Verification of a Rainfall-Runoff Model

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Why should a model be verified?

- Check that the result is realistic
- FEMA requirement

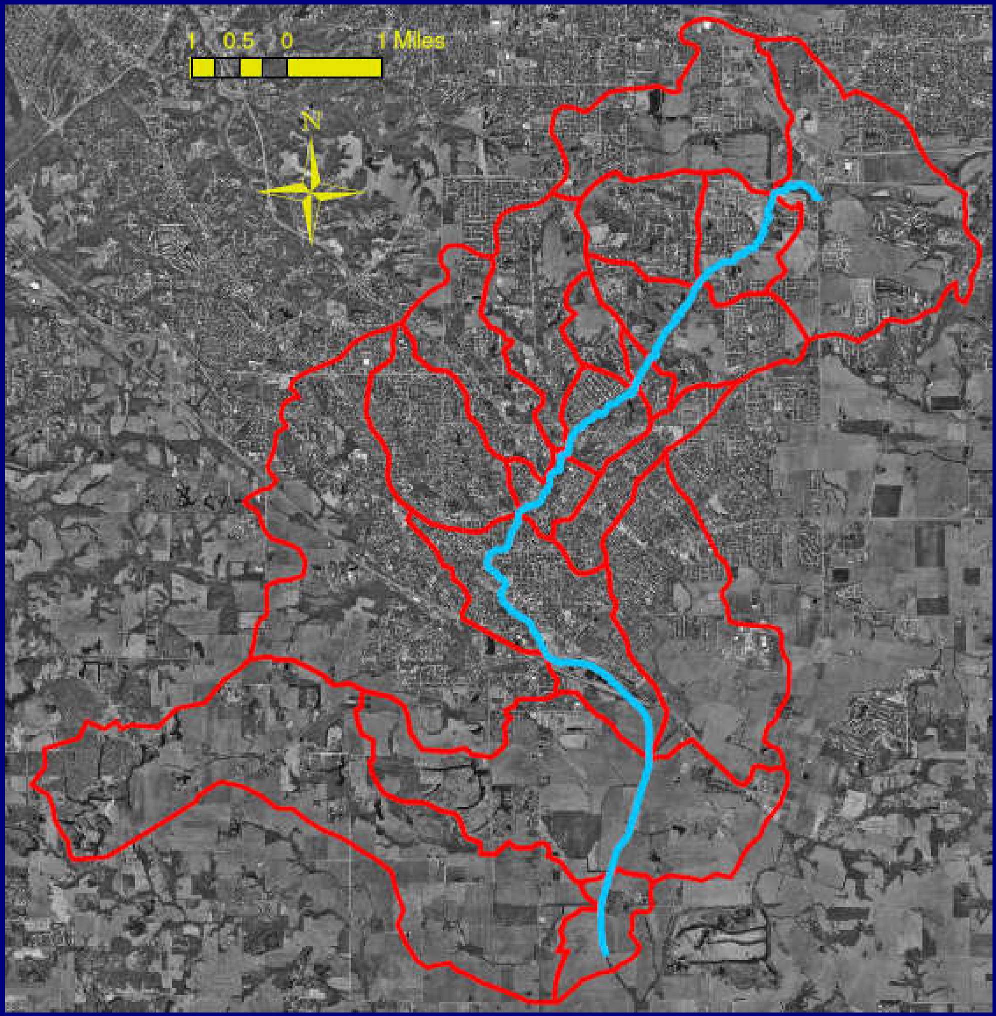
What data is available?

- Gage data (best option)
- Peak stage (more common)
- Regression results (always available, usually applicable)

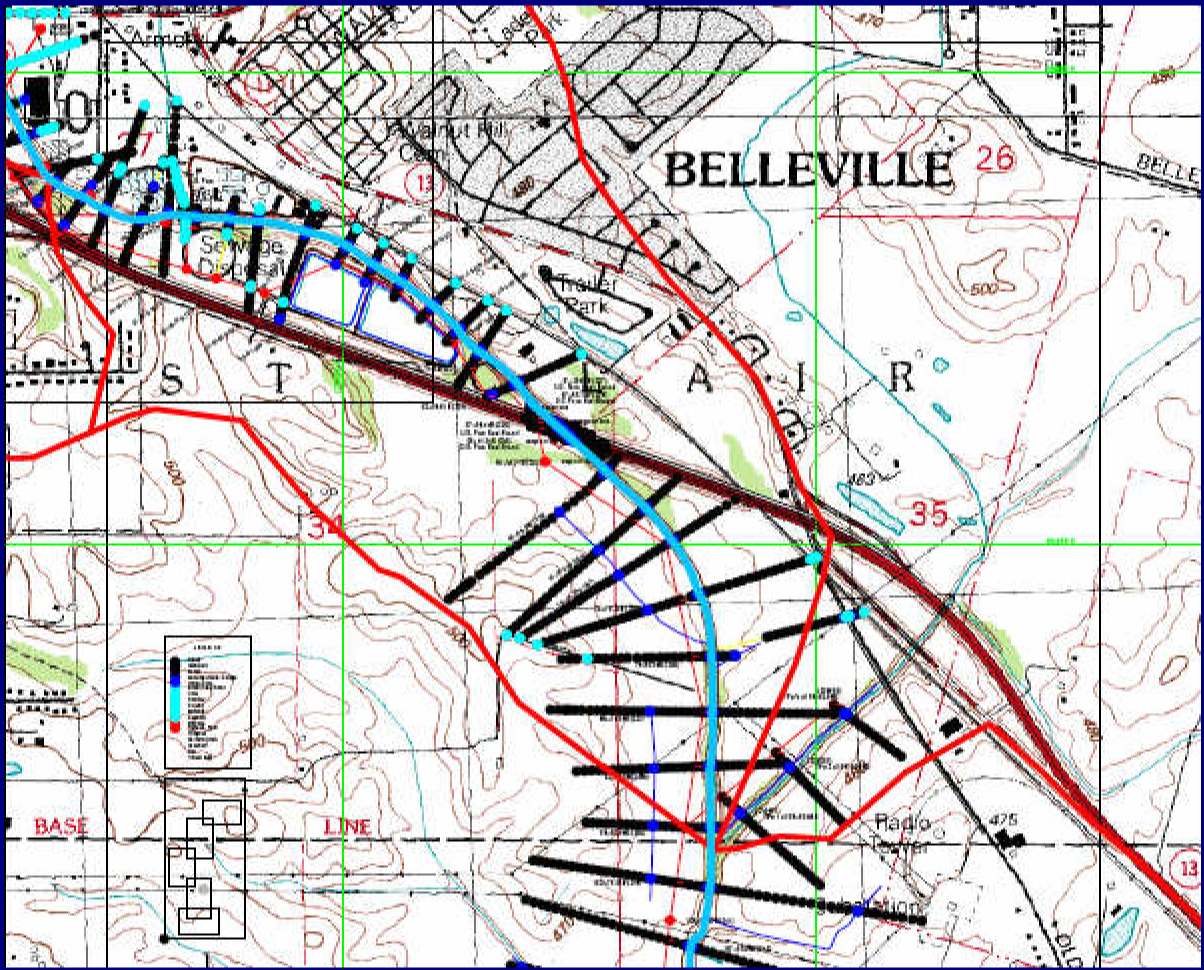
Approach

1. Survey high water mark and cross section
2. Create rating curves to translate stage to flow
3. Obtain rainfall data and create storm input
4. Compare model results to actual flows

