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Updated Urban Regional Flood Frequency for Illinois: Adjusting Peak Streamflow Records for the Effect of Urbanization and Next Steps

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U.S. Department of the Interior
U.S. Geological Survey

History

- Met with IDOT, IDNR-OWR, and USACE-Chicago to propose study in 2009.
- In 2010 USACE-Chicago agreed to fund phase 1: adjustment of the station records for urbanization that occurred during the period-of-record.
- That phase is now essentially finished.
- Will meet again next week with cooperators (including IDOT) to discuss/plan next steps.

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Purpose of Today’s Presentation

- Describe phase 1 results.
- Propose and discuss next steps.

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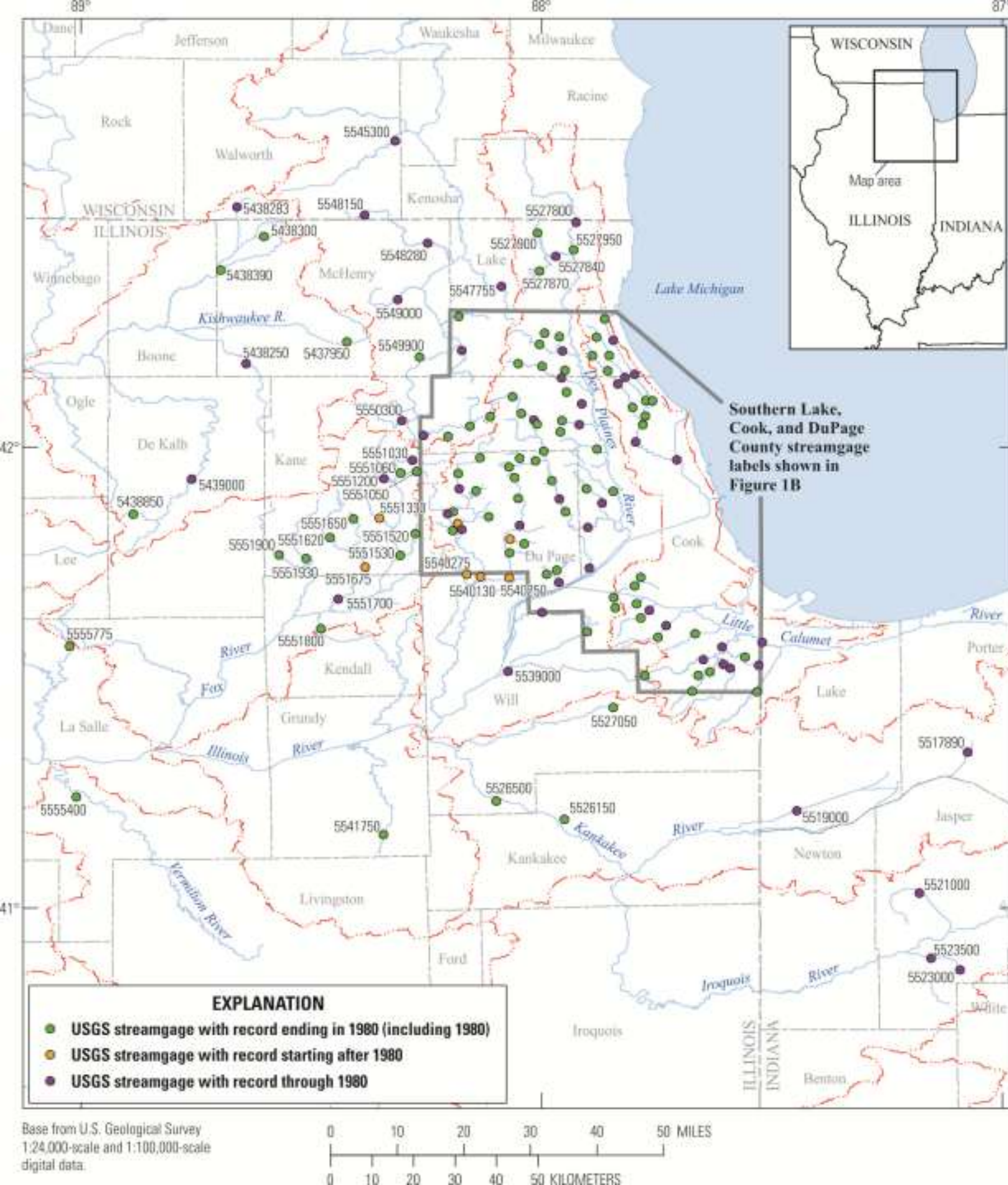
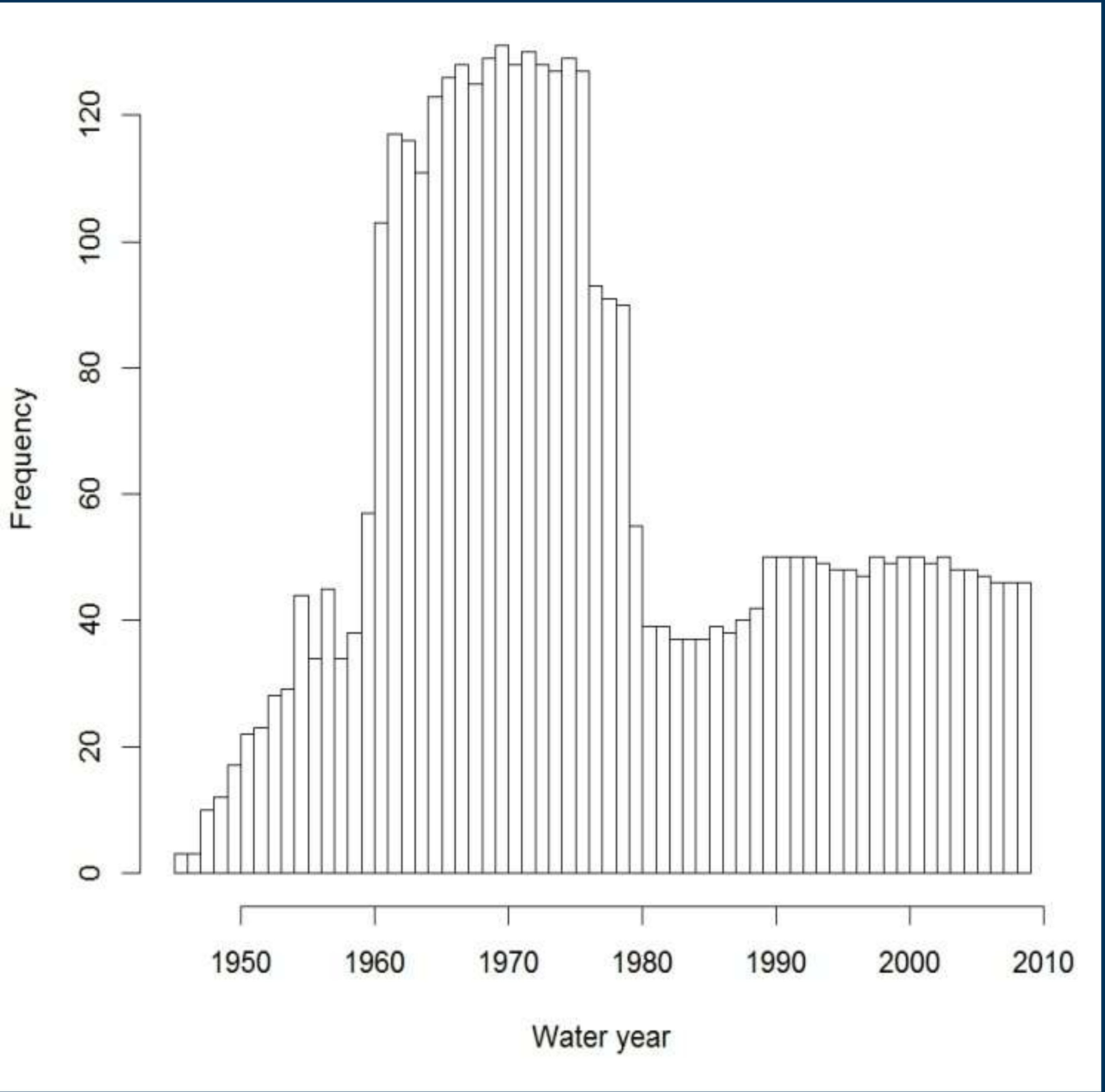


