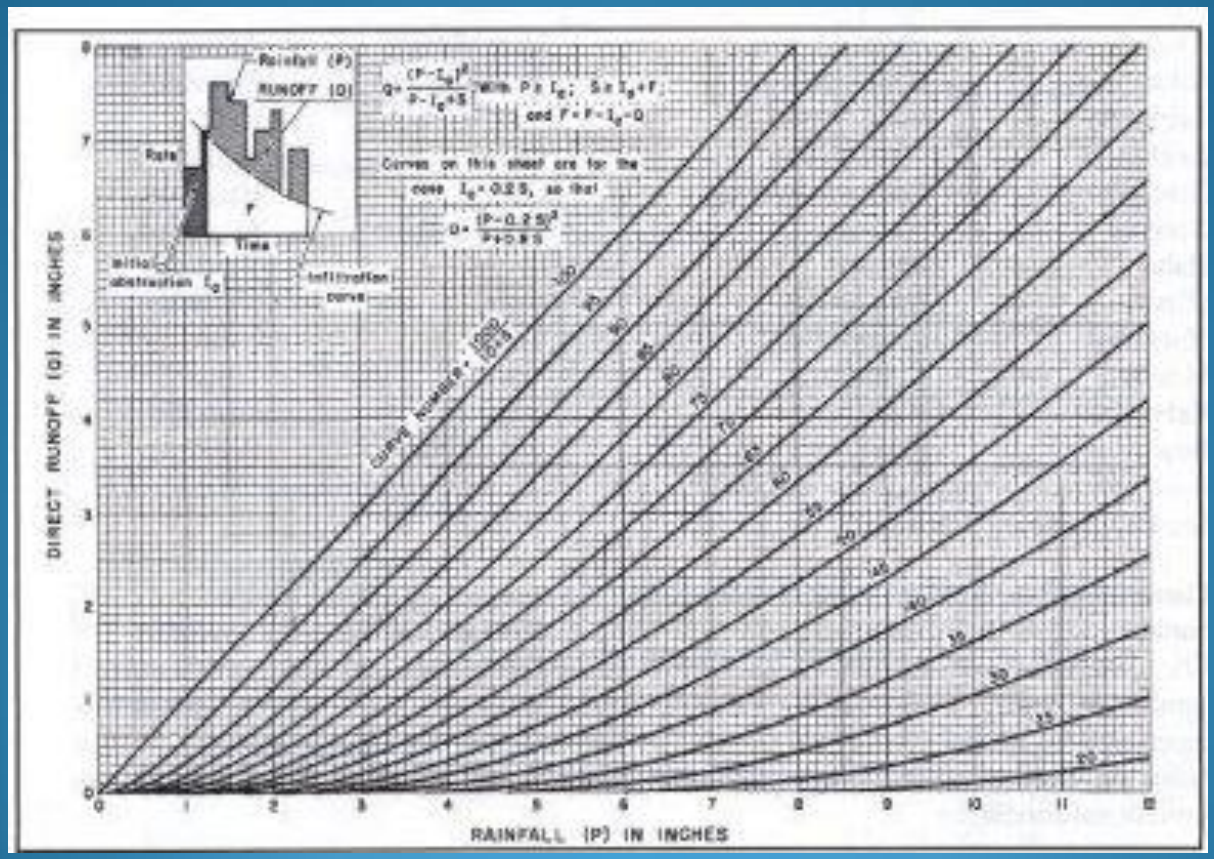
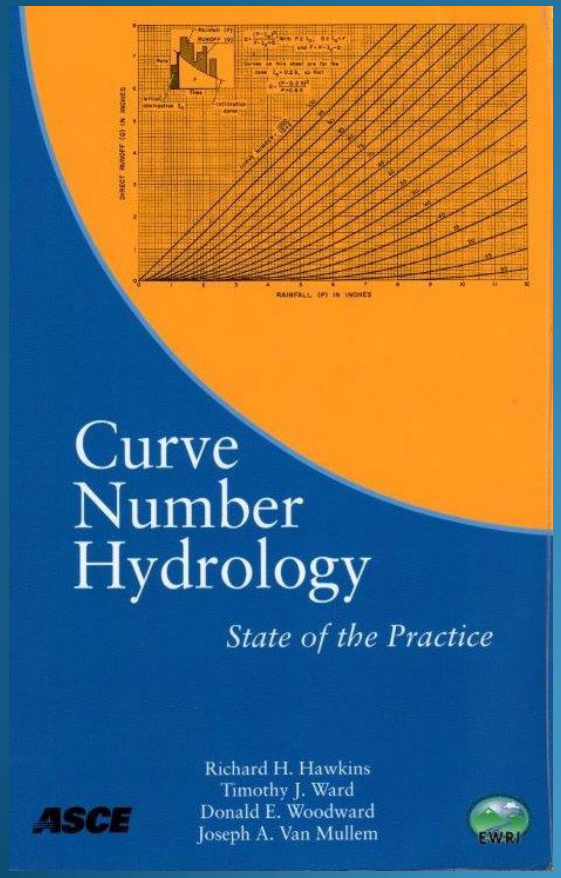
SCS Curve Number Hydrology

Considerations for Design Flood Determination



"Curve Number Hydrology"

State of the Practice



ASCE/EWRI Curve Number Hydrology Task Committee, Ed. Hawkins, R.H., Ward, T.J., Woodward, D.E., & Van Mullem, J.A. (2009)

Curve Number Method History

1. 1954 – Small Watershed & Flood Control Act
   - Develop uniform procedures for runoff volume estimates
   - Small watersheds
2. CN Method developed by SCS during 1950's
   - Popular and ubiquitous -- Easy to apply
3. Method Documentation
   - Little published 1st 10 years
   - Evolved over time: subject of # of articles
   - Primary source reference – NEH 4
4. Method Updates [No NRCS Ratification]
   - 1986 – TR55: Extension of method to urban lands
   - 1973 : Add CN's for additional land uses
   - 1993: Abandonment of AMC classes

Curve Number Method Approach

1. Computes an events direct runoff depth arising from:
   - Rainfall depth
   - A storage index
2. Not a Flood Peak or Hydrograph Method
   - Provides only rainfall – runoff depth == rainfall excess
3. Method Basis
   - CN tables from small agricultural watersheds -- 24 States
   - Documentation is sketchy
   - Urban Land CN's added in 1986 -- Little documentation
   - Watersheds: median size 20 acres (.24 acres to 72 mi^2)
4. Curve Number: Most sensitive parameter – least studied!!

ASCE/EWRI Curve Number Hydrology Task
Selected Committee Recommendations

1. Local Calibration – "*In actual usage most CNs are drawn from agency tables of unknown origin sources, or from consensus tables agreed to for local usage. Given this and the methods sensitivity to the selected CN, local calibrations on local rainfall and runoff data from local watersheds seem both appropriate and professional, and should be encouraged*."
2. Forested Watersheds – "*CN method is largely out of place*"
3. Hydrologic Soil Group – *Classifications not consistent*

SCS Dimensionless Unit Hydrograph Method

- A method to develop a Synthetic Unit Hydrograph
  - Transfers Precipitation Excess to Runoff
- Dimensionless Unit Hydrograph Procedure
  - Based on large number of actual unit hydrographs
    - Variety of watershed types by size and location
  - A National Method
    - Average unit hydrograph for those considered
    - Time to peak = 20% of time base
    - Inflection point = 1.7 times the time to peak

Clark Unit Hydrograph Method (1945)

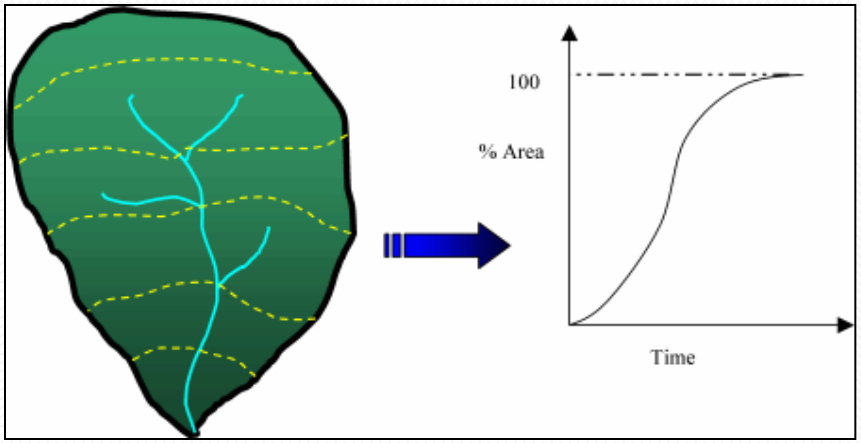
Clark, C.O. (1945), "Storage and the Unit Hydrograph", Transactions ASCE, 110, 1419 - 1446

A method to develop a Synthetic Unit Hydrograph, generally referred to as an "Instantaneous Unit Hydrograph" :

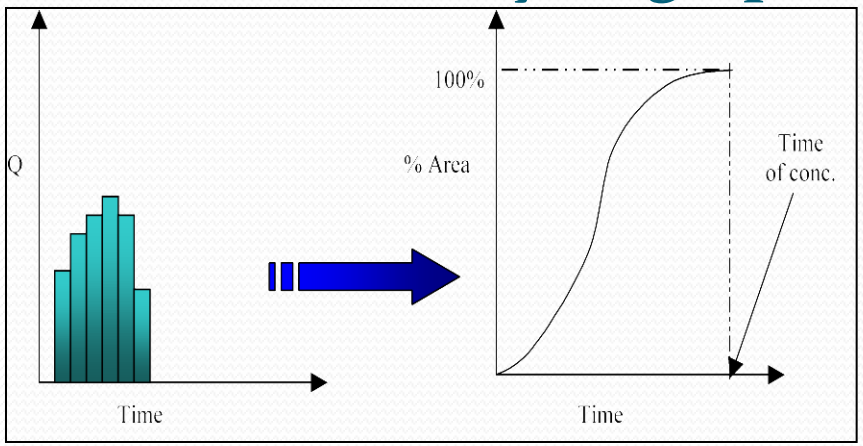
- Developed for gauged sites
- Relies on the concepts of :
  - Translation hydrograph development
  - Linear reservoir routing representing watershed storage

Clark Unit Hydrograph Method

*Time Area Method



**Translation Hydrograph



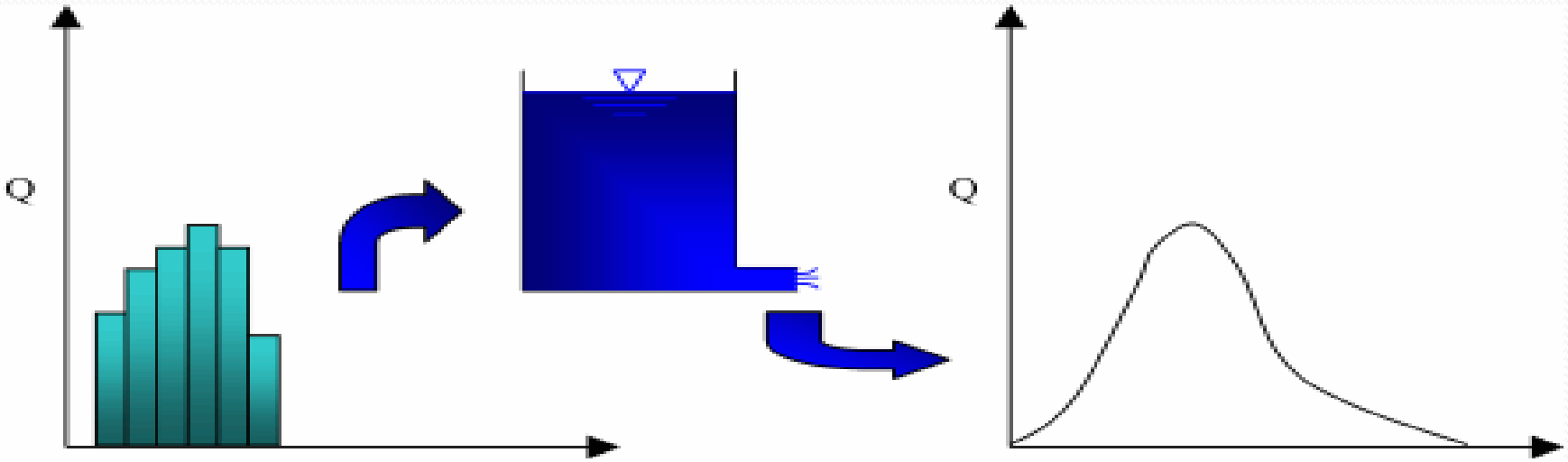
*HECHMS includes a typical “time area relationship applicable for most watersheds

**Representation of % of area producing runoff over time

Ref: National Weather Service – Unit Hydrograph Manual

Clark Unit Hydrograph Method

Translation Unit Hydrograph Routed through a "Linear Reservoir"



Represents watershed features that store and delay flow
= "R" coefficient

Ref: National Weather Service – Unit Hydrograph Manual

Clark Method Key Parameters

- "R" Storage coefficient
  - Estimated through calibration to gaged stream data
- Time of concentration
  - Defined as: *time for last drop of rainfall excess at most hydraulically distant point to reach the channel network*
    - Measured from stream gage storm hydrograph
- Rainfall abstraction
  - Initial and subsequent
- Baseflow