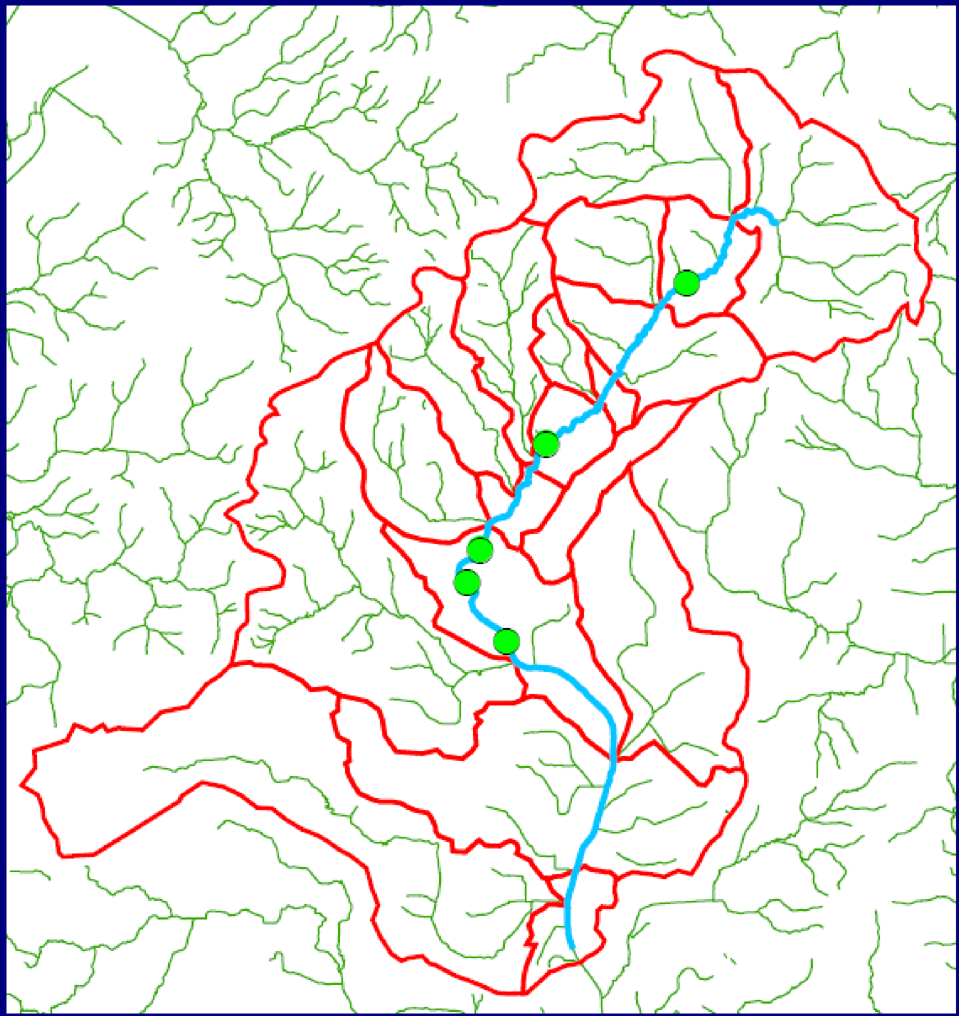
Richland Creek Watershed



Surveyed Bridges and Cross Sections



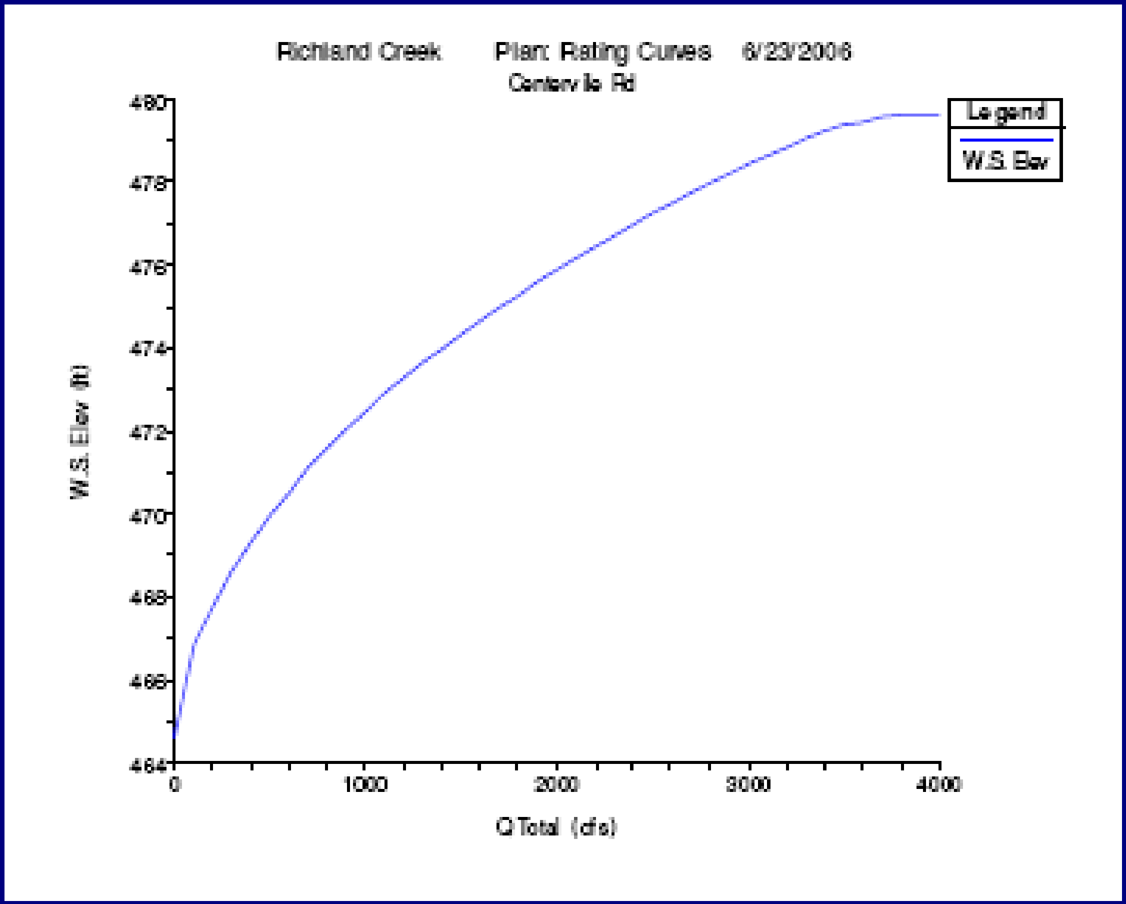
Crest Stage Gage Locations



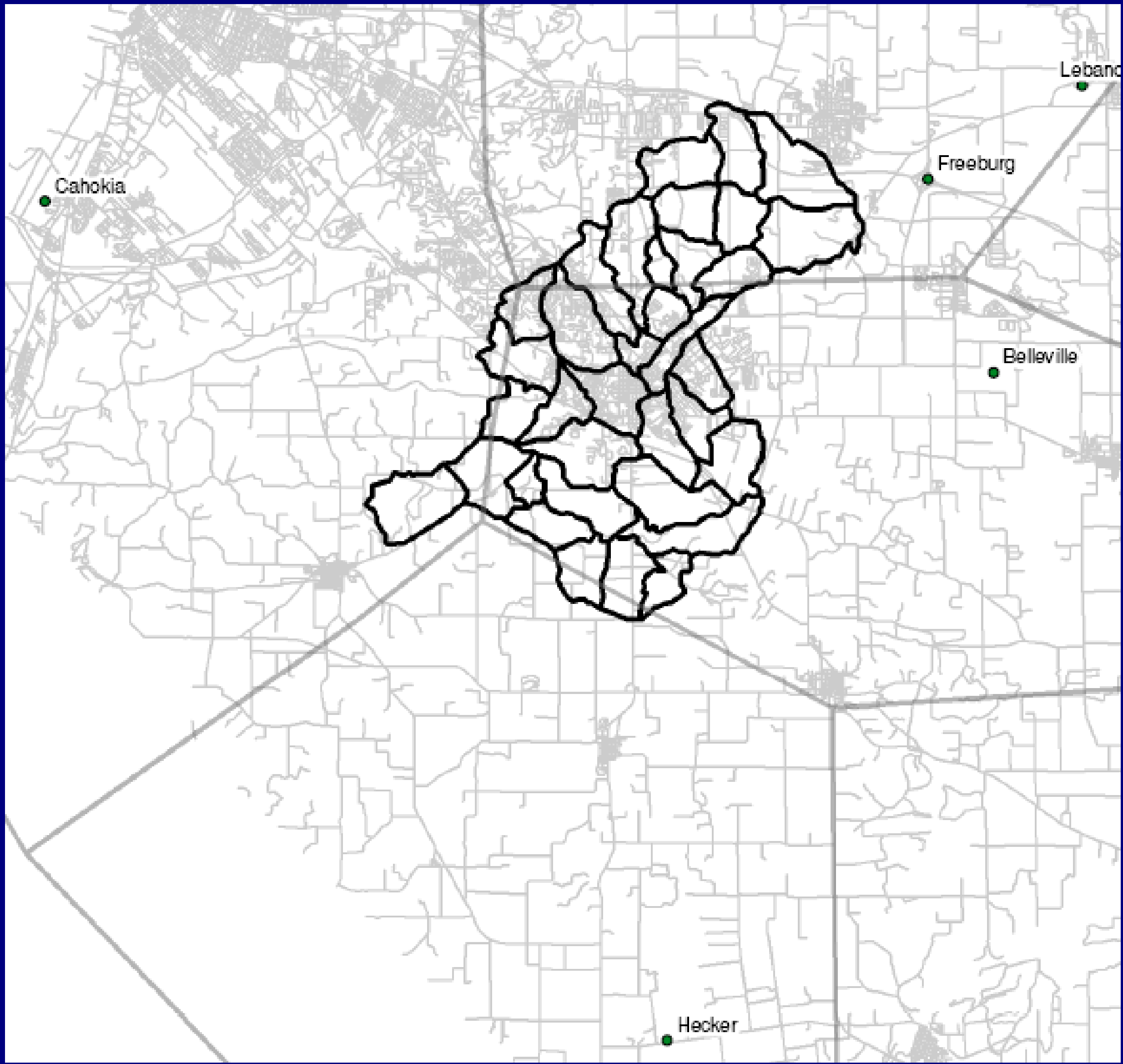
Crest Stage Gage Data

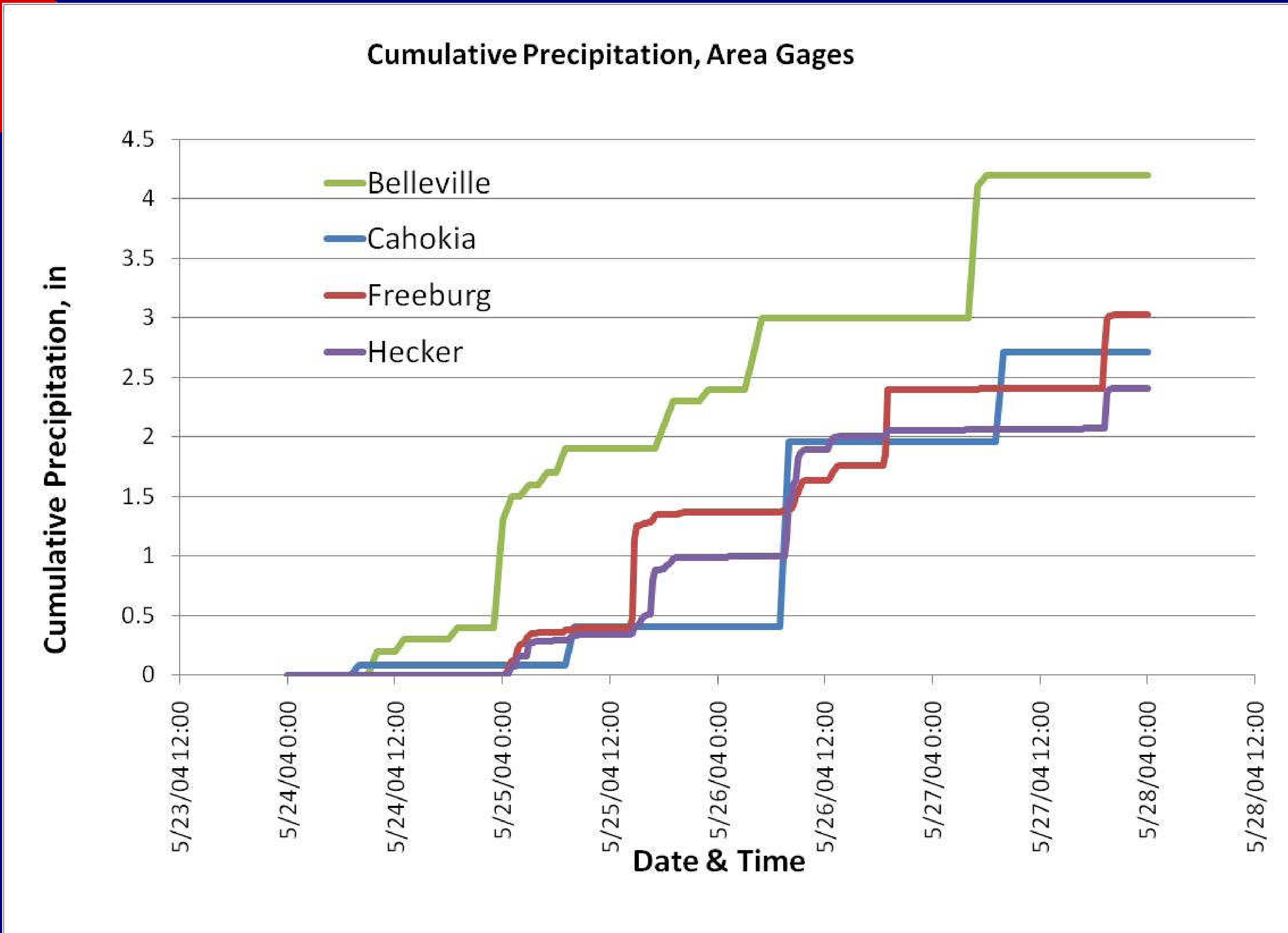
Location	May 2004 event peak stage, ft	May 2006 event peak stage, ft
DS side of Hartman Lane	No reading (below 513.59)	No reading (below 513.59)
DS wingwall of IL 161	492.74	No reading (below 492.72)
DS wingwall of C Street	480.65	479.81
DS wingwall of Centreville Road	474.90	473.41
DS wingwall of IL 159	No reading (below 465.20)	No reading (below 465.20)

