Increased Flood Peaks in Northeastern Illinois*

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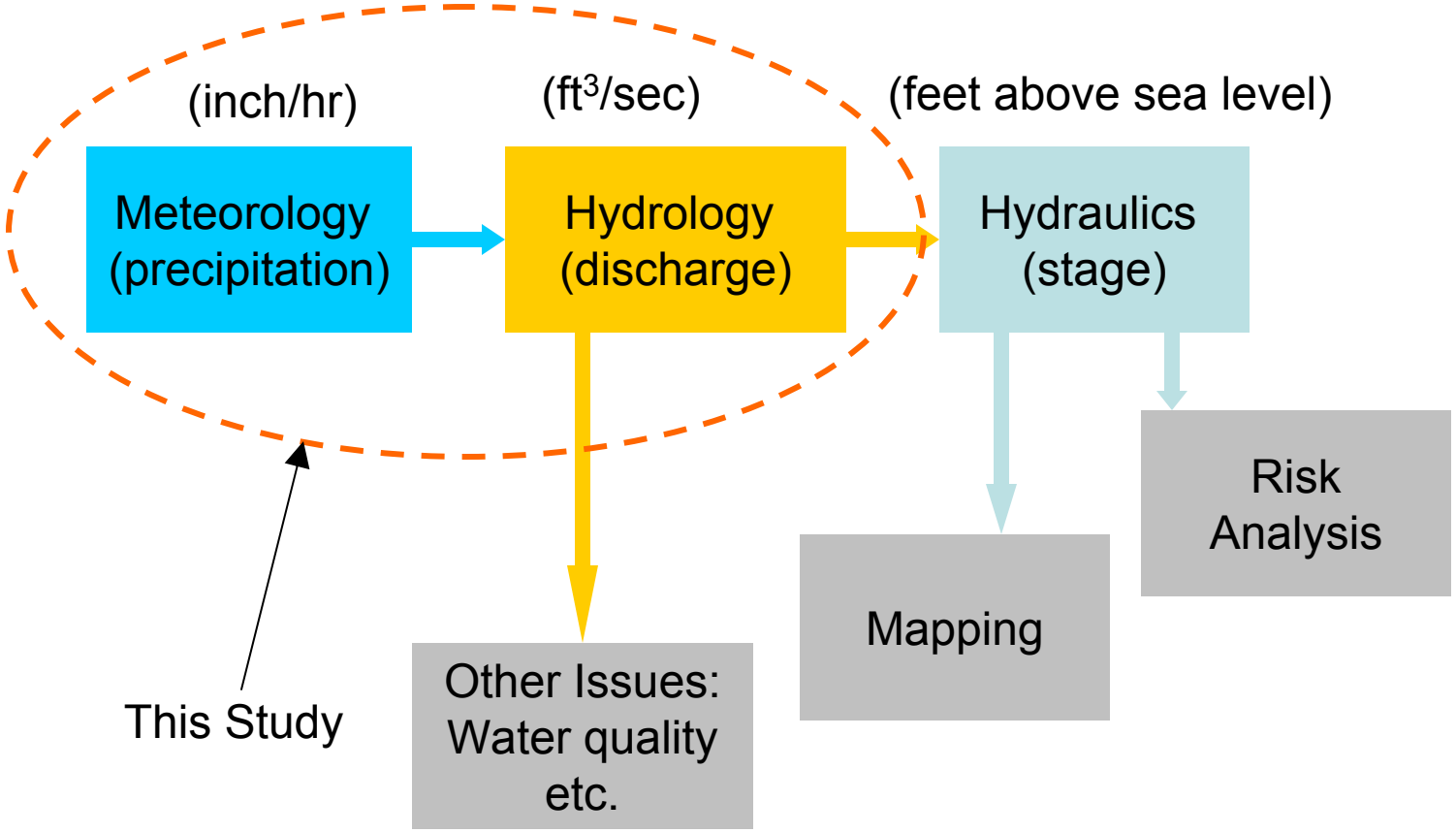
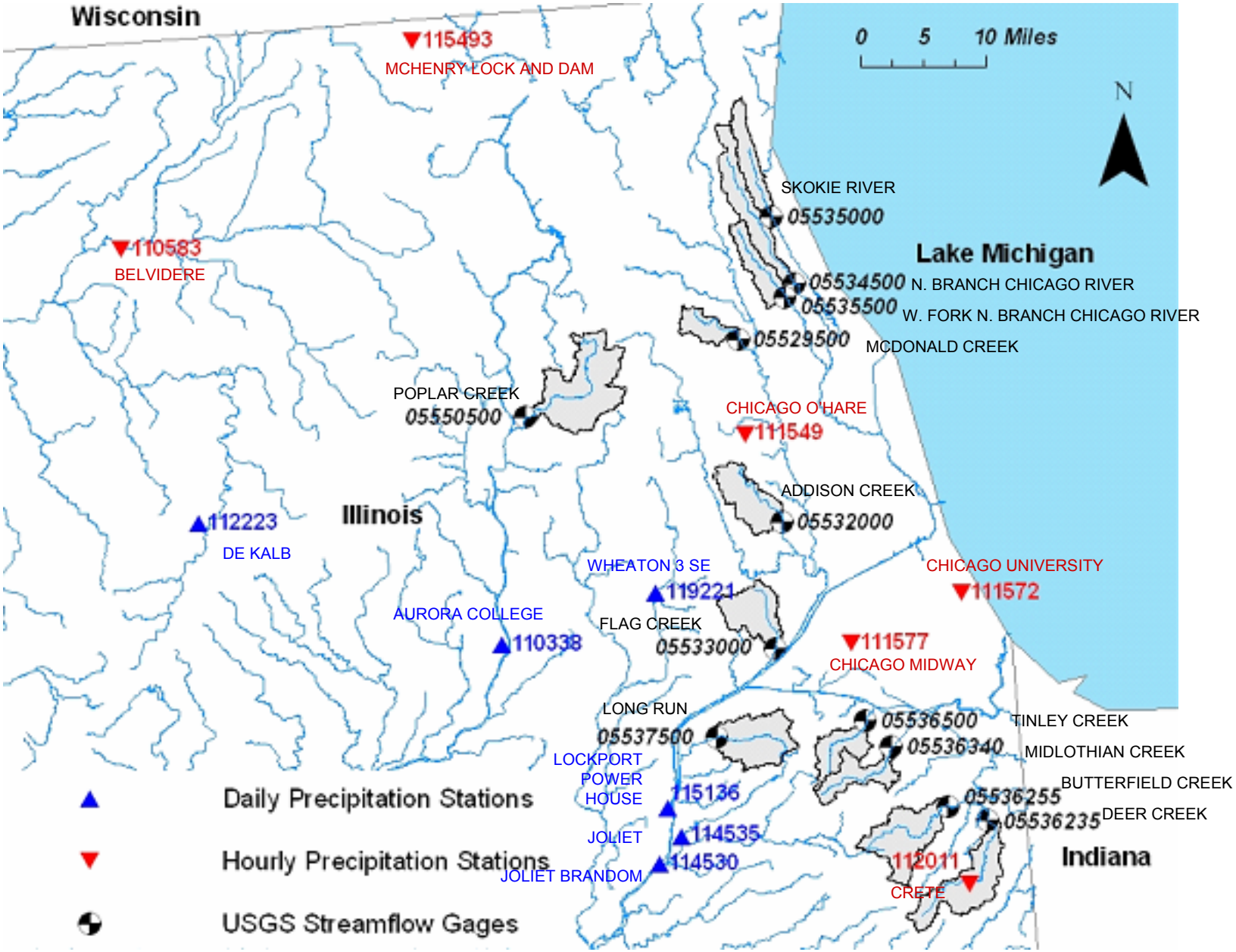
University of Illinois at Urbana-Champaign

*Funded by Illinois-Indiana Sea Grant, University of Illinois

Types of analysis




Wisconsin
115493
MCHENRY LOCK AND DAM
0 5 10 Miles
N
SKOKIE RIVER
05535000
Lake Michigan
110583
BELVIDERE
05534500
N. BRANCH CHICAGO RIVER
05535500
W. FORK N. BRANCH CHICAGO RIVER
05529500
MCDONALD CREEK
POPLAR CREEK
05550500
CHICAGO O'HARE
111549
ADDISON CREEK
05532000
Illinois
112223
DE KALB
WHEATON 3 SE
119221
CHICAGO UNIVERSITY
111572
AURORA COLLEGE
110338
FLAG CREEK
05533000
111577
CHICAGO MIDWAY
LONG RUN
05537500
05536500
TINLEY CREEK
05536340
MIDLOTHIAN CREEK
LOCKPORT POWER HOUSE
115136
BUTTERFIELD CREEK
05536255
05536235
DEER CREEK
JOLIET
114535
114530
JOLIET BRANDOM
112011
CRETE
Indiana
Daily Precipitation Stations
Hourly Precipitation Stations
USGS Streamflow Gages

THE STUDY GOALS:

1. Test the hypothesis that floods have been increasing in NE Illinois since the 1950s (on 12 small urbanizing watersheds <36 mi^2)
2. Estimate the individual contributions of precipitation increases and urbanization to the flood peak increases
3. ***Calculate base floods**** and compare them with the published sources
4. Perform a sensitivity analysis

* Floods having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the "100-year flood."

Base Flood Calculations Methods*

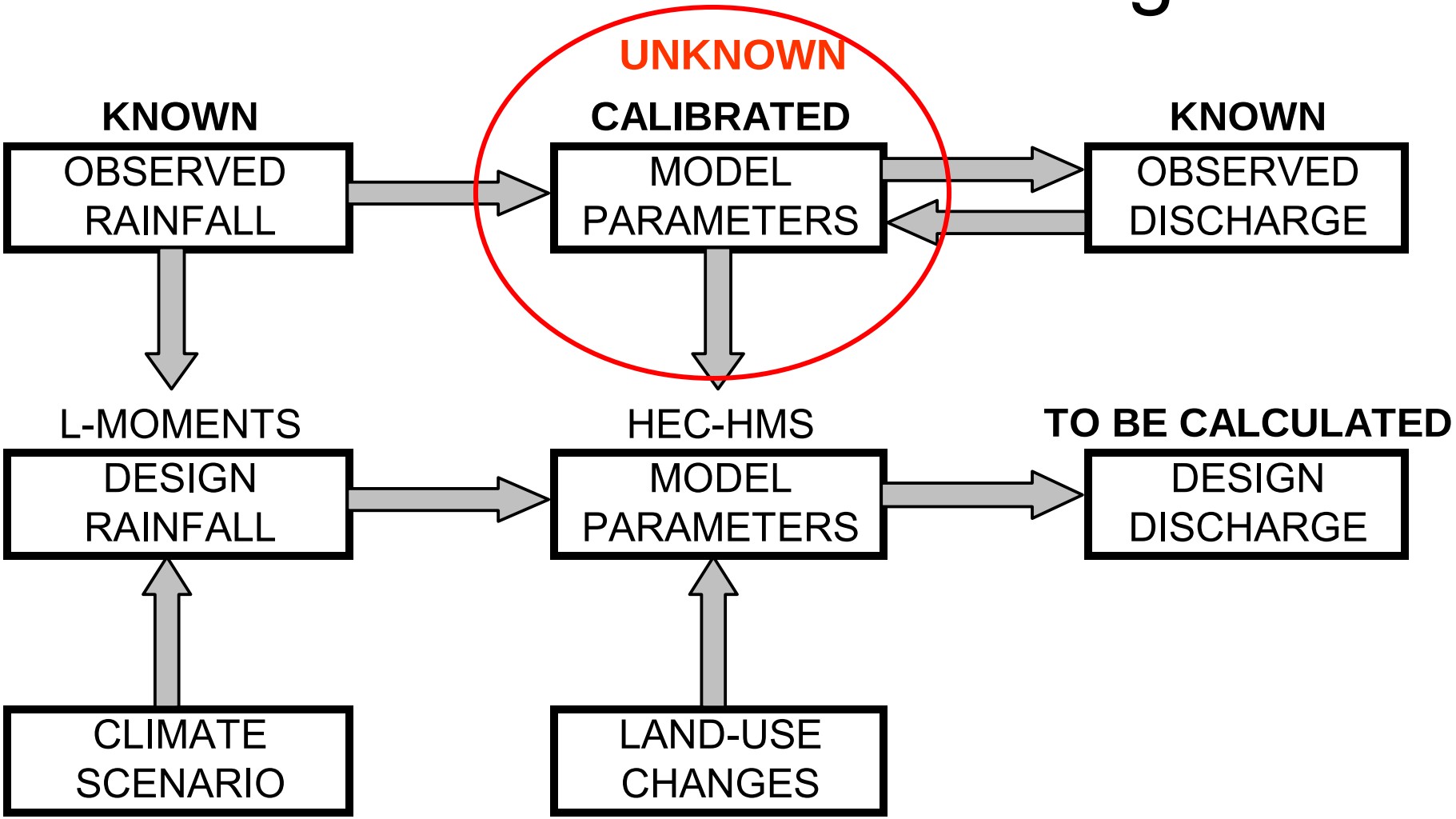
- Gage record statistical analysis (Bulletin 17B) to calculate discharges with various return periods (if flood records represent relatively constant watershed conditions)

