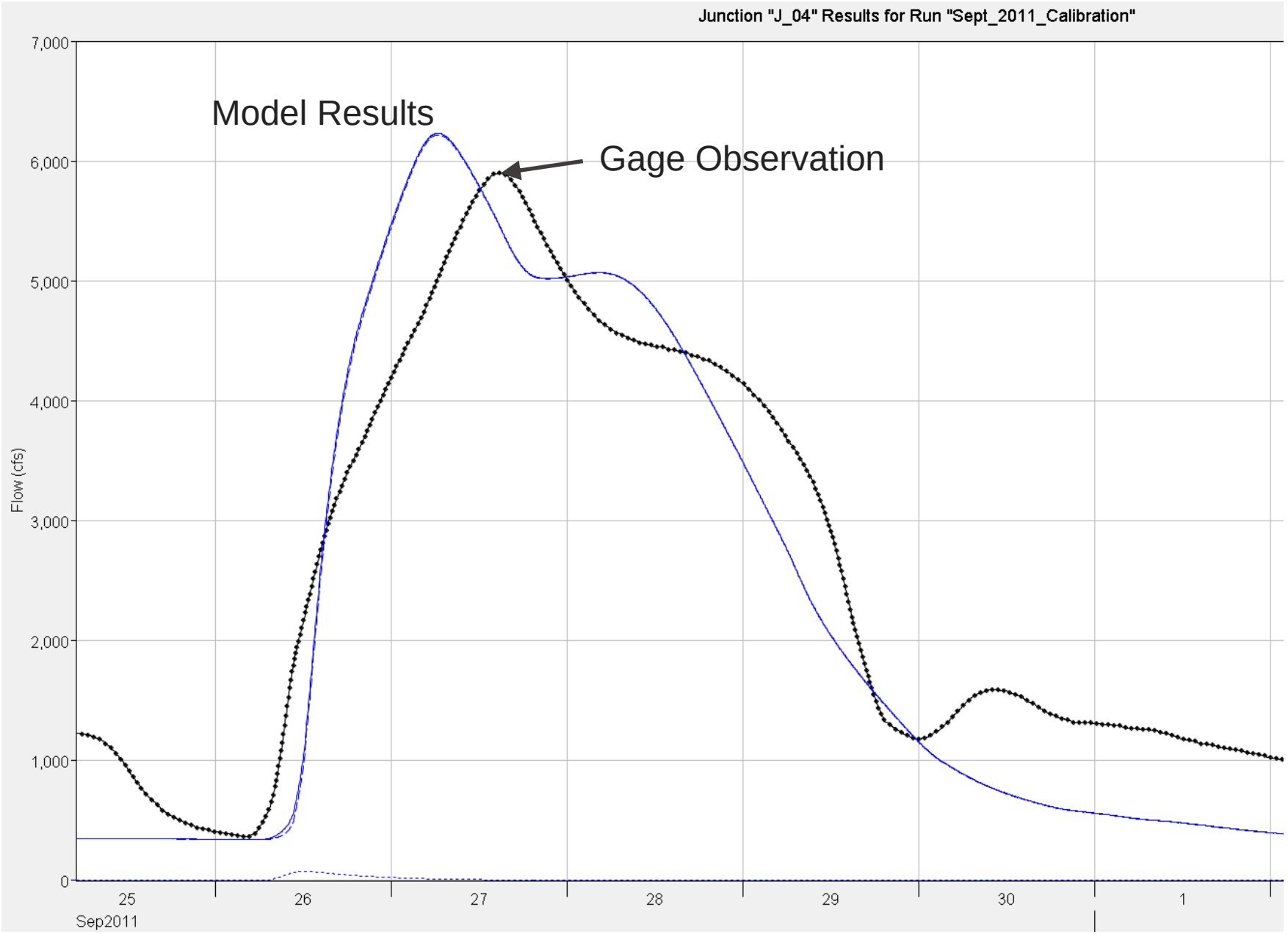
HEC-GridUtil



Calibration – September 2011

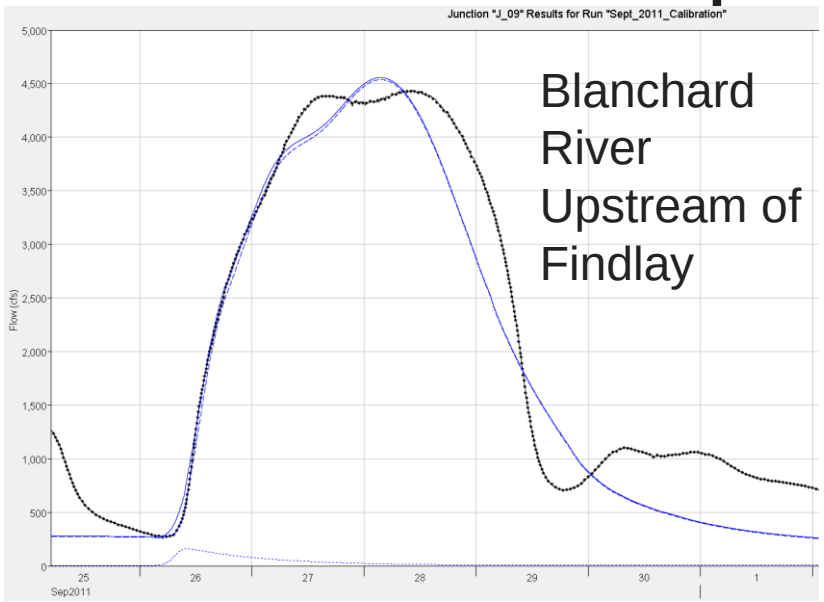
Stantec HEC-HMS Model

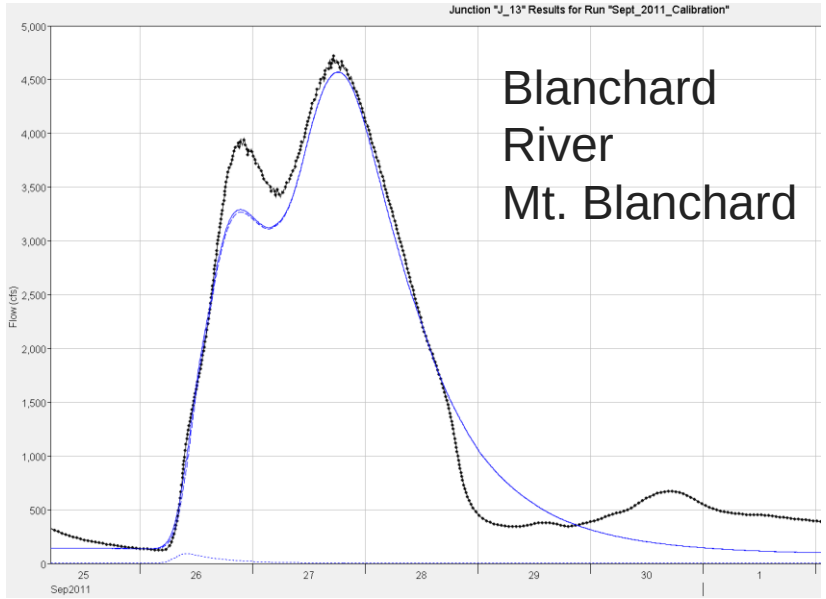
Blanchard River Downstream of Findlay

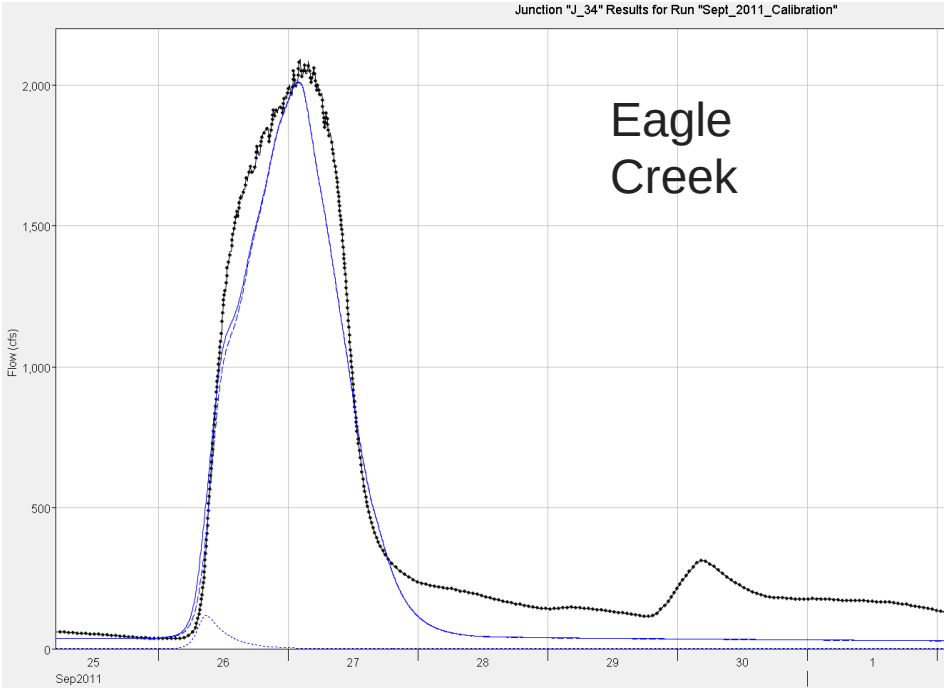


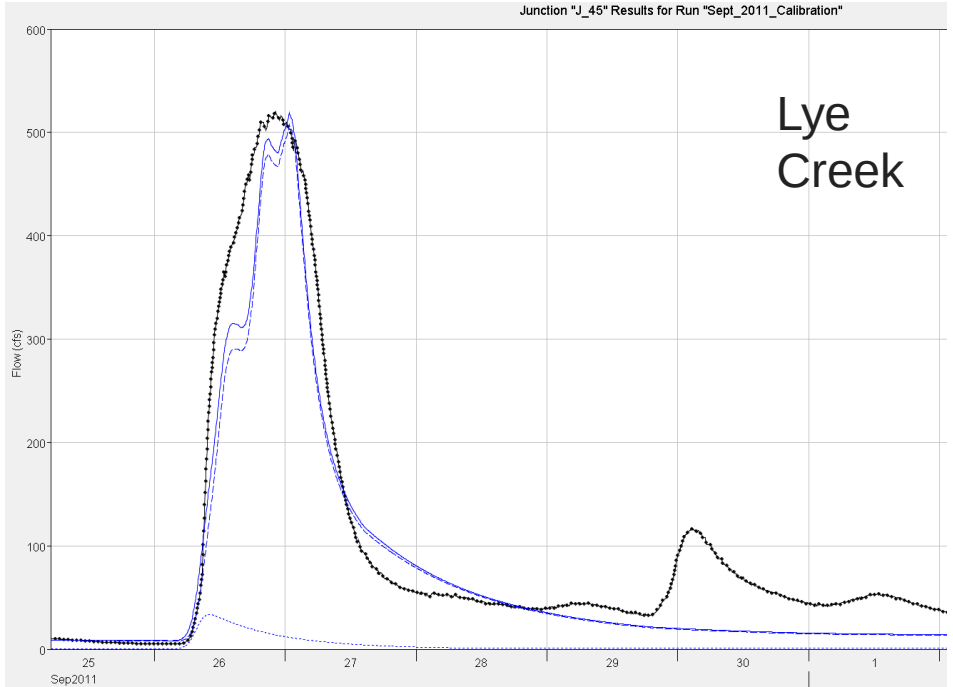
Stantec HEC-HMS Model

Calibration – September 2011



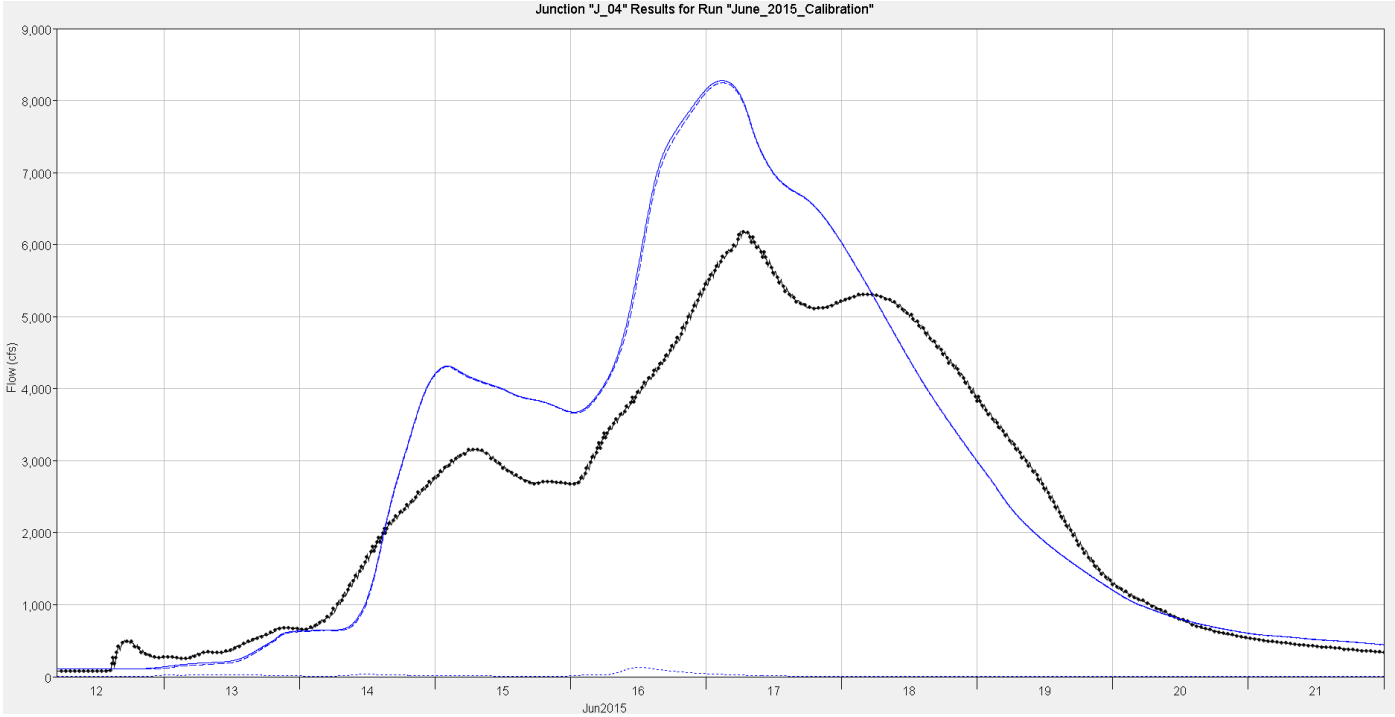




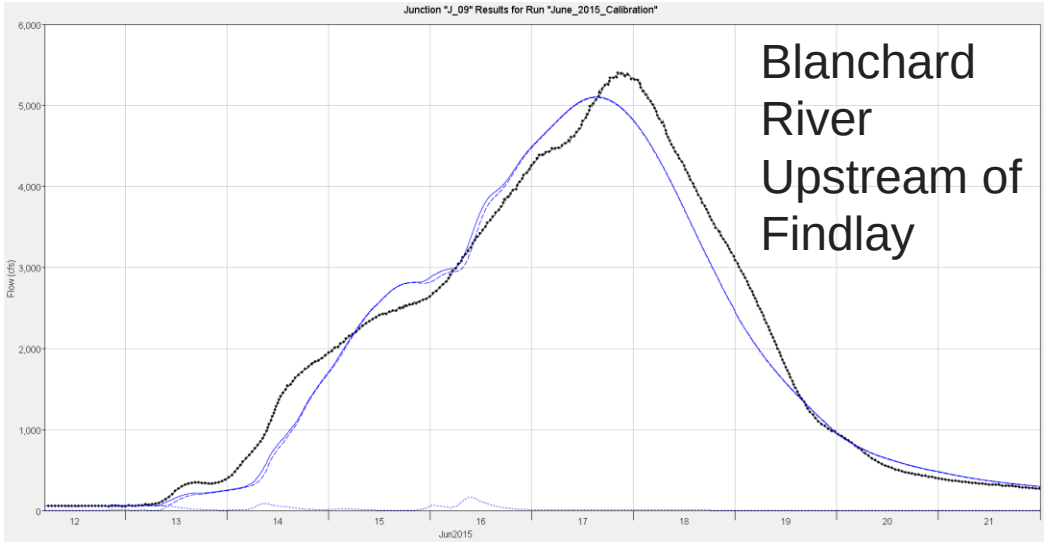


Stantec HEC-HMS Model

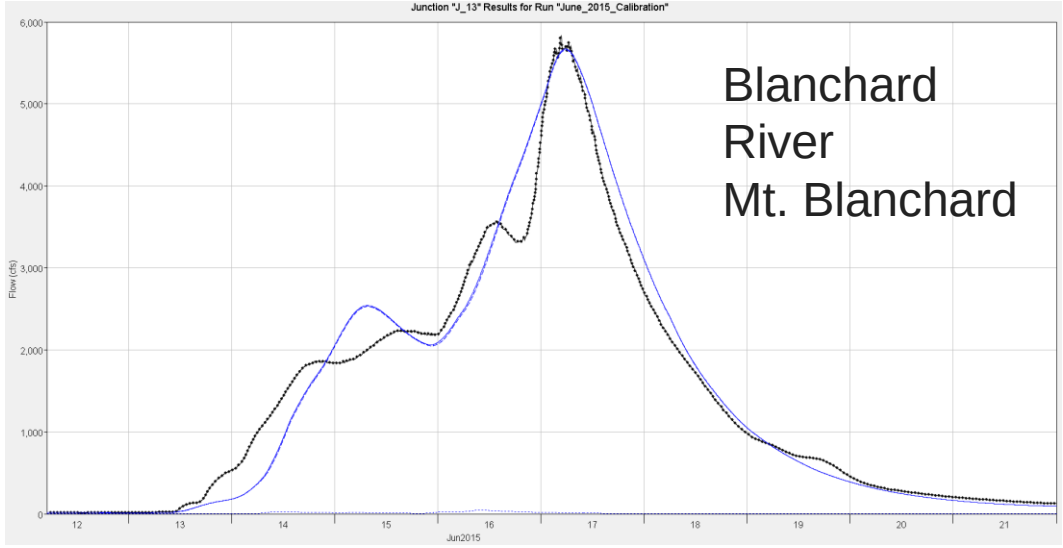
Calibration – June 2015



Blanchard River Downstream of Findlay