Stations available for study

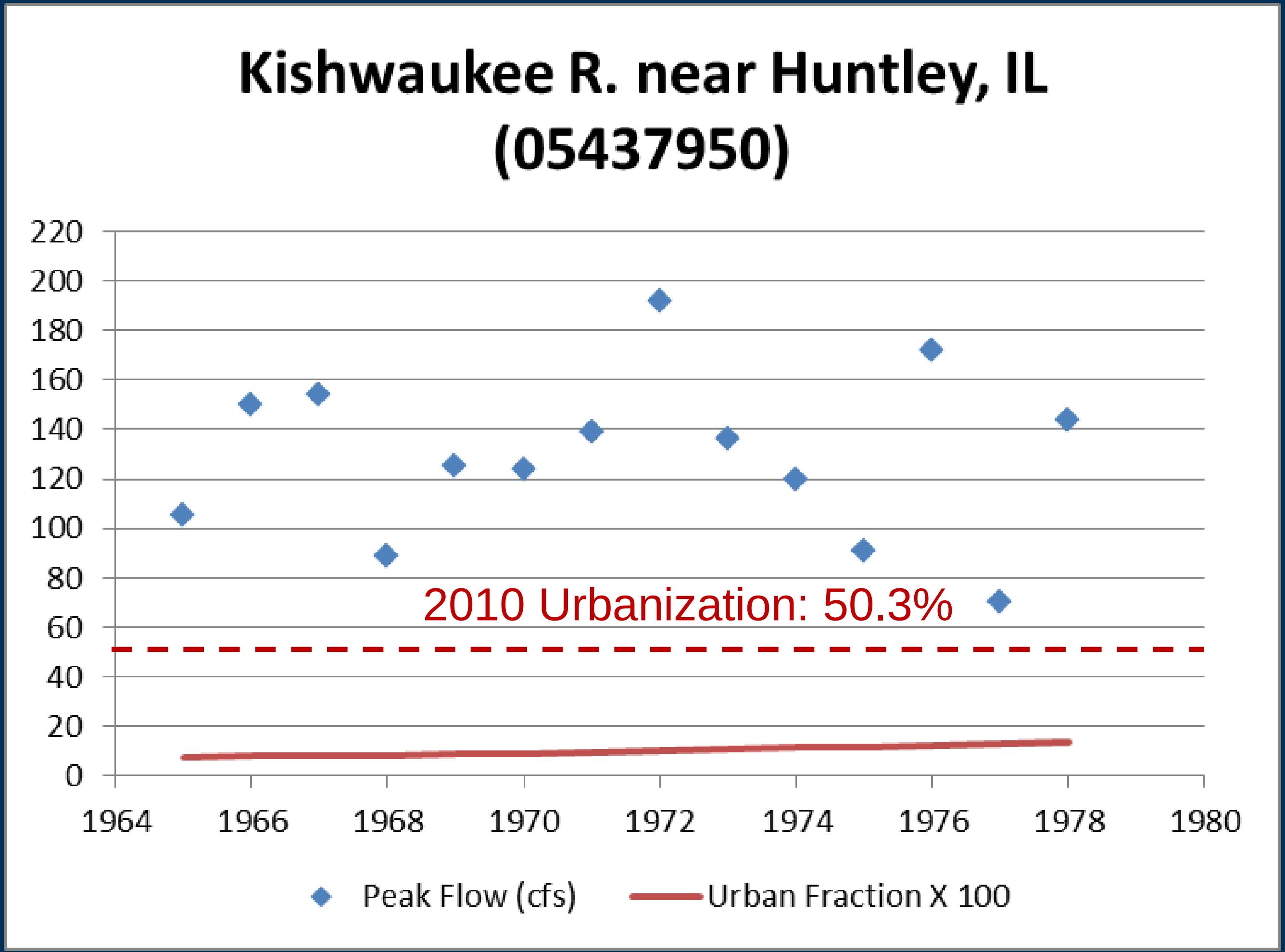
- 143 Stations with
  - > 10 years of record
  - Drainage Area (DA) < 200 sq. mi.
- Pre-1980 Records:
  - 83 ended by 1979
  - 82 of these were CSGs (note: have smaller DA values)
- Used record from 1945-2009



Number of stations available each year of study

What's the Problem?
1. Old Records

- Can't use at-site record now.
- To use in a regionalization study, need land use during 1970s.



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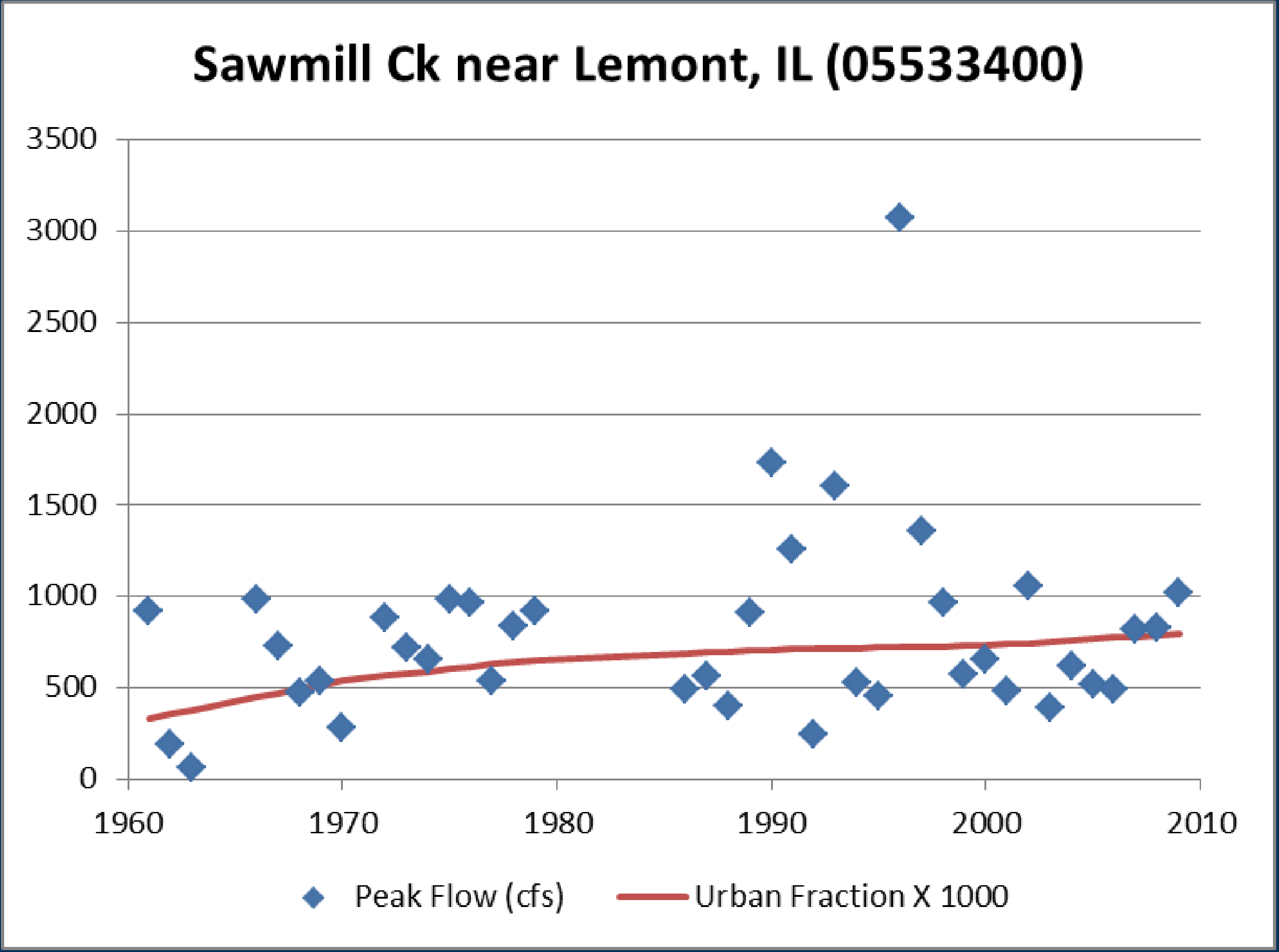
What's the Problem?

