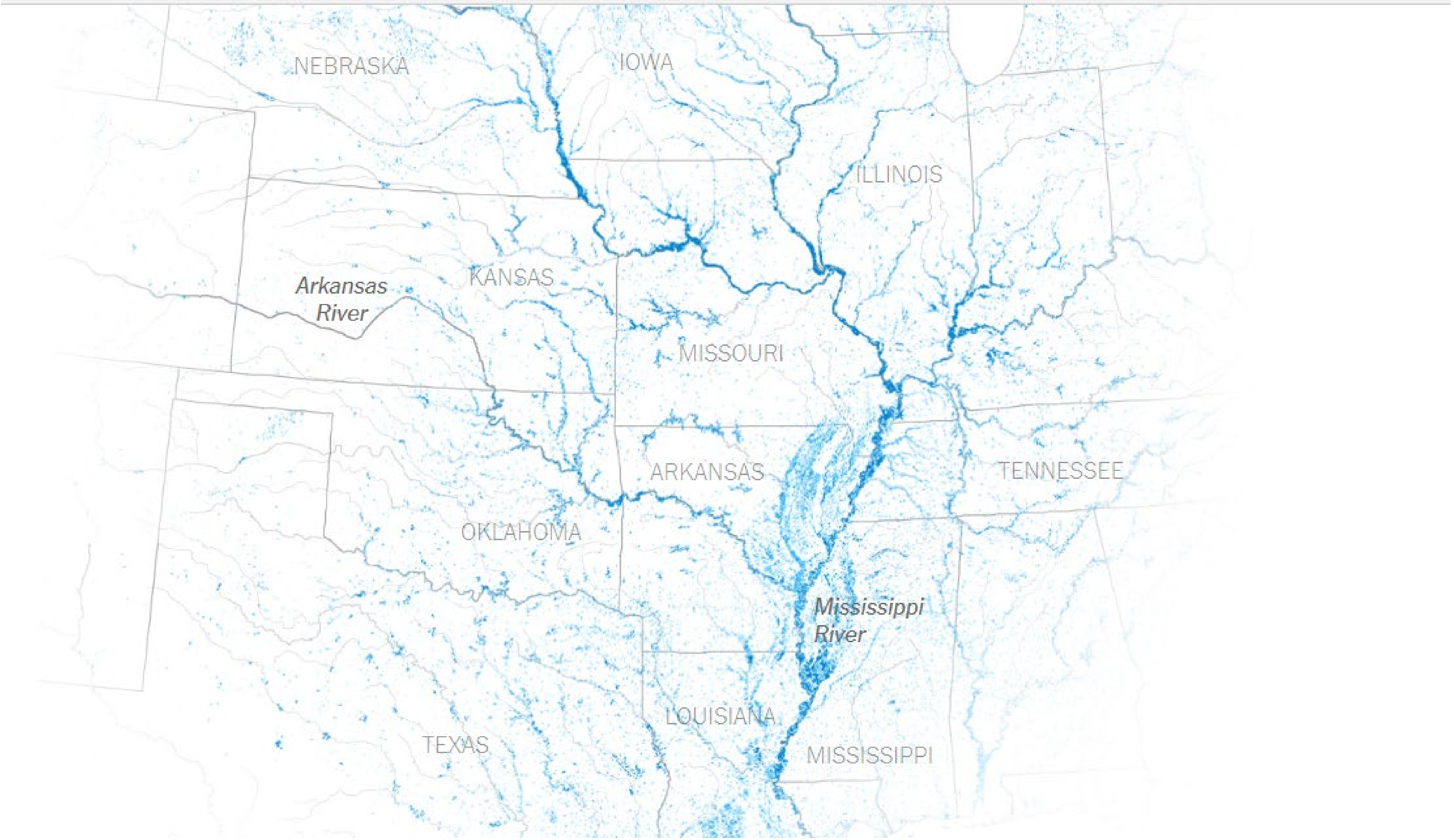
Resilience to Flooding and Fluvial Erosion in a Changing Climate

Robert Barr and Siavash Beik

LTAP Stormwater Conference

February 6, 2020



The Great Flood of 2019: A Complete Picture of a Slow-Motion Disaster
(Sarah Almukhtar, Blacki Migliozzi, John Schwartz and Josh Williams) NYT Sept. 11, 2019

Elkhorn River, Nebraska

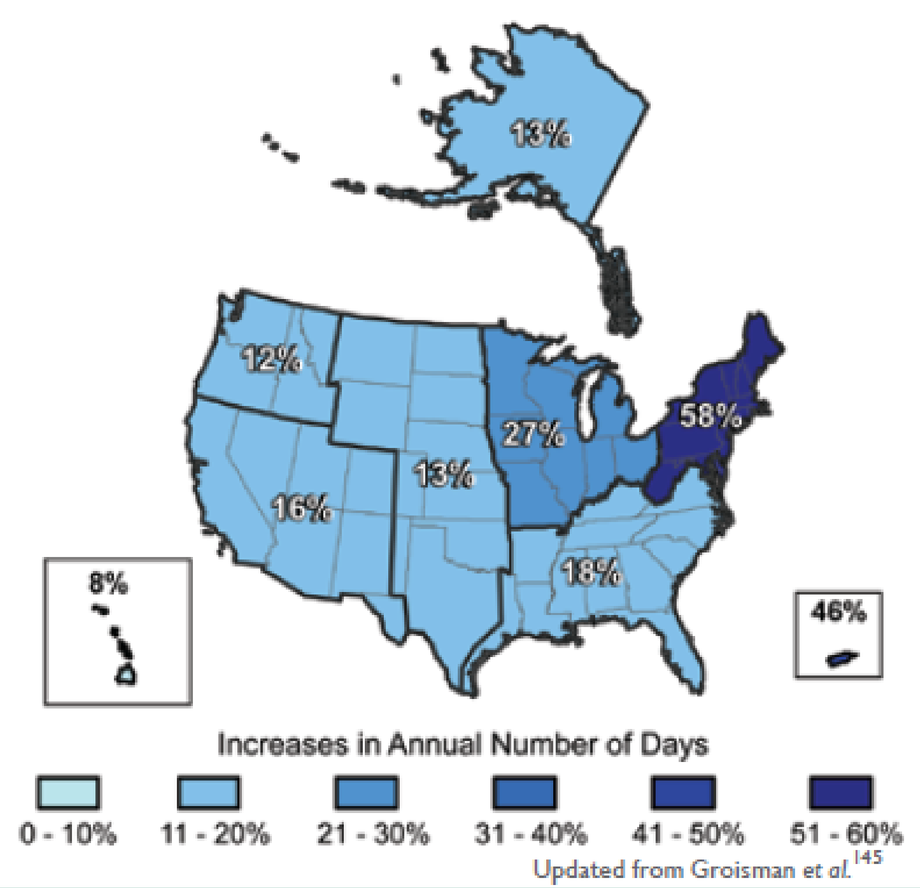
Mike Bossman, OPD, 2019

Lake County, Indiana

T. Larson, May, 2019

Whitewater River near Metamora, Indiana Feb 2019

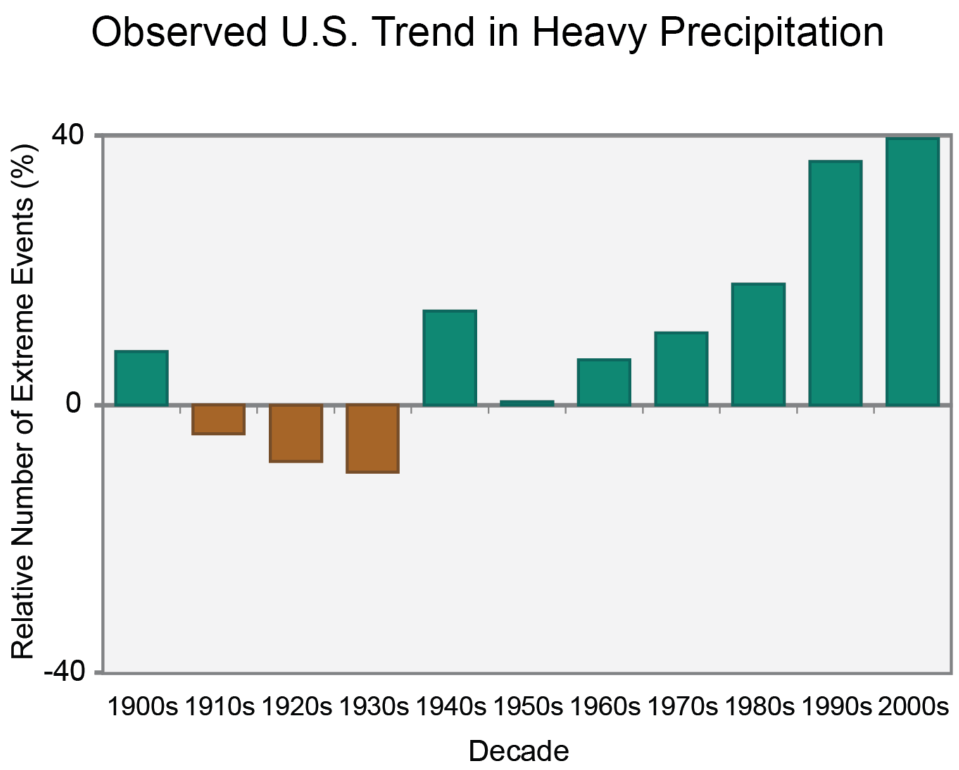
Increases in the Number of Days with Very Heavy Precipitation (1958 to 2007)



The map shows the percentage increases in the average number of days with very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends toward more days with very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

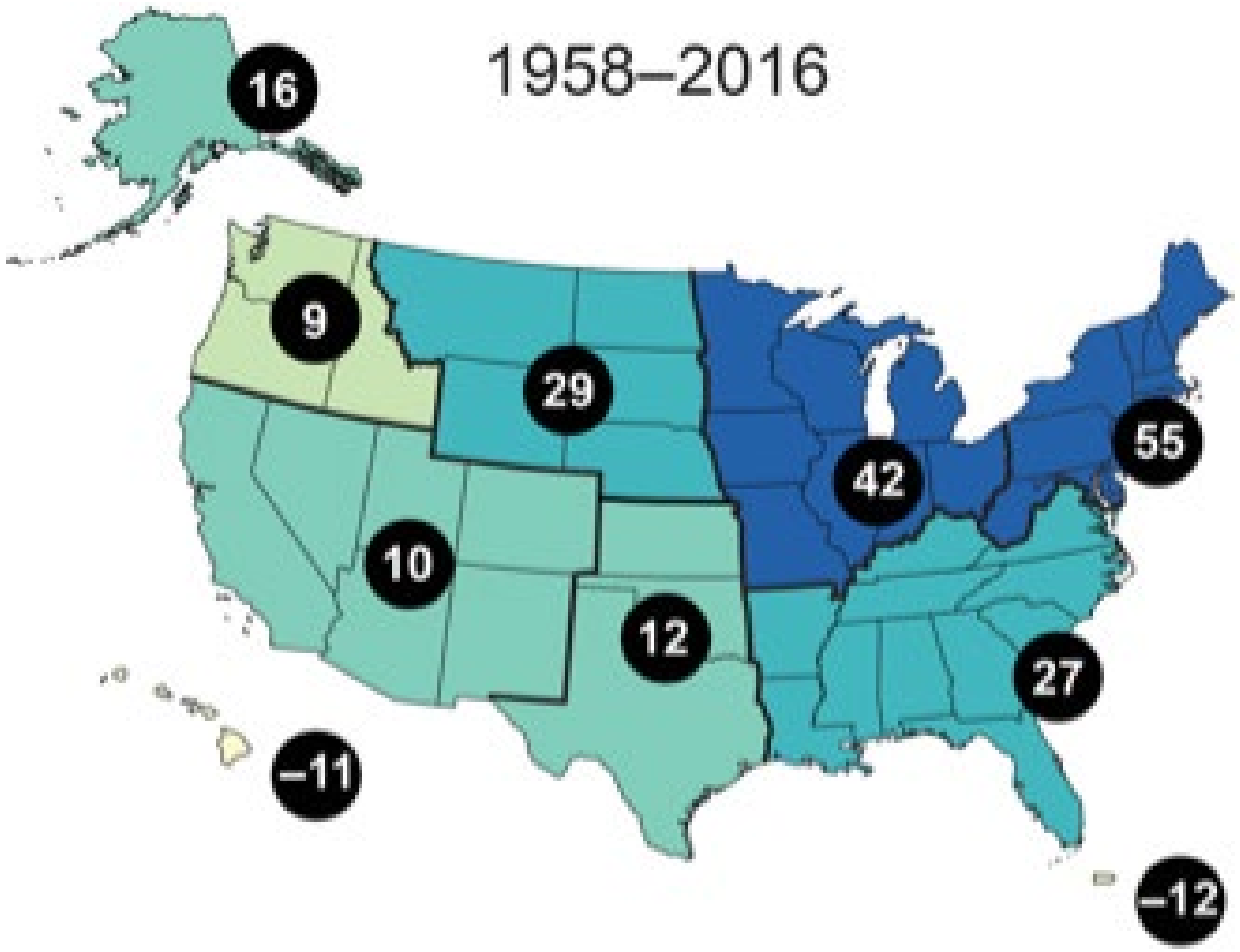
Global Climate Change Impacts in the United States, 2009.