- Regional (USGS or other) Regression Equations

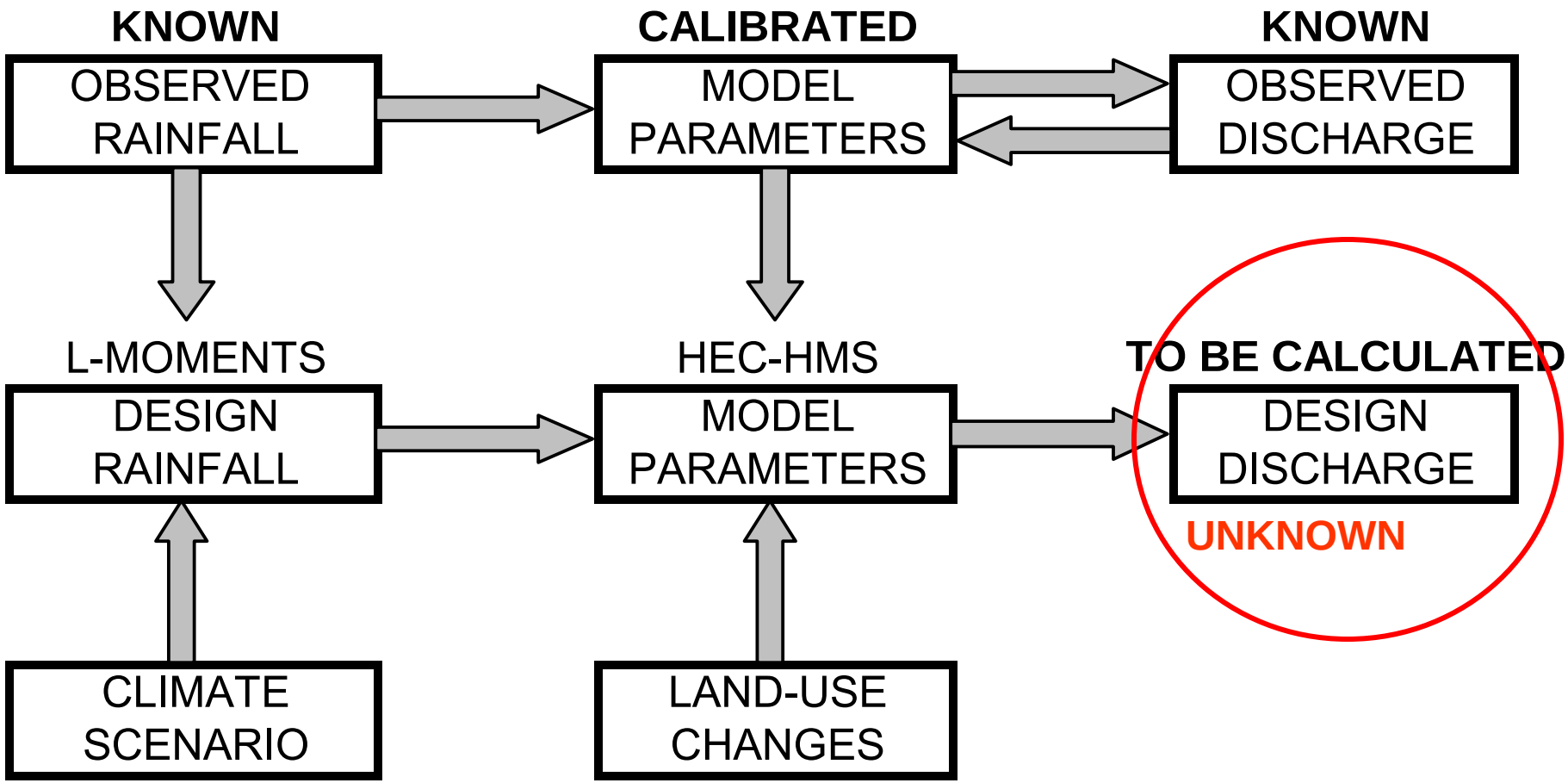
- **Rainfall-Runoff Models (e.g. HEC-HMS)**

* “Guidelines and specifications for flood hazard mapping partners, Appendix C, guidance for riverine flooding analyses and mapping.” FEMA, 2003

Study Framework
Rainfall-Runoff Model Stage 1

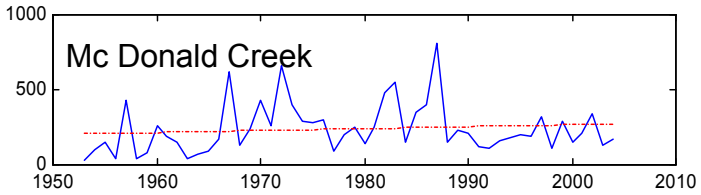


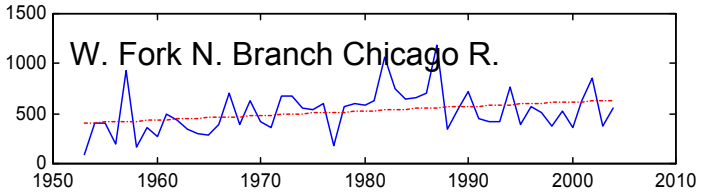
Study Framework
Rainfall-Runoff Model Stage 2

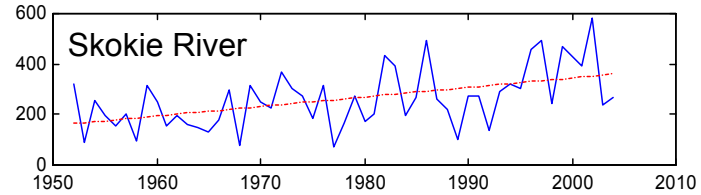


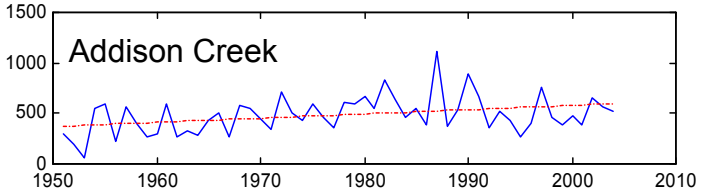
INCREASE IN FLOODS

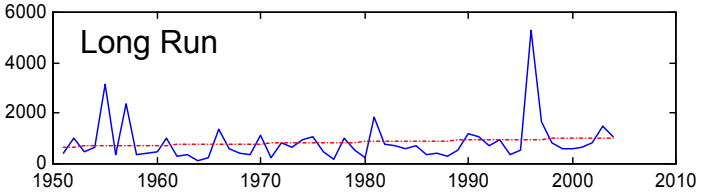
Maximum Annual Flood Peaks (cfs)

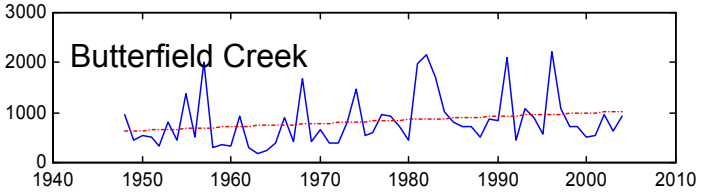


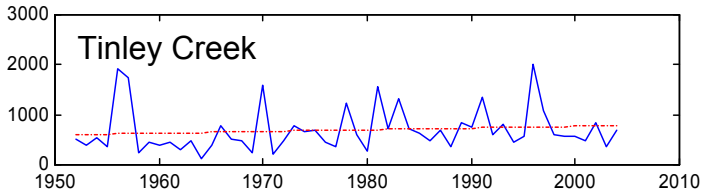


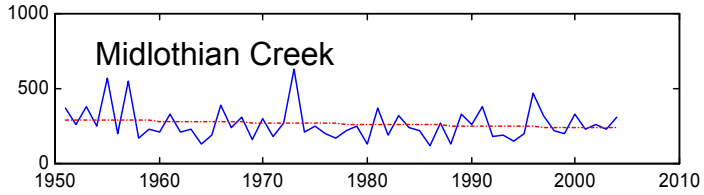


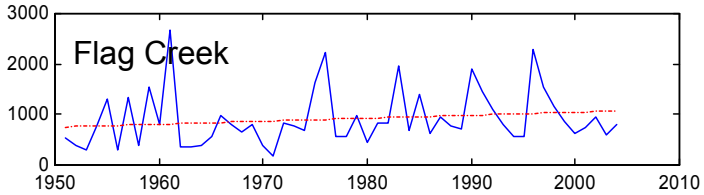


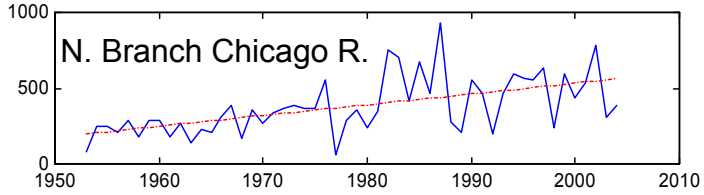


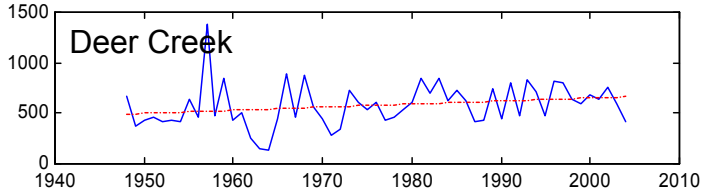


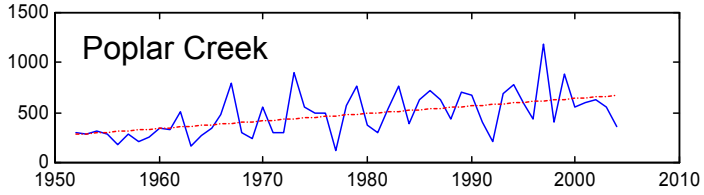












Statistical Significance of Trends

(Shaded areas indicate statistically significant trends)

USGS Station	Stream Name	Kendal τ	Confidence Level				
			80%	90%	95%	98%	99%
5529500	McDonald Creek	0.1373					
5536500	Tinley Creek	0.1792					
5535500	West Fork North Branch Chicago River	0.2300					
5536340	Midlothian Creek	-0.0552					
5535000	Skokie River	0.3215					
5533000	Flag Creek	0.1880					
5532000	Addison Creek	0.2313					
5534500	North Branch Chicago River	0.4351					
5537500	Long Run	0.1565					
5536235	Deer Creek	0.2218					
5536255	Butterfield Creek	0.1736					
5550500	Poplar Creek	0.3839					

INCREASE IN PRECIPITATION

- In NE Illinois, intensity and frequency of heavy rainfall events increased over the past century (Huff and Angel, 1989)

  (Huff, F. A. and J. R. Angel, 1989: Frequency Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois (Bulletin 70), Illinois State Water Survey, Champaign, Illinois, 177 pp)

- Angel and Huff (1997) demonstrated that that the assumption of stationarity of the extreme rainfall time series may not be true for portions of the Midwestern United States.

  (Angel J.R., and Huff, F.A., 1997, Changes in Heavy Rainfall in Midwestern United States, J. Water Resour. Plng. and Mgmt., Volume 123, Issue 4, pp. 246-249)

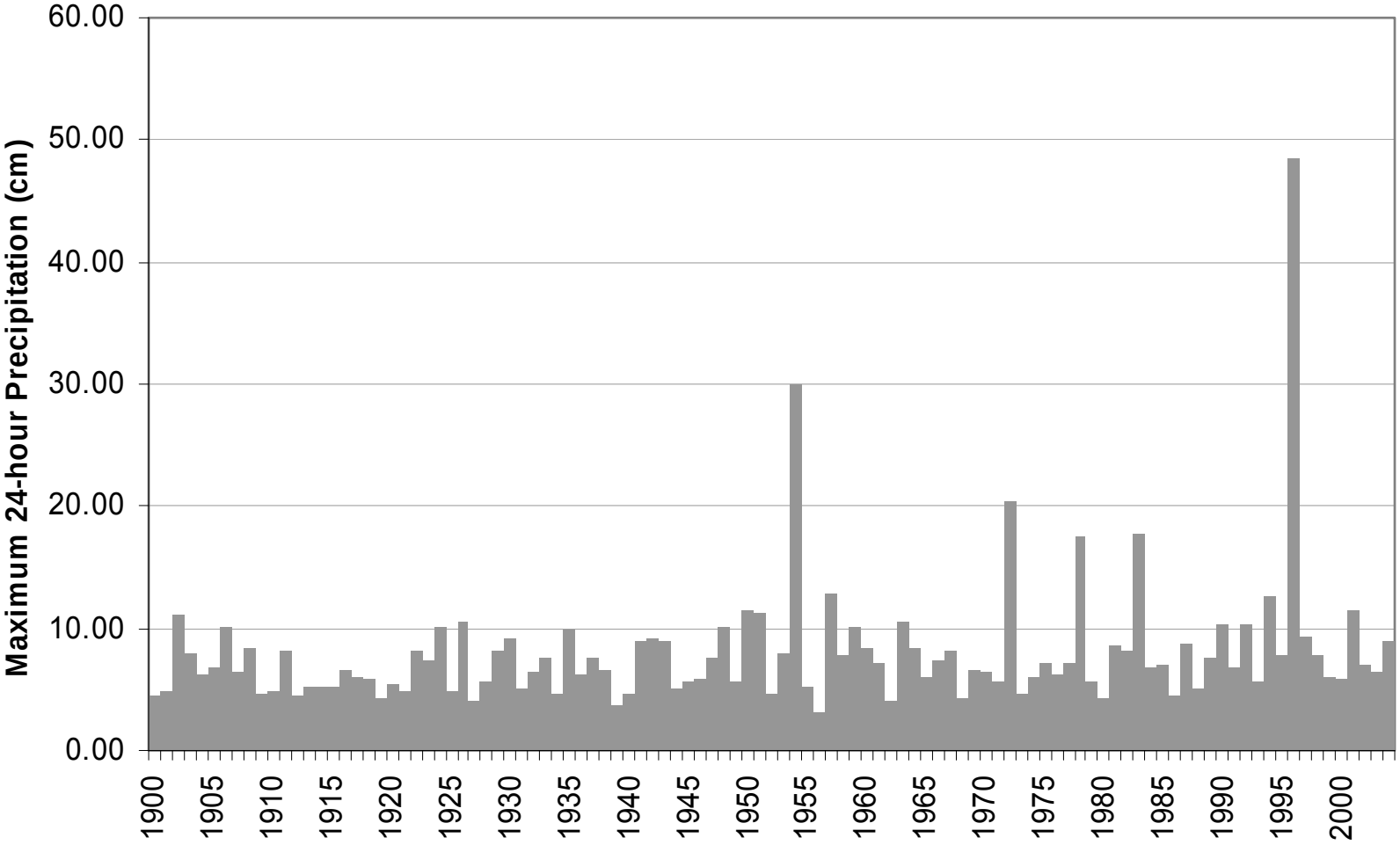
- Angel and Huff (1997) The number of extreme one-day precipitation events per year (≥ 2 in.) in the Chicago area showed a statistically significant positive trend over time.