Crest Stage Data to Flows

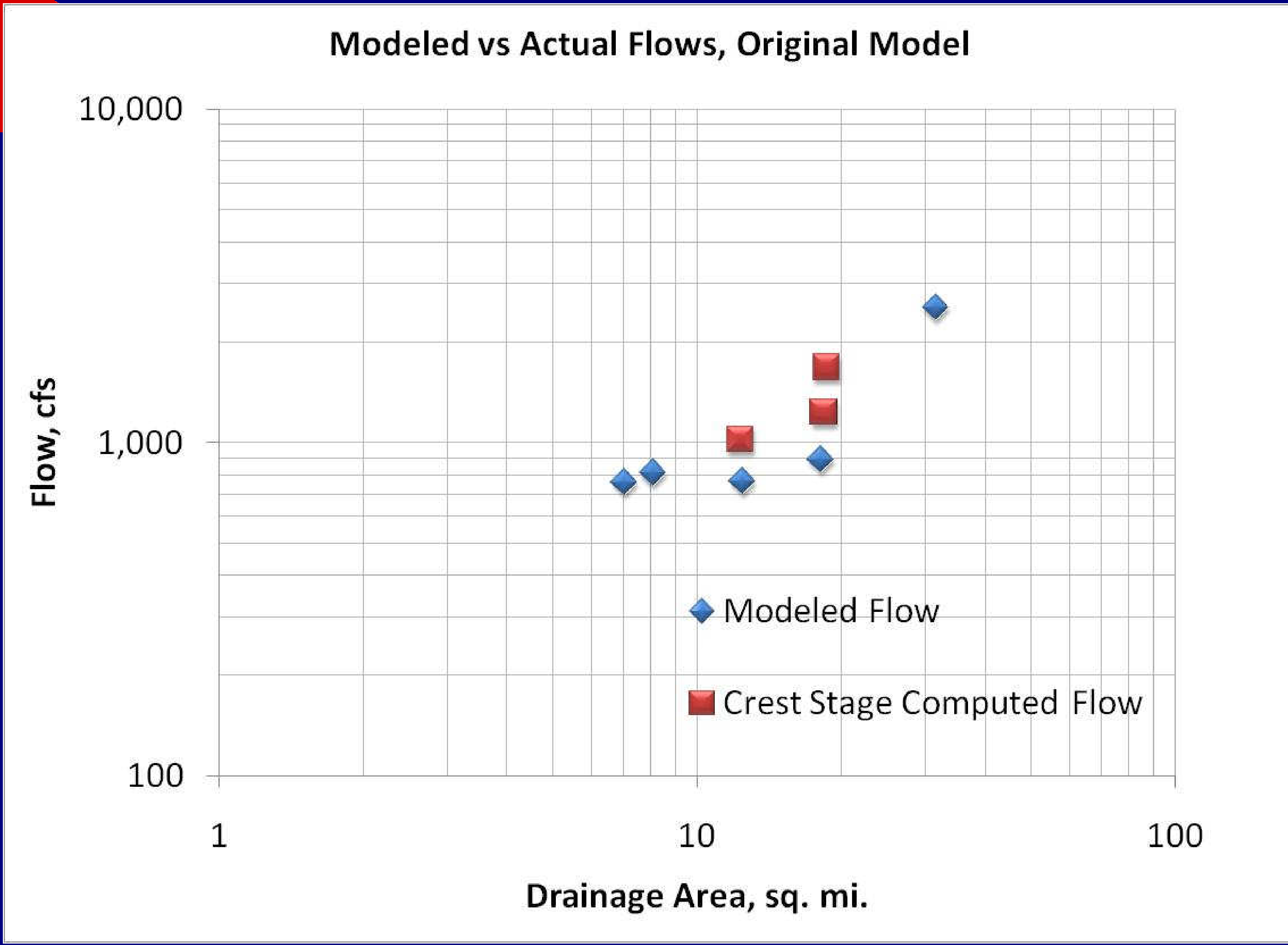


NWS/USGS Gage Data

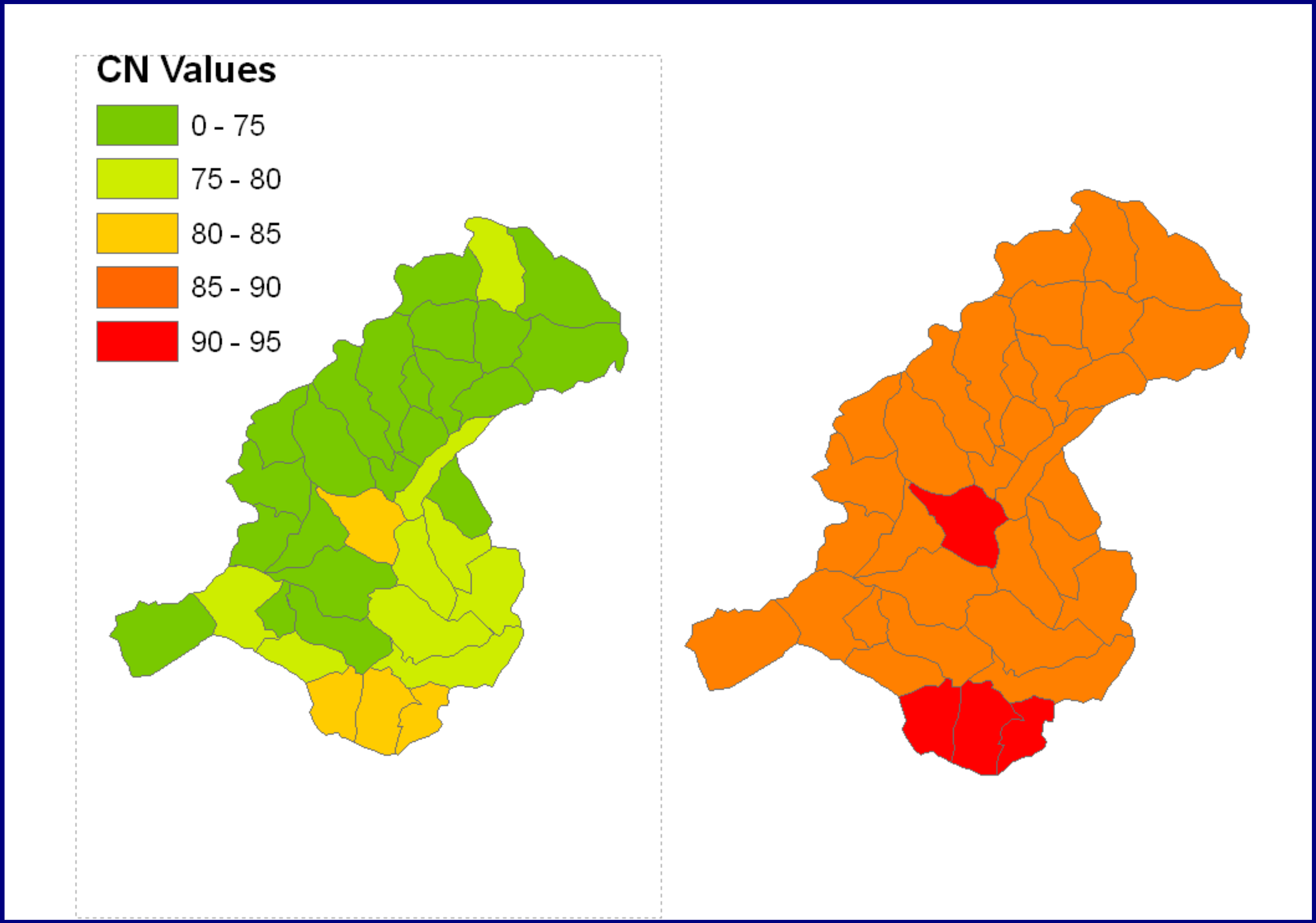


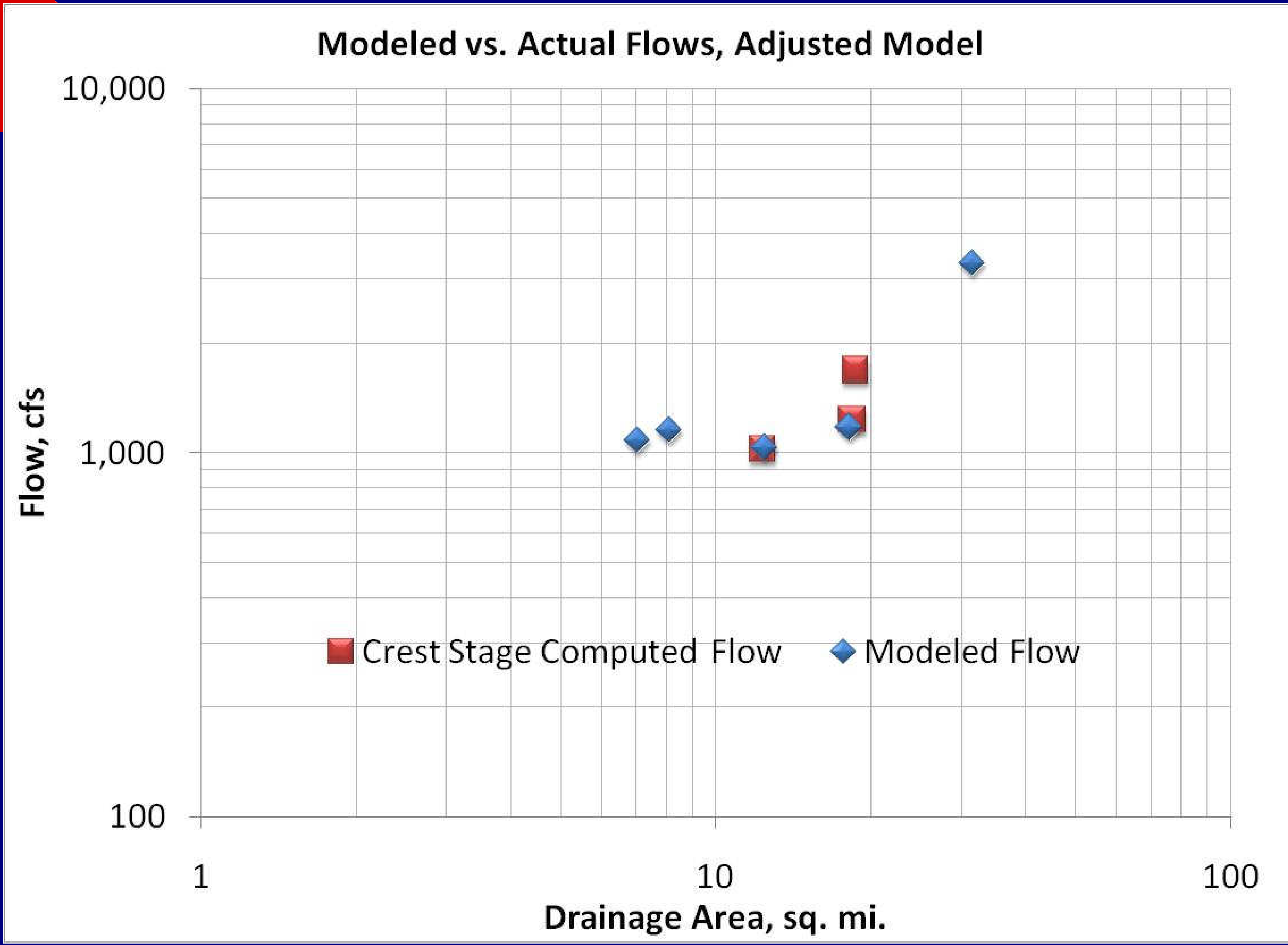


Cumulative Precipitation, Area Gages
Cumulative Precipitation, in
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Belleville
Cahokia
Freeburg
Hecker
5/23/04 12:00
5/24/04 0:00
5/24/04 12:00
5/25/04 0:00
5/25/04 12:00
5/26/04 0:00
5/26/04 12:00
5/27/04 0:00
5/27/04 12:00
5/28/04 0:00
5/28/04 12:00
Date & Time

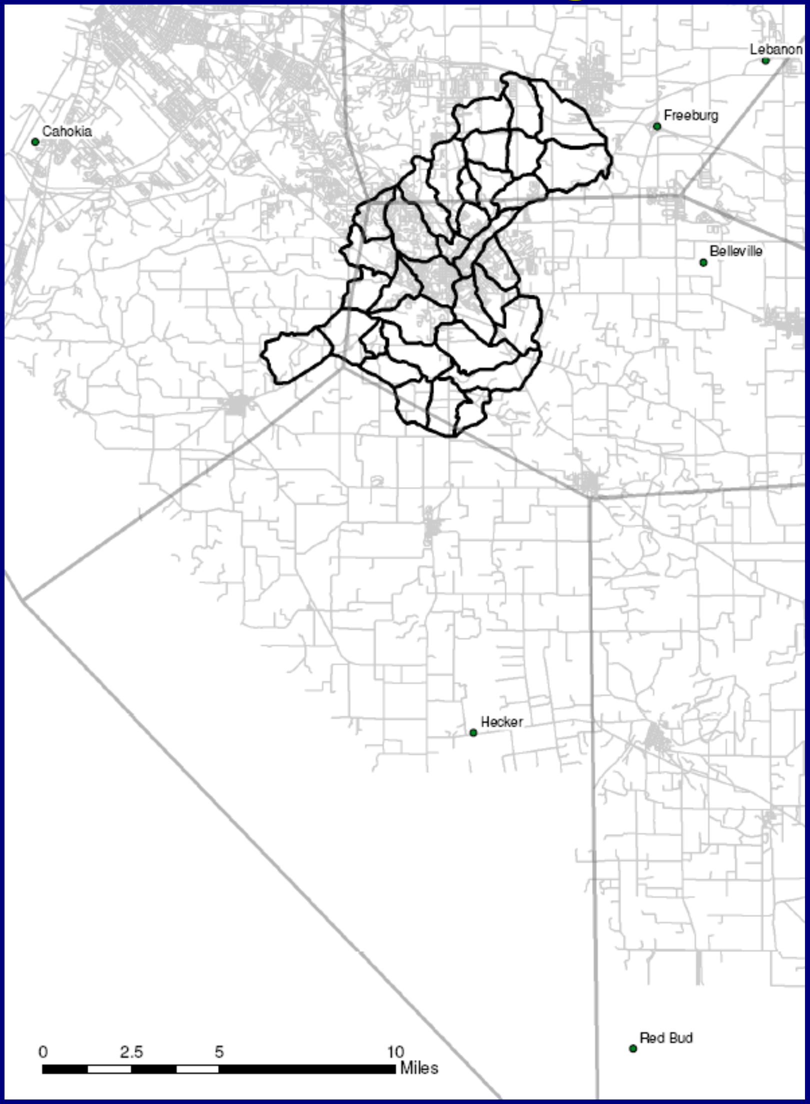

Modeled vs Actual Flows, Original Model
10,000
1,000
100
Flow, cfs
1
10
100
Drainage Area, sq. mi.
Modeled Flow
Crest Stage Computed Flow