2. Records with urbaniza-tion-related trends.



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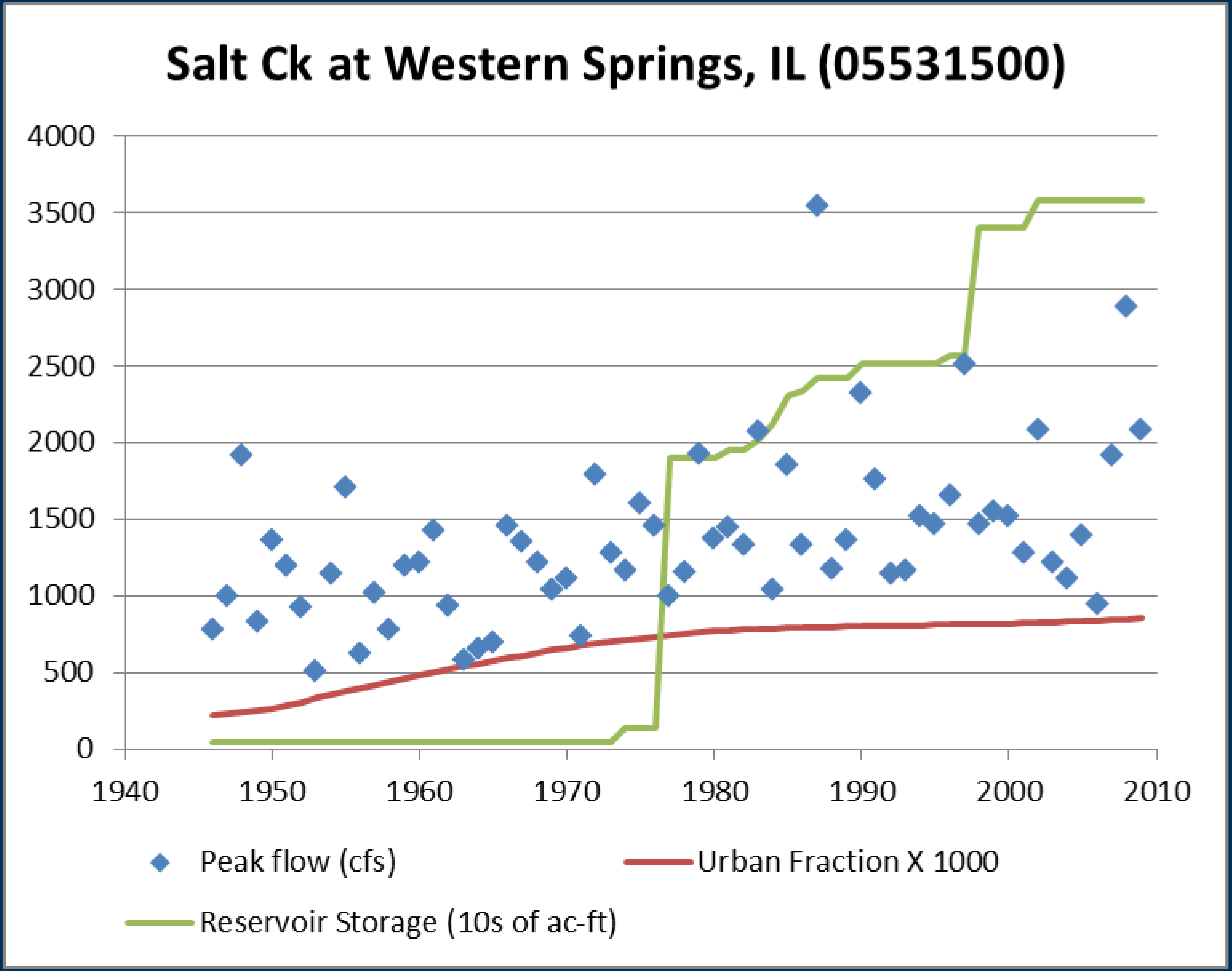
What's the Problem?

3. Trendy records with added flood control facilities



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Approaches to analysis of urban watersheds with changing conditions

- Usual approach:
  - *Truncate* record to most convenient quasi-stationary condition (usually most recent)
- Alternative approach:
  - *Adjust* record to some reference condition
- Advantages of adjustment approach:
  - Uses more of the record
  - Obtain estimates of effects of causal factors
  - Adjusted record available for at-site analyses

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Classes of causes of changes in flood peak distributions in urban watersheds

- Urbanizing land use:
  - increased imperviousness (direct and indirect)
  - compacted soils
  - gutters and storm drains
  - may or may not have detention basins
- Changes to the river:
  - reservoirs
  - channel improvements
- Climatic variation (same issue in rural).