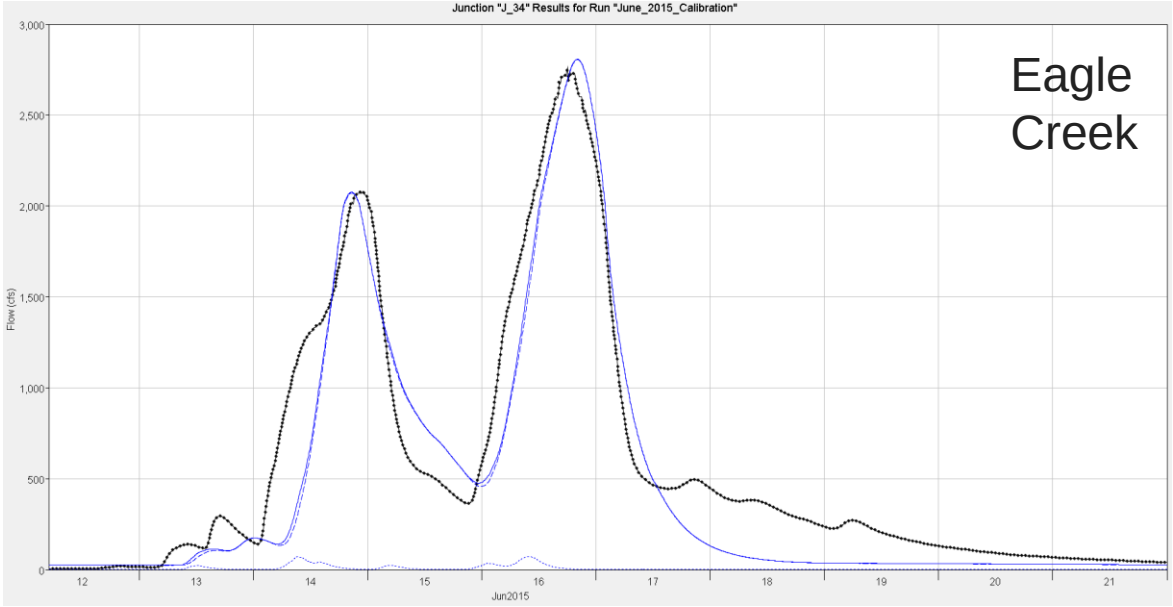
Blanchard River Upstream of Findlay

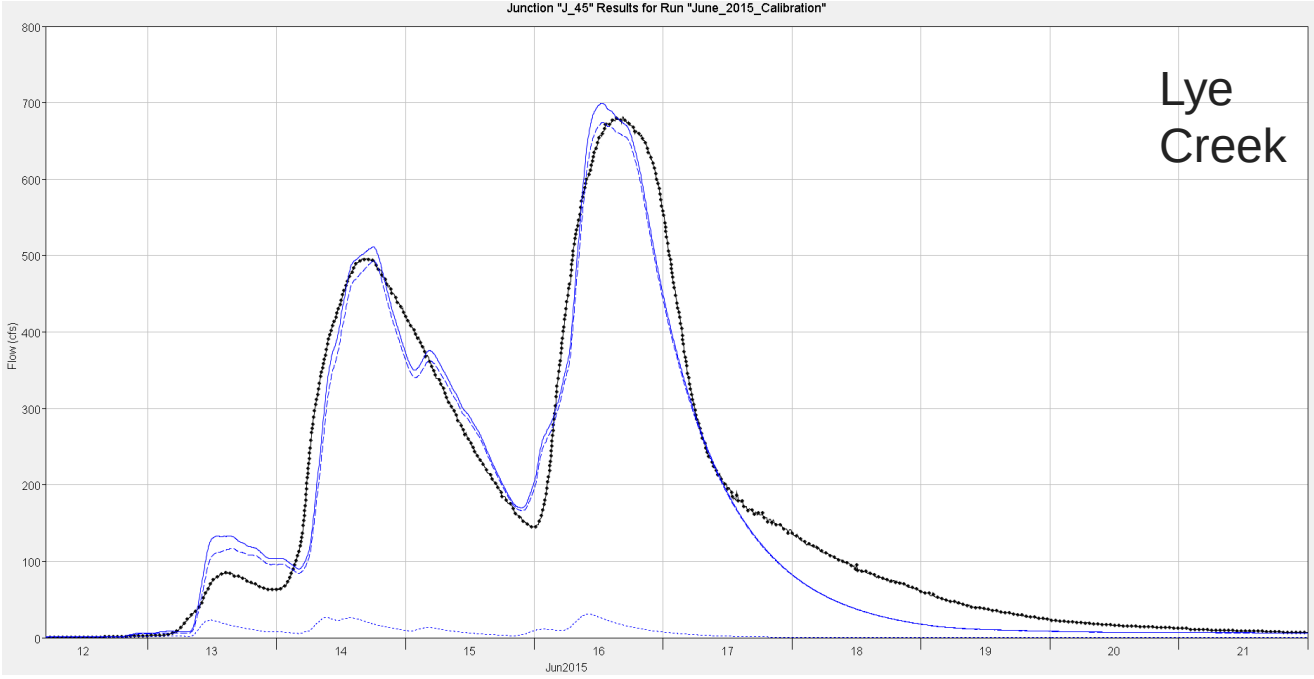


Blanchard River Mt. Blanchard

Stantec HEC-HMS Model

Calibration – June 2015

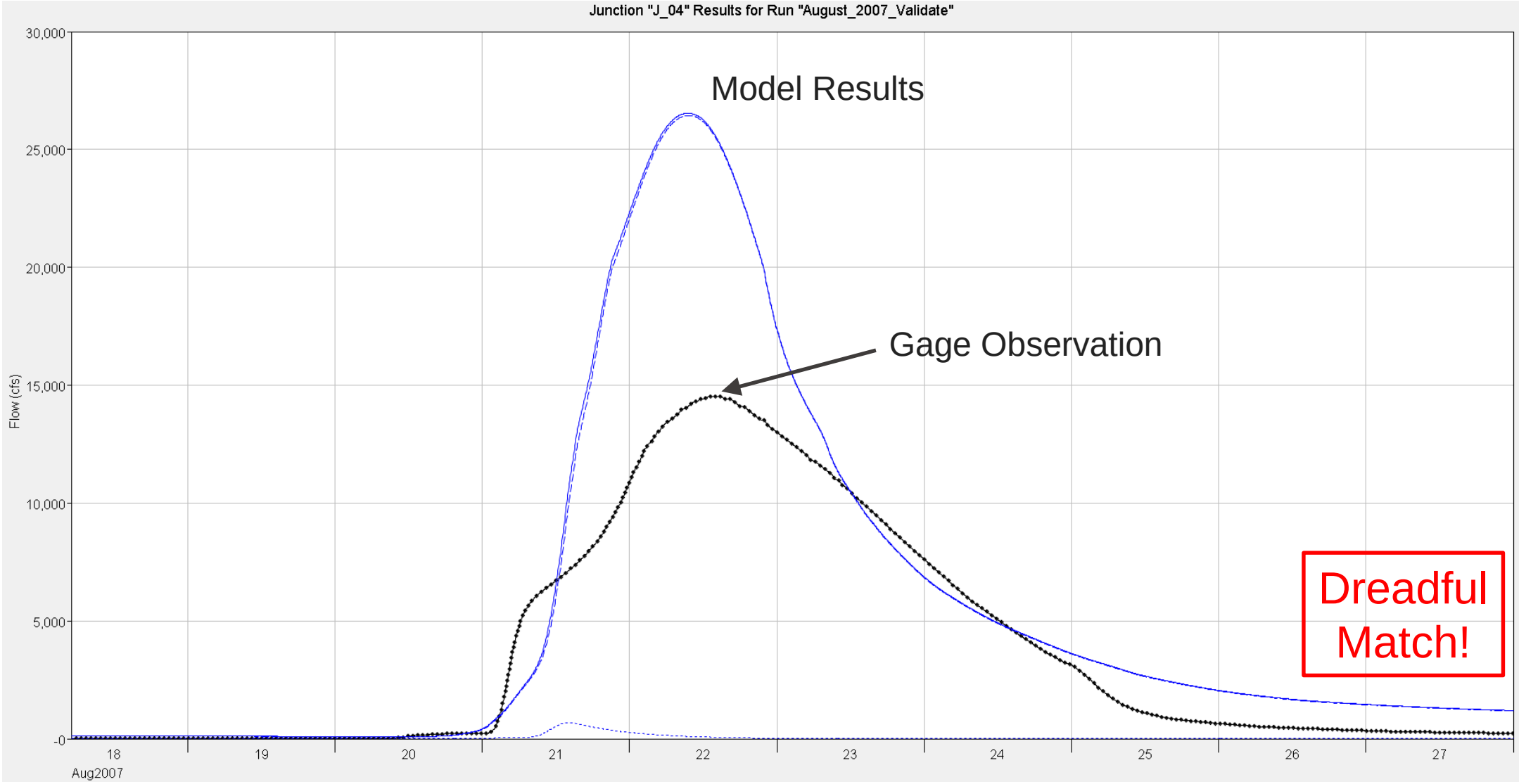




Validation – Aug. 2007 w/ June 2015 Geometry

Stantec HEC-HMS Model

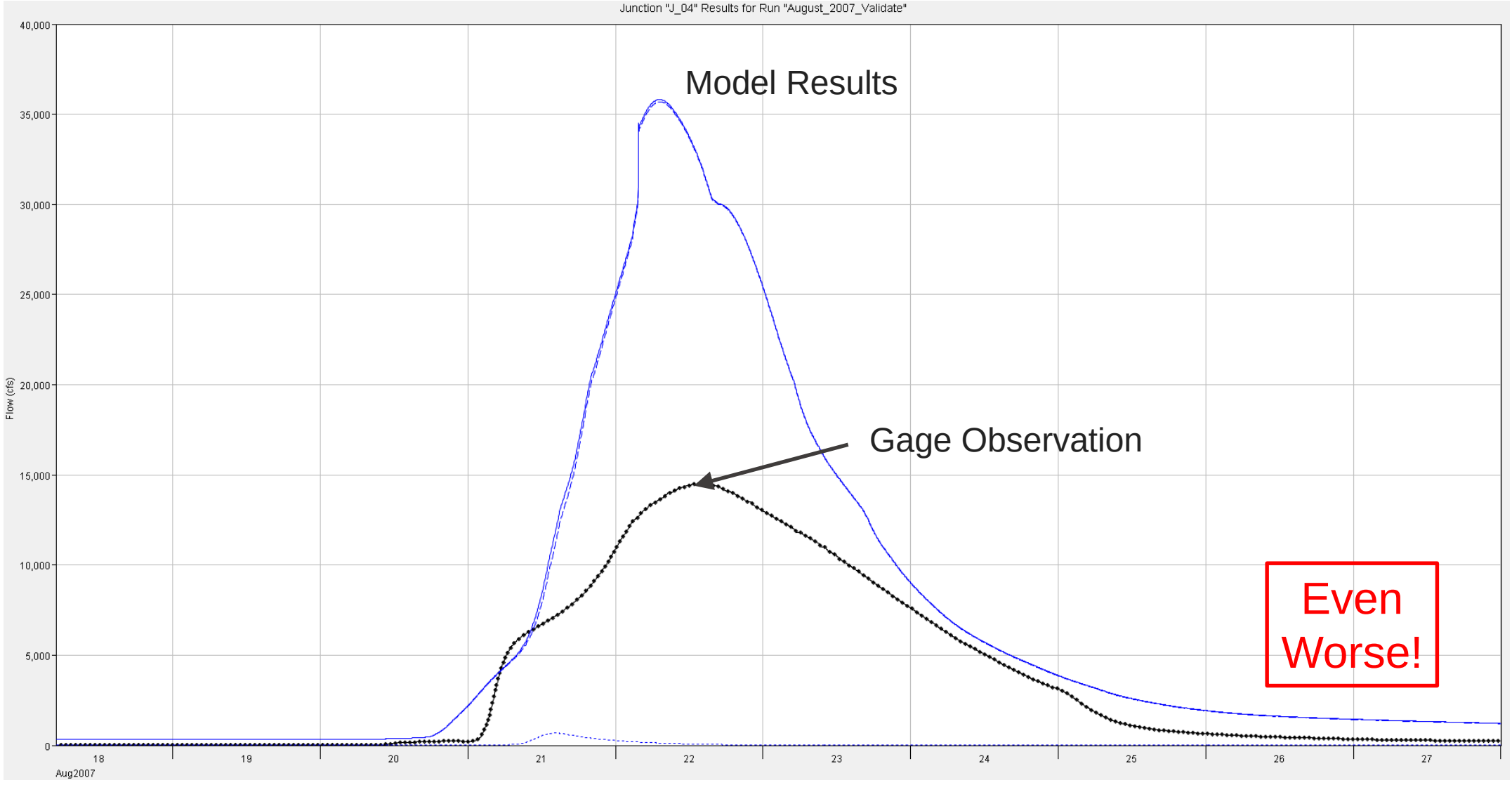
Blanchard River Downstream of Findlay



Validation – Aug. 2007 w/ Sept. 2011 Geometry

Stantec HEC-HMS Model

Blanchard River Downstream of Findlay

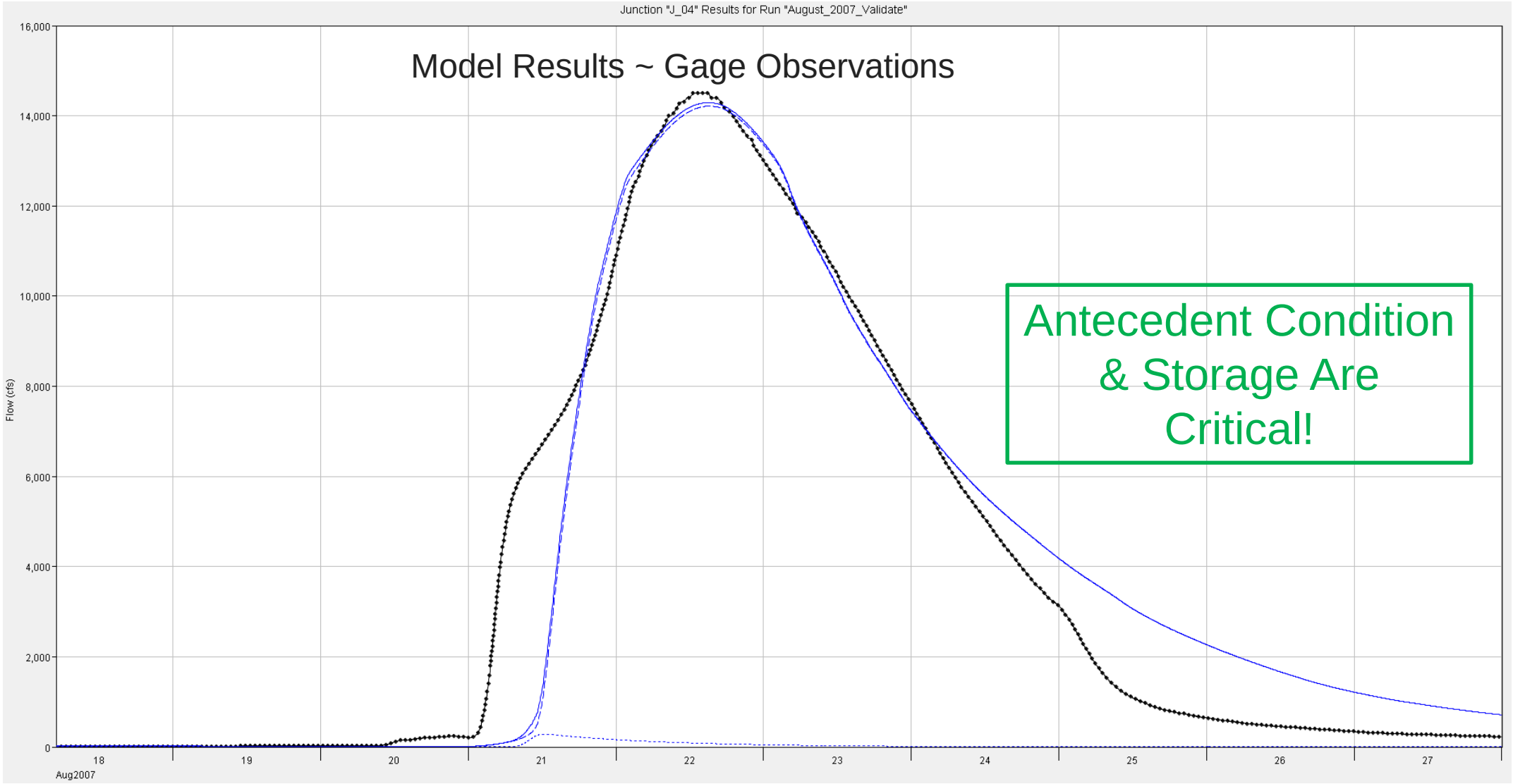