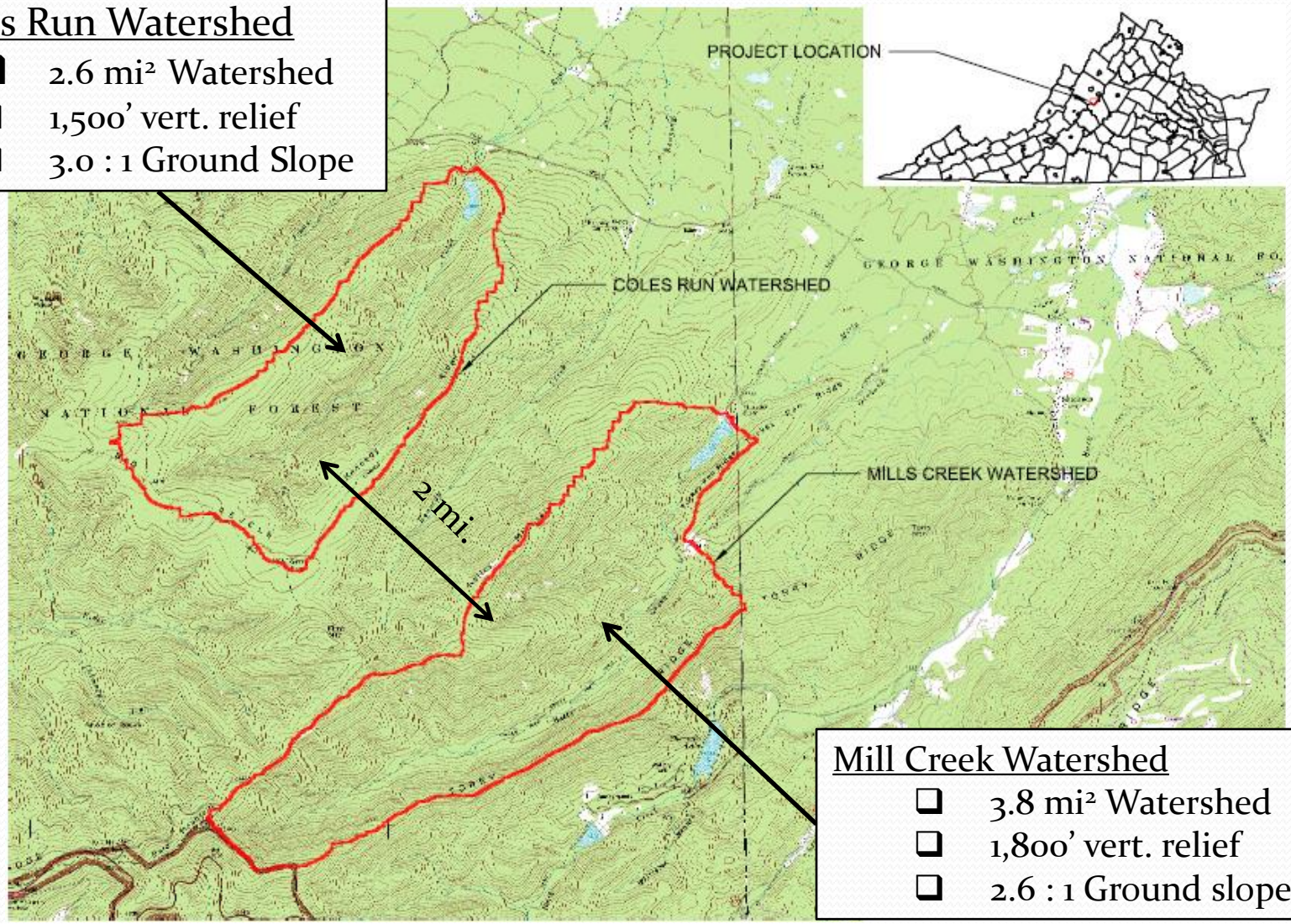
Coles Run & Mill Creek Watersheds

Augusta County, Virginia

Coles Run Dam Spillway Modification

- Blue Ridge Mountains

Watershed Setting



Coles Run Watershed

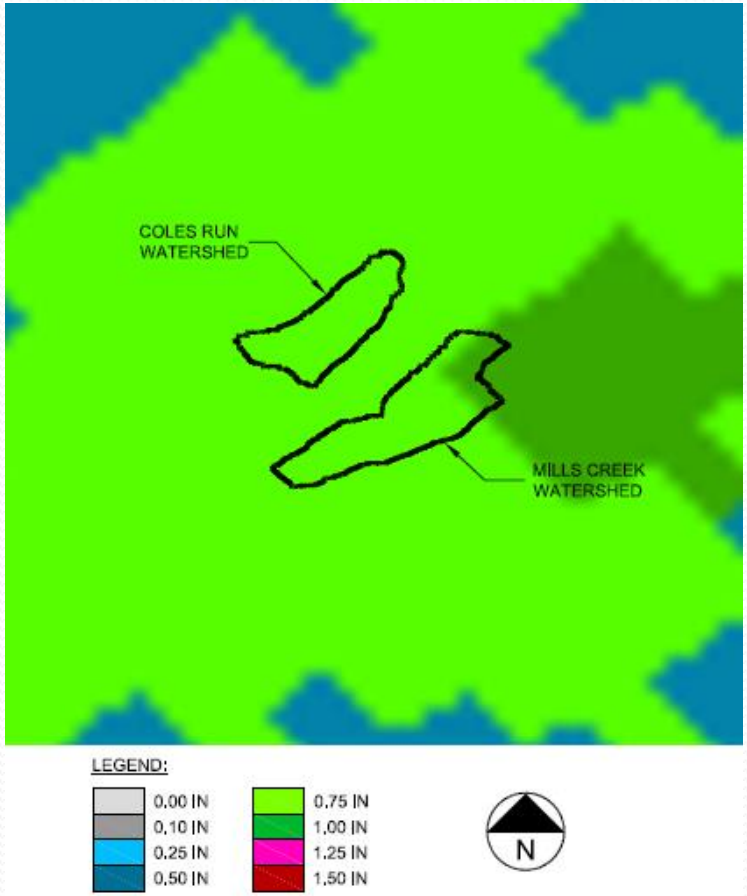
- 2.6 mi² Watershed
- 1,500' vert. relief
- 3.0 : 1 Ground Slope

Mill Creek Watershed

- 3.8 mi² Watershed
- 1,800' vert. relief
- 2.6 : 1 Ground slope

Mill Creek Watershed Aerial Photograph

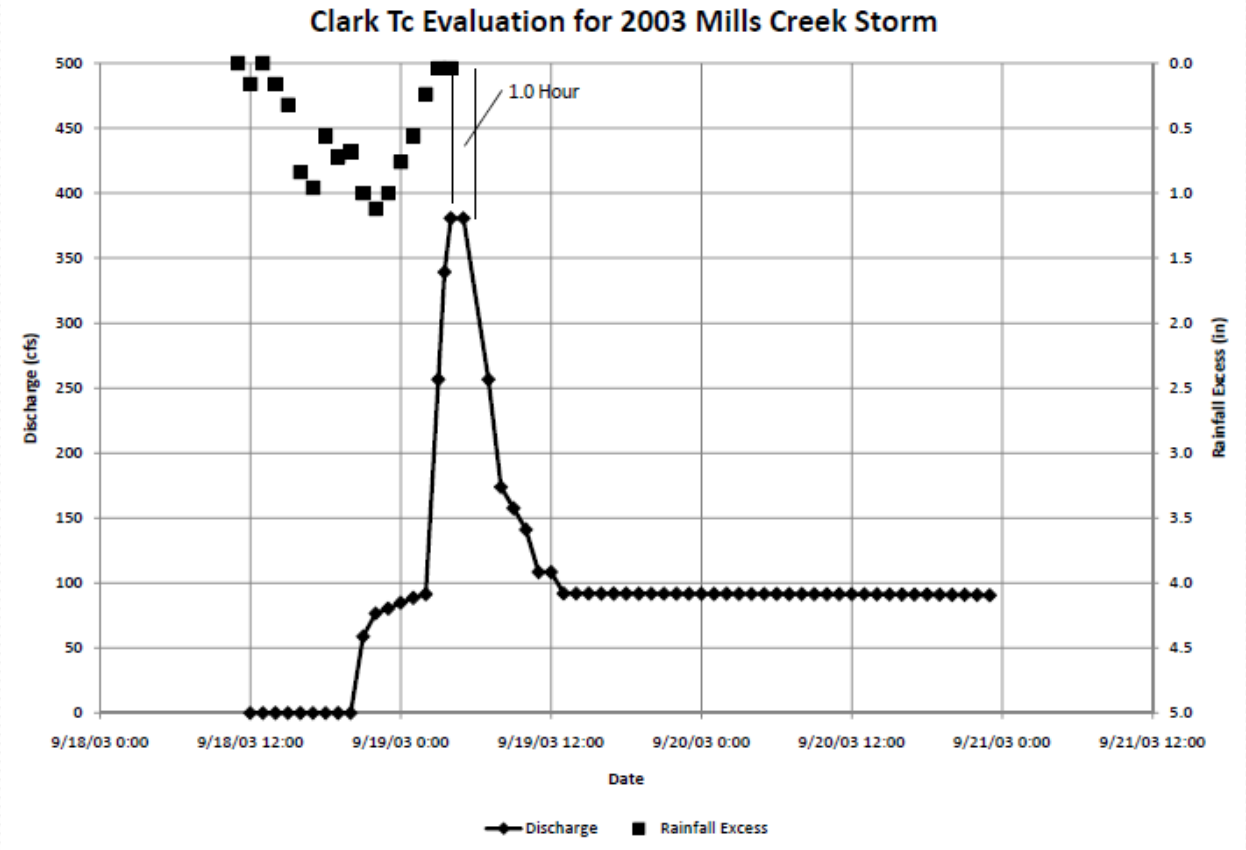
September 2003 Storm – Hurricane Isabel



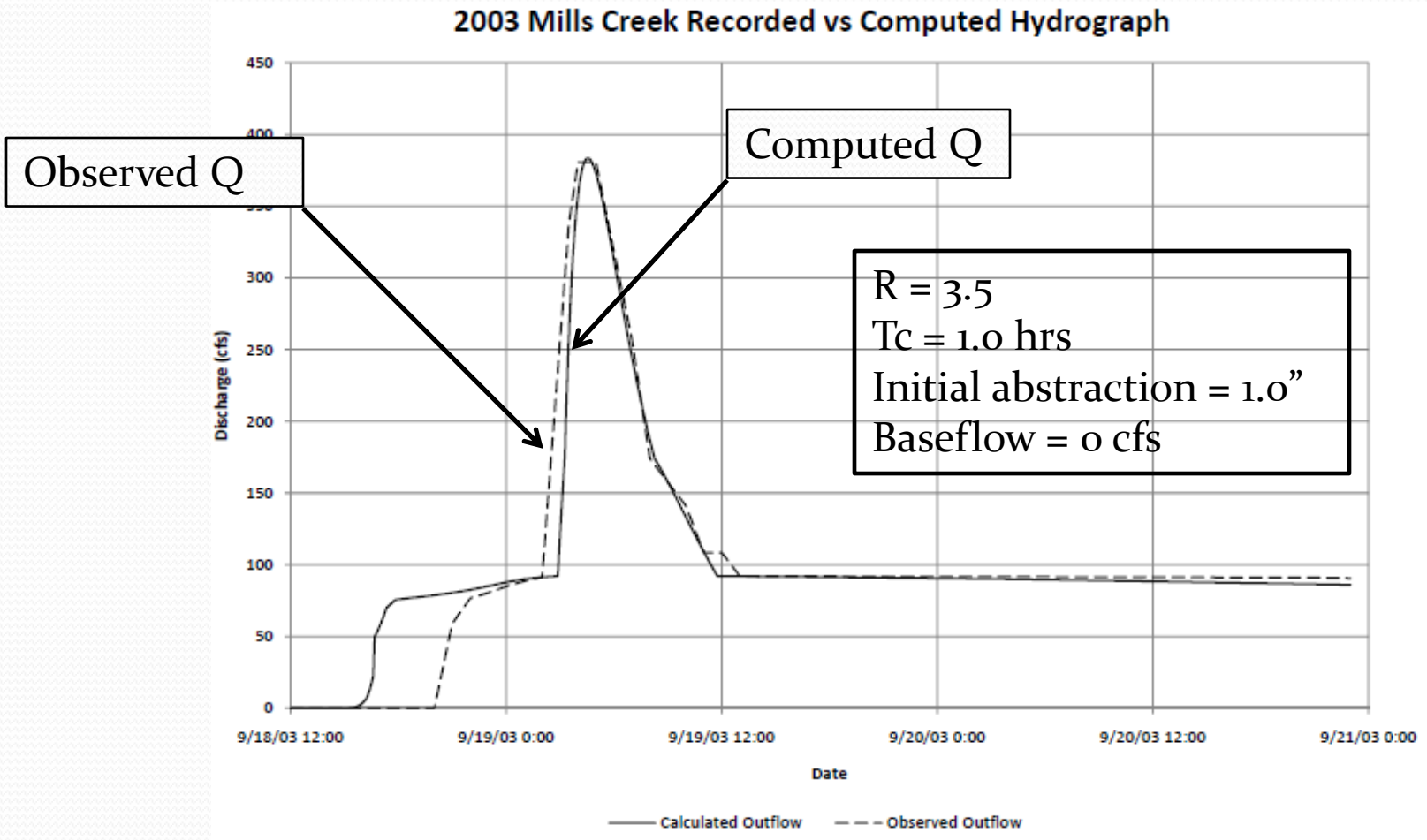
September, 2003 Storm Event:

- 9.16“ Rainfall
- Recurrence interval:
  - 100 year flood
- Mill Creek Rain Gage
- Nexrad Images – interpretation of rainfall distribution

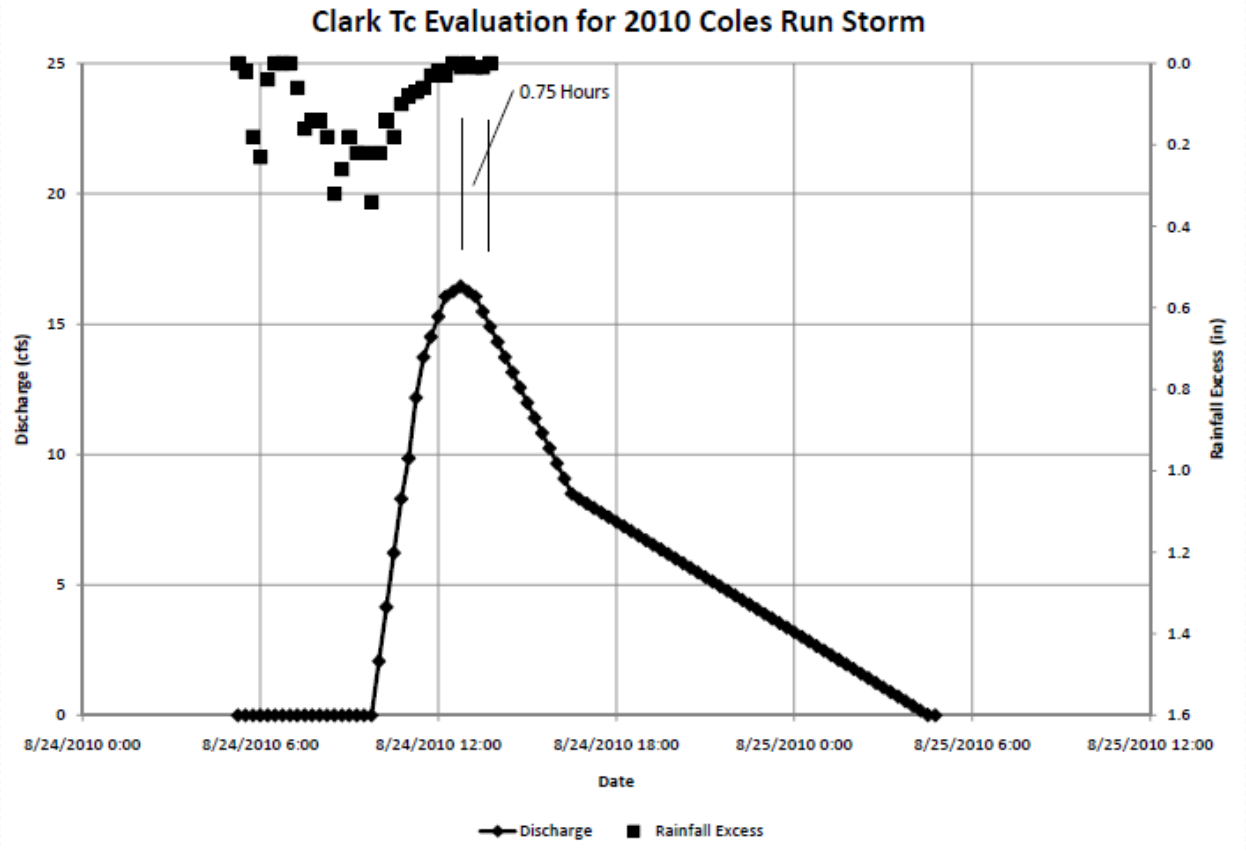
September, 2003 Storm – Clark Tc for Mills Creek Watershed