Observed Decadal Trend of Heavy Precipitation (2-day, 5-year RI) in Midwest (1901-2012 compared with 1901-1960)



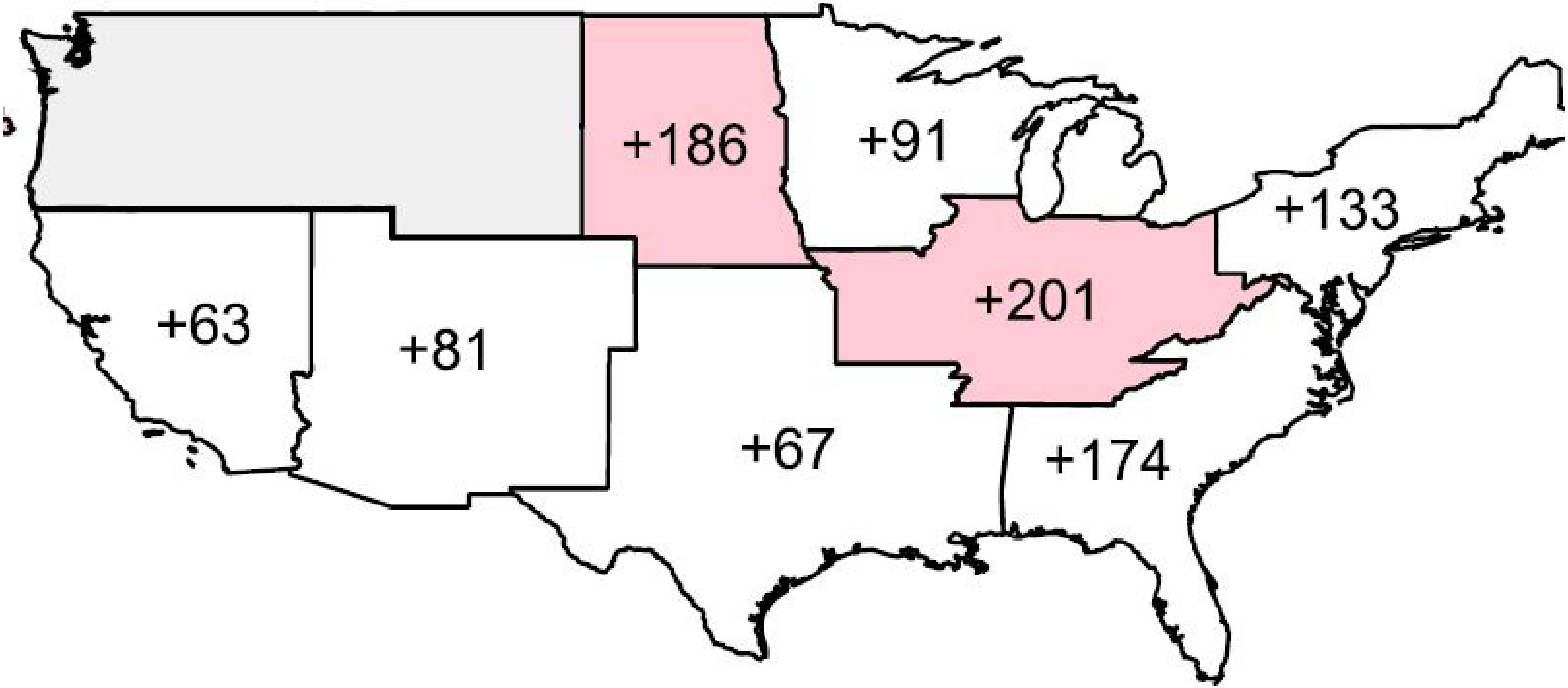
Source: USGRP, 2014, Third National Climate Assessment (adapted from Kunkel et al. 2013)

Observed % Change in Total Annual Precipitation Falling in the Heaviest 1% of Events (1958 – 2016)



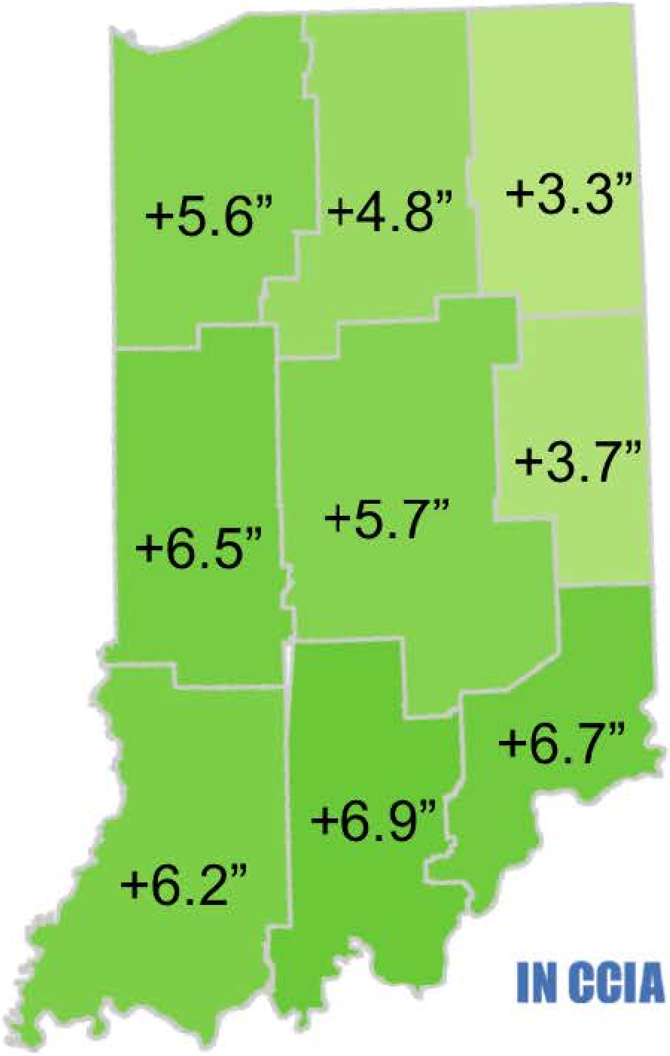
Source: USGRP, 2018, Fourth National Climate Assessment.

1950-2017 Observed Changes in 100-Year, 24-Hour Exceedance Events



Source: Wright, Bosma, and Lopez, Geophysical Research Letters (July 2019)

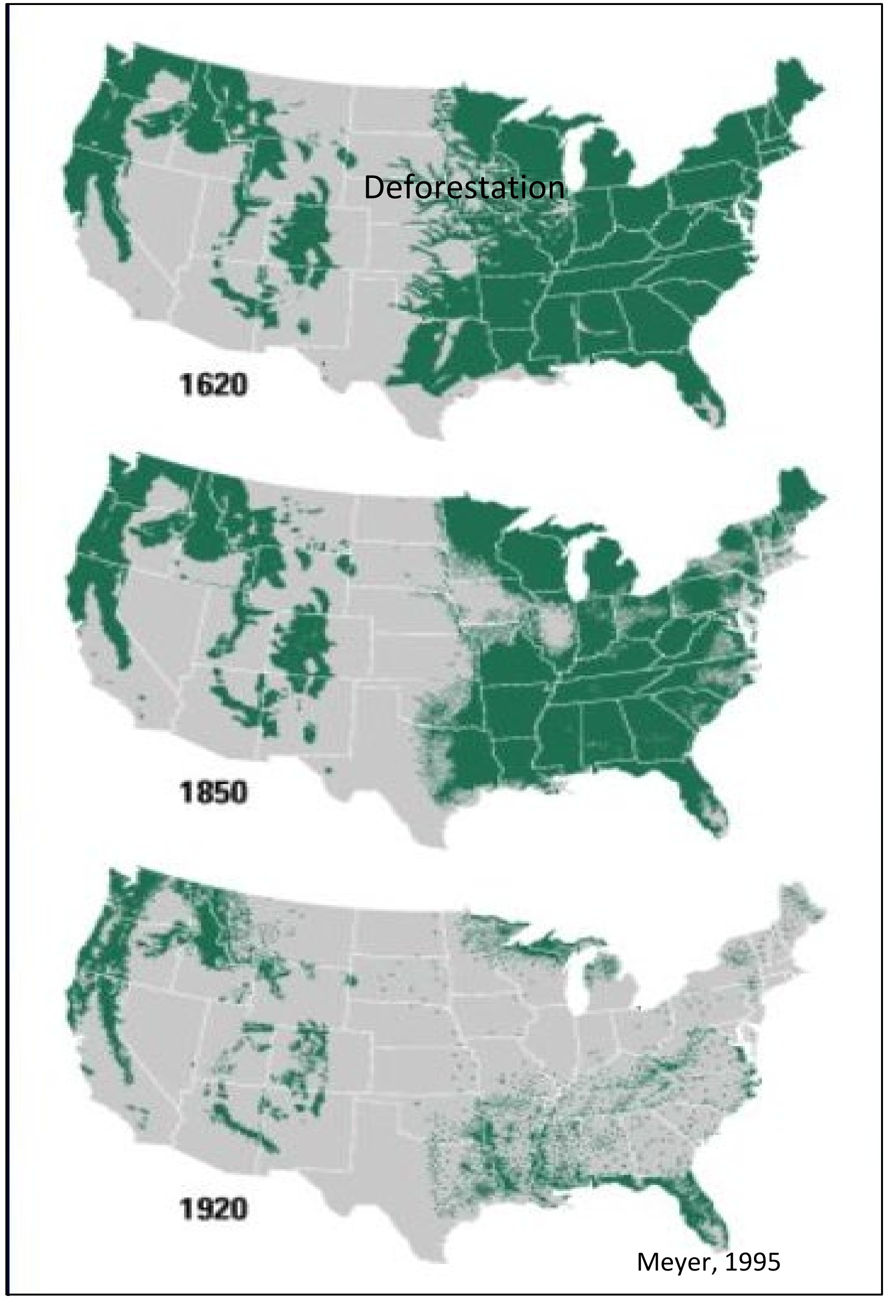
Annual Average Precipitation on the Rise



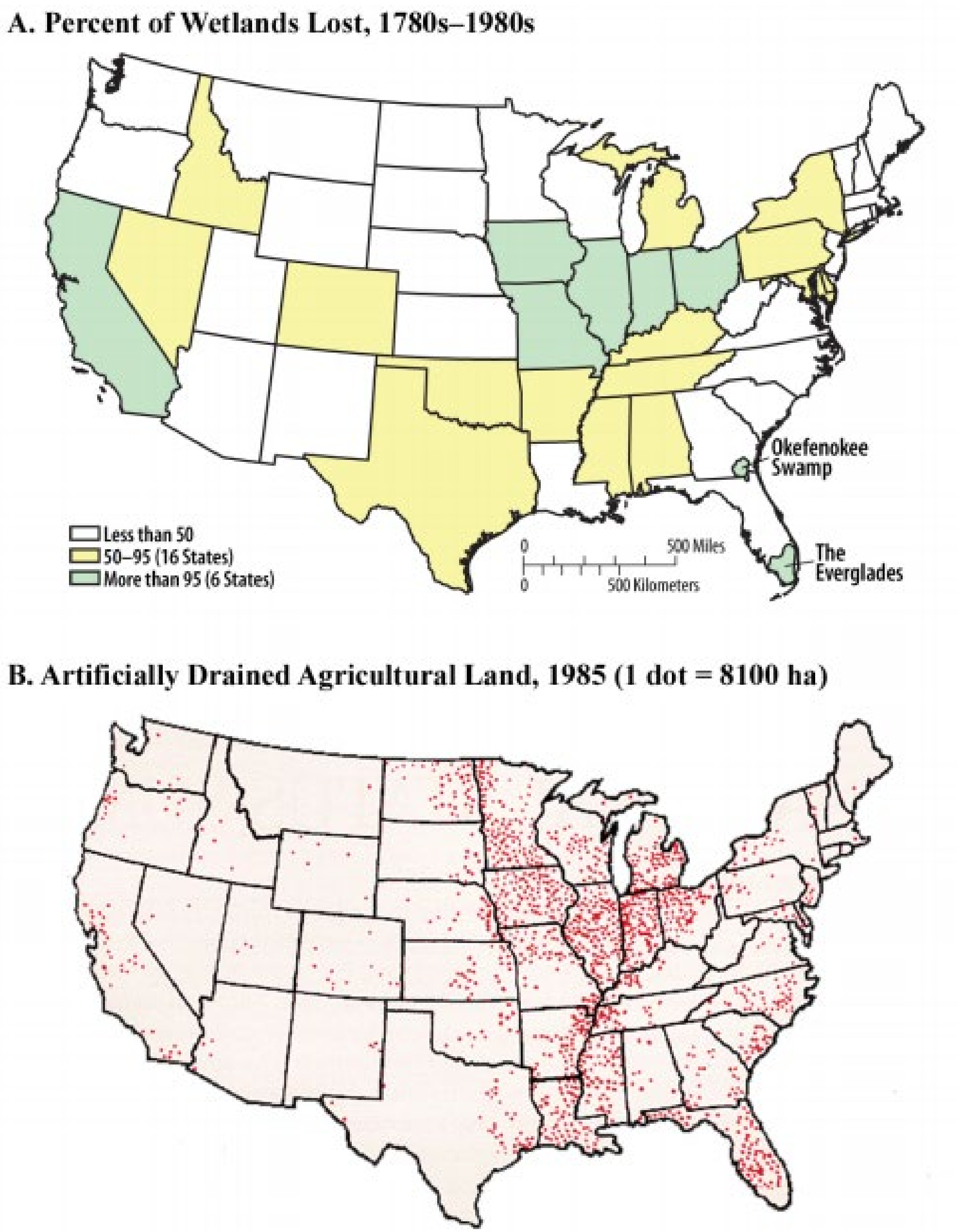
Change in annual average precipitation based on linear trend between 1895 to 2016

Human Modification of the Landscape and the Hydrologic Cycle

- Deforestation
- Agricultural drainage and piping
- Urbanization and residential development