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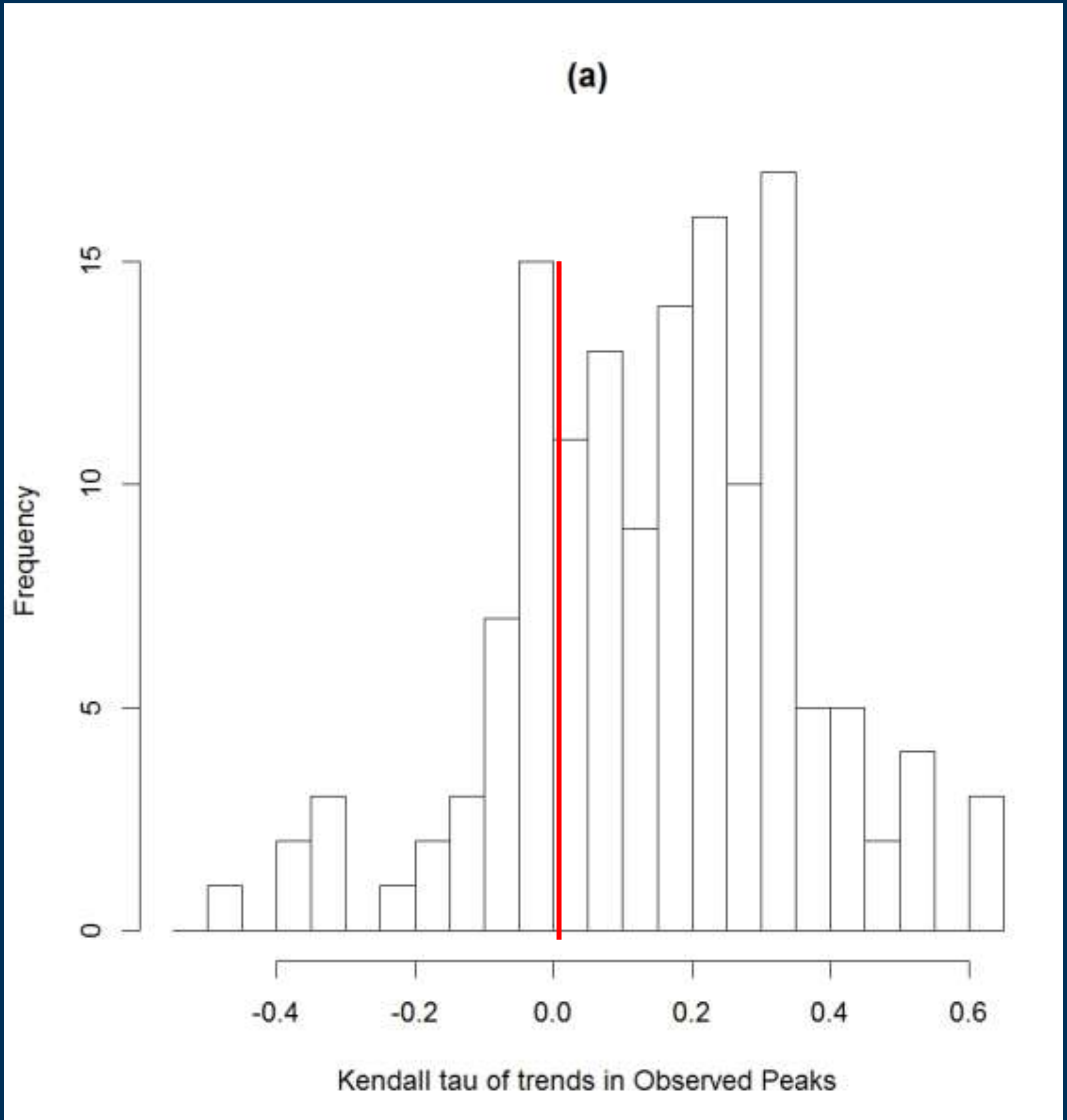

Trends in peak flow at stations in study

How much caused by

- **land use change**
- **changes to the river**
- **climatic variation?**

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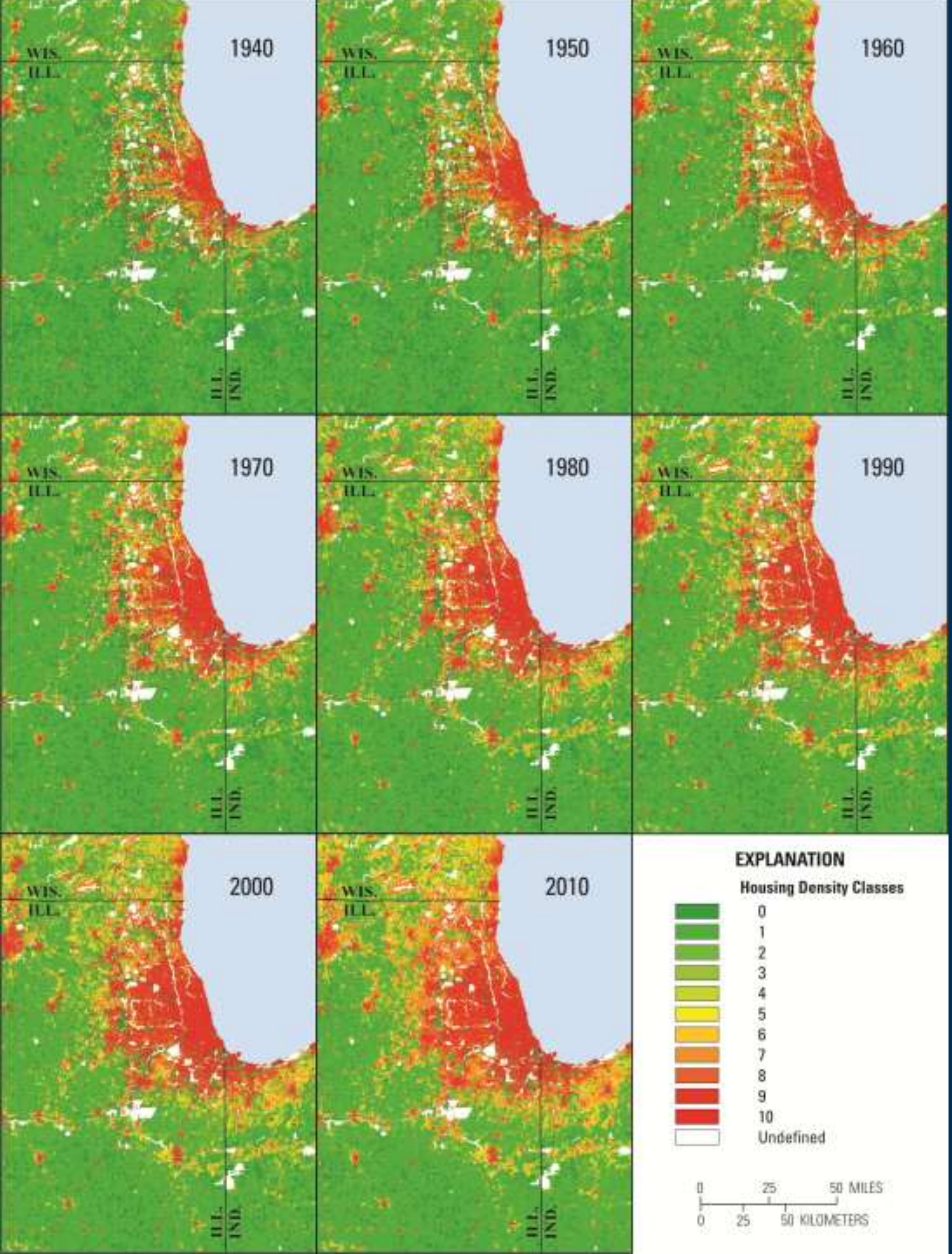

Land use data

- Census-based housing density data from Theobald (2005), classes 7-10:
- "Urban" in study:

< 10 acre lots plus commercial / industrial / transportation.