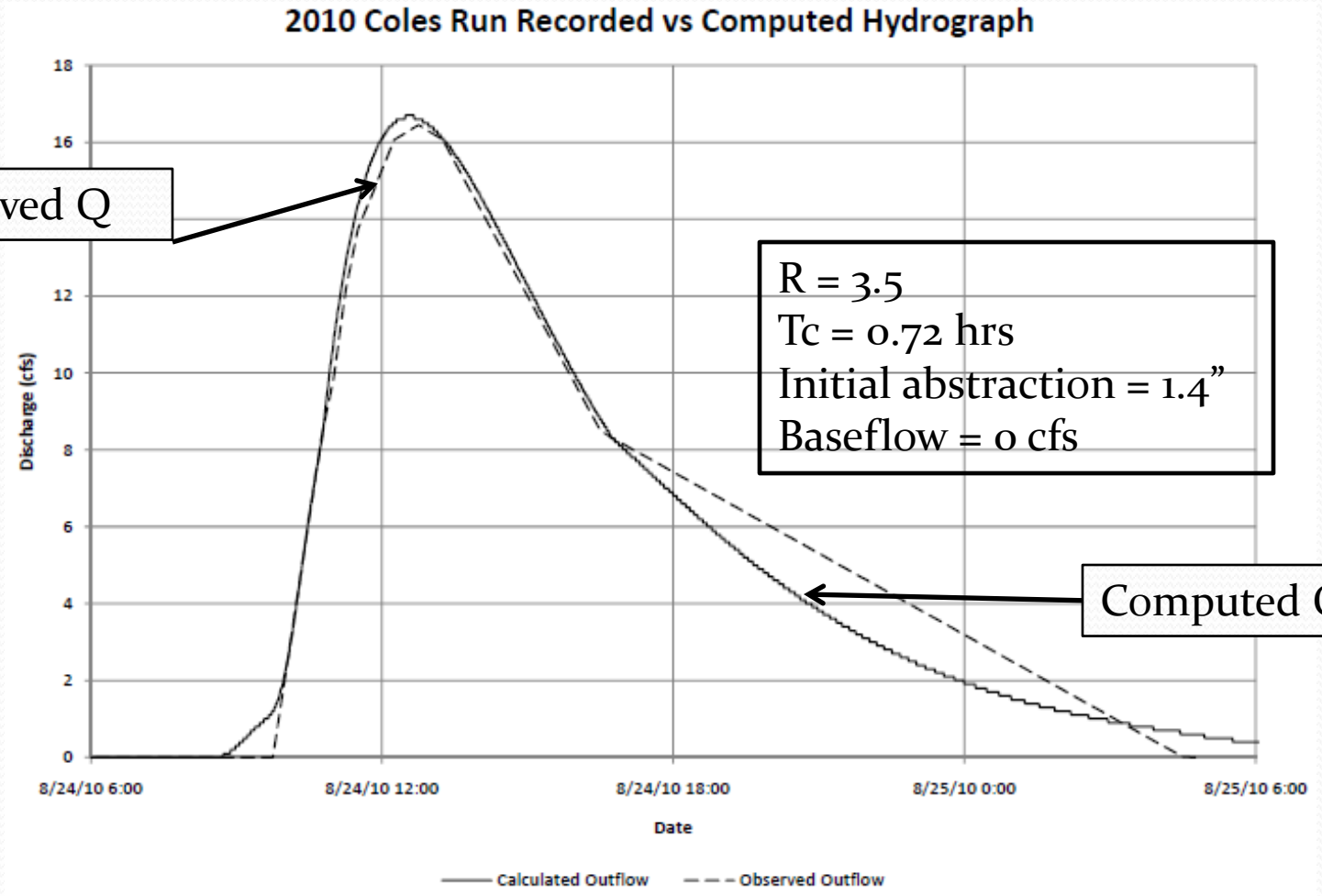
September, 2003 Storm Calibration – Mills Creek Watershed



August, 2010 Storm Tc Estimate – Coles Run Watershed



August, 2010 Storm Calibration – Coles Run Watershed



Observed Q

R = 3.5
Tc = 0.72 hrs
Initial abstraction = 1.4”
Baseflow = 0 cfs

Computed Q

Coles Run – PMF Analysis

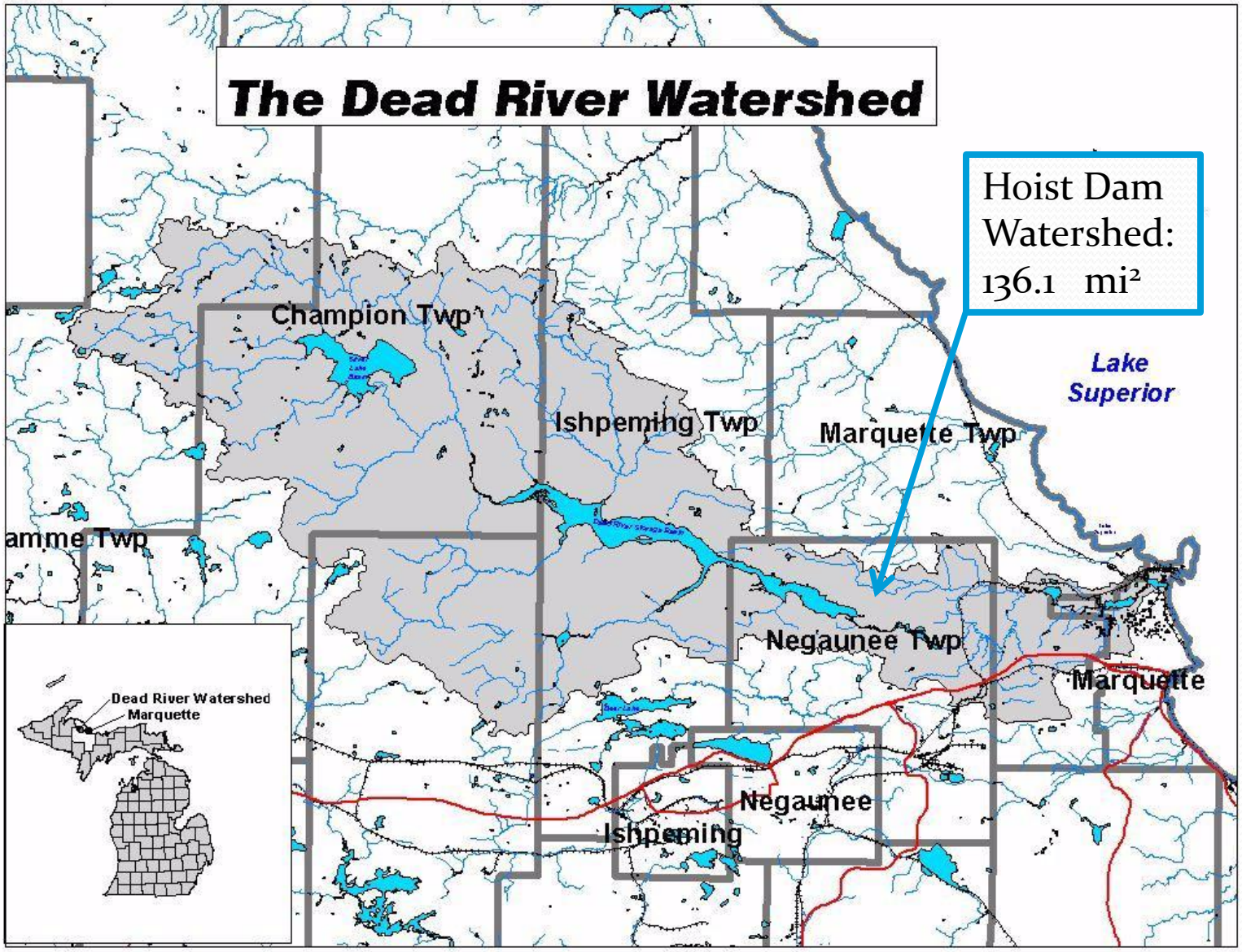
- Curve Number Method:
  - Runoff Curve Number = 60
  - TR55 Tc = 1.77 hours
  - **PMF Discharge = 14,790 cfs**

- Clark Unit Hydrograph Method:
  - Clark R Coefficient = 15
  - Clark Tc = 0.74 hours
  - Initial and Subsequent Rainfall Abstraction = 0
  - **Discharge = 8,760 cfs (40% Reduction)**