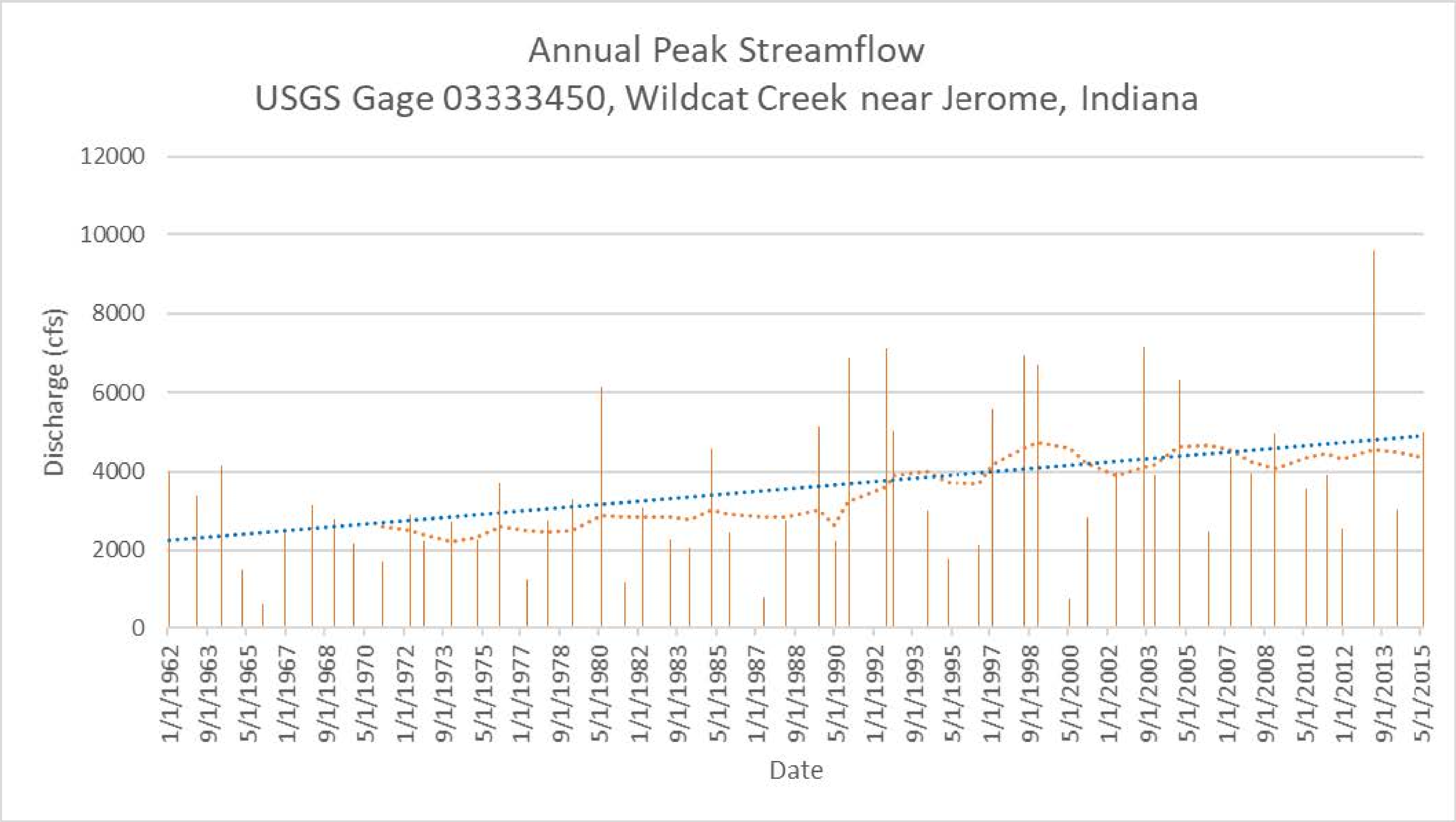


Comparison of percent wetland loss between (A) the 1780s and mid-1980s with (B) the distribution of artificially drained agricultural land in 1985. One dot equals 8100 ha. From Blann et al. (2009), as modified from Dahl (1990).



Hare Creek, Ritchey Woods State Nature Preserve

Plum Creek/Hart Ditch, Munster, Indiana


Annual Peak Streamflow
USGS Gage 03333450, Wildcat Creek near Jerome, Indiana
12000
10000
8000
6000
4000
2000
0
Discharge (cfs)
1/1/1962
9/1/1963
5/1/1965
1/1/1967
9/1/1968
5/1/1970
1/1/1972
9/1/1973
5/1/1975
1/1/1977
9/1/1978
5/1/1980
1/1/1982
9/1/1983
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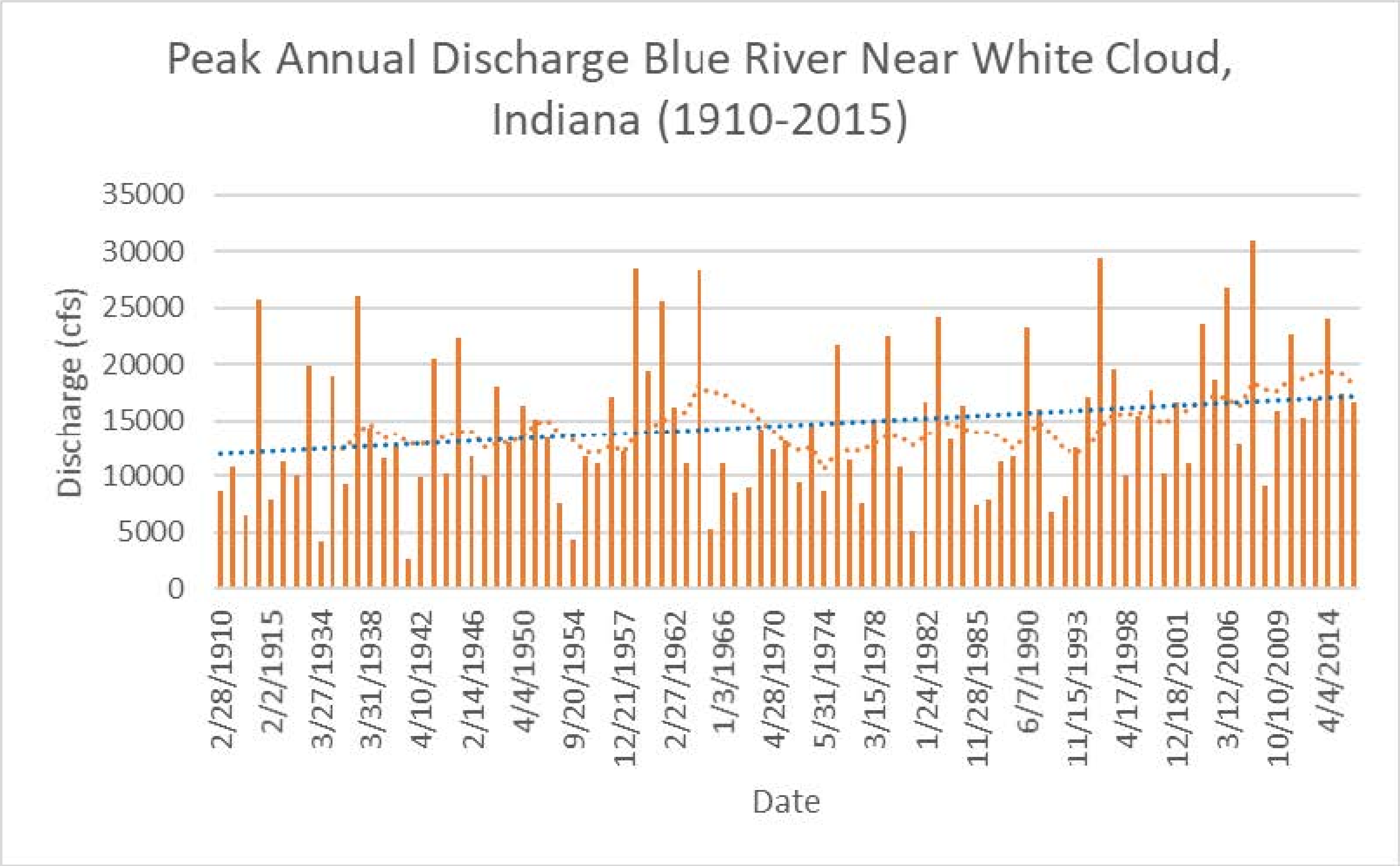
1/1/1987
9/1/1988
5/1/1990
1/1/1992
9/1/1993
5/1/1995
1/1/1997
9/1/1998
5/1/2000
1/1/2002
9/1/2003
5/1/2005
1/1/2007
9/1/2008
5/1/2010
1/1/2012
9/1/2013
5/1/2015
Date

Wildcat Creek near Jerome, IN



Peak Annual Discharge Blue River Near White Cloud, Indiana (1910-2015)
Discharge (cfs)
35000
30000
25000
20000
15000
10000
5000
0
2/28/1910
2/2/1915
3/27/1934
3/31/1938
4/10/1942
2/14/1946
4/4/1950
9/20/1954
12/21/1957
2/27/1962
1/3/1966
4/28/1970
5/31/1974
3/15/1978
1/24/1982
11/28/1985
6/7/1990
11/15/1993
4/17/1998
12/18/2001
3/12/2006
10/10/2009
4/4/2014
Date

Blue River, Harrison County, IN

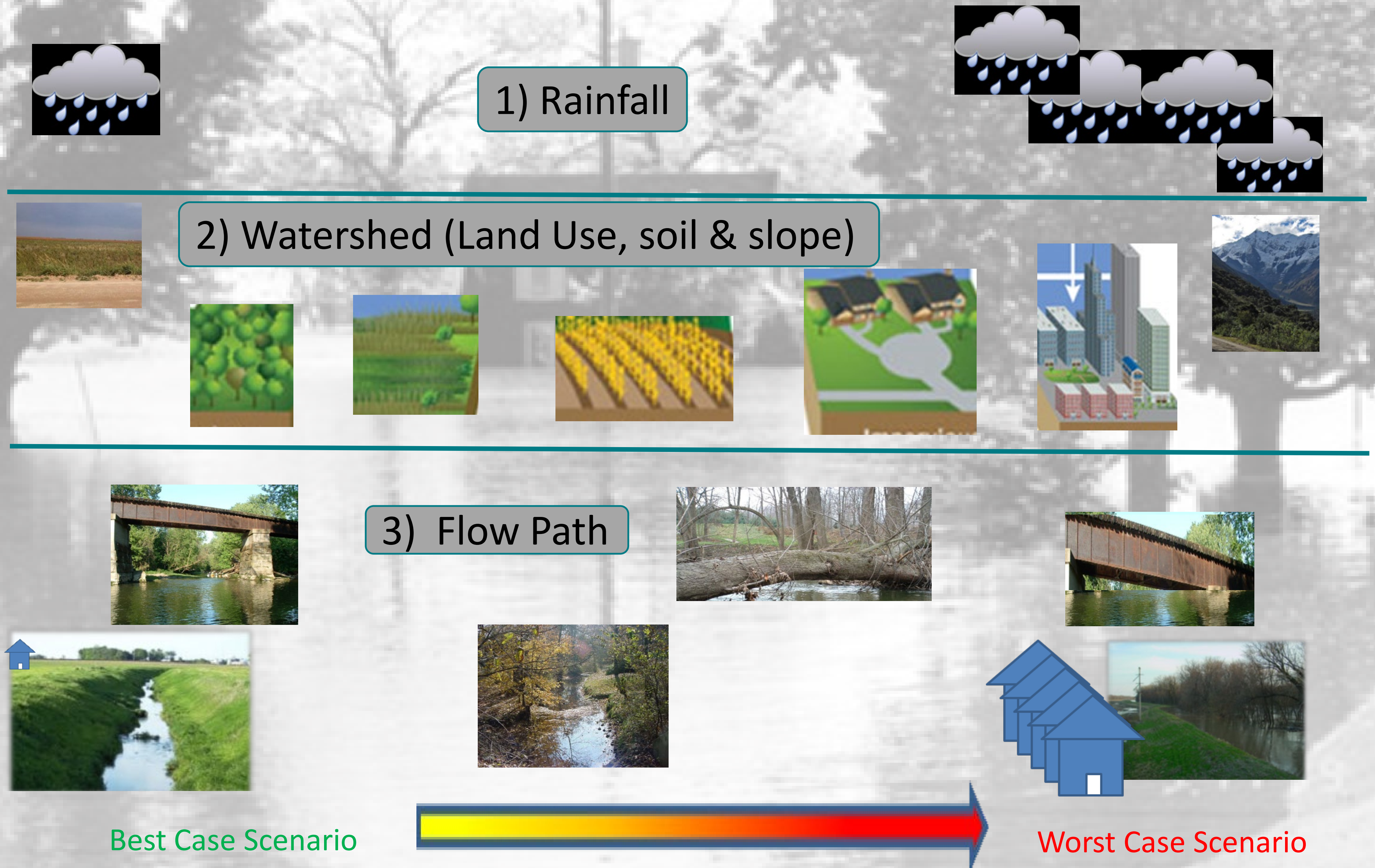
Sugar Creek near Crawfordsville, IN

MANAGING FLOODING & EROSION RISKS AND DESIGN CHALLENGES IN A CHANGING ENVIRONMENT

1. IS FLOODING GETTING WORSE?
   - What Factors go into Making a Flood?
   - What's happening with these factors?
   - What are the implications?