CN Adjustment

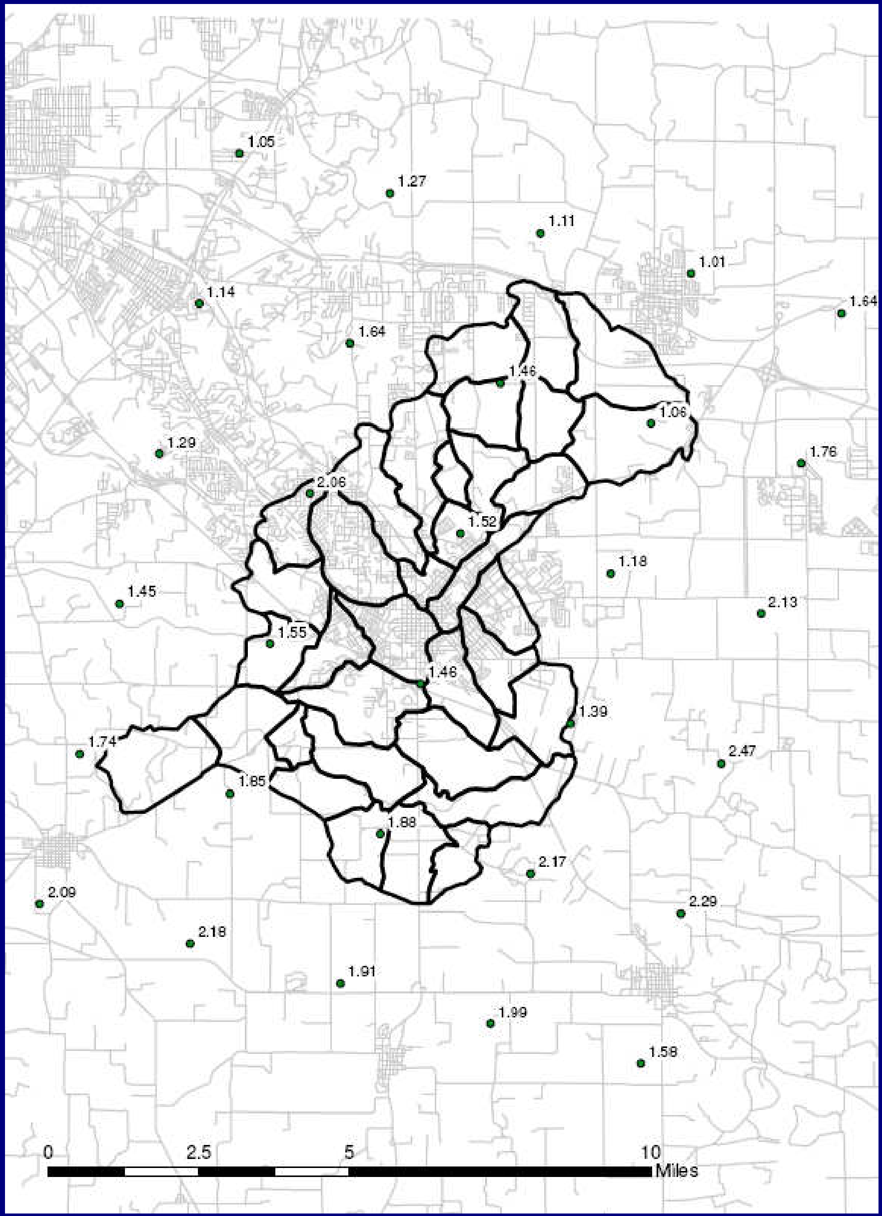


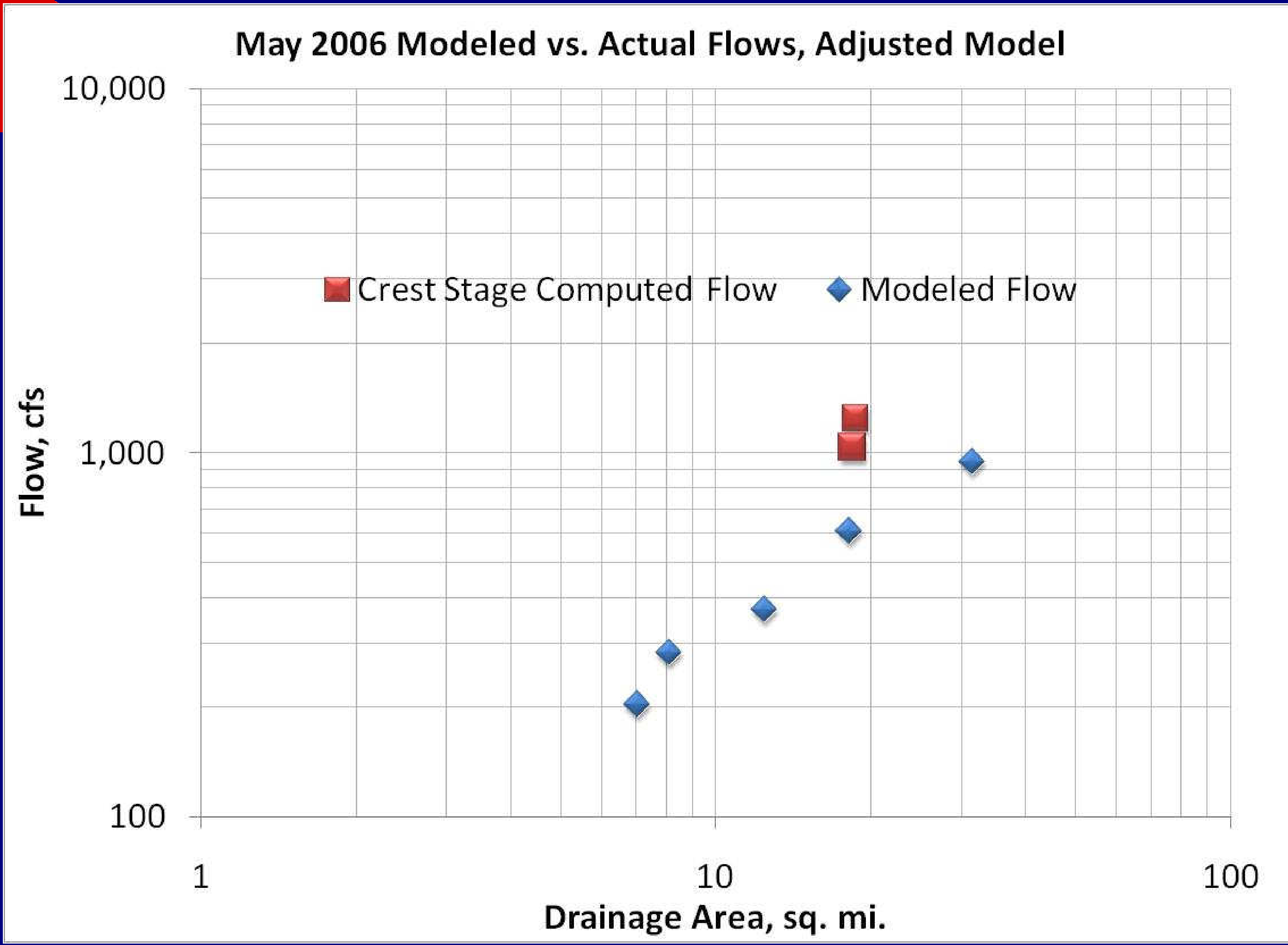

Modeled vs. Actual Flows, Adjusted Model
10,000
1,000
100
Flow, cfs
1
10
100
Drainage Area, sq. mi.
Crest Stage Computed Flow
Modeled Flow

Area Gages

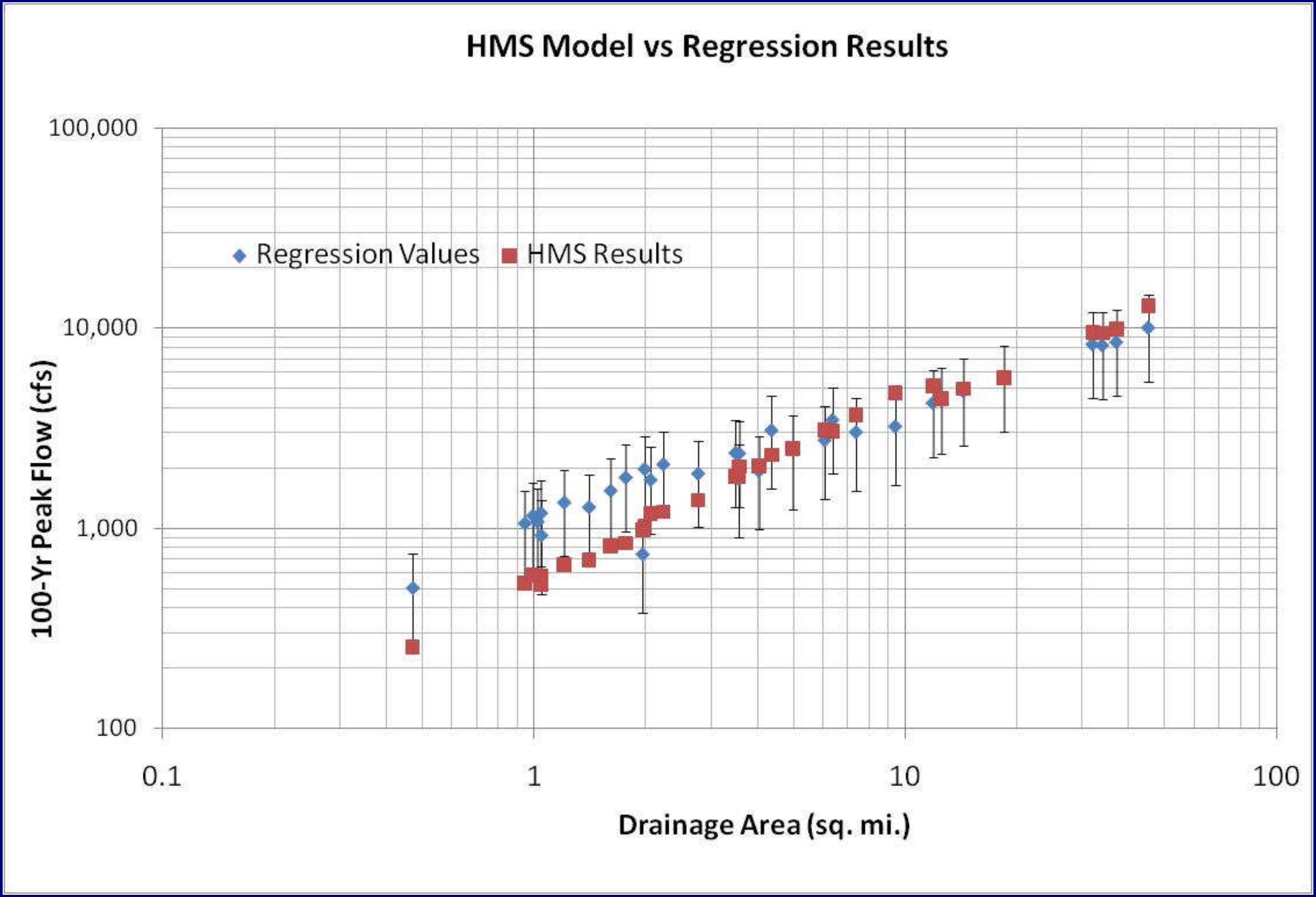

Lebanon
Freeburg
Cahokia
Belleville
Hecker
Red Bud
0
2.5
5
10
Miles

NEXRAD Data


1.05
1.27
1.11
1.01
1.64
1.14
1.64
1.46
1.06
1.29
1.76
2.06
1.52
1.18
1.45
2.13
1.55
1.46
1.39
1.74
2.47
1.85
1.88
2.17
2.09
2.29
2.18
1.91
1.99
1.58
0
2.5
5
10
Miles


May 2006 Modeled vs. Actual Flows, Adjusted Model
10,000
1,000
100
Flow, cfs
Crest Stage Computed Flow
Modeled Flow
1
10
100
Drainage Area, sq. mi.