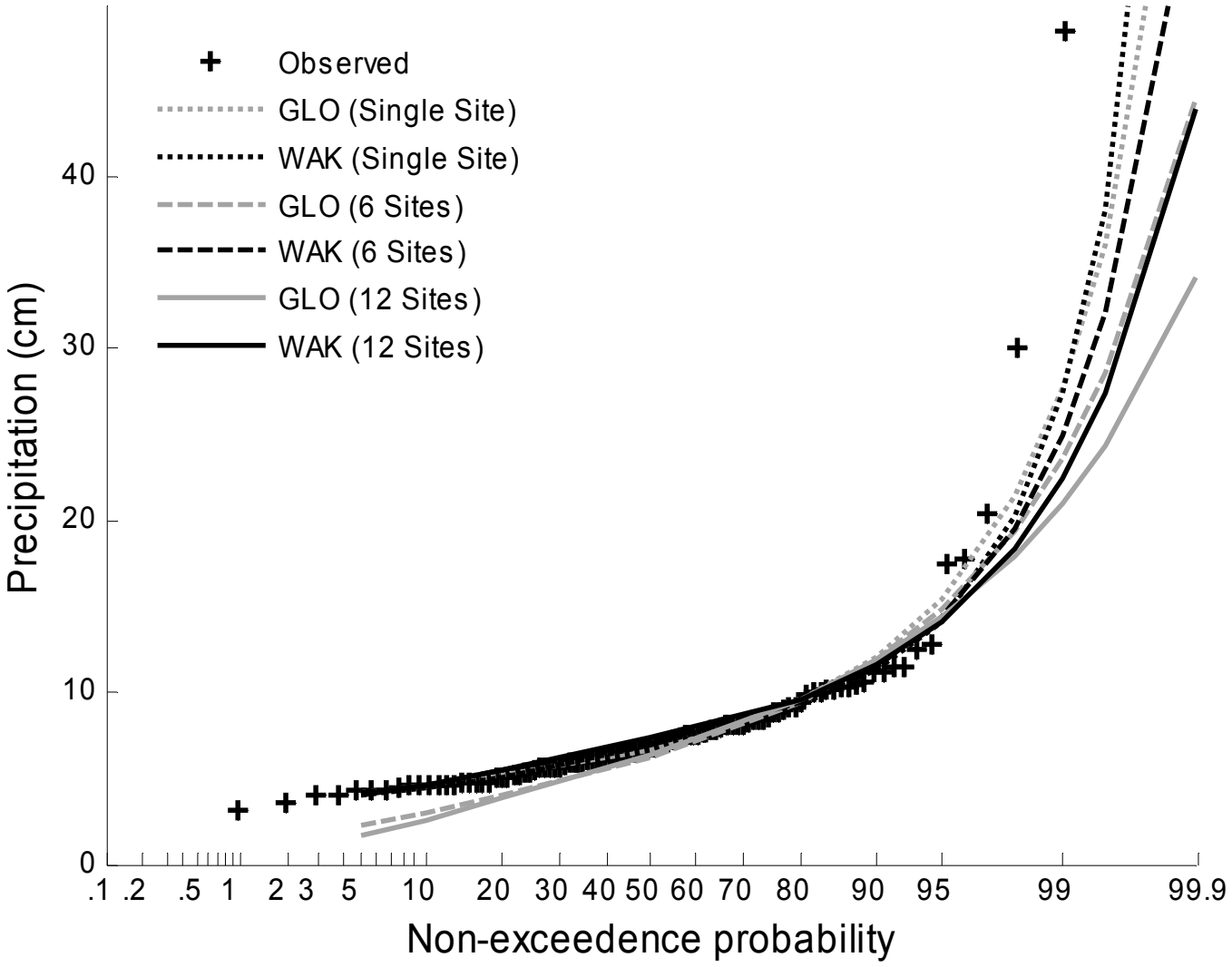
  (Angel J.R., and Huff, F.A., 1997, Changes in Heavy Rainfall in Midwestern United States, J. Water Resour. Plng. and Mgmt., Volume 123, Issue 4, pp. 246-249)

- Research by Changnon and Westcott (2002) points to "…continuing increases in the number of heavy rainstorms in future years, which has major implications for water managers in Chicago and elsewhere"

  (Changnon, S. and N. Westcott, 2002, Heavy Rainstorms in Chicago: Increasing Frequency, Altered Impacts, and Future Implications, Journal of the American Water Resources Association, 38(**5**))

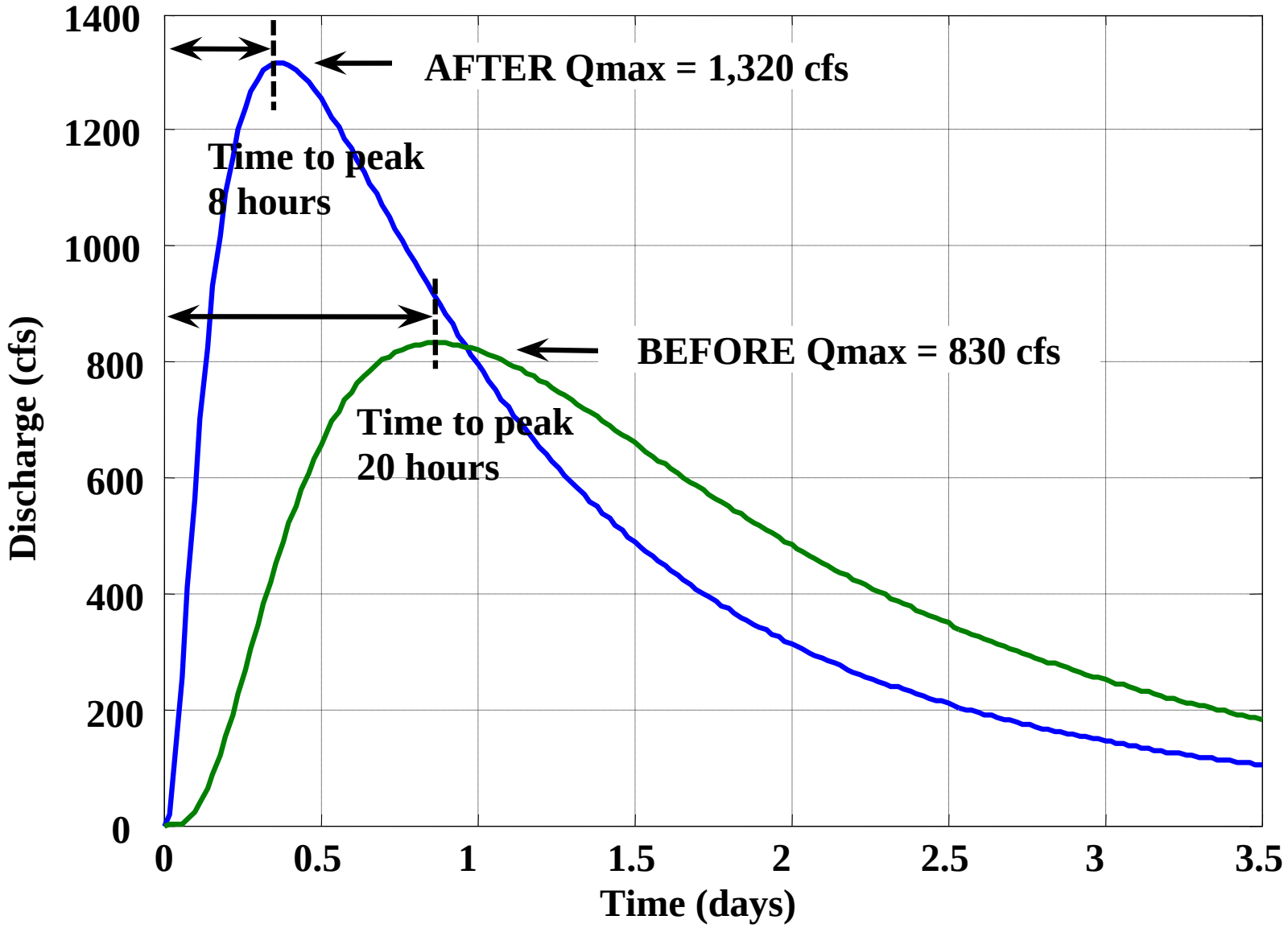
Aurora College Precipitation Station



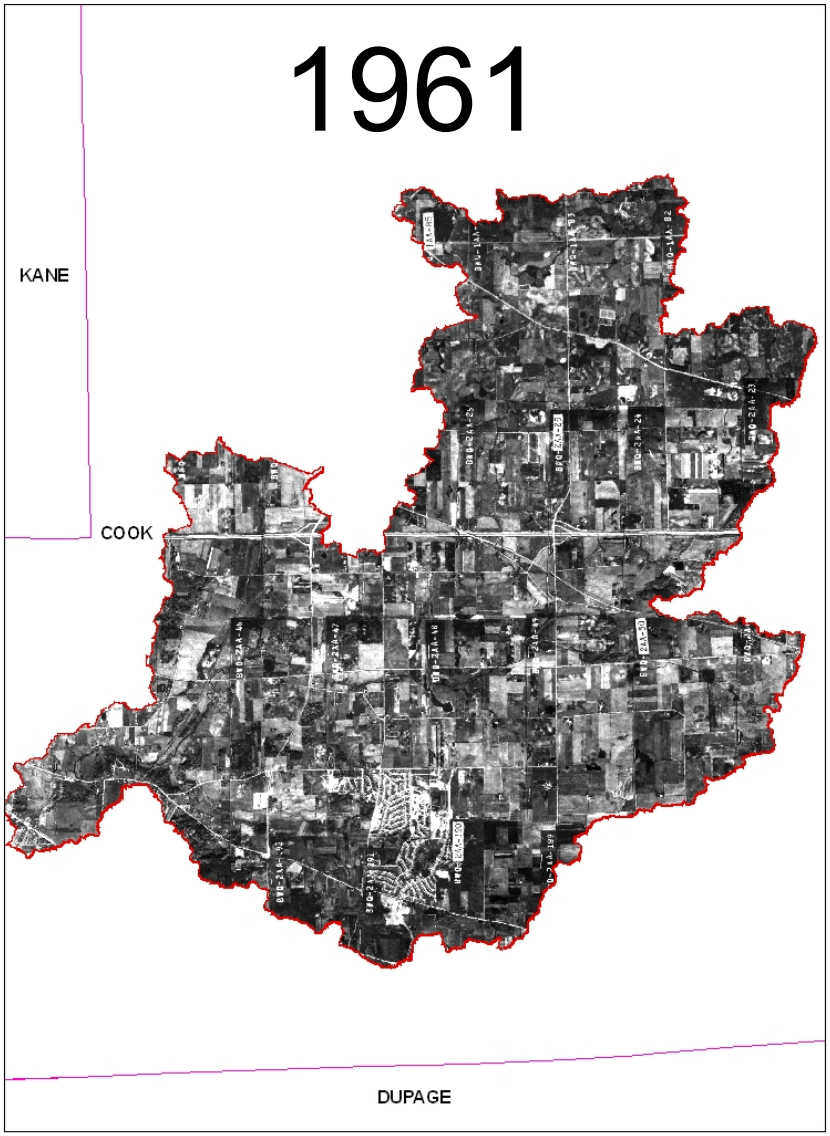

Observed
GLO (Single Site)
WAK (Single Site)
GLO (6 Sites)
WAK (6 Sites)
GLO (12 Sites)
WAK (12 Sites)
Precipitation (cm)
0
10
20
30
40
.1 .2 .5 1 2 3 5 10 20 30 40 50 60 70 80 90 95 99 99.9
Non-exceedence probability