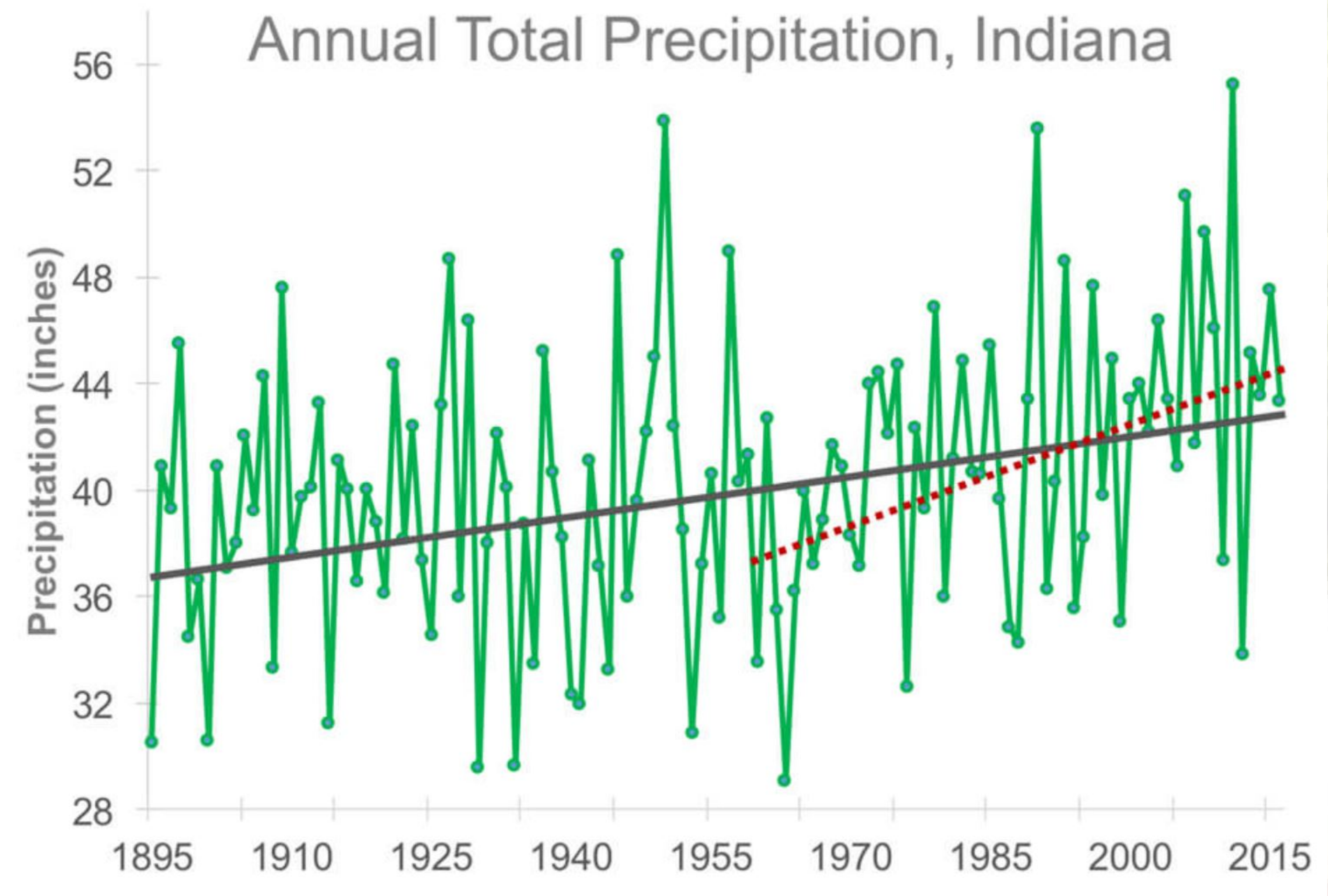
2. WHAT CAN STATE, LOCAL GOVERNEMNTS, AND DESIGNERS DO ?

FACTORS THAT IMPACT FLOODING



FACTORS THAT IMPACT FLOODING

1. **RAINFALL**
2. **WATERSHED/ LAND USE**
3. **FLOW PATH**



Source: Indiana's Past & Future Climate: A Report from the Indiana Climate Change Impacts Assessment. Purdue Climate Change Research Center, March 2018

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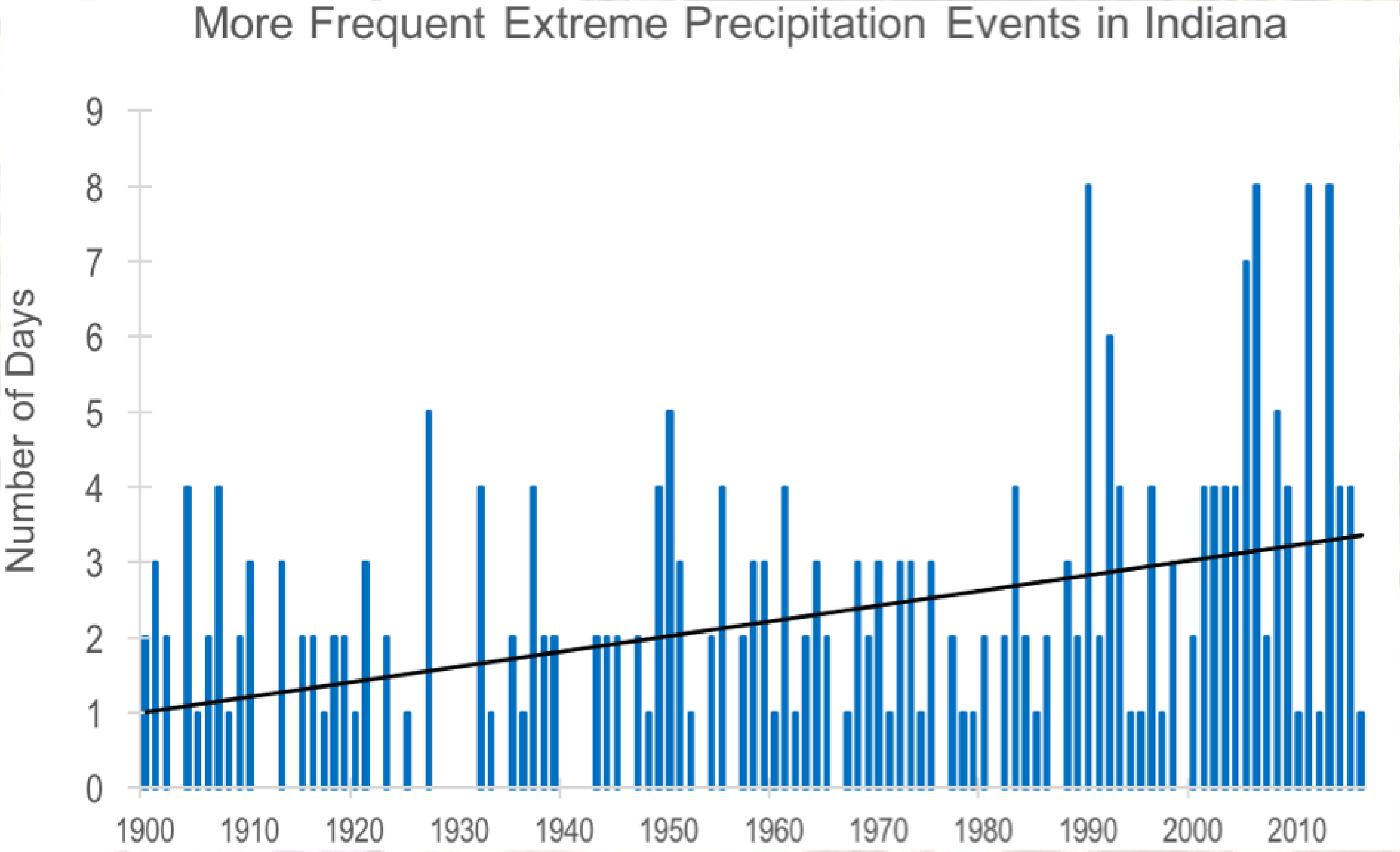
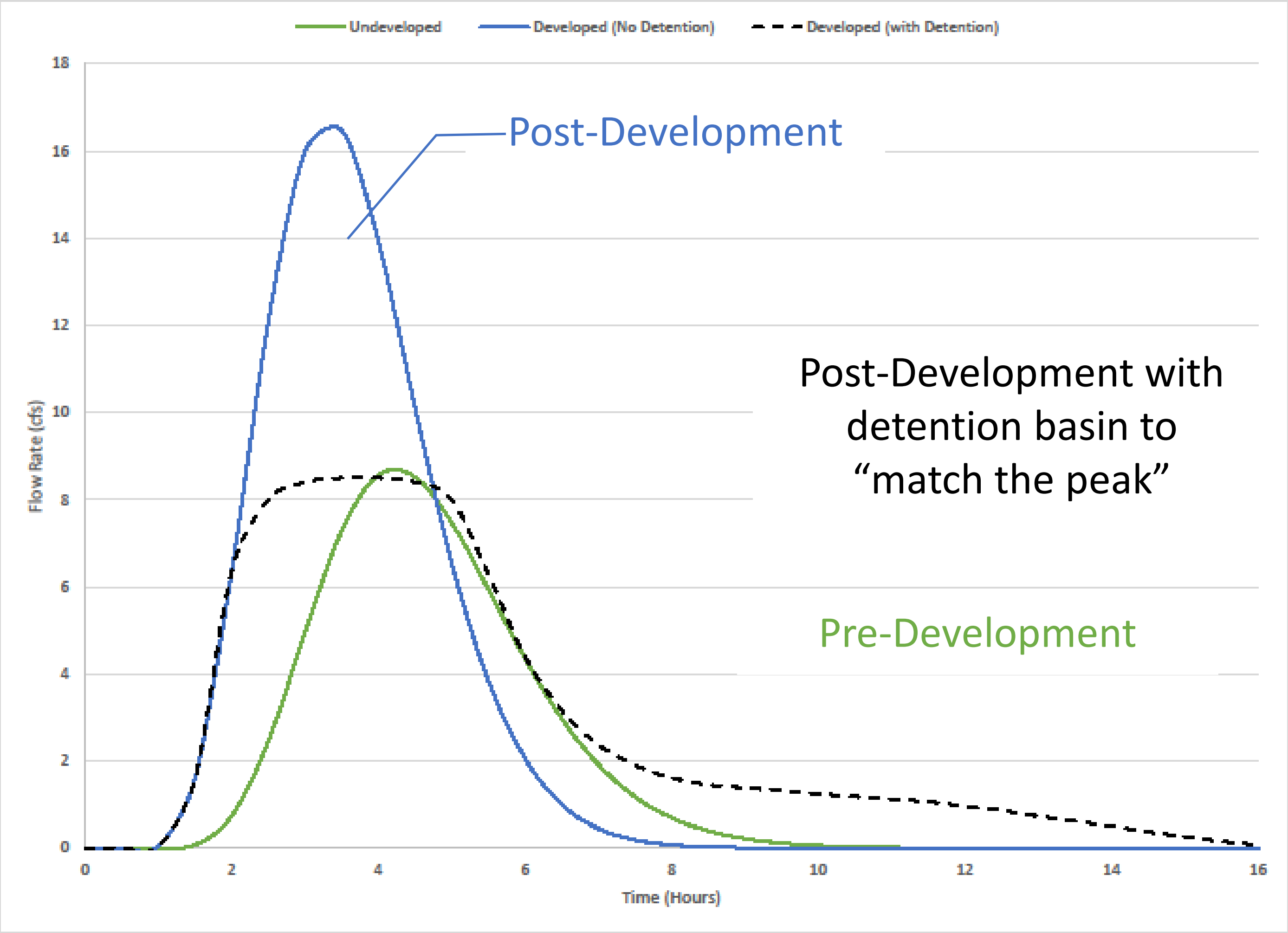


Source: Indiana's Past & Future Climate: A Report from the Indiana Climate Change Impacts Assessment. Purdue Climate Change Research Center, March 2018

FACTORS THAT IMPACT FLOODING: The “100-Year Storm”

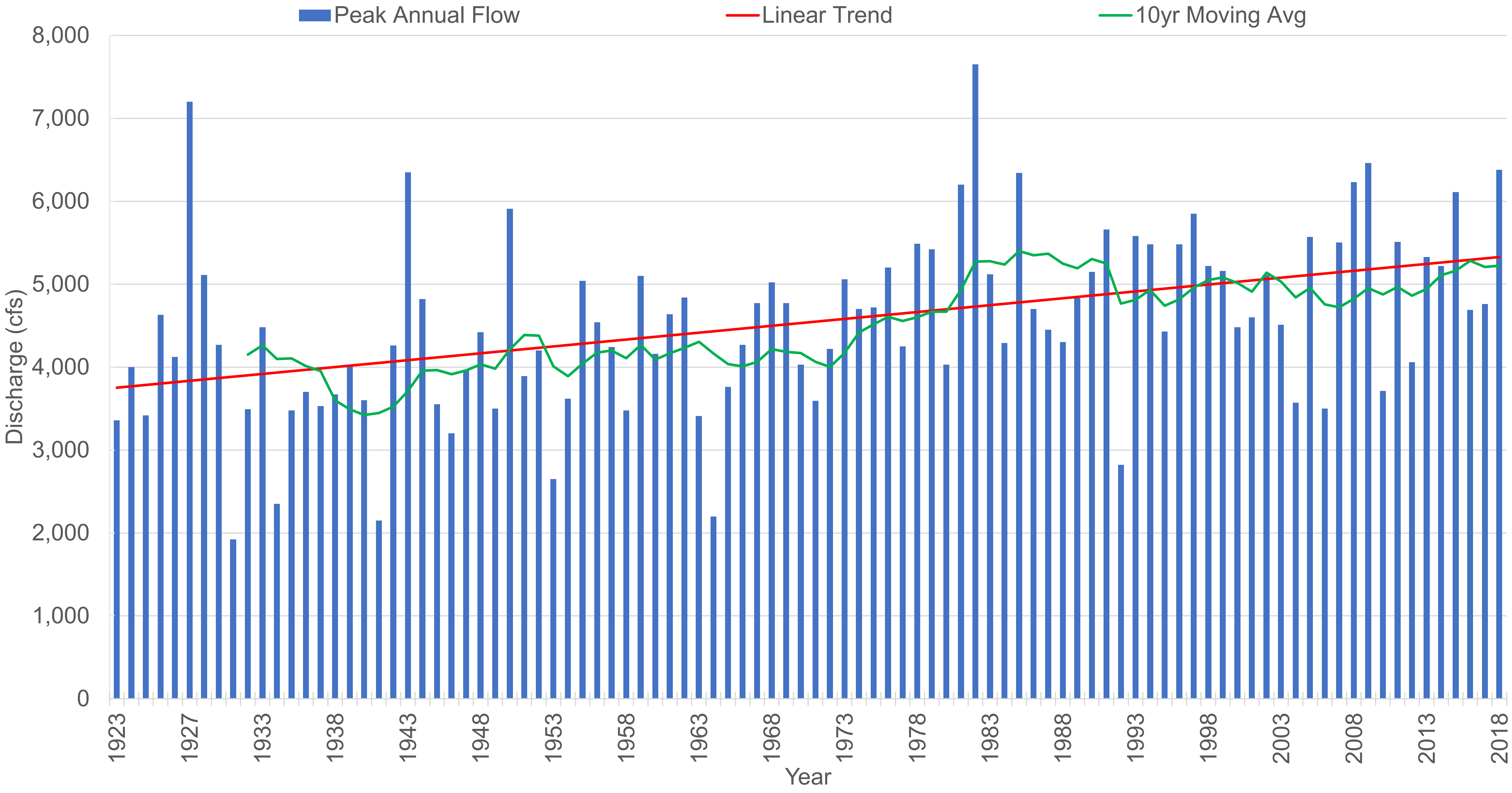
1. RAINFALL
2. WATERSHED/ LAND USE
3. FLOW PATH