Compare to Regression



Summary

- Adjusted model is a good fit to the crest stage gage data for the May 2004 storm;
- Adjusted model is not as good a fit for the May 2006 storm, and
- Original model compares well with the regression equation values.

Conclusions

- Adjusted model is perhaps valid for smaller storms
- Original, unadjusted model should be used for floodplain mapping

Modeling watersheds affected by Groundwater
Case study- East Branch Croton River Watershed, Putnam Co, NY

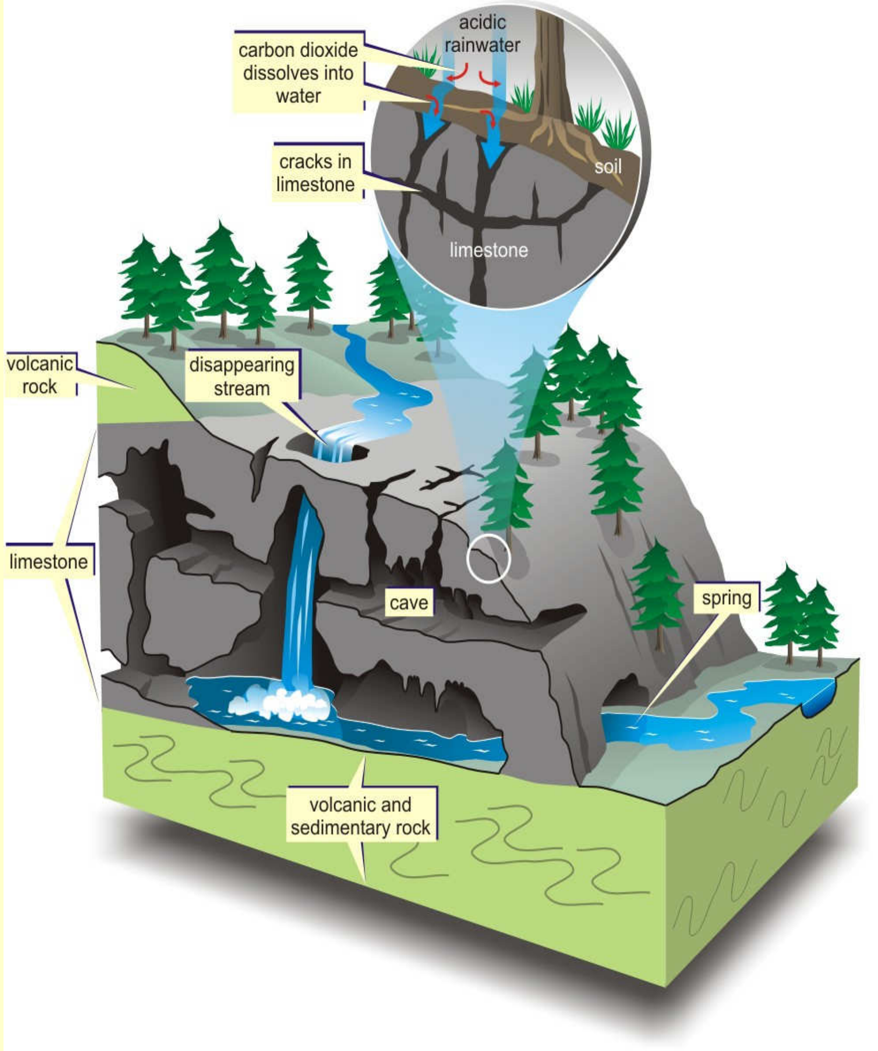
Prabha Madduri, P.E.,CFM
Tamrat Bedane, CFM

Outline

- Introduction- Karst Topography
- Runoff models
- Modeling Process in HECHMS
- Case study- EBCR watershed
- Modeling Challenges
- Results
- Conclusions

Karst Topography

- Landscape formed by the underground erosion of rocks such as limestone and marble that dissolve in water
- Subterranean drainage may cause very little surface water, also absence of all rivers and lakes
- Complex underground drainage systems like karst aquifers, extensive caves, cavern systems might form.
- In US Karst exists in 25-40% of the eastern US
- Subsurface Karst flow is not slow, especially during floods



Rainfall-runoff models

- Rainfall Runoff model- Physical model describing the rainfall- runoff relation of a rainfall catchment area or watershed
- Mainly used for ungaged streams and urban watersheds
- The way the model behaves depends to a large extent upon the input data, rainfall.
- It is necessary to check the accuracy of results obtained.
- Usually done by calibrating the model against known storm events.

Case Study: East Branch Croton River Watershed, NY

Putnam Co. NY- Part of Croton River Watershed System

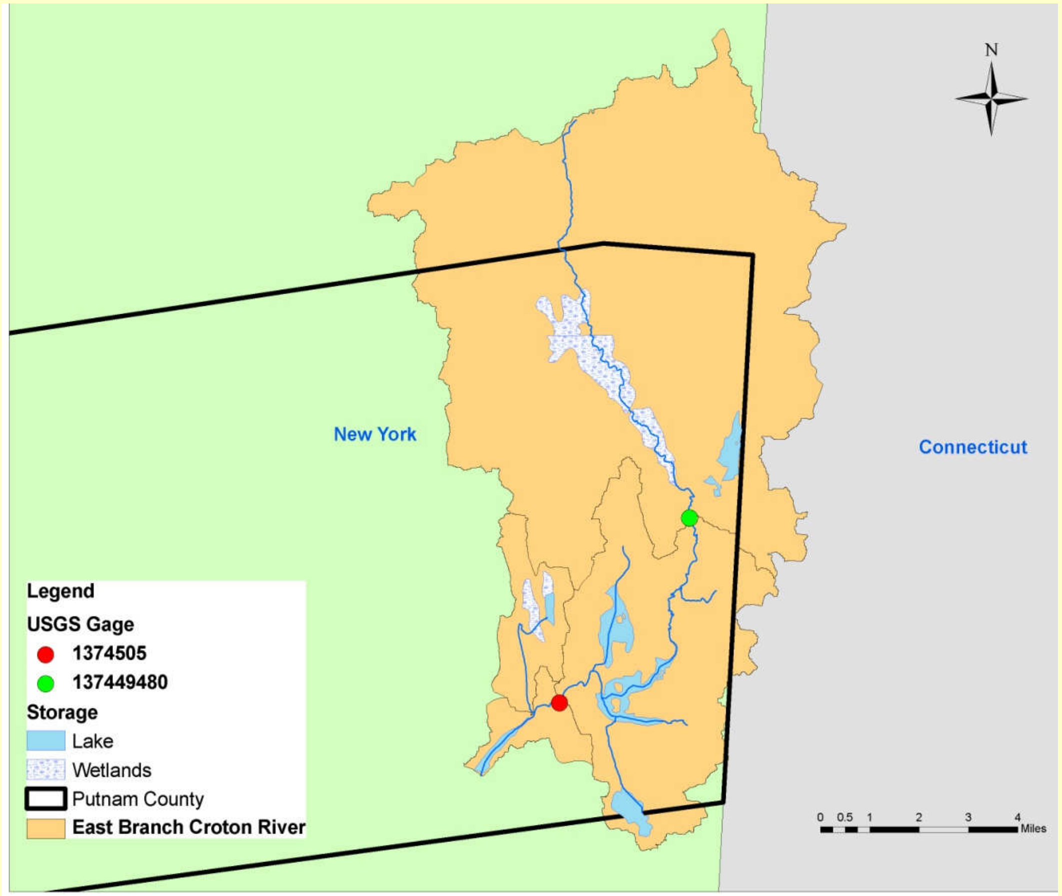
Part of New York City drinking water supply system

Approximately of 88 sq.mi Drainage area

Characterized by the presence of Carbonate layer and great swamp

There are several reservoirs situated in the watershed

Two USGS Gages (for calibration)



The Great Swamp in EBCR

•Flows in two directions

1- North flows into Swamp River

2- South becomes East Branch Croton River watershed

•Joins East Branch Croton Reservoir at the downstream

Modeling Approach:- Rainfall - Runoff

HEC-HMS Model

• Sub-basins = 45
• CN = 65 to 84

Methodology

•CN:- Based on Soil map and Landuse (SSURGO and NLCD)

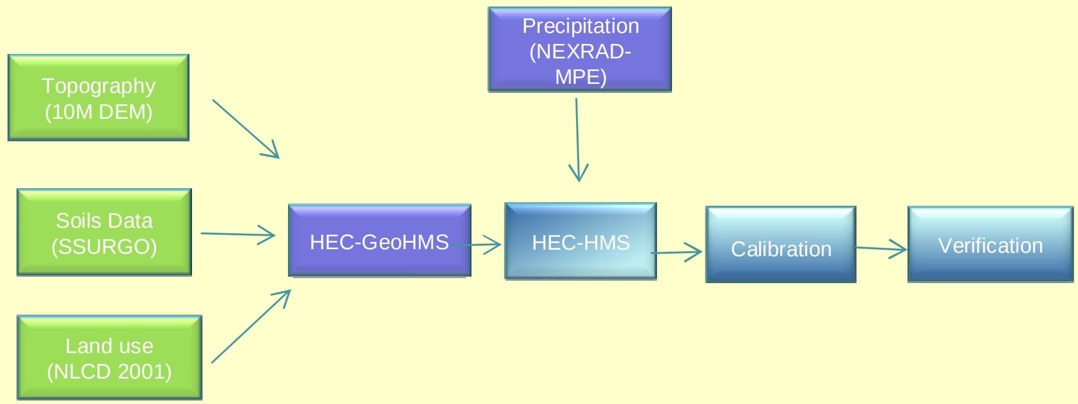
•Lag time:- TR55 method

•Reservoir Routing:- (Twin Reservoir)