Validation – Aug. 2007 w/ Custom Geometry

Tweaked Antecedent Conditions + Subbasin Storage

Stantec HEC-HMS Model

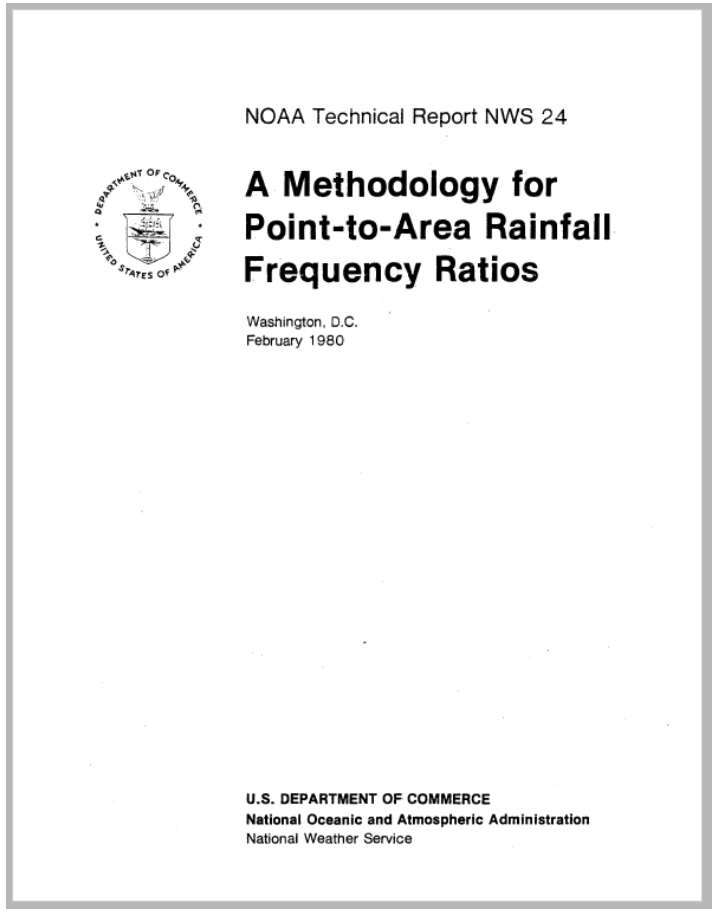
Blanchard River Downstream of Findlay



Stantec HEC-HMS Model

Spatial Variation

Areal Reduction Factors


NOAA Technical Report NWS 24

A Methodology for Point-to-Area Rainfall Frequency Ratios

Washington, D.C.
February 1980

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

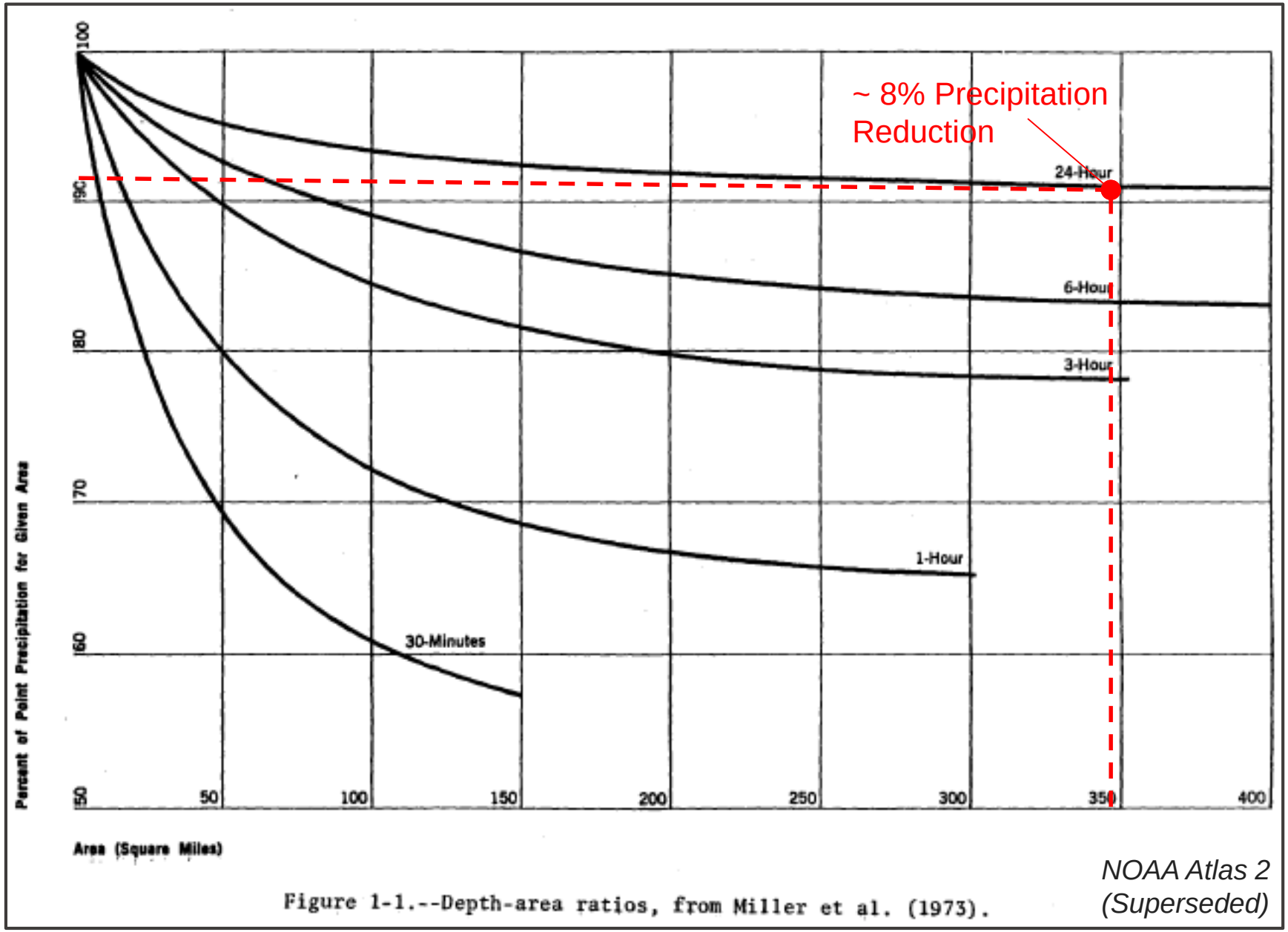


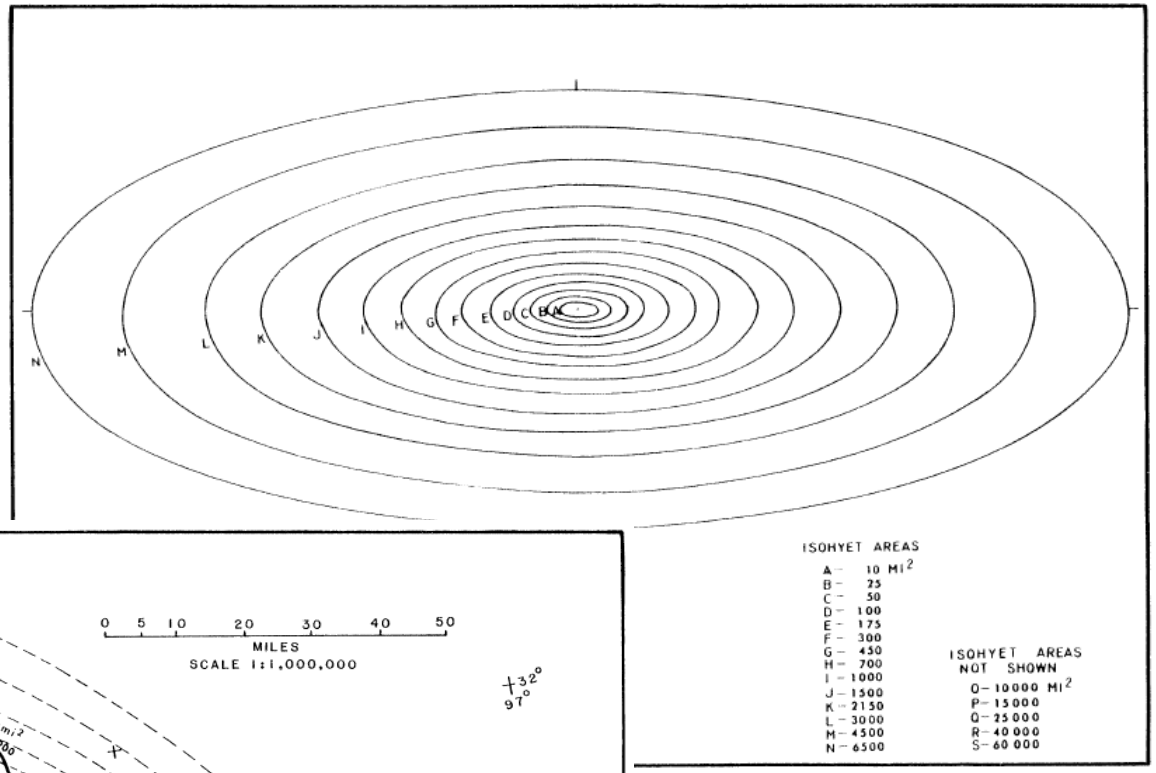
Figure 1-1.--Depth-area ratios, from Miller et al. (1973).