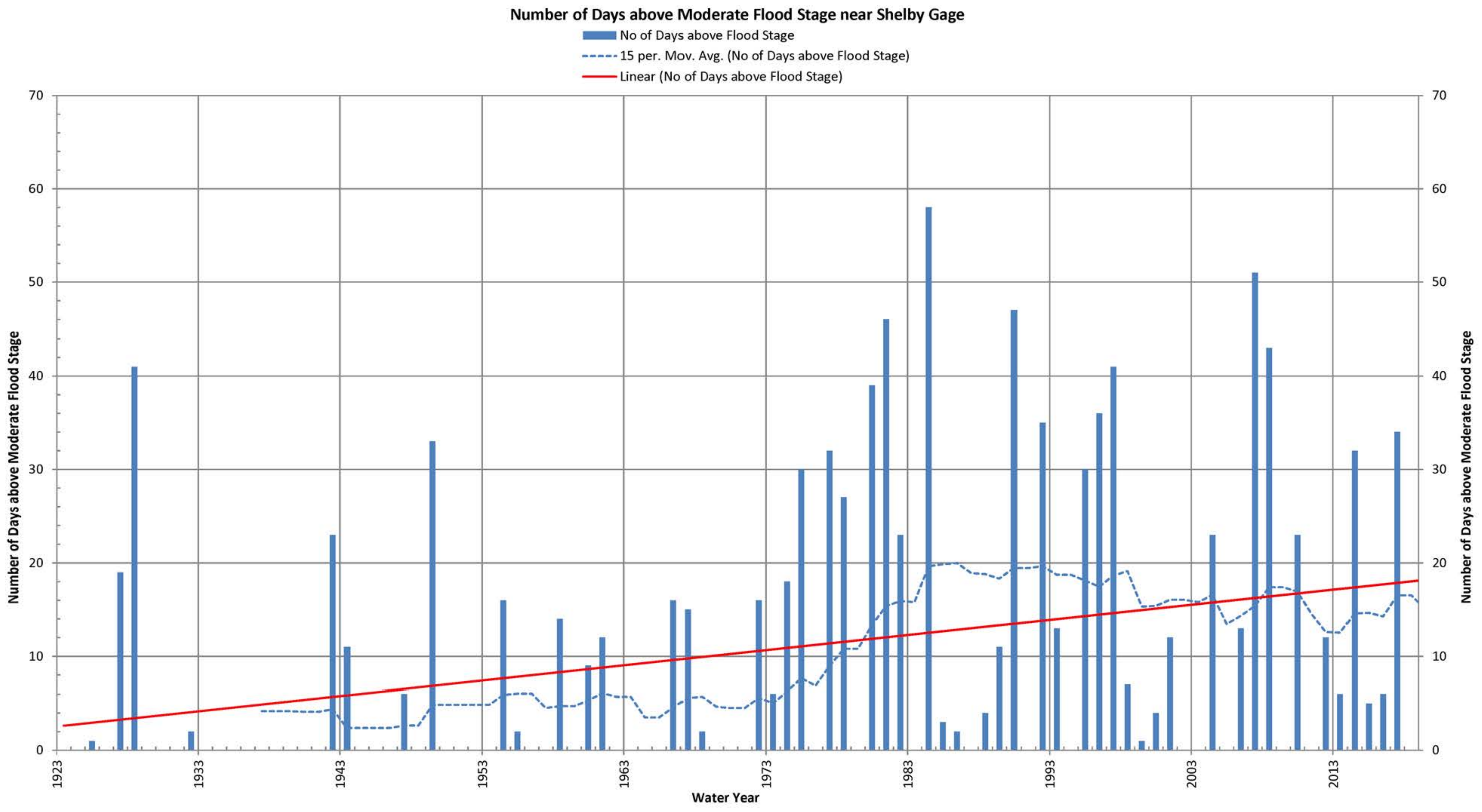


Release Rate requirements (detention)

Prevent a small range of runoff increases from becoming peak discharge increases, but increased runoff volumes are not addressed + results in extended bankfull discharge

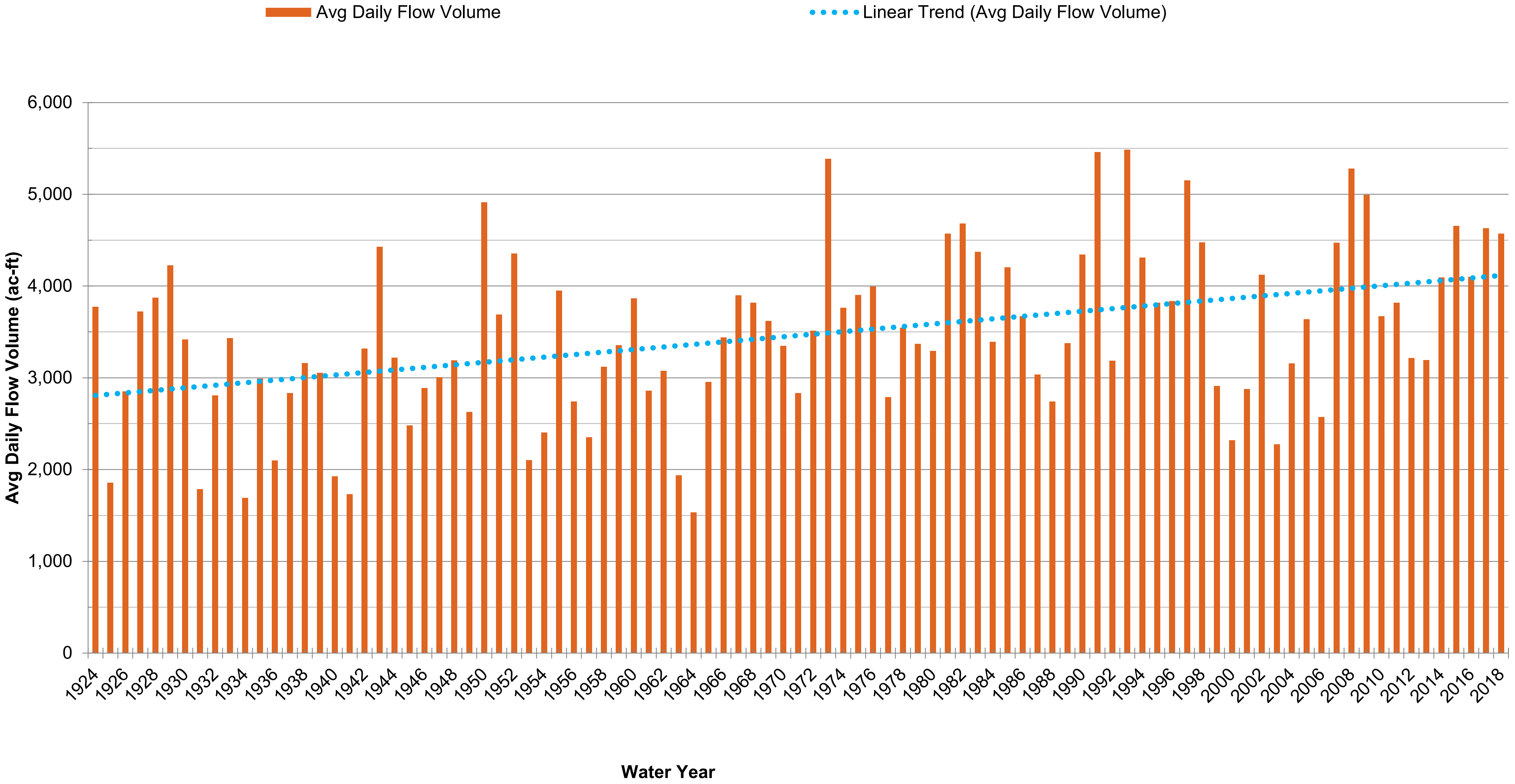
Recorded Peak Annual Discharges at Kankakee River at Shelby USGS Gage





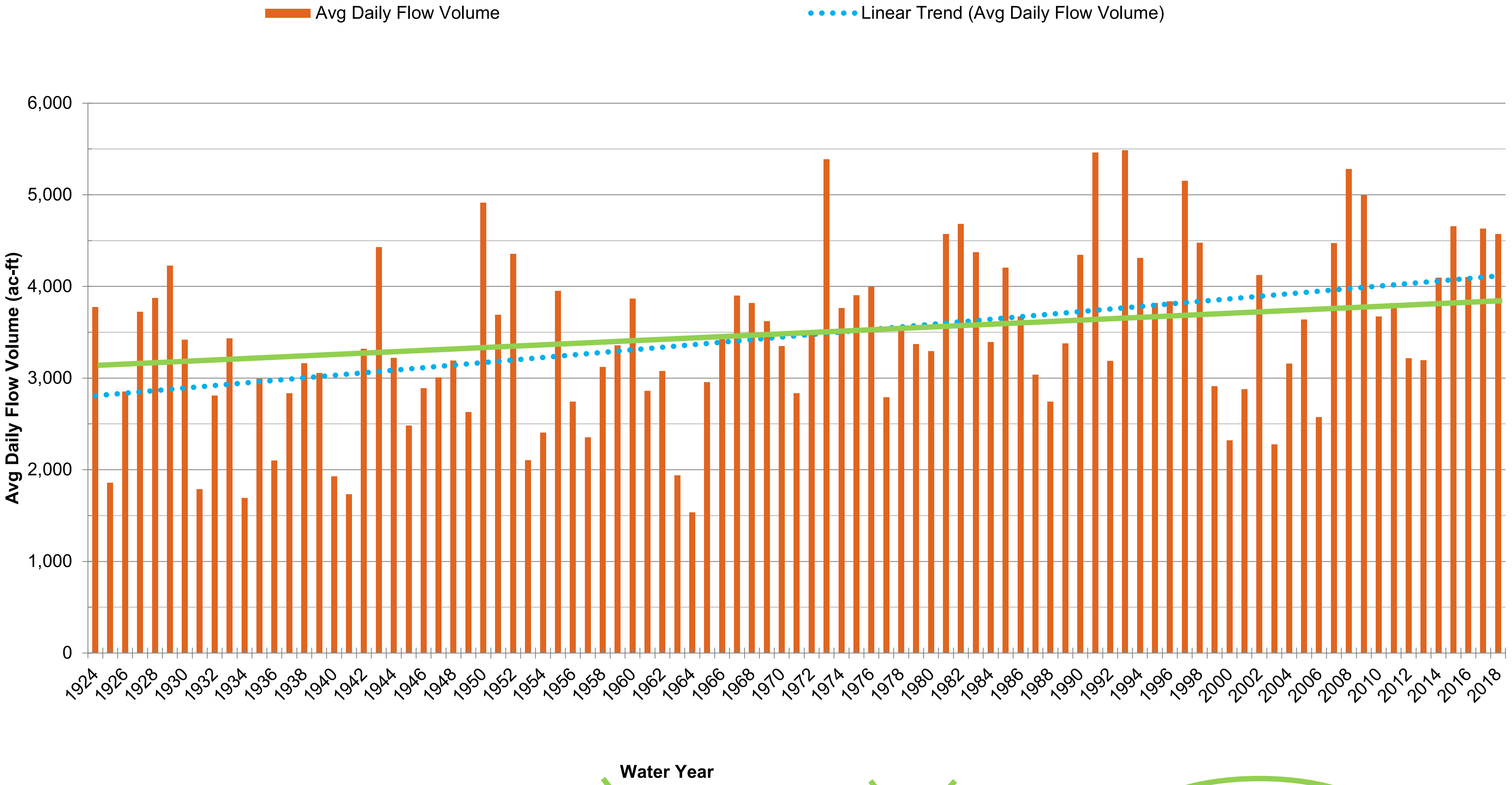
Number of Days above Moderate Flood Stage near Shelby Gage
No of Days above Flood Stage
15 per. Mov. Avg. (No of Days above Flood Stage)
Linear (No of Days above Flood Stage)
Number of Days above Moderate Flood Stage
0
10
20
30
40
50
60
70
1923
1933
1943
1953
1963
1973
1983
1993
2003
2013
Water Year