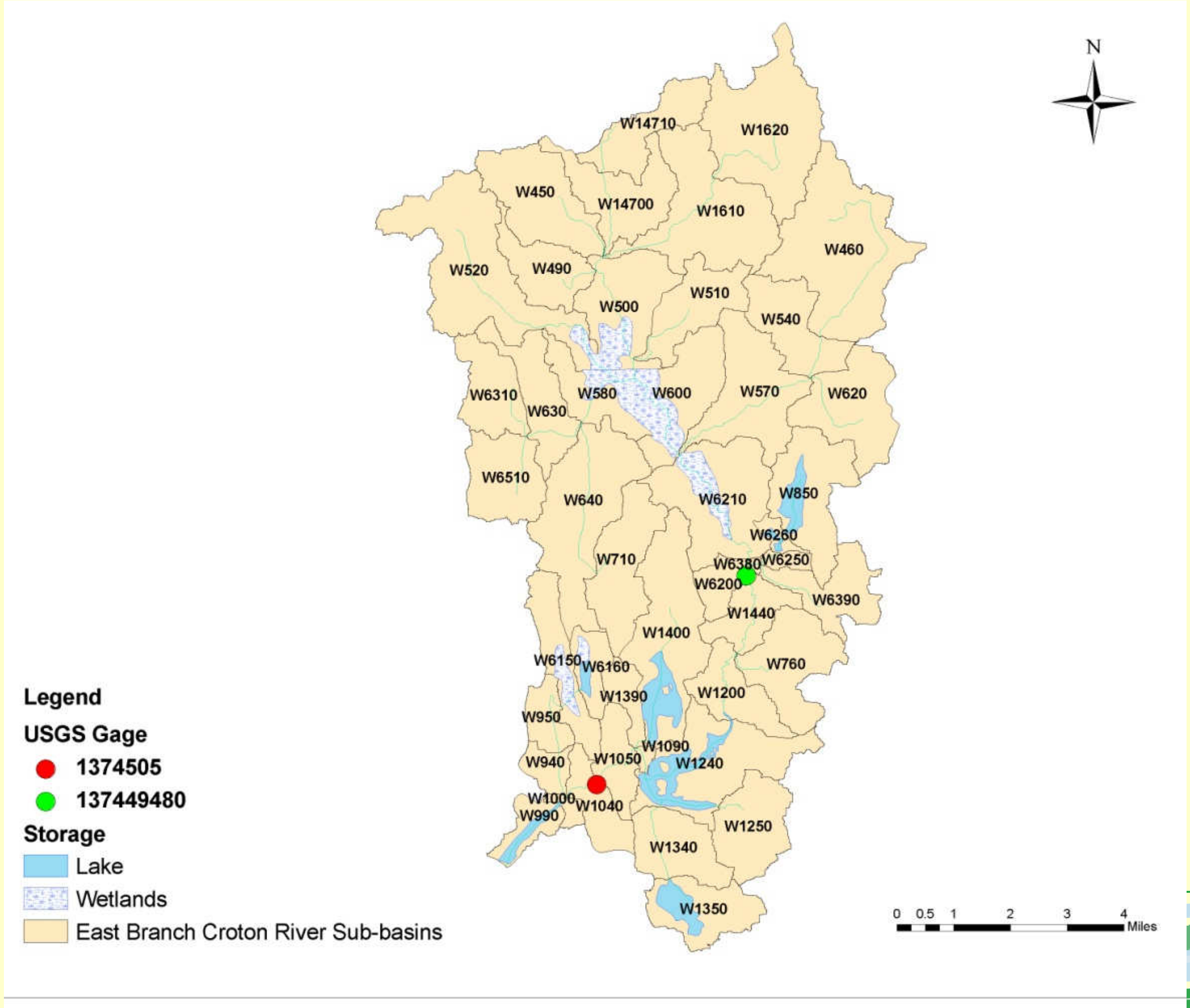
•Reach Routing:- Muskingum Cunge 8 point XS

Calibration

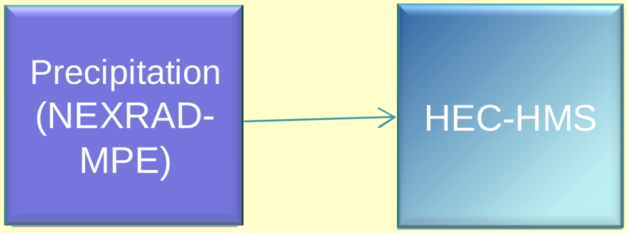
1.Sep 1999 (Calibration)
2.Apr 2007 (Verification)