Reservoir information

- **Locations, date of construction, capacity obtained from National Inventory of Dams and other sources.**
- **IDNR, MWRDGC, and County staff assisted in verifying / correcting information.**
- ***Records broken into segments* at years when reservoirs of significant capacity and drainage area were built in watershed.**

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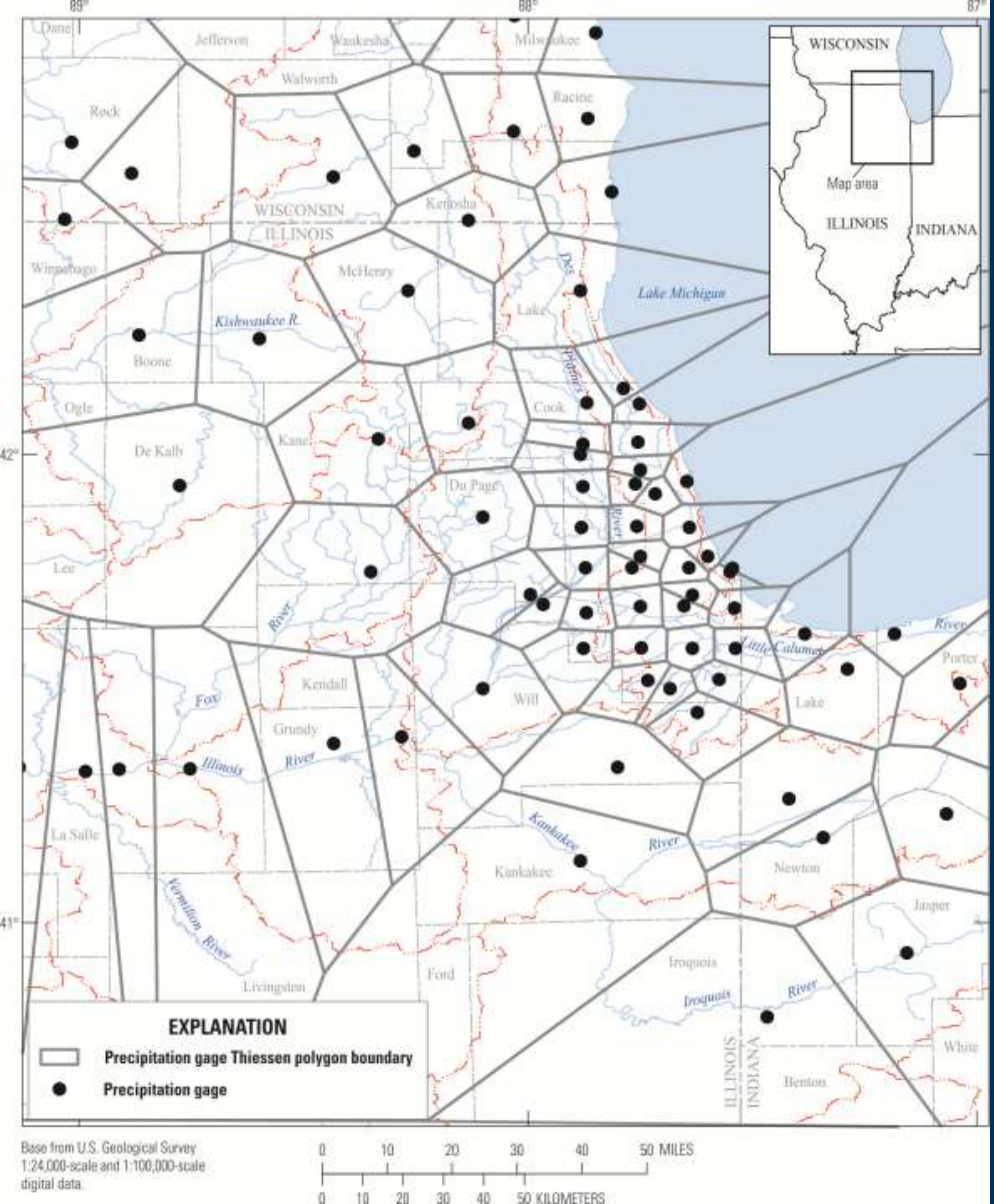

Precipitation data

- Daily time step (more stations)
- Distributed with Thiessen polygons
- Used maximum value from 3 days before to 1 day after date of peak.

Fitted regression model

For each segment *i* and year *t*,

$$\log_{10} Q_p(i,t) = a(i) + 0.5117U(i,t) + 0.0846P(i,t) + e(i,t),$$

where

Q_p = annual maximum flood peak

a = intercept: one per segment

U = urbanized fraction of watershed

P = maximum daily precipitation

e = error term

Notice *U* and *P* coefficients are assumed to apply to all segments (station records); they are *regional* coefficients (necessary for adjustment of old records).

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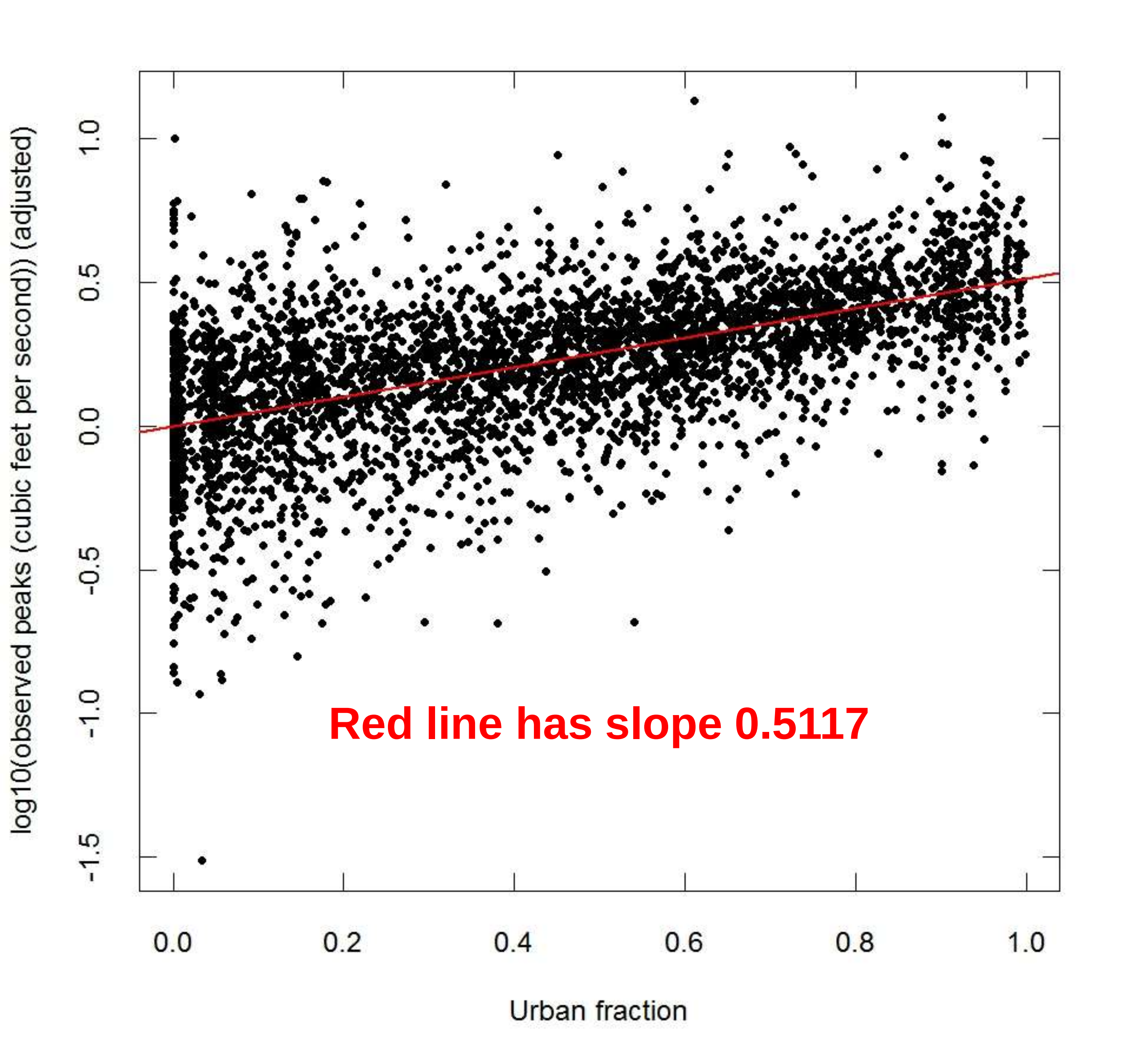
Dependence of logQ_p on urbanization