Annual Average Daily Flow Volume at Kankakee River at Shelby USGS Gage



39% Increase! Potential Causes >>> Rainfall ⬆ Urban Development ⬆ Ag Drainage ⬆

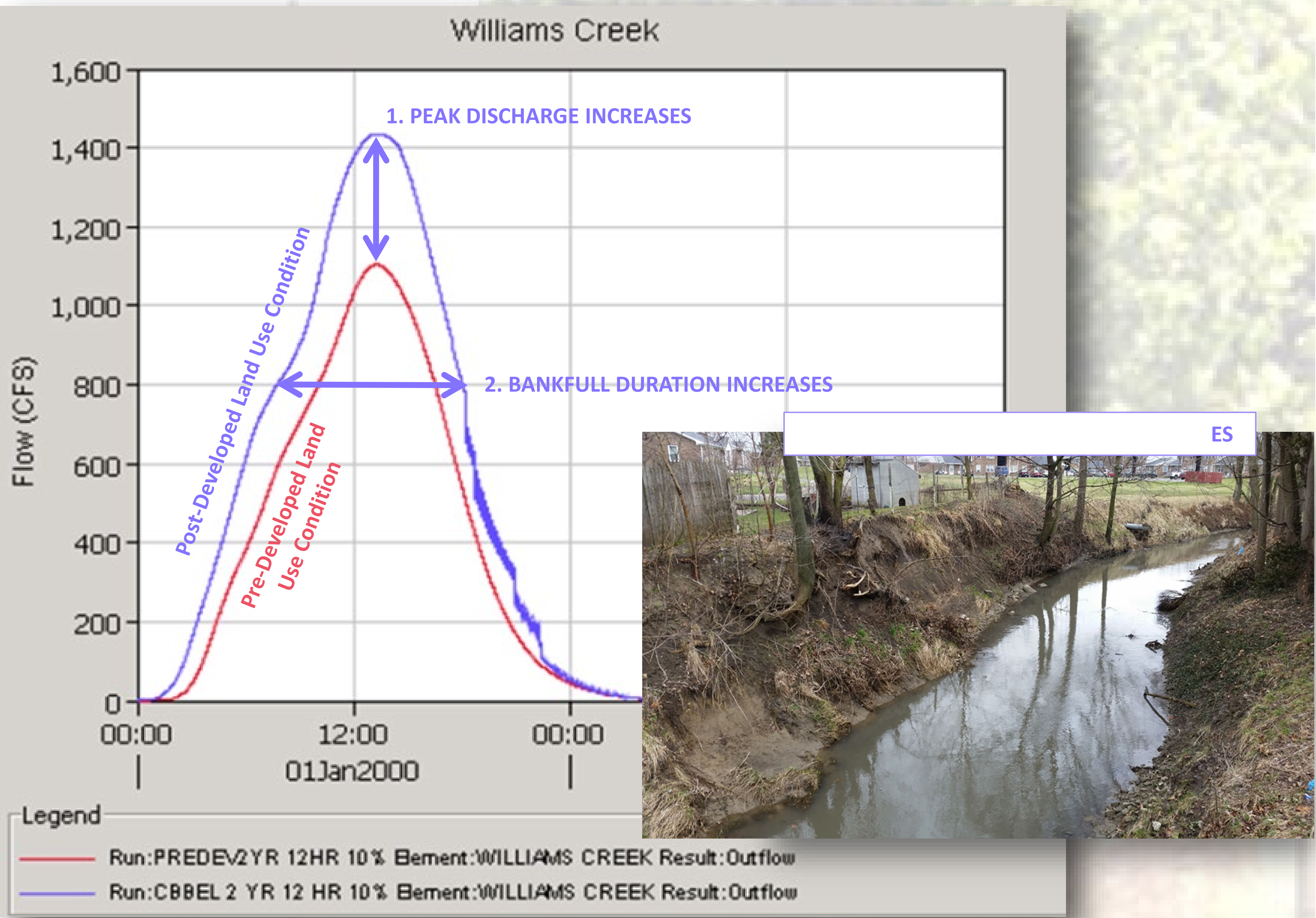
Annual Average Daily Flow Volume at Kankakee River at Shelby USGS Gage



20% ~~39%~~ Increase! Potential Causes >>> ~~Rainfall~~ ~~Urban Development~~ Ag Drainage

FACTORS THAT IMPACT FLOODING: The “2-Year Storm”

1. RAINFALL
2. WATERSHED/ LAND USE
3. FLOW PATH

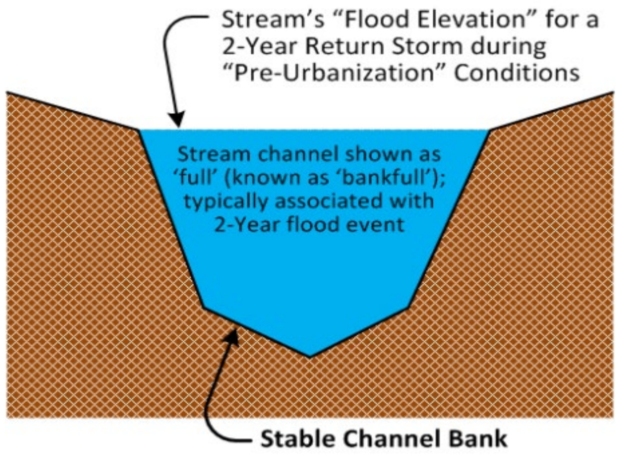


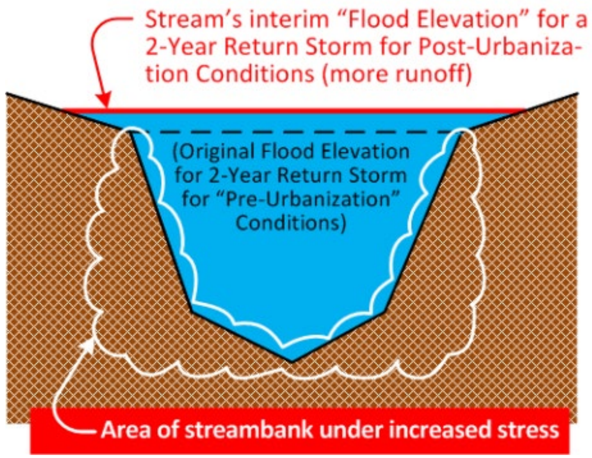
FACTORS THAT IMPACT FLOODING: “The 2-Year Storm”

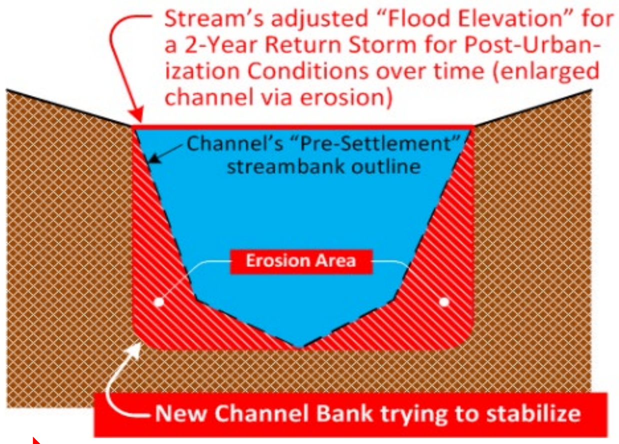
1. RAINFALL
2. WATERSHED/ LAND USE
3. FLOW PATH

Streambank Conditions and Water Level During 2-Year Storm

1. Pre-Urbanization Conditions	2. Interim Streambank Conditions after Urbanization	3. Final Streambank Conditions after Urbanization and after Stream Seeks New Location due to Higher Stream Flow for Small Rain Events







RISK OVER TIME WITH URBANIZATION:
Small Rain Events Raise Stream Levels & Erodes Streambanks

FACTORS THAT IMPACT FLOODING: Impact of Allowing Loss of Flood Conveyance and Storage (Fill, Levees, crossings, etc.)

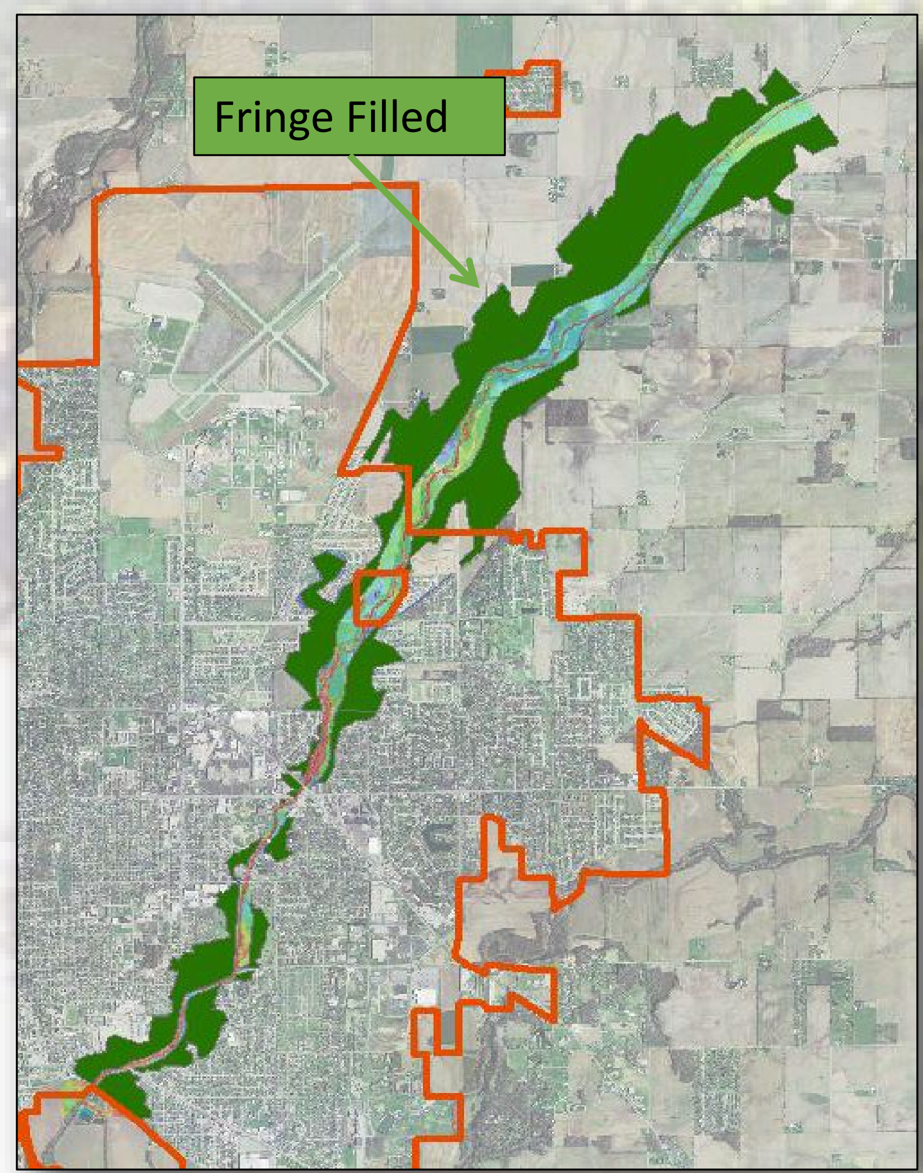
1. RAINFALL
2. WATERSHED/ LAND USE
3. FLOW PATH

- **Regulation of Floodway Only**
  - Impact of filling fringe areas (shown in green) as allowed by many community ordinances:

100-year peak flood elevations
- **½ - 1 ½ foot increases**

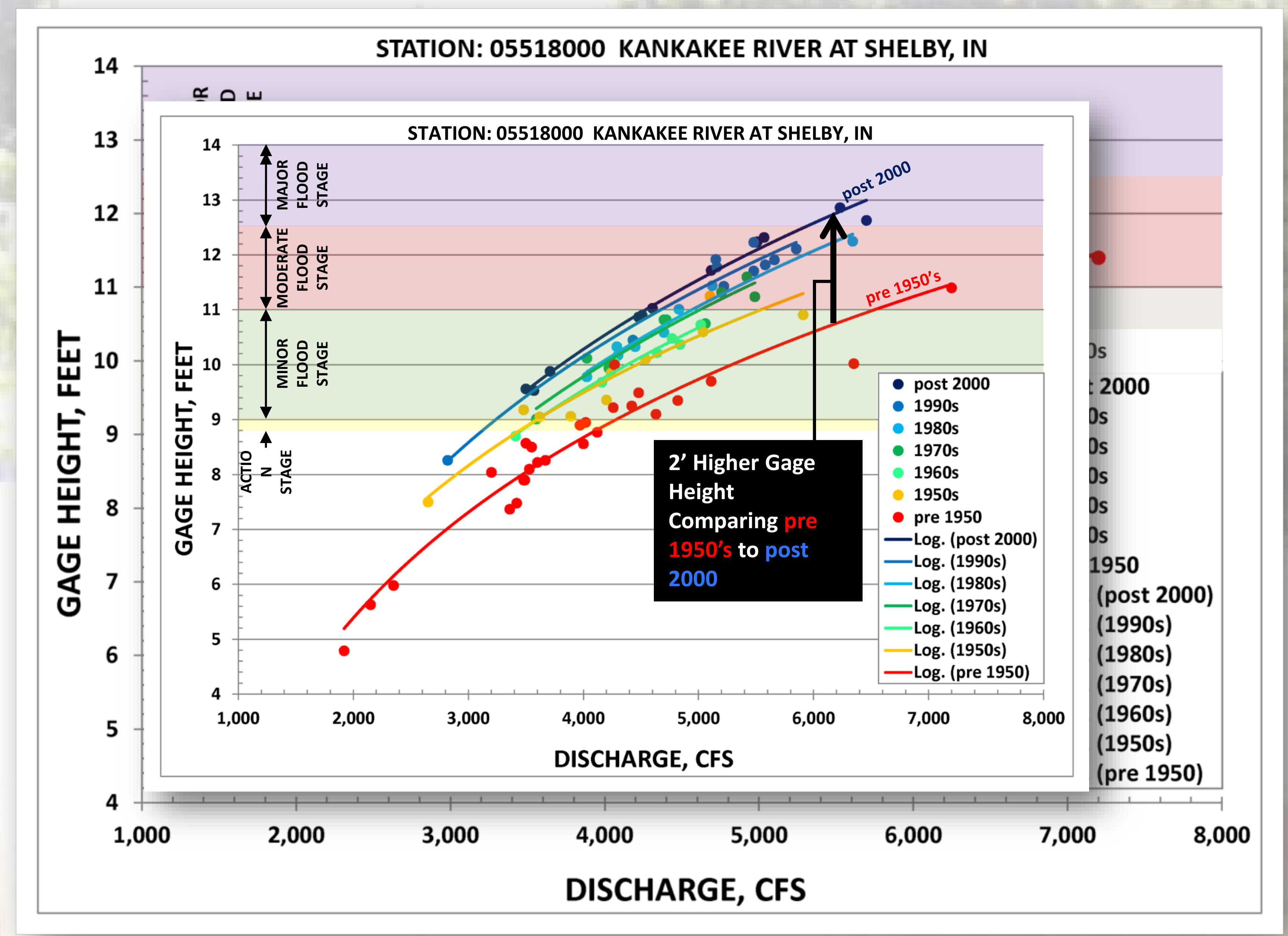
500-year peak flood elevations
- **1-5 foot increases**

- **Levees**
  - Impact on larger than 100-yr flows
- **Crossings**
  - Many are unregulated or are designed only for 100-yr flood
- **Channel Aggradation**
  - Increased Streambank Erosion



FACTORS THAT IMPACT FLOODING: Increasing River "Gage Heights"

1. RAINFALL
2. WATERSHED/ LAND USE
3. FLOW PATH



SO…. WHAT'S HAPPENING TO THE FACTORS THAT GO INTO MAKING A FLOOD?