NOAA Atlas 2 (Superseded)

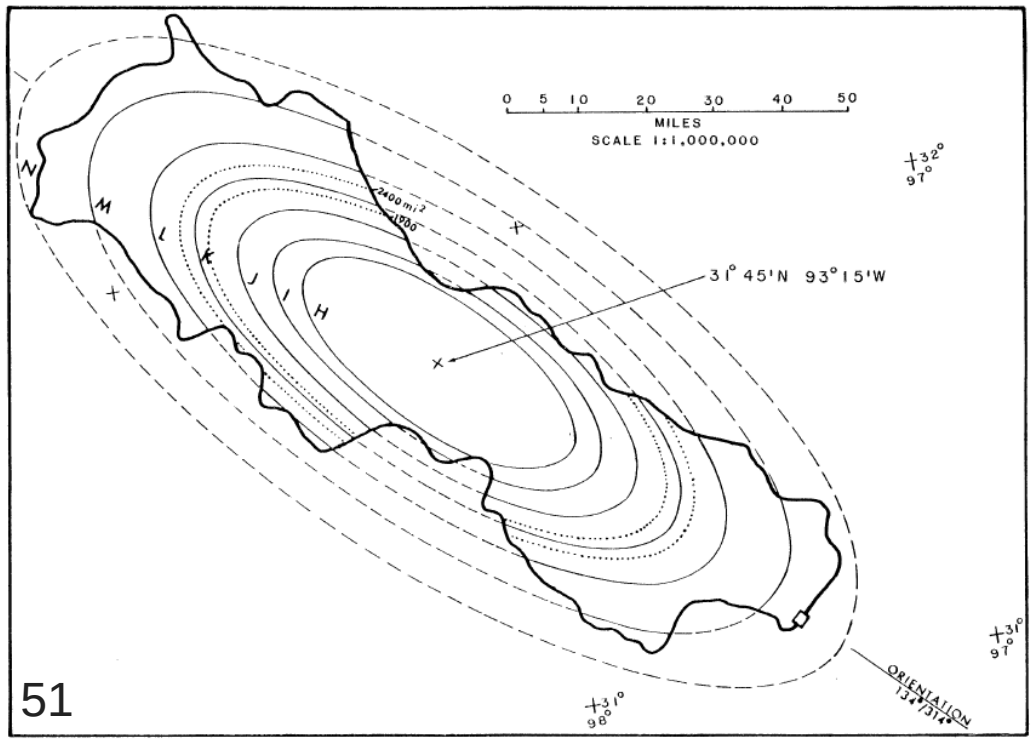
Stantec HEC-HMS Model

Spatial Variation

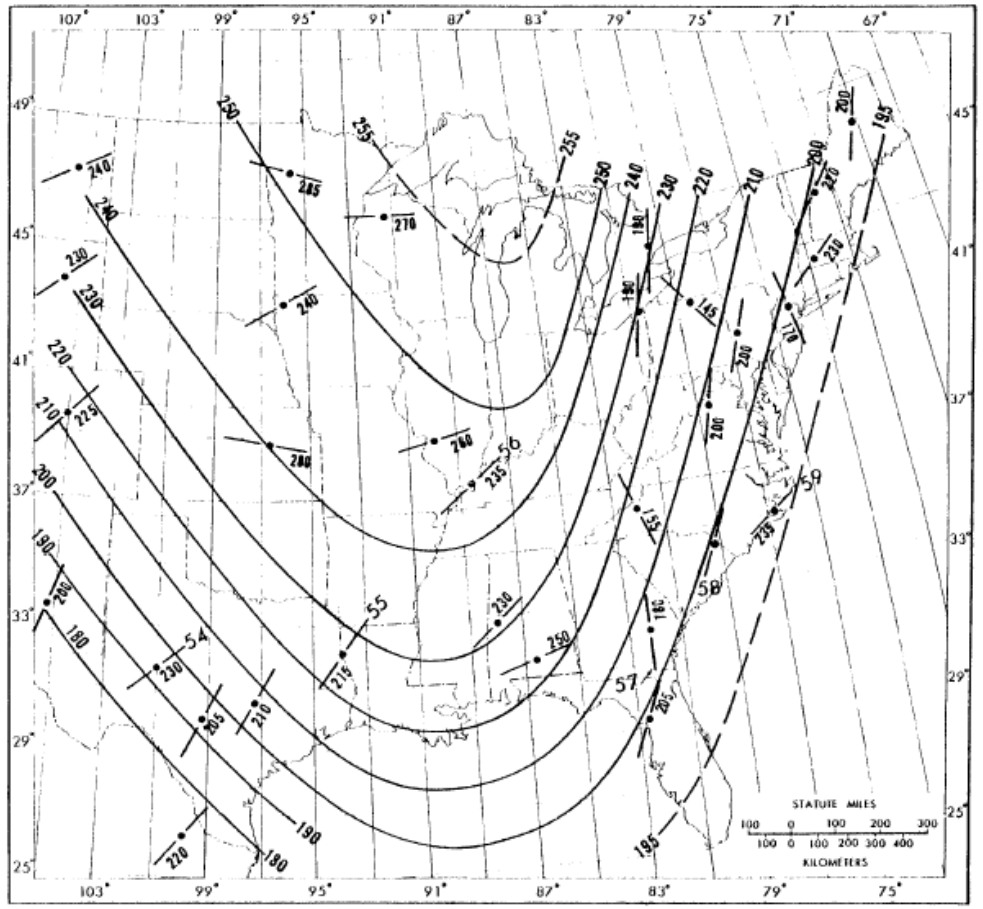
Spatial Distribution



distribution of PMP east of the 105th meridian



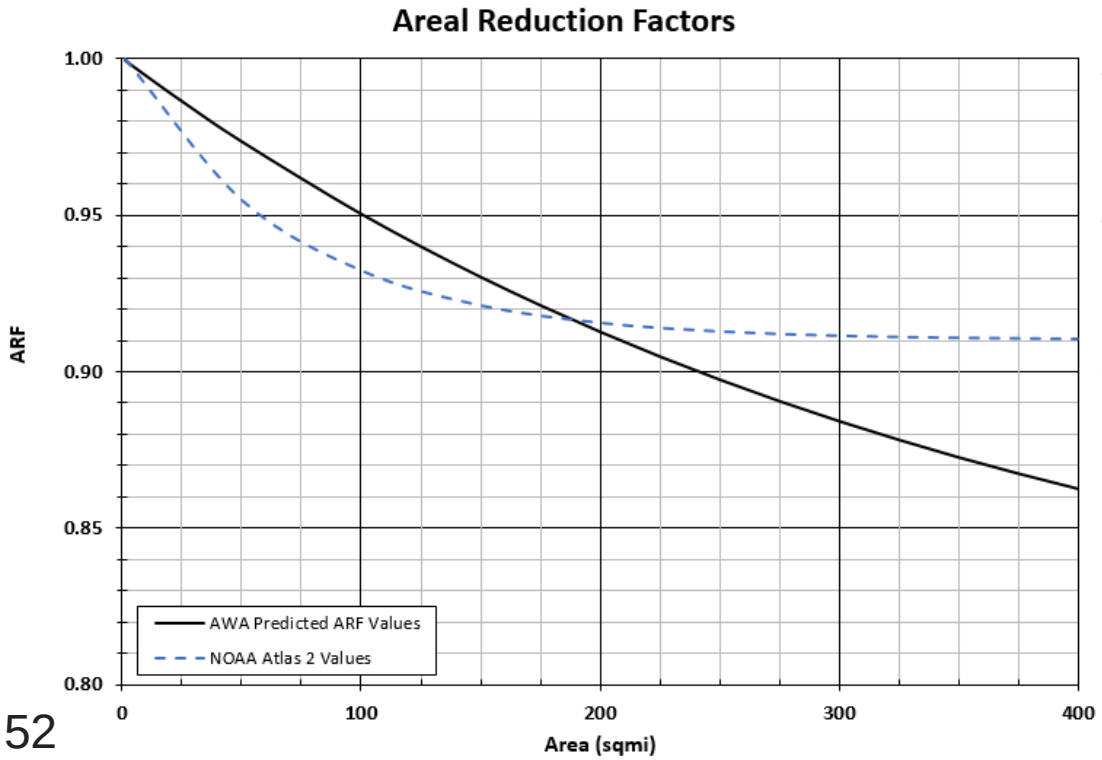
"Hydrometeorological Report No. 52 Application of Probable Maximum Precipitation Estimates in the United States East of the 105th Meridian" NOAA 1982