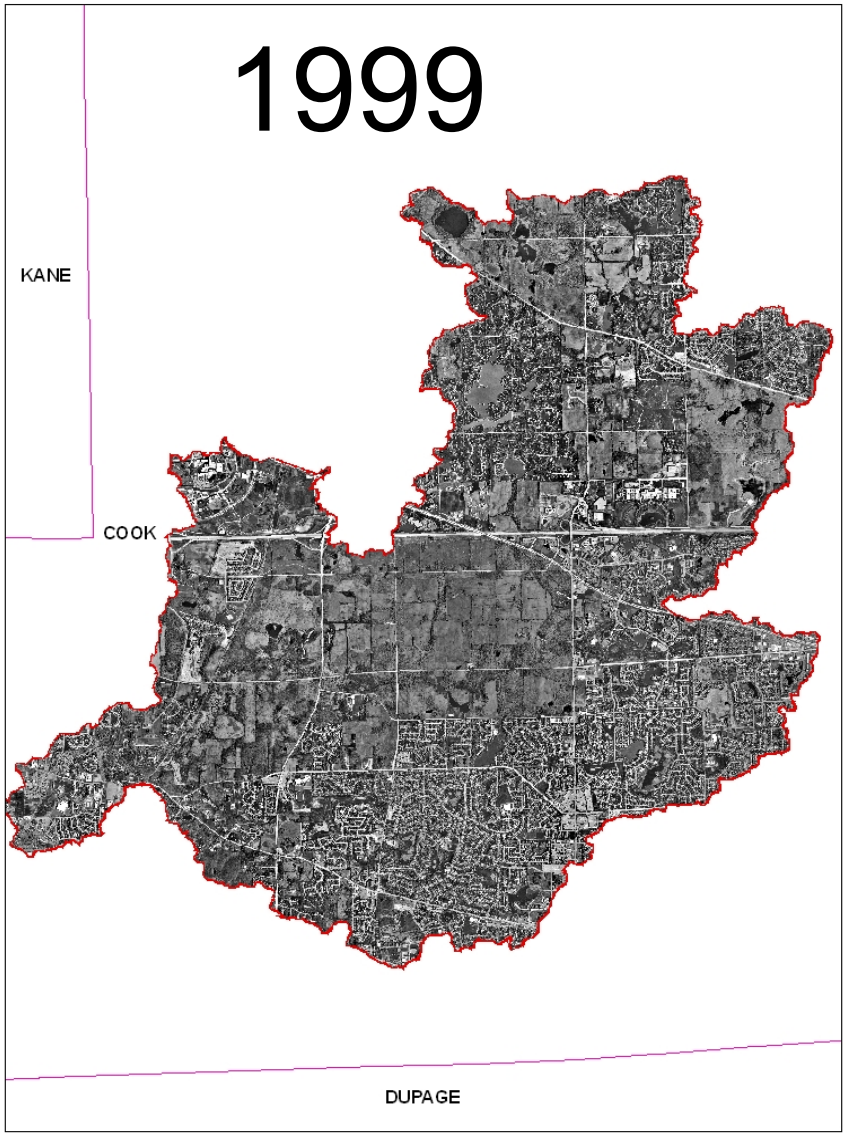
INCREASE IN URBAN AREAS

Flood hydrographs before and after urbanization



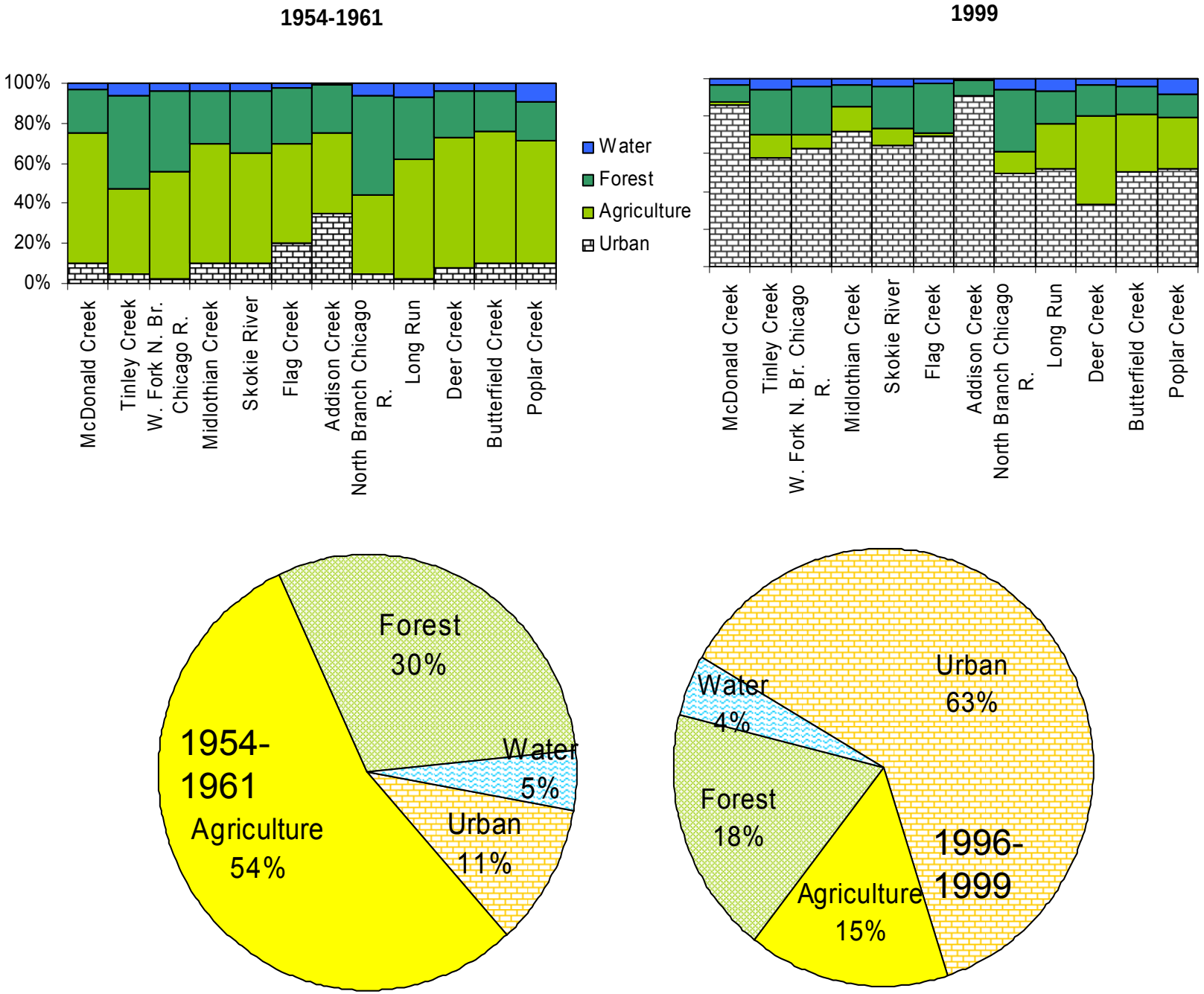
Poplar Creek at Elgin (USGS # 05550500)
Land-use/land cover change 1961-1999





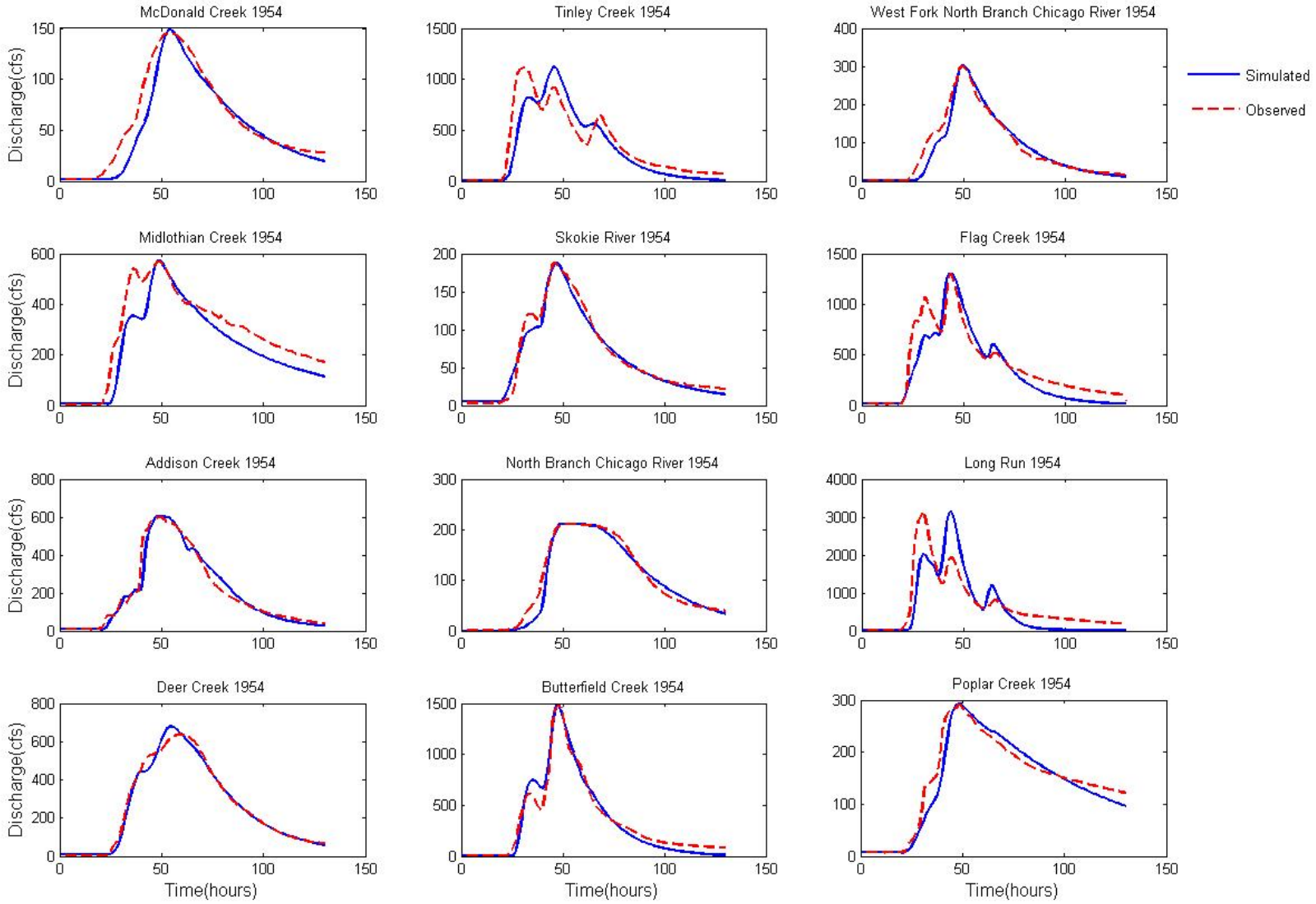
W. Fork
N. Branch
Chicago R.

Land-cover change 1954/ 1961-1999

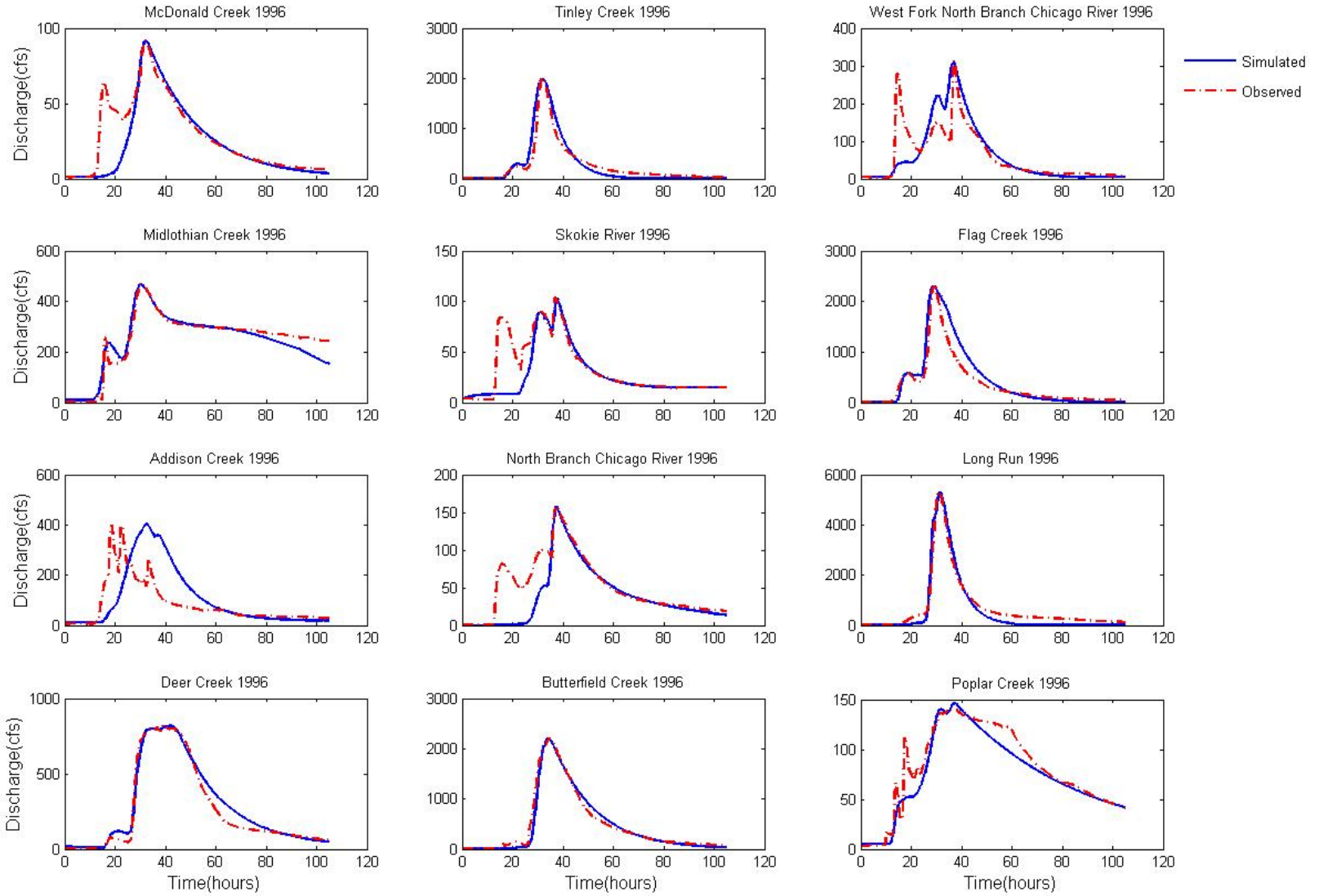

1954-1961
1999
100%
80%
60%
40%
20%
0%
Water
Forest
Agriculture
Urban
McDonald Creek
Tinley Creek
W. Fork N. Br. Chicago R.
Midlothian Creek
Skokie River
Flag Creek
Addison Creek
North Branch Chicago R.
Long Run
Deer Creek
Butterfield Creek
Poplar Creek
1954-1961
Forest 30%
Water 5%
Urban 11%
Agriculture 54%
1996-1999
Urban 63%
Water 4%
Forest 18%
Agriculture 15%