1) RAINFALL
   - **Heavy rainfall amounts appear to be increasing**
2) WATERSHED/LAND USE
   - If the community has adopted adequate & strict detention regulations, the peak discharges seems to be under control (but only at the regulated frequencies and urban development)
   - **More frequent discharges and runoff volumes that are not regulated are increasing with development**
   - We are also witnessing **significant increases in peak discharge and runoff volumes due to agricultural drainage activities**, which are not regulated at all!
3) FLOW PATH
   - Regulation of only the conventional floodway does not necessarily prevent increased flood stages due to development along river corridors
   - Human activities, including flood fringe filling, levee construction, restrictive crossings, floodway encroachments, and intentional/unintentional channel modifications (increased erosion and sedimentation leading to stream bed aggradation), seem to be big contributors to increased flood stages
   - **Many stream gages are showing increasing stages even for the same discharge!**

❖**Combined impact of the above 3 factors is of great concern!**

SO…. WHAT'S HAPPENING TO THE FACTORS THAT GO INTO MAKING A FLOOD?

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   - **Mo** … **development**
   - We … **agricultural drai**

WHAT CAN WE DO

3) FLOW
   - Regulation of only the conventional floodway does not necessarily prevent increased flood stages due to development along river corridors
   - Human activities, including flood fringe filling, levee construction, restrictive crossings, floodway encroachments, and intentional/unintentional channel modifications (increased erosion and sedimentation leading to stream bed aggradation), seem to be big contributors to increased flood stages
   - **Many stream gages are showing increasing stages even for the same discharge!**

❖**Combined impact of the above 3 factors is of great concern!**

ADDRESSING SYSTEMIC FLOODING AND EROSION IN THE FACE OF A CHANGING CLIMATE

1. Adaptation
   - ❑ Recognizing that flooding is going to occur and taking steps to reduce existing and future vulnerabilities to reduce pain and suffering

2. Mitigation
   - ❑ Reducing the stressors to the system and the Flooding and Sedimentation sources to the extent possible through common sense and feasible actions **without adverse impact to others**

WHAT IS NO-ADVERSE-IMPACT (NAI)

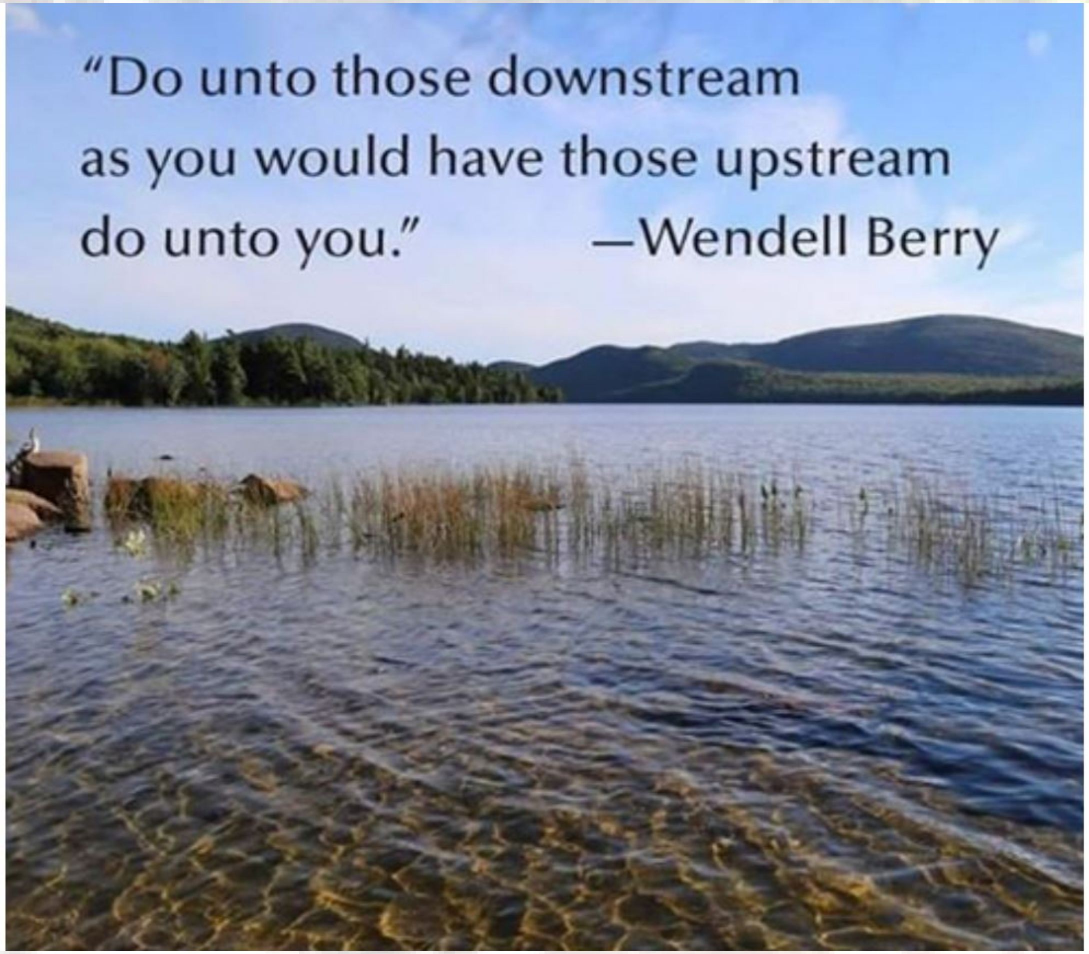
➢ No-Adverse-Impact (NAI)* Floodplain Management

- ASFPM Defines NAI as:

  "… an approach that ensures the action of any property owner, public or private, does not adversely impact the property and rights of others."

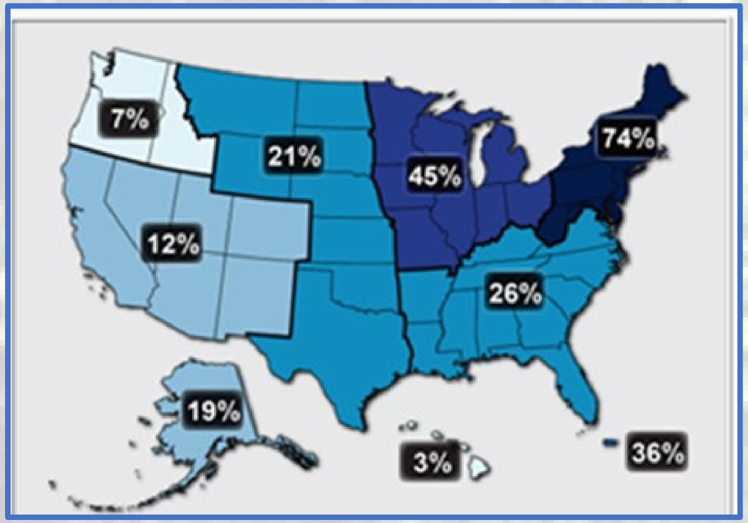
- NAI broadens property rights by protecting the property rights of those that would be adversely impacted by the actions of others.

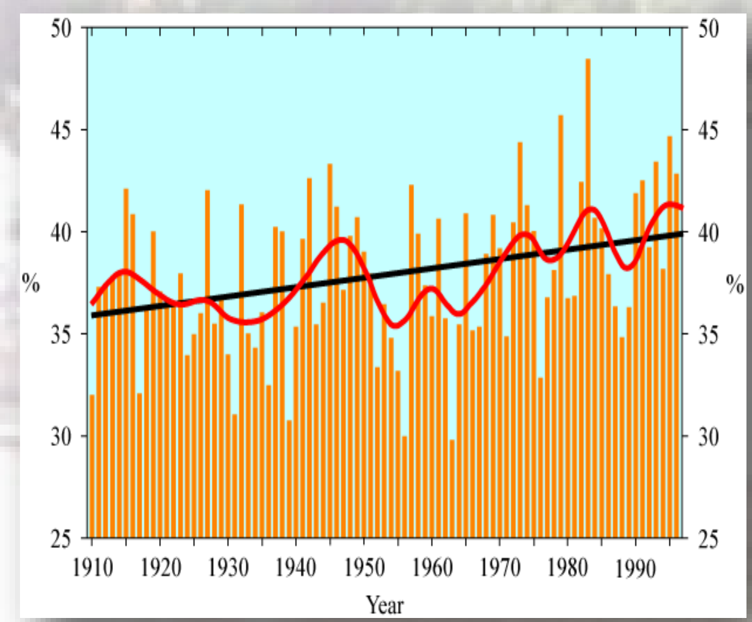
* NAI is an ASFPM Initiative (www.floods.org)



1) MEETING THE CHALLENGE OF HIGHER RAINFALLS

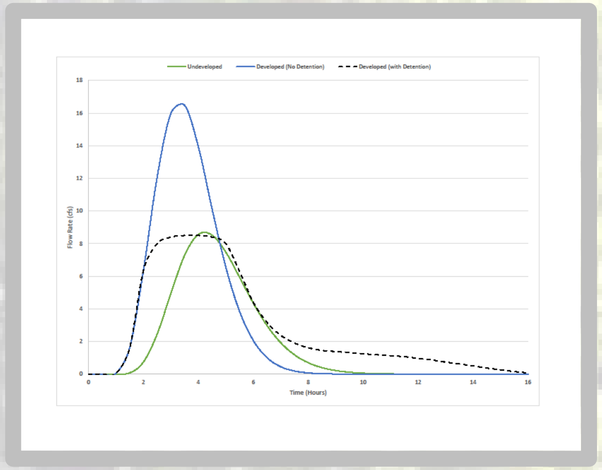
- **Use a higher rainfall depth for design** of new facilities (e.g, use 90% confidence interval values)
- **Use synthetic, nested rainfall distributions** instead of average observed distributions such as Huff, etc.
- **Design for higher flood stages** (consider future hydrology, higher freeboard, etc.)
- Identify **potential risk areas (above and beyond minimum NFIP criteria)** and stay away from them!
- Retrofit/floodproof **critical facilities with a higher freeboard**

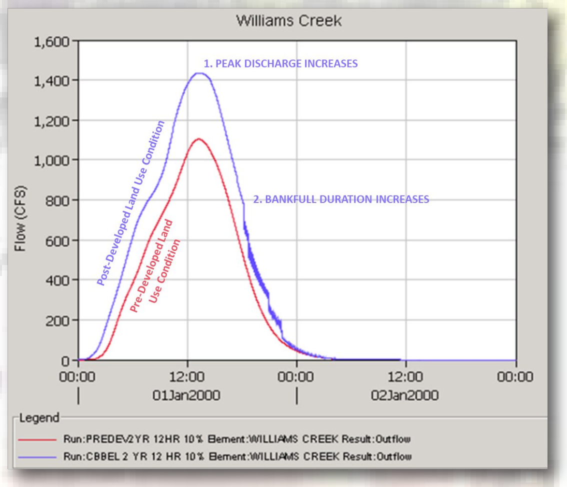




2) MEETING THE CHALLENGE OF LAND USE CHANGES

- **Incorporate "No-Adverse-Impact" (NAI) Measures into Local Stormwater Ordinance and Standards**
  - Preserve existing wetlands and depressional areas within Watershed
  - Detention ponds with **accurate range of release rates** to control peak discharges based on watershed hydrologic modeling
  - Retain/replace more pervious area to **control runoff volumes (through LID/Green techniques)**
  - **Channel Protection Volume retainage (through LID/Green)** or extended detention to control runoff volume and channel erosion
  - Start addressing **impacts from agricultural drainage activities**!