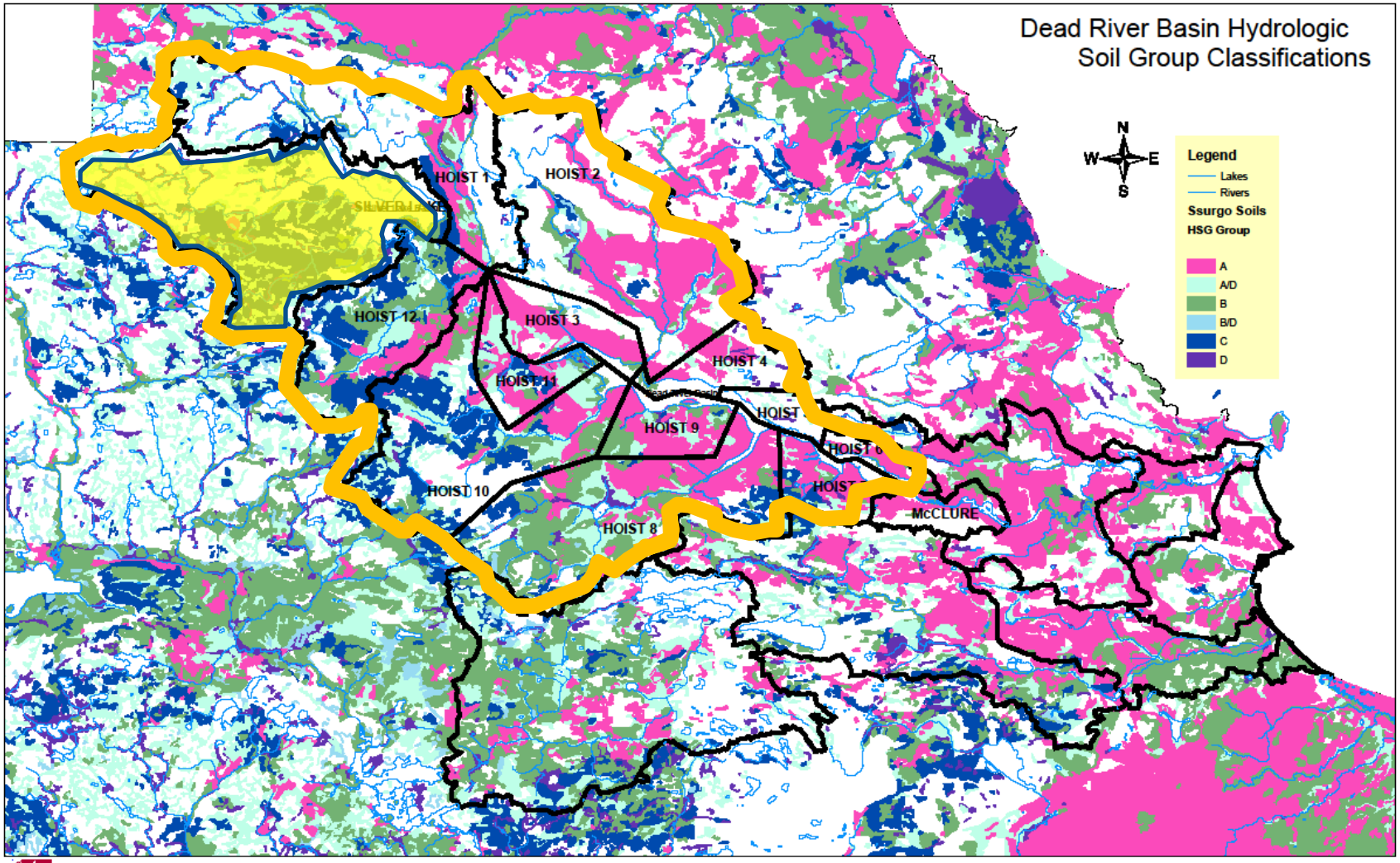
Dead River Watershed -- Hoist Dam

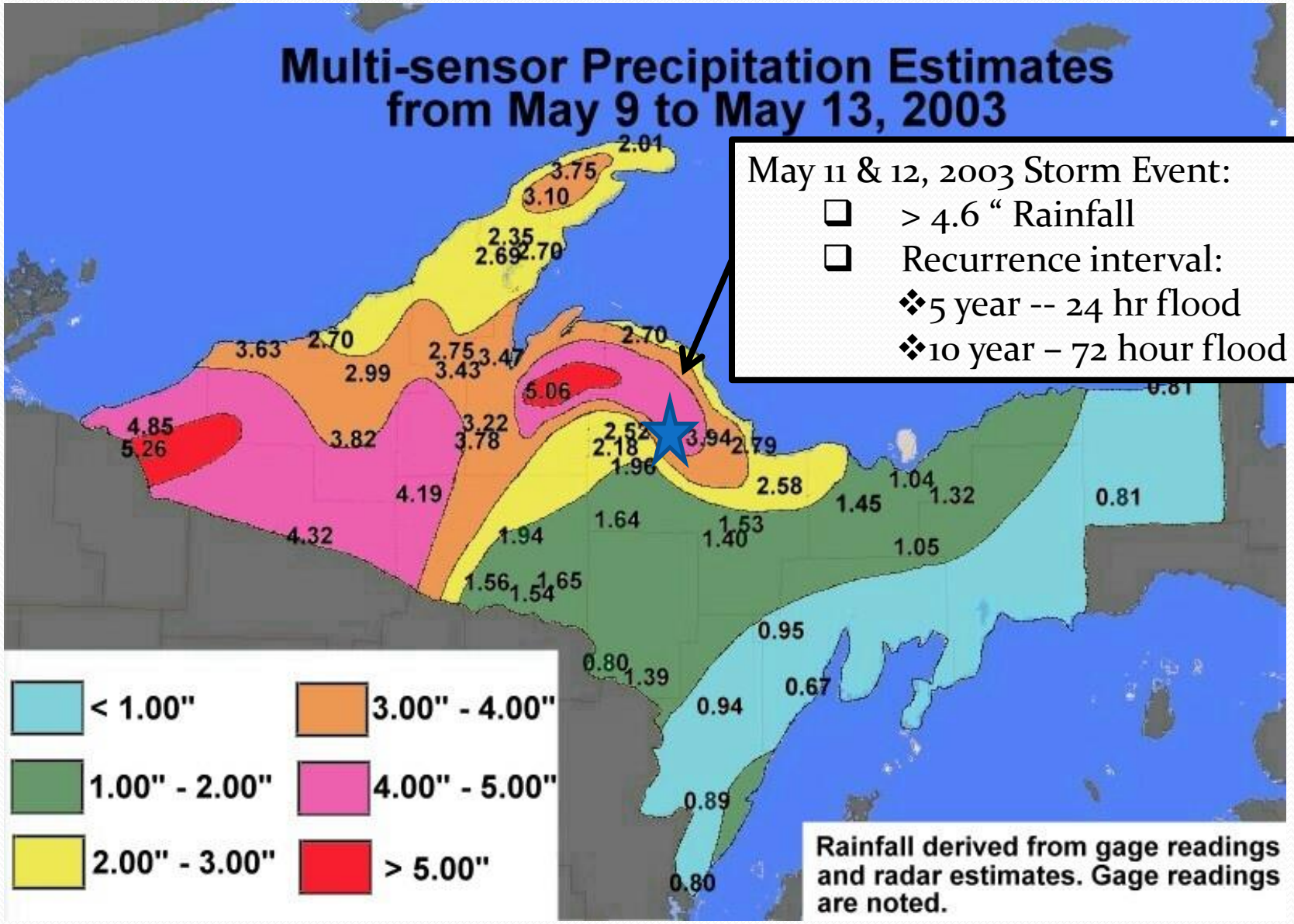
Upper Peninsula, Michigan

Watershed Analysis – flow determination for dam evaluation and design purposes

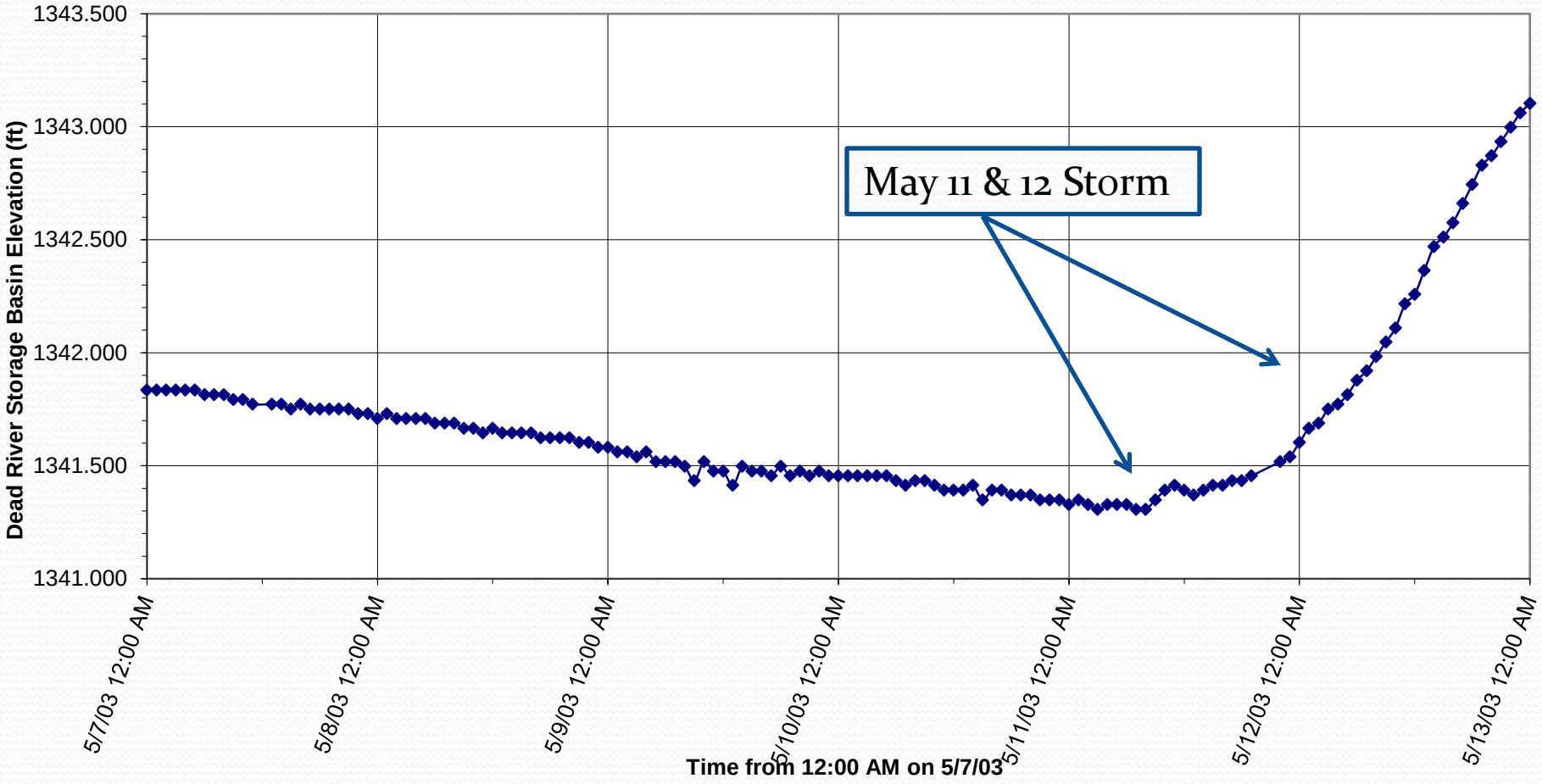

The Dead River Watershed
Hoist Dam Watershed: 136.1 mi²
Champion Twp
Ishpeming Twp
Marquette Twp
Lake Superior
amme Twp
Negaunee Twp
Marquette
Negaunee
Ishpeming
Dead River Watershed
Marquette

Dead River Watershed Aerial Photograph

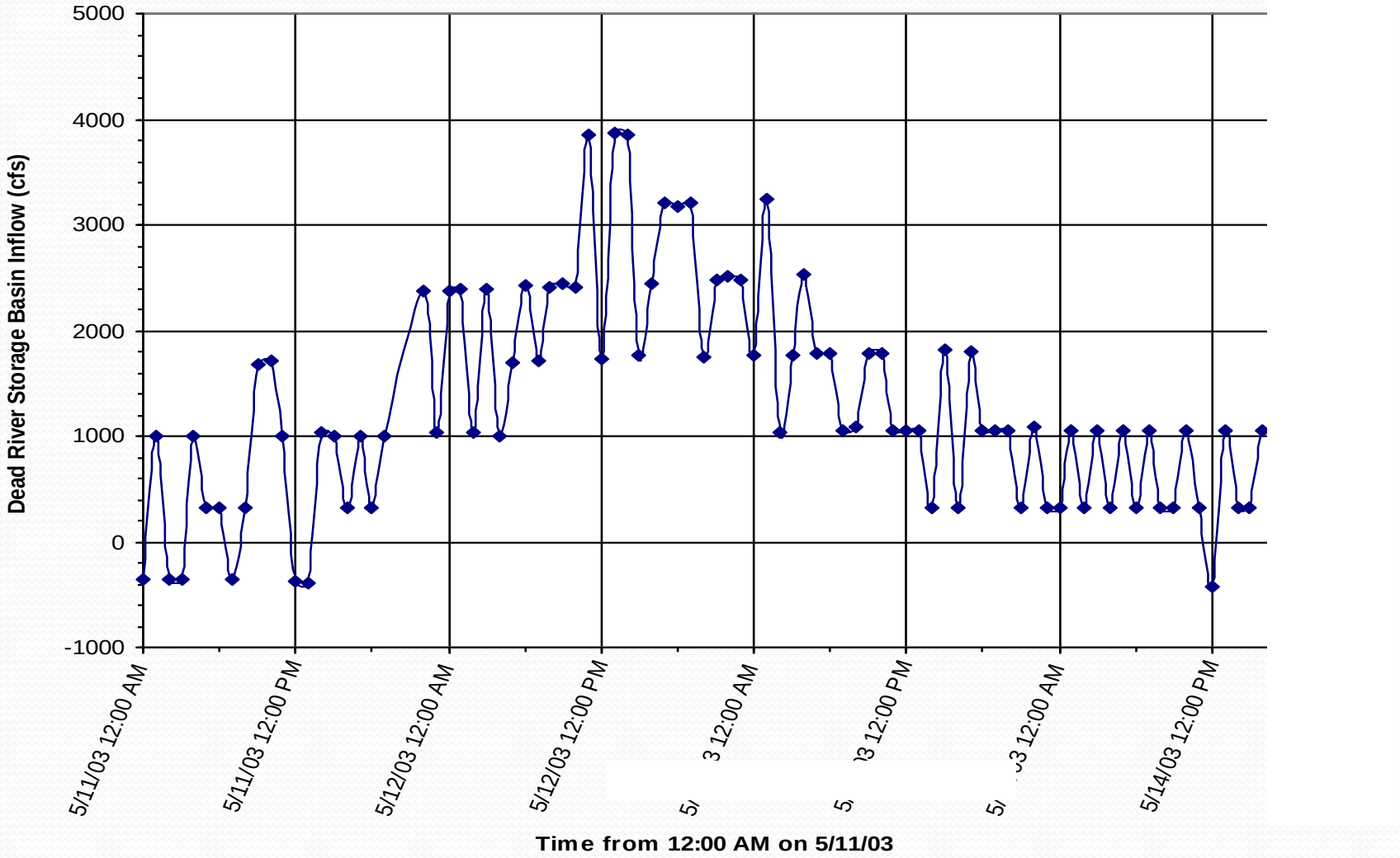

Dead River Basin Hydrologic
Soil Group Classifications
N
W
E
S
Legend
Lakes
Rivers
Ssurgo Soils
HSG Group
A
A/D
B
B/D
C
D
HOIST 1
HOIST 2
HOIST 3
HOIST 4
HOIST 8
HOIST 9
HOIST 10
HOIST 11
HOIST 12
McCLURE
STS Consultants
0
6,250
12,500
25,000
37,500
50,000
Feet
Data Source: Michigan Center for Geographic Information, MDEQ, MDNR, NRCS


Multi-sensor Precipitation Estimates
from May 9 to May 13, 2003
May 11 & 12, 2003 Storm Event:
❑ > 4.6 " Rainfall
❑ Recurrence interval:
❖5 year -- 24 hr flood
❖10 year – 72 hour flood
2.01
3.75
3.10
2.35
2.69
2.70
3.63
2.70
2.75
3.47
2.99
3.43
2.70
5.06
4.85
5.26
3.82
3.22
3.78
2.52
2.18
3.94
2.79
1.96
4.19
2.58
1.04
1.45
1.32
0.81
1.64
1.53
4.32
1.94
1.40
1.05
1.56
1.54
1.65
0.95
0.80
1.39
0.67
0.94
0.89
0.80
< 1.00"
3.00" - 4.00"
1.00" - 2.00"
4.00" - 5.00"
2.00" - 3.00"
> 5.00"
Rainfall derived from gage readings and radar estimates. Gage readings are noted.