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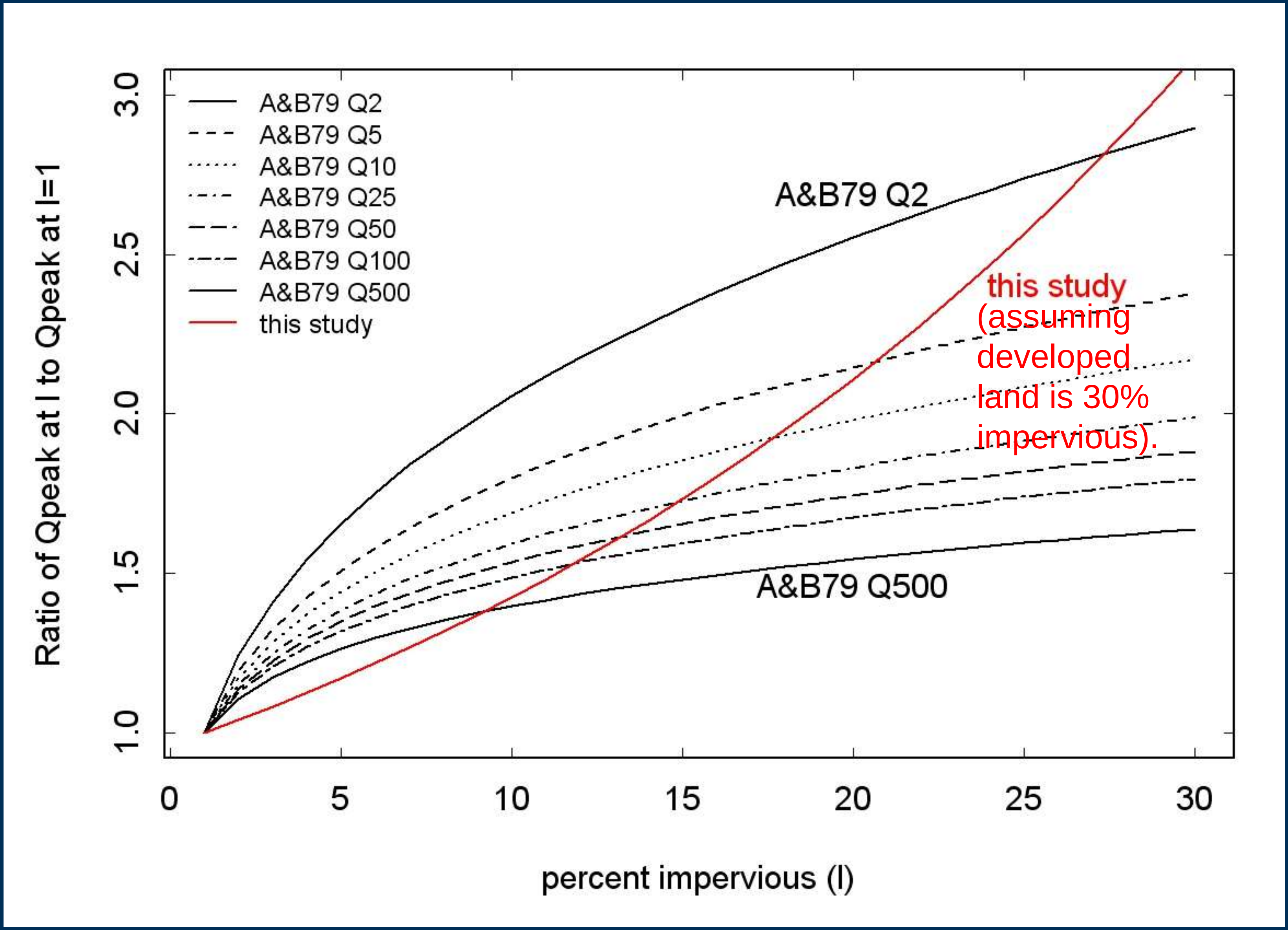
Comparison with Allen & Bejcek (1979)



Adjustment of peak flows

Fitted model was:

$\log_{10}Q_p(i,t) = a(i) + 0.5117U(i,t) + 0.0846P(i,t) + e(i,t)$.

To adjust to year 2010 urbanization:

$\log_{10}Q_{p,2000}(i,t) = \log_{10}Q_p(i,t) + 0.5117[U(i,2010) – U(i,t)]$

Examples:

- If *U* increases by 10%,

  Q_p increases $10^{0.1*0.5117} = 1.125 = 12.5\%$
- If *U* increases by 100%,

  Q_p increases $10^{1.0*0.5517} = 3.249 = 225\%$

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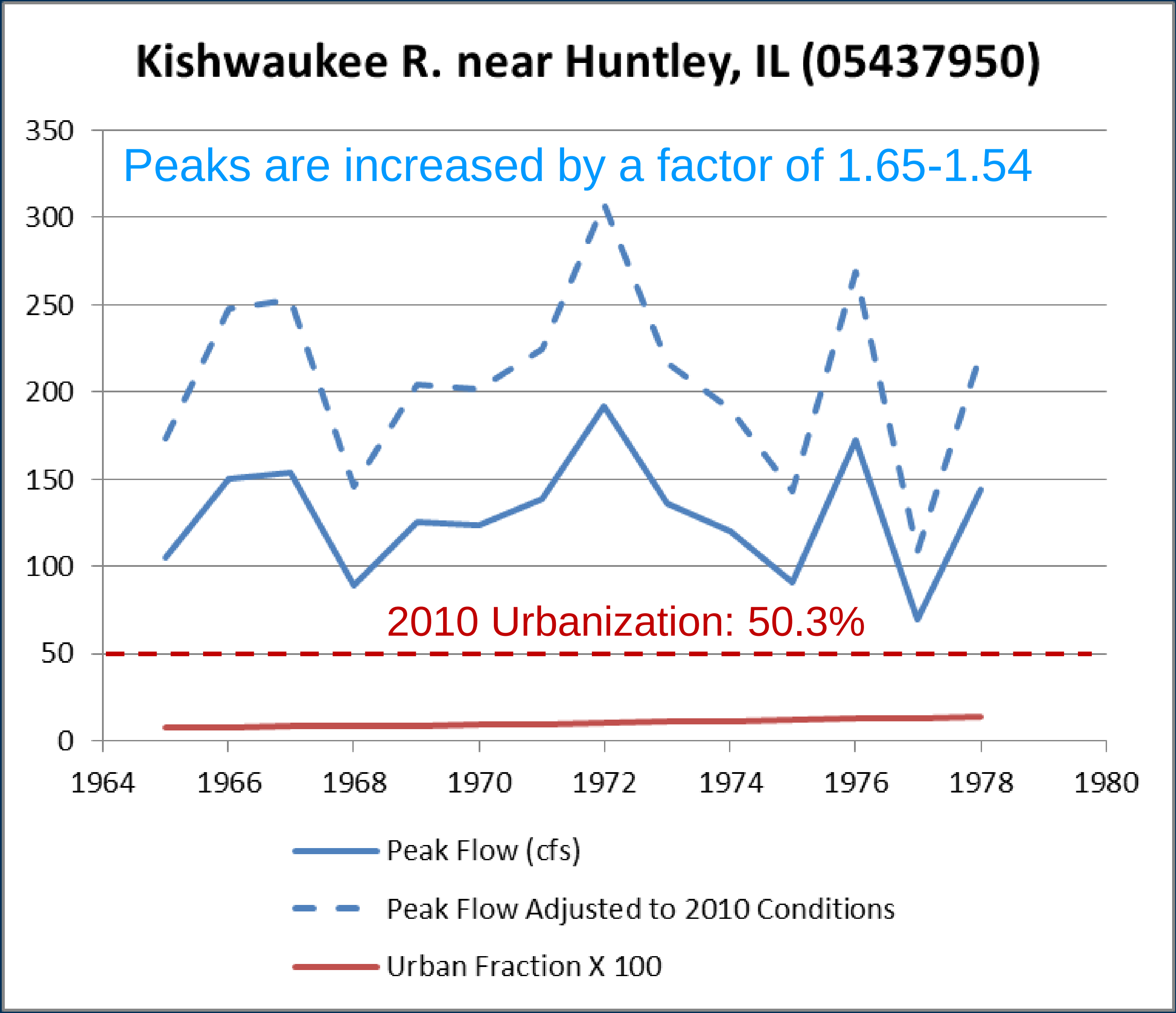
Example of Adjusted Record - Simple