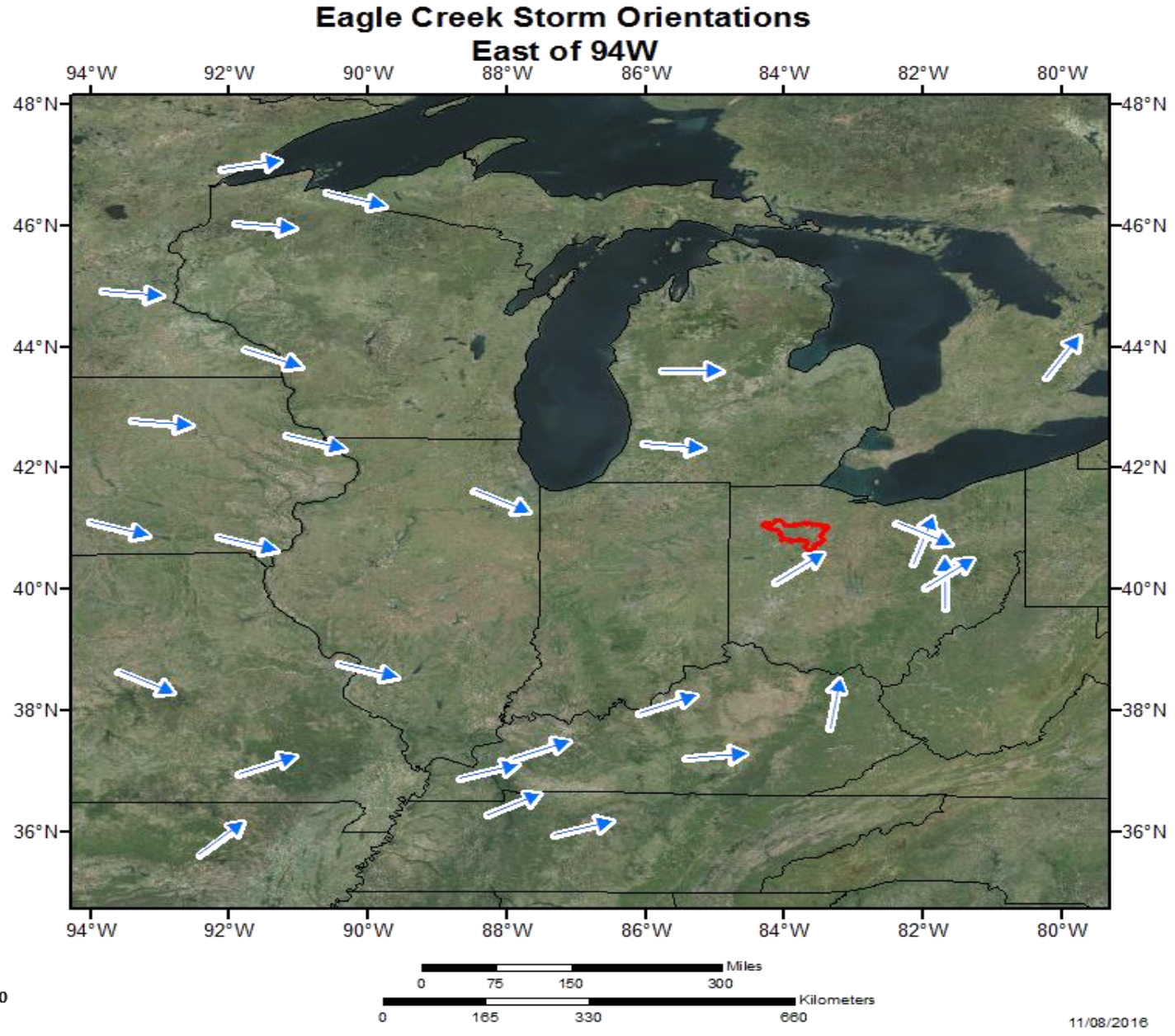


Stantec HEC-HMS Model

Spatial Variation

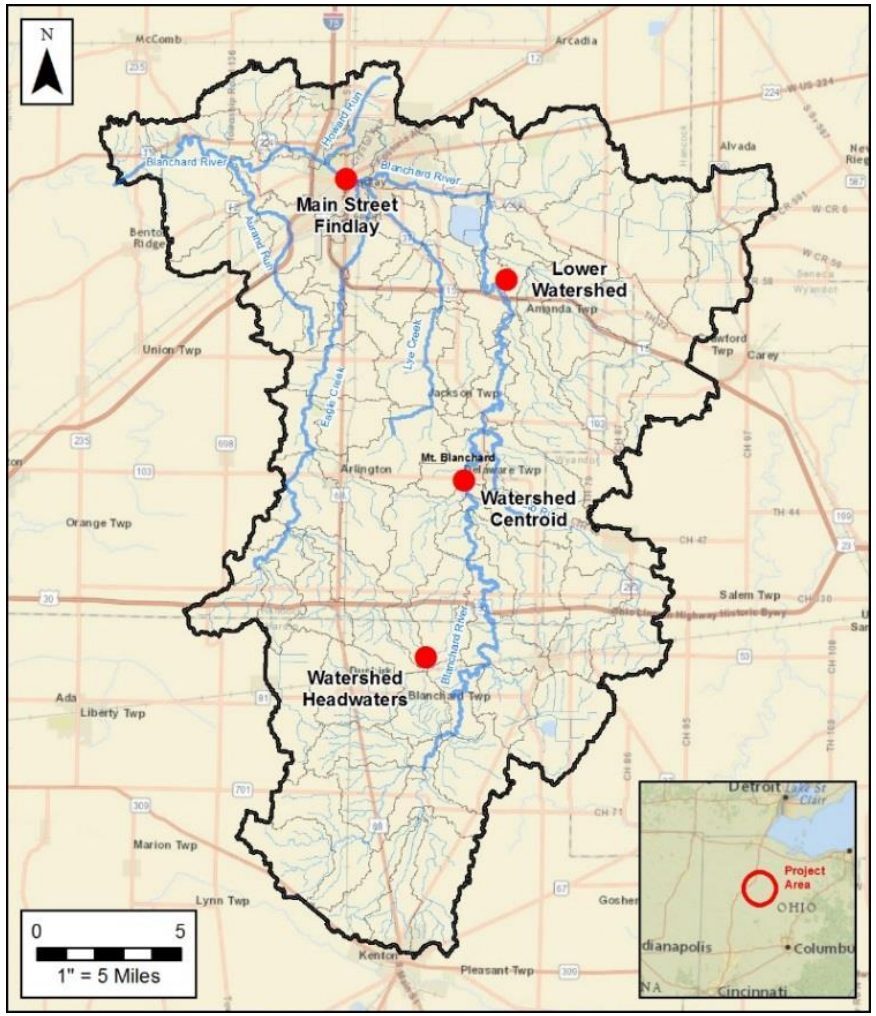
Spatial Distribution

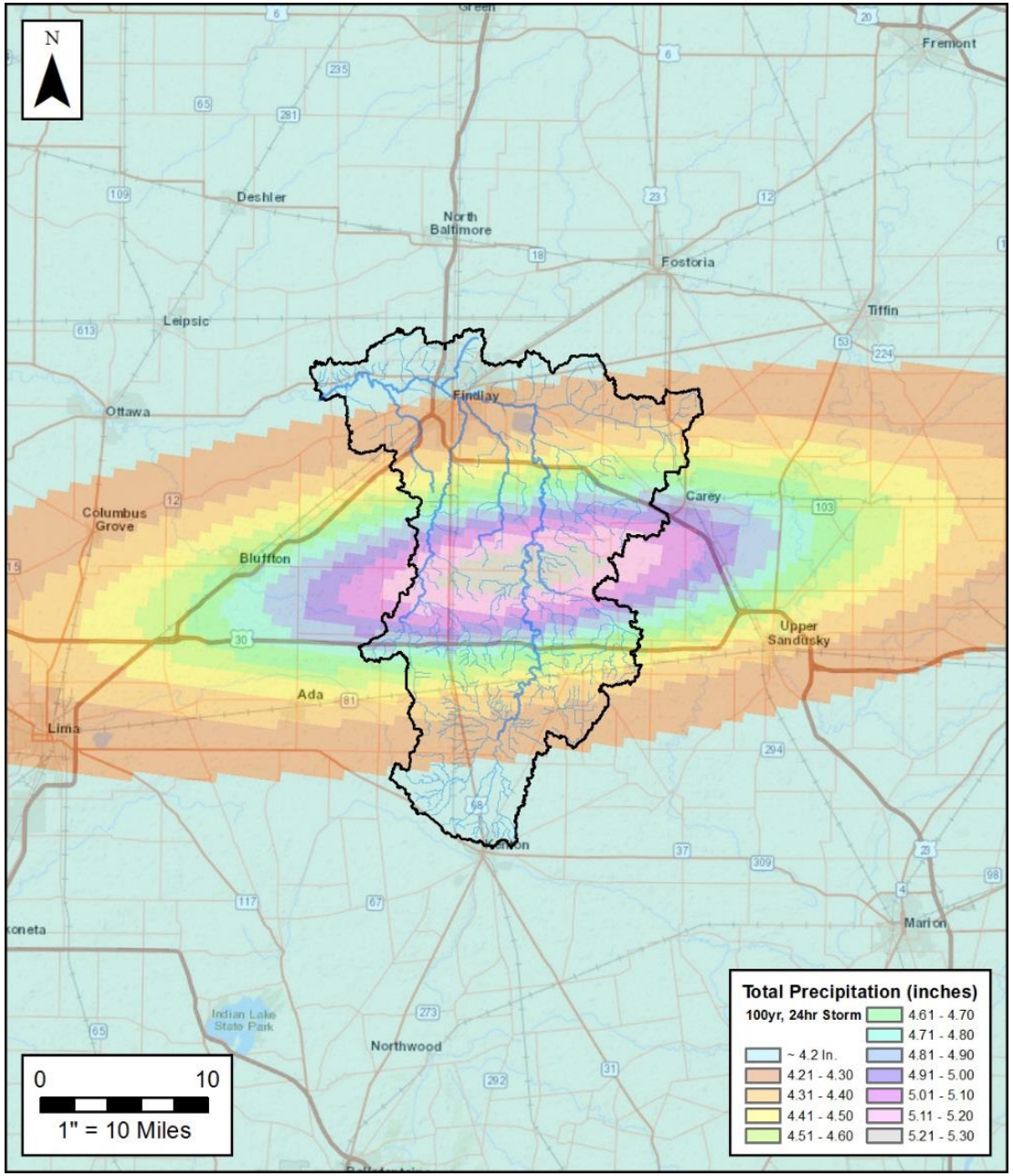




Spatial Distribution

– Custom Hypothetical Storm

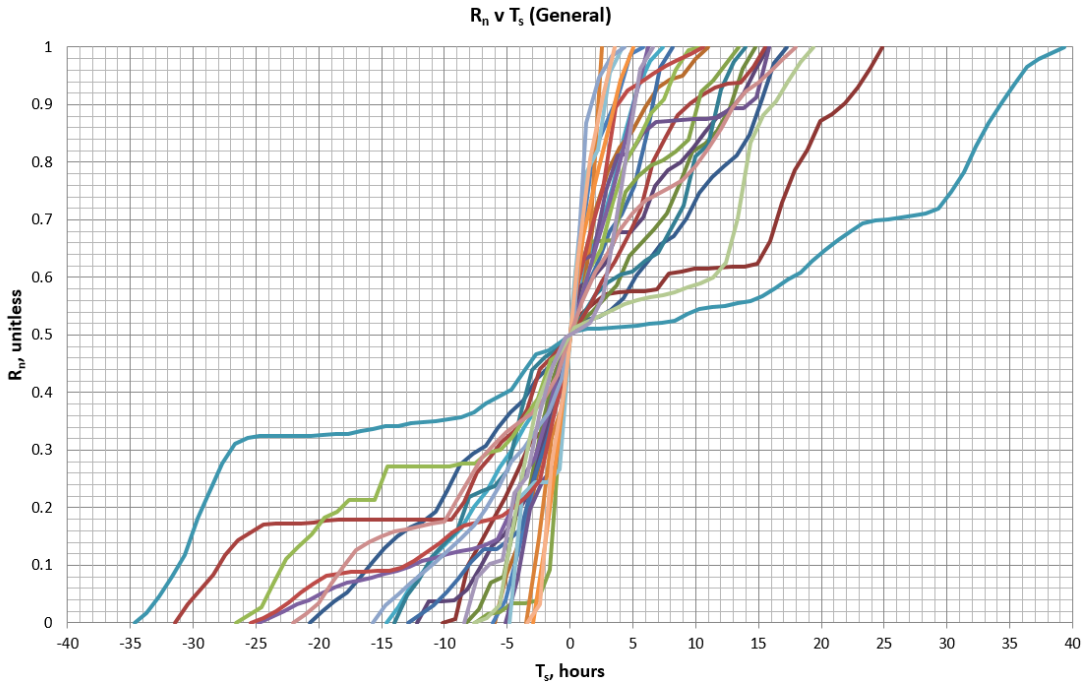


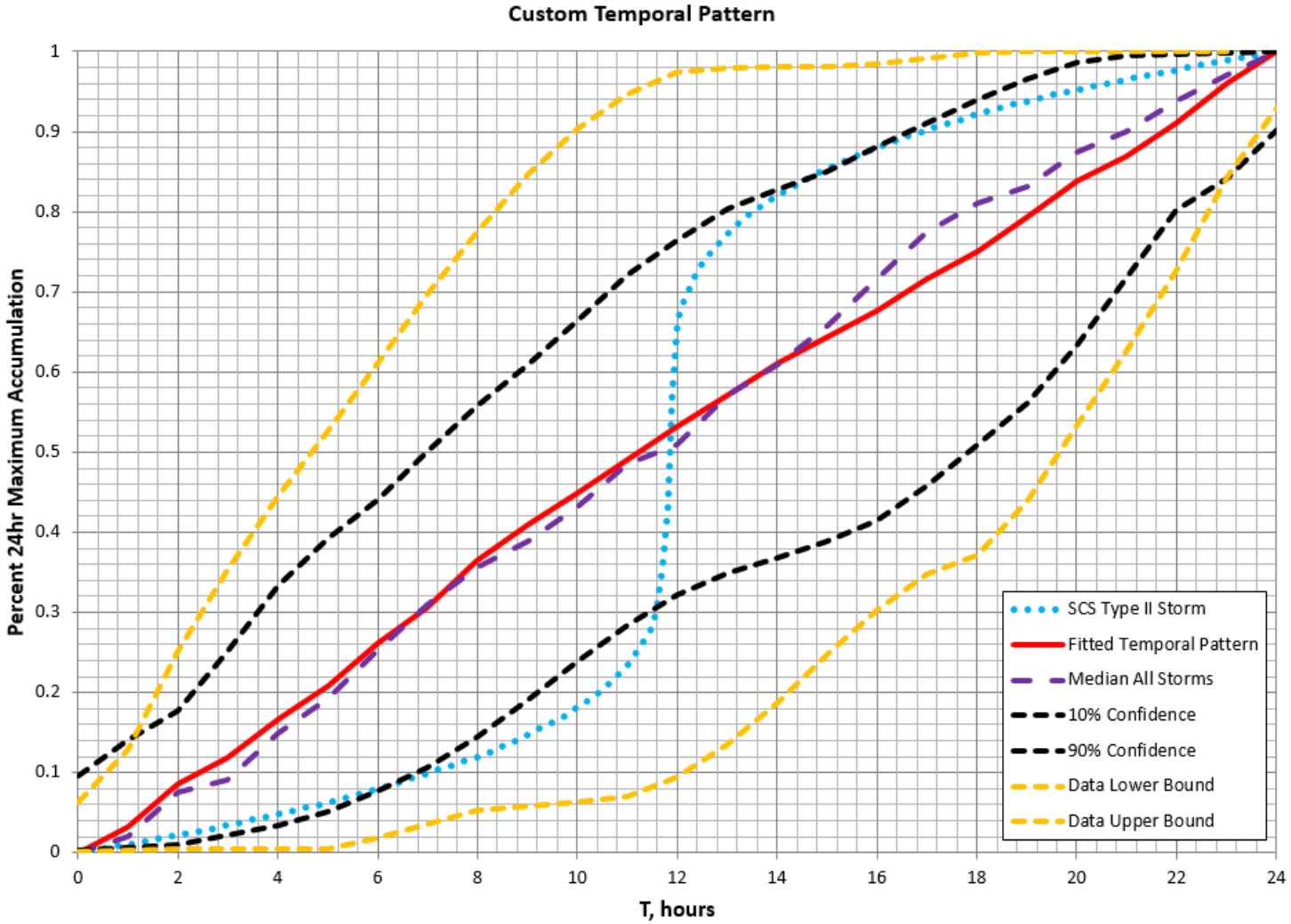


Stantec HEC-HMS Model

Temporal Pattern

Temporal Patterns

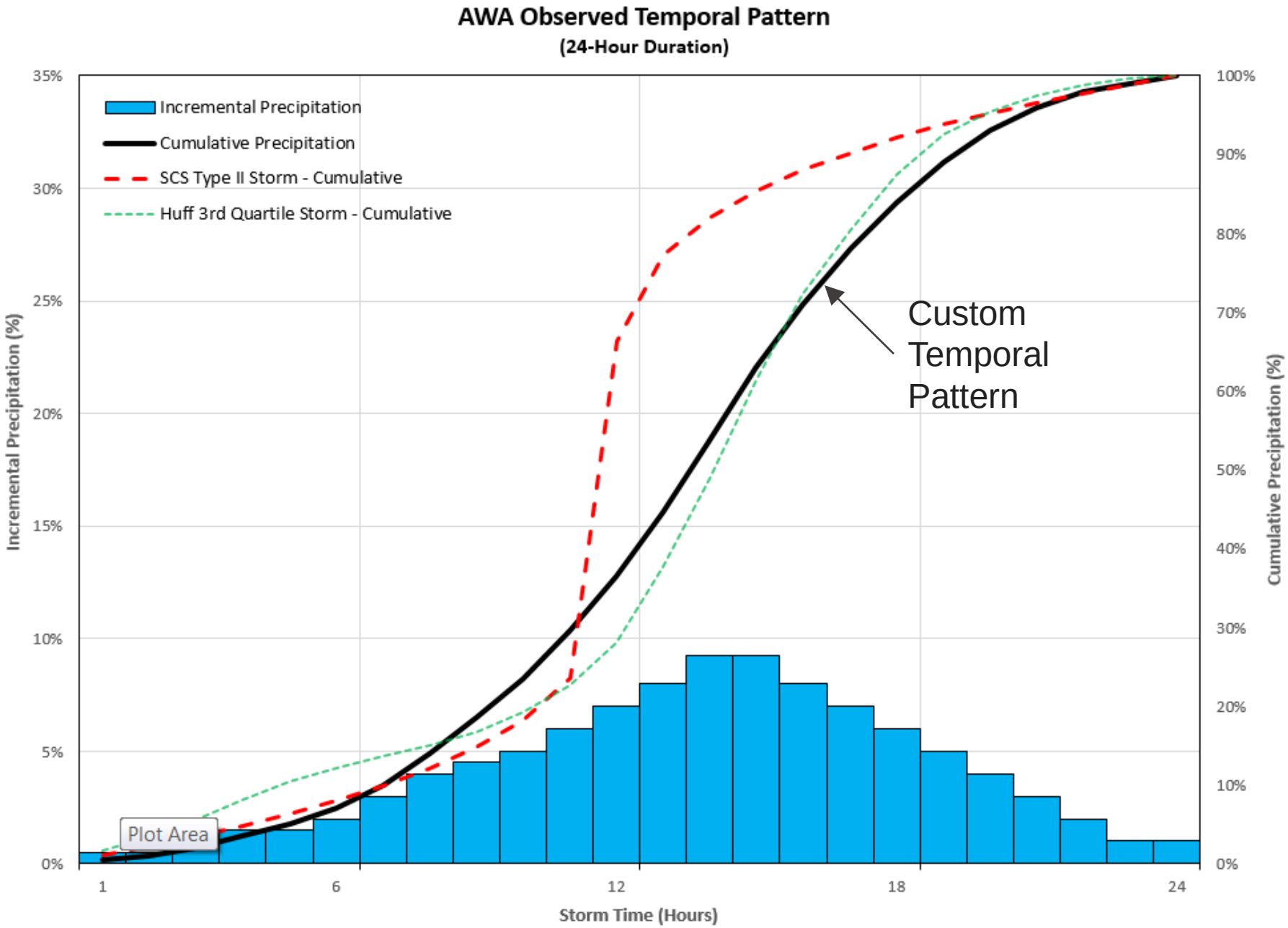




Stantec HEC-HMS Model

Temporal Pattern

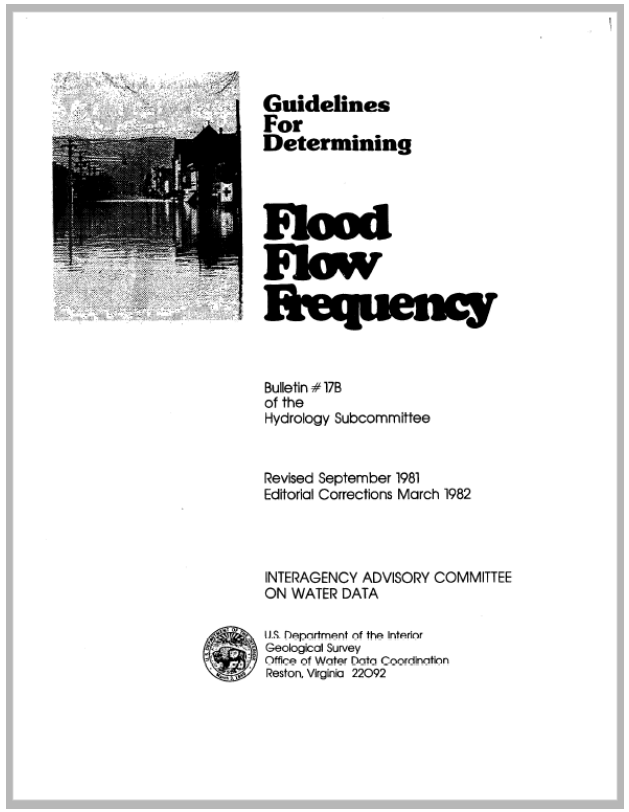
Temporal Patterns

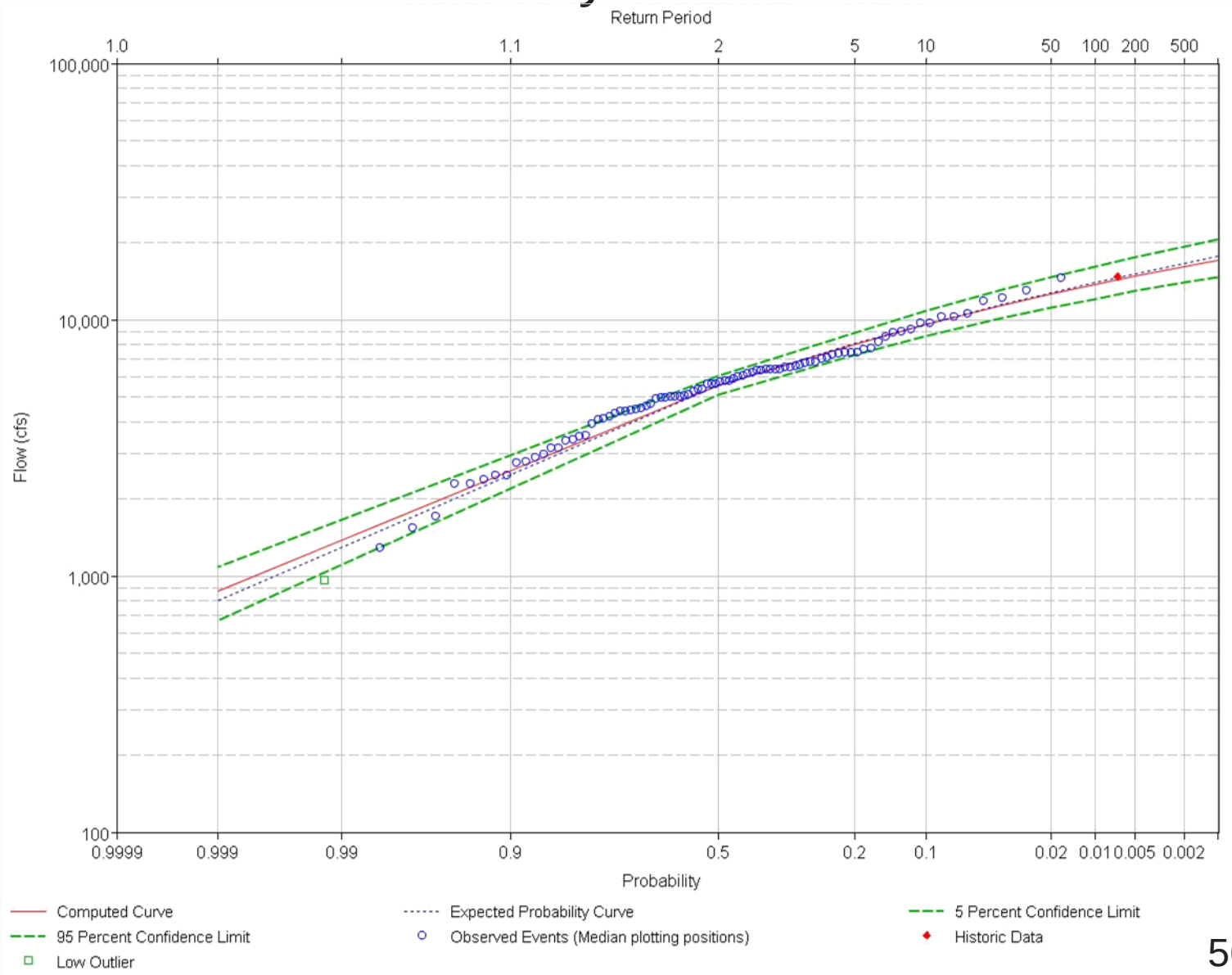


Stantec Gage Frequency Analyses