Calibration Results

Calibration 1954

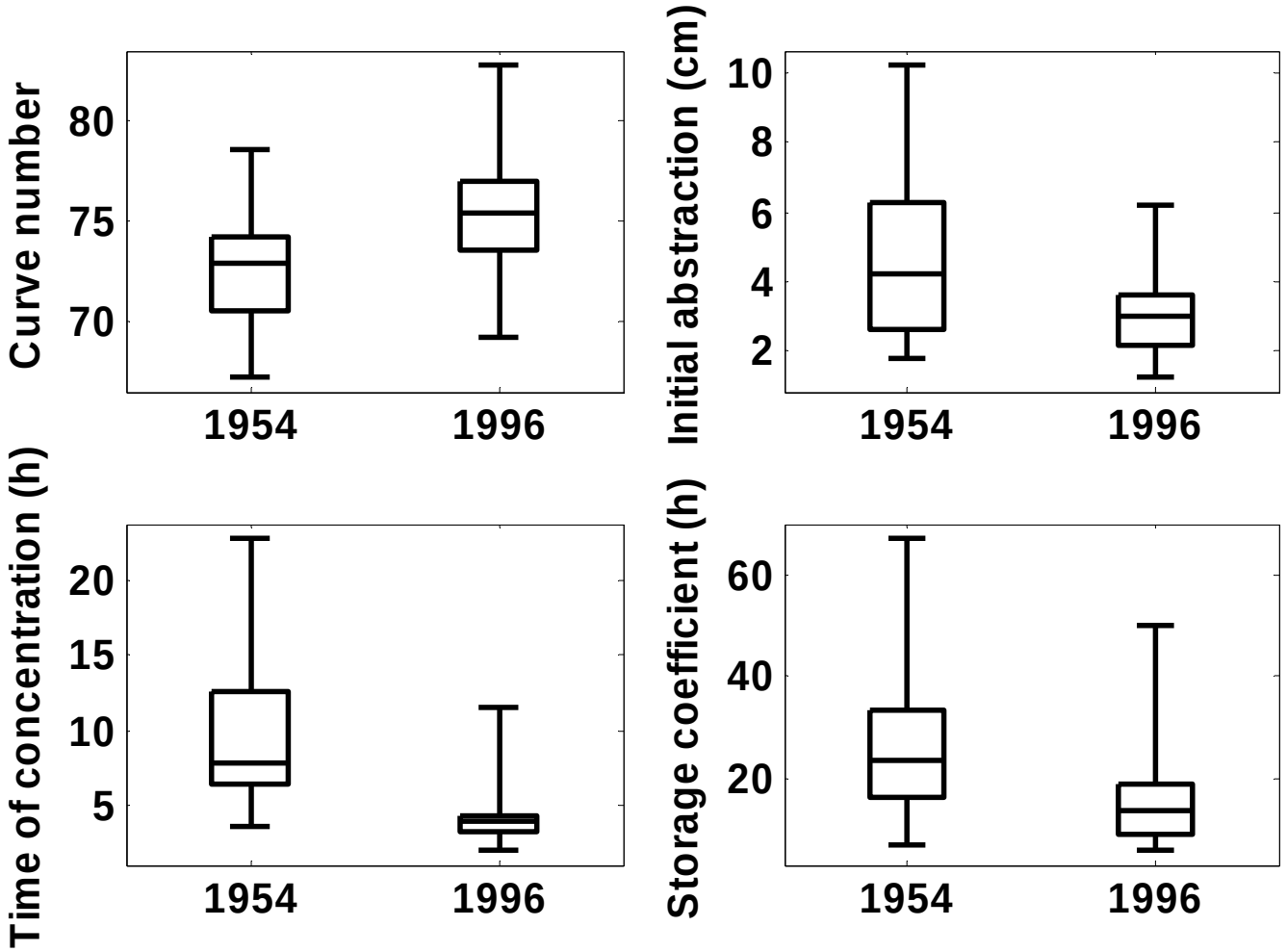


Calibration 1996



CALIBRATED PARAMETERS

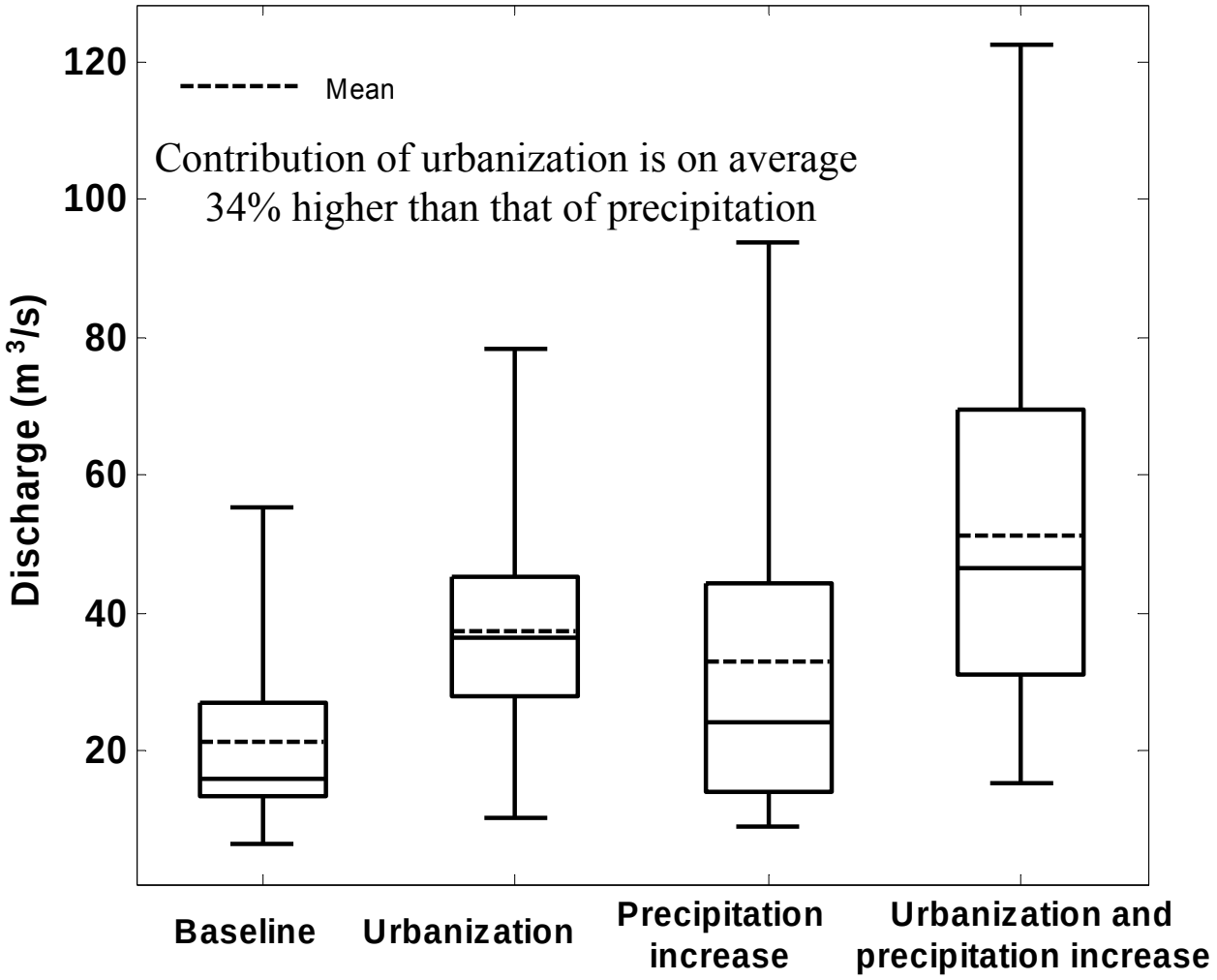
Hydrologic Model HEC-HMS Parameters



Relative contributions of the changes in land-use and in precipitation to increasing floods?

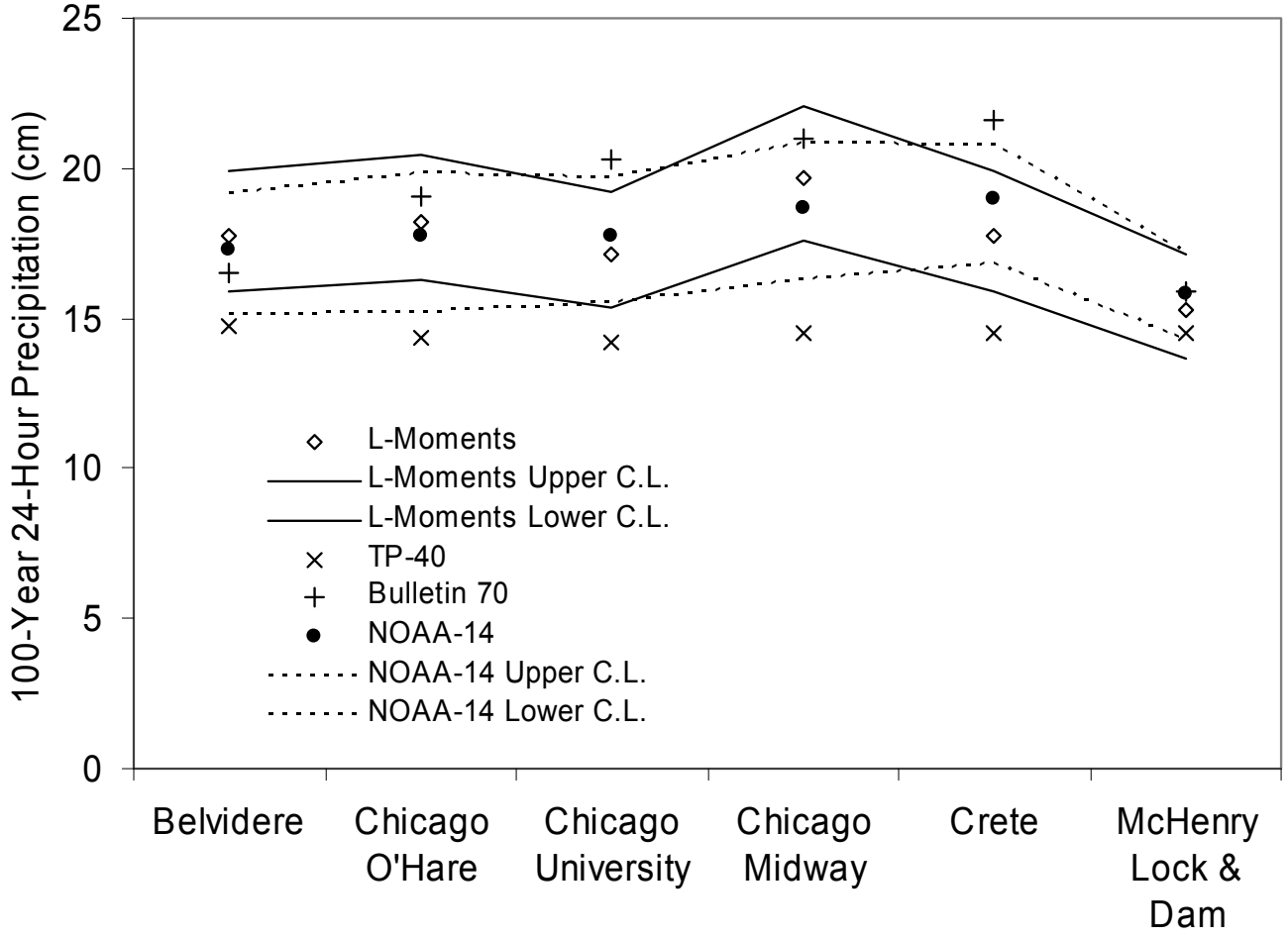
RAINFALL / LAND-USE	BEFORE (TP- 40)	AFTER (NOAA-14)
BEFORE (LAND-COVER 1954-1961) Hydrologic parameters OCTOBER 1954	BASELINE ("before")	ONLY RAINFALL CHANGED
AFTER (LAND-COVER 1999) Hydrologic Parameters JULY 1996	ONLY LAND-USE CHANGED	RAINFALL AND LAND-USE CHANGED ("after")