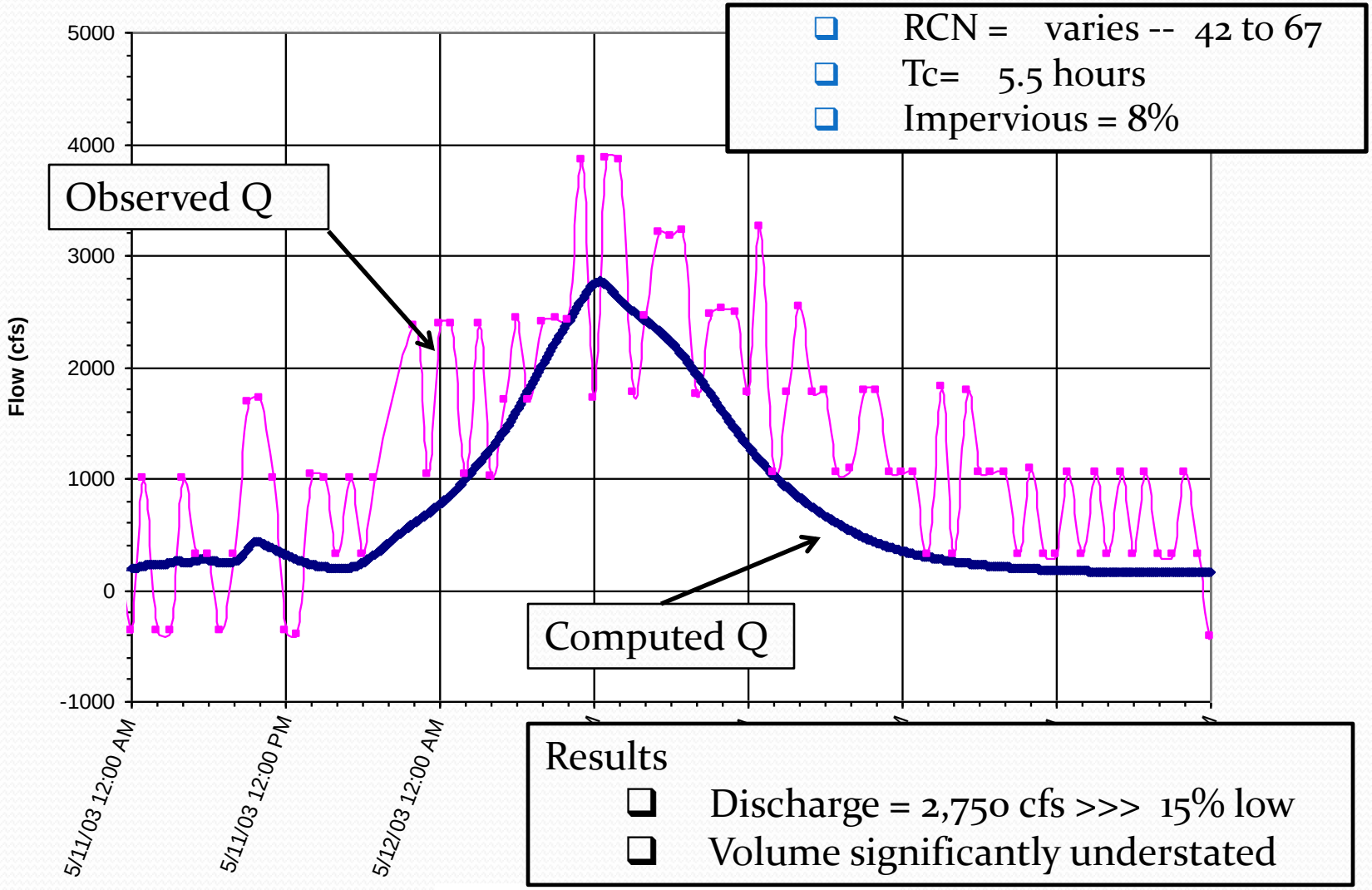
Inflow Curve of Dead River Storage Basin vs. Time Starting at 12:00 AM on 5/7/03



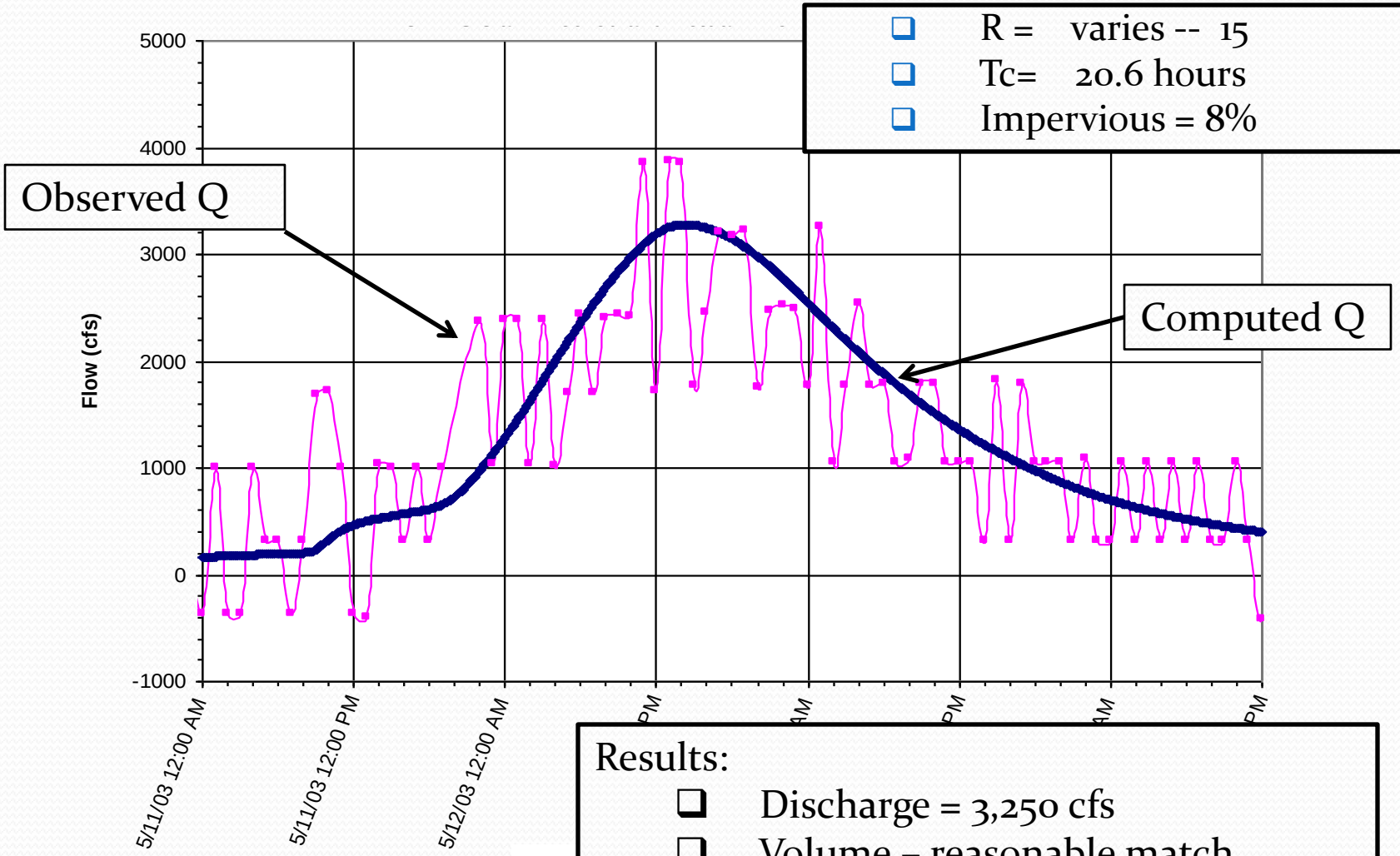
Interpreted Inflow Hydrograph



Curve Number Method Analysis



Clark Method Analysis



Results:

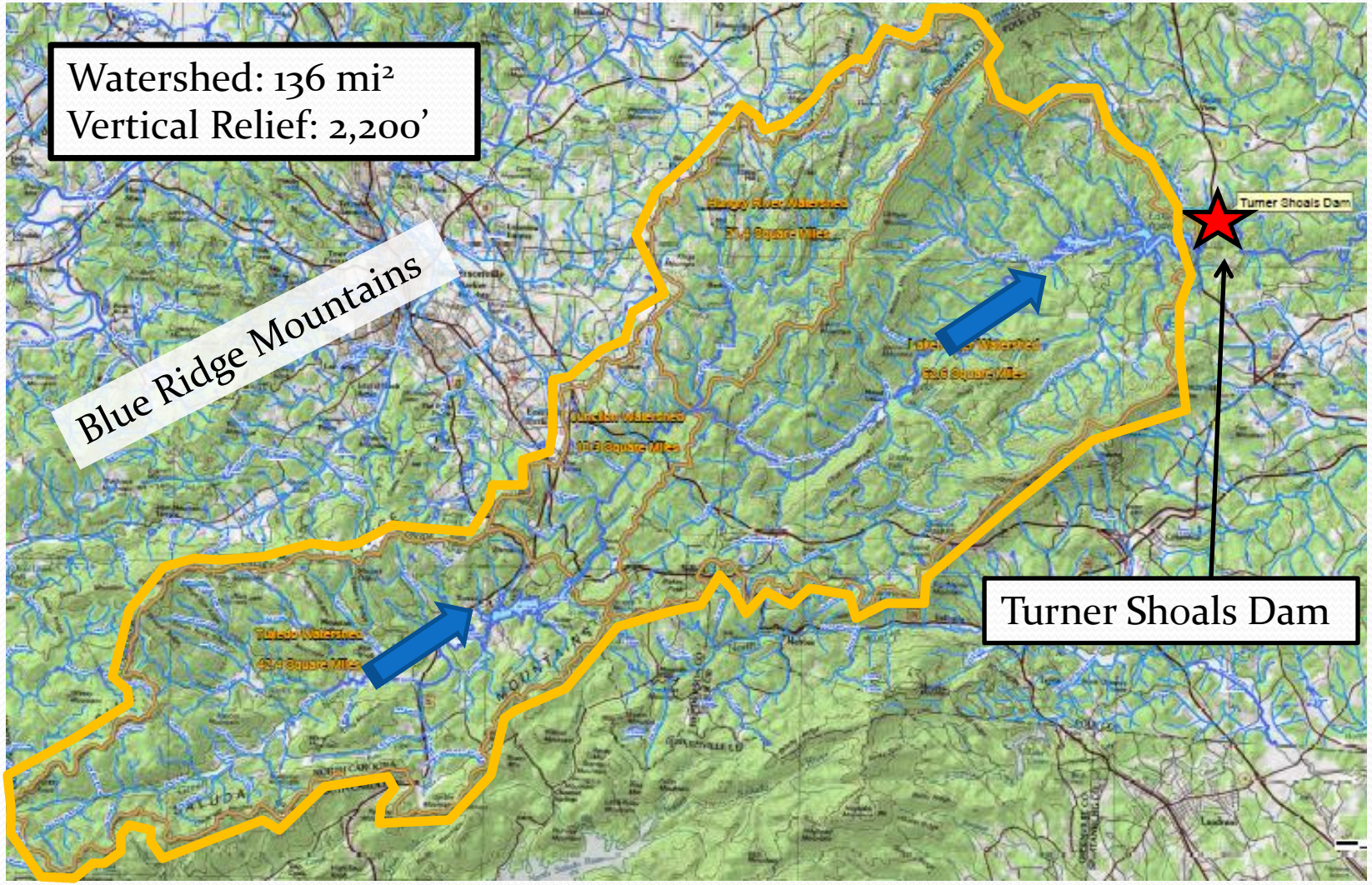
- Discharge = 3,250 cfs
- Volume – reasonable match