USGS Gage #04189000

Blanchard River Downstream of Findlay





Stantec Gage Frequency Analyses

USGS Gage #04189000

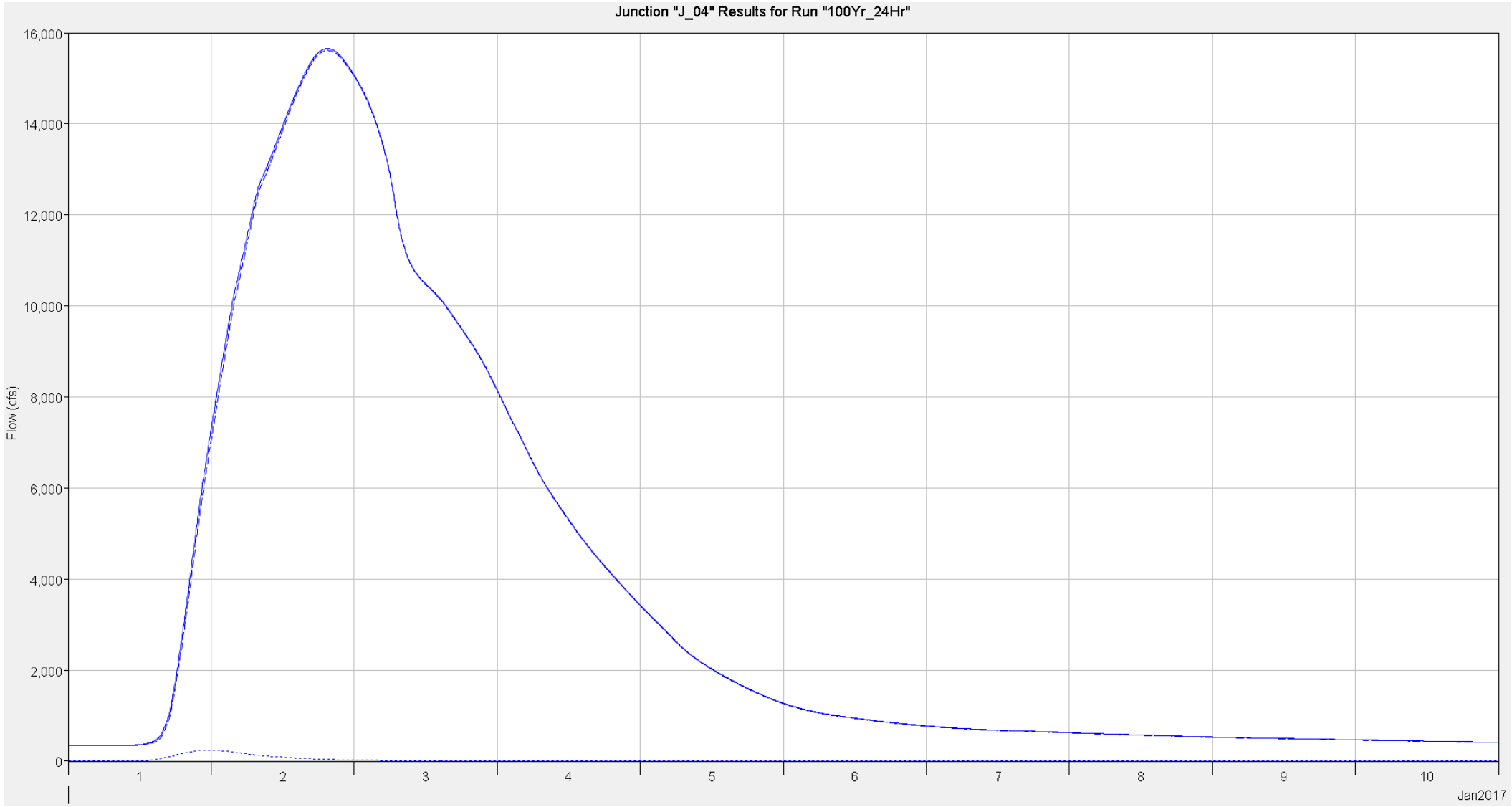
Blanchard River Downstream of Findlay

Percent Chance Exceedance	Average Recurrence Interval (years)	Computed Discharge (cfs)	Confidence Limits 0.05	0.95
0.1	1000	17,117	20,649	14,715
0.2	500	16,156	19,351	13,964
0.5	200	14,811	17,552	12,903
1.0	***100***	***13,727***	16,120	12,039
2.0	50	12,576	14,619	11,113
4.0	25	11,346	13,037	10,111
10.0	10	9,559	10,788	8,625
20.0	5	8,028	8,918	7,319
50.0	2	5,530	6,020	5,086
99.9	1	875	1,084	667