Note: Assumes no “changes to the river” since end of record..



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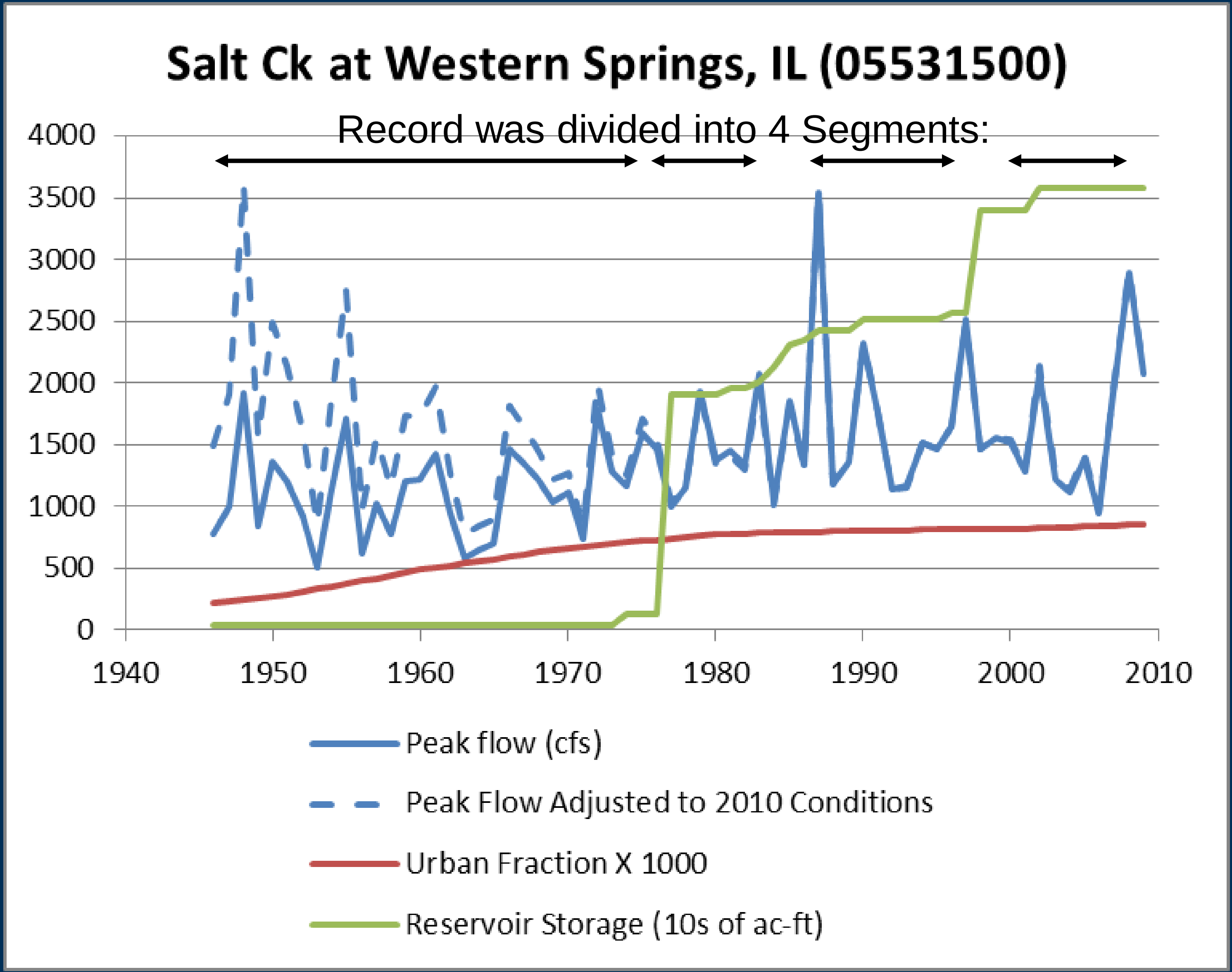
Example of Adjusted Record - Segmented



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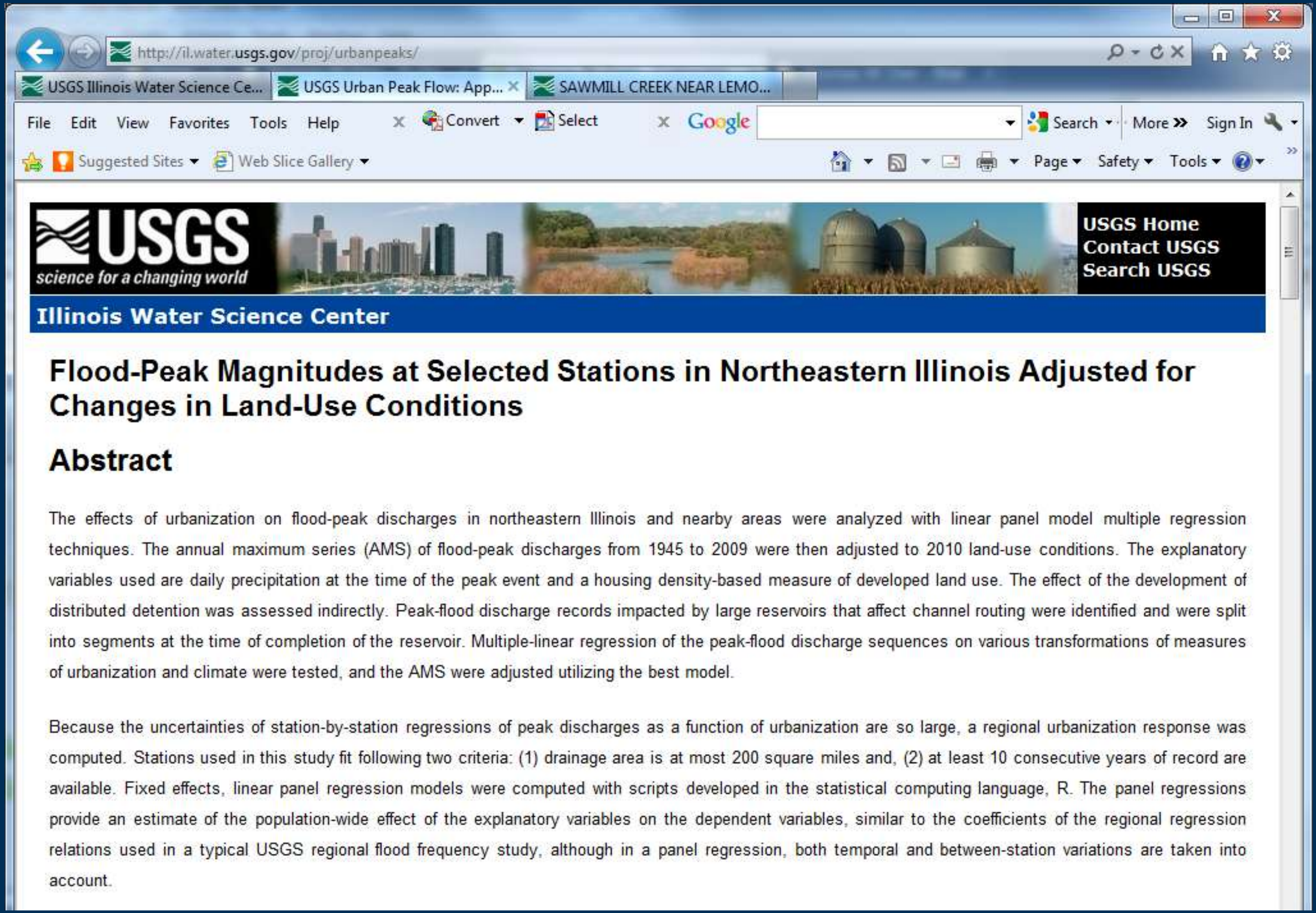
Adjusted peaks (under review) for all the stations are posted at a web page:



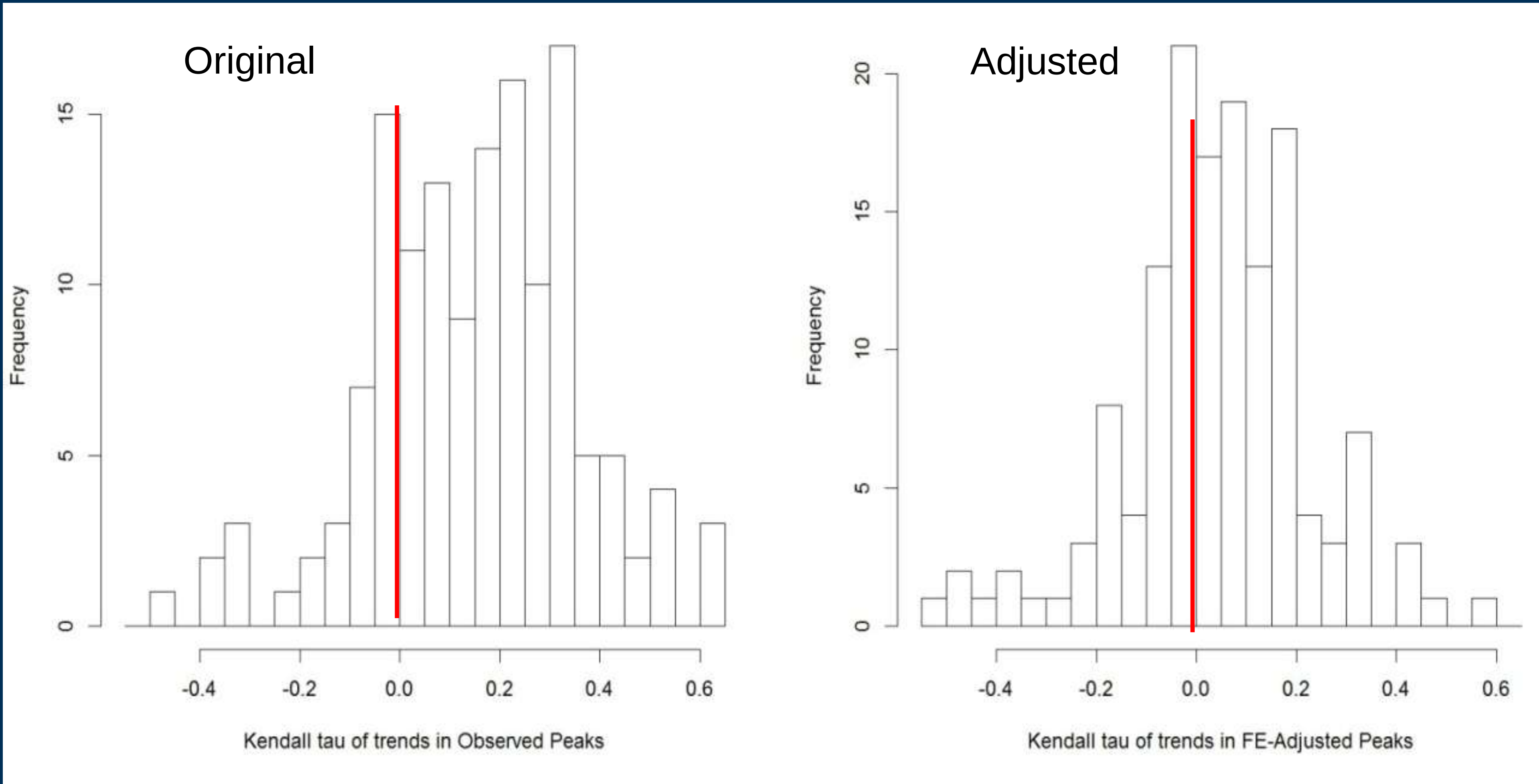
Flood-Peak Magnitudes at Selected Stations in Northeastern Illinois Adjusted for Changes in Land-Use Conditions

Abstract

The effects of urbanization on flood-peak discharges in northeastern Illinois and nearby areas were analyzed with linear panel model multiple regression techniques. The annual maximum series (AMS) of flood-peak discharges from 1945 to 2009 were then adjusted to 2010 land-use conditions. The explanatory variables used are daily precipitation at the time of the peak event and a housing density-based measure of developed land use. The effect of the development of distributed detention was assessed indirectly. Peak-flood discharge records impacted by large reservoirs that affect channel routing were identified and were split into segments at the time of completion of the reservoir. Multiple-linear regression of the peak-flood discharge sequences on various transformations of measures of urbanization and climate were tested, and the AMS were adjusted utilizing the best model.

Because the uncertainties of station-by-station regressions of peak discharges as a function of urbanization are so large, a regional urbanization response was computed. Stations used in this study fit following two criteria: (1) drainage area is at most 200 square miles and, (2) at least 10 consecutive years of record are available. Fixed effects, linear panel regression models were computed with scripts developed in the statistical computing language, R. The panel regressions provide an estimate of the population-wide effect of the explanatory variables on the dependent variables, similar to the coefficients of the regional regression relations used in a typical USGS regional flood frequency study, although in a panel regression, both temporal and between-station variations are taken into account.

Effect of adjustments on trends



Trends of adjusted peak series are similar to precipitation series trends (not shown)

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Next Steps

- Review and approval of adjustment methodology and peak flows
- Provides basis for update of Allen & Bejcek (1979) along with IL region 2 rural flood frequency equations:

  $$Q_T = a(TDA)^b(MCS)^c(\%Water+5)^d$$

  $$\rightarrow Q_T = a(TDA)^b(slope)^c(water)^d(urban)^e$$

- Other possibilities? (possibly rural and urban)
  - Design hydrographs (Tc & R)
  - Continuous streamflow at ungaged locations

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