Individual Contributions of Urbanization and Precipitation Increase

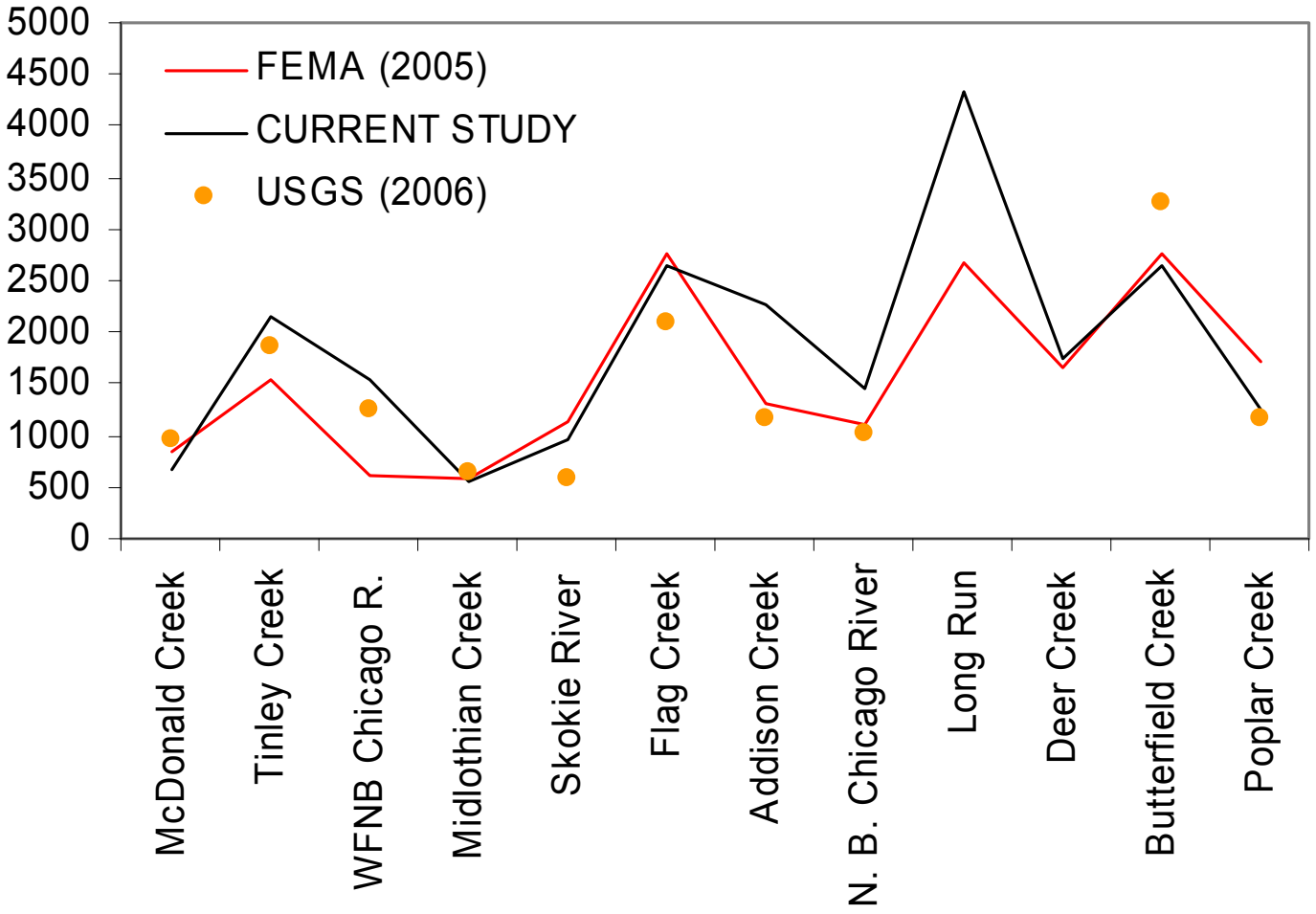


Comparison with published results

Design precipitation based on different studies



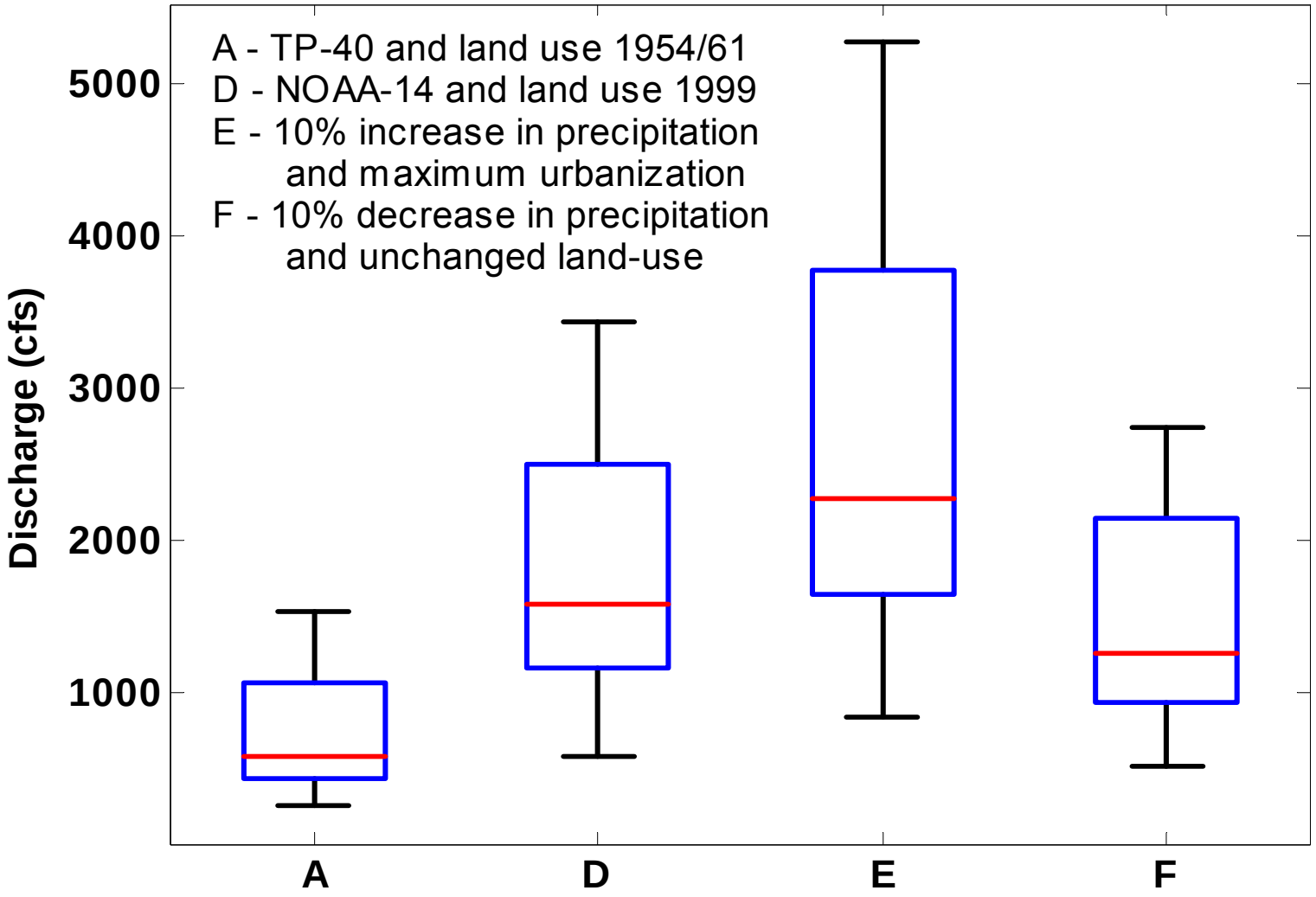
Base flood discharges for different studies



USGS (2006) = Moglen, G. E., and Shivers, D. E. (2006). "Methods for adjusting U.S. Geological Survey rural regression peak discharges in an urban setting." U.S. Geological Survey Scientific Investigations Report 2006-5270, 55 p.

HYPOTHETICAL SCENARIOS

Future precipitation and urbanization – arbitrary scenarios



Conclusions

- Flood peaks on small watersheds in NE Illinois in most cases significantly increased which is explained by precipitation increase and land-use change (urbanization).

- The contribution of the urbanization was on average 34% larger than the contribution of precipitation increase.

- Current (2009) discharges are on average at least 19% larger than the regulatory discharges (FEMA, 2005)

- This study determined which watersheds have highest discrepancies between published regulatory discharges and flood discharges calculated in this study. This information could be used to prioritizing future studies.

- The framework developed in this study also can be used as a planning tool to evaluate various future scenarios.

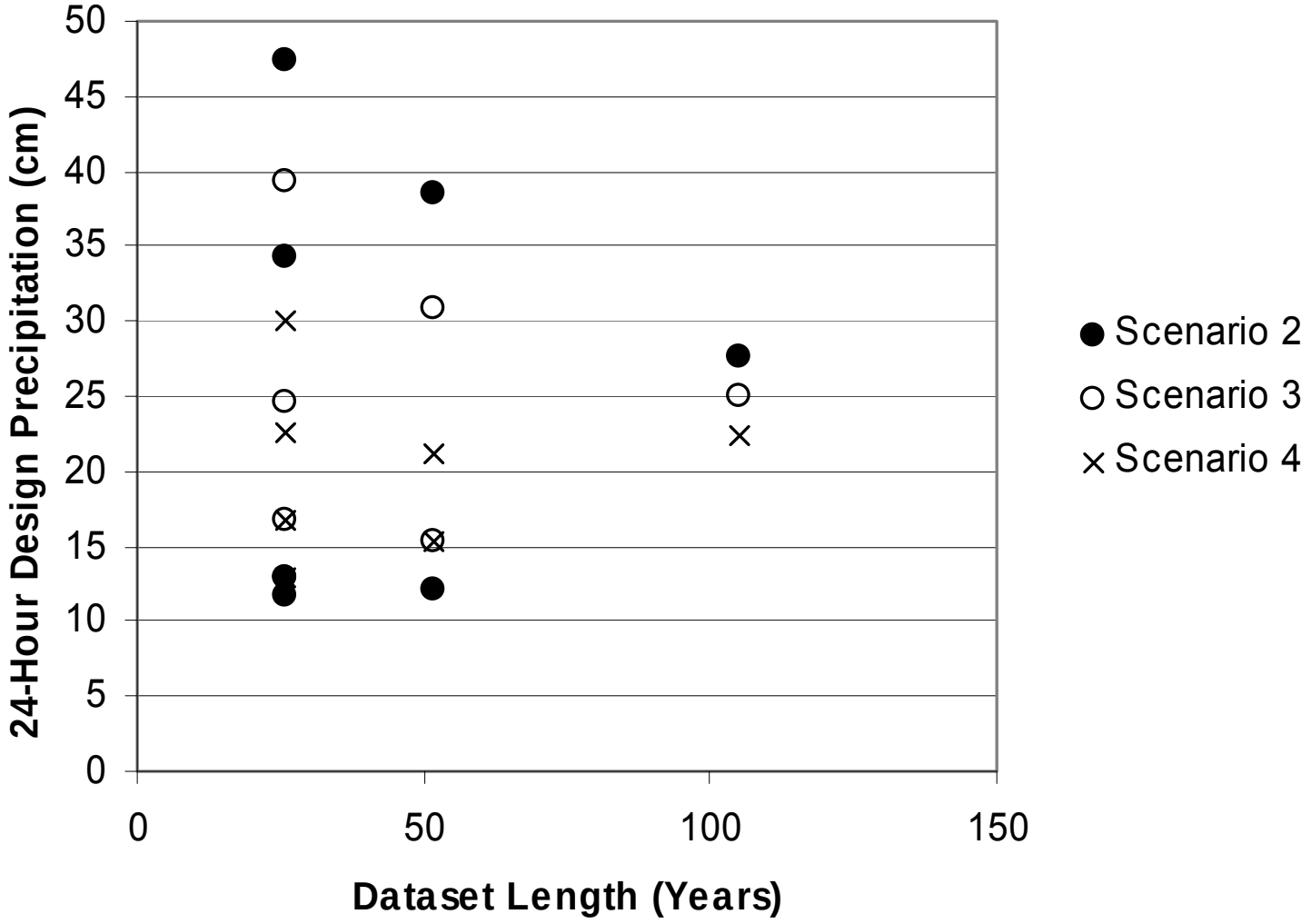
Questions?

- The 100-year precipitation values calculated in this study are within one percent of those given by NOAA-14 (2004/05), approximately 7.0% less than Bulletin 70 (1989), and 15.5% larger than TP-40 (1961).

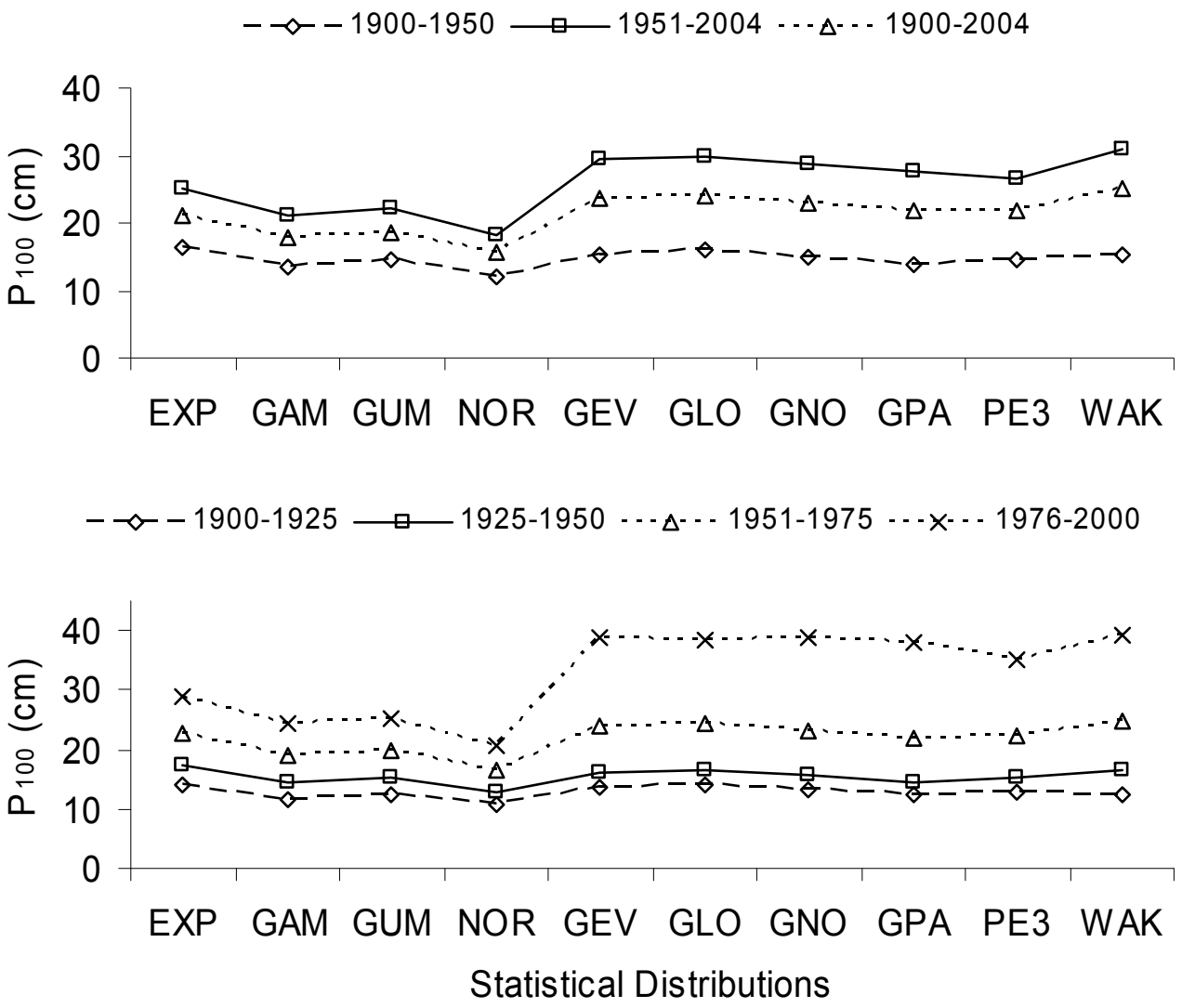
- The uncertainty based on 25- or 50-year records (up to 300%) far exceeded those based on the selection of statistical distribution (100%), region (30%), and precipitation analysis method selection (<2%)

Sensitivity Analysis at Aurora College station

Uncertainty of P100 estimates at Aurora College based on record length and scenario



Aurora College (six station scenario)



100-year flood has a 1-percent chance of being equaled or exceeded in any given year

100-year floods are used in planning, design, flood insurance, etc.