Stantec HEC-HMS Model Results

Sept. 2011 Calibrated Geometry

1% Annual Chance (100-Year) Flood Event

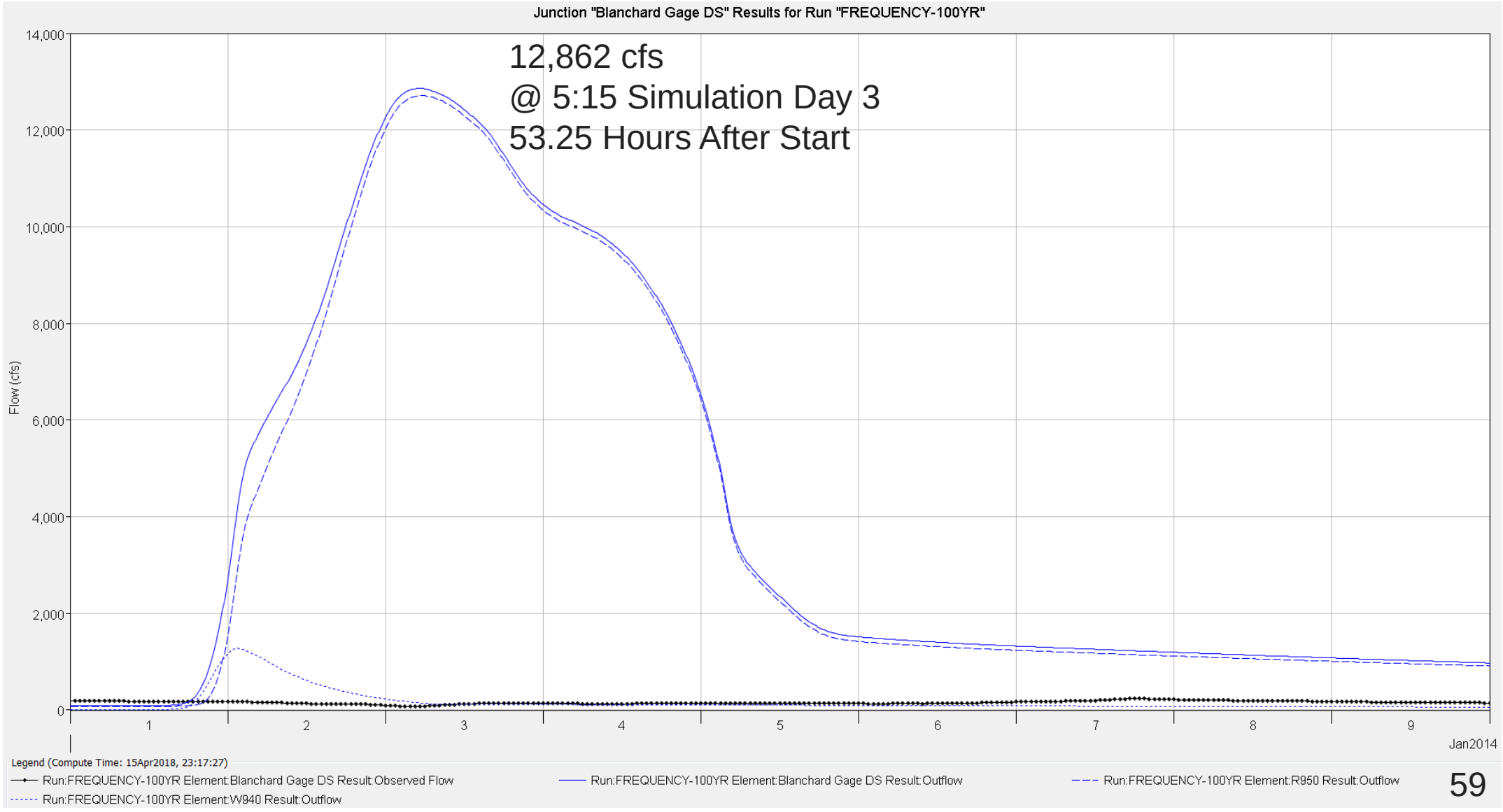


USACE

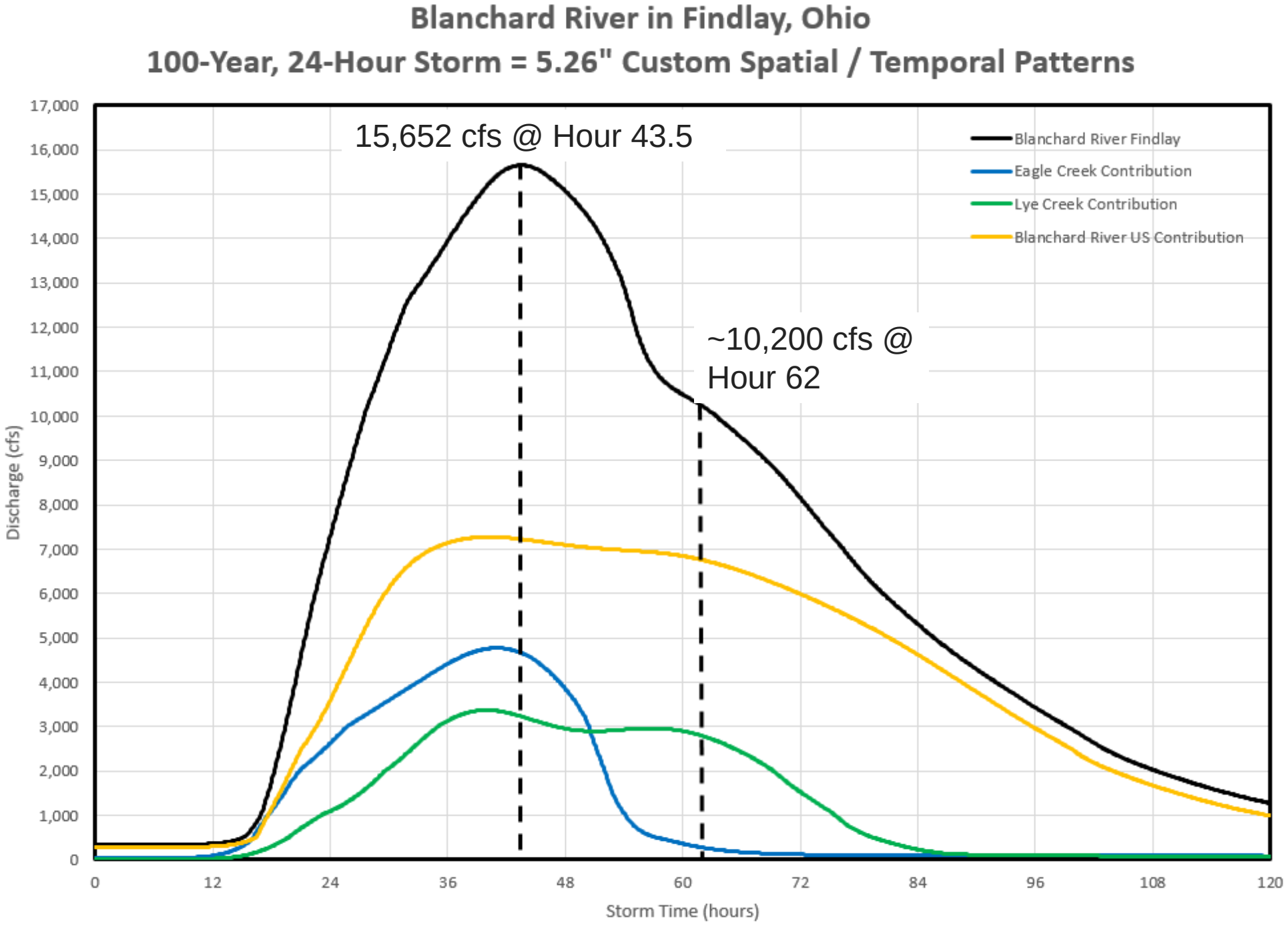
HEC-HMS Model

1% Annual Chance (100-Year) Flood Event

HEC-HMS Frequency Storm



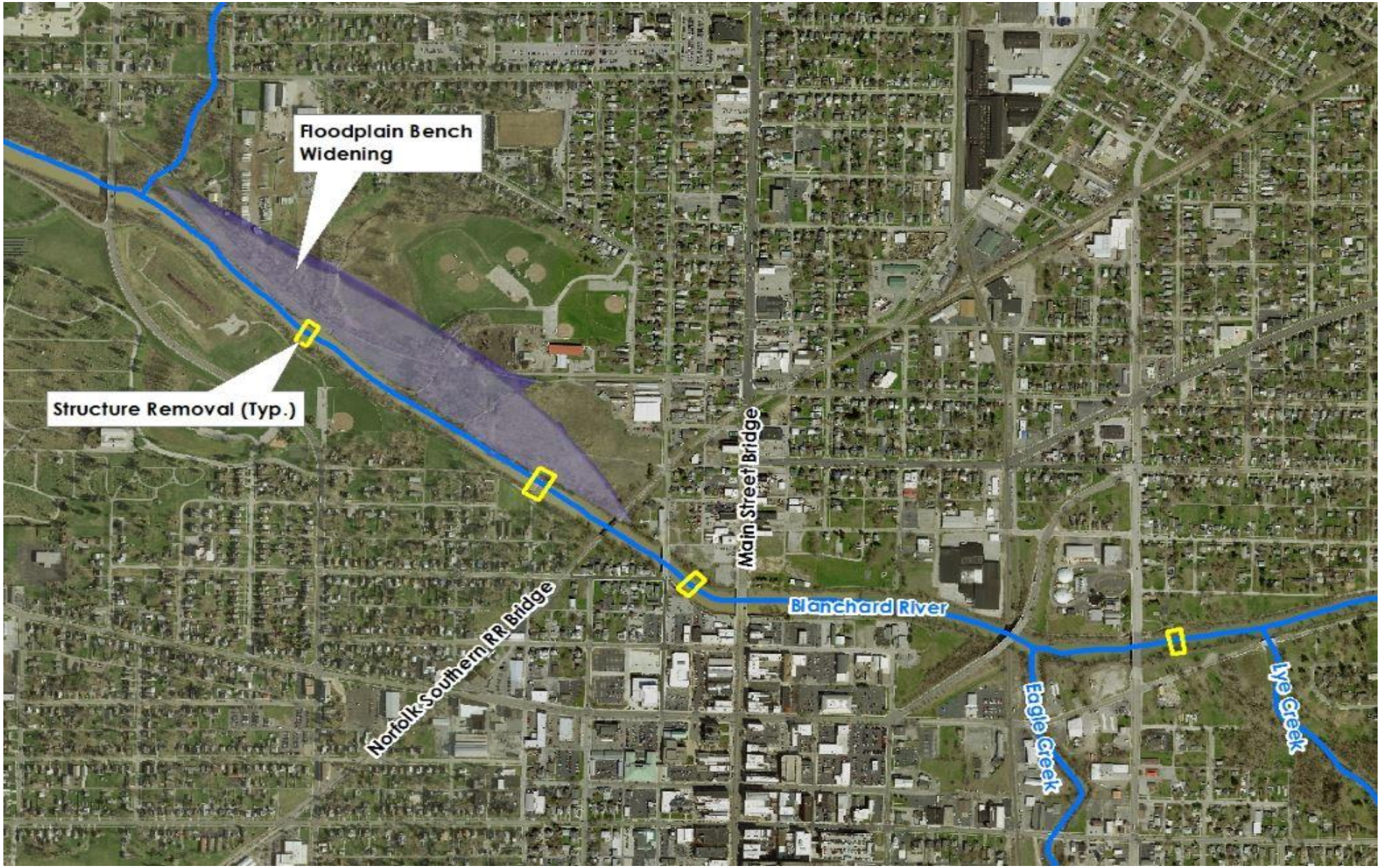
Stantec HEC-HMS Design Storm



Stantec

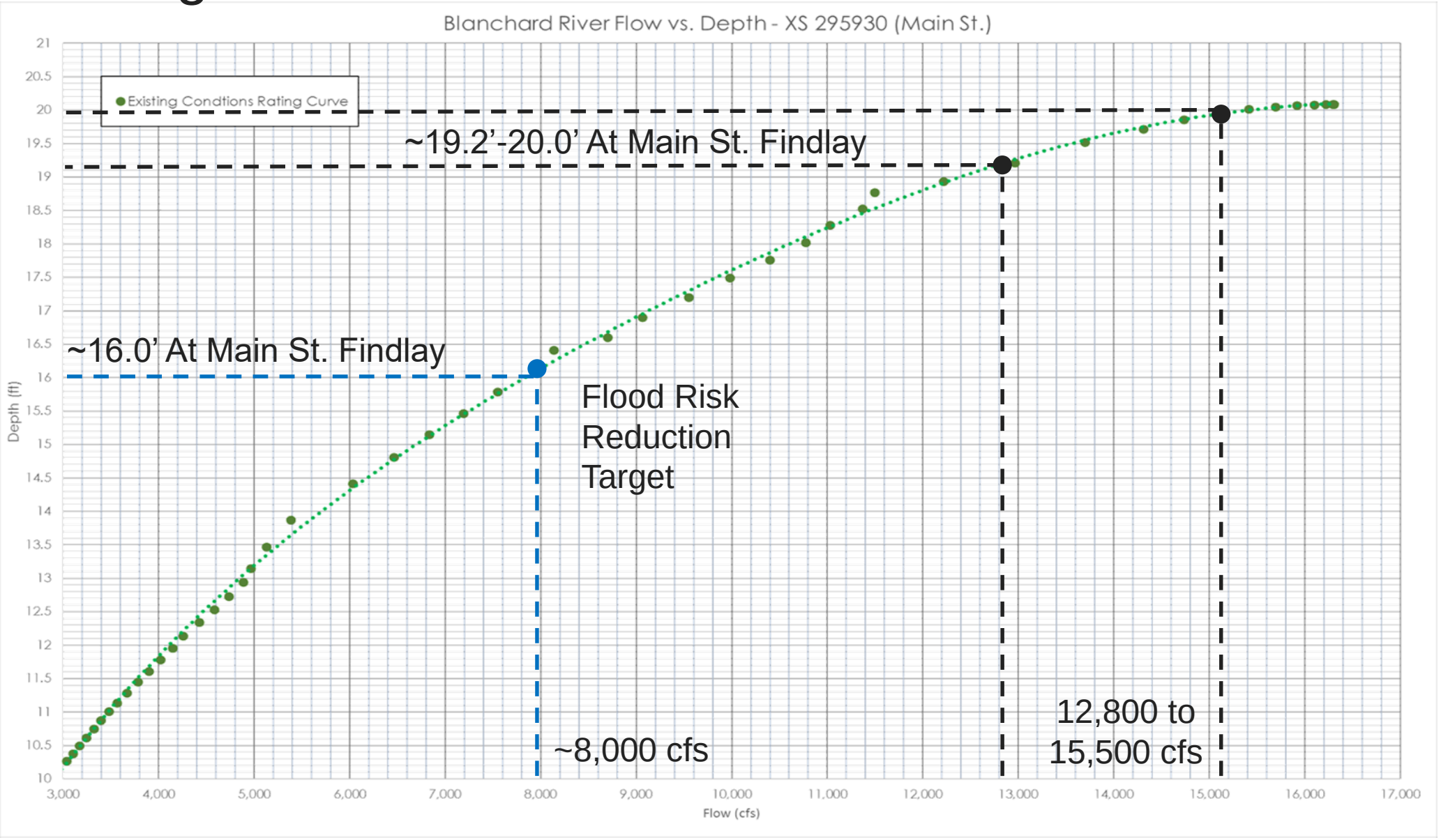
Stantec Conceptual Flood Risk Reduction Plan

Recommendation #1 – Channel Modifications



Blanchard River Hydraulic Rating Curve

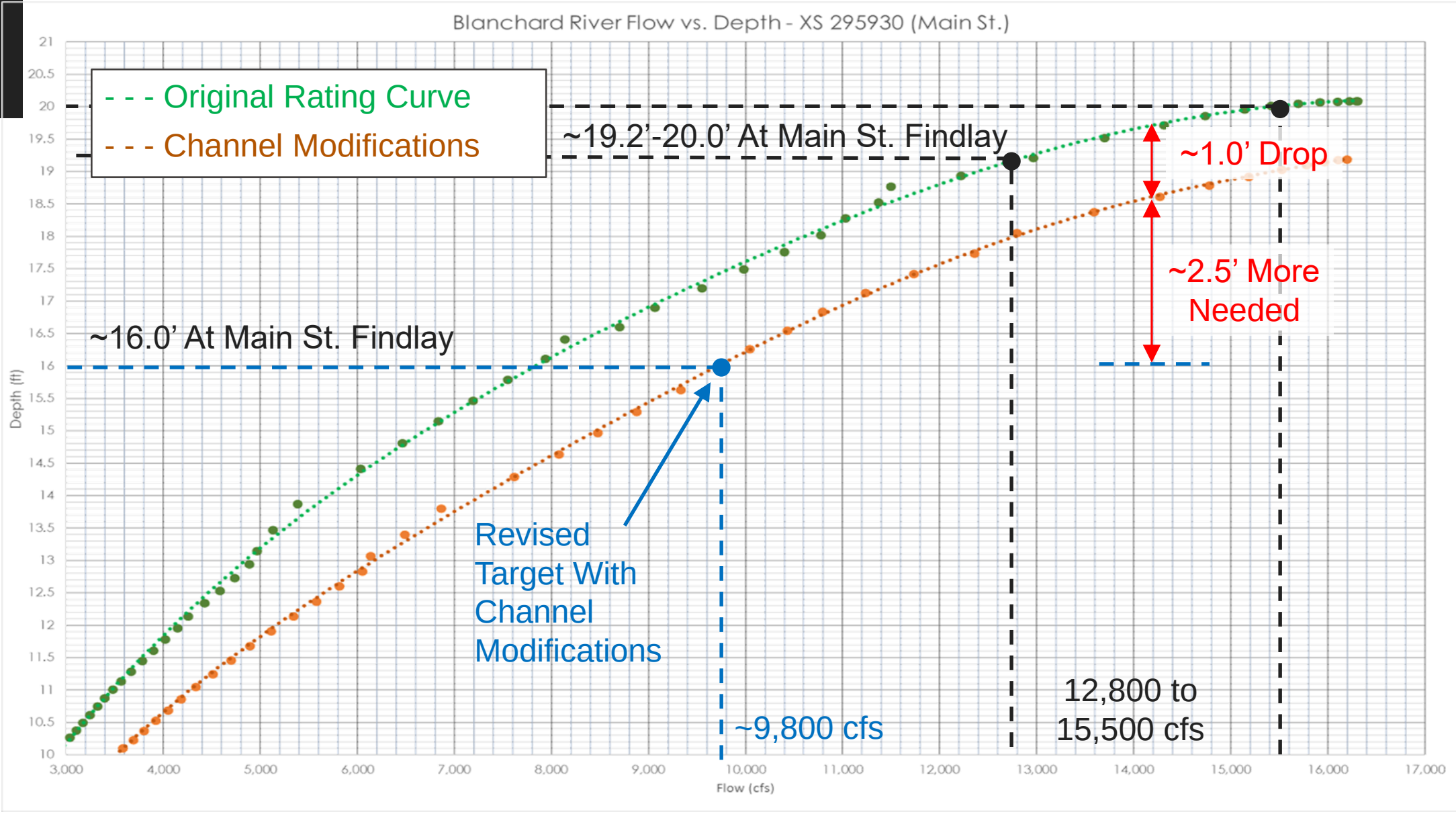
1% Annual Chance (100-Year) Flood Event Existing Conditions