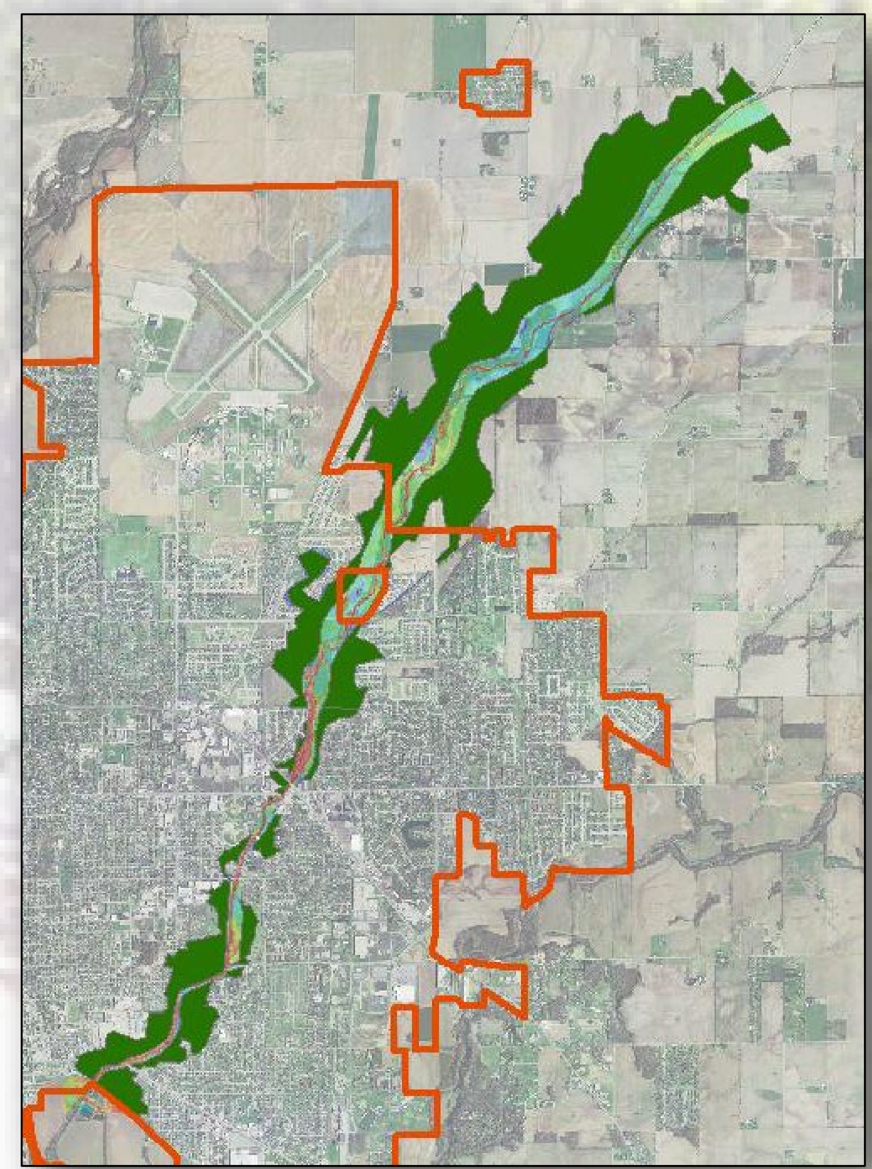




3) MEETING THE CHALLENGE OF IMPACTS ON THE FLOW PATH

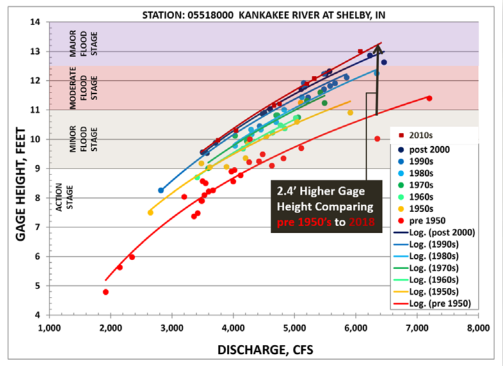
- **Accurately Identify Risk**
  - Accurately determine flood risk areas
  - Some situations warrant **unsteady state or 2D modeling** of stream corridor (incl. auxiliary flow paths)

- **Incorporate "No-Adverse-Impact" Measures into Stormwater and Floodplain Ordinance and Standards:**
  - **Avoid Floodplain areas** or ,at a minimum, Require compensatory floodplain storage
  - Identify and **protect/replace overflow paths** for higher floods
  - Evaluate encroachment **impacts for range of flows** (2-year thru 500-year or flood of record, if larger)
  - **Don't allow encroachments** if adverse impacts are expected!

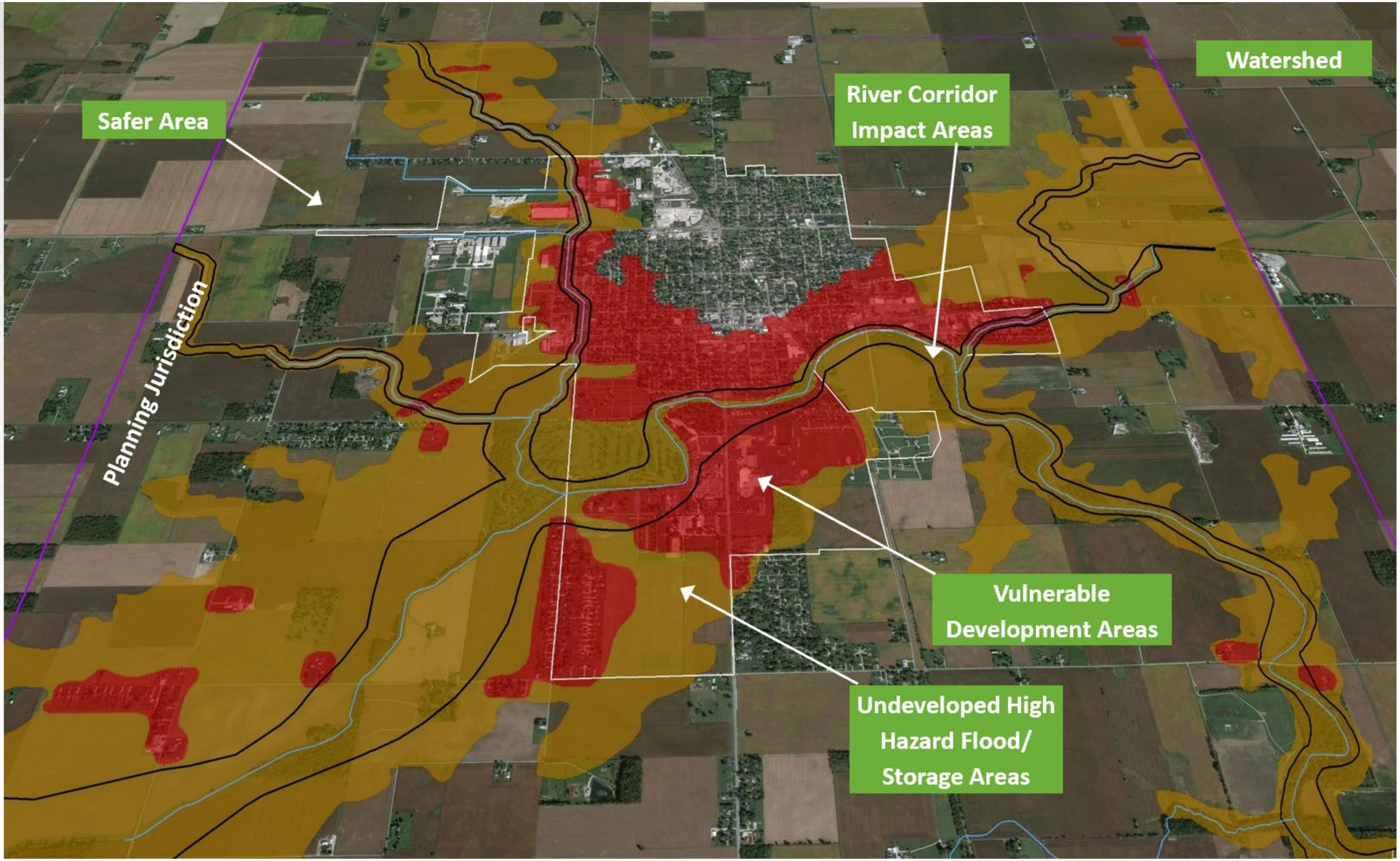


MEETING THE CHALLENGE OF HIGHER FLOOD STAGES (AND INCREASED EROSION) FOR THE SAME DISCHARGE

- ➢**Strictly Enforce regulations** designed to prevent increased flood stages
- ➢Select **freeboards sufficient to provide protection** from increasing stages
- ➢**Control Erosion and Sedimentation** to decrease streambed aggradation (2-stage ditch, cover crops, infiltrate/retain CPv)
- ➢Be mindful of **inadvertent stream channel de-stabilization** caused by piecemeal channel modification projects
- ➢**Don't allow encroachments within Floodways and Erosion hazard Corridors! (**these are impact areas where adverse impacts are expected!)
- ❖ **Adopt Smart Growth Resilience Strategies**



ZONE-SPECIFIC SMART GROWTH RESILIENCE STRATEGIES

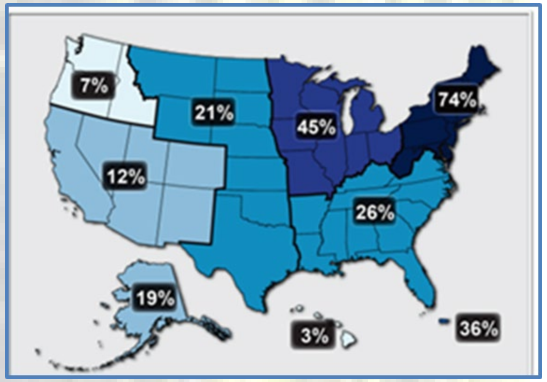


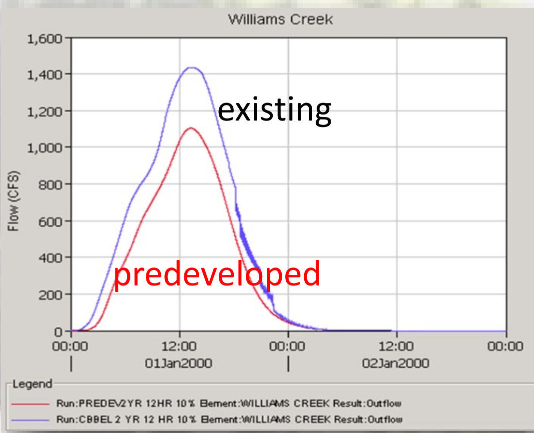
Responding Climate change - adaptation and mitigation

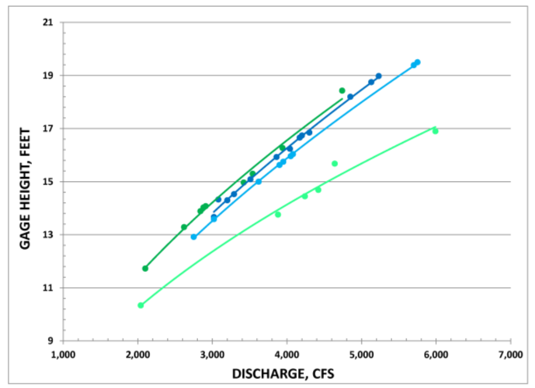
CBBEL, 2017

BOTTOM LINE – WHAT IS HAPPENING?

- Flooding is getting worse due to multiple factors (almost all human-induced!)
- Despite IDNR regulations and local detention requirements, we are witnessing:
  - Higher, more frequent flood stages
  - Increased streambank erosion
  - Higher channel maintenance costs
- Just complying with minimum federal and state regulations **have not and will not** protect against increased flood stages and streambank erosion

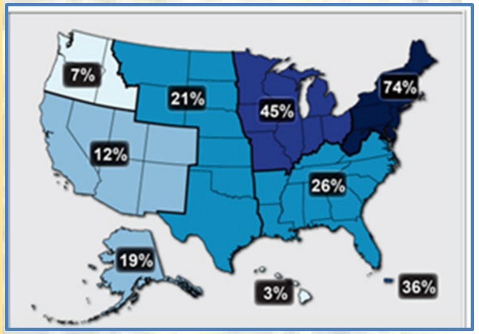


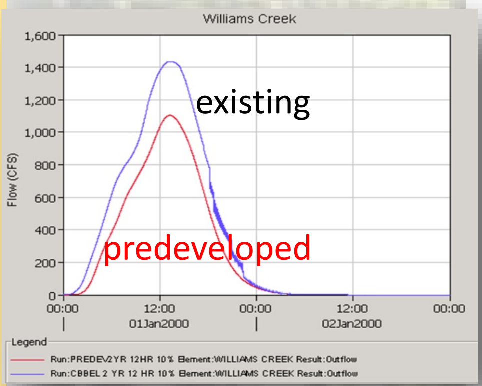


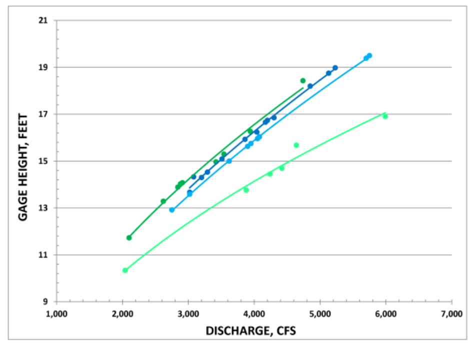


BOTTOM LINE – WHAT CAN YOU DO?

- State Government:
  - Develop **Climate Change-informed Guidance & Standards** for State Agencies and Local Governments to Follow
  - Encourage / **Require Addressing of Agricultural Drainage Impacts!**
  - Consider **Climate Change and FEH Factors** when permitting projects
- Local Governments:
  - Adopt and Enforce **No-Adverse-Impact Development Standards**
  - Adopt and Enforce **Higher Development Standards** (additional freeboard, regulating 500-year floodplain, etc)
  - Develop and Implement **Zone-specific Resilience Strategies**
- Designers:
  - Use **90% Confidence Interval Rainfall** Values
  - Use **95% Confidence Interval Peak Discharge** Values
  - Use **500-year discharge and floodplain** as a Surrogate for Future Conditions 100-year Values
  - Incorporate **Additional Freeboard/ Safety Factor** in Design
  - Account for **Increased Erosion** Potentials
  - Check the **Design Viability for a Higher Discharge** Value







QUESTIONS?

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