Green River Watershed – Turner Shoals Dam

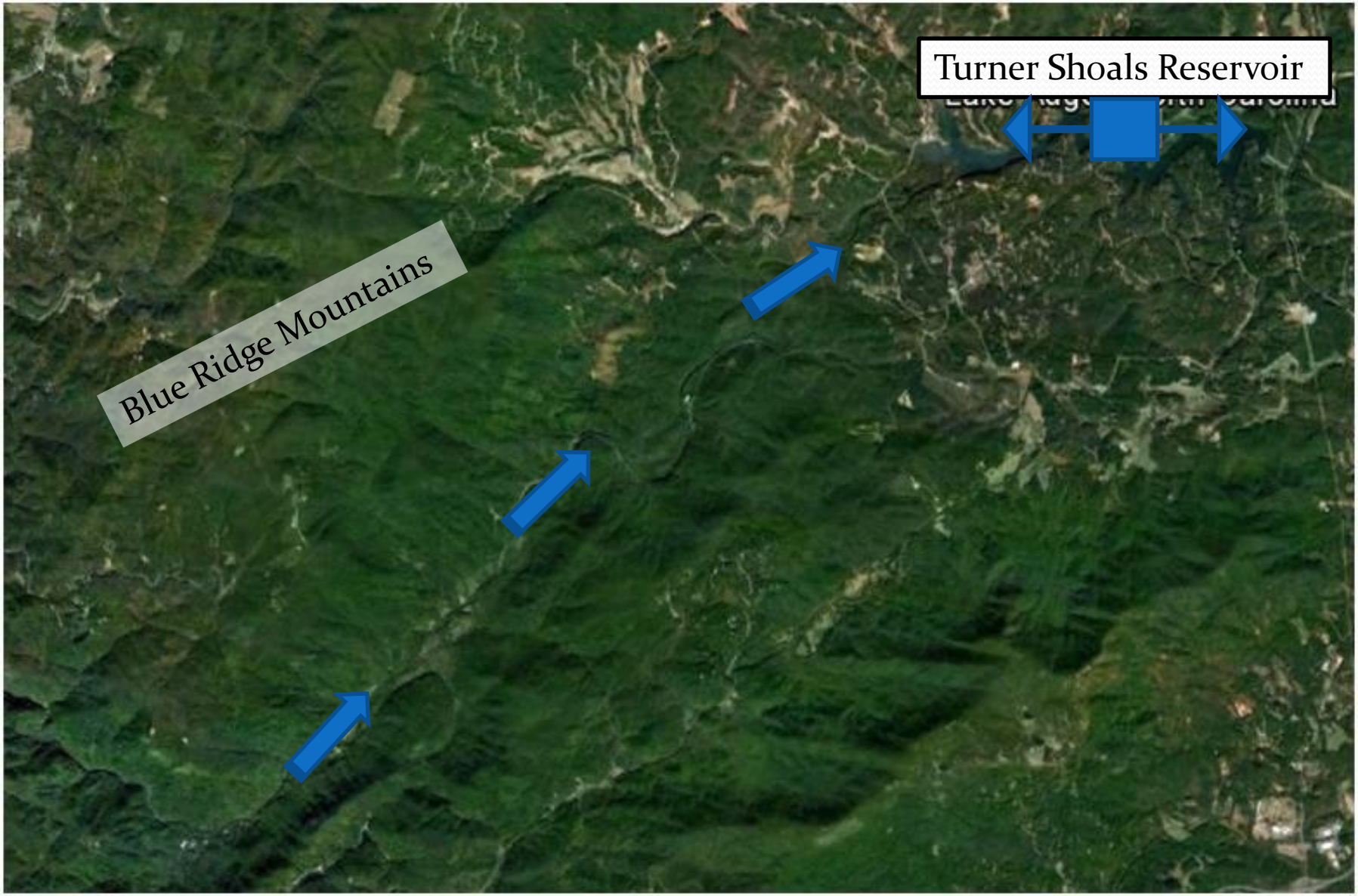
Polk County, North Carolina

Probable Maximum Flood Evaluation for Hydropower Dam Spillway Capacity Analysis

Green River Watershed Limits and Topography

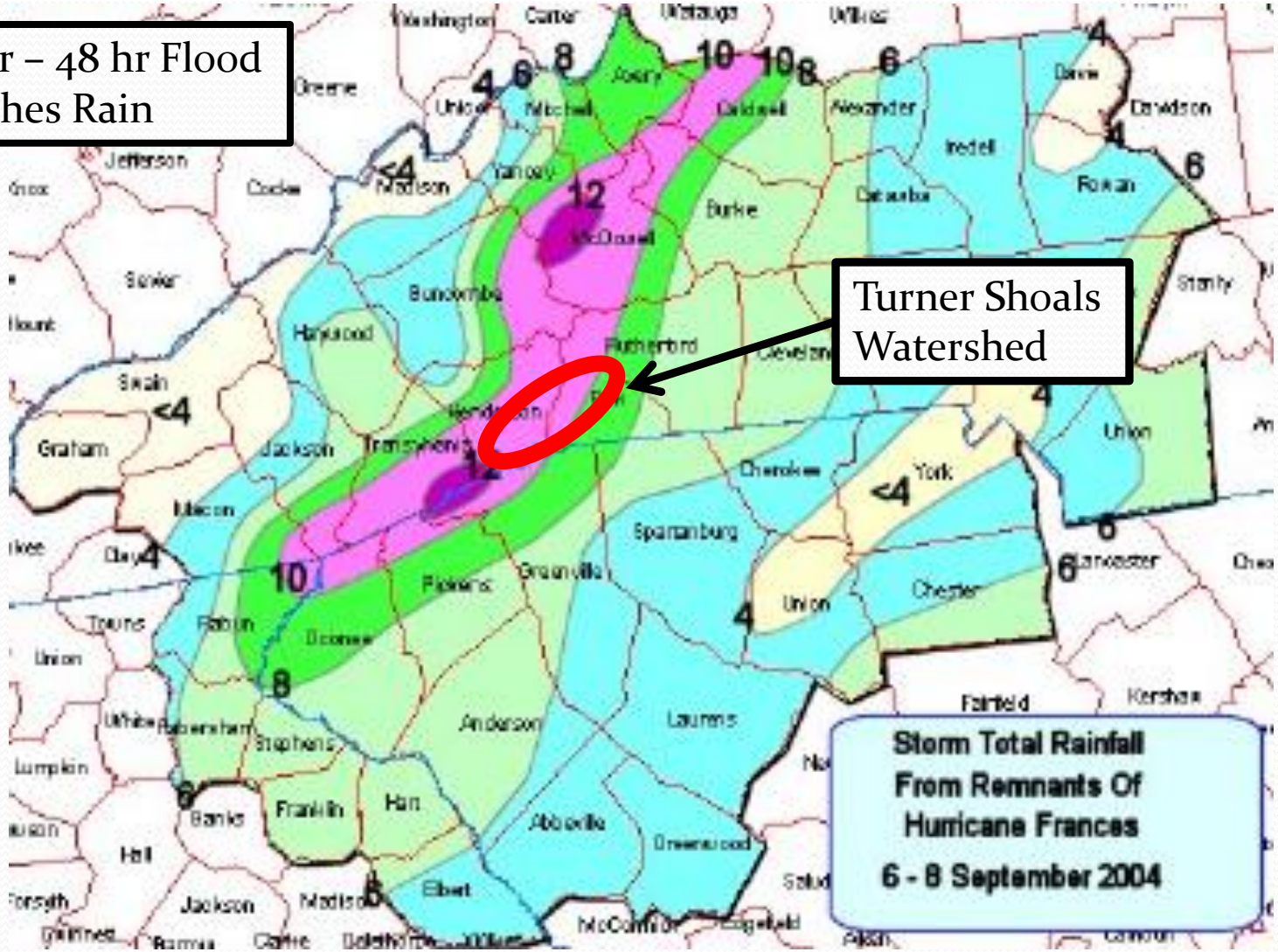


Green River Watershed Aerial Photograph

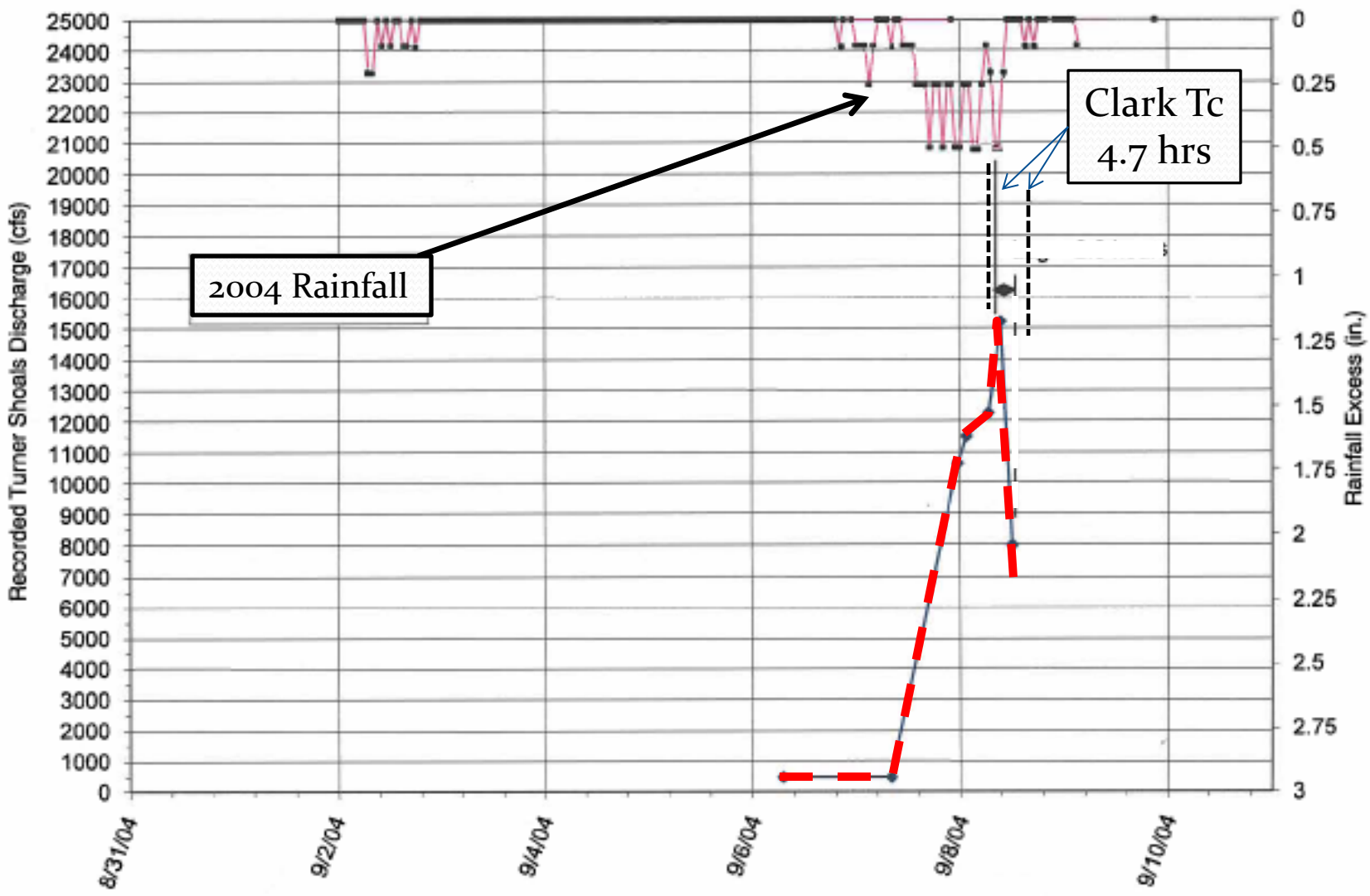


Hurricane Francis Storm Record

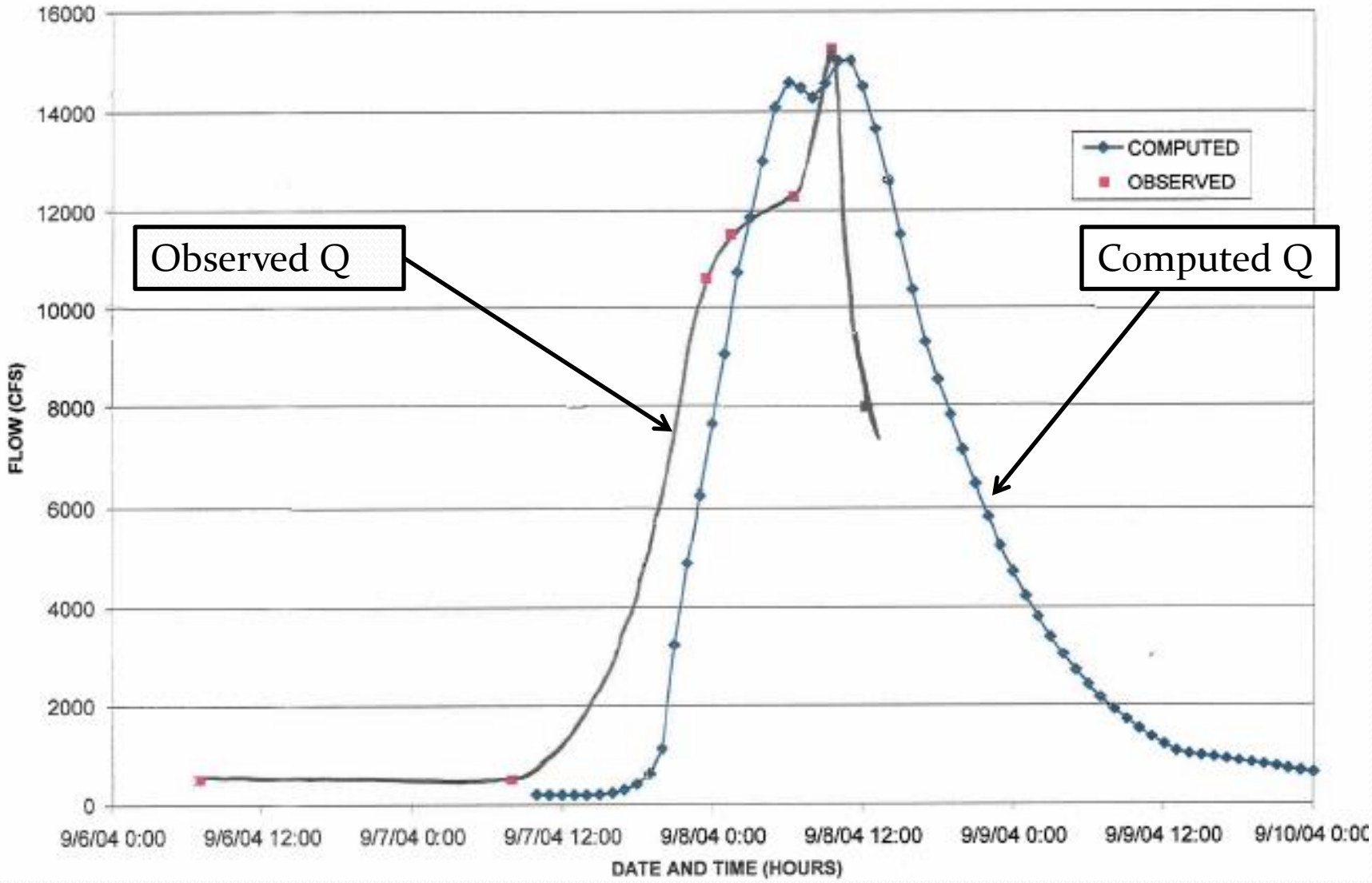
50 year – 48 hr Flood
9.1 inches Rain



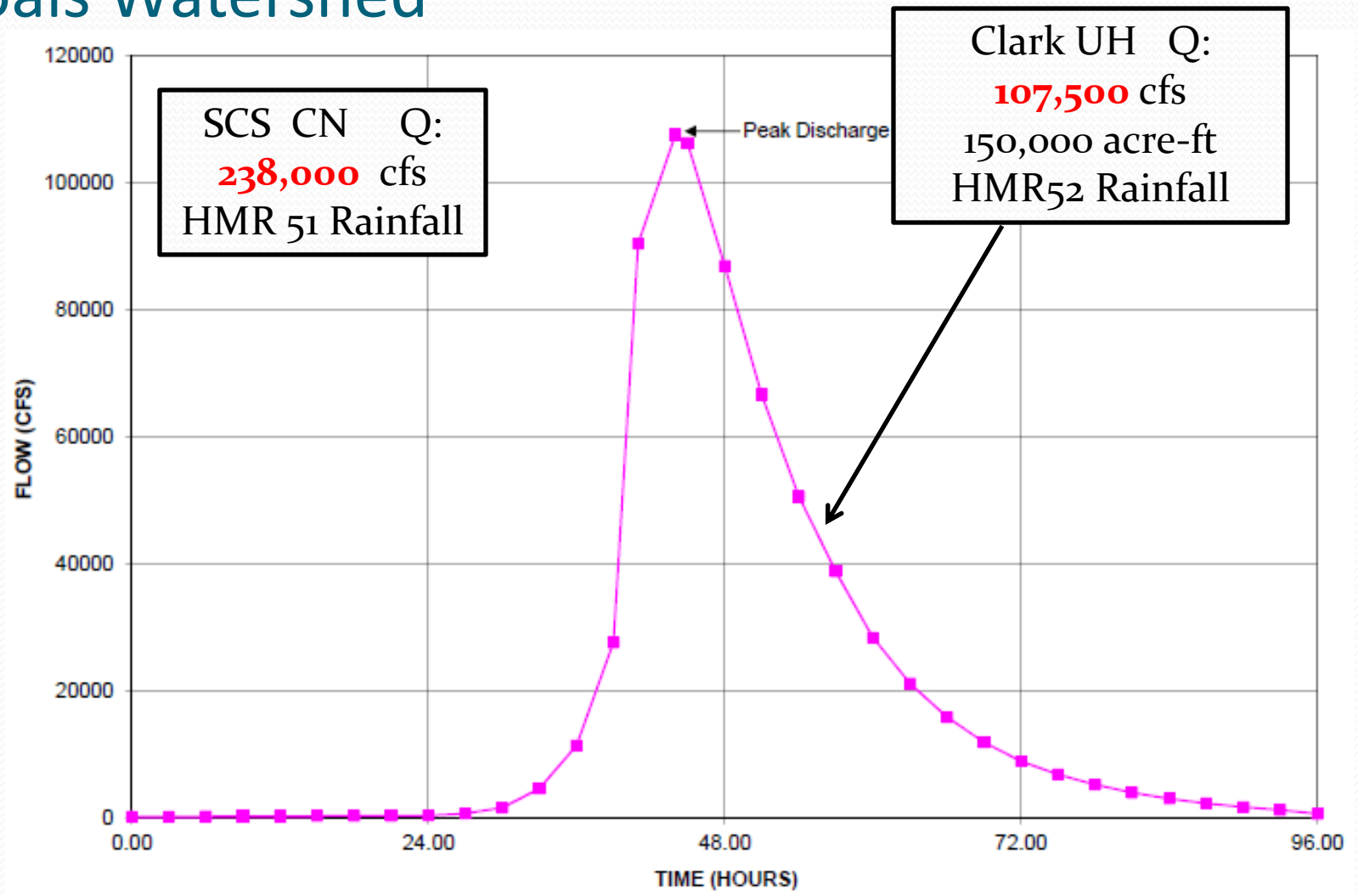
Sept, 2004 Storm – Clark Tc for Hurricane Francis