Chicago Flood Potential is Higher than Expected

Published: Aug. 2, 2007

Source: Momcilo Markus (217) 333-0237; momcilo@sws.uiuc.edu

URBANA - Flood peaks in the Chicago metropolitan area are higher than they used to be, and they are also higher than estimates currently used by water managers, according to an Illinois-Indiana Sea Grant study.

"Estimating future flood peaks accurately is critical in terms of allocating resources to minimize damage from these events," said Momcilo Markus, a researcher at the Illinois State Water Survey who studied Chicago area flood trends using data from the U.S. Geological Survey and NOAA. "Underestimating or overestimating 100-year flood levels can result in large economic losses on one hand or increased environmental degradation on the other."

He found that the steady increase in flood discharges in small streams over the past 100 years is due to increases in urbanization and precipitation, with urbanization playing the major role.

It's no surprise that urbanization has increased dramatically in the region. "Between 1954 and 1999, urbanization, on average, increased from about 11 percent to 62 percent in the 12 Chicago area watersheds in our study," said Markus.

Urban areas, unlike agricultural or forested areas, have hard surfaces such as roofs, parking lots and sidewalks, which cause water from large storms to rush into nearby storm sewers and waterways instead of being absorbed into the ground. Add to this an increase in frequency and intensity of heavy precipitation and the result is higher flood levels.

University of Illinois at Urbana-Champaign - Mozilla Firefox

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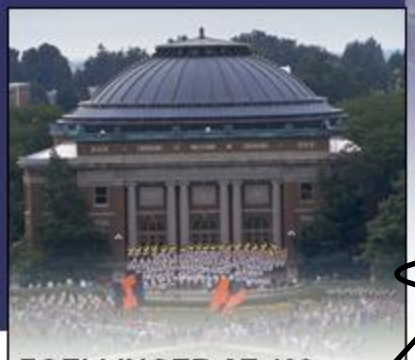
Services
Administration
Arts & Culture
Community
International
Sports & Recreation



FOELLINGER AT 100

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United Press International - A study led by Yang Yang in kinesiology and community health suggests traditional Chinese exercise might increase the efficacy of annual flu vaccines.

brilliant futures
THE CAMPAIGN FOR THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Calendars

18 Aug Move In Day Picnic
20 Aug New Student Convocation
21 Aug New Academic Staff Welcome
22 Aug Fall Semester Instruction Begins
28 Aug Farm Progress Show
04 Sep Study Abroad Fair
06 Sep Global Infotech Symposium

Announcements

Big Ten Network names football announcers
Introducing 'Always Illinois'
Online forms for Student/Staff Directory

Chancellor:
NSF endorses Illinois for petascale project

Journal of Hydrologic Engineering

- Hejazi, M., and Markus, M., 2009, Impacts of Urbanization and Climate Variability on Floods in Northeastern Illinois, Journal of Hydrologic Engineering. (in June 2009 issue)

Journal of Hydrology (2007) 347, 211–222

available at www.sciencedirect.com

journal homepage: www.elsevier.com/locate/jhydrol

Changing estimates of design precipitation in Northeastern Illinois: Comparison between different sources and sensitivity analysis

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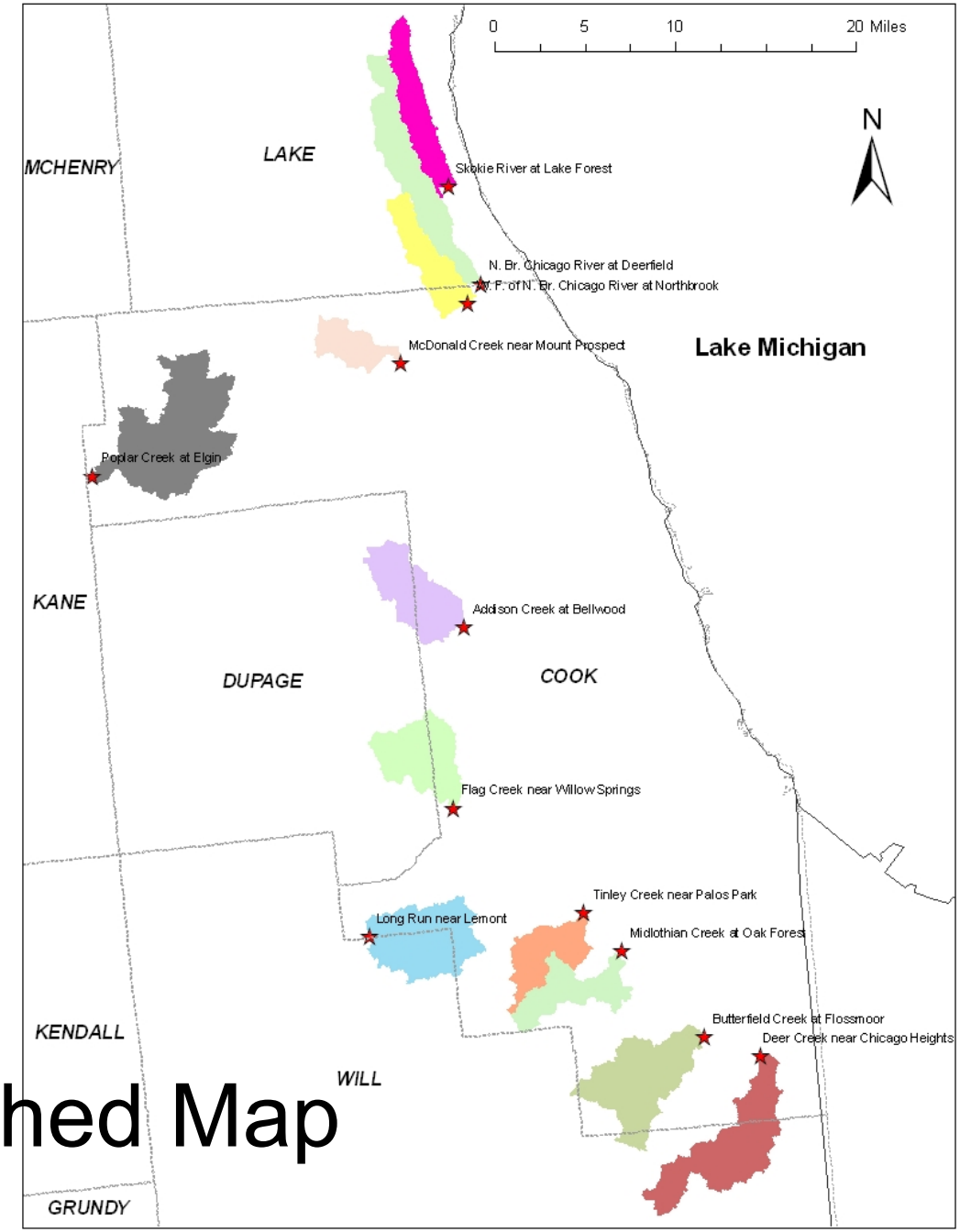
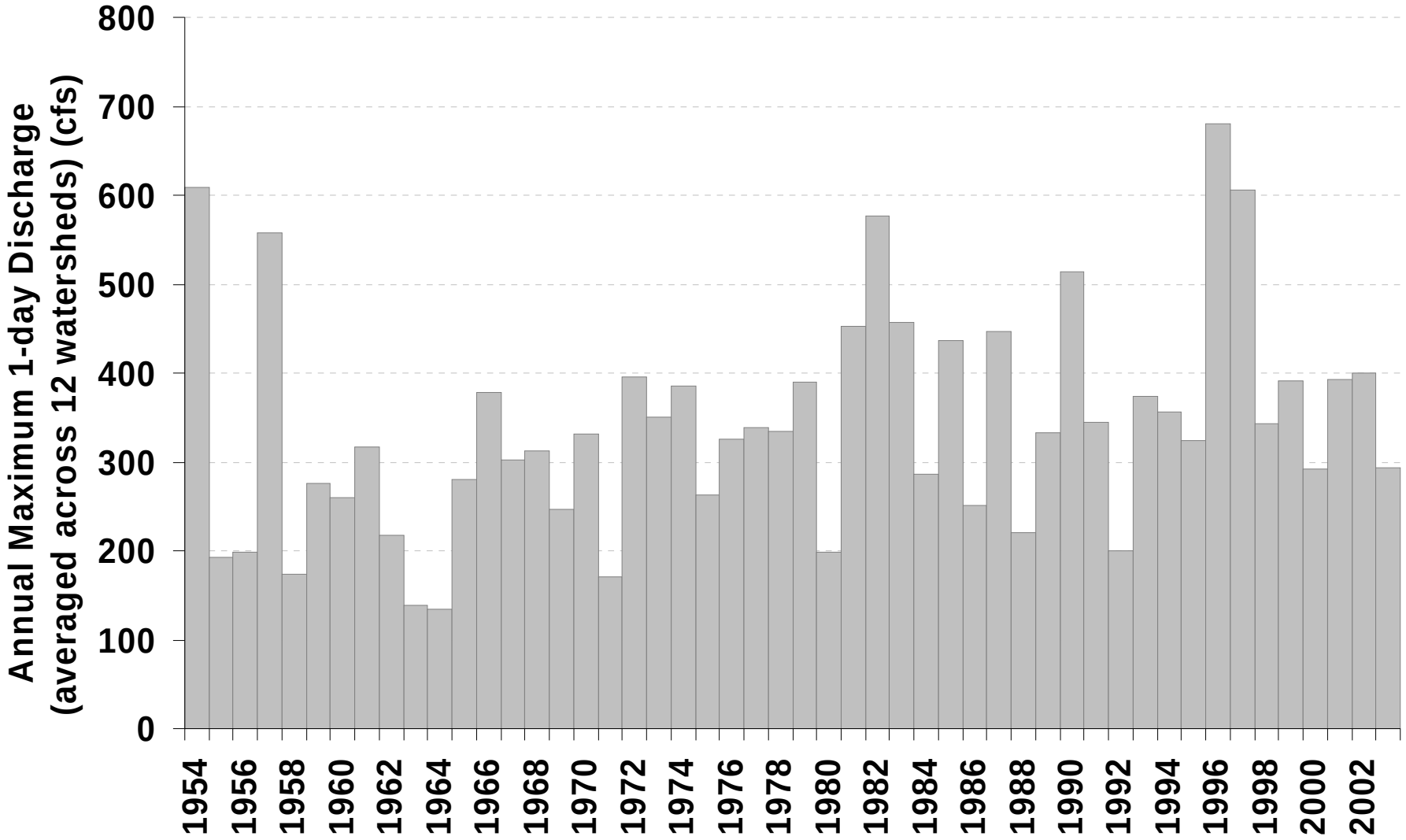
Watershed Map




Annual Maximum 1-day Discharge
(averaged across 12 watersheds) (cfs)
800
700
600
500
400
300
200
100
0
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

Stream gages

No.	Stream Name	USGS Station	County	Begin Date	End Date	Drainage Area (mi^2)
1	McDonald Creek	5529500	Cook	1953	2005	7.9
2	Tinley Creek	5536500	Cook	1952	2005	11.2
3	West Fork N. Branch Chicago R.	5535500	Cook	1953	2005	11.5
4	Midlothian Creek	5536340	Cook	1951	2005	12.6
5	Skokie River	5535000	Lake	1952	2005	13
6	Flag Creek	5533000	Cook	1952	2005	16.5
7	Addison Creek	5532000	Cook	1952	2005	17.9
8	North Branch Chicago River	5534500	Lake	1953	2005	19.7
9	Long Run	5537500	Cook	1952	2005	20.9
10	Deer Creek	5536235	Cook	1949	2005	23.1
11	Butterfield Creek	5536255	Cook	1949	2005	23.5
12	Poplar Creek	5550500	Cook	1952	2005	35.2