Stantec

Blanchard River Hydraulic Rating Curve

1% Annual Chance (100-Year) Flood Event With Channel Modifications

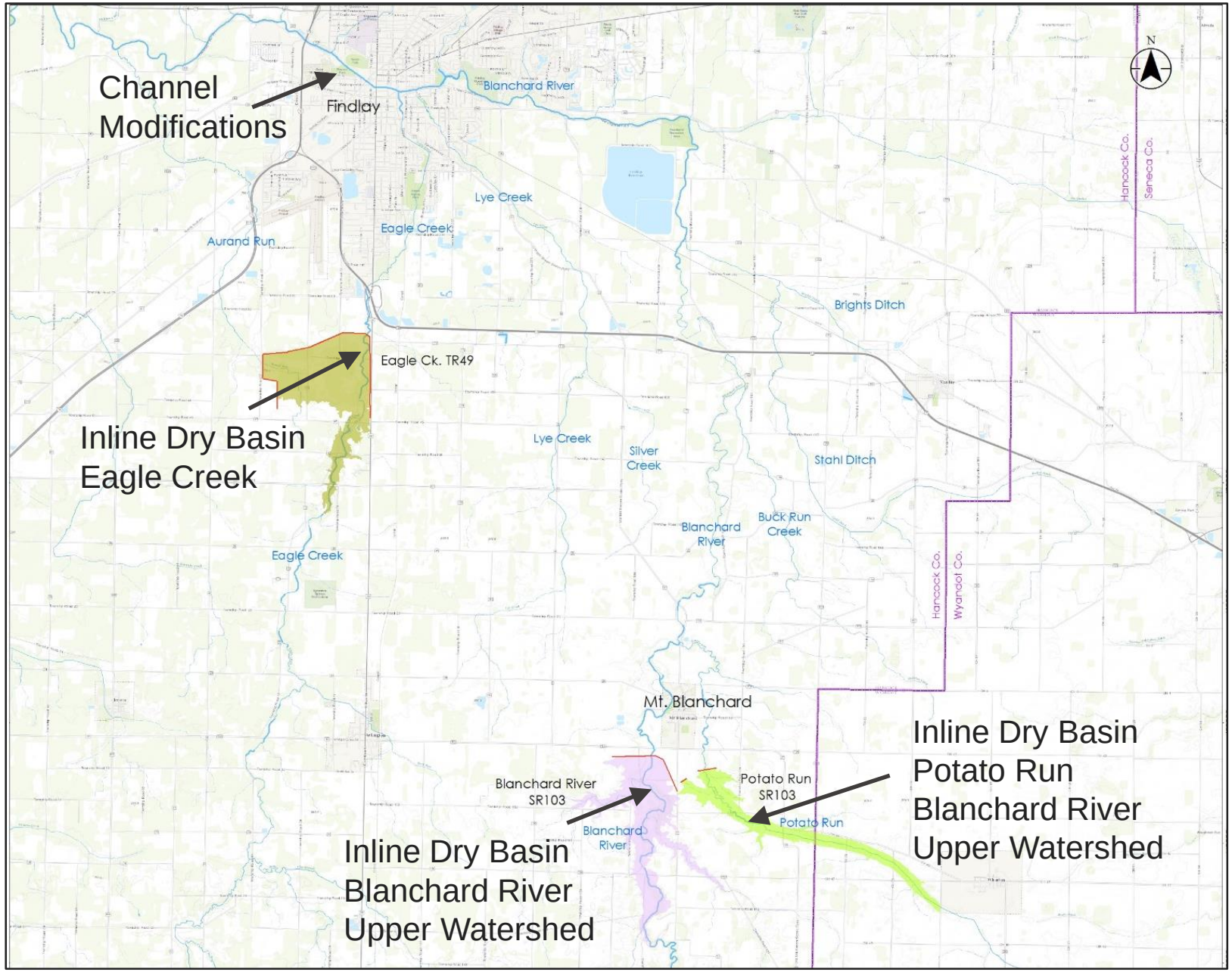


Stantec

Stantec Conceptual Flood Risk Reduction Plan

Other Flood Risk Reduction Measures

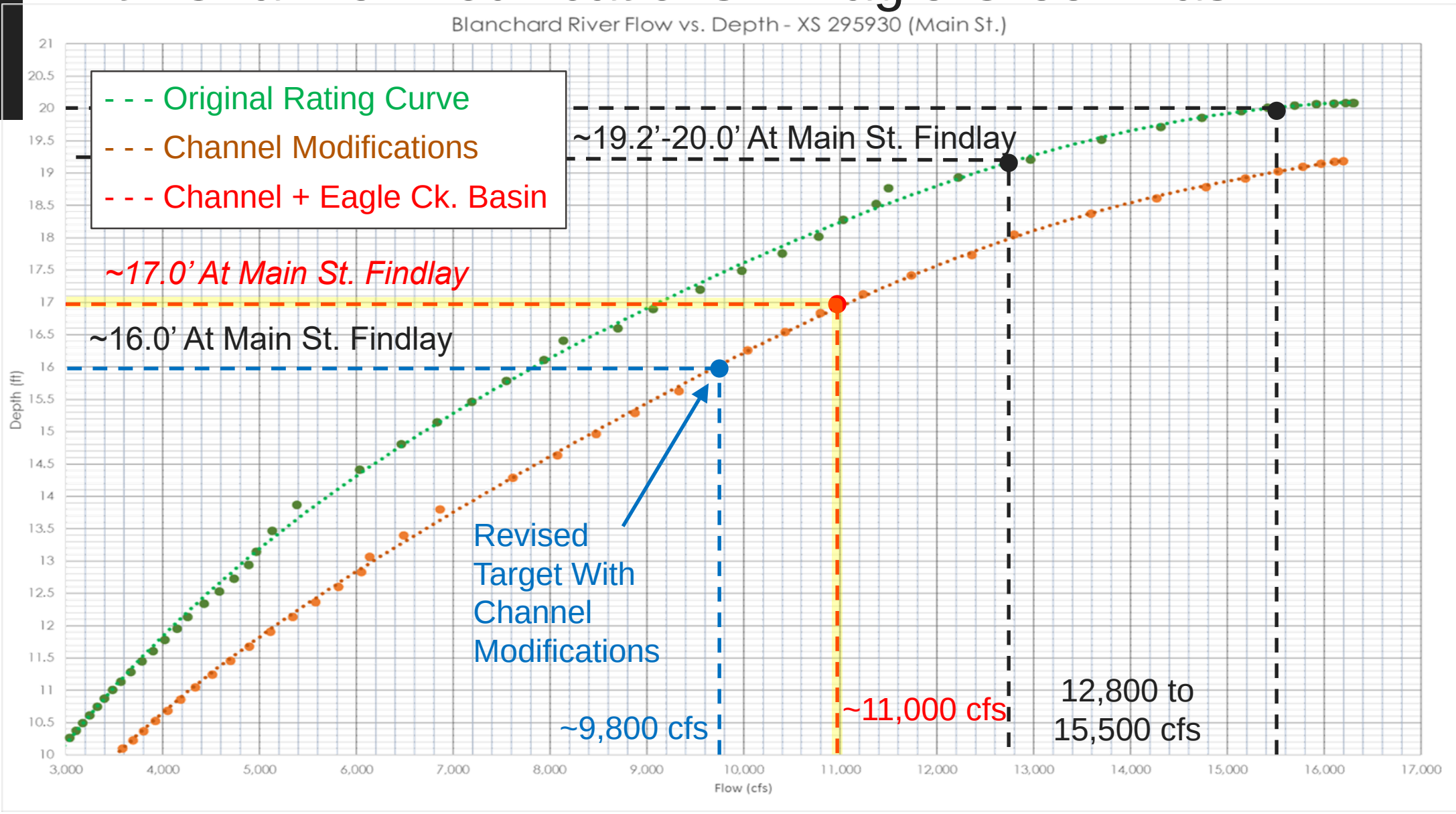
CONCEPTUAL FOR DISCUSSION PURPOSES ONLY



Stantec

Blanchard River Hydraulic Rating Curve

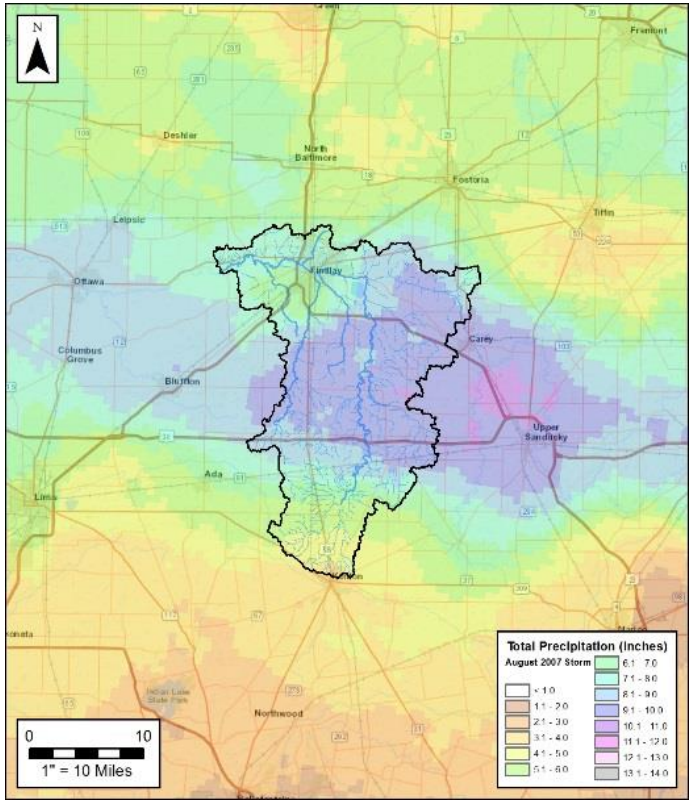
1% Annual Chance (100-Year) Flood Event With Channel Modifications + Eagle Creek Basin

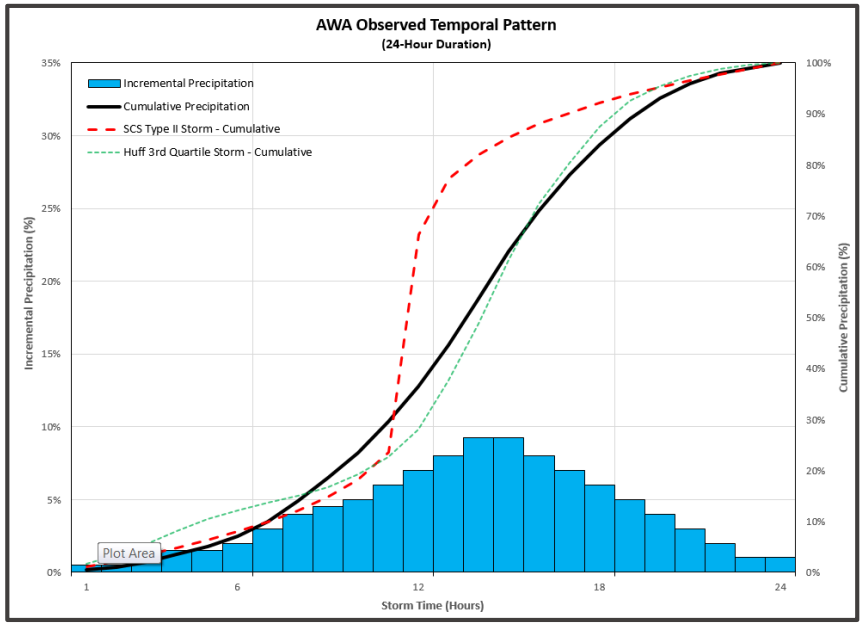


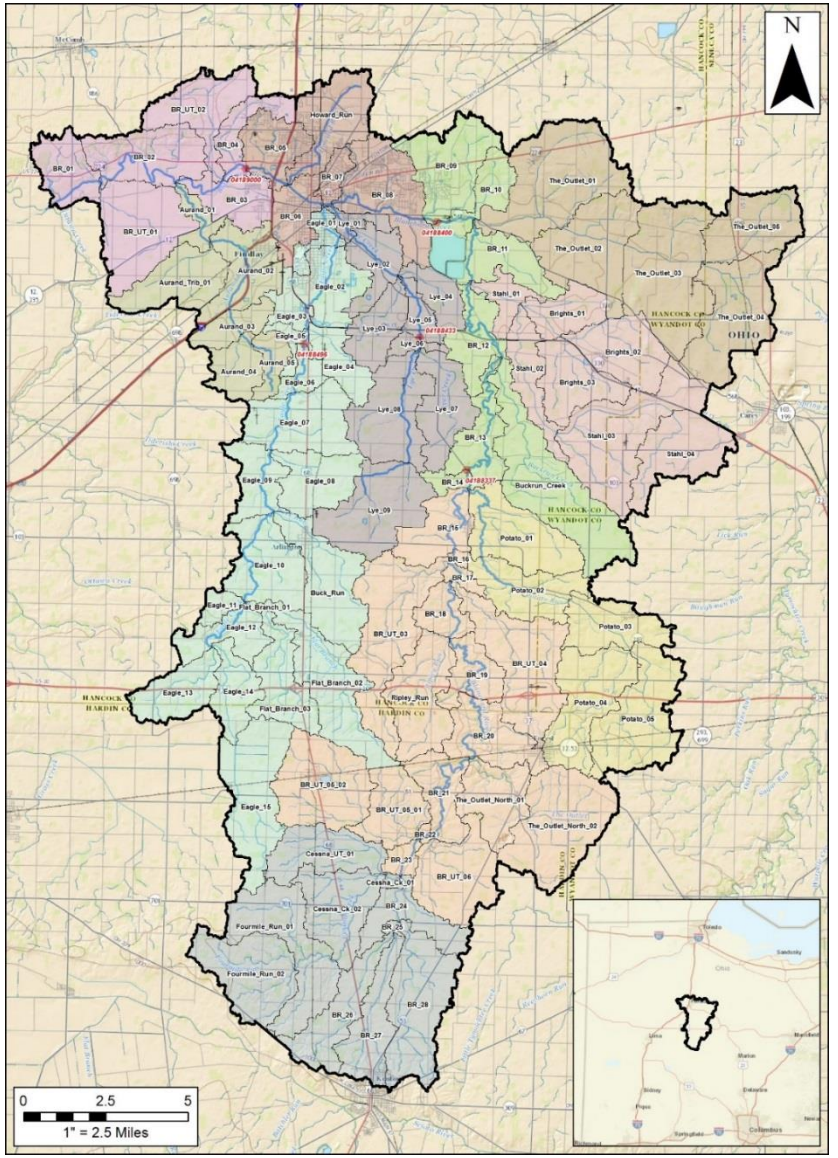
Stantec

Erman Caudill, PE, CFM
Senior Water Resources Engineer

Questions?
Comments?







Want More Info?
http://www.hancockcountyflooding.com/