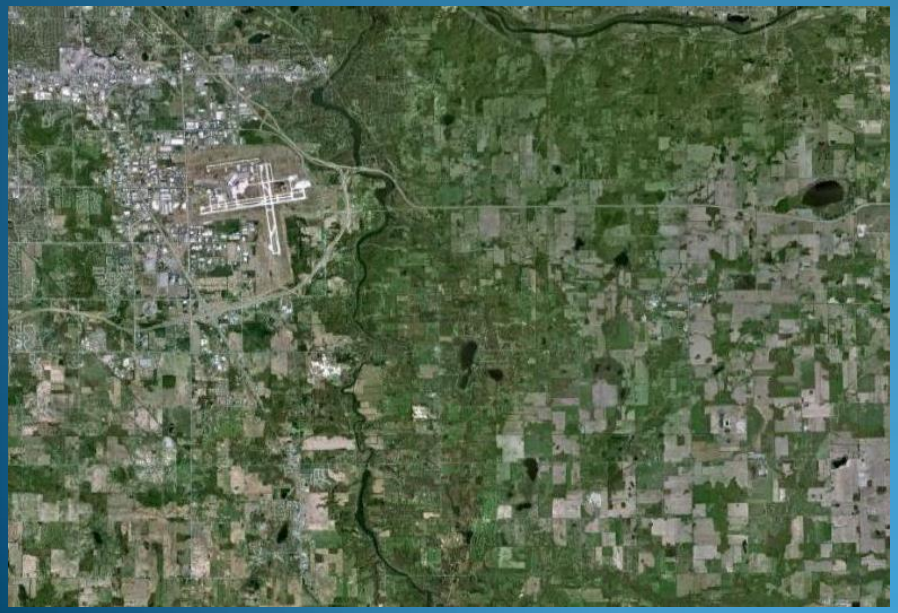
Sept 2004 Storm Calibration – Hurricane Francis



¾ PMF Projection Comparison – Turner Shoals Watershed



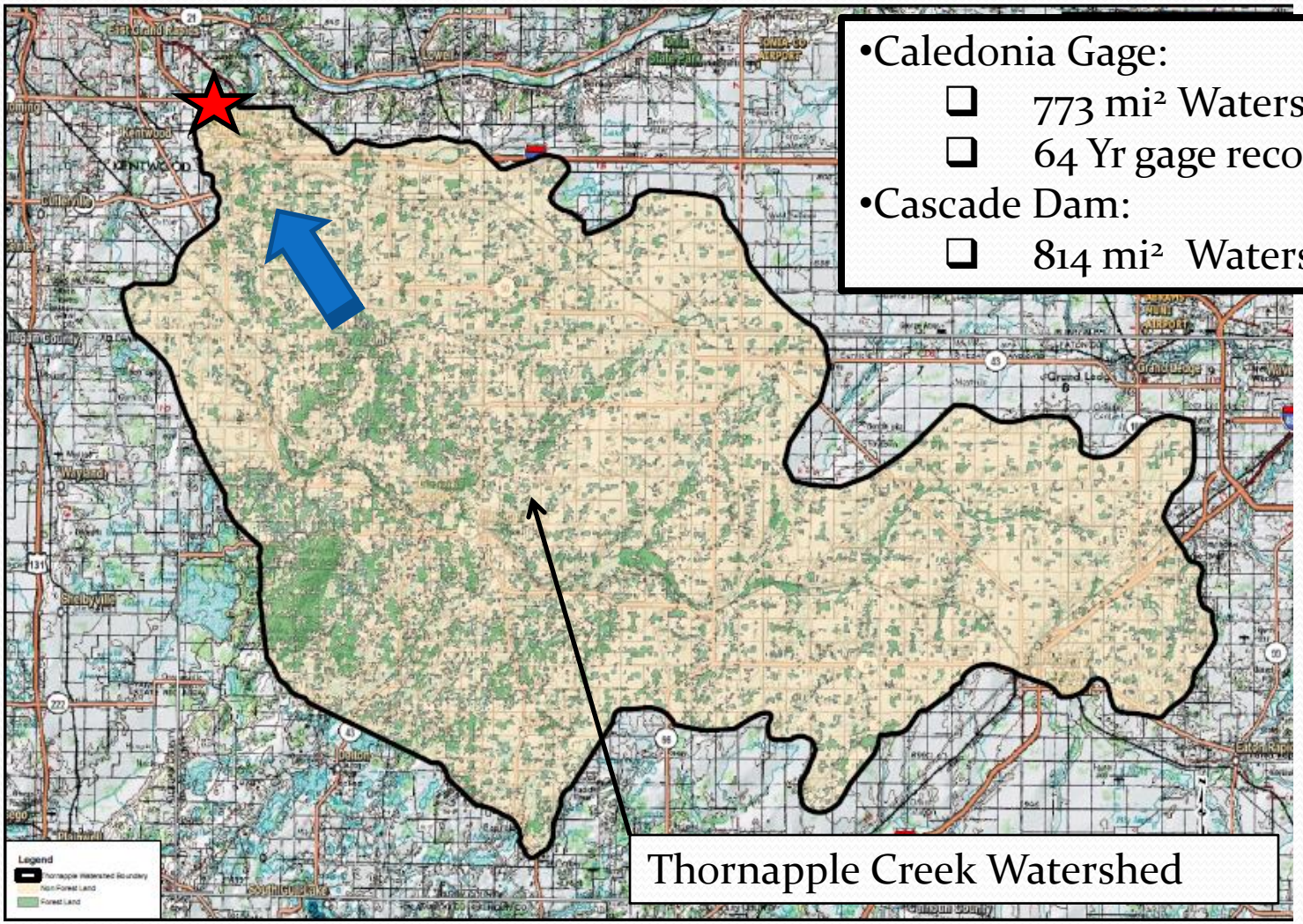
Thornapple River Watershed -- Cascade Dam Cascade, Michigan



Probable Maximum Flood Evaluation for Hydropower Dam Spillway Capacity Analysis

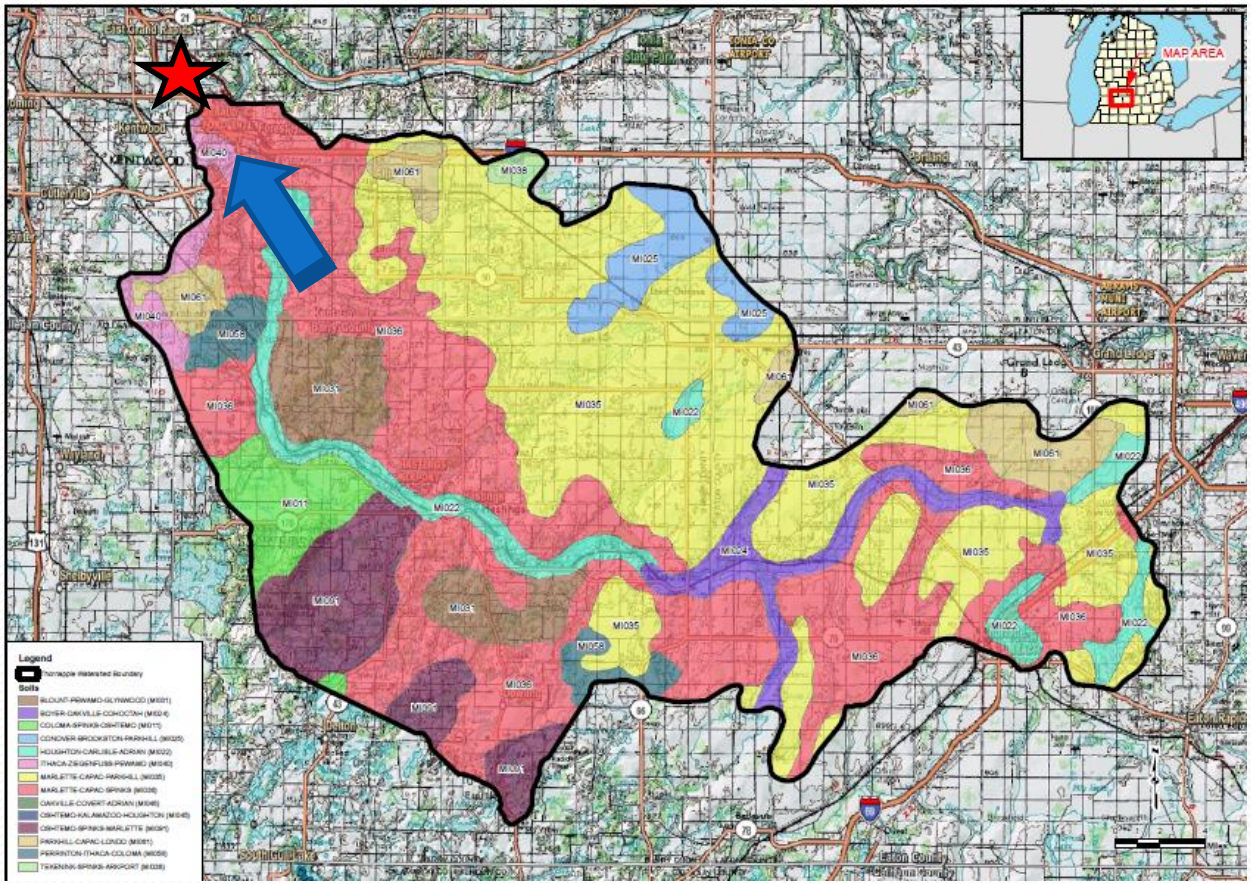
Thornapple Watershed Aerial Photograph

Watershed Forest Cover

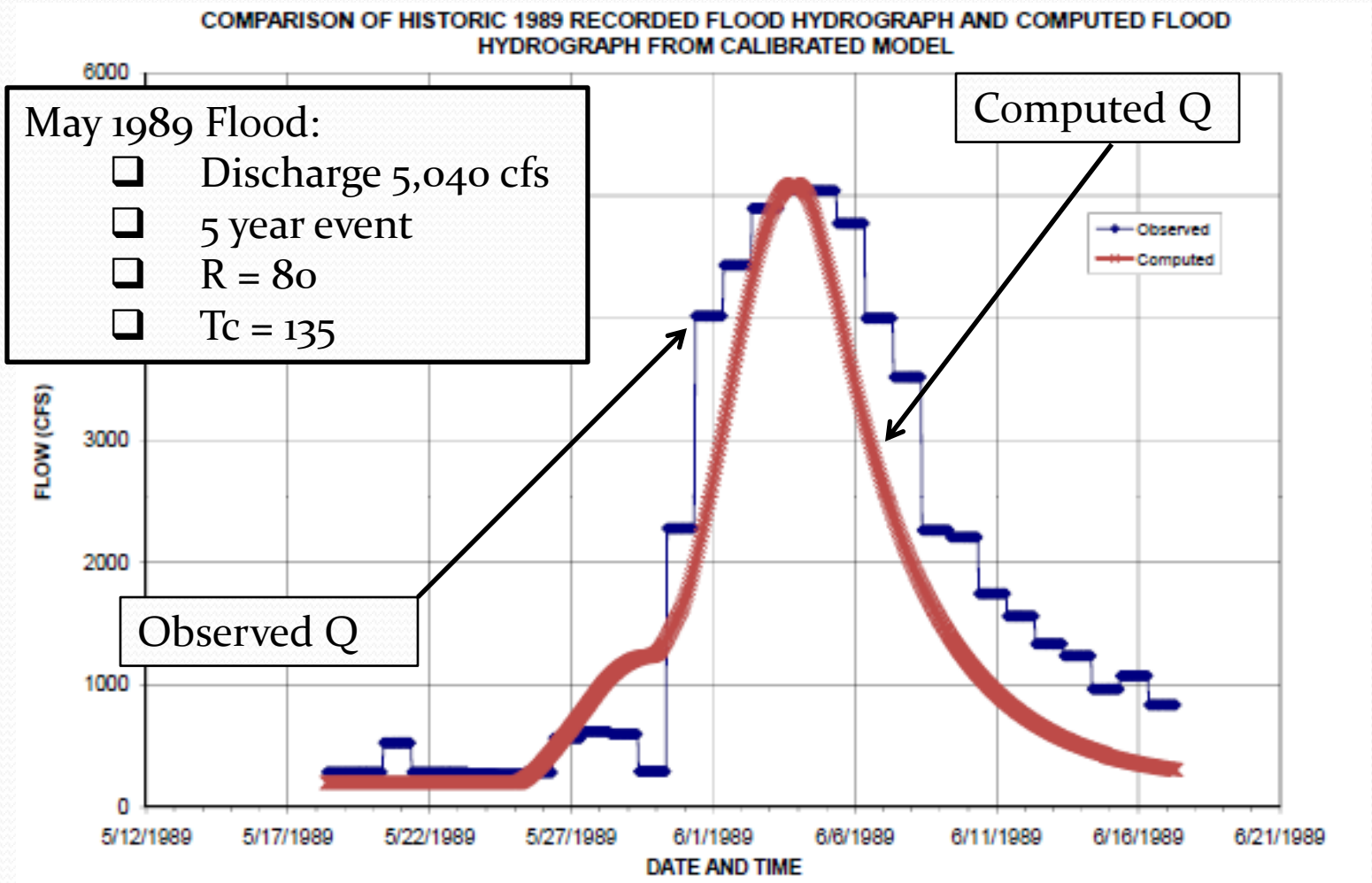


- Caledonia Gage:
  - 773 mi² Watershed
  - 64 Yr gage record
- Cascade Dam:
  - 814 mi² Watershed