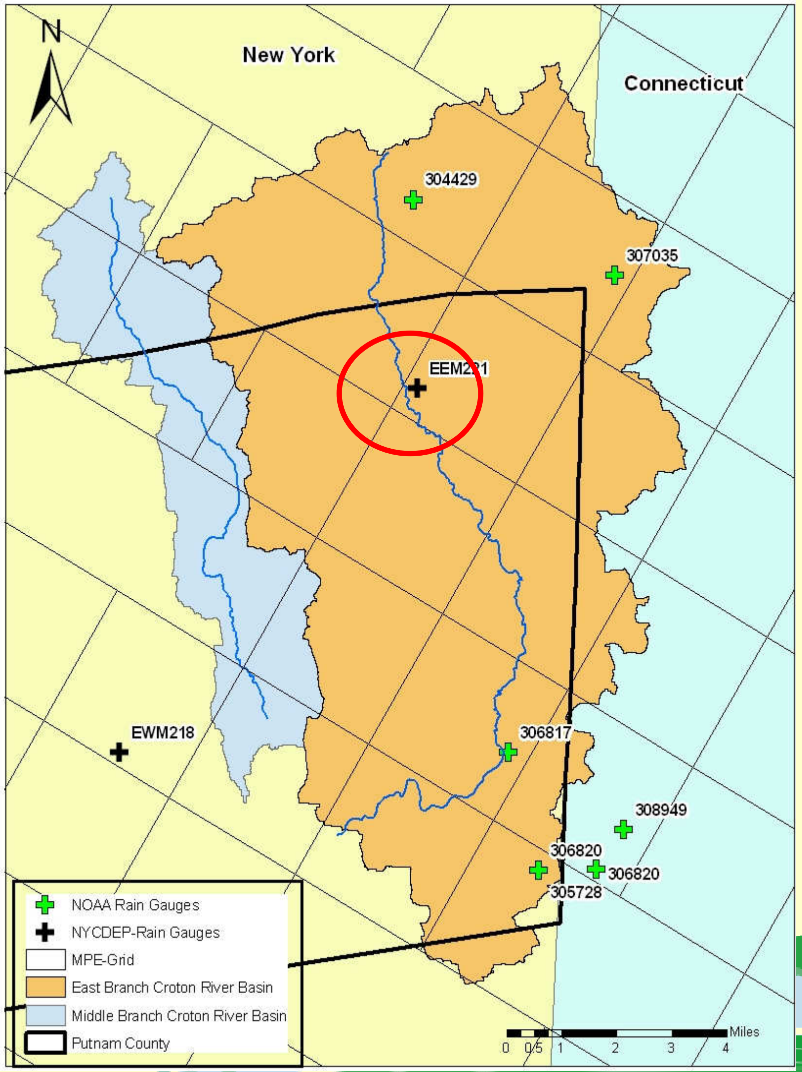


Modeling Approach - Subbasins



Modeling Approach- Rainfall





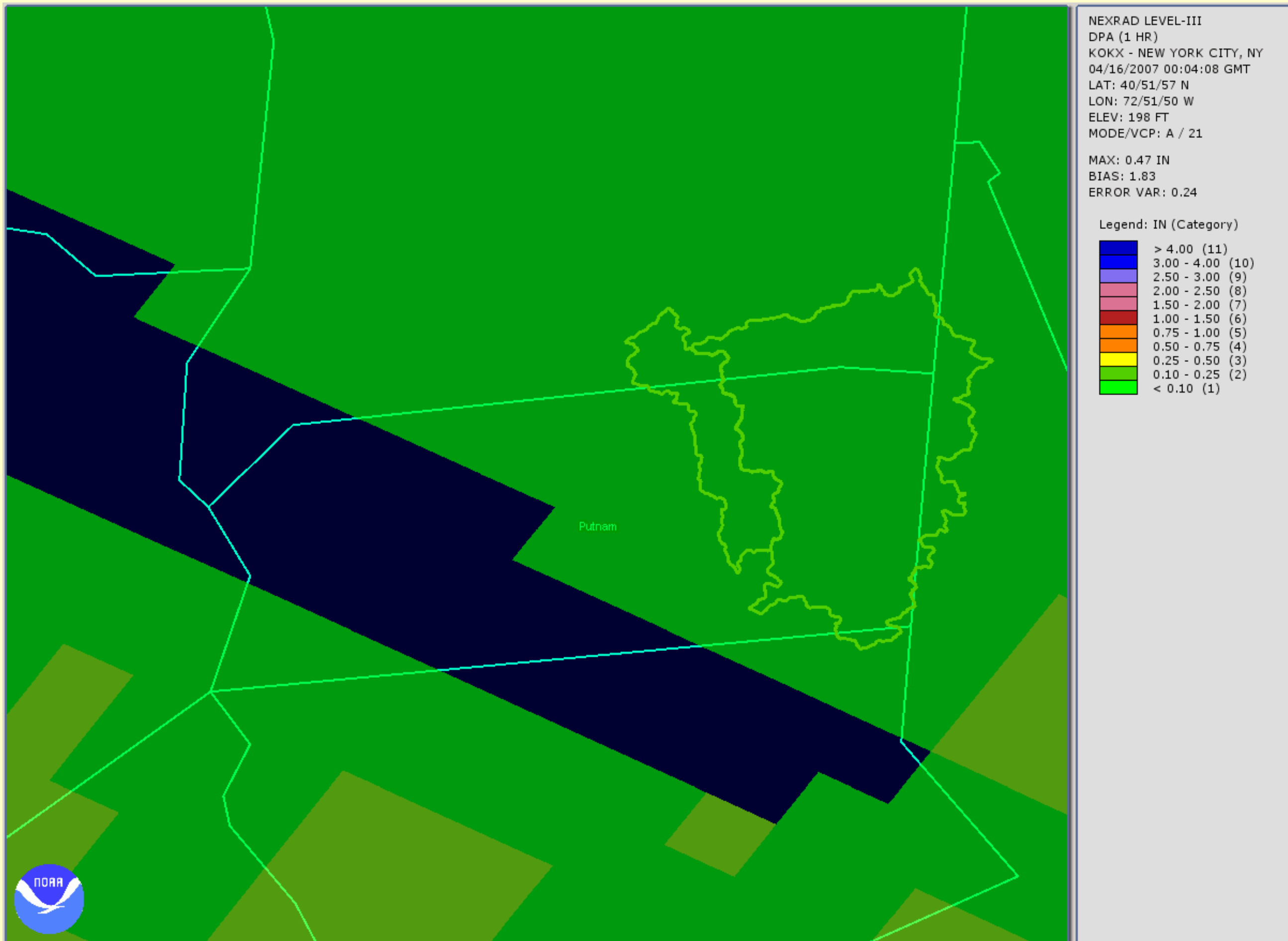
Two Precipitation sources

1.NYCDEP Rain Gages
2.NEXRAD

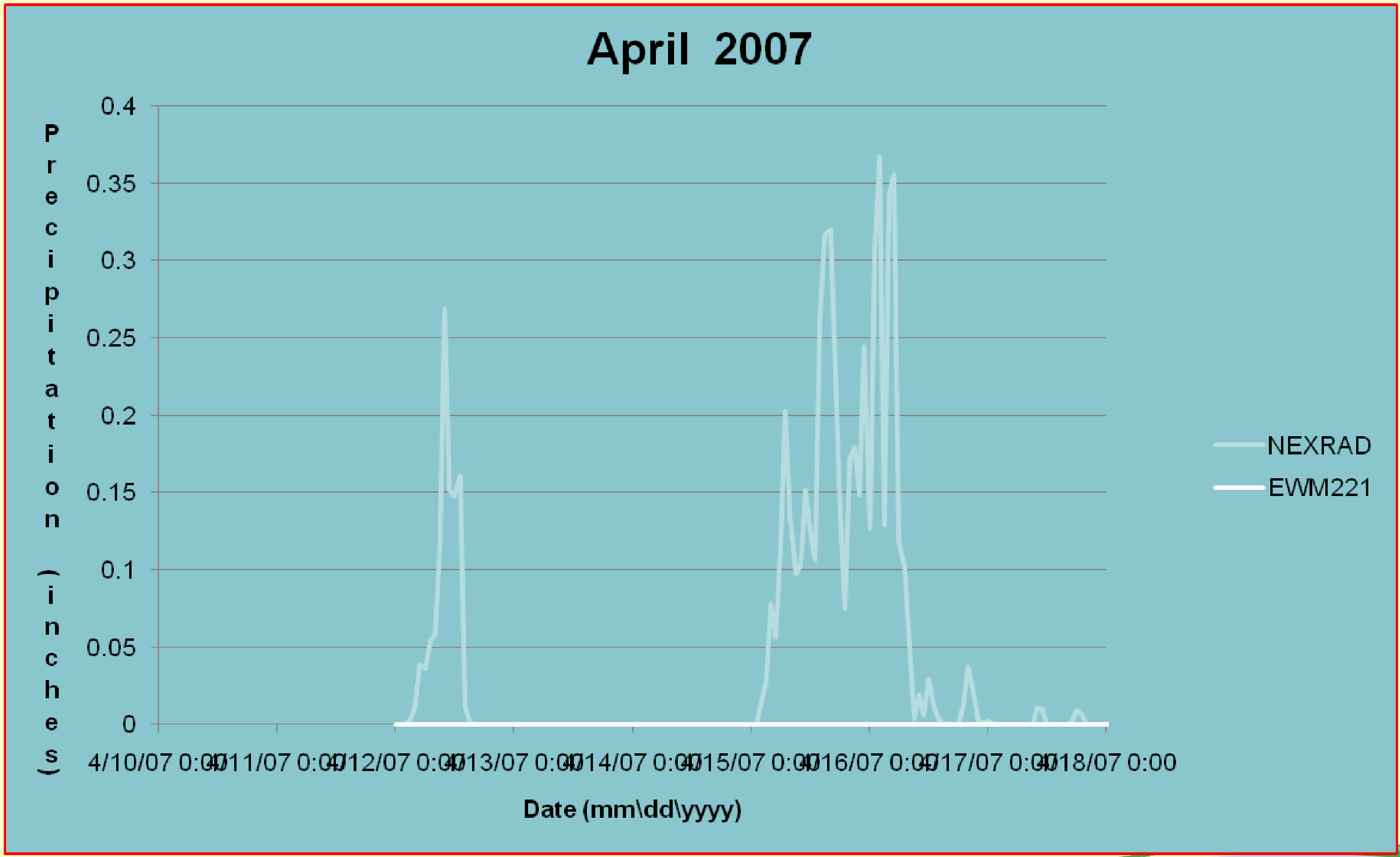
Binary NEXRAD was converted in to HEC-HMS ESRI Grid Time Series

Comparison of NYCDEP Rain gage, NEXRAD & NOAA Gages (no data)

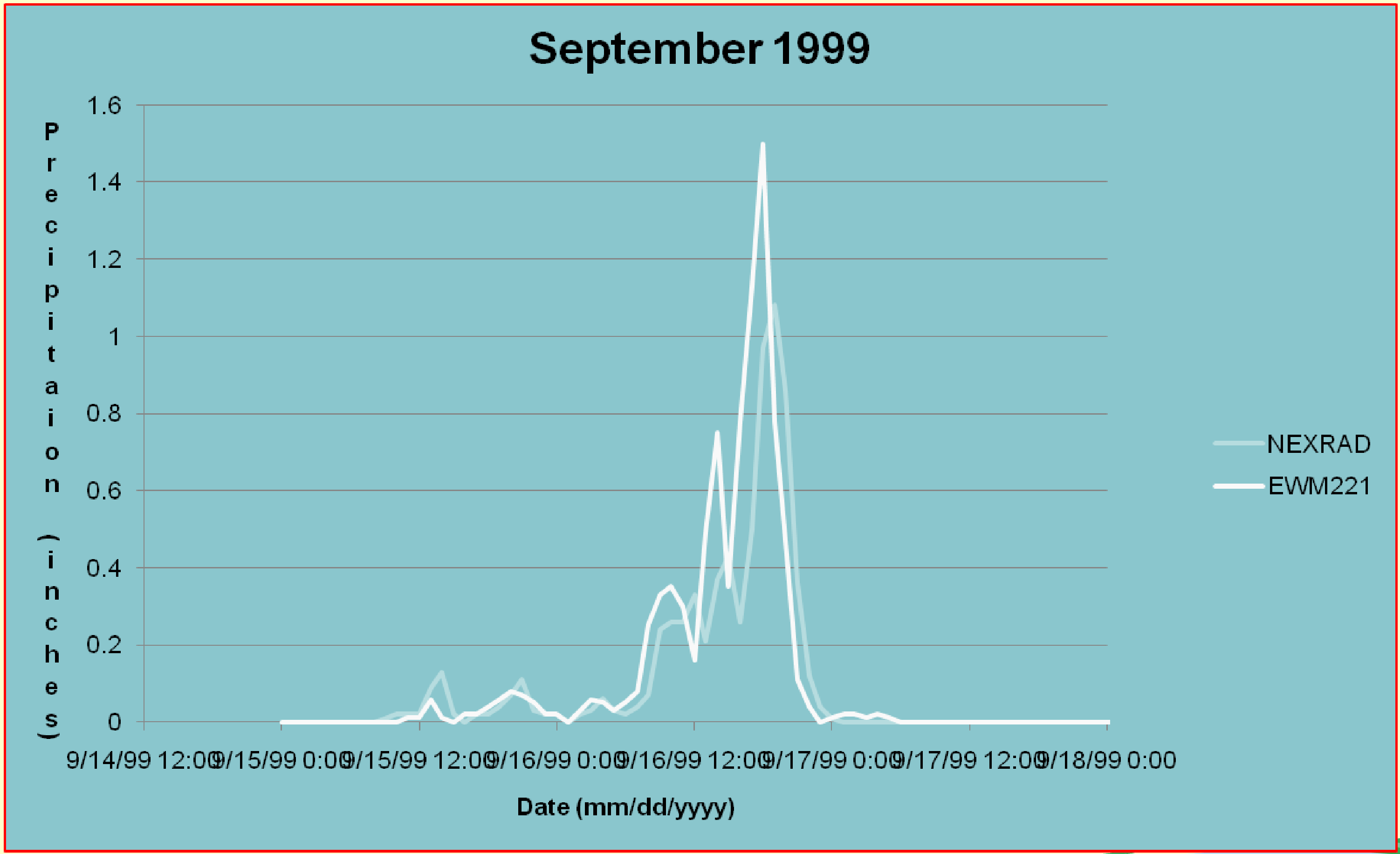
Modeling Approach- Rainfall



Modeling Approach- Rainfall



Modeling Approach- Rainfall



Initial Model Run

- Model Predicts higher discharge (>200%)

- Predicted time to peak occured before observed time to peak

- 64 sq.mi basin - ~2000 cfs (low yield)

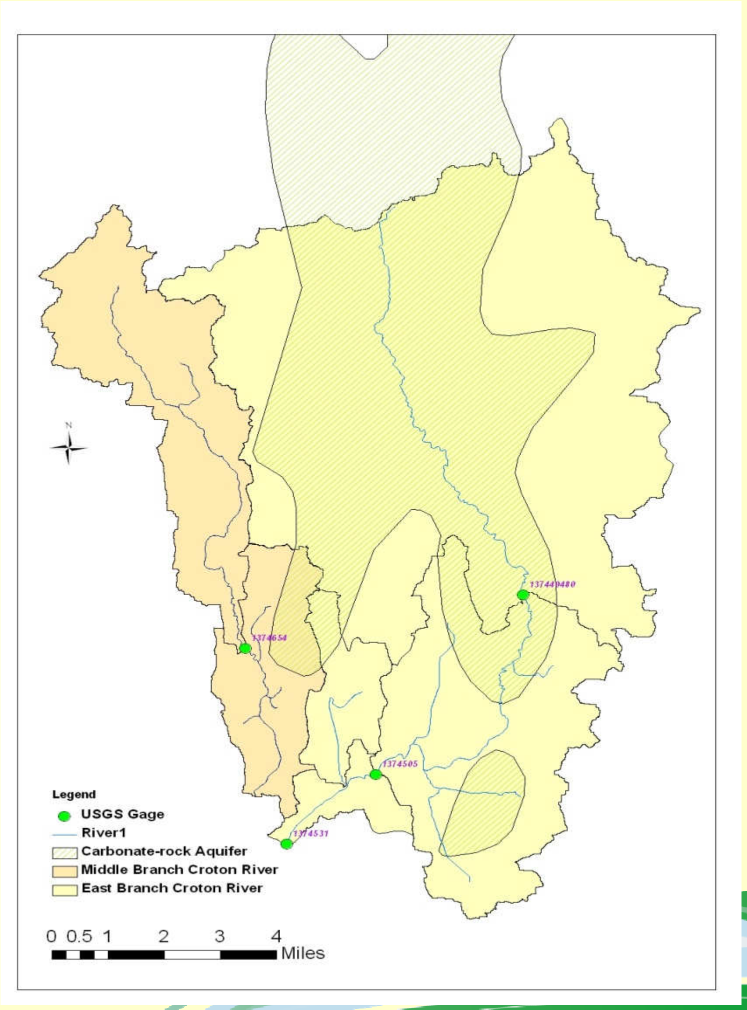
Calibration Issues

- Issues
  - Presence of Carbonate layer
  - Effect of Great Swamp

Modeling Challenges- Calibration
1. Carbonate Layer

Has an effect of storage and recharge

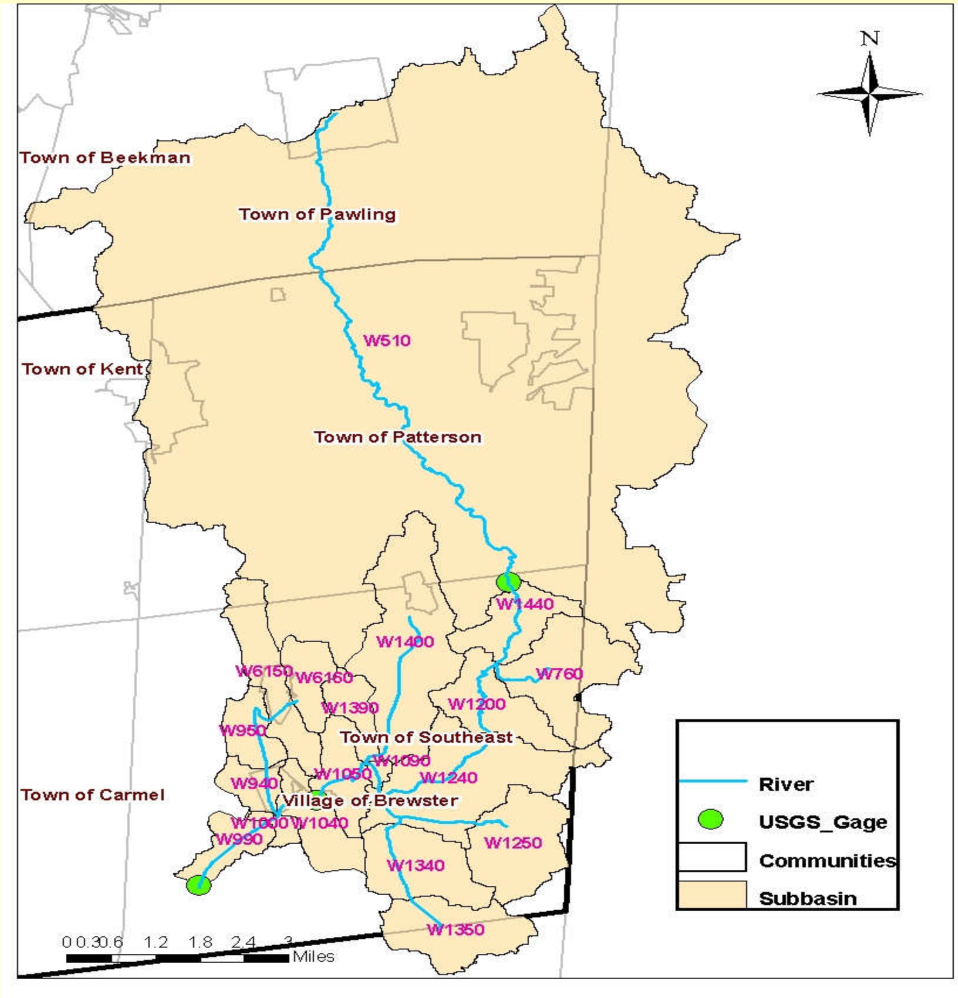
Is above the scope of HEC-HMS



Modeling Challenges- Calibration
2. The Great swamp

Cannot be just reflected by Reach Routing only

Combined effect of carbonate layer and great swamp was represented by Unit Hydrograph