Precipitation Stations

NCDC#	Name	Begin	End	Daily/Hourly
110583	Belvidere	1948	2004	Hourly
111549	Chicago O'Hare_	1962	2004	Hourly
111572	Chicago University	1948	1994	Hourly
111577	Chicago Midway	1948	2004	Hourly
112011	Crete	1948	2004	Hourly
115493	McHenry Lock & DAM	1948	2004	Hourly
115136	Lockport Power House	1948	1974	Hourly
110338	Aurora College	1900	2004	Daily
112223	De Kalb	1969	2004	Daily
114530	Joliet Brandom	1948	2004	Daily
114535	Joliet	1896	1974	Daily
119221	Wheaton 3 SE	1896	2004	Daily

Selection of Calibration Data

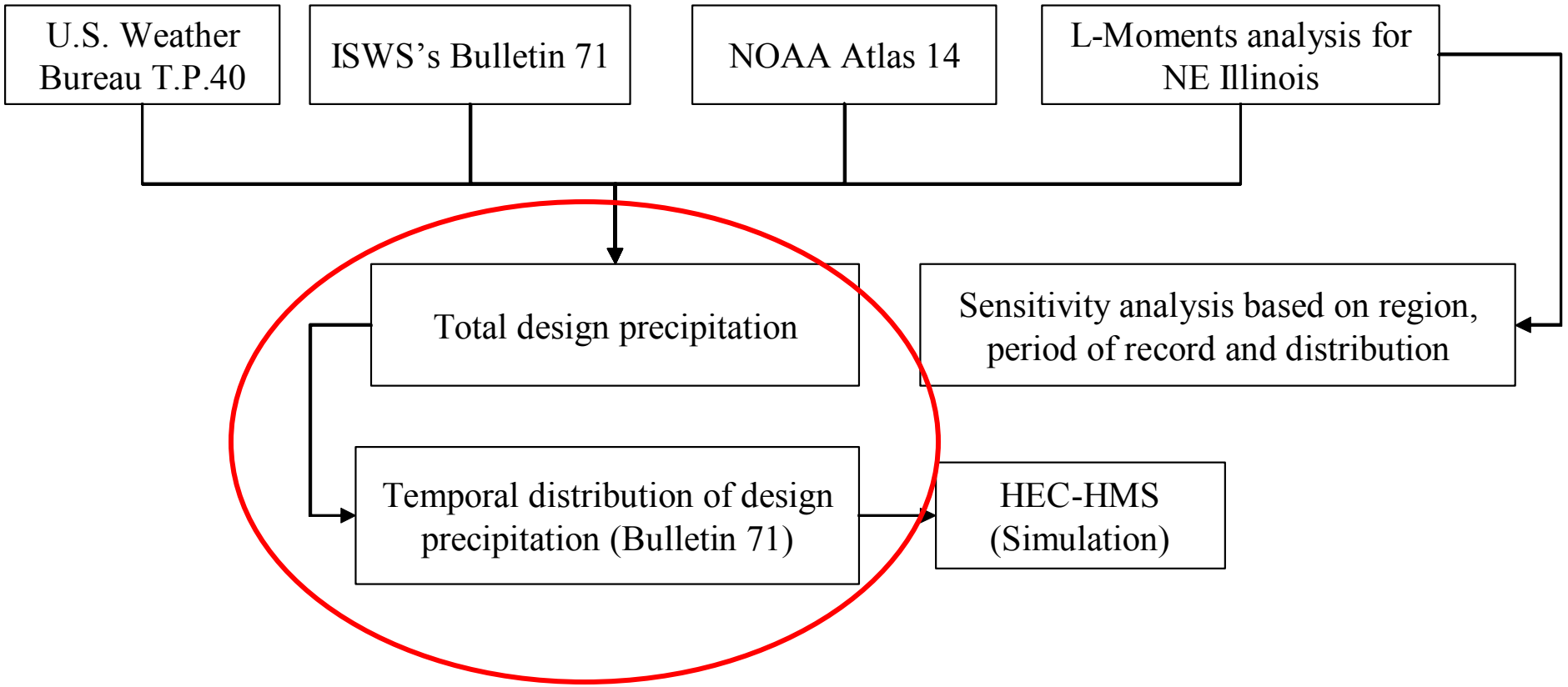
- Hourly data available for 1954 and 1996 events for the subject watersheds
- These flood events produced the largest average annual maximum daily discharges for the period of record
- Selected watersheds experienced significant urbanization between 1954 and 1996

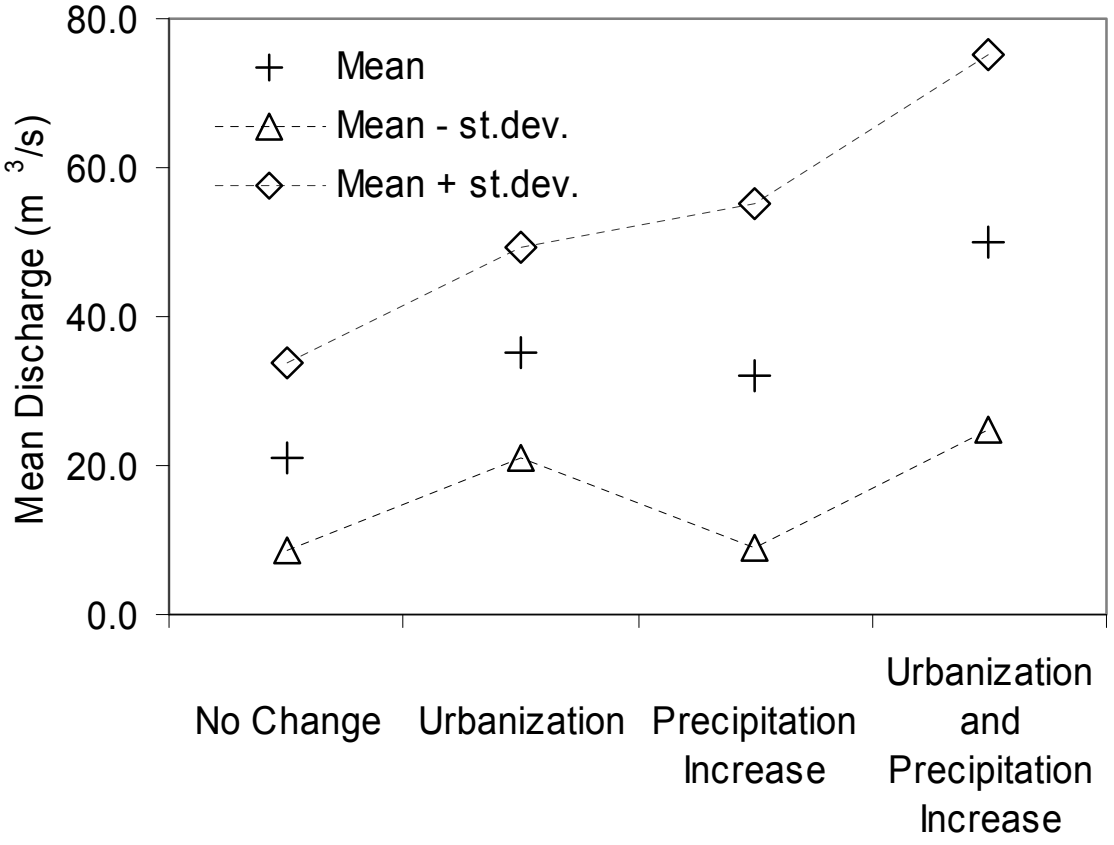
Data Sources:

- Daniels, W. S., and Hale, M. D. (1958). “Floods of October 1954 in the Chicago area, Illinois and Indiana.” U. S. Geological Survey Water-Supply Paper 1370-B.
- Holmes, R. R., Jr., and Kupka, A. L. (1997). “Floods of July 18-20, 1996, in Northern Illinois.” U. S. Geological Survey OFR 97-425.

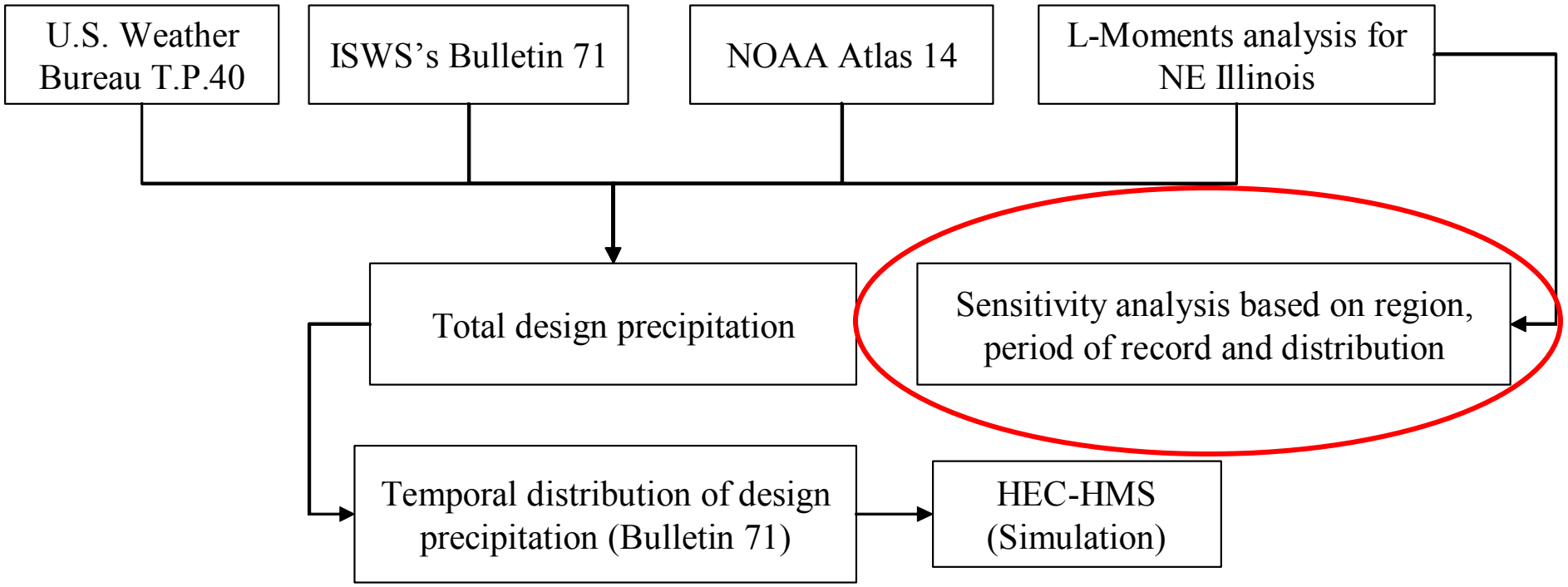
Design Storm Selection

Comparison between different sources, sensitivity analysis and hydrologic impact

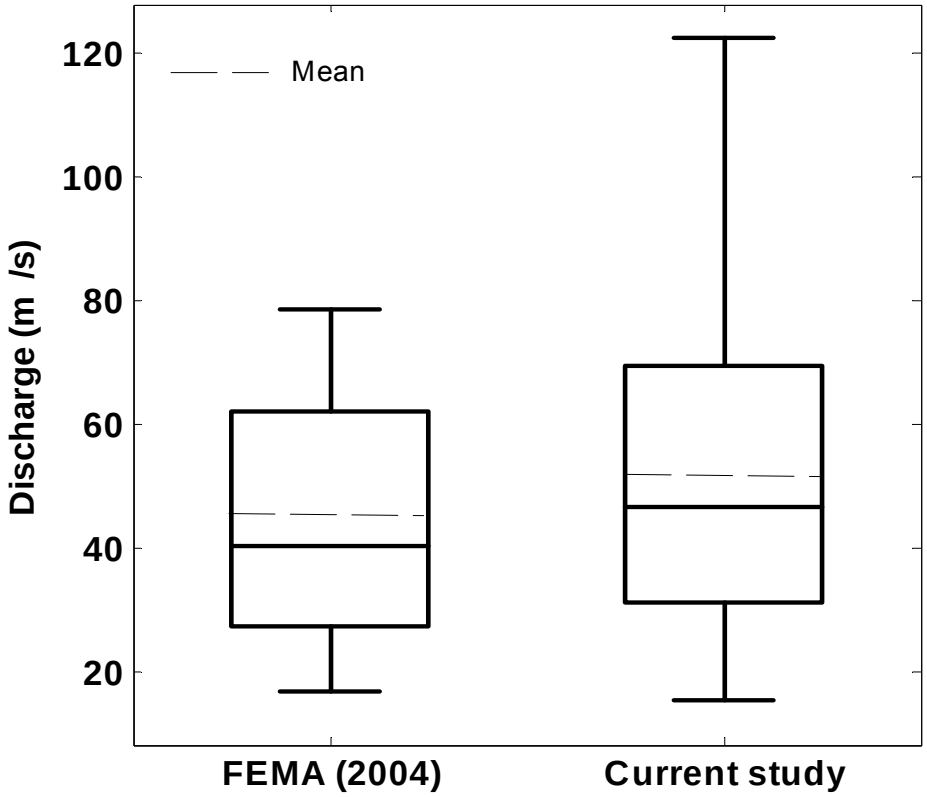



80.0
60.0
40.0
20.0
0.0
Mean Discharge (m 3/s)
Mean
Mean - st.dev.
Mean + st.dev.
No Change
Urbanization
Precipitation Increase
Urbanization and Precipitation Increase

Comparison between different sources, sensitivity analysis and hydrologic impact



100-year discharges for different studies



The calculated discharges are on average 19% larger than the regulatory discharges (FEMA, 2004)

Design precipitation based on different studies