Thornapple Watershed Soil Unit Map



May 1989 Storm Calibration – Thornapple Creek Watershed

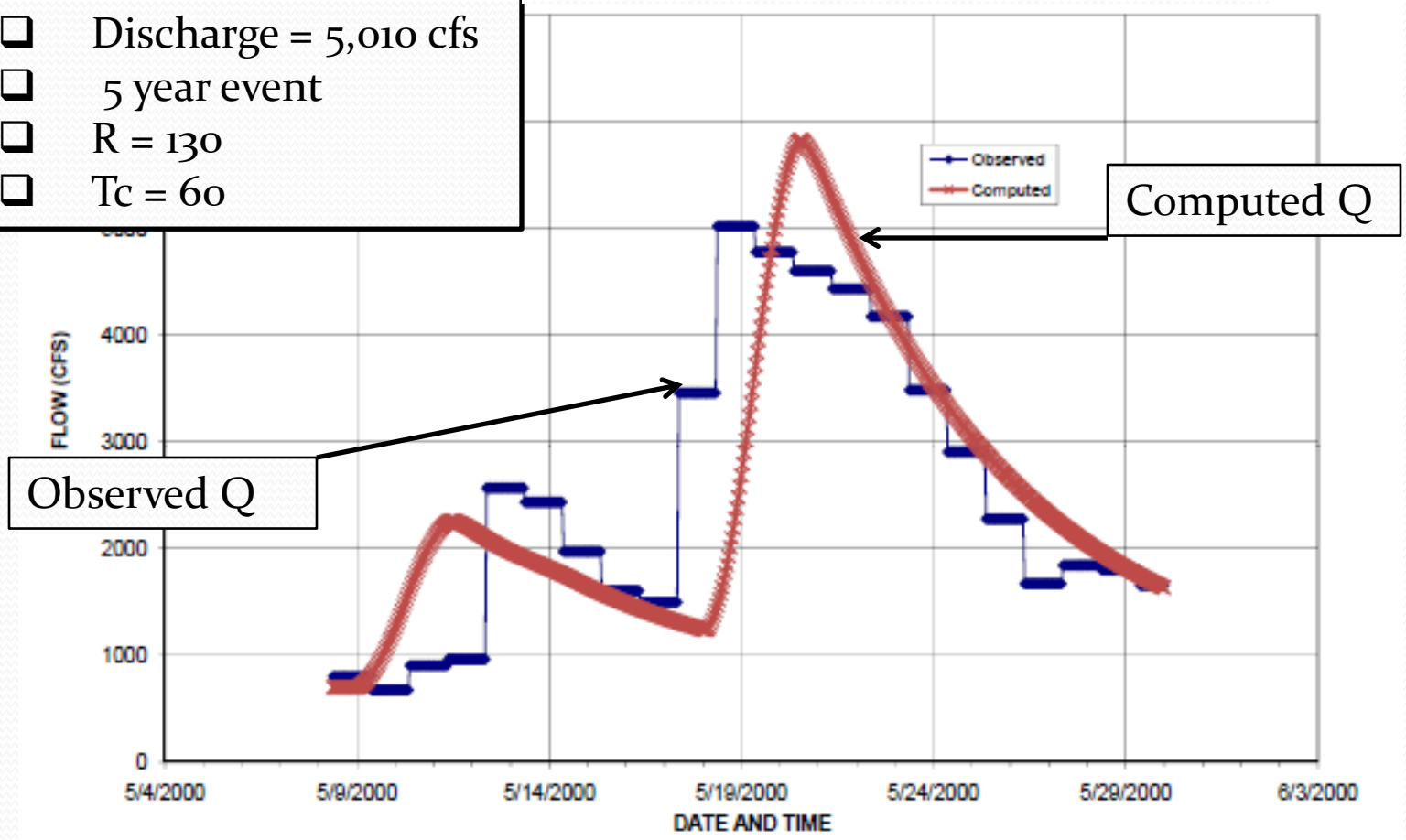


May 2000 Storm Calibration –

Thornapple Creek Watershed

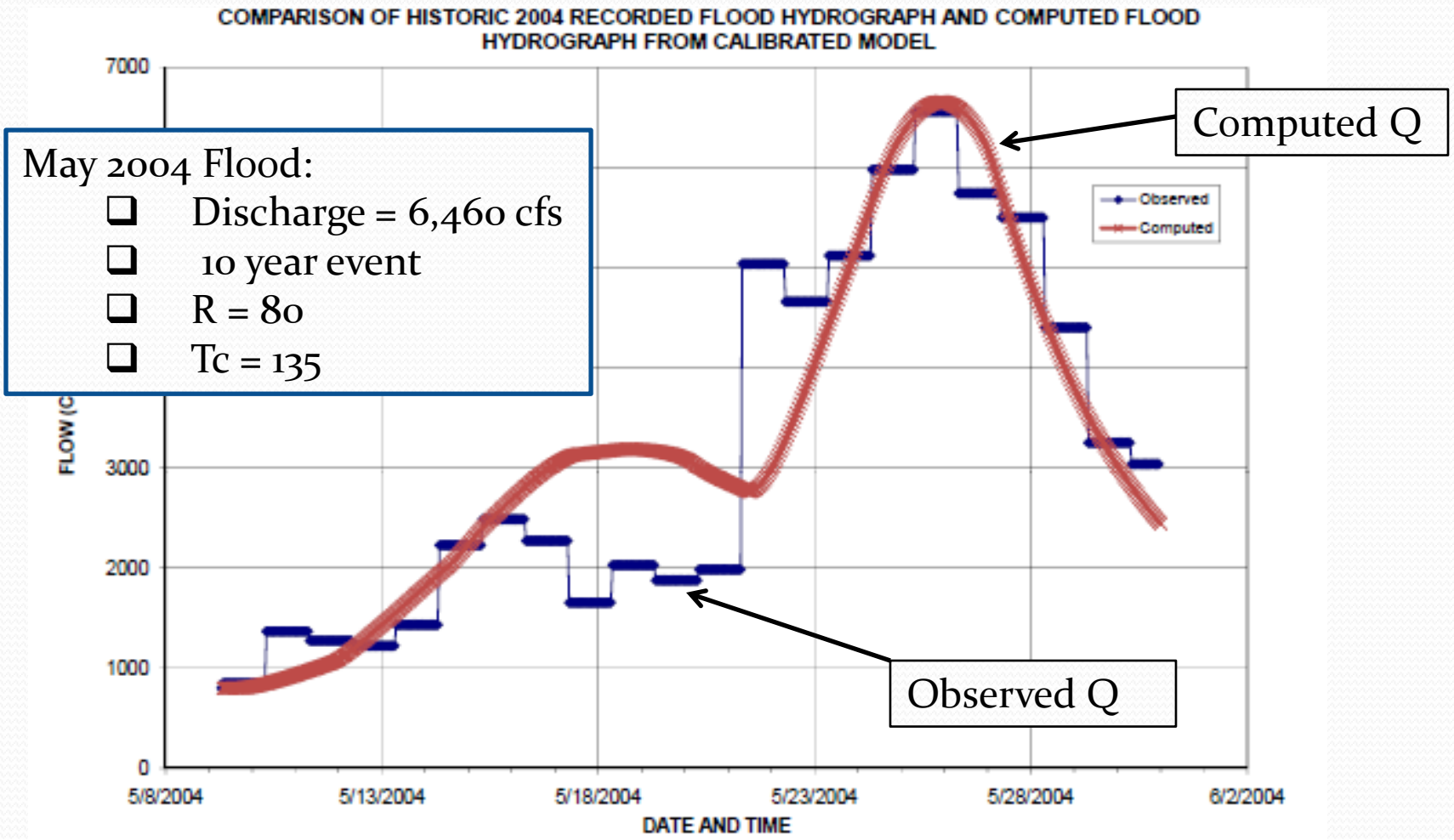
May 2000 Flood:

- Discharge = 5,010 cfs
- 5 year event
- R = 130
- Tc = 60

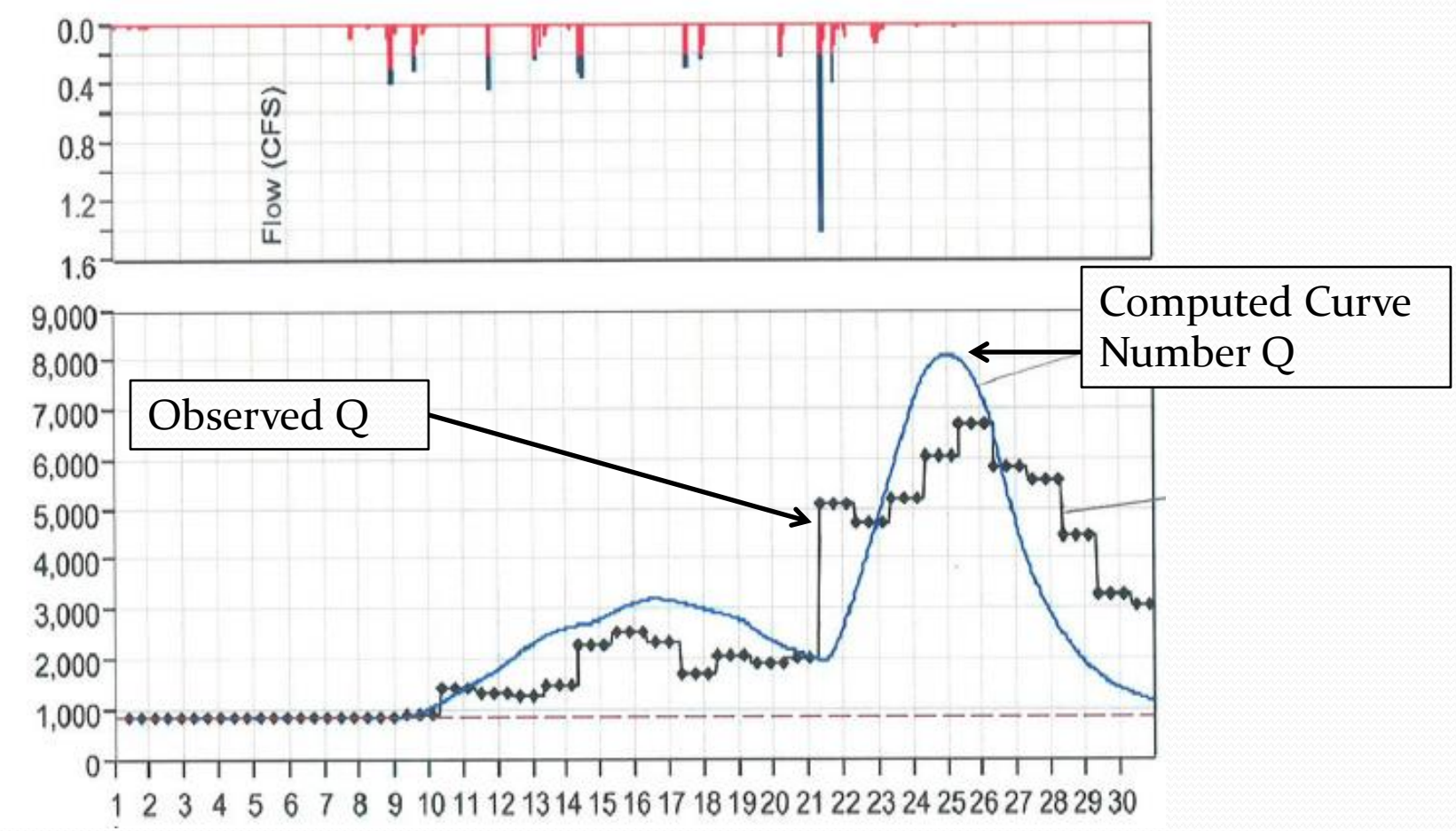


May, 2004 Storm Calibration –

Thornapple Creek Watershed

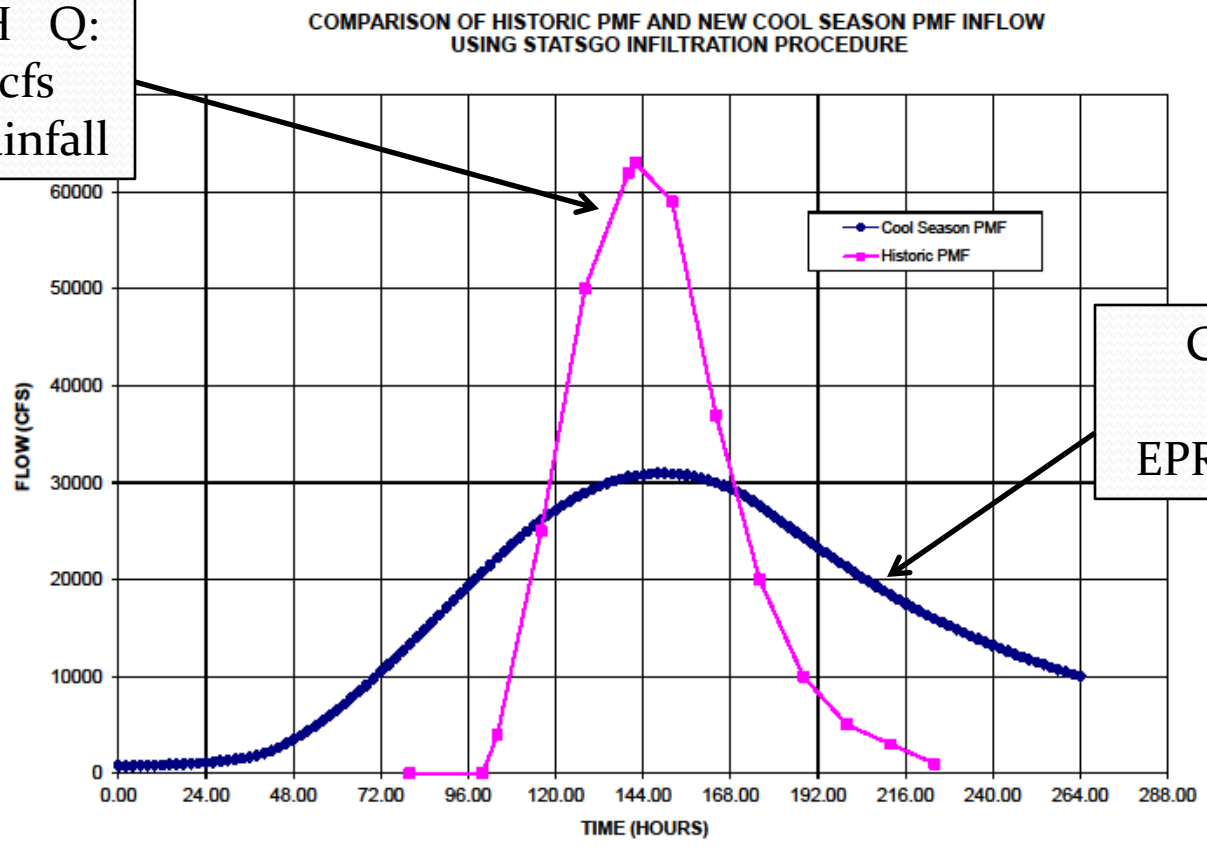


May, 2004 Storm Calibration Snyder UH Results – Thornapple Creek



PMF Projection Comparison – Thornapple Creek

Snyder UH Q:
63,000 cfs
HMR 51 Rainfall



Clark UH Q:
30,350 cfs
EPRI PMP Rainfall

SCS Curve Number Hydrology

Considerations for Design Flood Determination