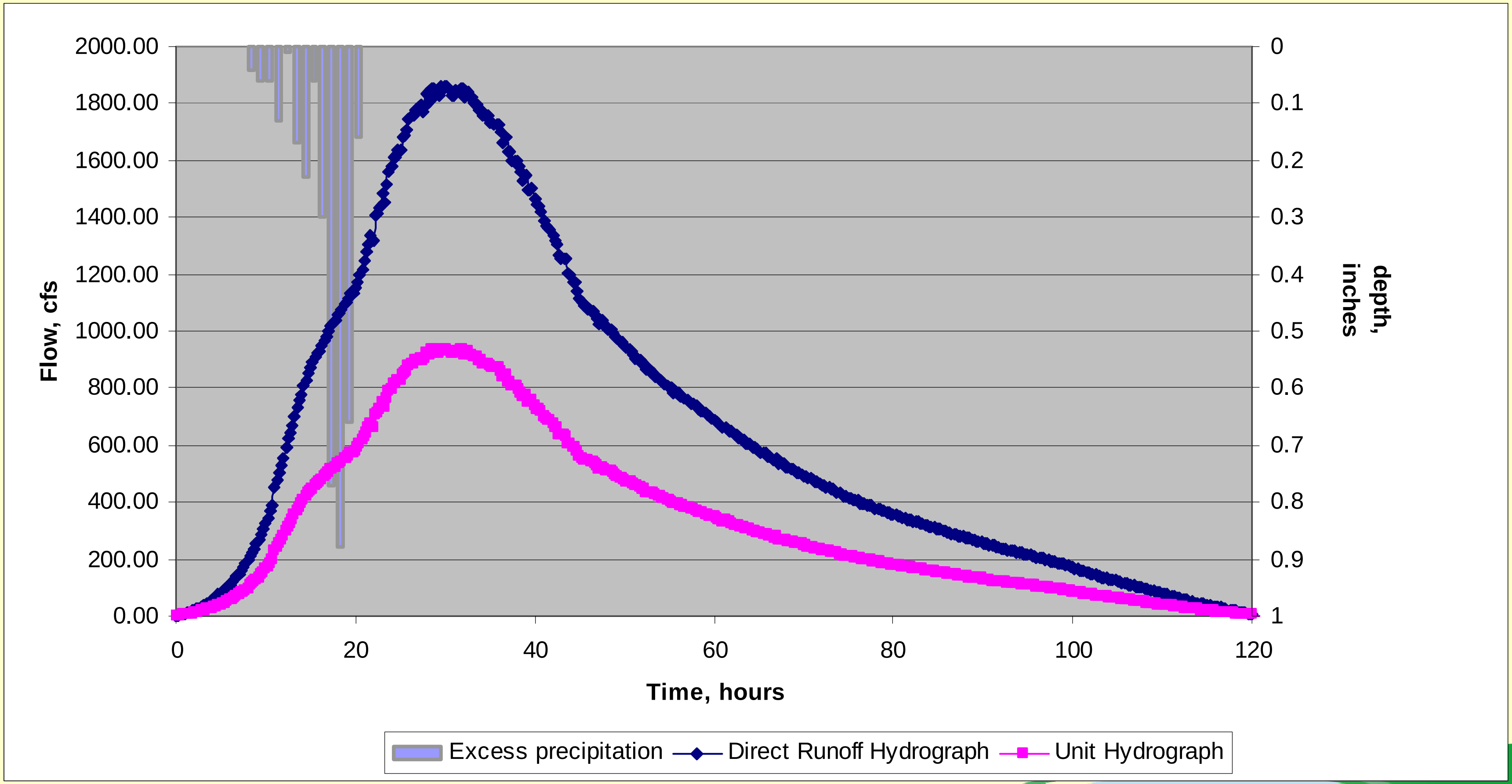


Unit Hydrograph Approach

- Defined as the direct runoff hydrograph resulting from 1in of excess rainfall

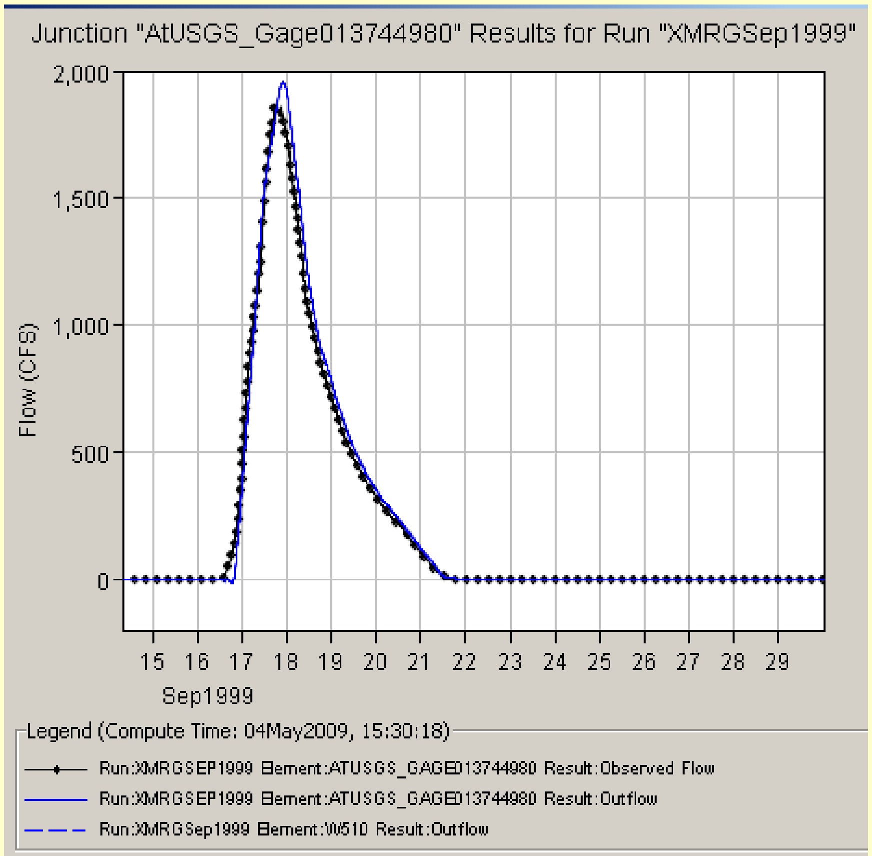
  The essential steps in deriving a unit hydrograph from a single storm are:
- Separate the base flow and obtain the direct runoff hydrograph.
- Compute the total volume of direct runoff. Convert this volume into equivalent depth (in inches or in centimeters) over the entire basin.
- Normalize the direct runoff hydrograph by dividing each ordinate by the equivalent volume (in or cm) of direct runoff (or effective rainfall).
- Compute effective rainfall and associated duration of the effective rainfall hyetograph. This duration is the duration associated with the unit hydrograph.
- Unit hydrographs are intimately linked with the duration of the effective rainfall event producing them. They can only be used to predict direct runoff from storms of the same duration as that associated with the UH.

Unit Hydrograph Approach



Modeling Result
1- Up stream Gage

Comparison of Simulated and Observed Direct Runoff Hydrographs at USGS Gage 013744980 for September 1999 Flood Event



Project: EBCrotonRiver
Simulation Run: XMRGSep1999 Junction: AtUSGS_Gage013744980

Start of Run: 14Sep1999, 08:00 | Basin Model: 1999CalibrationModel
End of Run: 30Sep1999, 00:00 | Meteorologic Model: XMRG
Compute Time: 04May2009, 15:30:18 | Control Specifications: XMRG_Sep1999

Volume Units: IN AC-FT

Computed Results

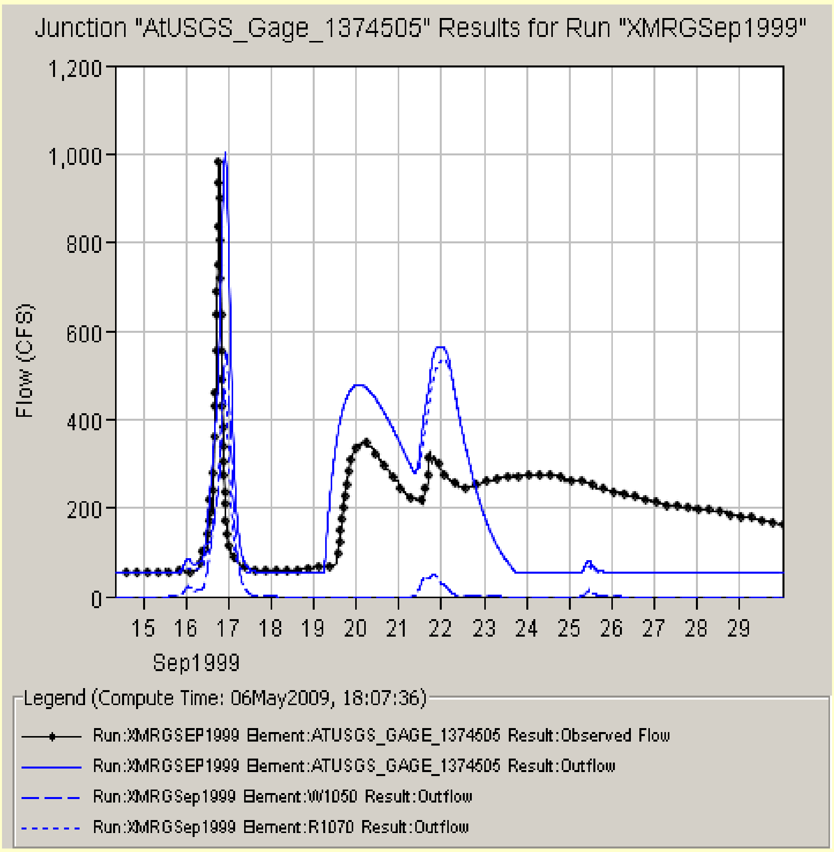
Peak Outflow : 1955.7 (CFS) | Date/Time of Peak Outflow : 17Sep1999, 22:15
Total Outflow : 2.08 (IN)

Observed Hydrograph at Gage USGSGage9480

Peak Discharge : 1860.20 (CFS) | Date/Time of Peak Discharge : 17Sep1999, 18:30
Avg Abs Residual : 19.28 (CFS)
Total Residual : 0.09 (IN) | Total Obs Q : 1.98 (IN)

Modeling Result
2- Down Stream Gage

Comparison of Simulated Versus Observed Discharge at USGS Gage 01374505 for September 1999 Flood Event



Project: EBCrotonRiver
Simulation Run: XMRGSep1999 Junction: AtUSGS_Gage_1374505

Start of Run:	14Sep1999, 08:00	Basin Model:	1999CalibrationModel
End of Run:	30Sep1999, 00:00	Meteorologic Model:	XMRG
Compute Time:	06May2009, 18:07:36	Control Specifications:	XMRG_Sep1999

Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Outflow : 1001.6 (CFS) Date/Time of Peak Outflow : 16Sep1999, 22:00
Total Outflow : 1.16 (IN)

Observed Hydrograph at Gage USGSGage505

Peak Discharge : 982.00 (CFS) Date/Time of Peak Discharge : 16Sep1999, 18:30
Avg Abs Residual : 123.93 (CFS)
Total Residual : -0.21 (IN) Total Obs Q : 1.38 (IN)

Conclusions

- Careful investigation of watershed characteristics is important during calibration

- Systematic approach where watershed is impacted by groundwater (ex. Unit Hydrograph)

Questions

- Thank you